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1 Introduction

This paper describes the implementation of a compiler for the vitaly programming language, which is largely extended with object oriented programming capabilities, a standard library including support for multi threading, among other extensions.
We begin by an introduction to the extended vitaly programming language, where all features of the language will be discussed along with examples. Afterwards the implementation of the compiler will be discussed in the following sections.

2 The Vitaly Programming Language

2.1 Basic Vitaly Programming

2.1.1 Hello World

By tradition the "Hello world" program is used when introducing a new programming language. Here is the vitaly version:

```
1 write "Hello world";
```

Saving that in a text file called `hw.vit` and compiling with

```
1 vitaly hw.vit
```

will generate an executable file `a.out` which prints

```
1 Hello world
```

when it's run.

Alternatively you might want to compile with

```
1 vitaly -o hello-world hw.vit
```

which will generate an executable called `hello-world` instead of the default `a.out` .

The global scope of a vitaly program is treated somewhat different from what we are used to from languages like Java and C.

In vitaly, statements and expressions are allowed in the global scope outside of functions. When a vitaly program is executed, the code in the global scope is executed first. If we define a `main` function, and compile the vitaly program with the `-m` option enabled, the `main` function gets called after the code in the global scope is executed.

We will discuss the `main` function, and functions in general in a later subsection.

As in most other programming languages, it is possible to insert comments which are ignored by the compiler. Line comments begin with `#` and block comments begin with `(*` and ends with `*)` . E.g.:

```
1 # This is a line comment
2 (* This is a
3   multi line
4   comment *)
```

2.1.2 Primitive Data Types

The vitaly programming language knows about the following primitive data types:

- `string` , string literals like `"Hello world"` .
- `char` , character literals like `'a'` and `'C'` .
- `int` , integers like `42` and `-1` .
- `bool` , the boolean values `true` or `false` .

For example:

```
var s:string = "my string";  # declare and initialize the string s.
var c:char = 'T';        # declare and initialize the char c.
var i:int = 300;         # declare and initialize the int i.
var b:bool = true;       # declare and initialize the bool b.
write s;
write c;
write i;
write b;
```

will output:

```
my string
T
300
true
```

Identifiers consist of the characters a-z, A-Z, 0-9, and underscore (_). Variable names, and identifiers in general, must begin with one of the characters a-z, A-Z or underscore (_), however.

Also, identifiers in vitaly are case sensitive. So, for example, the identifier `count` is different from the identifier `Count` .

We might be tempted to try to initialize a `string` with a `char` , initialize an `int` with a `bool` or maybe initialize a `char` with an `int` . E.g.:

```
var myString:string = 'S';
var myInt:int = true;
var myChar:char = 20;
```

Saving this in a file called `test.vit` and compiling with:

```
vitaly test.vit
```

produces the following output:

```
test.vit:1:21: (error) incompatible assignment of 'string' type from 'char' type
test.vit:2:15: (warning) implicit cast from 'bool' to 'int'
vitaly: 1 error, 1 warning
```

The first line of the output is an error an says that a `string` is not assignment compatible with a `char` value.

The second line is "only" a warning, it says that the `bool` value is implicitly casted to an `int` . This might come as a surprise to a Java programmer, when casted to an integer the `bool` value `true` is `1` and `false` is `0` .

The other way around is also possible, when an `int` different from `0` is casted to `bool` the result is `true` otherwise the result is `false` .

The third line of source code is not an error nor a warning. The vitaly programming language implicitly casts back and forth between `char` and `int` values.

A `char` variable is a 1 byte ASCII code, however when used in arithmetic `char` is implicitly casted to `int` .

For example:

```
var o:char = '1';
var t:char = '2';
var a:char = o + t;
```

Will cast `o` to an `int` , cast `t` to an `int` and afterwards add the numbers `48` (ASCII code for `'1'`) and `49` (ASCII code for `'2'`) producing the integer result `97` . In the end the `int` result is casted to the `char` `'a'` , since `97` is the ASCII code for `'a'` , and saved in the variable `a` .

We may initialize a `string` with the special value `null` , which is used to indicate that the `string` doesn't contain anything. E.g.:

```
var s:string = null;
```

We are going to talk more about `null` in later sections.

Vitaly supports 4 special escape sequences we can use when initializing `char` or `string` variables:

```
var str:string = "\'hello\'\n\t\"world\"";
write str;
```

Outputs:

```
'hello'
   "world"
```

The special sequence `\'` is replaced with a single `'` , the sequence `\n` is replaced with a new line character, `\t` is replaced by a tab character and `\"` is replaced with a `"` . We use the `\"` notation inside `string` literals when we want a `"` inside the literal instead of terminating the string literal. When we want a `'` inside a `char` literal we can use the `\'` escape sequence:

```
var c:char = '\'';
write c;
```

output:

```
'
```

Notice that the `var` keyword is optional, and we don't have to initialize variables right away. E.g.:

```
a:int;
a = 10;
```

is equivalent to:

```
var a:int = 10;
```

and:

```
a:int = 10;
```

2.1.3 Expressions

Vitaly provides a number of binary and unary operators. The following lists the operators from lowest precedence to highest, with the operators in the same box having the same precedence.

The comment to the left shows which type the operator expects its operands to have and which result type (`->`) the operator has (in the following example `type` means any type):

```
expr1 || expr2;  # bool || bool -> bool
```

```
expr1 && expr2;  # bool && bool -> bool
```

```
expr1 == expr2;  # type == type -> bool
expr1 != expr2;  # type != type -> bool
expr1 > expr2;  # int > int -> bool
expr1 < expr2;  # int < int -> bool
expr1 >= expr2;  # int <= int -> bool
expr1 <= expr2;  # int <= int -> bool
```

```
expr1 + expr2;  # int + int -> int
expr2 - expr2;  # int - int -> int
```

```
expr1 * expr2;  # int * int -> int
expr1 / expr2;  # int / int -> int
```

```
!expr;          # ! bool -> bool
```

```
|expr|;         # | int | -> int
(expr);         # ( type ) -> type
```

In most cases it is possible to feed the operator with a different type than it expects. However doing so will often produce an implicit cast warning.

It is possible to disable the implicit cast warnings with the `-w ign-implicit-cast` command line option, however doing so is not recommended. In a later subsection we will discuss another way to get rid of the implicit cast warnings.

Most of the operators supported by vitaly are equivalent to the operators found in the C-like languages. The only real surprise might be the `|expr|` operator which takes the absolute value of its `int` operand. The `| |` operator is also used for another purpose, but we will talk about that in a later subsection.

2.1.4 Control Flow

The vitaly programming language also supports the `if` statement:

```
if cond then {
   write "cond is true";
}
```

Note that when there is only one statement inside the `if` body you may omit the opening `{` and closing `}`. So the following is equivalent:

```
1  if cond then
2     write "cond is true";
```

The `if-else` statement:

```
1  if cond then
2     write "cond is true";
3  else
4     write "cond is false";
```

If `cond` is not a `bool` variable the vitaly compiler will by default output a warning about an implicit cast to `bool`.

`cond` does not have to be a variable it may also be an expression. For example:

```
1  if i + j < 10 then {
2     write i;
3     write j;
4  }
```

Notice that the `<` operator produces a `bool` result.

The vitaly programming language also supports the `while` statement:

```
1  i:int = 0;
2  while i < 3 do {
3     write i;
4     i = i + 1;
5  }
```

Instead of `i < 3` the condition may be any valid expression.

2.1.5 Arrays

Any type you can use in vitaly you can put inside an `array`. For example:

```
1  a:array of int;
2  b:array of bool;
3  c:array of string;
4  d:array of char;
5  e:array of array of int;
6  f:array of array of array of string;
7  # You got the point ...
```

The first line declares an `array` containing `int` values, the second line an `array` with `bool` values, and so on, until line 5 and 6 which declares arrays containing arrays.

The array differs from the primitive types in that we need to allocate memory for the array before we can use it. Example follows:

```
1  ary:array of int;
2  allocate ary of length 3;
3  i:int = 0;
4  while i < 3 do {
5     ary[i] = i + 10;
6     i = i + 1;
7  }
8  while i > 0 do {
9     i = i - 1;
10    write ary[i];
11 }
```

```
12 delete ary;
```

Note that the `[ ]` -operator has higher precedence than the other operators introduced this far. The program outputs:

```
1 12
2 11
3 10
```

Line 2 allocates memory for an `int` array with length 3. Line 5 initializes the array elements, note that a vitaly array always is `0` -indexed, that is the first element of a vitaly array is located at index `0` .

Line 10 prints the output and the last line deallocates memory used by the array.

Indexing an array with a negative index or indexing an array with and index larger than or equal to the length of the array results in undefined behaviour and should be avoided.

We can try to allocate an array with negative length, but doing so does not allocate any memory, it simply initializes the array with the special `null` value. E.g.:

```
1 a:array of int;
2 allocate a of length -1;
3 write a;
4 delete a;
```

Produces output:

```
1 null
```

Notice that it was not an error to `delete` the array when it's initialized with `null` .

A `string` is much like an `array` in that we index the string in much the same way. E.g.:

```
1 s:string = "hello";
2 i:int = 0;
3 while i < 5 do {
4    c:char = s[i]; # Note that s[i] is a char
5    write c;
6    i = i + 1;
7 }
```

Output:

```
1 h
2 e
3 l
4 l
5 o
```

Next we might be tempted to do the following:

```
1 s:string = "hello";
2 s[0] = 'H';
```

However when compiling this program the vitaly compiler produces an error telling us that the `string` elements are immutable, meaning we are not allowed to modify the `string` like that.

If we need to modify the `string` elements we must use an `array of char` instead. Example:

```
a:array of char;
allocate a of length 6;
s:string = "hello";
i:int = 0;
while i < 6 do {
   a[i] = s[i];
   i = i + 1;
}
a[0] = 'H';  # fine
delete a;   # remember to deallocate the array
```

Notice that we allocate an array of length 6 and not 5. We do this because vitaly strings, like C-strings, are `0` -terminated. That means the string "hello" has a size of 6 chars and that the last `char` is the `NULL char` with ASCII code `0`.

Later we will talk about how to convert an `array of char` to a `string`.

If we would like to obtain the length of an `array` we can use the `| |` -operator. E.g.:

```
a:array of char;
b:array of string;
allocate a of length 0;
allocate b of length 10;
write |a|;
write |b|;
delete a;
delete b;
```

Which first outputs the length of `a` and afterwards outputs the length of `b`:

```
0
10
```

Again the primitive `string` data type differs from the `array` in that we cannot obtain the length of a `string` using the `| |` -operator. If we want to compute the length of a string we can search for the terminating `NULL` character as follows:

```
s:string = "hello";
len:int = 0;
while s[len] != 0 do
   len = len + 1;
write len;
```

which outputs the length of the string "hello":

```
5
```

Vitaly supplies other ways to find the length of a `0` -terminated `string`. We are going to talk more about finding the length of a strings in a later subsection.

Like with strings it is possible to explicitly assign arrays with `null`:

```
a:array of bool = null;
s:string = null;
# a[0] = true;   program will crash.
# write s[0];  program will crash.
```

2.1.6 Type Cast

The vitaly programming language offers the opportunity to explicitly cast from one type to another. For example:

```
i:int = 0;
b:bool = true;
write cast(bool) i;
write cast(int) b;
```

Output:

```
false
1
```

We can also use the `cast` to cast from `array of char` to `string` as follows:

```
a:array of char;
allocate a of length 4;
a[0] = 'a'; a[1] = 'r'; a[2] = 'y'; a[3] = 0;
s:string = cast(string) a;
write s;
delete a; # do not deallocate a before we are done using s.
```

Output:

```
ary
```

What's important to note in the above example is that we can `cast` from `array of char` to `string` , but we must be careful not to `delete` the `array of char` before we are done using the `string` .

Type casting one array type to another is not possible, however it is possible to `cast` an `array` or `string` to `bool` . When the `array` or `string` is `null` the `cast` evaluates into `false` otherwise it evaluates into `true` .

Note that we can get the same effect with `ary != null` and `str != null` .

2.1.7 Records

The `record` is used for creating our own user defined data types. It is vitaly's answer to Java's classes and C's structs.

We declare a record as follows:

```
var point:record of {
   x:int,
   y:int
};
```

Notice that the `var` keyword is optional and that you can use the `;` instead of `,` inside the record. The following declarations are equivalent:

```
var point:record of {
   var x:int,
   var y:int
};
```

```
point:record of {
   x:int;
   y:int;
};
```

Like with arrays we `allocate` a record before using it. If we would like to use the `point record` we would allocate it as follows:

```
allocate point;
point.x = 1;
point.y = 2;
write point.x + point.y;
delete point;
```

Output:

```
3
```

Notice the `.` -operator used to access the records fields `x` and `y`. Like arrays, records may contain any data type. So we can declare arrays of records and we can declare records with arrays. Example:

```
outer:record of {
   innerAry:array of record of {
      s:string;
      c:char;
   };
   innerRec:record of {
      b:bool;
      i:int;
   };
};
allocate outer;
allocate outer.innerAry of length 1;
allocate outer.innerAry[0];
allocate outer.innerRec;

outer.innerAry[0].s = "Inner string";
outer.innerAry[0].c = 'C';
outer.innerRec.b = false;
outer.innerRec.i = 42;

delete outer.innerRec;
delete outer.innerAry[0];
delete outer.innerAry;
delete outer;
```

The `.` and `[ ]` operators have the same precedence and evaluates from left to right. So, for example, `outer.innerAry[0].s` means get `innerAry` from `outer`, get `record` at index `0` from `innerAry`, in the end, get field `s` from that `record`.

Like with `array` and `string` you can assign a `record` with `null` if needed.

Records are much more powerful than what we have seen this far. We will take a look a what vitaly records really are capable of in a later subsection.

2.1.8 Type Definitions

Say that we have two records `p1` and `p2` of the same type. E.g.:

```
p1:record of {
   x:int;
   y:int;
};
p2:record of {
   x:int;
   y:int;
};
```

Instead of typing the same record fields and their types over and over whenever we want to declare a record we can use a type definition, as follows:

```
type Point = record of {
   x:int;
   y:int;
};
p1:Point;
p2:Point;
```

Which is equivalent to the previous example, however in this example we have defined the type `Point` we can reuse whenever we want to declare a `record` of that type.

If we for some reason want to change something in the record, adding a new field for example, we only have to do this one place instead of having to locate all the places where we have declared a record of that type such that we can add the field to the declaration.

It also makes the code better self-documenting since we are forced to give the record a type name.

In general it is considered good practice to always give the records a type name.

Type names are not reserved for records. We can give any type we want a new type name. E.g.:

```
type A = array of bool;
type C = char;
type I = int;

a:A;
allocate a of length 2;
a[0] = true;
a[1] = false;
c:C = 'A';
i:I = 10;

write a[0];
write a[1];
write c;
write i;

delete a;
```

Which outputs:

```
true
false
A
10
```

In general vitaly is quite relaxed with what you are allowed to do with type definitions:

```
type A1 = A2;
type A2 = A1;
type A1 = int;

type P = record of { s:string };
type Q = record of { s:string };
type P = Q;
type P = record of { s:string };
type T = Q;
```

All of this is fine. Types `A1` and `A2` are aliases for type `int` and `P`, `Q` and `T` are of the same type `record of { s:string }`.

The following example does not compile:

```
type I = int;
type I = bool; # error I was previously defined as int.

```

```
type A = record of { i:int };
type B = record of { b:bool };
type A = B;  # error A was previously defined as another record type.

type P = Q;
type Q = P;  # Cycle in type definitions.
```

Although there was a cycle in the type definitions in the previous example involving `A1` and `A2`, the compiler was able to resolve the type of `A1` and `A2` because of the `A1 = int;` line of code.

There is no such line in this last example with `P` and `Q`, and thus vitaly is unable to determine the type of `P` and `Q`.

2.1.9 Functions

We can define a function as follows:

```
func foo():int
   return 0;
end foo
```

There are quite some things to notice in this example.

First we start the function definition of the function called `foo` with the `func` keyword and we specify that the function produces an `int` result with the `:int` syntax.

Inside the body of the function we `return` the `int` value `0`, and afterwards we end the function definition with the `end` keyword followed by the name of the function `foo`.

Thus this function always produces the result `0` when called. E.g.:

```
i:int = foo();
write i;
write foo();
```

Outputs:

```
0
0
```

A function can take any number of arguments:

```
func a(i:int, b:bool, a:array of int):int
   write i;
   write b;
   if a == null then
      return 0;
   return a[0];
end a
write a(10, true, null);
```

Outputs:

```
10
true
0
```

We can nest functions inside other functions:

```
func outer(outParm:bool):string
   ret:string = middle();
```

```
3
4     func middle():string
5        func inner():bool
6           return outParm;
7        end inner
8
9        if inner() then
10          return "yes";
11       else
12          return "no";
13    end middle
14
15    return ret;
16 end outer
17 s1:string = outer(true);
18 s2:string = outer(false);
19 write s1;
20 write s2;
```

Produces output:

```
1 yes
2 no
```

An important thing to notice here is that the `inner` function is able to access the `outer` function's parameter `outParm`.

The rules for declaring variables inside functions are the same as outside functions. A nested function can access the containing function's variables and the global variables not declared inside a function. Example:

```
1  type a = int;
2  a(1);
3  func a(a:a):int # function, parameter and type with the same name is fine
4     func b():int
5        a = 100;
6        glob = 1000;
7        return 10;
8     end b
9     write a;
10    b:int = b();
11    write b;
12    write a;
13
14    return 0;
15 end a
16 glob:int;
17 write glob;
```

Which outputs:

```
1 1
2 10
3 100
4 1000
```

Also notice that we can declare variables, functions and type definitions with the same name if we want.

Functions can return any type we can use in the vitaly programming language including a special type `void` (which is not really a type).

It is used when defining a function that does not return any result. Example:

```
1 f();
2 func f():void
3    write "Hello from f()";
4 end f
```

Which prints:

```
Hello from f()
```

What we should notice here is that the function `f` doesn't have a `return` statement, which is required when the function's return type is different from `void`.

We cannot use `void` for anything else than specifying that a function doesn't return anything.

Now that we have introduced functions another version of the `"Hello world"` program can be made using a `main` function:

```
func main():int
   write "Hello world";
   return 0;
end main
```

Saving this to a file called `main_hw.vit` and compiling with:

```
vitaly -m main_hw.vit
```

outputs an executable `a.out` which prints:

```
Hello world
```

when it's executed.

Note that we used the `-m` option when we invoked `vitaly` to tell the compiler there was a `main` function.

The main function must have return type `int` and the value returned from `main` will become the exit status of the executed program, like we are used to with C.

An alternative definition of the `main` function follows:

```
func main(args:array of string):int
   i:int = 0;
   while i < |args| do {
      write args[i];
      i = i + 1;
   }
   return 0;
end main
```

Saving in a file called `main_args.vit` and compiling with:

```
vitaly -m main_args.vit
```

Executing the `a.out` executable with command line arguments:

```
./a.out hello outside world
```

will output:

```
./a.out
hello
outside
world
```

Notice that the name of the executable is the first element of the `args` array.

The `main` function must have empty parameter list or one `array of string` parameter. Anything else is a compile time error.

2.1.10 Overloading functions

In the vitaly language it is possible to overload functions, hence the following is allowed:

```
1  func foo():int
2     return 0;
3  end foo
4
5  func foo(i:int):int
6     return i;
7  end foo
8
9  write foo();
10 write foo(10);
```

Which will output

```
1  0
2  10
```

When calling an overloaded function the function with parameters "best matching" the arguments is called. For example:

```
1  func foo(i:int):void
2     write "1";
3  end foo
4  {
5     func foo(c:char):void
6        write "2";
7     end foo
8
9     foo(1);
10 }
```

Outputs:

```
1  1
```

Without the outermost definition of the function `foo`, the argument `1` would get casted to a `char` and the output would have been `2`.

If multiple overloaded versions of a functions match the arguments equally well the closest definition is called.

To determine which function is closer the distance in terms of scopes is considered. Note that we are going to discuss scopes more carefully in a later subsection.

If multiple functions match equally well and are equally close, an error is reported.

Functions are not allowed to be overloaded based on return type. Hence the following vitaly program is illegal:

```
1  func foo():int   # multiple definitions of foo
2     return 0;
3  end foo
4
5  func foo():bool  # multiple definitions of foo
6     return false;
7  end foo
8
9  i:int = foo();
10 b:bool = foo();
```

Since function overloading ambiguities can arise. In the following example the two function definitions match equally well, therefore neither can be identified as the

correct one and the compiler reports an error:

```
1  func foo(x:int, y:char):void
2  end foo
3
4  func foo(y:char, x:int):void
5  end foo
6
7  a:int, b:int;
8  foo(a, b);  # Ambiguous call to foo
```

If one of the variables in the above example, say `a` , had been of type `char` instead of `int` , then there would be no ambiguity since function `foo(char, int)` would be an exact match and vice versa.
The ambiguity would also be resolved if `foo` was overloaded with the types `foo(int, int)` .

2.1.11 Scope

The body of a function and the body of a record opens a new scope. In fact, whenever we write an opening `{` we open a new scope. Thus in the following example there are 4 different scopes:

```
1  # Global scope.
2  {
3     # Scope inside opening { and closing }.
4  }
5  func foo():void
6     # Scope inside function foo.
7     r:record of {
8        # Scope inside record r.
9     };
10 end foo
```

We are not allowed to declare a variable with the same name twice in the same scope. Although `i` is declared with the same type, the following is an error:

```
1  i:int;
2  i:int;
```

This is also an error:

```
1  j:string;
2  j:char;
```

The following is not an error:

```
1  i:int = 1;
2  if i == 1 then { # New scope between { and }.
3     write i;
4     i:int = 2;
5     write i;
6  }
7  write i;
```

Output:

```
1  1
2  2
3  1
```

The inner scope inside the `if` statement body refers to the `i` variable in the outer global scope until the `i` variable inside the body of the `if` statement is declared.

The outer global scope refer to the `i` variable from it's own scope. We must declare variables before we use them.

Almost the same thing applies to type definitions and function definitions. However, if there is a type definition of type T in the current scope, we always refer to that T and never a T from an outer scope. The same thing applies to functions with equally matching parameter lists. E.g.:

```
1  type T = int;
2  i:T;
3  func f():void
4     i = 1;       # outer i
5
6     i:T;         # inner T (bool)
7
8     f();         # inner f()
9
10    func f():void
11       i = false; # inner i
12    end f
13
14    type T = bool;
15
16    write i;     # inner i
17 end f
18 f();
19 write i;
```

The program outputs:

```
1  false
2  1
```

If `vitaly` is compiled with the `NEST_ACCESS=after` option enabled, nested functions can access variables declared after the function definition. For example:

```
1  i:int;
2  func outer():void
3     func inner():void
4        i = 33;
5     end inner
6     inner();
7
8     i:int;
9
10    write i;
11 end outer
```

Output:

```
1  33
```

The noticeable thing here is that the inner function `inner` is accessing the `i` variable declared inside `outer` and not the global variable `i`.

This is probably not intuitive for most programmers, and is not the default behaviour. By default, when `vitaly` is not compiled with the `NEST_ACCESS=after` makefile option, `inner` will refer to the global `i` and give a warning about the variable `i` in function `outer` not being initialized before use.

The global scope is special regarding initialization of variables. Consider the following example:

```
1  global:int;
2  write global;
3  func f():void
4     local:int;
5     write local;
6  end f
7  f();
```

Compiling this example the vitaly compiler gives a warning telling us that the `local` variable is uninitialized before use, however it does not say anything about the `global` variable.

This is so because the variables in the global scope are automatically initialized to `0` or `null` when they are declared.

2.1.12 Import

It is possible to import global variables, functions and types from other vitaly source files using the `import` keyword. In the following simple example two files are considered `file1.vit` and `file2.vit`. In this subsection the files are assumed to be placed within the same directory, and compiled with:

```
1  vitaly -r file1.vit
```

which will recursively compile and link the files into one executable.

`file1.vit`:

```
1  import file2;
2
3  a:A;
4  allocate a;
5
6  a.i = 10;
7  foo(a.i);
8  b = b * 2;
9  foo(b);
10
11 delete a;
```

`file2.vit`:

```
1
2
3
4
5
6
7
func foo(i:int):void
   write i;
end foo

type A = record of { i:int };

b:int = 10;
```

By line 1 of `file1.vit`, it is now possible to use everything declared or defined in the global scope of `file2.vit`. Note that only the base name of `file2.vit` is used to indicate which file to use, hence the `.vit` file extension is omitted. The imported symbols are considered as residing in a parent scope to where they are specified. This implies that local symbols suppress imported symbols if name collisions occur, just like regular scope rules. Hence the following example can compile to a valid vitaly program:

file1.vit

```
1  import file2;
2  a = 10;  # imported a
3  a:int;
4  a = 20;  # local a
5  write a; # prints 20
```

file2.vit:

```
1
2
3
4
5
import file1;
a = 30;  # imported a
a:int;
a = 40   # local a
write a;  # prints 40
```

As mentioned earlier the code of the global scope is executed before a `main` function. There is no guarantee however in which order the global scopes will be executed in the compiled program. Thus it is undefined whether the program above will output `20` followed by `40` or the other way around. Therefore we cannot rely on which files are

initialized first. An exception to this is the vitaly standard library which is guaranteed to be initialized before the normal global scope we have seen this far.

Thus variables imported from the standard library can be used in the global scope. We will introduce the vitaly standard library in the following subsection.

Cycles among import statements, as in the example above, are allowed. Even type definitions can be defined with cycles across imported files, by the same rules as for normal type definitions. Hence the following is a valid vitaly program, since all types can be resolved to `int` :

file1.vit

```
import file2;
type A = B;
type C = D;
type C = int;
```

file2.vit:

```
import file1;
type B = C;
type D = A;
b:B = 10;
write b;
```

Outputs:

```
10
```

As mentioned there are no guarantee to which order the global scopes of imported files are executed. Only that they will all be executed before an optional call to a main function. Consider the following example:

file1.vit

```
import file2;
import file3;

(* We don't know whether a is
   initialized to 20 or whether
   b is initialized to 10 here *)

func main(args:array of string):int
   write a + b;
   i:int = 1;
   while i < |args| do {
      write args[i];
      i = i + 1;
   }
   return 0;
end main
```

file2.vit:

```
import file3;
b:int = 10;
```

file3.vit:

```
import file2;
a:int = 20;
```

If `a` or `b` is accessed in the global scope of `file1.vit` , as the comment points out the variables might not yet have been initialized and hence the behavior is undefined. When using the variables inside the main function, we know that all global sections of all imported files have been executed and the variables will therefore be initialized.

If the program above is compiled and run as follows:

```
vitaly -r -m file1.vit
./a.out hello wold
```

The program will output.

```
30
hello
world
```

Note that the first string of the array passed to the main function is the name of the executable itself, hence to access the command line arguments one must start from index 1 of the array.

Using imports can result in name collisions between symbols. Consider the following example:

file1.vit

```
1 import file2;
2 import file3;
3
4 a:A; # Conflicting type definitions
5
6 b:B;
```

file2.vit:

```
1 type A = bool;
2
3 type B = array of string;
```

file3.vit:

```
1 type A = int;
2
3 type B = array of string;
```

It is clear that the type `A` cannot be resolved since the imported definitions are conflicting. In contrast to this type `B` is resolved just fine since there is no ambiguity in this regard.

Imports statements are not restricted to the top of a vitaly source file, in fact imports can be placed anywhere a type definition can. Nested in functions, records, and even multiple times. This means that symbol collision can be avoided by nesting the import statements. For example:

file1.vit

```
1  func foo():void
2     write "File1";
3  end foo
4
5  {
6     import file2;
7     foo();
8  }
9  foo();
10 {
11    import file3;
12    foo();
13 }
```

file2.vit:

```
1 func foo():void
2    write "File2";
3 end foo
```

file3.vit:

```
1 func foo():void
2    write "File3";
3 end foo
```

Will output:

```
1 File2
2 File1
3 File3
```

Note how all ambiguities have been avoided by nesting the imports while still allowing three different version of the function `foo`. This also applies to variables and type definitions.

When importing a type from one file which in turn is defined by an import from another file, the indirect import does not need to be specified in the first file. Consider the following example:

file1.vit

```
1  import file2;
2  import file4;
3
4  # b:B # requires import file3;
5  a:A;
6  allocate a;
7
8  a.i = 10;
9  a.b = true;
10
11 foo(a);
12
13 delete a;
```

file2.vit:

```
1  import file3;
2  type A = B;
```

file3.vit:

```
1  type B = record of {
2     i:int;
3     b:bool;
4  };
```

file4.vit:

```
1  import file3;
2  func foo(b:B):void
3     write b.i;
4     write b.b;
5  end foo
```

Outputs:

```
1  10
2  true
```

Notice how `file1.vit` can access the fields of the record type `B` declared in `file3.vit`, although it is not directly imported. Even the function call on line 13 is valid since `a` is actually resolved to type `B`. As indicated on line 4, it is not possible to use the type `B` directly from `file1.vit` without directly importing `file3.vit`.

Nested imports can also override other imported definitions, imported in outer scopes:

file1.vit

```
1  func foo():void
2     write "File1";
3     foo();
4
5     func inner():int
6        import file3;
7        foo();
8        {
9           import file2;
10          import file2;
11          foo();
12          import file2;
13       }
14    end inner
15
16    inner();
17
18    import file2;
19 end foo
20
21 foo();
```

file2.vit:

```
1  func foo():void
2     write "File2";
3  end foo
```

file3.vit:

```
1  func foo():void
2     write "File3";
3  end foo
```

Will output:

```
1  File1
2  File2
3  File3
4  File2
```

Again imports are scope specific and can be placed wherever in any given scope. Note how both of the function calls in line 3 and 11, in the example above, refer to the definition of `foo()` found in `file2.vit`.

2.1.13 Organizing a Vitaly Project

So far all examples considered assumed the files to be in the same directory. This is however not necessary using keyword `package`. By using `package` vitaly source files can be grouped into packages much like Java. See the following example:

file1.vit

```
foo();
foo(200);
foo(true);

import pack.file2;

func foo(b:bool):void
   write 300;
end foo

import pack.file3;
```

pack/file2.vit:

```
package pack;
import file3;

func foo():void
   foo(100);
end foo
```

pack/file3.vit:

```
package pack;

func foo(i:int):void
   write i;
end foo
```

Will output:

```
100
200
300
```

Notice how the package name of the imported files are included in the import statements. The package name can be omitted if the imported file is located in the same package like `pack/file2.vit` can import `pack/file3.vit` simply by " `import file3;` " since they both are located in the package `pack` . If files are imported with " `import pack.name;` " then the imported file must specify a package, namely `pack` , otherwise an error is reported. Also if a file specifies a package it must be placed in a similar directory structure, hence a file `file.vit` specifying " `package pack1.pack2.pack3;` " must be located in a directory `*/pack1/pack2/pack3/`

2.2 Advanced Vitaly Programming

2.2.1 Finalize

The `finalize` keyword have two different purposes in vitaly. It can both be used to move code to a finalize subsection of the executable, and to define `finalize` functions which are vitaly's answer to destructors. This will be discussed in the subsection on record destructors later.
For now let us consider the first use. The finalize subsection of the executable, is executed when all other code has been executed, i.e. after the code from the global scope and the optional `main` function:

```
write "global1";
finalize
   write "finalize1";
write "global2";
finalize {
   write "finalize2";
   write "finalize3";
}
write "global3";
```

```
global1
global2
```

```
global3
finalize1
finalize2
finalize3
```

In the example above the code in the body of `finalize` is moved to the finalize subsection of the executable. This can be particularly useful when used for freeing memory, after execution. For example:

```
allocate rec;
finalize
   delete rec;
...
# use rec
...
```

This makes sure that the record `rec` will eventually be deleted, but only after all the code of the global scope and possible main function has been executed.

2.2.2 Inheritance

The vitaly programming language has good support for object oriented programming. For example:

```
type B = record of {
   s:string;
};
type D = record of B { # record D extends/inherits record B
   c:char;
};

func f(b:B):void
   write b.s;
end f

d:D;
allocate d;
d.c = 'c';
d.s = "str";

f(d);

write d.c;

delete d;
```

which prints:

```
str
c
```

The `record d` with type `D` is automatically casted to it's base record type `B` when passed as argument to function `f`.

A record can inherit as many records we want:

```
type A = record of {
   a:int;
};
type B = record of {
   b:bool;
};
type C = record of {
   c:char;
```

```
};
type ABC = record of A, B, C {};

abc:ABC;
allocate abc;
a:A = abc;
b:B = abc;
c:C = abc;

a.a = 10;
b.b = true;
c.c = 'c';

write abc.a;
write abc.b;
write abc.c;

delete abc;
```

Note that `abc` is automatically casted to the correct base records in the assignment statements. Output:

```
10
true
c
```

Alternatively:

```
type A = record of {
   a:int;
};
type B = record of A {
   b:bool;
};
type C = record of B {
   c:char;
};
type ABC = record of C {};

abc:ABC;
allocate abc;
a:A = abc;
b:B = abc;
c:C = abc;

a.a = 10;
b.b = true;
c.c = 'c';

write abc.a;
write abc.b;
write abc.c;

delete abc;
```

Same output:

```
10
true
c
```

Multiple inheritance is often referred to as a good structuring tool. On the other hand multiple inheritance is criticized because it increases complexity of programs when misused.

In reality, how to best structure the inheritance hierarchy is a design issue and varies from program to program.

Consider the diamond problem:

```
1  type Base = record of {
2     baseVal:int;
3     # ...
4  };
5
6  type Left = record of Base {
7     leftName:string;
8     # ...
9  };
10
11 type Right = record of Base {
12    rightName:string;
13    # ...
14 };
15
16 type Derived = record of Left, Right {
17    # ...
18 };
19
20 d:Derived;
21 allocate d;
22 d.baseVal = 0; # Ambiguous field reference
23 delete d;
```

Both record `Left` and record `Right` inherit a field named `baseVal` from record `Base`, so `Derived` actually has two fields named `baseVal`.

When compiling the program there is a problem on line 22, the `vitaly` compiler does not know whether we want to reference the `baseVal` from record `Left` or the `baseVal` from record `Right`.

Thus `vitaly` is unable to compile the program and gives an error about an ambiguous field reference.

A solution to the problem is to explicitly tell the compiler which `baseVal` field we want to reference using type cast. E.g.:

```
1 (cast(Left) d).baseVal = 0; # Set baseVal inherited from Left
2 (cast(Right) d).baseVal = 1; # Set baseVal inherited from Right
3
4 # We don't need cast to reference the other fields:
5 d.leftName = "left"; # Fine.
6 d.rightName = "right"; # Fine.
```

Notice that the `.` -operator has higher precedence than `cast`, thus we use parenthesis to cast `d` before referencing the `baseVal` record field.

Although this surely solved the ambiguity problem, facing the diamond problem almost always indicates that there is a problem in the design, and we probably need to consider whether we are doing something wrong.

When records are implicitly casted to extended (base) records. We might think that it is also possible to implicitly cast from a base record to a derived record type:

```
1  type B = record of { (* ... *) };
2  type D = record of B { (* ... *) };
3
4  func useD(d:D):void
5     # ...
6  end useD
7
8  d:D;
9  allocate d;
10 b:B = d;
11
12 useD(b); # Error, incompatible record type
13 delete d;
```

When compiling this program `vitaly` gives us an error telling us that it cannot find a function `useD` with a parameter list that matches the arguments given on line 12.

What we need is an explicit `cast` :

```
1  useD(cast(D) b); # Fine, but our own responsibility.
```

Casting `b` back to record `d` solves the problem for us.

We should note that it is our own responsibility that the `cast` of record `b` to type `D` is valid. In the previous example it was fine, but in the following example it is not:

```
1  b2:B;
2  allocate b2;
3  useD(cast(D) b2); # Likely runtime error.
4  delete b2;
```

As we have already seen, casting from type `B` to type `D` is possible because `D` inherits `B` .

The problem here is that record `b2` is allocated as a record with type `B` , so casting it to type `D` is not correct.

Casting from a base type to a derived type can be disastrous, and for that reason `vitaly` does not do such type casts implicitly. Having to do an explicit `cast` makes it easier to spot the mistake when it occurs.

We cannot type cast between two unrelated types:

```
1  type A = record of {i:int};
2  type B = record of {b:bool};
3
4  a:A;
5  b:B;
6
7  allocate a;
8  b = cast(B) a;  # Error, cast between unrelated record types.
9  delete a;
```

Casting from a record of type `A` to a record of type `B` is a compile time error.

2.2.3 Structural Equivalence

Vitaly uses structural equivalence when comparing records. E.g.:

```
1  type C1 = record of {
2     c:char;
3  };
4  type C2 = record of {
5     c:char;
6  };
7  c1:C1;
8  c2:C2;
9  c2 = cast(C2) c1; # Fine, cast to record of same type.
```

Casting from type `C1` to type `C2` is fine because they have equivalent structure. In fact we don't even need the `cast` to assign `c2` with `c1` , `c2 = c1` is also fine.

The structural equivalence in vitaly is different from what we normally think of as structural equivalence. In vitaly the record field names are significant when deciding whether records are equivalent. For example:

```
1  type A = record of {a:int};
2  type B = record of {b:int};
3  type T = record of {a:int};
4
```

```
5  a:A;
6  b:B;
7  t:T;
8  b = a;   # Error assignment from incompatible type.
9  t = a;   # Fine, same structure.
```

Line 8 is an error because the field name of the `int` inside record `a` and record `b` differ.

Line 9 is not an error because the `int` inside `t` has the same name as the `int` inside `a` , and thus they have equivalent structure.

A slightly more complex example:

```
1  type A1 = record of {
2     a:bool;
3     next:A2;
4  };
5  type A2 = record of {
6     a:bool;
7     next:A1;
8  };
9  a1:A1;
10 a2:A2 = a1;  # Same structure.
11
12 type B1 = record of {
13    b:char;
14    other:B1;
15 };
16 type B2 = record of {
17    b:char;
18    other:B1;
19 };
20 b1:B1;
21 b2:B2 = b1;  # Same structure.
```

The following is an error:

```
1  type A = record of {a:int};
2  type T = record of {a:char};
3  a:A;
4  t:T;
5  t = a;   # Error.
```

The field names are equivalent but the field types differ.

Structural equivalence also applies with record inheritance:

```
1  type B1 = record of {
2     b:bool;
3  };
4  type A1 = record of B1 {
5     a:int;
6  };
7  type B2 = record of {
8     b:bool;
9  };
10 type A2 = record of B2 {
11    a:int;
12 };
13
14 func test(b2:B2):void
15    # ...
16 end test
17
18 a1:A1;
19 a2:A2;
20 a2 = a1;    # Fine, same structure.
21
22 test(a1);   # Implicit cast to record of {b:bool}
```

Structural equivalence does have side effects. For example:

```
type A = record of {
   s:string;
};
type B = record of {
   s:string;
};
type D = record of A, B {}; # Error, extending the same record twice
```

When compiling the above program `vitaly` outputs 2 errors telling us that `A` and `B` are inaccessible due to ambiguity.

Imagine that was allowed and then consider:

```
func foo(r:record of {b:bool}):void
   # ...
end foo
d:D;
foo(d);  # Cast to A or cast to B?
```

We might think it is possible to type cast our way out of the problem:

```
foo(cast(A) d); # Still ambiguous.
```

`A` has type `record of {b:bool}`, thus casting `d` to type `A` is equivalent with:

```
foo(cast(record of {b:bool}) d);
```

And we still have the ambiguity.

In practice this will rarely become an issue, the solution is to change a field name or add an extra field inside `A` or `B` such that their structure differs.

It is possible to indirectly extend the same record twice as we saw in the diamond problem:

```
type Base = record of {
   baseVal:int;
   # ...
};
type Left = record of Base {
   leftName:string;
   # ...
};
type Right = record of Base {
   rightName:string;
   # ...
};
type Derived = record of Left, Right {
   # ...
};

func workWithBase(b:Base):void
   # ...
end workWithBase

d:Derived;
allocate d;

(* Ambiguous, use Base inherited from Left or Right? *)
workWithBase(d);
(* Fine, use base inherited from Left. *)
workWithBase(cast(Left) d);
(* Fine, use base inherited from Right. *)
workWithBase(cast(Right) d);

delete d;
```

On line 27 and 29 we `cast` our way out of the ambiguity.

2.2.4 Functions In Records

We can put functions inside records:

```
1  type R = record of {
2     val:int;
3     func set(v:int):void
4        val = v;
5     end set
6
7     func get():int
8        return val;
9     end get
10 };
11 r:R;
12 allocate r;
13 r.set(1);
14 write r.get();
15 delete r;
```

Prints:

```
1  1
```

Note that the functions `set` and `get` can reference the record field `val`. We can explicitly state that we want to reference a field inside a record using the `record` keyword:

```
1  type R = record of {
2     val:int;
3     func set1(val:int):void
4        record.val = val;
5     end set1
6
7     func set2(val:int):void
8        val = val; # Statement with no effect.
9     end set2
10
11    func get():int
12       return val;
13    end get
14 };
15 r:R;
16 allocate r;
17
18 r.set1(70);
19 write r.get();
20
21 r.set2(90);
22 write r.get();
23
24 delete r;
```

Output:

```
1  70
2  70
```

In function `set1` we use the `record` keyword to explicitly say that we want to reference the `val` field from the record and assign it with the parameter `val`. In function `set2` we don't use the `record` keyword and we simply assign the parameter `val` with itself, which doesn't have any effect.

Overriding functions is also possible:

```
type B = record of {
   func print():void
      write "hello from B";
   end print
};
type D = record of B {
   func print():void
      write "hello from D";
   end print
};
func testPrint(b:B):void
   b.print();
end testPrint

b:B;
allocate b;
testPrint(b);
delete b;

d:D;
allocate d;

b = d;
testPrint(b);
delete d;
```

Output:

```
hello from B
hello from D
```

Function overloading also applies to functions defined within records and functions inherited from parent records:

```
type B = record of {
   func foo(i:int):void
      write i;
   end foo
};

type A = record of B {
   func foo(c:char):void
      write c;
   end foo
   func foo(b:bool):void
      write b;
   end foo
};

a:A;
allocate a;

a.foo(1);
a.foo('a');
a.foo(true);

delete a;
```

Outputs:

```
1
a
true
```

If we really want to override function `foo` from `B` we must make sure to define the function `foo` inside `A` with the exact same signature. That is the same parameter types and same return type, the parameter names are not significant. For example:

```
type B = record of {
   func f(t:string):void
   end f
};
type D = record of B {
   # Does not override f from B (different parameter type)
   func f(t:char):void
   end f

   # Does not override f from B (different return type)
   func f(t:string):char
   end f

   # This one does override f from B
   func f(p:string):void
   end f
};
```

If we want to make sure we don't call a possibly overridden version of a record function, we can directly call a specific function from inside a record:

```
type P = record of {
   func f():void
      h();              # Record Q overrides h(), so we call Q.h()
      write "func P.f()";
      record[].h();     # Directly call P.h()
   end f

   func h():void
      write "func P.h()";
   end h
};
type Q = record of P {
   func f():void
      record[P].f();    # Directly call P.f()
      write "func Q.f()";
   end f

   func h():void
      write "func Q.h()";
   end h
};
q:Q;
allocate q;
q.f();      # Calls Q.f()
delete q;
```

Outputs:

```
func Q.h()
func P.f()
func P.h()
func Q.f()
```

2.2.5 Record Constructors

We use constructors to initialize a record such that invariants regarding the state of the record are respected from the point the record is allocated.

Vitaly supports record constructors using the `record` keyword, constructors must have `void` return type:

```
type R = record of {
   func record(s:string):void
      data = s;
   end record

```

```
6     data:string;
7  };
8  r:R;
9  allocate r of record("R data");  # Allocate r and invoke constructor.
10 write r.data;
11 delete r;
```

Output:

```
1  R data
```

In the example we allocate `r` and afterwards invoke its constructor.

If we try to allocate `r` with the allocate statement we have been using this far when allocating records (`allocate r;`), `vitaly` gives an error saying that `R` doesn't have a default constructor.

The default constructor is a constructor with an empty parameter list. We can overload the constructor and supply the default constructor if wanted:

```
1  type R = record of {
2     func record():void
3        data = "data 100";
4        val = 100;
5     end record
6
7     func record(s:string):void
8        data = s;
9        val = 200;
10    end record
11
12    func record(s:string, i:int):void
13       data = s;
14       val = i;
15    end record
16
17    func put():void
18       write data;
19       write val;
20    end put
21
22    data:string;
23    val:int;
24 };
25 r11:R;
26 r12:R;
27 r2:R;
28 r3:R;
29
30 # Implicitly invoke default constructor:
31 allocate r11;
32 # Explicitly invoke default constructor:
33 allocate r12 of record();
34 # Invoke constructor with string parameter:
35 allocate r2 of record("data 200");
36 # Invoke constructor with string and int parameter:
37 allocate r3 of record("data 300", 300);
38
39 r11.put();
40 r12.put();
41 r2.put();
42 r3.put();
43
44 delete r11;
45 delete r12;
46 delete r2;
47 delete r3;
```

Outputs:

```
data 100
100
data 100
100
data 200
200
data 300
300
```

Note that the default constructor with empty parameter list is implicitly called when allocating `r11`.

Default constructors of base records are automatically called:

```
type A = record of {
   func record():void
      write "Hello from A";
   end record
   a:int;
};
type B1 = record of {
   func record():void
      write "Hello from B1";
   end record
   b:int;
};
type B2 = record of B1 {
   func record():void
      write "Hello from B2";
   end record
};
type C = record of A, B2 {};

c:C;
allocate c;
delete c;
```

Results in output:

```
Hello from A
Hello from B1
Hello from B2
```

It is an error if the base record does not have a default constructor and we do not invoke it's constructor. For example:

```
type B = record of {
   func record(s:string):void
      write s;
   end record
};

# Compile time error, missing call to B's constructor
type D1 = record of B {};

# Compile time error, still missing call to B's constructor
type D2 = record of B {
   func record():void
      write "hello";
   end record
};
```

We call base record constructors explicitly as follows:

```
type A = record of {
   func record():void
      a = 333;
      write "hello from default A constructor";
   end record
```

```
6
7     func record(i:int):void
8        a = i;
9     end record
10    a:int;
11 };
12 type B = record of {
13    func record(s:string):void
14       b = s;
15    end record
16    b:string;
17 };
18 type AB = record of A, B {
19    func record():void
20       record[A](42);
21       record[B]("yes");
22    end record
23 };
24 ab:AB;
25 allocate ab;
26 write ab.a;
27 write ab.b;
28 delete ab;
```

Output:

```
1  42
2  yes
```

Note that the default constructor of type `A` is not invoked when we're explicitly invoking it's constructor. We are also allowed to explicitly invoke the default constructor if we want, but we may not invoke a constructor of the same base record twice. Consider:

```
1  type B = record of {
2     func record():void
3        write "B default constructor";
4     end record
5
6     func record(b:bool):void
7        write b;
8     end record
9  };
10 type D = record of B {
11    func record():void
12       record[B]();   # Fine, invoke default constructor
13    end record
14
15    func record(b:bool):void
16       record[B](true);
17       record[B]();   # Error, second invocation of B constructor
18    end record
19
20    func record(i:int):void
21       write i;
22       record[B]();   # Error, constructor invocations must be first
23    end record
24
25    # Error, we may not invoke a constructor from this function:
26    func foo(i:int):void
27       record[B]();
28    end foo
29 };
```

Note that calls to base constructors must be the first thing we do inside constructors. Also note that we are not allowed to invoke constructors unless we are inside a constructor.

Besides calling constructors of base records, records can call their own constructor:

```
type A = record of {
   func record(i:int):void
      a = i;
   end record
   a:int;
};
type B = record of {
   func record(s:string):void
      b = s;
   end record
   b:string;
};
type AB = record of A, B {
   func record():void
      record[](1, "yes");
   end record

   func record(val:int, str:string):void
      record[A](val);
      record[B](str);
   end record
};
ab:AB;

allocate ab;
write ab.a;
write ab.b;
delete ab;

allocate ab of record(0, "no");
write ab.a;
write ab.b;
delete ab;
```

Prints:

```
1
yes
0
no
```

Calls to own constructor must be the first statement. The record is not allowed to invoke base record constructors after invocation of its own constructor.

2.2.6 Records Destructors

The opposite of the constructor is the destructor. The destructor gets called when we `delete` a record.

We define the destructor using the `finalize` keyword:

```
type R = record of {
   data:array of char;
   func record(len:int):void
      write "construct R";
      allocate data of length len;
   end record

   func getS():string
      return "R is constructed";
   end getS

   func finalize():void
      write "finalize R, length of data is:";
      write |data|;
      delete data;
   end finalize
};
r:R;
allocate r of record(3);
```

```
20 write r.getS();
21 delete r;
```

Outputs:

```
1 construct R
2 R is constructed
3 finalize R, length of data is:
4 3
```

The `finalize` function (destructor) must have empty parameter list and must have `void` return type.

We cannot define more that one destructor per record.

As shown in the following example, destructors of base records are implicitly called when deleting a record:

```
1  type A = record of {
2     func record():void
3        write "construct A";
4     end record
5
6     func finalize():void
7        write "finalize A";
8     end finalize
9  };
10 type B = record of {
11    func record():void
12       write "construct B";
13    end record
14
15    func finalize():void
16       write "finalize B";
17    end finalize
18 };
19 type C = record of A, B {};
20 c:C;
21 allocate c;
22 delete c;
```

Produces:

```
1 construct A
2 construct B
3 finalize A
4 finalize B
```

2.2.7 Interfacing with C

A vitaly program can call any C function defined in the glibc library. For example if we would like to find the length of a string we can do as follows:

```
1 extern(C) func strlen(s:string):int;
2 str:string = "hello";
3 write strlen(str);
```

Output:

```
1 5
```

Or if we want the value of an environment variable:

```
1 extern(C) func getenv(name:string):string;
```

```
2  extern(C) func puts(s:string):int;
3  home:string = getenv("HOME");
4  if home != null then
5     puts(home);
```

Which outputs the value of the `HOME` environment variable if it exists.

2.3 Vitaly Standard Library

A small standard library, referred to as libvitaly, is included with the vitaly compiler. The library consists of the following:

```
std.string
std.array
std.comparator
std.object
std.math
std.sort
std.stdio
std.vector
std.indexable
std.errno
std.thread
std.lock
std.c.string
std.c.ctype
std.c.cstdio
std.c.stdio
```

2.3.1 std.c

This package contains interfaces to C functions. Such as a wrapper for the `strcmp` function of C.

2.3.2 std.object

The `Object` type made available by importing `std.object` contains no functions, and is merely used as a general interface for records in the standard library. This type should only be extended and used as a common interface. Uses of this type becomes clear in the following sections.

2.3.3 std.string

By importing " `import std.string;` ", the following functionality is available: functions `intToString(int):String` , `charToString(char):String` and type `String` .
`String` has constructors which are overloaded to take `int` , `char` , `bool` , `string` , `array of char` or `String` which will be converted to a string and the `String` variable will be initialize to this string
The `String` type has among others the following interesting functions:
`String.append()` and `String.assign()` which either appends to or assigns a variable of type `String` . These have both been overloaded just as thee constructors. All overload returns a self pointer to the variable, such that calls to these functions can be chained:

```
.assign("Hello").append(" ").append("World");
```

`String.compare(oth:String)` returns an int indicating whether the string is smaller greater or equal to another `String` variable.

Note that the `String` type will automatically expand as more memory is needed. Note also that the `String` type is extending the `Object` type. See example of the use of `String` below:

```
import std.string;

s:String;
allocate s of record("Hello");
s.append(" World!");
write s.str();  # to simple type string
write s.getLast(); # get last character
write s.len();  # get length of the string

s2:String = s.copy(); # allocate a copy of the string
write s.compare(s2);  # returns 0 if equal -1 or 1 otherwise
s2.assign("Goodbye");
write s2.str();
write s.compare(s2);

delete s;
delete s2;
```

Will output:

```
Hello World!
!
12
0
Goodbye
1
```

2.3.4 std.errno

By importing `std.errno` we have access to an errno variable, which is an interface to the `errno` provided by C. The `Errno` type has the following functions:
`get()` which returns the current value of errno.
`set(int)` which sets the value of errno and returning the old value of errno.
`clear()` which sets the value of errno to 0.
`assign(String)` and `append(String)` which respectively appends or assigns the error message corresponding to the current errno value, to the string given as argument.

Besides the variable `errno` we also have access to functions that return values of different error types such as `einval()` and `enomem()` which returns the values of the C constants `EINVAL` and `ENOMEM`. See the following example for use of `std.errno`:

```
import std.string;
import std.stdio;
import std.errno;

msg:String;
allocate msg;
errno.set(0);
errno.assignTo(msg);
stdo.putln(msg);

errno.set(einval());
```

```
12 errno.assignTo(msg);
13 stdo.putln(msg);
14
15 delete msg;
```

Output:

```
1 Success
2 Invalid argument
```

2.3.5 std.stdio

By importing " `std.stdio` " two global variables `stdo` and `stdi` are made available. `stdo` is of type `StdOstream` and `stdi` is of type `StdIstream` .The output stream `stdo` provides an interface to write to standard out and `stdi` an interface to read from standard in.

2.3.6 Strandard out - `stdo`

Various functions are available to write to the standard output stream `stdo` .
The functions `put()` and `putln()` will write to standard out and when calling `putln()` a line break will follow. Both functions have been overloaded to take `int` , `bool` , `char` , `string` , `String` and `Errno` as parameters. A third function available is `ln()` which simply prints a line break to standard out.
Common to all three functions is that they return a self pointer to the `stdo` variable, which enables chaining of calls to `put()` , `putln()` and `ln()` . See the following example on the use of `stdo` :

```
1  import std.string;
2  import std.stdio;
3
4  s:String;
5  allocate s of record("String");
6
7  a:array of char;
8  allocate a of length 3;
9  a[0] = 'a';
10 a[1] = 'r';
11 a[2] = 'y';
12
13 stdo.putln("raw string")
14    .putln(s)
15    .putln(a)
16    .putln(true)
17    .ln()
18    .putln('c')
19    .put(0 - 12345)
20    .put(" ")
21    .putln(54321);
22
23 delete s;
24 delete a;
```

Outputs:

```
1 raw string
2 String
3 ary
4 true
5
```

```
6  c
7  -12345 54321
```

2.3.7 Standard in - `stdi`

The standard input stream `stdi` have two interesting functions: `get(String)` and `getln(String)`. Both functions takes as parameter a String variable to which the read input will be appended. They also both return a self pointer to `stdi`, to allow chained reads from the input stream.
`get()` is a blocking read of the next word ended by whitespace on the input stream. White spaces are stripped before the word. `getln()` is also a blocing read, but it reads a until line break or end of file is reached. See the example below:

```
1  import std.string;
2  import std.stdio;
3
4  s:String;
5  q:String;
6  allocate q of record("q");
7  allocate s;
8
9  while s.compare(q) != 0 do {
10    s.assign("");
11    stdi.getln(s);
12 }
13 delete q;
14 delete s;
```

The example above will keep reading words of the input stream until the word consisting of a single "q" is read.

2.3.8 std.math

Currently the only feature available by importing `std.math` is a single function `mod(int, int)` which returns the first parameter modulo the second. Hence

```
1  import std.math
2  write mod(23, 10);
3  write mod(4, 4);
```

will output:

```
1  3
2  0
```

2.3.9 std.indexable

The type `Indexable` is meant as an interface to data structures which provides random access to variables by index. The interface made available by this type consists of basic functions like `get(int):Object`, `set(int, Object):void` and `size():int` which must be overridden in types that extends `Indexable`. See `std.array` and `std.vector`.
Here the use of the `Object` type is clear, as it allows the `Indexable` type to be more general.

2.3.10 std.array

The `Array` is used as a fixed length array of objects. The `Array` type extends `Indexable` and overrides the functions of `Indexable`.

```
1  import std.object;
2  import std.array;
3
4  type E = record of Object {
5     s:string;
6     func record(s:string):void
7        record.s = s;
8     end record
9
10    func str():string
11       return s;
12    end str
13
14    func finalize():void
15       delete s;
16    end finalize
17 };
18
19 a:Array;
20 allocate a of record(3);
21 e1:E;
22 e2:E;
23 e3:E;
24 allocate e1 of record("e1");
25 allocate e2 of record("e2");
26 allocate e3 of record("e3");
27
28 a.set(0, e1);
29 a.set(2, e3);
30 a.set(1, e2);
31
32 i:int = 0;
33 while (i < a.size()) do {
34    write (cast(E)a.get(i)).str();
35    i = i + 1;
36 }
37
38 a.destroy();
```

Output:

```
1 e1
2 e2
3 e3
```

2.3.11 std.vector

The `Vector` type is extending `Array` and implements a vector of objects. The `Vector` overrides the `size()` function of `Array` and add a new function `append()` to append `Object`'s to the vector, if more space is needed to append another object, the vector will dynamically resize itself. The use is much similar to that of `Array` discussed in the previous subsection.

See later subsection std.sort for an example of use.

2.3.12 std.comparator

The `Comparator` type has a single function `compare(Object, Object):int` and is used as an interface that compares two `Object` type variables. The `Comparator`

should be extended and `Comparator.compare()` overridden such that the object can be cast to the desired type and correctly be compared. See the example below:

```
1  import std.object;
2  import std.comparator;
3
4  type MyType = record of Object {
5     val:int;
6     func record(i:int):void
7        val = i;
8     end record
9  };
10
11 type MyTypeComparator = record of Comparator {
12    func compare(o1:Object, o2:Object):int
13       v:MyType = cast(MyType)o1, v2:MyType = cast(MyType)o2;
14       if(v.val < v2.val) then
15          return 0 - 1;
16       if(v.val > v2.val) then
17          return 1;
18       return 0;
19    end compare
20 };
21
22 v:MyType, v2:MyType;
23 comp:MyTypeComparator;
24 allocate v of record(1);
25 allocate v2 of record(2);
26 allocate comp;
27
28 write comp.compare(v, v2);
29 write comp.compare(v2, v);
30
31 delete comp;
32 delete v2;
33 delete v;
```

Outputs:

```
1  -1
2  1
```

2.3.13 std.sort

By importing " `std.sort` " a function `sort(Indexable, Comparator):void` is available. This function is sorting the indexable, by quick sort using the `Comparator` to compare two objects in the indexable. Since both `Array` and `Vector` are extending `Indexable` they can be sorted by this sort function.

```
1  import std.sort;
2  import std.comparator;
3  import std.vector;
4  import std.object;
5  import std.stdio;
6
7  type CharVector = record of Vector {
8     func print():void
9        i:int = 0;
10       stdo.put("{");
11       while (i < size()-2) do {
12          stdo.put((cast(MyChar)get(i))._c).put(", ");
13          i = i + 1;
14       }
15       i = i + 1;
16       stdo.put((cast(MyChar)get(i))._c).put("}").ln();
17    end print
18
```

```
19      func println():void
20          print();
21          stdo.ln();
22      end println
23  };
24
25  type MyChar = record of Object {
26      _c:char;
27      func record(c:char):void
28          _c = c;
29      end record
30  };
31
32  type CharComparator = record of Comparator {
33      func compare(o1:Object, o2:Object):int
34          if ((cast(MyChar)o1)._c < (cast(MyChar)o2)._c) then
35              return 0 - 1;
36          if ((cast(MyChar)o1)._c > (cast(MyChar)o2)._c) then
37              return 1;
38          return 0;
39      end compare
40  };
41
42  vec:CharVector;
43  allocate vec;
44
45  c:char = 'z';
46  while (c >= 'a') do {
47      tmp:MyChar;
48      allocate tmp of record(c);
49      vec.append(tmp);
50      c = c - 1;
51  }
52
53  vec.print();
54
55  comp:CharComparator;
56  allocate comp;
57  sort(vec, comp);
58  delete comp;
59
60  vec.print();
61
62  vec.destroy();
```

Output:

```
1  {z, y, x, w, v, u, t, s, r, q, p, o, n, m, l, k, j, i, h, g, f, e, d, c, a}
2  {a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, z}
```

2.3.14 std.thread

This is the package containing the `Thread` record which we extend when we need an extra thread of execution. We must make sure to compile with the `-thread` option enabled if we want to import the `Thread`.

To create a new thread we extend the `Thread` record and override the `run()` function. This function is called once the thread is started.

The `Thread` record defines a function called `start()`. We use the `start()` function to start the execution of the thread.

After we have started a thread we may call the `join()` function to wait for the thread to finish execution.

The functions inside the `Thread` record return `true` if they succeed and `false` if they fail. Upon failure `errno` is set accordingly.

An example of using the `Thread` record follows:

```
import std.thread;
import std.stdio;
import std.errno;
import std.stdlib;

type Resource = record of {
   val:int;

   func record():void
      val = 0;
   end record

   func inc():void
      val = val + 1;
   end inc

   func put():void
      stdo.putln(val);
   end put
};

type T = record of Thread {
   res:Resource;
   func record(r:Resource):void
      res = r;
   end record

   func run():void
      i:int = 0;
      while i < 1000000 do {
         res.inc();
         i = i + 1;
      }
      res.put();
   end run
};

res:Resource;
allocate res;

t1:T;
t2:T;
t3:T;
allocate t1 of record(res);
allocate t2 of record(res);
allocate t3 of record(res);

if t1.error() || t2.error() || t3.error() then {
   stdo.putln(errno);
   exit(2);
}

if !t1.start() || !t2.start() || !t3.start() then {
   stdo.putln(errno);
   exit(3);
}

if !t1.join() || !t2.join() || !t3.join() then {
   stdo.putln(errno);
   exit(4);
}

delete t1;
delete t2;
delete t3;
delete res;
```

Saving this to a file called `nondet_thread.vit` and compiling with

```
vitaly nondet_thread.vit --thread
```

will output the executable `a.out`.

Since three threads `t1`, `t2` and `t3` are simultaneously accessing the same resource `res` without use of synchronization, the output of this program is nondeterministic.

Whenever we run this program we will often experience different outputs. An example output is:

```
1035767
1794331
2333902
```

2.3.15 std.lock

We import `std.lock` whenever we need to synchronize the execution of threads, `std.lock` exposes the `Lock` record.

The `Lock` record has the functions `lock()` and `unlock()` which are used when we need to acquire and release a resource respectively.

When one thread have a `lock()` on a `Lock` record other threads calling the `lock()` function are put to sleep until the first thread releases the lock by calling `unlock()`.

That is, only one thread is allowed to have a lock at any given time. A modification of the example from the previous subsection using `Lock` is shown below:

```
import std.thread;
import std.lock;
import std.stdio;
import std.errno;
import std.stdlib;

type Resource = record of {
   val:int;
   lock:Lock;

   func record():void
      val = 0;
      allocate lock;
   end record

   func error():bool
      return lock.error();
   end error

   func acquire():bool
      return lock.lock();
   end acquire

   func release():bool
      return lock.unlock();
   end release

   func inc():void
      val = val + 1;
   end inc

   func put():void
      stdo.putln(val);
   end put

   func finalize():void
      delete lock;
   end finalize
};

type T = record of Thread {
```

```
42     res:Resource;
43     func record(r:Resource):void
44        res = r;
45     end record
46
47     func run():void
48        res.acquire();
49        i:int = 0;
50        while i < 1000000 do {
51           res.inc();
52           i = i + 1;
53        }
54        res.put();
55        res.release();
56     end run
57  };
58
59  res:Resource;
60  allocate res;
61  if res.error() then {
62     stdo.putln(errno);
63     exit(1);
64  }
65
66  t1:T;
67  t2:T;
68  t3:T;
69  allocate t1 of record(res);
70  allocate t2 of record(res);
71  allocate t3 of record(res);
72
73  if t1.error() || t2.error() || t3.error() then {
74     stdo.putln(errno);
75     exit(2);
76  }
77
78  if !t1.start() || !t2.start() || !t3.start() then {
79     stdo.putln(errno);
80     exit(3);
81  }
82
83  if !t1.join() || !t2.join() || !t3.join() then {
84     stdo.putln(errno);
85     exit(4);
86  }
87
88  delete t1;
89  delete t2;
90  delete t3;
91  delete res;
```

Saving that in a file called `det_thread.vit` and compiling with:

```
1  vitaly det_thread.vit --thread
```

will give us the executable `a.out`. In contrast to the example from the previous subsection we use the `Lock` record to synchronize the threads. Thus, assuming no errors, the output from this program is deterministic:

```
1  1000000
2  2000000
3  3000000
```

3 Compiler flags

In the following sections the different flags of the compiler will shortly be introduced.

3.1 General flags

General purpose flags:

```
--help (-h)
  display this message
--help=optimize
  display information about optimization options
--help=warning
  display information about warning options
--help=dump
  display information about options for dumping internal
  data structures

--output=OUTFILE (-o OUTFILE)
  write output to OUTFILE
--main (-m)
  insert code that calls function main when linking program
--ign-main
  ignore the --main (-m) option
--lib-init
  put code in the global scope into an initialization section
  executed before the normal initialization section
--ign-lib-init
  ignore the --lib-init option
--thread
  include support for libvitaly threads
--ign-thread
  ignore the --thread option
--no-libvit (-x)
  do not link with libvitaly (standard library becomes inaccessible)
--ign-no-libvit
  ignore the --no-libvit (-x) option
--lib-path=PATH (-L PATH)
  add PATH to the list of paths with library files
--lib=LIB (-l LIB)
  link against library LIB accessible though one of the library
  search paths
--import-path=PATH (-i PATH)
  add PATH to the list of paths searched when looking for import files
--max-msg=n
  do not produce more than n error and warning messages
--stubborn
  keep compiling new input source files, even when errors are detected
--ign-stubborn
  ignore the --stubborn option
--compile-only (-c)
  assemble, compile and keep object files, but do not link
--ign-compile-only
  ignore the --compile-only (-c) option
--asm-only (-s)
  produce assembly output, do not compile or link
--ign-asm-only
  ignore the --asm-only (-s) option
--keep-obj (-k)
  keep generated object files
--ign-keep-obj
  ignore the --keep-obj (-k) option
--verbose (-v)
  print verbose output to standard output
--ign-verbose
  ignore the --verbose (-v) option
--recursive (-r)
  recursive compilation, automatically compile imported files
--ign-recirsive
  ignore the --recursive (-r) option
--gen-viti (-I)
  generate a .viti file used as import file instead of the
  corresponding .vit file
--ign-gen-viti
  ignore the --gen-viti (-I) option
```

3.2 Optimize flags

Options for enabling and disabling optimizations

```
--optimize=OPTION[,OPTION]... (-O OPTION[,OPTION]...)
  OPTION
    all [enabled by default]
      enable all optimizations
    ign-all
      disable all optimization options

    const-prop [enabled by default]
      do constant propagation optimization
    ign-const-prop
      ignore the const-prop optimization option
    instr-elim [enabled by default]
      do instruction elimination optimization (dead code elimination)
    ign-instr-elim
      ignore the instr-elim optimization option
    unused-mov [enabled by default]
      try to minimize the number register to register mov instructions
    ign-unused-mov
      ignore the unused-mov optimization option
    unused-set [enabled by default]
      try to eliminate useless set instructions
    ign-unused-set
      ignore the unused-set optimization option
    reg-vars [enabled by default]
      try to keep variables in registers when possible
    ign-reg-vars
      ignore the reg-vars optimization option
    def-to-use [enabled by default]
      move definitions of variables closer to where they are used
    ign-def-to-use
      ignore the def-to-use optimization option
    func-access [enabled by default]
      detect information about which variables functions are using
    ign-func-access
      ignore the func-access optimization option
```

3.3 Warning flags

Options for enabling and disabling warnings

```
--warning=OPTION[,OPTION]... (-w OPTION[,OPTION]...)
  OPTION
    all
      enable all warning options
    ign-all
      disable all warning options

    is-error
      treat warnings as errors
    ign-is-error
      ignore the is-error warning option

    no-finalize
      show warning when extended records doesn't have a finalize function
    ign-no-finalize
      ignore the no-finalize warning option
    implicit-cast [enabled by default]
      give warning about implicit type casts
    ign-implicit-cast
      ignore the implicit-cast warning option
    ref-compare [enabled by default]
      give warning when comparing reference types
    ign-ref-compare
      ignore the ref-compare warning option
    overflow [enabled by default]
      give warning when overflow is detected
```

```
   ign-overflow
    ignore the overflow warning option
   div-zero [enabled by default]
    give warning when division by zero is detected
   ign-div-zero
    ignore the div-zero warning option
   uninitialized [enabled by default]
    give warning when variables might be uninitialized before use
   ign-unitialized
    ignore the unitialized warning option
```

3.4 Dump flags

Options for dumping internal data structures:

```
--dump=OPTION[,OPTION]...
  OPTION
    parse-tree
     dump XML parse tree
    parse-tree-graph
     dump PDF parse tree
    symbol-table
     dump ACSII symbol table
    symbol-table-graph
     dump PDF symbol table
    init-ic
     dump initial intermediate code representation
    norm-addr-ic
     dump intermediate code representation right after initial
     normalization of addressing instructions
    const-prop-ic
     dump intermediate code after each constant propagation pass
    instr-elim-ic
     dump intermediate code after dead instruction elimination passes
    def-to-use-ic
     dump intermediate code after def-to-use optimization pass
    norm-x86-32-ic
     dump intermediate code after instructions have been converted to
     x86-32 compatible instructions
    unused-mov-ic
     dump intermediate code after elimination of unused mov instructions
    reg-alloc-x86-32-ic
     dump intermediate code right after register allocation
    reg-vars-liveness-ic
     dump liveness analysis before deciding which variables should
     stay in registers
    reg-vars-ic
     dump liveness analysis after register variables have been chosen
    init-liveness-x86-32-ic
     dump liveness analysis before register allocation
    liveness-x86-32-ic
     dump liveness analysis right before assigning pseudo registers to
     x86-32 registers
    reg-alloc-x86-32-ic
     dump intermediate code right after register allocation
    warn-uninit-liveness-ic
     dump liveness analysis before locating variables which might be
     uninitialized before use
    final-x86-32-ic
     dump final intermediate code representation before emitting
     machine code
    c-header
     dump C header file with vitaly record declarations as C structs
    asm
     dump assembly source file before assembling
```

4 Compiler Library

The C programming language has been chosen as implementation language for the vitaly compiler. The most noticeable advantages of C are efficiency and portability, especially because of the `gcc` C compiler which we are using in the project.

However, as a general purpose programming language, C does have disadvantages. Noticeable is the lack of commonly used data structures like linked lists, hash maps and search trees in the standard library, and the limited support for object oriented features like inheritance and polymorphism.

To cope with the missing data structures in the C standard library we have implemented a little, but efficient, library offering the most common data structures needed. The report contains a section which shortly describes this library.

The compiler library implements:

1. String data structure.
2. Single linked list.
3. Double linked list.
4. Vector.
5. Dynamic hash map.
6. Red black tree.
7. Debugging facilities.

4.1 String

The `String` data structure is heavily used in the project, thus we are going to take a through discussion of this data structure and how to use it.

The `String` data structure is preferred over the raw `char *` for the following reasons:

- The `String` data type is dynamic. With a single line of code reassign the string without thinking about freeing and allocating memory.
- The `String` data structure is getting stronger and stronger. Every time we need new functionality from the `String` data type it is implemented.
- Our `String` is as easy to initialize as a `char *`.
- The `String` data structure is almost as efficient as `char *`.

How do we use the `String` data structure?

```
1 String s = STRING_INIT(s, "I'm a string");
2 Const_String cs = S("I'm a constant String");
```

In the example above we are initializing a new `String` named `s` with the value `"Im' a string"`. If this happens inside a function the string is allocated on the stack and no string copying is done. The string is internally assigned the `"I'm a string" const char *`. The `S()` macro is defined to allow convenient initialization of constant strings (`Const_String`) as in the example. A decent amount of functions in the project take strings as arguments.

The following code example will show some of the benefits of the `String` data structure:

```
1  // Declare and initialize str with "He"
2  STRING(str, "He");
3  // Internally str is pointing to the const char * "He"
4
5  // Append "llo" to str
6  string_append(str, S("llo"));
7  // Now str is assigned a dynamically allocated char * "Hello"
8
9  // Get a copy of str
10 String cpy = string_duplicate(str);
11
12 // Print: Hello
13 print_message(cpy);
14
15 // Allocate a new string from the format "%S %S",
16 // where %S is to String what %s is to char *
17 String fmt = string_from_format(S("%S %S"), cpy, str);
18
19 // Print: Hello Hello
20 print_message(fmt);
21
22 // Print: Hello Hello Hello
23 print_message(S("%S %S"), str, fmt);
24
25 // Clean up
26 string_clear(str);
27 string_destroy(cpy);
28 string_destroy(fmt);
```

Note that `str` was allocated on the stack and we use `string_clear` to deallocate memory used by that `String`. The strings `cpy` and `fmt` was dynamically allocated and `string_destroy()` was used to deallocate them.

Want more information on strings? Take a look at the `src/str.h` and `src/str.c` appendices.

4.2 Linked Lists

Our library also implements two linked list data structures, single linked list and double linked list. Some of the data structures in the library make use of the object oriented concept "inheritance" the linked lists are among those data structures. E.g. if we want to make use of the double linked list (`Double_List`) we must create a struct which inherits/contains the `Double_List_Node` struct. An example follows:

```
1  struct Db_Entry {
2     Double_List_Node dbnode;
3     String data;
4  };
```

Initializing a new double list and appending a `struct Db_Entry our_entry` to the list works as follows:

```
1  DOUBLE_LIST(dblist);
2  double_list_append(&dblist, &our_entry.dbnode);
```

Think of `&our_entry.dbnode` as casting the `struct Db_Entry` to a `Double_List_Node`.

If we want to iterate through all the nodes in the double linked list `dblist` from the previous example. We do as follows:

```
struct Db_Entry *entry;
Double_Lide_Node *n;
DOUBLE_LIST_FOR_EACH(&dblist, n) {
   entry = DOUBLE_LIST_ENTRY(n, struct Db_Entry, dbnode);
   process_data(entry->data); // Or whatever
}
```

Essentially what we are doing is: for each `Double_List_Node *n` in the double linked list we are casting it back into the inheriting/containing `struct Db_Entry *`.

The `DOUBLE_LIST_ENTRY()` macro makes use of `gcc` extensions to the C programming language.

The single linked list (`Single_List`) works in much the same way.

For more info on the linked list data structures see the `src/double_list.h`, `src/double_list.c`, `src/single_list.h` and `src/single_list.c` appendices.

4.3 Vector

Essentially the same data structure as the C++ `vector` or Javas `ArrayList`, a dynamic array.

The vector is initialized with some size `n`. When `n` elements are inserted in the vector it automatically expands to size `n := 2*n`. When removing elements from the vector it decreases its size to `n := n/2` when the number of elements is less than `n/4`.

The `Vector` data structure is very efficient, and we don't inherit anything to use it. Calling `vector_append(v, data)` will append data to the end of the `Vector *v`.

For more information on `Vector` check out the `src/vector.h` and `src/vector.c` appendices.

4.4 Dynamic Hash Map

Our dynamic hash map (`Hash_Map`) is using the `Single_List` data structure for chaining. It automatically increases the number of hash slots when the load factor exceeds `0.75` and decreases the number of slots when the load factor drops below `0.1875`.

When initializing a new hash map we must pass it a `Hash_Map_Comparator` function used when searching the hash map for data. An example of inserting data in a `Hash_Map` might be:

```
struct Hash_Entry {
   Hash_Map_Slot hslot;
   String data;
};

bool comparator(String search_str, Hash_Map_Slot *map_slot) {
   struct Hash_Entry *e = HASH_MAP_ENTRY(map_slot, struct Hash_Entry, hslot)
   return string_compare(search_str, e->data) == 0;
}

HASH_MAP(hmap, comparator);

void insert(String s) {
   struct Hash_Entry *e = malloc(sizeof(struct Hash_Entry));
   e->data = string_duplicate(s);
```

```
16    hash_map_insert(&hmap, &e->hslot, string_hash_code(s));
17 }
```

Again, we are making use of inheritance to cast between `struct Hash_Entry *` and `Hash_Map_Slot *`.

The dynamic hash map also has a for-each loop. To emphasize how far we go to provide such a feature, just take a look at the following implementation of the `Hash_Map` for-each loop:

```
1  // XXX - Use goto to break this loop.
2  #define HASH_MAP_FOR_EACH(map, slot)                        \
3     if ((map)->slots)                                        \
4        for (Single_List_Node *___n, *___i = 0;               \
5              PTR_TO_UINT(___i) < (map)->num_slots;           \
6              ___i = INT_TO_PTR(PTR_TO_UINT(___i) + 1))       \
7           SINGLE_LIST_FOR_EACH(&(map)->slots[PTR_TO_UINT(___i)], ___n) \
8              if ((slot = HASH_MAP_SLOT_OF(___n)) || !slot)
```

The `Hash_Map` data structure is used in the symbol table implementation. For more information on `Hash_Map` take a look at the appendices `src/hash_map.h` and `src/hash_map.c`.

4.5 Red Black Tree

The red black tree also makes use of inheritance and is implemented much like the red black tree inside of the Linux kernel and is described in Thomas H. Cormen ... [et al.] - Introduction To Algorithms.

The red black tree implementation is very much optimized compared to the one described in Thomas H. Cormen ... [et al.]. If you are interested in the red black tree implementation check out the `src/rb_tree.h` and `src/rb_tree.c` appendices.

4.6 Debugging Facilities

The last feature from the compiler library we are going to discuss is the debugging facilities. Two macros `DEBUG()` and `DLOG()` are defined. We feed the `DEBUG()` macro with source code for debugging purposes. For example:

```
1  #undef DEBUG_TYPE
2  #define DEBUG_TYPE my-debug-type
3  DEBUG(
4     file_print_message(stderr, S("Log this to stderr\n"));
5  );
```

Note that the `DEBUG_TYPE` macro is redefined. This is done to specify how to enable the statements inside the `DEBUG()` macro. Whenever the `DEBUG` environment variable matches the regular expression `(.*:)?my-debug-type(:.*)?` and the `NDEBUG` preprocessor macro is undefined and execution reaches line 4 in the example, the `file_print_message()` function is called.

So if we want to enable multiple debug types we can export the `DEBUG` environment variable such that `DEBUG=symbol-table:parser-parse:parser-recover` .

The `DLOG()` macro is defined as follows

```
1  #define DLOG(fmt, ...) \
2     DEBUG(file_print_message(stderr, S(fmt), ## __VA_ARGS__);)
```

The `__VA_ARGS__` is a `gcc` extension and essentially allows us to pass a variable number of arguments to macros.

There is more information about the debugging facilities in the appendices `src/debug.h` and `src/debug.c`.

5 The Vitaly Grammar

Our parser extends the standard Vitaly grammar to offer some more advanced features. A simplified version of the extended Vitaly grammar is described below. Terminals are written in **bold** font and non-terminals are surrounded with angle brackets.

⟨*start*⟩ ::= ⟨*opt-package*⟩ ⟨*start-body*⟩

⟨*start-body*⟩ ::= ⟨*decl-stmt-list*⟩
| ϵ

⟨*opt-package*⟩ ::= ⟨*package*⟩
| ϵ

⟨*package*⟩ ::= **package module-const ;**

⟨*function*⟩ ::= ⟨*func-head*⟩ ⟨*opt-decl-stmt-list*⟩ ⟨*func-tail*⟩

⟨*func-head*⟩ ::= **func** ⟨*func-id*⟩ **(** ⟨*opt-par-decl-list*⟩ **) :** ⟨*void-type*⟩

⟨*func-tail*⟩ ::= **end** ⟨*func-id*⟩

⟨*func-id*⟩ ::= **id**
| **finalize**
| **record**

⟨*extern-function*⟩ ::= **extern (id) func id (** ⟨*opt-par-decl-list*⟩ **) :** ⟨*void-type*⟩

⟨*opt-par-decl-list*⟩ ::= ⟨*par-decl-list*⟩
| ϵ

⟨*par-decl-list*⟩ ::= ⟨*par-decl-list*⟩ **,** ⟨*var-type*⟩
| ⟨*var-type*⟩

⟨*void-type*⟩ ::= ⟨*type*⟩
| **void**

⟨*type*⟩ ::= **id**
| **int**
| **bool**
| **array of** ⟨*type*⟩
| **char**
| **string**
| ⟨*record-decl*⟩

⟨*record-decl*⟩ ::= ⟨*record-head*⟩ **{** ⟨*opt-record-decl-list*⟩ **}**

⟨*record-head*⟩ ::= **record of** ⟨*opt-extend-list*⟩

⟨*opt-extend-list*⟩ ::= ⟨*extend-list*⟩
| ϵ

⟨*extend-list*⟩ ::= ⟨*extend-list*⟩ **, id**
| **id**

⟨*opt-record-decl-list*⟩ ::= ⟨*record-decl-list*⟩
| ϵ

⟨*record-decl-list*⟩ ::= ⟨*record-decl-list*⟩ ⟨*record-member*⟩
| ⟨*record-member*⟩

⟨*record-member*⟩ ::= ⟨*function*⟩
| ⟨*var-type*⟩ ⟨*record-seperator*⟩
| **var** ⟨*var-type*⟩ ⟨*record-seperator*⟩
| ⟨*type-def*⟩ ⟨*record-seperator*⟩
| ⟨*import-start*⟩ ⟨*record-seperator*⟩
| ⟨*record-seperator*⟩

⟨*record-seperator*⟩ ::= **,**
| **;**

⟨*var-decl-list*⟩ ::= ⟨*var-decl-list*⟩ **,** ⟨*var-decl-type*⟩
| ⟨*var-decl-type*⟩

⟨*var-decl-type*⟩ ::= ⟨*var-type*⟩
| ⟨*var-type*⟩ **=** ⟨*expression*⟩

⟨*var-type*⟩ ::= **id :** ⟨*type*⟩

⟨*opt-decl-stmt-list*⟩ ::= ⟨*decl-stmt-list*⟩
| ϵ

⟨*decl-stmt-list*⟩ ::= ⟨*decl-stmt-list*⟩ ⟨*decl-stmt*⟩
| ⟨*decl-stmt*⟩

⟨*decl-stmt*⟩ ::= ⟨*declaration*⟩
| ⟨*statement*⟩

⟨*declaration*⟩ ::= ⟨*function*⟩
| ⟨*extern-function*⟩ **;**
| ⟨*type-def*⟩ **;**
| **var** ⟨*var-decl-list*⟩ **;**
| ⟨*var-decl-list*⟩ **;**

⟨*type-def*⟩ ::= **type id =** ⟨*type*⟩

⟨*statement*⟩ ::= **;**
| ⟨*import-start*⟩ **;**
| **allocate** ⟨*variable*⟩ **;**
| **allocate** ⟨*variable*⟩ **of record (** opt-exp-list **) ;**
| **allocate** ⟨*variable*⟩ **of length** ⟨*expression*⟩ **;**
| **delete** ⟨*variable*⟩ **;**
| **return ;**
| **return** ⟨*expression*⟩ **;**
| **write** ⟨*expression*⟩ **;**
| ⟨*variable*⟩ **=** ⟨*expression*⟩ **;**
| ⟨*expression*⟩ **;**
| **if** ⟨*expression*⟩ **then** ⟨*decl-stmt*⟩ ⟨*opt-else*⟩
| **while** ⟨*expression*⟩ **do** ⟨*decl-stmt*⟩
| **{** ⟨*opt-decl-stmt-list*⟩ **}**
| **finalize** ⟨*decl-stmt*⟩

⟨*opt-else*⟩ ::= **else** ⟨*decl-stmt*⟩
| ϵ

⟨*import-start*⟩ ::= **import module-const**

⟨*expression*⟩ ::= ⟨*expression*⟩ ⟨*bin-op*⟩ ⟨*expression*⟩
| ⟨*term*⟩

⟨*term*⟩ ::= ⟨*variable*⟩
| **(** ⟨*expression*⟩ **)**
| **|** ⟨*expression*⟩ **|**
| **!** ⟨*term*⟩
| ⟨*type-cast*⟩ ⟨*term*⟩
| **int-const**
| **char-const**
| **string-const**
| **true**
| **false**
| **null**

⟨*variable*⟩ ::= ⟨*variable*⟩ **.** ⟨*variable-id*⟩
| ⟨*variable*⟩ [⟨*expression*⟩]
| **(** ⟨*variable*⟩ **)**
| ⟨*type-cast*⟩ ⟨*variable*⟩
| ⟨*record-id*⟩
| ⟨*direct-record-ref*⟩ **.** ⟨*variable-id*⟩
| ⟨*direct-record-ref*⟩ **(** ⟨*opt-exp-list*⟩ **)**

⟨*record-id*⟩ ::= ⟨*variable-id*⟩
| **record**

⟨*variable-id*⟩ ::= **id**
| **id (** ⟨*opt-exp-list*⟩ **)**

⟨*direct-record-ref*⟩ ::= **record** [**id**]
| **record** [ ]

⟨*type-cast*⟩ ::= **cast** (⟨*type*⟩)

⟨*opt-exp-list*⟩ ::= ⟨*exp-list*⟩
| ϵ

⟨*exp-list*⟩ ::= ⟨*exp-list*⟩ **,** ⟨*expression*⟩
| ⟨*expression*⟩

⟨*bin-op*⟩ ::= **||**
| **&&**
| **==**
| **!=**
| **<**
| **>**
| **<=**
| **>=**
| **+**
| **-**
| *****
| **/**

Most of the terminal symbols (the symbols written in **bold**) are literally as they appear in the grammar, i.e. they are either keywords or special symbols. However there are 5 terminals **id**, **int-const**, **char-const**, **string-const** and **module-const** which differ from this rule.

- The terminal **id** is any identifier not a keyword and recognized by the regular expression `[a-zA-Z_][a-zA-Z_0-9]*`.
- The **int-const** is any non negative integer.
- **char-const** is a character surrounded by single quotes or an escape character, much like we know escape characters like `'\n'` from the C programming language.
- **string-const** is a string literal surrounded by double quotes. Like C strings our strings also support escape characters inside of them. Thus an example of a string literal is `"Hello\n"`.
- The **module-const** terminal symbol is one or more identifiers optionally separated by **.**, that is the regular expression:
  `([a-zA-Z_][a-zA-Z_0-9]*\.?)*[a-zA-Z_][a-zA-Z_0-9]*`

Our Vitaly grammar extends the original Vitaly grammar in the following ways:

1. New primitive types: `string`, `char`.
2. Functions and variables may be declared anywhere.
3. Variables can be initialized, where they are declared (`var i:int = 10;`).

4. Support for multiple dot references (`rec.ary[0].fun(1, 2).field`).
5. Added `delete` keyword to free memory allocated by `allocate` .
6. Extensions to functions:

   Added return type `void` .

   Allow empty function bodies.
7. Extensions to records:

   Record fields can also be separated by ';'.

   Allow unlimited number of separators between record fields.

   Allow `var` keyword before record field declarations.

   Allow type definitions inside records.

   Functions can be defined inside records.

   Records can extend multiple other records (multiple inheritance).

   Records can have empty bodies.
8. Added type cast with `cast(T) v` , where `T` is a type and `v` is a variable which is casted to type `T` .
9. Added `finalize` statement to put code into a special finalize section.
10. Added `import` keyword to import other vitaly source files.
11. Added `package` keyword to organize imports.
12. Added extern function declarations, ability to call C functions from vitaly.
13. Record function can directly reference its base record, or its own, functions using the `record[id].fun()` syntax.

The extensions in the list are discussed more thoroughly in other sections.

6 Parsing

Our parser is using `flex` and `bison` for scanning and parsing respectively. The `flex` tool reads/scans files and converts them into token streams which the `bison` tool can use for parsing.

The tools `flex` and `bison` introduce some limitations when it comes to error recovery, however with proper hacking we can tweak the tools and implement decent error recovery and error reporting mechanisms.

6.1 Scanning

The `flex` file is attached as appendix `src/parser/scanner.l` , and basically gives the parser the next token in the input whenever asked for it. The `flex` file is so simple we will refer to the appendix `src/parser/scanner.l` for more info on the scanner implementation.

6.2 Parsing

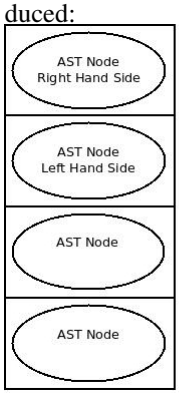
The `bison` file is in the appendix `src/parser/parser.y`.

Our goal of parsing is to generate an abstract syntax tree (AST). Nodes in the AST can have an arbitrary number of children and the AST nodes are often generated when grammar productions are reduced.

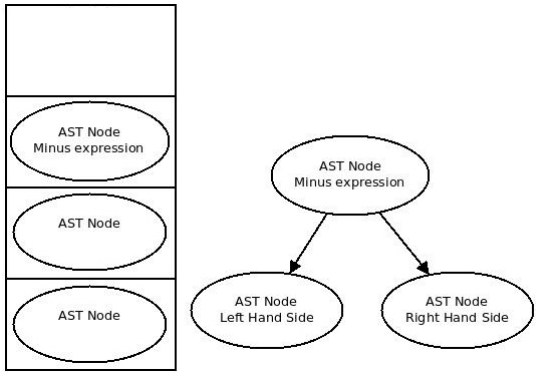
Whenever a production like $\langle expression \rangle$ is reduced an AST node is pushed on a stack.

As an example we will consider what happens when a binary expression like $\langle expression \rangle$ - $\langle expression \rangle$ is reduced to $\langle expression \rangle$.

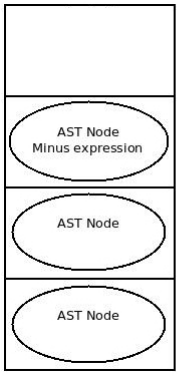
We know there are two AST nodes on top of the stack. The first AST node was pushed on the stack when the expression on the left hand side was reduced and the other AST node was pushed on the stack when the right hand side expression was reduced:



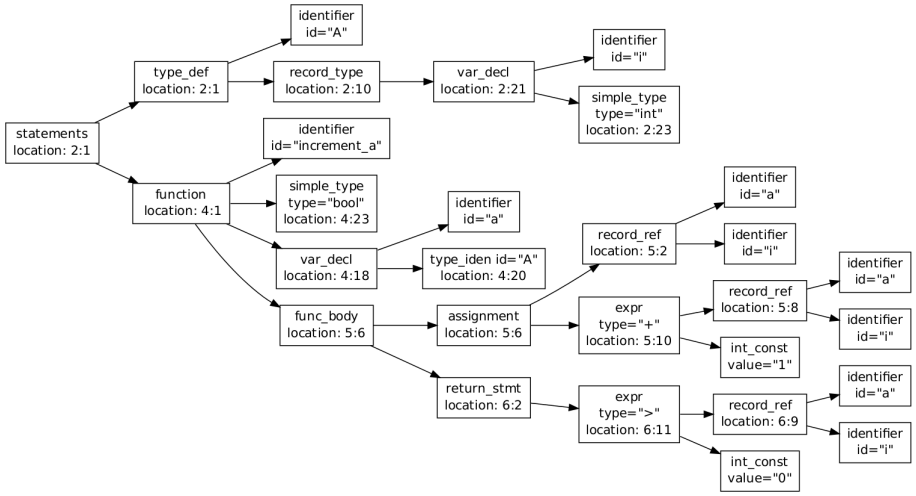
Thus we can pop these two AST nodes from the stack and generate a new AST node with the recently popped AST nodes as children:



At last we push the minus expression node back onto the stack:



After parsing a simple program the AST might look something like:



Which is an AST generated by the compiler with the `-dump=parse-tree-graph` option enabled. As we can see the AST nodes contain information about the parsed program. For instance the function AST node contains a function identifier, a return type, a list of parameters, and a function body.

One thing common to all AST nodes is that they have a location, that is a line number and a column number. We use `bison` s semantic values to keep track of token locations and string representations. In most cases we are relying on `bison` s default action for setting the semantic value of a symbol which is:

```
1 $$ = $1 // Save semantic value of first symbol in resulting symbol $$
```

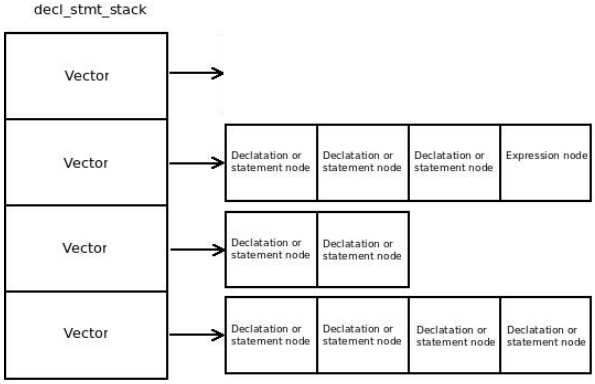
We are using a number of `Vector` data structures as AST node stacks. To understand how it's working we will consider what happens when recognizing an if-statement. The slightly simplified `bison` code looks as follows:

```
1 statement
2    : TKN_IF_KEY expression TKN_THEN_KEY {
3       push_vector_stack(&decl_stmt_stack);
4    } decl_stmt {
5       Vector *statements = pop_vector_stack(&decl_stmt_stack);
6       Ast_Node *s = GET_STMT_LIST(AST_STMT_LIST, statements);
7       push_ast_node(&decl_stmt_stack, s);
8       PARSER_BINARY_NODE(AST_IF_STMT, $1.lineno, $1.startcol);
```

```
9       }
10      // Other production rules
```

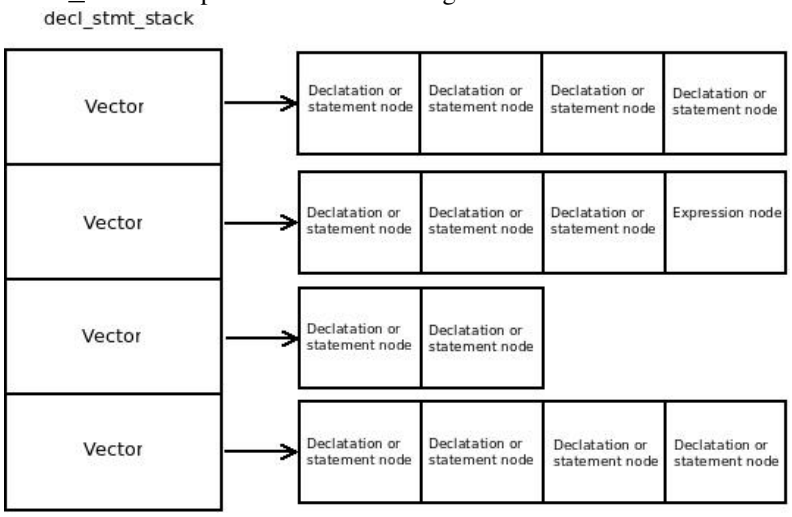
The `decl_stmt_stack` is a stack of vectors and when we have recognized the **if** keyword, an $\langle expression \rangle$ and the **then** keyword we will (in the mid-rule action) push a new `Vector` for declaration and statement AST nodes on top of the `decl_stmt_stack`. Whenever we recognize a declaration or statement we allocate an AST node for it and append that AST node to the end of the `Vector` on top of the `decl_stmt_stack`.

So right before starting to recognize `decl_stmt` the picture looks something like this:



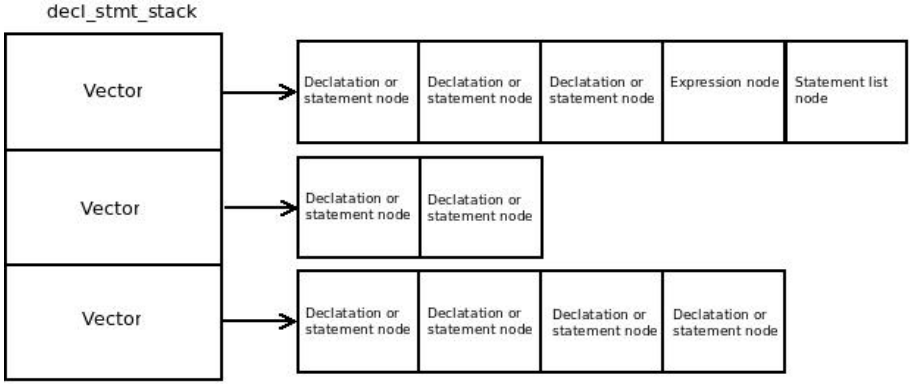
Where the `Vector` on the top is also the `Vector` on top of the `decl_stmt_stack`.

As we know one of the `decl_stmt` productions is involving a list of declarations and statements, so we don't know how many statements or declarations we will append to the `Vector` on top of the `decl_stmt_stack` before reducing `decl_stmt`. Anyway, right after reducing `decl_stmt` the picture looks something like this:

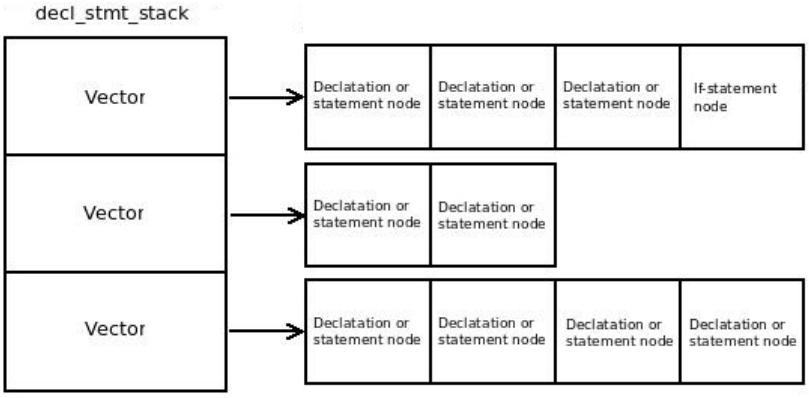


Now we (in the end-of-rule action) pop the `Vector` on top of the `decl_stmt_stack` and allocate a new statement list AST node which we append to the `Vector` which is now on top of the `decl_stmt_stack`. Note that the `Vector` which was popped from the `decl_stmt_stack` is passed to the statement list AST node.

The picture now looks as follows:



The last thing we do (with the `PARSER_BINARY_NODE()` macro) is to pop the statement list node and expression node from the `Vector` on top of the `decl_stmt_stack` and append an if-statement node instead. After the $\langle statement \rangle$ has been reduced the `decl_stmt_stack` is as shown below:



This example should serve as a good introduction to how the parser algorithm is implemented.

The tool `bison` is great as long as we don't care about recovering from syntax errors or supplying the user with good error messages. We certainly do care about this, thus we had to find some reasonable way to recover from errors.

We are relying on `bison` s error recovery mechanism in a pretty limited fashion in our implementation. An example of it's use is:

```
1  decl_stmt
2     : declaration {
3        // ...
4     }
5     | statement {
6        // ...
7     }
8     | errors %prec decl_stmt_prec {
9        RECOVER_EXPEC(decl_stmt_recover, $errors.lineno,
10             $errors.startcol);
11    }
12    ;
```

When an unexpected token comes in the middle of a statement or declaration we catch the error with the `errors` non-terminal. But after catching the error we take care of recovering ourselves.

The `RECOVER_EXPEC()` macro is responsible for reporting the syntax error and calling the `decl_stmt_recover()` function. The `decl_stmt_recover()` function eats up tokens from `flex` until it discovers a consistent state such that it can give back control to `bison` and let `bison` do what it's good at, namely parsing syntactically correct code.

By defining

```
%define parse.lac full
%error-verbose
```

we tell bison to supply more verbose error messages. However we don't use `bison` 's error messages. We process the messages to extract the information we need and supply our own error messages. Although it isn't perfect, it does result in better error messages to the user.

6.3 Abstract Syntax Tree

Once we have generated the abstract syntax tree (AST) from the `bison` file `src/parser/parser.y` we want to be able to traverse the tree, e.g. at some point we want to generate a symbol table and do type checking given the AST. In this section we will discuss how to implement such an AST traversal, which is called an AST pass in this project, in particular we will talk about how the `src/ast/ast_visitor_print.c` file implements a pretty printer for the AST using an AST pass.

The file `src/ast/ast_visitor.h` contains the `Ast_Visitor` struct which we can think of as an abstract super class supplying the interface that any AST visitor base struct must implement.

Implementing an AST visitor does take some time, the `Ast_Visitor` is declaring 55 abstract methods which must be implemented by any AST visitor base struct.

To implement an AST pass we must first declare a struct which inherits the `Ast_Visitor` . This is done using the `AST_VISITOR_STRUCT_BEGIN()` and `AST_VISITOR_STRUCT_END()` macro pair. The AST pretty printer struct is called `Ast_Visitor_Print` and declared as follows:

```
AST_VISITOR_STRUCT_BEGIN(Ast_Visitor_Print)
   Uns indentation;
   FILE *output_file;
AST_VISITOR_STRUCT_END(Ast_Visitor_Print)
```

Now we must implement the interface specified by the Ast_Visitor, that means we must implement 55 methods. If we don't do so the code will not even compile. The benefit of this is that we make sure not to forget to implement some method which is expected to exist. The `src/ast/ast_visitor.h` file defines the macro pair `ASTVF_BEGIN()` and `ASTVF_END` we need in order to implement the "abstract" methods declared in the `Ast_Visitor` struct. An example of such a method implementation follows:

```
ASTVF_BEGIN(AST_EXPR_FUNC_CALL, Ast_Visitor_Print, v, Ast_Expr_Func_Call, n)
   PRINT_OPEN(v->output_file, "func_call line=\"%U\" column=\"%U\"",
         v->indentation,
         n->ast_node.location.line,
         n->ast_node.location.column);

   v->indentation += INDENT_COUNT;

```

```
9     n->identifier->accept_visitor(n->identifier, AST_VISITOR_OF(v));
10
11    Ast_Node *arg;
12    Vector *vargs = n->arguments;
13    VECTOR_FOR_EACH_ENTRY(vargs, arg)
14       arg->accept_visitor(arg, AST_VISITOR_OF(v));
15
16    v->indentation -= INDENT_COUNT;
17
18    PRINT_CLOSE(v->output_file, "func_call", v->indentation);
19 ASTVF_END
```

In this example we are defining the `Ast_Visitor_Print` method which implements the functionality for pretty printing function call AST nodes (`Ast_Expr_Func_Call`).

The first thing the method does when called is to print an opening `func_call` tag with attributes `line` and `column`.

Later the method is responsible for notifying its AST node children that `Ast_Visitor_Print` wants to visit them. This is done by calling the children node's `accept_visitor()` method. In the above example the `accept_visitor()` methods of the function identifier and function argument nodes are called.

The last thing the method in the example does is to print a closing `func_call` tag.

The AST node's `accept_visitor()` method is responsible for calling the correct `Ast_Visitor` method based on the AST node's type. For example the function call node's `accept_visitor()` method is responsible for calling the function call node `Ast_Visitor` method. The function call AST node `accept_visitor()` method is cryptically defined as follows:

```
1 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_FUNC_CALL);
```

If you are interested in the details how the things in this section is even possible, you should note that all AST node types are given a unique name which is used by macros to generate the correct function and method names. You probably want to take a look at the `src/ast/ast.h`, `src/ast/ast.c`, `src/ast/ast_visitor.h` and `src/ast/ast_visitor_print.c` files to fully understand the magic behind the `Ast` and `Ast_Visitor` implementation.

Given the `inc.vit` file:

```
1 type A = record of {i:int};
2 func increment_a(a:A):bool
3    a.i = a.i + 1;
4    return a.i > 0;
5 end increment_a
```

we can compile the file and get the `Ast_Visitor_Print` output when we specify the `-dump=parse-tree` option:

```
1 vitaly --dump=parse-tree inc.vit
```

This generates a file named `inc.vit.vitaly.parse-tree`, containing an xml representation of the parse tree for `inc.vit`. The xml representation looks as follows:

```
1 <statements line="1" column="1">
2    <type_def line="1" column="1">
3       <identifier id="A" type="record" line="1" column="6" />
```

```
4        <record_type line="1" column="10">
5           <var_decl line="1" column="21">
6              <identifier id="i" type="int" line="1" column="21" />
7              <simple_type type="int" line="1" column="23" />
8           </var_decl>
9        </record_type>
10    </type_def>
11    <function line="2" column="1">
12       <identifier id="increment_a" type="bool" line="2" column="6" />
13       <simple_type type="bool" line="2" column="23" />
14       <var_decl line="2" column="18">
15          <identifier id="a" type="record" line="2" column="18" />
16          <type_iden id="A" line="2" column="20" />
17       </var_decl>
18       <func_body line="3" column="6">
19          <assignment line="3" column="6">
20             <record_ref type="int" line="3" column="2">
21                <identifier id="a" type="record" line="3" column="2" />
22                <identifier id="i" type="int" line="3" column="4" />
23             </record_ref>
24             <expr_plus type="int" line="3" column="10">
25                <record_ref type="int" line="3" column="8">
26                   <identifier id="a" type="record" line="3" column="8" />
27                   <identifier id="i" type="int" line="3" column="10" />
28                </record_ref>
29                <int_const value="1" line="3" column="14" />
30             </expr_plus>
31          </assignment>
32          <return_stmt line="4" column="2">
33             <expr_gt type="bool" line="4" column="11">
34                <record_ref type="int" line="4" column="9">
35                   <identifier id="a" type="record" line="4" column="9" />
36                   <identifier id="i" type="int" line="4" column="11" />
37                </record_ref>
38                <int_const value="0" line="4" column="15" />
39             </expr_gt>
40          </return_stmt>
41       </func_body>
42    </function>
43 </statements>
```

6.4 Error Recovery

Most of the testing of the parser has been to verify that we were outputting an acceptable number of error messages, with correct line and column numbers. The parser was tested with Vitaly source files containing errors much more frequently than it was tested with correct Vitaly source files. The test file `test_programs/errors.vit` is shown below:

```
1  # Error recovery test
2  # Working example
3  type A = record of record of {i:int}, B {s:string};
4  type B = record of {c:char};
5  func equals(a:A, b:B):bool
6     var ret:bool = true;
7     if a != cast(A) b then
8        ret = false;
9     return ret;
10 end equals
11
12 type T1 = record of A B {};
13 type T2 = record of {
14    a a;
15    func foo()
16    end foo;
17 };
18 type T3 = record of };
19 func foo(r:record of):int end foo
20 func foo(i i, b b):bool end foo
```

```
func foo(@):bool end foo
func foo():int
   func foo():record of A {var a:int, bbool};
      return 0 0
   end foo
   type R = record f {};
end foo
```

Feeding our compiler with that file gives the following output:

```
errors.vit:3:20: (error) unexpected 'record', expected '{' or identifier
errors.vit:5:15: (error) unable to resolve type 'A'
errors.vit:7:15: (error) unable to resolve type 'A'
errors.vit:12:23: (error) unexpected 'B', expected ',' or '{'
errors.vit:14:4: (error) unexpected 'a'
errors.vit:16:2: (error) unexpected 'end', expected ':'
errors.vit:18:21: (error) unexpected '}', expected '{' or identifier
errors.vit:19:21: (error) unexpected ')'
errors.vit:20:12: (error) unexpected 'i'
errors.vit:21:10: (error) unexpected '@'
errors.vit:23:23: (error) unable to resolve type 'A'
errors.vit:23:42: (error) unexpected '}'
errors.vit:24:12: (error) unexpected '0'
errors.vit:26:18: (error) unexpected 'f', expected 'of'
vitaly: 14 errors
```

As we see, in this example program, the error recovery is alright. The error messages could have been better, however they are precise about the error locations.

7 Symbol Table

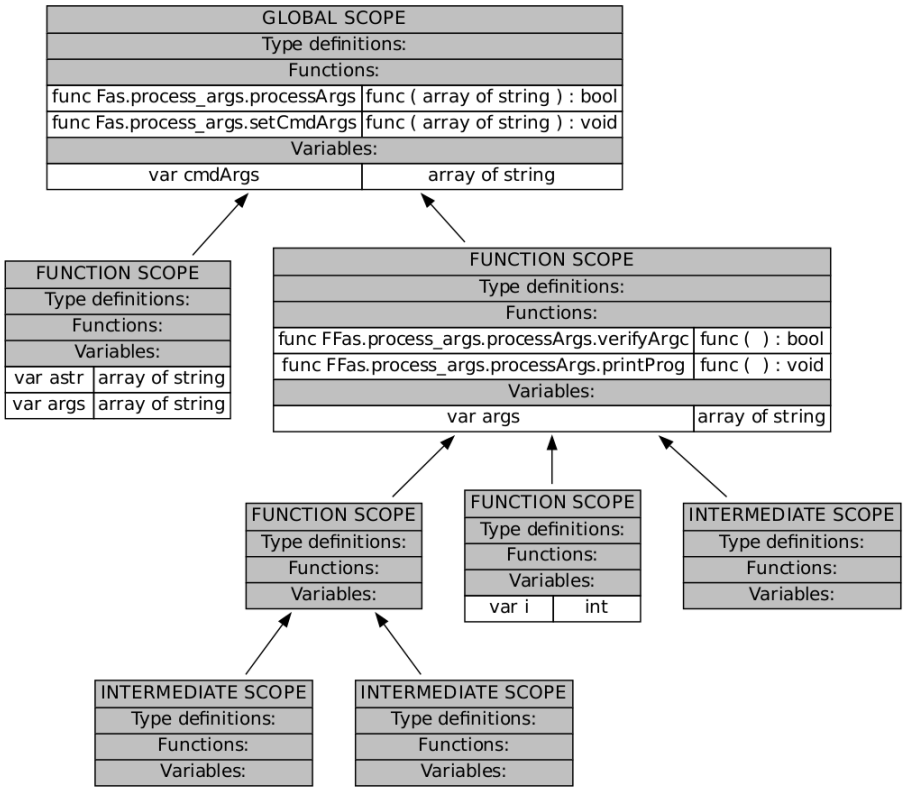
Given a function name, a type name or a variable name we use the symbol table to lookup its type.

One AST pass, implemented in `src/ast/ast_visitor_symbol_table.c`, is dedicated to generating the symbol table.

Invoking vitaly with the `-dump=symbol-table-graph` option and the `process_args.vit` input file:

```
cmdArgs:array of string;
func setCmdArgs(args:array of string):void
   astr:array of string = args;
   cmdArgs = astr;
end setCmdArgs

func processArgs(args:array of string):bool
   func verifyArgc():bool
      if |args| > 1 then
         return true;
      else
         return false;
   end verifyArgc

   func printProg():void
      i:int = 0;
      write args[i];
   end printProg

   if !verifyArgc() then
      return false;

   printProg();
   setCmdArgs(args);
   # Do other stuff ...
   return true;
end processArgs
```

produces the PDF file `process_args.vit.vitaly.symbol-table.pdf` containing a graphical representation of the symbol table:



This graph is a good illustration of how the symbol table works.

The nodes in the graph are referred to as symbol table nodes. Except from the root node, each symbol table node contains a reference to its parent symbol table node.

Entering the body of a function or an if-statement opens a new scope and a new symbol table node is inserted in the graph.

With this symbol table structure we make sure the `processArgs()` function cannot access variables, type definitions or functions declared in the `setCmdArgs()` function, and vice versa. The same thing applies to the intermediate scopes from the if-else-statement in function `verifyArgc()` , they cannot access identifiers declared in the `printProg()` or `setCmdArgs()` functions, however they can access identifiers declared in the global scope or the `processArgs()` function for example.

You may have noticed some strange identifiers in the graph, e.g. the `processArgs()` function is inserted in the symbol table node as `Fas.process_args.processArgs` .

This is so because we are allowing function overloading. It is called name mangling, and is discussed in the next section.

Once the declared identifiers are inserted in the symbol table the whole symbol table is resolved. This is done in order to determine the type of variables, functions and type definitions.

After the identifiers in the symbol table are resolved the record types in the symbol table are finalized. For example, records are allowed to inherit multiple other records

thus the symbol table is respolsible for inserting record fields from base records into the derived record's symbol table node.

7.1 Name Mangling

Functions, variables and records are given unique names based on where they are declared, e.g. such that the user can declare a record with the same name in different vitaly source files and different scopes.

Besides location of declaration, the unique name given to a function is also determined by parameter types.

Consider the vitaly source file `module.vit` :

```
1  package path;
2
3  type Sum = record of {
4     func add(lhs:int, rhs:int):int
5        return lhs + rhs;
6     end add
7  };
8
9  func add(s:Sum, lhs:int, rhs:int):int
10    return s.add(lhs, rhs);
11 end add
12
13 func add(s:Sum, lhs:int, rhs:bool):int
14    return add(s, lhs, cast(int) rhs);
15 end add
16
17 globalStr:string;
```

Initially the unique name `.path.module` is generated based on package name and file name.

Entering the type definition of `Sum` a `T` , for (t)ype definition, is prepended, an `R` , for (r)ecord, is prepended and the record name `Sum` is appended to the unique name: `RT.path.module.Sum`

This unique name is used when generating the virtual method table for records declared with type `Sum` , we will discuss virtual method tables in a later section.

Next entering the `add` function inside the record `Fii` is prepended to the unique name, `Fii` stands for (f)unction taking two (i)nt arguments. And the function name is appended to the unique name: `FiiRT.path.module.Sum.add` , which is the unique name given to the function.

Once we have left the `Sum` type definition the current unique name is reset to what it was before entering the type definition: `.path.module`

Entering the first `add` function in the global scope prepends `F$Sum$ii` to the unique name, standing for (f)unction taking type `Sum` (`$Sum$`) and two (i)nt arguments. And the function name `add` is appended: `F$Sum$ii.path.module.add` , which is the unique name for that function.

The last `add` function gets the name: `F$Sum$ib.path.module.add`

The only difference between this and the previous name is a `b` instead of an `i` because this last definition of the `add` function takes a (b)ool instead of an int as the third argument.

The last line defines a global variable which gets the unique name: `V.path.module.globalStr` , the `V` is prepended because it is a (v)ariable.

Variables and functions defined in files with other names or other package names are always given different unique names because the initial unique name will be different.

Thus the user can define variables and functions in one file without having to consider whether the names will clash with another variable or function in another file.

As we saw, the parameter types was also used when generating unique names to functions to allow function overloading. The type checker is responsible for determining which overloaded function is best suited to function call arguments. We discuss the type checker in another section.

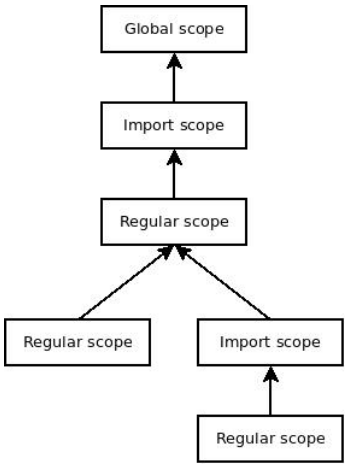
On line 14 in the example, the type checker will decide that the `add` function taking type `Sum`, `int` and `int` arguments is called (`F$Sum$ii.path.module.add`), since that function matches the given arguments better than the version taking `Sum` , `int` and `bool` arguments (`F$Sum$ib.path.module.add`).

8 Imports

To extend the usability of the vitaly programming language a feature to import symbols from other sources have been implemented. This enables one source file to access variables, types and functions defined in the global scope of other modules.
Throughout this section modules refer to objects which can be imported such as other source files, and viti files. The viti file type will be discussed in a later section. As an example one could import the module `mod` by " `import mod;` ".

As mentioned in the introduction to the vitaly programming language, packages can be used to organize source files just like packages in Java. When a source file specifies a package, the file must be located within a corresponding directory structure. Hence a file specifying the package " `package subpack.pack;` " must be located in a directory `*/subpack/pack` .

The actual importing of symbols happens by introducing a new symbol scope in which the symbol are inserted. This import scope will be placed in the scope hierarchy as indicated below:



In the figure above `Regular scope` means any scope except scopes introduced by imports. Putting the imported symbols in a parent scope to the importing scope makes sure that local symbols will have higher priority. This means that when looking up a symbol, a symbol declared in the local scope will be found before any symbol with the

same name that might be imported, since these are placed in a parent scope.
If a scope imports multiple modules, all imported symbols will be placed in a single parent import scope. Thus all imported symbols will have equal priority, regardless of the order of the import statements.

When importing a module the types of the import should be fully resolved, even if the types are defined by modules not directly imported. See the example in the introduction to the vitaly programming language on accessing indirect type fields. To understand what indirect use of a type means, consider a module `car` which defines a type `Car`. This type extends another type `Vehicle` which in turn is a type imported from the module `vehicle`. Now assume that `Vehicle` has a function `drive()`. Then by importing the module `car` one is able to call `c.drive()` on a variable `c` of type `Car`, even though this function is only defined in the module `vehicle` which is not imported. Since `vehicle` is not directly imported it is not possible to use the type `Vehicle` directly (such as in casts or variable declarations), unless the module `vehicle` is explicitly imported.

This means we can access fields and functions of a type not directly imported, but only through a type that is indeed directly imported. Notice how this does not make symbols directly usable if they are not directly imported.

Handling imports consists of two parallel actions. One to handle statements, expressions and references throughout the AST and another to handle the import statements themselves.
The first part will run through the AST and translate variable names, functions identifiers and types to their real names. For example if a variable `a` is used somewhere in the AST, we must identify whether the `a` refers to a local variable or `a` refers to a variable imported from another module. If it is an imported variable `a` should be replaced by the unique name of the imported variable. The same applies to any type definition which might contain type identifiers of types not locally defined. This translation is done with a special lookup, which first tries to looks up the symbol in the local current local scope. If the symbol is found locally nothing will be done. Otherwise the set of modules imported in the local symbol table node will be iterated to lookup the symbol in each module. If the symbol is still not found this process iterates towards the root of the symbol table.

Whenever an imported module is need, by means of accessing its symbols, a hash map of scanned and parsed modules will be searched for the module. If the module is not yet scanned and parsed this will be done and the module will be added to the hash map. Thus any module which might be needed for the compilation will only be scanned and parsed once.
When searching the file system for an imported module, the compiler will first search the current package for the module that is the directory corresponding to the package of the file specifying the import statement. If the module is not found the search will continue from the project root and finally the include paths specified by the `-I` command line argument. This means that when working within a package, one does not have to prepend the current package to the import statements, if the modules are located within this package.
Note that the project root is determined by the package name of the file which the compilation was started. Thus if a file say `*/dir/pack1/pack2/file1.vit`

specifies a package such as:

```
package pack1.pack2;

...
```

then the project root will be `*/dir`.

8.1 The Merge Table

The scanned and parsed modules will be contained in a struct containing a copy of the symbol table generated from the AST of the module. This table is need to create a special merge table, which is a single symbol table containing all direct and indirect imported modules. The symbol types of the copied module symbol table will be updated prior to being merged into the merge table. The symbol type update changes type identifiers, referring to types defined in the global scope or in other modules to the unique name of the symbols. When the symbol types have been updated, the symbols will be copied copied into the merge table, using only their unique names as identifiers. This ensures the symbols inserted are all still valid in terms of their types and no name collisions between symbol can occur due to the uniqueness of the symbol names.

After creating a combined merge table with all modules needed to resolve all imported types, the merge table is resolved just like a normal symbol table would be resolved. Then the symbols of the directly imported modules can be copied into the relevant import scopes of the file currently being compiled. Notice also that it can be necessary to add to and resolve this table multiple times during compilation. Consider the following simple example:

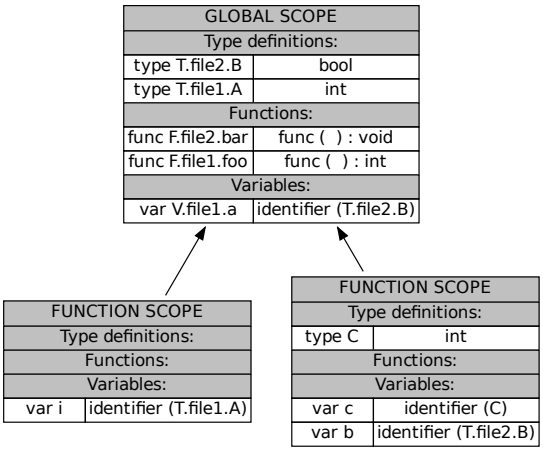
file1.vit

```
import file2;

type A = int;

func foo():int
   i:A;
   return 0;
end foo

a:B;
```

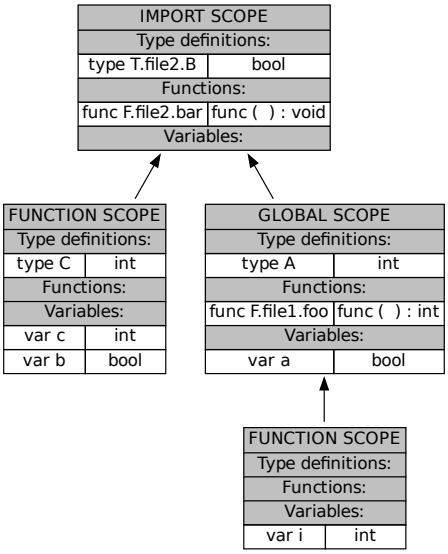
file2.vit:

```
import file1;

type B = bool;

func bar():void
   type C = int;
   b:B;
   c:C;
end bar
```

The unresolved merge table when making the import pass for `file1` is seen below:



Both `file1` and `file2` are included in the merge table, since `file1` needs `file2` to be in the merge table which in turn needs `file1` to be in the merge table. Notice that the type identifiers for `a`, `b` and `i` have been updated to use unique identifiers as opposed to the variable `c`. This is due to the fact that the type `C` if not defined in a global scope or in an import. Also notice that the name of the symbols in the global scope are using their unique names.
Because the merge table is resolved before copying the needed symbols to import scopes we ensure that we can use types indirectly.
The final symbol table for `file1` after the import phase is seen below:



Notice how an import scope containing the symbols of `file2` is inserted as parent

scope to the global scope, and that the type of `a` is correctly resolved to `bool`.

8.2 Nested imports

As mentioned in the introduction to the vitaly programming language, we allow nested imports, meaning that import statements can be placed in any scope. This is handled in almost the same way as the example above only differing in where to place the import scope. Thus no more complexity is added towards implementing this feature.

8.3 Import collisions

So far we have not considered what happens if multiple imports specify variables, types or functions with the same name. If only a single import defines the symbol the unique name can easily be found. However if multiple imported modules specify symbols of the same type with the same name either of the following three cases happen:

- The conflicting symbols are variables:
  In this case multiple definitions are not allowed and an error is reported.
- The conflicting symbols are functions:
  Since function overloading if allowed, this is valid as long as the functions have different parameter lists otherwise the type checker will find an error because of equally matching functions. See the section on type checking.
- The conflicting symbols are type definitions:
  To handle import collisions of type definitions, additional type definitions are inserted. That is if a type `A` is equal to the imported type `B` which is imported from both `file1` and `file2`, then the type definition `type A = B;` is replaced a type definition for each import `B` is found in: `type A = T.file1.B;` and `type A = T.file2.B`. If conflicting types for `B` exist errors will be reported when the symbol table is resolved.

We do allow all three cases without any action if the symbol if not used. That is we can import two modules both declaring a global variable with the same name since the unique name ensures no collision by default, there is no problem in allowing this. If it is used errors will be reported as described above.

8.4 Viti, Vitaly Interface Files

To improve import parsing performance and provide a way to generate interfaces for libraries the viti file format has been designed. This is essentially a valid vit file, without function bodies and types and symbols not reachable from the global scope. Consider the following example from the vitaly standard library:

std/sort.vit

```
package std;

import object;
import indexable;
import comparator;

func sort(ary:Indexable, c:Comparator):
     void

   ...

   func quicksort(f:int, l:int):void
      if (f < l) then {
         q:int = partition(f, l);
         quicksort(f, q - 1);
         quicksort(q + 1, l);
      }
   end quicksort

   quicksort(0, ary.size() - 1);
end sort
```

std/sort.viti:

```
package std;
import std.object;
import std.indexable;
import std.comparator;

func sort(ary:indexable, c:comparator):
     void
end sort
```

It is clear how all implementation details of the vit file is omitted, but all the information needed to do type checking, imports and translation of symbol names is still preserved. Thus the viti file provides an interface to the original vit file. It is also obvious how this will significantly reduce scanning/parsing time and reduce the overall size of the AST for imported modules. Notice also that all functions type definitions and variable declarations appears in the same order in the viti file as in the vit file. This ensures that unamed records are properly named when the viti file is parsed.
As a side effect of this implementation one could also declare private variables, functions and types by a simple nesting. See the following example:

```
a:int;          # This is public

func foo():void # This is public
end foo

type B = bool;  # This is public

{
   type C = array of B; # This is private

   b:B;         # This is private
}
```

Notice that since only the outermost scope is accessible via imports type `C` and variable `b` are kept private if the file is imported.

8.5 Recursive compilation

Another feature of the compiler is its ability to compile files recursively and link automatically. When compiling a file with the command line argument `-r` set, all imported files, both directly and indirectly imported, are compiled and linked into the executable. Thus there is no need to specify a makefile system or otherwise specify dependencies. If some viti files are used when importing, these are however not compiled, since these only provide interfaces to already compiled files. It is in this case up to the user to link the corresponding object files manually.
The feature simplifies the compilation task significantly, since only one file needs to be specified as argument to the compiler, even when building larger projects.

9 Type Checking

After the symbol table has been created and resolved the type checker, which you can find in the appendix `src/ast/ast_visitor_type_check.c`, is used to: verify that identifiers in the program are used correctly, verify that expressions evaluate into valid types, verify that arguments given to function calls are compatible with the parameters the functions was defined with, etc.

In most cases it is okay to use different types in an expression, for instance:

```
1 i:int = 300; b:bool = true;
2 write i - b;
```

By default, when compiling that program `vitaly` gives a warning saying that the `bool b` is implicitly casted to an `int`, and when the compiled program is executed it outputs:

```
1 299
```

However, we cannot cast a reference type like `string`, `array` or `record` to an `int`, on the other hand casting a reference type to a `bool` is fine.

9.1 Structural Equivalence

The vitaly type checker compares records by structure, e.g. when deciding whether two record types are equivalent the type checker compares the record fields one by one, starting from the first field declared in the records. If all the record fields are equivalent the records are equivalent otherwise the records are distinct.

Determining whether two record structures are equivalent is basically the same problem as determining whether two deterministic finite automatons are equivalent.

We now describe an efficient algorithm to do structural comparison between records.

In the description of the algorithm, a base type can be one of the following:

- `record`
- `array`
- `string`
- `char`
- `bool`
- `int`

So type record has base type `record` and type array has base type `array`, etc.

We can get the element type of an array type by indexing it with `1`. E.g. If we want the type of the elements of an array with name `ary` we get it with the syntax `ary[1]`.

We get the type of a record field in much the same way. Say we want the type of field number `5` of the record type called `rec`, we do as follows `rec[5]`.

The first thing we do is to initialize a map `cmp_results`, mapping two records to a comparison result. The possible comparison results are `true` (the records are equivalent) and `false` (the records are distinct).

The procedure `compare(lhs, rhs)` for structurally comparing two types `lhs` and `rhs` is as follows:

1. If the base type of `lhs` is different from the base type of `rhs` return `false`
2. If the base type of `lhs` is different from `record` and different from `array` return `true`
3. If the base type of `lhs` is `array` recursively call `compare(lhs[1], rhs[1])` and return the result.
4. Then the base type of `lhs` and `rhs` is `record`. If the number of fields in the records `lhs` and `rhs` are different return `false`
5. Make a lookup in `cmp_results`, if the map contains a comparison result between `lhs` and `rhs` then return that result.
6. In the map `cmp_results` insert the comparison result `true` between records `lhs` and `rhs`.
7. For each `i = 1` to the number of fields in `lhs` do
   - Recursively call `compare(lhs[i], rhs[i])`, if the result is `false` then replace the comparison result between `lhs` and `rhs` in the map `cmp_results` with `false` and return `false`
8. Then the records `lhs` and `rhs` are equivalent, keep the comparison result `true` in the map `cmp_results` and return `true`

In vitaly the field names of the records are significant, however the algorithm is easily extended to take this into account.

Vitaly records may contain functions, we can extend the algorithm to take functions into consideration by comparing the functions parameter types and return type.

Vitaly also supports record inheritance. Extending the algorithm to take this into consideration is not a problem either, since we can compare inherited records in the same way we compared the record field types.

9.2 Overloaded Function Selection

Faced with a function call, the type checker must be able to decide which overloaded version of a function best matches the given argument types.

The algorithm uses a metric called `score` to determine how well a function matches given arguments. A `score` of `0` means that the function does not match the given arguments and a `score` of $(n+1)^2+1$, where n is the number of arguments given, is the best possible `score`.

Starting with `score = 1`.
For each argument do the following:

1. If the argument and the parameter is equivalent add $n+1$ to the score.
2. Else if the argument is a record and the parameter is a base to the argument, then it is possible to implicitly cast the argument record to the parameter record, add n to the score.
3. Else if the argument can be implicitly casted to the parameter, e.g. if the argument has type `int` and the parameter type is `bool`, continue.

4. Else return with `score = 0`, the argument and parameter is not compatible then.

When two or more overloaded versions of a function in the same scope have the same `score > 0`, then the type checker will report an error because the function call is ambiguous.

When two or more overloaded versions of a function in different scopes have the same `score > 0`, then the type checker will select the function in the closest scope.

And, obviously, when all the overloaded versions of a function have `score = 0`, the type checker will report an error, telling the arguments did not match the function parameters.

Example:

```
# Global scope.

type B = record of {};
type D = record of B {};

func f(d:D, b:B):void
end f

func f(b:B, d:D):void
end f

func f(b:bool, b:B):void
end f

func f(b:B):void
end f

func f(d:D):void
end f

d:D;

{
   # Inner scope.

   func f(b:B):void
   end f

   f(d);           # Call f(d:D) from global scope.

   f(cast(B) d);   # Call f(b:B) from inner scope.

   f(d, d);        (* Ambiguous, f(b:B, d:D) and f(d:D, b:B) from
                      global scope matches equally well. *)

   f(cast(B) d, d); # Call f(b:B, d:D) from global scope.

   f(cast(bool) d, d); # Call f(b:bool, b:B) from global scope.
}

f(cast(B) d);   # Call f(b:B) from global scope.
```

10 Intermediate Code Generation

The intermedite code in the vitaly compiler is called Abstract Intel Assembly (AIA). It uses a 3 operand instruction set with 2 source operands and one destination operand.

Consider the vitaly program:

```
func b(p:bool):bool
   tmp:bool = p;
```

```
3     return tmp;
4  end b
5
6  result:string;
7  if b(true) then
8     result = "yes";
9  else
10    result = "no";
```

Compiling that program with the `-dump=init-ic` option vitaly dumps the initial AIA code representation of the program, a simplified version of the dump is shown below:

```
1  .section .init
2     .movz @size(1) $1 -> @size(4) %0
3     .mov @size(4) %0 -> @size(4) %1
4     .mov @size(4) %1 -> @size(4) @arg(0)
5     .call @size(4) Fb.tmp.b -> @size(1) %2
6     .cmp @size(1) %2, $0
7     .je @size(4) .IF.else.5, .IF.then.3
8  .IF.then.3:
9     .mov @size(4) $.STR.7 -> @size(4) V.tmp.result
10    .jmp @size(4) .IF.end.4
11 .IF.else.5:
12    .mov @size(4) $.STR.8 -> @size(4) V.tmp.result
13    .jmp @size(4) .IF.end.4
14 .IF.end.4:
15
16 .section .text
17 @procedure(Fb.tmp.b)
18    @param(VFb.tmp.b.p)
19    @var(VFb.tmp.b.ret)
20 Fb.tmp.b:
21    .mov @size(1) @local(VFb.tmp.b.p) -> @size(1) @local(VFb.tmp.b.ret)
22    .ret @size(1) @local(VFb.tmp.b.ret)
23
24 .section .data
25 V.tmp.result:
26    .long 0
27
28 .section .rodata
29 .STR.7:
30    .byte 121,101,115,0
31 .STR.8:
32    .byte 110,111,0
```

It is very much resembles x86-32 gas assembly. Although it's quite bizzare, AIA is a complete programming language in its own right.

Besides the 3 operand instruction set, some noticeable differences between x86-32 gas assembly and Abstract Intel Assembly (AIA) are:

- It is more high level than gas assembly, e.g. in AIA code there is no stack.
- There is an infinite number of registers `%0, %1, ...`
- If an instruction has a destination operand, that operand is right of the arrow `->`
- `@size` is used to specify the byte size of operands.
- Conditional jumps have 2 jump targets. The label to the left is taken on `true`, the label to the right is taken on `false`. There is a conditional jump example on line 7.
- When passing arguments to functions the first argument is moved to `@arg(0)`, the second argument moved to `@arg(1)`, etc. See line 4.

- We declare functions using `@function` (line 17), we declare the function parameters using `@param` (line 18), we declare local function variables using `@var` (line 19)
- Functions reference their local variables using `@local` , as we can see on line 21 and 22.

An Abstract Syntax Tree (AST) pass implemented in the file `src/ast/ast_visitor_aia.c` is used to generate intermediate AIA code representation.

10.1 Nesting Functions

AIA code is aware of nested functions, a nested function can access its parent function's local variables using `@display_ref` for example:

```
1  @procedure(outer)
2     @push_display(-1)
3     @var(outer.i)
4  outer:
5     .ret
6
7  @procedure(inner)
8     @param(.disp.0)
9  inner:
10    .mov @size(4) $0 -> @size(4) @display_ref(@local(.disp.0)::outer::outer.i)
11    .ret
```

`@push_display(-1)` is used to indicate that functions nested inside `outer` can reference local variables inside `outer` .

Function `inner` accesses the local variable `outer.i` of function `outer` using `@display_ref` .

The way this is done in AIA code might seem rather random, but there is a method behind the madness.

While Intel was designing the 80206 processor the Pascal programming language was popular, Pascal is a block structured language, i.e. Pascal is also allowing nested functions. Thus the Intel engineers studied the problem with nested functions accessing local variables of parent functions carefully.

They came up with two new instructions `enter` and `leave` . While the `leave` instruction is simple and is equivalent with the standard function epilogue:

```
1  movl  %ebp, %esp
2  popl  %ebp
```

The `enter` instruction is quite complex. The instruction takes two immediate constant operands, the first being the number of bytes to reserve for local variables and the second operand being the lexical nesting of the function. The `enter $L, $0` instruction is equivalent with the standard function prologue:

```
1  pushl %ebp        # Save frame pointer for caller
2  movl  %esp, %ebp  # Setup own frame pointer
3  subl  $L, %esp    # Make room for L bytes of local variables
```

The `enter $L, $1` instruction is equivalent with:

```
1  pushl %ebp        # Save frame pointer for caller
2  movl  %esp, %ebp  # Setup own frame pointer
3  pushl %ebp        # Preserve own frame pointer
4  subl  $L, %esp    # Make room for L bytes of local variables
```

The `enter $L, $2` instruction is equivalent with:

```
1 pushl %ebp        # Save frame pointer for caller
2 pushl -4(%ebp)    # Save frame pointer for caller's caller
3 leal  4(%esp), %ebp # Setup own frame pointer
4 pushl %ebp        # Preserve own frame pointer
5 subl  $L, %esp    # Make room for L bytes of local variables
```

And the `enter $L, $3` instruction is equivalent with:

```
1 pushl %ebp        # Save frame pointer for caller
2 pushl -4(%ebp)    # Save frame pointer for caller's caller
3 pushl -8(%ebp)    # Save frame pointer for caller's caller's caller
4 leal  8(%esp), %ebp # Setup own frame pointer
5 pushl %ebp        # Preserve own frame pointer
6 subl  $L, %esp    # Make room for L bytes of local variables
```

The idea with the `enter` instruction is good. Using the `enter` instruction a nested function can access any parent function's local variables in constant time regardless of how deep the function is nested.

The biggest problem with the `enter` instruction is that the `C/C++` programming languages became more popular than Pascal shortly after Intel introduced the `enter` instruction, so Intel never bothered to optimize `enter`.

Thus, if we want the kind of prologue the `enter` instruction implements we should push the frame pointers ourselves as shown above. Pushing the frame pointers ourselves also introduces more flexibility which the vitaly compiler makes use of, as we will soon see.

This rather automated method is alright since it guarantees constant time access to variables of parent functions, but what if the nested function doesn't access some parent function's variables?

The vitaly compiler has an AST pass dedicated to discovering which local variables of parent functions are accessed by nested functions, to avoid preserving frame pointers when it isn't necessary. This AST pass is implemented in `src/ast/ast_visitor_dependency.c`.

Also, the vitaly compiler does not setup the frame pointer `ebp`, it uses `esp` to access parameters and local variables instead.

Thus the prologue for a function without nested functions simply look as follows:

```
1 subl  $L + A, %esp
```

where `L` is the number of bytes needed for local variables and `A` is the number of bytes needed by the function call taking most arguments.

For example, if our function has one `int` local variable and our function makes two function calls. One function call takes 1 `int` argument, and the other function call takes 2 `int` arguments. Then the prologue would be:

```
1 subl  $4 + 2*4, %esp
```

The first `4` bytes are subtracted to make room for the local `int` variable, the other `2*4` bytes are subtracted to make room for the arguments to the function taking two `int` arguments. If the function has one or more nested functions accessing its local variables the prologue look as follows:

```
1 subl  $L + A + 4, %esp
2 # Preserve own frame pointer as first parameter to the nested functions
3 movl  %esp, A(%esp)
```

Consider the following vitaly code:

```
func a():void
   i:int;
   func b():void
      j:int;
      func c():void
         i = 1;
         j = 2;
      end c
      c();
   end b
   b();
end a
```

Here function `b` should preserve the frame pointer for `a` and preserve its own frame pointer. Which is done as follows:

```
subl  $L + A + 8, %esp
# Preserve own frame pointer as first parameter to the nested function c.
movl  %esp, A(%esp)
movl  P(%esp), %eax
# Preserve frame pointer for function a as second argument to c.
movl  %eax, A + 4(%esp)
```

Where `P` is the offset to `a`'s frame pointer which was pushed on the stack by `a`. By now, the previously discussed Abstract Intal Assembly (AIA) syntax `@push_display(-1)` probably makes more sense. It means the function should preserve its own frame pointer for a nested function.

There are more interesting details regarding how vitaly sets up frame pointers for nested functions, this was an introduction.

10.2 Records and Multiple Inheritance

Multiple inheritance is the most advanced feature of the vitaly programming language.

First we will consider a record in its simplest form:

```
type D = record of {
   i:int;
   j:int;
};
```

The memory layout of such a record is:

```
|-----|
|  i  |
|-----|
|  j  |
|-----|
```

When `D` inherits another record:

```
type A = record of {
   # ...
};
type D = record of A {
   a:int;
   b:int;
};
```

then the memory layout of `D` is:

```
|-----|
|  A  |
|-----|
|  i  |
|-----|
|  j  |
|-----|
```

And inheriting multiple records:

```
type A = record of { (* ... *) };
type B = record of { (* ... *) };
type C = record of { (* ... *) };
type D = record of A, B, C {
   a:int;
   b:int;
};
```

Gives `D` the memory layout:

```
|-----|
|  A  |
|-----|
|  B  |
|-----|
|  C  |
|-----|
|  i  |
|-----|
|  j  |
|-----|
```

It is easy to see that we can cast a pointer `d` pointing to a record of type `D` to a record of type `A` without doing anything. We can cast `d` to a record of type `B` by adding the offset to the `B` record, and cast to `C` by adding the offset to `C`.

If we want to cast the other way, e.g. if we want to cast a pointer to a record of type `B` to `D`, we subtract the offset to `B` instead.

If we have a record with a function inside:

```
type R = record of {
   i:int;
   func f():void (* .. *) end f
   func g():void (* .. *) end g
   j:int;
};
```

Then a pointer to a table containing pointers to the functions inside the record is inserted, we refer to this table of functions as a Virtual Method Table (VMT):

```
R:          vmt:
|-----|   |-----|
| vmt |   |  f  |
|-----|   |-----|
|  i  |   |  g  |
|-----|   |-----|
|  j  |
|-----|
```

When allocating the record the field `vmt` is initialized with a pointer to the record's VMT such that the record can reference its functions.

Inheriting one record with a VMT:

```
type A = record of {
   func f():void (* .. *) end f
```

```
3     func g():void (* .. *) end g
4  };
5  type D = record of A {
6     i:int;
7     func h():void (* .. *) end h
8     j:int;
9  };
```

Then the memory layout for `A` is:

```
1  A:          amt:
2  |-----|   |-----|
3  | amt |   | A.f |
4  |-----|   |-----|
5             | A.g |
6             |-----|
```

where `amt` is the Virtual Method Table (VMT) for `A`. And the memory layout for `D` becomes:

```
1  D:          dmt:
2  |-----|   |-----|
3  |  A  |   | A.f |
4  |-----|   |-----|
5  |  i  |   | A.g |
6  |-----|   |-----|
7  |  j  |   | D.h |
8  |-----|   |-----|
```

where `dmt` is the VMT for `D`. When allocating a record of type `D` the VMT inside `A` is initialized to point to `dmt`.

Notice that the offsets to the functions inherited from `A` are located at the same offsets in the VMT as they were in `amt`. Thus having a pointer to a record of type `D` we can simply treat it as a pointer to a record of type `A`.

Overriding a function:

```
1  type A = record of {
2     func f():void (* .. *) end f
3     func g():void (* .. *) end g
4  };
5  type D = record of A {
6     i:int;
7     func f():void (* .. *) end f
8     func h():void (* .. *) end h
9     j:int;
10 };
```

Record `A` has the same memory layout, but the memory layout for `D` becomes:

```
1  D:          dmt:
2  |-----|   |-----|
3  |  A  |   | D.f |
4  |-----|   |-----|
5  |  i  |   | A.g |
6  |-----|   |-----|
7  |  j  |   | D.h |
8  |-----|   |-----|
```

Notice that `A.f` has been overridden by `D.f` in the VMT for `D` (`dmt`).

We can still treat a pointer to a record of type `D` as a pointer to a record of type `A`, when calling function `f` the version defined by `D` (`D.f`) is invoked.

Inheriting multiple records with VMTs:

```
1  type A = record of {
```

```
2     func f():void (* .. *) end f
3  };
4  type B = record of {
5     func g():void (* .. *) end g
6  };
7  type D = record of A, B {
8     func h():void (* .. *) end h
9     i:int;
10    j:int;
11 };
```

We know the memory layout of `A` and `B`. The layout of `D` becomes:

```
1  D:          dmt:
2  |-----|   |-----|
3  |  A  |   | A.f |
4  |-----|   |-----|
5  |  B  |   | D.h |
6  |-----|   |-----|
7  |  i  |   | B.g |
8  |-----|   |-----|
9  |  j  |
10 |-----|
```

Allocating a record of type `D` we initialize the Virtual Method Table (VMT) in `A` with a pointer to `dmt` and initialize the VMT in `B` with the pointer to `dmt` + offset to `B.g`.

Overriding functions with multiple inheritance:

```
1  type A = record of {
2     func f():void (* .. *) end f
3  };
4  type B = record of {
5     func g():void (* .. *) end g
6  };
7  type D = record of A, B {
8     func f():void (* .. *) end f
9     func g():void (* .. *) end g
10    func h():void (* .. *) end h
11    i:int;
12    j:int;
13 };
```

We still know the memory layout of `A` and `B`. And the layout of `D` is:

```
1  D:          dmt:
2  |-----|   |-----|
3  |  A  |   | D.f |
4  |-----|   |-----|
5  |  B  |   | D.g |
6  |-----|   |-----|
7  |  i  |   | D.h |
8  |-----|   |-----|
9  |  j  |   | D.t |
10 |-----|   |-----|
```

Still, when a record of type `D` is allocated the VMT inside `A` is initialized with a pointer to `dmt`, but now the VMT in `B` is initialized with the pointer to `dmt` + offset to `D.t`, we talk about function `D.t` later.

We can still treat a pointer to a record of type `D` as a pointer to a record of type `A`, and when function `f` is called the version of `f` defined in `D` is called.

The function `D.t` is a trampoline to the function `D.g`. The trampoline function `D.t` casts a record pointer of type `B` to a record pointer of type `D` by subtracting the offset to `B` inside `D`. Afterwards the function `D.t` jumps to the function `D.g`.

An example of an AIA trampoline function is:

```
1  @trampoline(RT.tmp.B$FRT.tmp.D.g)
2     @param(.slf)
3  RT.tmp.B$FRT.tmp.D.g:
4     .add @size(4) @local(.slf), $-4 -> @size(4) %0
5     .mov @size(4) %0 -> @size(4) @local(.slf)
6     .jmp @size(4) FRT.tmp.D.g
```

Again, we have omitted some details, but this section gives a general idea about how to implement multiple inhertitance.

11 Optimization

There are two main reasons for intermediate code (IC) representation. One reason for IC is to convert it into multiple different machine code targets. The other reason is that we can design the IC such that it is easier to do optimization on it.

While designing the Abstract Intel Assembly (AIA) code representation our main goal was optimization. We wanted an IC which was easy to traverse and modify. We did not have much time, thus an important design decision with AIA was to make it easily convertible to x86-32 assembly. Considering AIA was our first attempt, ever, designing an IC representation, we are satisfied with the result.

AIA might look like linear assembly code when it's dumped to a file, but really it is not, it is a Control Flow Graph (CFG) where jump instructions represent directed edges in the graph and basic blocks are nodes in the graph.

That is why conditional jump instructions have two target labels, it is also the reason we often find jumps to labels right beneath the jump instruction like in the following AIA if-statement:

```
1     .cmp @size(4) %2, $0
2     .je @size(4) .IF.end.4, .IF.then.3
3  .IF.then.3:
4     .mov @size(4) %2 -> @size(4) V.tmp.result
5     .jmp @size(4) .IF.end.4
6  .IF.end.4:
```

In real assembly we would never insert the jump instruction on line `5`, but the AIA code needs the jump as an edge in the CFG.

The files `src/aia/aia.h`, `src/aia/aia_instr.h` and `src/aia/aia_operand.h` exposes a collection of functions we use when traversing and modifying AIA code, some examples are:

- We traverse an AIA function depth first with the `aia_func_for_each_block_depth()` function.
- We iterate the instructions inside a basic block using the `AIA_BLOCK_FOR_EACH_INSTRUCTION()` macro.
- We iterate through an instruction's operands with the `AIA_INSTR_FOR_EACH_OPERAND()` macro.
- We replace an AIA instruction with another using the `aia_instr_replace()` function.

11.1 Constant Propagation

The combined constant propagation and constant folding pass implemented in `src/aia/aia_const_prop.c` is used to simplify constant expressions and substitute variable references with constants when possible.

Constant propagation is one of the simplest AIA passes. The pass imaginary executes the code, simplifying constant expressions while keeping track of known values of variables. Consider the vitaly program:

```
1  i:int;
2  result:int = 1;
3
4  i = 10;
5  if i >= 10 then {
6     tmp:bool = i != 10;
7     i = i + 30;
8     if tmp then {
9        # Dead code
10       i = i - 123456;
11       result = i;
12    } else {
13       if !tmp then
14          i = i + 2 * result;
15    }
16    result = result * i;
17 } else {
18    # Dead code
19    i = 0;
20    result = 0;
21 }
22
23 write result; # Print 42
```

Before the first constant propagation pass the simplified AIA code looks as follows:

```
1  .section .init
2     .mov @size(4) $1 -> @size(4) V.cp18.result
3     .mov @size(4) $10 -> @size(4) V.cp18.i
4     .cmp @size(4) V.cp18.i, $10
5     .setge -> @size(1) %0
6     .cmp @size(1) %0, $0
7     .je @size(4) .IF.else.4, .IF.then.2
8  .IF.then.2:
9     .cmp @size(4) V.cp18.i, $10
10    .setne -> @size(1) %1
11    .mov @size(1) %1 -> @size(1) V.2.1.cp18.tmp
12    .add @size(4) V.cp18.i, $30 -> @size(4) %2
13    .mov @size(4) %2 -> @size(4) V.cp18.i
14    .cmp @size(1) V.2.1.cp18.tmp, $0
15    .je @size(4) .IF.else.7, .IF.then.5
16 .IF.then.5:
17    .sub @size(4) V.cp18.i, $123456 -> @size(4) %3
18    .mov @size(4) %3 -> @size(4) V.cp18.i
19    .mov @size(4) V.cp18.i -> @size(4) V.cp18.result
20    .jmp @size(4) .IF.end.6
21 .IF.else.7:
22    .cmp @size(1) V.2.1.cp18.tmp, $0
23    .sete -> @size(1) %4
24    .cmp @size(1) %4, $0
25    .je @size(4) .IF.end.9, .IF.then.8
26 .IF.then.8:
27    .imul @size(4) $2, V.cp18.result -> @size(4) %5
28    .add @size(4) V.cp18.i, %5 -> @size(4) %6
29    .mov @size(4) %6 -> @size(4) V.cp18.i
30    .jmp @size(4) .IF.end.9
31 .IF.end.9:
32    .jmp @size(4) .IF.end.6
33 .IF.end.6:
34    .imul @size(4) V.cp18.result, V.cp18.i -> @size(4) %7
35    .mov @size(4) %7 -> @size(4) V.cp18.result
```

```
36     .jmp @size(4) .IF.end.3
37  .IF.else.4:
38     .mov @size(4) $0 -> @size(4) V.cp18.i
39     .mov @size(4) $0 -> @size(4) V.cp18.result
40     .jmp @size(4) .IF.end.3
41  .IF.end.3:
42     .mov @size(4) V.cp18.result -> @size(4) @arg(0)
43     .call @size(4) _Vit_writelni
44
45  .section .data
46  .align 4
47  V.cp18.i:
48     .long 0
49  .align 4
50  V.cp18.result:
51     .long 0
52  V.2.1.cp18.tmp:
53     .byte 0
```

And after the last constant propagation pass the simplified AIA code is:

```
1   .section .init
2      .jmp @size(4) .IF.then.2
3   .IF.then.2:
4      .jmp @size(4) .IF.else.7
5   .IF.else.7:
6      .jmp @size(4) .IF.then.8
7   .IF.then.8:
8      .jmp @size(4) .IF.end.9
9   .IF.end.9:
10     .jmp @size(4) .IF.end.6
11  .IF.end.6:
12     .jmp @size(4) .IF.end.3
13  .IF.end.3:
14     .mov @size(4) $42 -> @size(4) @arg(0)
15     .call @size(4) _Vit_writelni
16
17  .section .data
18  .SECT.1:
19  .align 4
20  V.cp18.i:
21     .long 42
22  .align 4
23  V.cp18.result:
24     .long 42
25  V.2.1.cp18.tmp:
26     .byte 0
```

For completeness, here is the x86-32 assembly code the compiler produces:

```
1   .section .init
2   .SECT.0:
3      addl  $-4, %esp
4   .IF.then.2:
5   .IF.else.7:
6   .IF.then.8:
7   .IF.end.9:
8   .IF.end.6:
9   .IF.end.3:
10  # line 24
11     movl  $42, (%esp)
12     call  _Vit_writelni
13     addl  $4, %esp
14
15  .section .data
16  .SECT.1:
17  # line 1
18  .globl V.cp18.i
19  .type V.cp18.i, @object
20  .size V.cp18.i, 4
21  .align 4
22  V.cp18.i:
```

```
23      .long 42
24  # line 2
25  .globl V.cp18.result
26  .type V.cp18.result, @object
27  .size V.cp18.result, 4
28  .align 4
29  V.cp18.result:
30      .long 42
31  # line 6
32  .type V.2.1.cp18.tmp, @object
33  .size V.2.1.cp18.tmp, 1
34  V.2.1.cp18.tmp:
35      .byte 0
```

11.2 Instruction Elimination

The instruction elimination pass implemented in `src/aia/aia_instr_elim.c` is the compiler's dead code elimination pass. It uses the function `aia_instr_live_sets()` implemented in `src/aia/aia_instr_live_sets.c` to get a liveness analysis.

The idea of the pass is to find out whether an instruction's destination operand is live out of the instruction. If not, then it is often safe to remove (eliminate) the instruction.

Note that the `aia_instr_live_sets()` function also is used by other AIA passes, the `src/aia_warn_undefined.c` file is using the liveness analysis to give warnings about variables which might be uninitialized before use.

11.3 Register Variables

The register variables optimization pass is implemented in `src/x86_32/x86_32_reg_vars.c`. It is called register variable optimization because it locates when and where it is possible to keep variables in registers.

The register variables optimization is located in the `src/x86_32` directory since it optimizes on the AIA code after it has been converted to a form close to x86-32 assembly by the `src/x86_32/x86_32_normalize.c` file.

It is easy to keep a variable in a register, the tricky thing is to find out when the value of the variable might be expected to be in memory.

The optimization pass is global, meaning it's analyzing a whole function at a time. It keeps track of two per instruction sets, a use set and a def (definition) set.

The use set contains memory variables which are used or redefined by some function which might get called later. If a variable is in the use set we must move the value of the variable to memory, because a function might need it.

The def set contains memory variables which gets redefined by some function which might have been called. Initially all memory variables used in the current function are in the def set. If a variable is in the def set the variable might have been redefined by a function, thus if we have the value for the variable in a register that value is not valid any more.

Consider the vitaly program:

```
1  func f():void
2      func g():void
3          write i;
4      end g
5
6      func h():void
7          i = 10;
8      end h
```

```
9
10      i:int = 1; # move value of i into register esi.
11
12      # Do stuff here, with i kept in register esi ...
13
14      g();  # Save i in memory before this call.
15
16      # Do stuff here, with i in register esi ...
17
18      h();  # Save i in memory before this call.
19
20      # Previous function call might have redefined i, thus
21      # the value of i in register esi might not be valid anymore.
22      # Move i back into a register before using it next time...
23  end f
```

A 64 bit linux installation running on an Intel core i7 CPU, the vitaly program located in `unit_tests/ExamplePrograms/knapsack/O_Knapsack.vit` compiled with register variables optimization disabled (`-Oign-reg-vars`) takes approximately 11.5 seconds to execute. With register variable optimization enabled the program takes approximately 9.2 seconds to execute. That is quite significant.

Note that a `C` implementation of that program is located in `unit_tests/ExamplePrograms/knapsack/knapsack.c` compiled with `gcc -O3 -m32` that program takes approximately 8.9 seconds to execute.

12 Register allocation

Before code can be generated, we need to assign the temporaries introduced by the AIA to actual registers. To do this we perform a liveness analysis of registers and temporaries. For each live set the following must hold:

$$\text{in}[n] = \text{use}[n] \cup \left(\left(\bigcup_{s \in \text{succ}[n]} \text{in}[s] \right) - \text{def}[n] \right)$$

where $\text{in}[n]$ is the set of registers (and temporaries) that are live into the instruction n. The set $\text{use}[n]$ is the set of registers being used by instruction n that is the registers being used as source operands in instruction n. Similar the set $\text{def}[n]$ is the set of operands being defined by instruction n that is the registers being used as destination operands. To perform the analysis the instructions of the AIA are linked with a live set which are iteratively filled with operands according to the formula above. When the live sets have reached a state where they no longer change the liveness analysis is complete.

Below is a dump of initial liveness analysis shown:

```
1  # AIA block start
2  .WHILE.top.4: # live { 8 }
3      .mov @size(4) %8 -> @size(4) %eax # live { 8 }
4      .cdq @size(4) %eax -> @size(4) %edx # live { eax 8 }
5      .mov @size(4) $2 -> @size(4) %7 # live { eax 8 edx }
6      .idiv @size(4) %eax, %7 -> @size(4) %eax # live { 7 eax 8 edx }
7      .cmp @size(4) %eax, $0 # live { eax 8 }
8      .jne @size(4) .IF.else.7, .IF.then.5 # live { 8 }
9  # AIA block end
```

Notice how `%eax` is live into line 4 until it is last used in line 7. Similarly `%edx` is live in lines 5 and 6, and `%7` is only live in line 6. See also how the temporary `%8` is live through the whole block, the reason for this is outside the scope of this block. The

use of the liveness analysis becomes clear now as we can see that the two temporaries `%7` and `%8` must be assigned to different registers and further more they may not be assigned to the registers `eax` or `edx`. This is due to the fact that the temporaries and registers appear in the same live set at some instruction.

To implement this application of the liveness analysis we have implemented an interference graph, which captures the interferences of the live sets as edges and the registers and temporaries as nodes in the graph. Then the problem can be solved as a graph coloring problem where the colors represent actual registers. It is of course preferable to use the as few colors as possible when coloring the interference graph, since this corresponds to using the least number of registers. This is important due to the fact that the number of registers is limited.

To approximate a minimum graph coloring we have use color by simplification. This works by iteratively choosing a node of insignificant degree, meaning the node has fewer neighbours than the number of registers available. The chosen node is removed from the graph and queued on a stack, waiting to get colored. When the node is removed the neighbouring nodes will have their degree lowered and possibly become of insignificant degree. If at some point no nodes can be removed a node is chosen for a potential spill, removed from the graph, added to the stack and the algorithm continues. In our implementation we choose the node of highest degree among the remaining for spill.

It is clear that some measures must be taken for pre-colored nodes, that is register which are already assigned. For example register `eax` and `edx` in relation to division instructions. To handle this we simply insert these as normal operands in the graph, but we do not allow for them to be removed from the graph and put into the coloring stack.

After the stack is created we simply pop the nodes from the stack, rebuilding the interference graph while assigning registers to them.

If spills were necessary the spills are handled by introducing a spill variable in memory, which is inserted in place of the spilled register where ever it is used. Then another passes will take care of normalizing the affected instructions, and the whole process can be repeated. Instead of always introducing new variables when spill occur, we utilize the fact that some temporaries are replacements of existing variables, therefore if a mapping from a spilled temporary to a variable exists, this variable is used instead of creating a new. Thus the total amount of memory used by the executable is reduced.

Returning to the example from above, we have the following register allocation:

```
1 # AIA block start
2 .WHILE.top.4:
3    .mov @size(4) %ecx -> @size(4) %eax
4    .cdq @size(4) %eax -> @size(4) %edx
5    .mov @size(4) $2 -> @size(4) %ebx
6    .idiv @size(4) %eax, %ebx -> @size(4) %eax
7    .cmp @size(4) %eax, $0
8    .jne @size(4) .IF.else.7, .IF.then.5
9 # AIA block end
```

Notice how `%8` is assigned to `%ecx` and `%7` to `%ebx`, that they are not assigned to

the same register and that they are different from `eax` and `edx` as expected.

13 Unused Move Elimination

This optimization phase is actually run just before the register allocation but it uses the information obtained from liveness analysis, which we introduced in the previous section on register allocation. For this reason this section is placed after register allocation.

In this phase we try to eliminate `mov` instructions which could be avoided. The ideaof this phase is to identify moves from a register or temporary to a temporary, where the temporary we are moving to can be replaced by the register we are moving from.
If we consider:

```
1 .mov @size(4) %1 -> @size(4) %2
2 .mov @size(4) %eax -> @size(4) %3
```

we would like to replace the temporary `%2` with the temporary `%1` , and replace `%3` by `%eax` . If this is possible the `mov` instruction is insignificant and can simply be removed.
In the following we call the register or temporary we are replacing with `A` and the temporary we are replacing `B` . The temporary `B` can be replaced by `A` if and only if the following conditions hold:

- `B` may not be redefined while `A` is live.
- If the `A` is a caller save register then no `call` instructions are allowed in the live range of `B`
- `A` may only be redefined in the live range of `B` if it is by a `mov` instruction where either `A` or `B` is the source.

We now consider the first condition. Assume `B` was replaced by `A` . Then if `B` was redefined while `A` is live, then we introduce a redefinition of `A` before its use hence we `A` is not guaranteed to be valid when it is used. Thus this condition must hold for a replacement to be valid.
If the temporary `B` were replaced by a caller save register and a call instruction is executed before `B` is used, we cannot guarantee `B` to be valid after the call instruction. Thus the second condition must hold.
Finally consider the last condition which is almost symmetric to the first condition only slightly more relaxed. If `B` is replaced by `A` then in either case of the condition corresponds to an insignificant move and hence this case is allowed. Otherwise the same reasoning as for the first condition applies.
Consider the following example from Knapsack
(`--dump=init-liveness-x86-32-ic`):

```
1 # AIA block start
2 .IF.then.34: # live { 251 252 245 246 247 248 249 }
3   .mov @size(4) %251 -> @size(4) %68 # live { 251 252 245 246 247 248 249 }
4   .add @size(4) %68, $1 -> @size(4) %68 # live { 252 68 245 246 247 248 249 }
5   .mov @size(4) %68 -> @size(4) %251 # live { 252 68 245 246 247 248 249 }
6   .mov @size(4) %251 -> @size(4) %69 # live { 251 252 245 246 247 248 249 }
7   .mov @size(4) %69 -> @size(4) @arg(0) # live { 251 252 69 245 246 247 248 249 }
8   .mov @size(4) %252 -> @size(4) %70 # live { 251 252 245 246 247 248 249 }
```

```
9    .mov @size(4) %70 -> @size(4) @arg(1) # live { 251 252 70 245 246 247 248 249 }
10   .call @size(4) Fii.O_Knapsack.exchange -> @size(1) %al # live { 251 252 245 246
         247 248 249 }
11   .mov @size(1) %al -> @size(1) %71 # live { 251 252 al 245 246 247 248 249 }
12   .jmp @size(4) .IF.end.35 # live { 251 252 245 246 247 248 249 }
13 # AIA block end
```

We start by trying to replace `%68` with `%251` through the live range of `%68`. We see that the conditions hold and do the replacement. Notice that `%68` is defined in line 4, but `%251` is not live. In a similar manner `%69` is replaced by `%251`, `%70` by `%252` and `%71` by `%al`. The result can be seen below (`--dump=unused-mov`):

```
1  # AIA block start
2  .IF.then.34: # live { 251 252 245 246 247 248 249 }
3    .mov @size(4) %251 -> @size(4) %251 # live { 251 252 245 246 247 248 249 }
4    .add @size(4) %251, $1 -> @size(4) %251 # live { 251 252 245 246 247 248 249 }
5    .mov @size(4) %251 -> @size(4) %251 # live { 251 252 245 246 247 248 249 }
6    .mov @size(4) %251 -> @size(4) %251 # live { 251 252 245 246 247 248 249 }
7    .mov @size(4) %251 -> @size(4) @arg(0) # live { 251 252 245 246 247 248 249 }
8    .mov @size(4) %252 -> @size(4) %252 # live { 251 252 245 246 247 248 249 }
9    .mov @size(4) %252 -> @size(4) @arg(1) # live { 251 252 245 246 247 248 249 }
10   .call @size(4) Fii.O_Knapsack.exchange -> @size(1) %al # live { 251 252 245 246
         247 248 249 }
11   .mov @size(1) %al -> @size(1) %al # live { 251 252 al 245 246 247 248 249 }
12   .jmp @size(4) .IF.end.35 # live { 251 252 245 246 247 248 249 }
13 # AIA block end
```

This gives us that lines 3, 5, 6 and 8 can be identified as unused moves and therefore can be removed. Note that a separate pass takes care of removing the introduced no-op `mov` instructions. To see the final impact of this pass, consider the following assembler output for our running example:

Without unused move elimination:

```
1  .IF.then.34:
2  # line 114
3     movl  %esi, %eax
4     addl  $1, %eax
5     movl  %eax, %esi
6  # line 115
7     movl  %esi, %eax
8     movl  %eax, (%esp)
9     movl  %edi, %eax
10    movl  %eax, 4(%esp)
11    call  Fii.O_Knapsack.exchange
```

With unused move elimination:

```
1  .IF.then.34:
2  # line 114
3     addl  $1, %edi
4  # line 115
5     movl  %edi, (%esp)
6     movl  %ebx, 4(%esp)
7     call  Fii.O_Knapsack.exchange
```

It is clear how the some `mov` instructions have been identified as unused and has been eliminated. The outputs above can be generated with the compile flags `-s` and `-s -Oign-unused-mov`.

14 Testing

Throughout the implementation of the compiler a number of test cases have been implemented. Some of these tests files are included in the test_programs directory. The vitaly test programs contained in this directory are meant to test various aspects of the compiler such as error reporting, invalid files and optimization passes impact on emitted assembler.
Furthermore we have spend time to improve overall software quality of the compiler by ensuring it is free of memory leaks. This can be tested with Valgrind, like in the following example:

```
valgrind --leak-check=full ./vitaly --stubborn test_programs/*
```

This will try to compile all files in the `test_programs` directory. Because of the `-stubborn` flag the compiler will continue through all files even though errors have been reported. Finally valgrind will output something like:

```
==12949== HEAP SUMMARY:
==12949==  in use at exit: 0 bytes in 0 blocks
==12949== total heap usage: 644,394 allocs, 644,394 frees, 47,525,439 bytes
     allocated
==12949==
==12949== All heap blocks were freed -- no leaks are possible
==12949==
==12949== For counts of detected and suppressed errors, rerun with: -v
==12949== ERROR SUMMARY: 0 errors from 0 contexts (suppressed: 2 from 2)
```

Indicating that everything allocated have been successfully freed before termination of the compiler.

Other test programs located in the unit_test directory, are all valid vitaly programs and can automatically be compiled, run and output correctness tested by:

```
unit_tests/test.sh
```

Notice to further check the compiler for memory leaks and invalid reads one can specify the command line argument `valg` when running `test.sh` which enables valgrind for each time a program is compiled. An output from running `test.sh` can be seen below:

```
vitaly ./string.vit
vitaly ./import7_1.vit
vitaly ./ctor01.vit
vitaly ./declarations.vit
vitaly ./std_stdo.vit
vitaly ./import3_1.vit
vitaly ./import1_1.vit
vitaly ./func_overload02.vit
vitaly ./unused_import_collision2.vit
vitaly ./empty_statements.vit
vitaly ./finalize.vit
vitaly ./import7_2.vit
vitaly ./unused_import_collision1.vit
vitaly ./import4_1.vit
vitaly ./import1_2.vit
vitaly ./import2_1.vit
vitaly ./immediate_var_init.vit
vitaly ./ary0.vit
vitaly ./short_circuit2.vit
vitaly ./multiple_dot.vit
vitaly ./import2_3.vit
vitaly ./record_sep.vit
vitaly ./call_nest2.vit
vitaly ./empty_func_body.vit
vitaly ./std_string01.vit
vitaly ./std_errno.vit
vitaly ./call_nest1.vit
vitaly ./import2_2.vit
vitaly ./import5_3.vit
vitaly ./unused_import_collision3.vit
vitaly ./vector01.vit
vitaly ./expression_as_statement.vit
vitaly ./std_math.vit
vitaly ./thread01.vit
vitaly ./import5_2.vit
```

```
36 vitaly ./import3_2.vit
37 vitaly ./std_array.vit
38 vitaly ./nest1.vit
39 vitaly ./char.vit
40 vitaly ./methods.vit
41 vitaly ./import5_1.vit
42 vitaly ./import6_2.vit
43 vitaly ./import6_1.vit
44 vitaly ./func_overload03.vit
45 vitaly ./import4_2.vit
46 vitaly ./func_overload01.vit
47 vitaly ./import7_3.vit
48 vitaly ./var_in_rec.vit
49 vitaly ./std_comparator.vit
50 vitaly ./empty_record_body.vit
51 vitaly ./short_circuit1.vit
52 (51/51) successful tests
```

Notice that all the tests are successful. If a test failed, either errors from the compiler, or differences of output compared to the expected output would be reported. This test is particularly useful for a fast test if changes to the compiler introduced runtime and compile time bugs. For a more comprehensive test one should test compilation of the programs in `test_programs` since these as mentioned also include tests of error messages. The implementation of the test programs can be found in the mentioned directories.

A Source Code

A.1 src/main.c

```
#include <sys/stat.h>
#include <unistd.h>
#include <getopt.h>
#include <main.h>
#include <parser.h>
#include <errno.h>
#include <debug.h>
#include <string_builder.h>
#include <test/test_include.h>
#include <ast/symbol_table.h>
#include <ast/ast_visitor_type_check.h>
#include <ast/ast_visitor_import.h>
#include <ast/ast_visitor_aia.h>
#include <aia/aia_functions_return.h>
#include <aia/aia_normalize_addr.h>
#include <aia/aia_optimize.h>
#include <aia/aia_block_elim.h>
#include <x86_32/x86_32.h>
#include <import_handler.h>
#include <help_msg.h>

#undef DEBUG_TYPE
#define DEBUG_TYPE main

#ifndef DEFAULT_OBJ_DIR
#error Missing macro definition DEFAULT_OBJ_DIR
#endif

#define DEFAULT_MAX_MSG INT32_MAX

Command_Line_Options cmdopts = {
    .vitaly_program_name = NULL,
    .output_name = NULL,
    .import_search_paths = VECTOR_STATIC_INIT(),
    .working_directory = NULL,

    .dump_parse_tree = false,
    .dump_parse_tree_graph = false,
    .dump_symbol_table_graph = false,
    .dump_symbol_table = false,

    .dump_init_ic = false,
    .dump_norm_addr_ic = false,
    .dump_const_prop_ic = false,
    .dump_instr_elim_ic = false,

    .dump_norm_x86_32_ic = false,
    .dump_init_liveness_x86_32_ic = false,
    .dump_liveness_x86_32_ic = false,
    .dump_reg_alloc_x86_32_ic = false,
    .dump_unused_mov_ic = false,
    .dump_reg_vars_liveness_ic = false,
    .dump_reg_vars_ic = false,
    .dump_final_x86_32_ic = false,
    .dump_def_to_use_ic = false,
    .dump_warn_uninit_liveness_ic = false,

    .dump_c_header = false,
    .dump_asm = false,

    .opt_func_access = true,
    .opt_const_prop = true,
    .opt_instr_elim = true,
    .opt_unused_mov = true,
    .opt_unused_set = true,
    .opt_reg_vars = true,
    .opt_def_to_use = true,

```

```
69      .warn_no_finalize = false,
70      .warn_implicit_cast = true,
71      .warn_ref_compare = true,
72      .warn_overflow = true,
73      .warn_div_zero = true,
74      .warn_uninitialized = true,
75      .warn_is_error = false,
76
77      .compile_only = false,
78      .assemble_only = false,
79      .keep_obj = false,
80
81      .library_init = false,
82      .link_libvitaly = true,
83      .with_threads = false,
84      .has_main = false,
85
86      .recursive_compile = false,
87      .generate_viti = false,
88
89      .stubborn = false,
90      .verbose_output = false,
91
92      .max_msg = DEFAULT_MAX_MSG
93  };
94
95  typedef enum Option_Parse_Status {
96      OPTION_PARSE_CONTINUE,
97      OPTION_PARSE_EXIT_SUCCESS,
98      OPTION_PARSE_EXIT_FAILURE
99  } Option_Parse_Status;
100
101 enum Option_Indices {
102     OUT_OPTION,
103     MAIN_OPTION,
104     LIB_INIT_OPTION,
105     IGN_LIB_INIT_OPTION,
106     NO_LIB_VIT_OPTION,
107     THREAD_OPTION,
108     IGN_THREAD_OPTION,
109     IGN_NO_LIB_VIT_OPTION,
110     LIB_PATH_OPTION,
111     LIB_OPTION,
112     IMPORT_PATH_OPTION,
113     IGN_MAIN_OPTION,
114     DUMP_OPTION,
115     OPTIMIZE_OPTION,
116     MAX_MSG_OPTION,
117     STUBBORN_OPTION,
118     IGN_STUBBORN_OPTION,
119     WARNING_OPTION,
120     COMPILE_ONLY_OPTION,
121     IGN_COMPILE_ONLY_OPTION,
122     ASM_ONLY_OPTION,
123     IGN_ASM_ONLY_OPTION,
124     KEEP_OBJ_OPTION,
125     IGN_KEEP_OBJ_OPTION,
126     VERBOSE_OPTION,
127     IGN_VERBOSE_OPTION,
128     HELP_OPTION,
129     RECURSIVE_COMPILE_OPTION,
130     IGN_RECURSIVE_COMPILE_OPTION,
131     GENERATE_VITI_OPTION,
132     IGN_GENERATE_VITI_OPTION,
133     NULL_OPTION // Must be last.
134 };
135
136 static const char short_options[] = "Irvskmhcxw:o:L:l:O:i:";
137
138 static struct option long_options[] = {
139     [OUT_OPTION] = {
140         "output",
141         required_argument,
142         NULL,
```

```
143         'o'
144     },
145 #define OUT_OPTION_CSTR QFY("-o") " (" QFY("--output") ")"
146     [MAIN_OPTION] = {
147         "main",
148         required_argument,
149         NULL,
150         'm'
151     },
152     [IGN_MAIN_OPTION] = {
153         "ign-main",
154         required_argument,
155         NULL,
156         0
157     },
158     [LIB_INIT_OPTION] = {
159         "lib-init",
160         no_argument,
161         NULL,
162         0
163     },
164     [IGN_LIB_INIT_OPTION] = {
165         "ign-lib-init",
166         no_argument,
167         NULL,
168         0
169     },
170     [THREAD_OPTION] = {
171         "thread",
172         no_argument,
173         NULL,
174         0
175     },
176 #define THREAD_OPTION_CSTR QFY("--thread")
177     [IGN_THREAD_OPTION] = {
178         "ign-thread",
179         no_argument,
180         NULL,
181         0
182     },
183     [NO_LIB_VIT_OPTION] = {
184         "no-libvit",
185         no_argument,
186         NULL,
187         'x'
188     },
189 #define NO_LIB_VIT_OPTION_CSTR QFY("-x") " (" QFY("--no-libvit") ")"
190     [IGN_NO_LIB_VIT_OPTION] = {
191         "ign-no-libvit",
192         no_argument,
193         NULL,
194         0
195     },
196     [LIB_PATH_OPTION] = {
197         "lib-path",
198         required_argument,
199         NULL,
200         'L'
201     },
202     [LIB_OPTION] = {
203         "lib",
204         required_argument,
205         NULL,
206         'l'
207     },
208     [IMPORT_PATH_OPTION] = {
209         "import-path",
210         required_argument,
211         NULL,
212         'i'
213     },
214     [DUMP_OPTION] = {
215         "dump",
216         required_argument,
```

```
217         NULL,
218         0
219     },
220 #define DUMP_OPTION_CSTR QFY("--dump")
221     [OPTIMIZE_OPTION] = {
222         "optimize",
223         required_argument,
224         NULL,
225         'O'
226     },
227 #define OPTIMIZE_OPTION_CSTR QFY("-O") " (" QFY("--optimize") ")"
228     [MAX_MSG_OPTION] = {
229         "max-msg",
230         required_argument,
231         NULL,
232         0
233     },
234     [STUBBORN_OPTION] = {
235         "stubborn",
236         no_argument,
237         NULL,
238         0
239     },
240     [IGN_STUBBORN_OPTION] = {
241         "ign-stubborn",
242         no_argument,
243         NULL,
244         0
245     },
246     [WARNING_OPTION] = {
247         "warning",
248         required_argument,
249         NULL,
250         'w'
251     },
252 #define WARNING_OPTION_CSTR QFY("-w") " (" QFY("--warning") ")"
253     [COMPILE_ONLY_OPTION] = {
254         "compile-only",
255         no_argument,
256         NULL,
257         'c'
258     },
259 #define COMPILE_ONLY_OPTION_CSTR QFY("-c") " (" QFY("--compile-only") ")"
260     [IGN_COMPILE_ONLY_OPTION] = {
261         "ign-compile-only",
262         no_argument,
263         NULL,
264         0
265     },
266     [ASM_ONLY_OPTION] = {
267         "asm-only",
268         no_argument,
269         NULL,
270         's'
271     },
272 #define ASM_ONLY_OPTION_CSTR QFY("-s") " (" QFY("--asm-only") ")"
273     [IGN_ASM_ONLY_OPTION] = {
274         "ign-asm-only",
275         no_argument,
276         NULL,
277         0
278     },
279     [KEEP_OBJ_OPTION] = {
280         "keep-obj",
281         no_argument,
282         NULL,
283         'k'
284     },
285     [IGN_KEEP_OBJ_OPTION] = {
286         "ign-keep-obj",
287         no_argument,
288         NULL,
289         0
290     },
```

```
291     [VERBOSE_OPTION] = {
292        "verbose",
293        no_argument,
294        NULL,
295        'v'
296     },
297     [IGN_VERBOSE_OPTION] = {
298        "ign-verbose",
299        no_argument,
300        NULL,
301        0
302     },
303     [RECURSIVE_COMPILE_OPTION] = {
304        "recursive",
305        no_argument,
306        NULL,
307        'r'
308     },
309  #define RECURSIVE_OPTION_CSTR QFY("-r") " (" QFY("--recursive") ")"
310     [IGN_RECURSIVE_COMPILE_OPTION] = {
311        "ign-recursive",
312        no_argument,
313        NULL,
314        0
315     },
316  #define IGN_RECURSIVE_OPTION_CSTR QFY("--ign-recursive")
317     [GENERATE_VITI_OPTION] = {
318        "gen-viti",
319        no_argument,
320        NULL,
321        'I'
322     },
323     [IGN_GENERATE_VITI_OPTION] = {
324        "ign-gen-viti",
325        no_argument,
326        NULL,
327        0
328     },
329     [HELP_OPTION] = {
330        "help",
331        optional_argument,
332        NULL,
333        'h'
334     },
335     [NULL_OPTION] = {
336        NULL,
337        0,
338        NULL,
339        0
340     }
341  };
342
343  static String assemble(Const_String asm_file, Const_String src_file);
344
345  VECTOR(gen_object_files);
346  VECTOR(cmd_object_files);
347  VECTOR(lib_paths);
348  VECTOR(lib_names);
349
350  static void ___add_object_file(Vector *vec, String obj, Const_String err_msg)
351  {
352     if (obj) {
353        errno = 0;
354        if (!file_access_read(obj)) {
355           if (errno)
356              report_error(obj, S("%S [%m]\n"), err_msg);
357           else
358              report_error(obj, S("%S\n"), err_msg);
359           string_destroy(obj);
360        } else {
361           vector_append(vec, obj);
362        }
363     }
364  }
```

```
365
366 static void add_object_file(Vector *vec, String obj)
367 {
368    ___add_object_file(vec, obj,
369          S("unable to open object file"));
370 }
371
372 void add_gen_object_file(String obj)
373 {
374    add_object_file(&gen_object_files, obj);
375 }
376
377 static void add_cmd_object_file(String obj)
378 {
379    if (cmdopts.assemble_only) {
380       report_warning(obj, S("file ignored since the "
381                ASM_ONLY_OPTION_CSTR
382                " option is enabled\n"));
383       goto err_out;
384    }
385    if (cmdopts.compile_only) {
386       report_warning(obj, S("file ignored since the "
387                COMPILE_ONLY_OPTION_CSTR
388                " option is enabled\n"));
389       goto err_out;
390    }
391
392    add_object_file(&cmd_object_files, obj);
393    return;
394
395 err_out:
396    string_destroy(obj);
397 }
398
399 static void add_cmd_library_file(String obj)
400 {
401    ___add_object_file(&cmd_object_files, obj,
402          S("unable to open library file"));
403 }
404
405 static void assemble_add_object(Const_String asm_file)
406 {
407    if (cmdopts.assemble_only) {
408       report_warning(asm_file, S("assembly source file ignored since the "
409                ASM_ONLY_OPTION_CSTR " option is enabled\n"));
410       return;
411    }
412
413    String obj_file = assemble(asm_file, asm_file);
414    add_gen_object_file(obj_file);
415 }
416
417 static bool verify_dir_path(Const_String pathname,
418       Const_String path_type)
419 {
420    struct stat s;
421    if (pathname) {
422       int ret = stat(string_to_cstr(pathname), &s);
423       if (ret == -1) {
424          report_error(pathname, S("cannot access %S [%m]\n"), path_type);
425          return false;
426       } else if (!S_ISDIR(s.st_mode)) {
427          report_error(pathname, S("%S expected to be a directory\n"),
428                path_type);
429          return false;
430       } else {
431          return true;
432       }
433    }
434    return false;
435 }
436
437 static void add_lib_path(String path)
438 {
```

```
439     if (verify_dir_path(path, S("library path")))
440        vector_append(&lib_paths, path);
441     else
442        string_destroy(path);
443  }
444
445  static void add_lib_name(String lib)
446  {
447     vector_append(&lib_names, lib);
448  }
449
450  static void add_import_path(String path)
451  {
452     if (verify_dir_path(path, S("import path")))
453        vector_append(&cmdopts.import_search_paths, path);
454     else
455        string_destroy(path);
456  }
457
458  static bool get_int32_argument(const char *option_name,
459        int32_t min_val, int32_t *result)
460  {
461     int32_t n;
462     errno = 0;
463     n = string_base10_to_int32(S(optarg));
464     if (errno) {
465        if (errno == EINVAL) {
466           print_error(S("option " QFY("%s") " requires integer argument, "
467                    "found " QFY("%s") "\n"),
468                 option_name, optarg);
469        } else if (errno == ERANGE) {
470           print_error(S("option " QFY("%s") " argument " QFY("%s")
471                    " %s integer\n"),
472                 option_name,
473                 optarg,
474                 n == INT32_MAX ? "overflows" : "underflows");
475        } else {
476           print_error(S("unable to convert option " QFY ("%s")
477                    " argument " QFY("%s") " to integer\n"),
478                 option_name, optarg);
479        }
480        goto err_out;
481     }
482     if (n < min_val) {
483        print_error(S("option " QFY("%s") " requires integer argument bigger "
484                 "than %" PRId32 " found " QFY("%s") "\n"),
485              option_name, min_val, optarg);
486        goto err_out;
487     }
488
489     *result = n;
490     return true;
491
492  err_out:
493     return false;
494  }
495
496  static bool get_int32_argument_long_option(const char *option_name,
497        int32_t min_val, int32_t *result)
498  {
499     bool ret;
500     STRING(opt_str, "--");
501     string_append(opt_str, S(option_name));
502     ret = get_int32_argument(string_to_cstr(opt_str), min_val, result);
503     string_clear(opt_str);
504     return ret;
505  }
506
507  static UNUSED bool get_int32_argument_short_option(Int option_name,
508        int32_t min_val, int32_t *result)
509  {
510     bool ret;
511     option_name &= ~0xff;
512     option_name <<= 8;
```

```
513     option_name |= '-';
514     ret = get_int32_argument((char *)&option_name, min_val, result);
515     return ret;
516  }
517
518  static inline void set_warn_all(bool b)
519  {
520     cmdopts.warn_implicit_cast = b;
521     cmdopts.warn_no_finalize = b;
522     cmdopts.warn_ref_compare = b;
523     cmdopts.warn_overflow  = b;
524     cmdopts.warn_div_zero  = b;
525     cmdopts.warn_uninitialized = b;
526  }
527
528
529  static Option_Parse_Status parse_warn_option_argument(Const_String arg)
530  {
531     Option_Parse_Status ret = OPTION_PARSE_CONTINUE;
532     if (!string_compare(arg, S("implicit-cast"))) {
533        cmdopts.warn_implicit_cast = true;
534     } else if (!string_compare(arg, S("ign-implicit-cast"))) {
535        cmdopts.warn_implicit_cast = false;
536     } else if (!string_compare(arg, S("no-finalize"))) {
537        cmdopts.warn_no_finalize = true;
538     } else if (!string_compare(arg, S("ign-no-finalize"))) {
539        cmdopts.warn_no_finalize = false;
540     } else if (!string_compare(arg, S("ref-compare"))) {
541        cmdopts.warn_ref_compare = true;
542     } else if (!string_compare(arg, S("ign-ref-compare"))) {
543        cmdopts.warn_ref_compare = false;
544     } else if (!string_compare(arg, S("is-error"))) {
545        cmdopts.warn_is_error = true;
546     } else if (!string_compare(arg, S("ign-is-error"))) {
547        cmdopts.warn_is_error = false;
548     } else if (!string_compare(arg, S("overflow"))) {
549        cmdopts.warn_overflow = true;
550     } else if (!string_compare(arg, S("ign-overflow"))) {
551        cmdopts.warn_overflow = false;
552     } else if (!string_compare(arg, S("div-zero"))) {
553        cmdopts.warn_div_zero = true;
554     } else if (!string_compare(arg, S("ign-div-zero"))) {
555        cmdopts.warn_div_zero = false;
556     } else if (!string_compare(arg, S("uninitialized"))) {
557        cmdopts.warn_uninitialized = true;
558     } else if (!string_compare(arg, S("ign-uninitialized"))) {
559        cmdopts.warn_uninitialized = false;
560     } else if (!string_compare(arg, S("all"))) {
561        set_warn_all(true);
562     } else if (!string_compare(arg, S("ign-all"))) {
563        set_warn_all(false);
564     } else {
565        print_error(S("unrecognized " WARNING_OPTION_CSTR " option argument "
566              QFY("%S") "\n"), arg);
567        ret = OPTION_PARSE_EXIT_FAILURE;
568     }
569     return ret;
570  }
571
572  static inline void set_optimize_all(bool b)
573  {
574     cmdopts.opt_func_access  = b;
575     cmdopts.opt_const_prop  = b;
576     cmdopts.opt_instr_elim  = b;
577     cmdopts.opt_unused_mov  = b;
578     cmdopts.opt_unused_set  = b;
579     cmdopts.opt_reg_vars  = b;
580     cmdopts.opt_def_to_use  = b;
581  }
582
583  static Option_Parse_Status parse_optimize_option_argument(Const_String arg)
584  {
585     Option_Parse_Status ret = OPTION_PARSE_CONTINUE;
586     if (!string_compare(arg, S("func-access"))) {
```

```
587         cmdopts.opt_func_access = true;
588      } else if (!string_compare(arg, S("ign-func-access"))) {
589         cmdopts.opt_func_access = false;
590      } else if (!string_compare(arg, S("const-prop"))) {
591         cmdopts.opt_const_prop = true;
592      } else if (!string_compare(arg, S("ign-const-prop"))) {
593         cmdopts.opt_const_prop = false;
594      } else if (!string_compare(arg, S("instr-elim"))) {
595         cmdopts.opt_instr_elim = true;
596      } else if (!string_compare(arg, S("ign-instr-elim"))) {
597         cmdopts.opt_instr_elim = false;
598      } else if (!string_compare(arg, S("unused-mov"))) {
599         cmdopts.opt_unused_mov = true;
600      } else if (!string_compare(arg, S("ign-unused-mov"))) {
601         cmdopts.opt_unused_mov = false;
602      } else if (!string_compare(arg, S("unused-set"))) {
603         cmdopts.opt_unused_set = true;
604      } else if (!string_compare(arg, S("ign-unused-set"))) {
605         cmdopts.opt_unused_set = false;
606      } else if (!string_compare(arg, S("reg-vars"))) {
607         cmdopts.opt_reg_vars = true;
608      } else if (!string_compare(arg, S("ign-reg-vars"))) {
609         cmdopts.opt_reg_vars = false;
610      } else if (!string_compare(arg, S("def-to-use"))) {
611         cmdopts.opt_def_to_use = true;
612      } else if (!string_compare(arg, S("ign-def-to-use"))) {
613         cmdopts.opt_def_to_use = false;
614      } else if (!string_compare(arg, S("all"))) {
615         set_optimize_all(true);
616      } else if (!string_compare(arg, S("ign-all"))) {
617         set_optimize_all(false);
618      } else {
619         print_error(S("unrecognized " OPTIMIZE_OPTION_CSTR " option argument "
620               QFY("%S") "\n"), arg);
621         ret = OPTION_PARSE_EXIT_FAILURE;
622      }
623      return ret;
624   }
625
626   static Option_Parse_Status parse_dump_option_argument(Const_String arg)
627   {
628      Option_Parse_Status ret = OPTION_PARSE_CONTINUE;
629
630      if (!string_compare(arg, S("parse-tree"))) {
631         cmdopts.dump_parse_tree = true;
632      } else if (!string_compare(arg, S("ign-parse-tree"))) {
633         cmdopts.dump_parse_tree = false;
634      } else if (!string_compare(arg, S("symbol-table"))) {
635         cmdopts.dump_symbol_table = true;
636      } else if (!string_compare(arg, S("ign-symbol-table"))) {
637         cmdopts.dump_symbol_table = false;
638      } else if (!string_compare(arg, S("parse-tree-graph"))) {
639         cmdopts.dump_parse_tree_graph = true;
640      } else if (!string_compare(arg, S("ign-parse-tree-graph"))) {
641         cmdopts.dump_parse_tree_graph = false;
642      } else if (!string_compare(arg, S("symbol-table-graph"))) {
643         cmdopts.dump_symbol_table_graph = true;
644      } else if (!string_compare(arg, S("ign-symbol-table-graph"))) {
645         cmdopts.dump_symbol_table_graph = false;
646      } else if (!string_compare(arg, S("c-header"))) {
647         cmdopts.dump_c_header = true;
648      } else if (!string_compare(arg, S("ign-c-header"))) {
649         cmdopts.dump_c_header = false;
650      } else if (!string_compare(arg, S("init-ic"))) {
651         cmdopts.dump_init_ic = true;
652      } else if (!string_compare(arg, S("ign-init-ic"))) {
653         cmdopts.dump_init_ic = false;
654      } else if (!string_compare(arg, S("norm-addr-ic"))) {
655         cmdopts.dump_norm_addr_ic = true;
656      } else if (!string_compare(arg, S("ign-norm-addr-ic"))) {
657         cmdopts.dump_norm_addr_ic = false;
658      } else if (!string_compare(arg, S("const-prop-ic"))) {
659         cmdopts.dump_const_prop_ic = true;
660      } else if (!string_compare(arg, S("ign-const-prop-ic"))) {
```

```
661         cmdopts.dump_const_prop_ic = false;
662      } else if (!string_compare(arg, S("instr-elim-ic"))) {
663         cmdopts.dump_instr_elim_ic = true;
664      } else if (!string_compare(arg, S("ign-instr-elim-ic"))) {
665         cmdopts.dump_instr_elim_ic = false;
666      } else if (!string_compare(arg, S("norm-x86-32-ic"))) {
667         cmdopts.dump_norm_x86_32_ic = true;
668      } else if (!string_compare(arg, S("ign-norm-x86-32-ic"))) {
669         cmdopts.dump_norm_x86_32_ic = false;
670      } else if (!string_compare(arg, S("liveness-x86-32-ic"))) {
671         cmdopts.dump_liveness_x86_32_ic = true;
672      } else if (!string_compare(arg, S("ign-liveness-x86-32-ic"))) {
673         cmdopts.dump_liveness_x86_32_ic = false;
674      } else if (!string_compare(arg, S("init-liveness-x86-32-ic"))) {
675         cmdopts.dump_init_liveness_x86_32_ic = true;
676      } else if (!string_compare(arg, S("ign-init-liveness-x86-32-ic"))) {
677         cmdopts.dump_init_liveness_x86_32_ic = false;
678      } else if (!string_compare(arg, S("reg-vars-liveness-ic"))) {
679         cmdopts.dump_reg_vars_liveness_ic = true;
680      } else if (!string_compare(arg, S("ign-reg-vars-liveness-ic"))) {
681         cmdopts.dump_reg_vars_liveness_ic = false;
682      } else if (!string_compare(arg, S("reg-vars-ic"))) {
683         cmdopts.dump_reg_vars_ic = true;
684      } else if (!string_compare(arg, S("ign-reg-vars-ic"))) {
685         cmdopts.dump_reg_vars_ic = false;
686      } else if (!string_compare(arg, S("unused-mov-ic"))) {
687         cmdopts.dump_unused_mov_ic = true;
688      } else if (!string_compare(arg, S("ign-unused-mov-ic"))) {
689         cmdopts.dump_unused_mov_ic = false;
690      } else if (!string_compare(arg, S("reg-alloc-x86-32-ic"))) {
691         cmdopts.dump_reg_alloc_x86_32_ic = true;
692      } else if (!string_compare(arg, S("ign-reg-alloc-x86-32-ic"))) {
693         cmdopts.dump_reg_alloc_x86_32_ic = false;
694      } else if (!string_compare(arg, S("def-to-use-ic"))) {
695         cmdopts.dump_def_to_use_ic = true;
696      } else if (!string_compare(arg, S("ign-def-to-use-ic"))) {
697         cmdopts.dump_def_to_use_ic = false;
698      } else if (!string_compare(arg, S("warn-uninit-liveness-ic"))) {
699         cmdopts.dump_warn_uninit_liveness_ic = true;
700      } else if (!string_compare(arg, S("ign-warn-uninit-liveness-ic"))) {
701         cmdopts.dump_def_to_use_ic = false;
702      } else if (!string_compare(arg, S("final-x86-32-ic"))) {
703         cmdopts.dump_final_x86_32_ic = true;
704      } else if (!string_compare(arg, S("ign-final-x86-32-ic"))) {
705         cmdopts.dump_final_x86_32_ic = false;
706      } else if (!string_compare(arg, S("asm"))) {
707         cmdopts.dump_asm = true;
708      } else if (!string_compare(arg, S("ign-asm"))) {
709         cmdopts.dump_asm = false;
710      } else {
711         print_error(S("unrecognized " DUMP_OPTION_CSTR " option argument "
712               QFY("%S") "\n"), arg);
713         ret = OPTION_PARSE_EXIT_FAILURE;
714      }
715
716      return ret;
717   }
718
719   static inline Option_Parse_Status parse_list_option_arguments(
720         Option_Parse_Status (*option_parser)(Const_String arg))
721   {
722      Option_Parse_Status ret = OPTION_PARSE_CONTINUE;
723
724      STRING(optarg_str, optarg);
725      Vector *args = string_split(optarg_str, S(","));
726      string_clear(optarg_str);
727
728      String arg;
729      VECTOR_FOR_EACH_ENTRY(args, arg)
730         if ((ret = option_parser(arg)) != OPTION_PARSE_CONTINUE)
731            break;
732      vector_destroy(args, (Vector_Destructor)string_destroy);
733
734      return ret;
```

```
735 }
736
737 static int unrecognized_short_option_count;
738
739 static Option_Parse_Status option_parse_error(char *argv[])
740 {
741    int i;
742    const char *tmp, *tmp_str;
743    Option_Parse_Status ret = OPTION_PARSE_EXIT_FAILURE;
744
745    tmp = argv[optind - 1];
746    if (strstr(tmp, "--") == tmp) {
747       tmp_str = tmp + 2;
748       for (i = 0; i < NULL_OPTION; i++) {
749          if (strcmp(tmp_str, long_options[i].name) == 0) {
750             print_error(S("option " QFY("%s")
751                      " requires an argument\n"), tmp);
752             goto out;
753          }
754       }
755       print_error(S("unrecognized option " QFY("%s") "\n"), tmp);
756       goto out;
757    } else if (strchr(short_options, optopt)) {
758       print_error(S("option " QFY("-%c") " requires an argument\n"), optopt);
759       goto out;
760    }
761
762    ++unrecognized_short_option_count;
763    print_error(S("unrecognized option " QFY("-%c") "\n"), optopt);
764
765 out:
766    return ret;
767 }
768
769 static Option_Parse_Status parse_help_option_argument(Const_String arg)
770 {
771    Option_Parse_Status ret = OPTION_PARSE_EXIT_SUCCESS;
772
773    if (!string_compare(arg, S("dump"))) {
774       print_message(dump_help_msg);
775    } else if (!string_compare(arg, S("warning"))) {
776       print_message(warn_help_msg);
777    } else if (!string_compare(arg, S("optimize"))) {
778       print_message(opt_help_msg);
779    } else {
780       print_error(S("unrecognized " DUMP_OPTION_CSTR " option argument "
781             QFY("%S") "\n"), arg);
782       ret = OPTION_PARSE_EXIT_FAILURE;
783    }
784    return ret;
785 }
786
787 static Option_Parse_Status parse_help_option()
788 {
789    Option_Parse_Status ret = OPTION_PARSE_EXIT_SUCCESS;
790    if (optarg)
791       ret = parse_help_option_argument(S(optarg));
792    else
793       print_message(help_msg, cmdopts.vitaly_program_name);
794    return ret;
795 }
796
797 static Option_Parse_Status parse_long_option(int idx)
798 {
799    Option_Parse_Status ret = OPTION_PARSE_CONTINUE;
800    switch (idx) {
801    case DUMP_OPTION:
802       ret = parse_list_option_arguments(parse_dump_option_argument);
803       break;
804    case MAX_MSG_OPTION:
805       if (!get_int32_argument_long_option(long_options[idx].name, 1,
806             &cmdopts.max_msg))
807          ret = OPTION_PARSE_EXIT_FAILURE;
808       break;
```

```
809     case STUBBORN_OPTION:
810        cmdopts.stubborn = true;
811        break;
812     case IGN_STUBBORN_OPTION:
813        cmdopts.stubborn = false;
814        break;
815     case IGN_COMPILE_ONLY_OPTION:
816        cmdopts.compile_only = false;
817        break;
818     case IGN_ASM_ONLY_OPTION:
819        cmdopts.assemble_only = false;
820        break;
821     case IGN_KEEP_OBJ_OPTION:
822        cmdopts.keep_obj = false;
823        break;
824     case IGN_MAIN_OPTION:
825        cmdopts.has_main = false;
826        break;
827     case IGN_VERBOSE_OPTION:
828        cmdopts.verbose_output = false;
829        break;
830     case IGN_GENERATE_VITI_OPTION:
831        cmdopts.generate_viti = false;
832        break;
833     case IGN_RECURSIVE_COMPILE_OPTION:
834        cmdopts.recursive_compile = false;
835        break;
836     case LIB_INIT_OPTION:
837        cmdopts.library_init = true;
838        break;
839     case IGN_LIB_INIT_OPTION:
840        cmdopts.library_init = false;
841        break;
842     case IGN_NO_LIB_VIT_OPTION:
843        cmdopts.link_libvitaly = true;
844        break;
845     case THREAD_OPTION:
846        cmdopts.with_threads = true;
847        break;
848     case IGN_THREAD_OPTION:
849        cmdopts.with_threads = false;
850        break;
851     case NO_LIB_VIT_OPTION:
852        /* Should not happen. */
853     case KEEP_OBJ_OPTION:
854        /* Should not happen. */
855     case OPTIMIZE_OPTION:
856        /* Should not happen. */
857     case WARNING_OPTION:
858        /* Should not happen. */
859     case MAIN_OPTION:
860        /* Should not happen. */
861     case COMPILE_ONLY_OPTION:
862        /* Should not happen. */
863     case ASM_ONLY_OPTION:
864        /* Should not happen. */
865     case OUT_OPTION:
866        /* Should not happen. */
867     case VERBOSE_OPTION:
868        /* Should not happen. */
869     case HELP_OPTION:
870        /* Should not happen. */
871     case NULL_OPTION:
872        /* Should not happen. */
873        break;
874     }
875
876     return ret;
877  }
878
879  static Option_Parse_Status set_output_name()
880  {
881     string_destroy(cmdopts.output_name);
882     cmdopts.output_name = string_alloc(S(optarg));
```

```
883     return OPTION_PARSE_CONTINUE;
884 }
885
886 static bool verify_long_option_name(int option_index UNUSED,
887       char *argv[] UNUSED)
888 {
889 #if 0
890     if (!option_index)
891        return true;
892
893     int arg_idx;
894     if (long_options[option_index].has_arg)
895        arg_idx = optind - 2;
896     else
897        arg_idx = optind - 1;
898
899     if (strcmp(long_options[option_index].name, argv[arg_idx] + 2)) {
900        print_error(S("unrecognized option " QFY("%s") "\n"), argv[arg_idx]);
901        return false;
902     }
903 #endif
904
905     return true;
906 }
907
908 static Option_Parse_Status merge_new_parse_status(Option_Parse_Status prev_opt,
909       Option_Parse_Status new_opt)
910 {
911     Option_Parse_Status ret = prev_opt;
912
913     switch (new_opt) {
914     case OPTION_PARSE_CONTINUE:
915        break;
916     case OPTION_PARSE_EXIT_SUCCESS:
917        if (ret != OPTION_PARSE_EXIT_FAILURE)
918           ret = OPTION_PARSE_EXIT_SUCCESS;
919        break;
920     case OPTION_PARSE_EXIT_FAILURE:
921        ret = OPTION_PARSE_EXIT_FAILURE;
922        break;
923     };
924
925     return ret;
926 }
927
928 static Option_Parse_Status parse_cmd_options(int argc, char *argv[])
929 {
930     int c, option_index;
931     Option_Parse_Status ret = OPTION_PARSE_CONTINUE;
932     Option_Parse_Status tmp_opt;
933
934     cmdopts.vitaly_program_name = string_basename(S(argv[0]));
935
936     opterr = 0;
937     option_index = 0;
938     while ((c = getopt_long(argc, argv, short_options,
939           long_options, &option_index)) != -1) {
940
941        if (!verify_long_option_name(option_index, argv)) {
942           ret = OPTION_PARSE_EXIT_FAILURE;
943           goto skip_arg;
944        }
945
946        switch (c) {
947        case 0:
948           tmp_opt = parse_long_option(option_index);
949           ret = merge_new_parse_status(ret, tmp_opt);
950           break;
951
952        case 'h':
953           tmp_opt = parse_help_option();
954           ret = merge_new_parse_status(ret, tmp_opt);
955           break;
956
```

```
957         case 'w':
958            tmp_opt = parse_list_option_arguments(parse_warn_option_argument);
959            ret = merge_new_parse_status(ret, tmp_opt);
960            break;
961
962         case 'c':
963            cmdopts.compile_only = true;
964            break;
965
966         case 'r':
967            cmdopts.recursive_compile = true;
968            break;
969
970         case 's':
971            cmdopts.assemble_only = true;
972            break;
973
974         case 'k':
975            cmdopts.keep_obj = true;
976            break;
977
978         case 'x':
979            cmdopts.link_libvitaly = false;
980            break;
981
982         case 'o':
983            tmp_opt = set_output_name();
984            ret = merge_new_parse_status(ret, tmp_opt);
985            break;
986
987         case 'm':
988            cmdopts.has_main = true;
989            break;
990
991         case 'L':
992            add_lib_path(string_alloc(S(optarg)));
993            break;
994
995         case 'l':
996            add_lib_name(string_alloc(S(optarg)));
997            break;
998
999         case 'i':
1000           add_import_path(string_alloc(S(optarg)));
1001           break;
1002
1003        case 'I':
1004           cmdopts.generate_viti = true;
1005           break;
1006
1007        case 'v':
1008           cmdopts.verbose_output = true;
1009           break;
1010
1011        case 'O':
1012           tmp_opt = parse_list_option_arguments(parse_optimize_option_argument);
1013           ret = merge_new_parse_status(ret, tmp_opt);
1014           break;
1015
1016        default:
1017           tmp_opt = option_parse_error(argv);
1018           ret = merge_new_parse_status(ret, tmp_opt);
1019           break;
1020        }
1021
1022        if (unrecognized_short_option_count >= 3)
1023           goto out;
1024
1025     skip_arg:
1026        option_index = 0;
1027     }
1028
1029  out:
1030     return ret;
```

```
1031 }
1032
1033 static CONST_STRING(x86_32_as_fmt, "as -g --32 -o %S %S");
1034
1035 /* Returns name of the object file on success. NULL on error. */
1036 static String assemble(Const_String asm_fname, Const_String src_fname)
1037 {
1038    String obj_file;
1039    if (cmdopts.compile_only || cmdopts.keep_obj) {
1040       if (cmdopts.compile_only && cmdopts.output_name) {
1041          obj_file = string_duplicate(cmdopts.output_name);
1042       } else {
1043          obj_file = string_duplicate(src_fname);
1044          string_replace_from(obj_file, '.', OBJ_SUFFIX_STR);
1045       }
1046    } else {
1047       obj_file = string_to_tmp_file(OBJ_SUFFIX_STR);
1048    }
1049
1050    String cmd = string_from_format(x86_32_as_fmt, obj_file, asm_fname);
1051
1052    if (cmdopts.verbose_output)
1053       file_print_message(stdout, S("%S\n"), cmd);
1054
1055    Int sys_ret = sys_cmd(cmd);
1056
1057    if (sys_ret) {
1058       string_destroy(obj_file);
1059       obj_file = NULL;
1060    }
1061
1062    string_destroy(cmd);
1063    return obj_file;
1064 }
1065
1066 /* Returns name of the object file on success. NULL on error. */
1067 static String compile(Ast *ast)
1068 {
1069    import_handler_init();
1070    String ret = ___compile(ast, false);
1071    import_handler_clear();
1072    return ret;
1073 }
1074
1075 String ___compile(Ast *ast, bool is_import)
1076 {
1077    Aia *aia;
1078    Symbol_Table *t;
1079    String ret = NULL;
1080
1081    if (!ast_is_valid(ast))
1082       goto ast_out;
1083
1084    if (!ast_visitor_import_handle(ast, is_import))
1085       goto ast_out;
1086
1087    t = ast_get_resolve_symbol_table(ast);
1088
1089    if (cmdopts.dump_symbol_table)
1090       symbol_table_dump(t, ast_get_file_name(ast));
1091
1092    if (cmdopts.dump_symbol_table_graph)
1093       symbol_table_dump_graph(t, ast_get_file_name(ast));
1094
1095    ast_visitor_type_check(ast);
1096
1097    if (cmdopts.dump_parse_tree)
1098       ast_dump_parse_tree(ast);
1099
1100    if (cmdopts.dump_parse_tree_graph)
1101       ast_dump_parse_tree_graph(ast);
1102
1103    aia = ast_visitor_aia_create(ast, ast_get_file_name(ast));
1104
```

```
1105     if (!aia_is_valid(aia))
1106        goto ast_out;
1107
1108     if (!is_import)
1109        ast_destroy(ast);
1110
1111     ast = NULL;
1112
1113     if (!aia_functions_return(aia))
1114        goto aia_out;
1115
1116     aia_normalize_addr(aia);
1117
1118     aia_optimize(aia);
1119
1120     String asm_file = x86_32_gen(aia);
1121     if (!asm_file)
1122        goto aia_out;
1123
1124     ret = assemble(asm_file, aia_get_file_name(aia));
1125     if (!cmdopts.dump_asm)
1126        file_unlink_temp(asm_file);
1127     string_destroy(asm_file);
1128
1129  aia_out:
1130     aia_destroy(aia);
1131
1132  ast_out:
1133     if (!is_import)
1134        ast_destroy(ast);
1135
1136     return ret;
1137  }
1138
1139  CONST_STRING(link_fmt,
1140        "gcc "               //
1141        "-m32 "              // link x86-32 code
1142        "-o%S "              // executable name
1143        "-L" DEFAULT_OBJ_DIR " " // libvitaly directory
1144        DEFAULT_OBJ_DIR "/ini.o " // start of _init() and _fini()
1145        DEFAULT_OBJ_DIR "/lib.o " // write, allocate, etc.
1146        DEFAULT_OBJ_DIR "/%S.o " // which main function to use
1147        "%S "                // object files & libraries
1148        "%S "                // further options ("" is fine)
1149        "%S "                // optional libvitaly.a
1150        "%S "                // optional string to link threads.
1151        DEFAULT_OBJ_DIR "/end.o"); // end of _init() and _fini()
1152
1153  CONST_STRING(def_exec_name, "a.out");
1154
1155  static void object_link_add_libs(String_Builder *sb)
1156  {
1157     Const_String tmp;
1158
1159     VECTOR_FOR_EACH_ENTRY(&lib_paths, tmp) {
1160        string_builder_append(sb, S(" -L "));
1161        string_builder_append(sb, tmp);
1162     }
1163     VECTOR_FOR_EACH_ENTRY(&lib_names, tmp) {
1164        string_builder_append(sb, S(" -l "));
1165        string_builder_append(sb, tmp);
1166     }
1167  }
1168
1169  static void object_link()
1170  {
1171     if (cmdopts.compile_only  ||
1172           cmdopts.assemble_only ||
1173           get_error_count())
1174        return;
1175
1176     String_Builder objs = STRING_BUILDER_INIT();
1177
1178     String ob;
```

```
1179     VECTOR_FOR_EACH_ENTRY(&cmd_object_files, ob) {
1180        string_builder_append_char(&objs, ' ');
1181        string_builder_append(&objs, ob);
1182     }
1183
1184     VECTOR_FOR_EACH_ENTRY(&gen_object_files, ob) {
1185        string_builder_append_char(&objs, ' ');
1186        string_builder_append(&objs, ob);
1187     }
1188
1189     Const_String start_file;
1190     if (cmdopts.has_main)
1191        start_file = S("vitmain");
1192     else
1193        start_file = S("retmain");
1194
1195     String_Builder optional = STRING_BUILDER_INIT();
1196     string_builder_assign(&optional, S(""));
1197
1198     object_link_add_libs(&optional);
1199
1200     Const_String executable;
1201     if (cmdopts.output_name)
1202        executable = cmdopts.output_name;
1203     else
1204        executable = def_exec_name;
1205
1206     Const_String libvit;
1207     if (cmdopts.link_libvitaly)
1208        libvit = S("-Wl,--whole-archive -lvitaly -Wl,--no-whole-archive");
1209     else
1210        libvit = S("");
1211
1212     Const_String pthread;
1213     if (cmdopts.with_threads)
1214        pthread = S("-pthread "
1215              "-Wl,--whole-archive -lvitaly-thread -Wl,--no-whole-archive");
1216     else
1217        pthread = S("");
1218
1219     String cmd = string_from_format(link_fmt,
1220           executable,
1221           start_file,
1222           string_builder_const_str(&objs),
1223           string_builder_const_str(&optional),
1224           libvit,
1225           pthread);
1226
1227     if (cmdopts.verbose_output)
1228        file_print_message(stdout, S("%S\n"), cmd);
1229
1230     sys_cmd(cmd);
1231
1232     string_destroy(cmd);
1233     string_builder_clear(&objs);
1234     string_builder_clear(&optional);
1235
1236     if (!cmdopts.keep_obj) {
1237        VECTOR_FOR_EACH_ENTRY(&gen_object_files, ob)
1238           file_unlink_temp(ob);
1239     }
1240  }
1241
1242  static void unrecognized_suffix(Const_String file)
1243  {
1244     String base = string_basename(file);
1245     Const_String suffix = STRING_AFTER_LAST(base, '.');
1246     if (string_compare(suffix, base))
1247        report_error(file, S("unrecognized file extension " QFY("%S") "\n"),
1248              suffix);
1249     else
1250        report_error(file, S("file name missing " QFY(".") " extension\n"));
1251     string_destroy(base);
1252  }
```

```
1253
1254  static Ast *parse_input_file(Const_String file)
1255  {
1256     Ast *ast = NULL;
1257     if (string_ends_with(file, SOURCE_SUFFIX_STR))
1258        ast = parse(file);
1259     else if (string_ends_with(file, OBJ_SUFFIX_STR))
1260        add_cmd_object_file(string_duplicate(file));
1261     else if (string_ends_with(file, STATIC_LIB_SUFFIX_STR))
1262        add_cmd_library_file(string_duplicate(file));
1263     else if (string_ends_with(file, ASM1_SUFFIX_STR))
1264        assemble_add_object(file);
1265     else if (string_ends_with(file, ASM2_SUFFIX_STR))
1266        assemble_add_object(file);
1267     else
1268        unrecognized_suffix(file);
1269     return ast;
1270  }
1271
1272  #ifdef STDIN_INPUT_ENABLED
1273  #define STDIN_BUF_SIZE 1024
1274  static String stdin_to_tmp_file()
1275  {
1276     ssize_t nread;
1277     char buf[STDIN_BUF_SIZE];
1278     String fname = string_to_unique_file(STDIN_FILE_SUFFIX_STR);
1279     FILE *tmpf = file_open(fname, S("w"));
1280     if (!tmpf) {
1281        fatal_error(S("unable to create temporary file %S "
1282                  "for stdin input [%m]\n"),
1283              fname);
1284     }
1285
1286     do {
1287        nread = read(STDIN_FILENO, buf, STDIN_BUF_SIZE);
1288        if (nread == -1)
1289           fatal_error(S("error writing to temporary file %S [%m]\n"), fname);
1290        fwrite(buf, 1, nread, tmpf);
1291     } while (nread);
1292
1293     file_close(tmpf);
1294     return fname;
1295  }
1296  #endif
1297
1298  static inline void too_many_src_files_error()
1299  {
1300     fatal_error(S("only one source file allowed when the "
1301              OUT_OPTION_CSTR " option is specified with the "
1302              COMPILE_ONLY_OPTION_CSTR " or "
1303              ASM_ONLY_OPTION_CSTR " option\n"));
1304  }
1305
1306  static void verify_cmd_options(int argc, char *argv[])
1307  {
1308     int vit_src_cnt = 0;
1309     int asm_src_cnt = 0;
1310
1311     inline void vit_file(Const_String file UNUSED)
1312     {
1313        ++vit_src_cnt;
1314     }
1315
1316     inline void asm_file(Const_String file)
1317     {
1318        if (cmdopts.assemble_only)
1319           report_warning(file, S("assembly source file ignored since the "
1320                    ASM_ONLY_OPTION_CSTR " option is enabled\n"));
1321        ++asm_src_cnt;
1322     }
1323
1324     inline int src_file_count()
1325     {
1326        return vit_src_cnt + asm_src_cnt;
```

```
1327     }
1328
1329     if (cmdopts.compile_only && cmdopts.output_name) {
1330        for (int i = optind; i < argc; i++) {
1331           CONST_STRING(src, argv[i]);
1332
1333           if (string_ends_with(src, SOURCE_SUFFIX_STR))
1334              vit_file(src);
1335           else if (string_ends_with(src, ASM1_SUFFIX_STR))
1336              asm_file(src);
1337           else if (string_ends_with(src, ASM2_SUFFIX_STR))
1338              asm_file(src);
1339
1340           if (src_file_count() > 1)
1341              too_many_src_files_error();
1342        }
1343     }
1344
1345     if (cmdopts.recursive_compile && cmdopts.output_name) {
1346        if (cmdopts.assemble_only) {
1347           fatal_error(S("option " RECURSIVE_OPTION_CSTR
1348                     " disallowed when both " ASM_ONLY_OPTION_CSTR
1349                     " and " OUT_OPTION_CSTR " options are enabled\n"));
1350        } else if (cmdopts.compile_only) {
1351           fatal_error(S("option " RECURSIVE_OPTION_CSTR
1352                     " disallowed when both " COMPILE_ONLY_OPTION_CSTR
1353                     " and " OUT_OPTION_CSTR " options are enabled\n"));
1354        }
1355     }
1356
1357     if (cmdopts.compile_only && cmdopts.assemble_only)
1358        report_warning(cmdopts.vitaly_program_name,
1359              S("option " COMPILE_ONLY_OPTION_CSTR
1360                 " ignored since the " ASM_ONLY_OPTION_CSTR
1361                 " option is enabled\n"));
1362
1363     if (cmdopts.with_threads && !cmdopts.link_libvitaly) {
1364        report_warning(cmdopts.vitaly_program_name,
1365              S("option " THREAD_OPTION_CSTR
1366                 " has no effect when the " NO_LIB_VIT_OPTION_CSTR
1367                 " option is enabled\n"));
1368        cmdopts.with_threads = false;
1369     }
1370  }
1371
1372  static bool process_input_file(Const_String in_file)
1373  {
1374     Ast *ast;
1375
1376     report_reset();
1377     ast = parse_input_file(in_file);
1378     String obj = compile(ast);
1379     add_gen_object_file(obj);
1380     show_reports_clear();
1381
1382     if (was_error_reported() && !cmdopts.stubborn)
1383        return false;
1384     if (report_exhausted())
1385        return false;
1386     return true;
1387  }
1388
1389  static void process_stdin()
1390  {
1391  #ifdef STDIN_INPUT_ENABLED
1392     String stdin_file = stdin_to_tmp_file();
1393     process_input_file(stdin_file);
1394     file_unlink_temp(stdin_file);
1395     string_destroy(stdin_file);
1396  #else
1397     fatal_error(S("no input files, try\n\t%S --help\n"),
1398           cmdopts.vitaly_program_name);
1399  #endif
1400  }
```

```
1401
1402  static void process_input_files(int argc, char *argv[])
1403  {
1404     for (Int i = optind; i < argc; i++) {
1405        if (!process_input_file(S(argv[i])))
1406           return;
1407     }
1408  }
1409
1410  static inline void destroy_string_vec(Vector *v)
1411  {
1412     vector_for_each_destroy(v, (Vector_Destructor)string_destroy);
1413  }
1414
1415  void cd_working_dir()
1416  {
1417     if (chdir(string_to_cstr(cmdopts.working_directory)))
1418        fatal_error(S("unable to change to directory %S [%m]"),
1419              cmdopts.working_directory);
1420
1421  }
1422
1423  static inline void save_working_dir()
1424  {
1425     char *dir = getcwd(NULL, 0);
1426     cmdopts.working_directory = string_alloc(S(dir));
1427     free_mem(dir);
1428  }
1429
1430  static inline void add_default_import_paths()
1431  {
1432     if (cmdopts.link_libvitaly)
1433        vector_append(&cmdopts.import_search_paths,
1434              string_alloc(S(DEFAULT_OBJ_DIR)));
1435     if (cmdopts.with_threads)
1436        vector_append(&cmdopts.import_search_paths,
1437              string_alloc(S(DEFAULT_OBJ_DIR "/_vit_thread")));
1438  }
1439
1440  int main(int argc, char *argv[])
1441  {
1442     int ret;
1443
1444     switch (parse_cmd_options(argc, argv)) {
1445     case OPTION_PARSE_CONTINUE:
1446        break;
1447     case OPTION_PARSE_EXIT_SUCCESS:
1448        ret = EXIT_SUCCESS;
1449        goto out;
1450     case OPTION_PARSE_EXIT_FAILURE:
1451        ret = EXIT_FAILURE;
1452        goto out;
1453     }
1454     verify_cmd_options(argc, argv);
1455
1456     save_working_dir();
1457     add_default_import_paths();
1458
1459     if (optind >= argc)
1460        process_stdin();
1461     else
1462        process_input_files(argc, argv);
1463
1464     parse_cleanup();
1465     object_link();
1466     report_print();
1467
1468     ret = get_error_count() ? EXIT_FAILURE : EXIT_SUCCESS;
1469  out:
1470     destroy_string_vec(&cmdopts.import_search_paths);
1471     destroy_string_vec(&gen_object_files);
1472     destroy_string_vec(&cmd_object_files);
1473     destroy_string_vec(&lib_names);
1474
```

```
1475     string_destroy(cmdopts.vitaly_program_name);
1476     string_destroy(cmdopts.output_name);
1477     string_destroy(cmdopts.working_directory);
1478
1479     return ret;
1480 }
```

A.2 src/main.h

```
1  #ifndef MAIN_H
2  #define MAIN_H
3
4  #include <std_define.h>
5  #include <std_include.h>
6  #include <vector.h>
7  #include <ast/ast.h>
8
9  typedef struct Command_Line_Options {
10    String vitaly_program_name;
11    String output_name;
12    Vector import_search_paths;
13    String working_directory;
14    bool dump_parse_tree;
15    bool dump_parse_tree_graph;
16    bool dump_symbol_table_graph;
17    bool dump_symbol_table;
18    bool dump_c_header;
19    bool dump_init_ic;
20    bool dump_norm_addr_ic;
21    bool dump_const_prop_ic;
22    bool dump_instr_elim_ic;
23    bool dump_norm_x86_32_ic;
24    bool dump_liveness_x86_32_ic;
25    bool dump_reg_vars_liveness_ic;
26    bool dump_reg_vars_ic;
27    bool dump_init_liveness_x86_32_ic;
28    bool dump_unused_mov_ic;
29    bool dump_reg_alloc_x86_32_ic;
30    bool dump_final_x86_32_ic;
31    bool dump_def_to_use_ic;
32    bool dump_warn_uninit_liveness_ic;
33    bool dump_asm;
34    bool opt_func_access;
35    bool opt_const_prop;
36    bool opt_instr_elim;
37    bool opt_unused_mov;
38    bool opt_unused_set;
39    bool opt_reg_vars;
40    bool opt_def_to_use;
41    bool stubborn;
42    bool warn_implicit_cast;
43    bool warn_no_finalize;
44    bool warn_ref_compare;
45    bool warn_overflow;
46    bool warn_is_error;
47    bool warn_div_zero;
48    bool warn_uninitialized;
49    bool compile_only;
50    bool assemble_only;
51    bool keep_obj;
52    bool verbose_output;
53    bool library_init;
54    bool link_libvitaly;
55    bool with_threads;
56    bool has_main;
57    bool recursive_compile;
58    bool generate_viti;
59    int32_t max_msg;
60 } Command_Line_Options;
61
```

```
62 String ___compile(Ast *ast, bool is_import);
63
64 void add_gen_object_file(String obj);
65
66 extern Command_Line_Options cmdopts;
67
68 void cd_working_dir();
69
70 #endif // MAIN_H
```

A.3 Scanning/Parsing

:

A.3.1 src/ast/ast.c

```
1  #include "ast_visitor.h"
2  #include "ast_visitor_delete.h"
3  #include "ast_visitor_symbol_table.h"
4  #include "ast_visitor_print.h"
5  #include "ast_visitor_print_graph.h"
6  #include "symbol_table.h"
7  #include "ast_string.h"
8
9  Const_String const ___ast_expr_type_strings[AST_EXPR_TYPE_COUNT] = {
10    [AST_EXPR_TYPE_UNSPECIFIED] = S("unspecified"),
11    [AST_EXPR_TYPE_UNKNOWN]  = S("unknown"),
12    [AST_EXPR_TYPE_VOID]  = S("void"),
13    [AST_EXPR_TYPE_INT]   = S("int"),
14    [AST_EXPR_TYPE_BOOL]  = S("bool"),
15    [AST_EXPR_TYPE_CHAR]  = S("char"),
16    [AST_EXPR_TYPE_STRING]  = S("string"),
17    [AST_EXPR_TYPE_REC]   = S("record"),
18    [AST_EXPR_TYPE_ARY]   = S("array"),
19    [AST_EXPR_TYPE_NULL]  = S("null")
20 };
21
22 #define AST_NODE_ACCEPT_VISITOR_DEF(node_type)  \
23    AST_NODE_ACCEPT_VISITOR_DECL(node_type)   \
24    {                                         \
25       v->AST_VISITOR_FUNC(node_type)(v, n);  \
26    }
27
28 String ast_module_string(Const_String initial)
29 {
30    String str = string_duplicate(initial);
31    string_replace_all(str, '.', '/');
32    return str;
33 }
34
35 static inline bool ast_string_has_expected_last(Ast_Node *n, String str,
36       Int expected)
37 {
38    Uns len = string_length(str);
39    if (string_get(str, len - 1) != (char)expected) {
40       expected &= (Int)0xff;
41       report_error_location(&n->location,
42             S("expected terminating " QFY("%s") " before end of line\n"),
43             &expected);
44       string_set(str, len - 1, '\0');
45       return false;
46    }
47    return true;
48 }
49
50 int32_t ast_char_to_int32(Ast_Expr_Char *n, String char_str)
51 {
52    Uns len;
```

```
53     int32_t ret = 0;
54
55     if (!ast_string_has_expected_last(&n->ast_node, char_str, '\''))
56        goto out;
57     string_remove_first_last(char_str);
58
59     String orig = string_duplicate(char_str);
60
61     len = string_length(char_str);
62     if (len == 0) {
63        report_error_location(&n->ast_node.location,
64              S("Expected " QFY("char") " inside single quotes ''\n"));
65     } else if (len > 2 || (len == 2 && string_get(char_str, 0) != '\\')) {
66        report_error_location(&n->ast_node.location,
67              S("Invalid char " QFY("%S") "\n"), orig);
68     } else if (___ast_string_unescape(&n->ast_node, char_str)) {
69           ret = string_get(char_str, 0);
70     }
71
72     string_destroy(orig);
73
74  out:
75     return ret;
76  }
77
78  String ast_get_expr_string(Ast_Expr_String *n, String str)
79  {
80     String ret = string_duplicate(str);
81     if (ast_string_has_expected_last(&n->ast_node, ret, '\"')) {
82        string_remove_first_last(ret);
83        ___ast_string_unescape(&n->ast_node, ret);
84     }
85     return ret;
86  }
87
88  void ast_release_nodes(Ast *ast)
89  {
90     if (ast)
91        if (ast->root) {
92           ast_visitor_delete_accept_visitor(ast->root);
93           ast->root = NULL;
94        }
95  }
96
97  void ast_release_symbol_table(Ast *ast)
98  {
99     if(ast)
100       if (ast->symbol_table) {
101          symbol_table_destroy(ast->symbol_table);
102          ast->symbol_table = NULL;
103       }
104 }
105
106 void ast_destroy(Ast *ast)
107 {
108    ast_release_nodes(ast);
109    ast_release_symbol_table(ast);
110    if (ast) {
111       string_destroy(ast->dir);
112       string_destroy(ast->file);
113       free_mem(ast);
114    }
115 }
116
117 Symbol_Table *ast_get_symbol_table(Ast *ast)
118 {
119    if (!ast->symbol_table)
120       ast->symbol_table = ast_visitor_symbol_table_gen(ast);
121    return ast->symbol_table;
122 }
123
124 Const_String ast_get_dirname(Ast *ast)
125 {
126    if (!ast->dir)
```

```
127         ast->dir = string_dirname(ast_get_file_name(ast));
128     return ast->dir;
129 }
130
131 Const_String ast_get_package(Ast *ast)
132 {
133     return ast->package;
134 }
135
136 Symbol_Table *ast_get_resolve_symbol_table(Ast *ast)
137 {
138     Symbol_Table *symbol_table = ast_get_symbol_table(ast);
139     symbol_table_resolve(symbol_table);
140     return symbol_table;
141 }
142
143 Symbol_Table *ast_move_symbol_table(Ast *ast)
144 {
145     Symbol_Table *ret = ast->symbol_table;
146     ast->symbol_table = NULL;
147     return ret;
148 }
149
150 void ast_dump_parse_tree(Ast *ast)
151 {
152     ast_visitor_print_accept_visitor(ast->root, ast->file);
153 }
154
155 void ast_dump_parse_tree_graph(Ast *ast)
156 {
157     ast_visitor_print_graph_accept_visitor(ast->root, ast->file);
158 }
159
160 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_LOR);
161 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_LAND);
162 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_EQ);
163 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_NEQ);
164 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_GT);
165 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_LT);
166 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_GTEQ);
167 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_LTEQ);
168 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_PLUS);
169 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_MINUS);
170 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_MUL);
171 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_DIV);
172 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_CAST);
173 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_LNOT);
174 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_ABS);
175 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_INT);
176 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_BOOL);
177 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_NULL);
178 AST_NODE_ACCEPT_VISITOR_DEF(AST_VARIABLE_IDEN);
179 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_ARY_REF);
180 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_FUNC_CALL);
181 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_DOT_REF);
182 AST_NODE_ACCEPT_VISITOR_DEF(AST_SIMPLE_TYPE_INT);
183 AST_NODE_ACCEPT_VISITOR_DEF(AST_SIMPLE_TYPE_BOOL);
184 AST_NODE_ACCEPT_VISITOR_DEF(AST_TYPE_IDEN);
185 AST_NODE_ACCEPT_VISITOR_DEF(AST_VAR_DECL);
186 AST_NODE_ACCEPT_VISITOR_DEF(AST_TYPE_DEF);
187 AST_NODE_ACCEPT_VISITOR_DEF(AST_TYPE_ARY);
188 AST_NODE_ACCEPT_VISITOR_DEF(AST_TYPE_REC);
189 AST_NODE_ACCEPT_VISITOR_DEF(AST_STMT_LIST);
190 AST_NODE_ACCEPT_VISITOR_DEF(AST_FUNC_DEF);
191 AST_NODE_ACCEPT_VISITOR_DEF(AST_IF_STMT);
192 AST_NODE_ACCEPT_VISITOR_DEF(AST_IF_ELSE_STMT);
193 AST_NODE_ACCEPT_VISITOR_DEF(AST_ALLOC_REC);
194 AST_NODE_ACCEPT_VISITOR_DEF(AST_ALLOC_ARY);
195 AST_NODE_ACCEPT_VISITOR_DEF(AST_WHILE_STMT);
196 AST_NODE_ACCEPT_VISITOR_DEF(AST_RETURN_STMT);
197 AST_NODE_ACCEPT_VISITOR_DEF(AST_WRITE_STMT);
198 AST_NODE_ACCEPT_VISITOR_DEF(AST_ASSIGNMENT);
199 AST_NODE_ACCEPT_VISITOR_DEF(AST_FUNC_BODY);
200 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_CHAR);
```

```
201 AST_NODE_ACCEPT_VISITOR_DEF(AST_SIMPLE_TYPE_CHAR);
202 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_STRING);
203 AST_NODE_ACCEPT_VISITOR_DEF(AST_SIMPLE_TYPE_STRING);
204 AST_NODE_ACCEPT_VISITOR_DEF(AST_IMPORT_STRING);
205 AST_NODE_ACCEPT_VISITOR_DEF(AST_PACKAGE_STRING);
206 AST_NODE_ACCEPT_VISITOR_DEF(AST_REC_SELF_PTR);
207 AST_NODE_ACCEPT_VISITOR_DEF(AST_SIMPLE_TYPE_VOID);
208 AST_NODE_ACCEPT_VISITOR_DEF(AST_FIN_FUNC_DEF);
209 AST_NODE_ACCEPT_VISITOR_DEF(AST_DELETE);
210 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXT_FUNC_DECL);
211 AST_NODE_ACCEPT_VISITOR_DEF(AST_FIN_STMT_LIST);
212 AST_NODE_ACCEPT_VISITOR_DEF(AST_REC_FUNC_DEF);
213 AST_NODE_ACCEPT_VISITOR_DEF(AST_EXPR_DIRECT_REF);
214 AST_NODE_ACCEPT_VISITOR_DEF(AST_ALLOC_REC_CALL);
```

:

A.3.2 src/ast/ast.h

```
1  #ifndef AST_H
2  #define AST_H
3
4  #include <std_define.h>
5  #include <std_include.h>
6  #include <vector.h>
7
8  typedef struct Symbol_Table Symbol_Table;
9
10 typedef struct Symbol_Table_Node Symbol_Table_Node;
11
12 typedef struct Ast_Visitor Ast_Visitor;
13
14 // Unary expression nodes:
15 #define AST_EXPR_LNOT   expr_lnot      // !expr
16 #define AST_EXPR_ABS    expr_abs       // |expr|
17 // Unary nodes:
18 #define AST_ALLOC_REC   alloc_rec      // allocate rec
19 #define AST_ALLOC_REC_CALL  alloc_rec_call  // allocate rec of record()
20 #define AST_DELETE      delete_ptr     // delete var
21 #define AST_RETURN_STMT   return_stmt   // return expr
22 #define AST_WRITE_STMT   write_stmt    // write expr
23
24 // Binary expression nodes:
25 #define AST_EXPR_LOR    expr_lor       // expr || expr
26 #define AST_EXPR_LAND   expr_land      // expr && expr
27 #define AST_EXPR_EQ     expr_eq        // expr == expr
28 #define AST_EXPR_NEQ    expr_neq       // expr != expr
29 #define AST_EXPR_GT     expr_gt        // expr > expr
30 #define AST_EXPR_LT     expr_lt        // expr < expr
31 #define AST_EXPR_GTEQ   expr_gteq      // expr >= expr
32 #define AST_EXPR_LTEQ   expr_lteq      // expr <= expr
33 #define AST_EXPR_PLUS   expr_plus      // expr + expr
34 #define AST_EXPR_MINUS   expr_minus    // expr - expr
35 #define AST_EXPR_MUL    expr_mul       // expr * expr
36 #define AST_EXPR_DIV    expr_div       // expr / expr
37 #define AST_EXPR_CAST   expr_cast      // (My_Type)expr
38 #define AST_EXPR_ARY_REF  expr_ary_ref  // ary[expr]
39 #define AST_EXPR_DOT_REF  expr_dot_ref  // rec.field
40 #define AST_EXPR_DIRECT_REF  expr_direct_ref  // record[type].field
41 // Binary nodes:
42 #define AST_VAR_DECL    var_decl       // i:int
43 #define AST_TYPE_DEF    type_decl      // type i = int
44 #define AST_ALLOC_ARY   alloc_ary      // allocate a of length 42
45 #define AST_IF_STMT     if_stmt        // if expr then stmt
46 #define AST_WHILE_STMT   while_stmt    // while expr do stmt
47 #define AST_ASSIGNMENT   assignment    // i = 42
48
49 // Ternary nodes:
50 #define AST_IF_ELSE_STMT  if_else_stmt  // if ... else ...
51
52 // Function call node:
```

```
53  #define AST_EXPR_FUNC_CALL  expr_func_call  // foo(expr,..., expr)
54
55  // Statement lists:
56  #define AST_STMT_LIST   stmt_list      // list of decl and stmts
57  #define AST_FIN_STMT_LIST  fin_stmt_list  // list of decl and stmts
58  #define AST_REC_STMT_LIST  rec_stmt_list  // list of decl and stmts
59  #define AST_FUNC_BODY   func_body      // decls and stmts in func
60
61  // Function definition:
62  #define AST_FUNC_DEF    func_def       // func foo(e, ..., e) ...
63  // Extern function declaration:
64  #define AST_EXT_FUNC_DECL  ext_func_decl  // extern(C) func foo( ...
65  // Record finalize function definition:
66  #define AST_FIN_FUNC_DEF  fin_func_def  // func finalize()
67  // Record 'record' function definition:
68  #define AST_REC_FUNC_DEF  rec_func_def  // func record(e, ..., e)
69
70  // Nodes with constant values:
71  #define AST_EXPR_INT    expr_int       // 42
72  #define AST_EXPR_BOOL   expr_bool      // true or false
73  #define AST_EXPR_NULL   expr_null      // null
74  #define AST_EXPR_CHAR   expr_char      // 'A'
75  #define AST_EXPR_STRING   expr_string   // "Hello"
76  // Immediate identifier (iden = iden + 1)
77  #define AST_VARIABLE_IDEN  expr_iden
78  #define AST_REC_SELF_PTR  expr_rec_self  // record.foo();
79
80  // Contains module package name.
81  #define AST_PACKAGE_STRING  package_str   // package pack.name;
82  // Contains string for imported module.
83  #define AST_IMPORT_STRING  import_str   // import pack.name.file;
84
85  // Simple type nodes:
86  // int type (var i:int or type i = int)
87  #define AST_SIMPLE_TYPE_INT  type_int
88  // bool type (var b:bool or type b = bool)
89  #define AST_SIMPLE_TYPE_BOOL type_bool
90  // char type (var c:char or type c = char)
91  #define AST_SIMPLE_TYPE_CHAR type_char
92  // string type (var s:string or type s = string)
93  #define AST_SIMPLE_TYPE_STRING type_string
94  // void type (func f():void ...)
95  #define AST_SIMPLE_TYPE_VOID type_void
96
97  // Complex type nodes:
98  // Identifier type (var i:iden or type i = iden)
99  #define AST_TYPE_IDEN   type_iden
100 // Array type (var a:array of something or type a = array of something)
101 #define AST_TYPE_ARY    type_ary
102 // Record type (var r:record of {...} or type r = record of {...})
103 #define AST_TYPE_REC    record_decl
104
105 #define ___AST_NODE_ACCEPT_VISITOR_FUNC(node_type) \
106    ___ast_ ## node_type ## _accept_visitor
107
108 #define AST_NODE_ACCEPT_VISITOR_FUNC(node_type) \
109    ___AST_NODE_ACCEPT_VISITOR_FUNC(node_type)
110
111 #define AST_NODE_ACCEPT_VISITOR_DECL(node_type) \
112    void AST_NODE_ACCEPT_VISITOR_FUNC(node_type)(Ast_Node *n, Ast_Visitor *v)
113
114 /* Expression types. What type expressions evaluate into.
115  * Simple expressions like immediate int constants don't
116  * have an Ast_Expr_Type field because we already know its type. */
117 typedef enum Ast_Expr_Type {
118    /* Type not yet set. */
119    AST_EXPR_TYPE_UNSPECIFIED,
120    /* Expression has conflicting operand types so the expression
121     * evaluates to an unknown type. */
122    AST_EXPR_TYPE_UNKNOWN,
123    /* Expression operands evaluate to void. */
124    AST_EXPR_TYPE_VOID,
125    /* Expression operands evaluate to int. */
126    AST_EXPR_TYPE_INT,
```

```
127     /* Expression operands evaluate to bool. */
128     AST_EXPR_TYPE_CHAR,
129     /* Expression operands evaluate to string. */
130     AST_EXPR_TYPE_BOOL,
131     /* Expression operands evaluate to char. */
132     AST_EXPR_TYPE_STRING,
133     /* Expression operands evaluate to record type, used to alloc records. */
134     AST_EXPR_TYPE_REC,
135     /* Expression operands evaluate to array type, used to alloc arrays. */
136     AST_EXPR_TYPE_ARY,
137     /* Expression is the null constant, which can be used to assign
138      * records and arrays. */
139     AST_EXPR_TYPE_NULL // Must be last
140 } Ast_Expr_Type;
141
142 #define AST_EXPR_TYPE_COUNT (AST_EXPR_TYPE_NULL + 1)
143
144 static inline Const_String ast_expr_type_to_string(Ast_Expr_Type t)
145 {
146     extern Const_String const ___ast_expr_type_strings[AST_EXPR_TYPE_COUNT];
147     return ___ast_expr_type_strings[t];
148 }
149
150 typedef struct Ast_Node Ast_Node;
151
152 typedef struct Ast {
153     Ast_Node *root;
154     String file;
155     String dir;
156     Const_String package;
157     Symbol_Table *symbol_table;
158 } Ast;
159
160 static inline Ast_Node *ast_get_root(Ast *ast)
161 {
162     return ast->root;
163 }
164
165 static inline Ast *ast_alloc(Const_String file_name)
166 {
167     Ast *ast = ALLOC_NEW(Ast);
168     ast->file = string_duplicate(file_name);
169     ast->root = NULL;
170     ast->dir = NULL;
171     ast->package = NULL;
172     ast->symbol_table = NULL;
173     return ast;
174 }
175
176 static inline bool ast_is_valid(Ast *ast)
177 {
178     if (ast)
179         return ast->root;
180     return false;
181 }
182
183 static inline Const_String ast_get_file_name(Ast *ast)
184 {
185     assert(ast);
186     assert(ast->file);
187     return ast->file;
188 }
189
190 Const_String ast_get_dirname(Ast *ast);
191
192 Const_String ast_get_package(Ast *ast);
193
194 /* Returns NULL if ast is invalid. */
195 Symbol_Table *ast_get_symbol_table(Ast *ast);
196
197 Symbol_Table *ast_get_resolve_symbol_table(Ast *ast);
198
199 Symbol_Table *ast_move_symbol_table(Ast *ast);
200
```

```
201 void ast_dump_parse_tree(Ast *ast);
202
203 void ast_dump_parse_tree_graph(Ast *ast);
204
205 void ast_release_nodes(Ast *ast);
206
207 void ast_release_symbol_table(Ast *ast);
208
209 void ast_destroy(Ast *ast);
210
211 typedef void (*Ast_Node_Accept_Visitor)(Ast_Node *this_n, Ast_Visitor *v);
212
213 struct Ast_Node {
214    Ast_Node_Accept_Visitor accept_visitor;
215    Symbol_Table_Node *sym_table_node;
216    File_Location location;
217 };
218
219 static inline Symbol_Table_Node *ast_node_get_symbol_table_node(Ast_Node *n)
220 {
221    return n->sym_table_node;
222 }
223
224 static inline void ast_node_set_symbol_table_node(Ast_Node *n,
225       Symbol_Table_Node *sym_node)
226 {
227    n->sym_table_node = sym_node;
228 }
229
230 static inline File_Location *ast_node_get_file_location(Ast_Node *n)
231 {
232    return &n->location;
233 }
234
235 #define AST_NODE_FIELD ast_node
236
237 #define AST_NODE_STRUCT_BEGIN(name) \
238    typedef struct name {    \
239       Ast_Node AST_NODE_FIELD;
240 #define AST_NODE_STRUCT_END(name) } name;
241
242 #define AST_NODE_OF(container) (&(container)->AST_NODE_FIELD)
243
244 #define AST_CONTAINER_OF(ast_node, type) \
245    CONTAINER_OF(ast_node, type, AST_NODE_FIELD)
246
247 #define AST_NODE_INIT(node_type, node_location) ((Ast_Node){ \
248    .accept_visitor = AST_NODE_ACCEPT_VISITOR_FUNC(node_type), \
249    .location = node_location,                    \
250    .sym_table_node = NULL                        \
251 })
252
253 #define AST_NODE_ALLOC(type_name, node_type, node_location) ({  \
254    type_name *____n = ALLOC_NEW(type_name);         \
255    *AST_NODE_OF(____n) = AST_NODE_INIT(node_type, node_location); \
256    ____n;                                           \
257 })
258
259 // Nodes with two operands.
260 AST_NODE_STRUCT_BEGIN(Ast_Node_Binary)
261    Ast_Node *lhs, *rhs;
262 AST_NODE_STRUCT_END(Ast_Node_Binary)
263
264 #define AST_NODE_BINARY_ALLOC(node_type, node_location,    \
265       left_operand, right_operand) ({              \
266    Ast_Node_Binary *___n = AST_NODE_ALLOC(Ast_Node_Binary,   \
267          node_type, node_location);                \
268    ___n->lhs = left_operand;                       \
269    ___n->rhs = right_operand;                      \
270    AST_NODE_OF(___n);                              \
271 })
272
273 // Nodes with two operands.
274 typedef struct Ast_Expr_Binary {
```

```
275     Ast_Node_Binary bin_node; // Must be first
276     Ast_Expr_Type expr_type;
277 } Ast_Expr_Binary;
278
279 static inline void ast_expr_binary_set_expr_type(Ast_Expr_Binary *n,
280         Ast_Expr_Type t)
281 {
282     n->expr_type = t;
283 }
284
285 static inline Ast_Expr_Type ast_expr_binary_get_expr_type(Ast_Expr_Binary *n)
286 {
287     return n->expr_type;
288 }
289
290 static inline Const_String ast_expr_binary_get_expr_str(Ast_Expr_Binary *n)
291 {
292     Const_String ret =
293           ast_expr_type_to_string(ast_expr_binary_get_expr_type(n));
294     assert(ret);
295     return ret;
296 }
297
298 #define AST_EXPR_BINARY_OF(node_binary) \
299     CONTAINER_OF(node_binary, Ast_Expr_Binary, bin_node)
300
301 #define AST_EXPR_BINARY_ALLOC(node_type, node_location,     \
302       left_operand, right_operand) ({                       \
303     Ast_Expr_Binary *___n = ALLOC_NEW(Ast_Expr_Binary);     \
304     *AST_NODE_OF(&___n->bin_node) = AST_NODE_INIT(node_type, node_location); \
305     ___n->bin_node.lhs = left_operand;                      \
306     ___n->bin_node.rhs = right_operand;                     \
307     ___n->expr_type = AST_EXPR_TYPE_UNSPECIFIED;            \
308     AST_NODE_OF(&___n->bin_node);                           \
309 })
310
311 // Nodes with three operands.
312 AST_NODE_STRUCT_BEGIN(Ast_Node_Ternary)
313     Ast_Node *lhs, *mid, *rhs;
314 AST_NODE_STRUCT_END(Ast_Node_Ternary)
315
316 #define AST_NODE_TERNARY_ALLOC(node_type, node_location,    \
317       left_operand, mid_operand, right_operand) ({          \
318     Ast_Node_Ternary *___n = AST_NODE_ALLOC(Ast_Node_Ternary,  \
319           node_type, node_location);                        \
320     ___n->lhs = left_operand;                               \
321     ___n->mid = mid_operand;                                \
322     ___n->rhs = right_operand;                              \
323     AST_NODE_OF(___n);                                      \
324 })
325
326 // Nodes with one operand.
327 AST_NODE_STRUCT_BEGIN(Ast_Node_Unary)
328     Ast_Node *expr;
329 AST_NODE_STRUCT_END(Ast_Node_Unary)
330
331 #define AST_NODE_UNARY_ALLOC(node_type, node_location, operand) ({ \
332     Ast_Node_Unary *___n = AST_NODE_ALLOC(Ast_Node_Unary,   \
333           node_type, node_location);                        \
334     ___n->expr = operand;                                   \
335     AST_NODE_OF(___n);                                      \
336 })
337
338 // Expression nodes with one operand.
339 typedef struct Ast_Expr_Unary {
340     Ast_Node_Unary una_node; // Must be first
341     Ast_Expr_Type expr_type;
342 } Ast_Expr_Unary;
343
344 static inline void ast_expr_unary_set_expr_type(Ast_Expr_Unary *n,
345       Ast_Expr_Type t)
346 {
347     n->expr_type = t;
348 }
```

```
349
350 static inline Ast_Expr_Type ast_expr_unary_get_expr_type(Ast_Expr_Unary *n)
351 {
352    return n->expr_type;
353 }
354
355 static inline Const_String ast_expr_unary_get_expr_str(Ast_Expr_Unary *n)
356 {
357    Const_String ret =
358          ast_expr_type_to_string(ast_expr_unary_get_expr_type(n));
359    assert(ret);
360    return ret;
361 }
362
363 #define AST_EXPR_UNARY_ALLOC(node_type, node_location, operand) ({ \
364    Ast_Expr_Unary *___n = ALLOC_NEW(Ast_Expr_Unary);    \
365    *AST_NODE_OF(&___n->una_node) = AST_NODE_INIT(node_type, node_location); \
366    ___n->una_node.expr = operand;                    \
367    ___n->expr_type = AST_EXPR_TYPE_UNSPECIFIED;      \
368    AST_NODE_OF(&___n->una_node);                     \
369 })
370
371 #define AST_EXPR_UNARY_OF(node_unary) \
372    CONTAINER_OF(node_unary, Ast_Expr_Unary, una_node)
373
374 typedef struct Symbol_Type_Func Symbol_Type_Func;
375
376 // Function call.
377 AST_NODE_STRUCT_BEGIN(Ast_Expr_Func_Call)
378    Ast_Node *identifier;
379    Vector *arguments;
380    Symbol_Type_Func *func; // set by type checker
381    Ast_Expr_Type expr_type;
382 AST_NODE_STRUCT_END(Ast_Expr_Func_Call)
383
384 static inline Symbol_Type_Func *ast_expr_func_call_get_func(
385       Ast_Expr_Func_Call *c)
386 {
387    return c->func;
388 }
389
390 static inline void ast_expr_func_call_set_expr_type(Ast_Expr_Func_Call *n,
391       Ast_Expr_Type t)
392 {
393    n->expr_type = t;
394 }
395
396 static inline Ast_Expr_Type ast_expr_func_call_get_expr_type(
397       Ast_Expr_Func_Call *n)
398 {
399    return n->expr_type;
400 }
401
402 static inline Const_String ast_expr_func_call_get_expr_str(
403       Ast_Expr_Func_Call *n)
404 {
405    Const_String ret =
406          ast_expr_type_to_string(ast_expr_func_call_get_expr_type(n));
407    assert(ret);
408    return ret;
409 }
410
411 /* Allocate a vector and pass to to this macro.
412  * The ast node will take care of deleting the vector. */
413 #define AST_EXPR_FUNC_CALL_ALLOC(node_type, node_location, iden, vec_args) ({ \
414       Ast_Expr_Func_Call *___n = AST_NODE_ALLOC(Ast_Expr_Func_Call, \
415             node_type, node_location);                  \
416       ___n->identifier = iden;                          \
417       ___n->arguments = vec_args;                       \
418       ___n->expr_type = AST_EXPR_TYPE_UNSPECIFIED;      \
419       ___n->func = NULL;                                \
420       AST_NODE_OF(___n);                                \
421 })
422
```

```
423 // Record declaration node (record of {...}).
424 AST_NODE_STRUCT_BEGIN(Ast_Type_Rec)
425    Vector *extend_list;
426    Vector *body;
427    Symbol_Table_Node *body_node;
428 AST_NODE_STRUCT_END(Ast_Type_Rec)
429
430 /* Allocate vector arguments and pass them tp the macro.
431  * The AST node will take care of freeing the vectors. */
432 #define AST_TYPE_REC_ALLOC(node_type, node_location,     \
433       vec_extend, vec_body) ({                           \
434    Ast_Type_Rec *___n = AST_NODE_ALLOC(Ast_Type_Rec,     \
435          node_type, node_location);                      \
436    ___n->extend_list = vec_extend;                       \
437    ___n->body = vec_body;                                \
438    AST_NODE_OF(___n);                                    \
439 })
440
441 // Variable identifier node.
442 AST_NODE_STRUCT_BEGIN(Ast_Variable_Iden)
443    String iden;
444    Ast_Expr_Type expr_type;
445 AST_NODE_STRUCT_END(Ast_Variable_Iden)
446
447 static inline void ast_variable_iden_set_expr_type(Ast_Variable_Iden *n,
448       Ast_Expr_Type t)
449 {
450    n->expr_type = t;
451 }
452
453 static inline Ast_Expr_Type ast_variable_iden_get_expr_type(
454       Ast_Variable_Iden *n)
455 {
456    return n->expr_type;
457 }
458
459 static inline Const_String ast_variable_iden_get_expr_str(
460       Ast_Variable_Iden *n)
461 {
462    Const_String ret =
463          ast_expr_type_to_string(ast_variable_iden_get_expr_type(n));
464    assert(ret);
465    return ret;
466 }
467
468 #define AST_VARIABLE_IDEN_ALLOC(node_type, node_location, identifier) ({ \
469    Ast_Variable_Iden *___n = AST_NODE_ALLOC(Ast_Variable_Iden,    \
470          node_type, node_location);                      \
471    ___n->iden = string_duplicate(identifier);            \
472    ___n->expr_type = AST_EXPR_TYPE_UNSPECIFIED;          \
473    AST_NODE_OF(___n);                                    \
474 })
475
476 // 32 bit integer constant node.
477 AST_NODE_STRUCT_BEGIN(Ast_Expr_Int)
478    int32_t val;
479 AST_NODE_STRUCT_END(Ast_Expr_Int)
480
481 int32_t ast_string_to_int32(Ast_Expr_Int *n, String str);
482
483 #define AST_EXPR_INT_ALLOC(node_type, node_location, string_val) ({ \
484    Ast_Expr_Int *___n = AST_NODE_ALLOC(Ast_Expr_Int,     \
485          node_type, node_location);                      \
486    ___n->val = ast_string_to_int32(___n, string_val);    \
487    AST_NODE_OF(___n);                                    \
488 })
489
490 // Boolean constant node.
491 AST_NODE_STRUCT_BEGIN(Ast_Expr_Bool)
492    bool val;
493 AST_NODE_STRUCT_END(Ast_Expr_Bool)
494
495 #define AST_EXPR_BOOL_ALLOC(node_type, node_location, bool_val) ({  \
496    Ast_Expr_Bool *___n = AST_NODE_ALLOC(Ast_Expr_Bool,     \
```

```
497           node_type, node_location);                    \
498     ___n->val = bool_val;                               \
499     AST_NODE_OF(___n);                                  \
500 })
501
502 // Char constant ('c')
503 AST_NODE_STRUCT_BEGIN(Ast_Expr_Char)
504     int32_t val;
505 AST_NODE_STRUCT_END(Ast_Expr_Char)
506
507 int32_t ast_char_to_int32(Ast_Expr_Char *n, String char_str);
508
509 #define AST_EXPR_CHAR_ALLOC(node_type, node_location, char_str) ({  \
510     Ast_Expr_Char *___n = AST_NODE_ALLOC(Ast_Expr_Char,     \
511           node_type, node_location);                    \
512     ___n->val = ast_char_to_int32(___n, char_str);      \
513     AST_NODE_OF(___n);                                  \
514 })
515
516 // String constant ("my string")
517 AST_NODE_STRUCT_BEGIN(Ast_Expr_String)
518     String val;
519 AST_NODE_STRUCT_END(Ast_Expr_String)
520
521 String ast_get_expr_string(Ast_Expr_String *n, String str);
522
523 #define AST_EXPR_STRING_ALLOC(node_type, node_location, string_str) ({ \
524     Ast_Expr_String *___n = AST_NODE_ALLOC(Ast_Expr_String,    \
525           node_type, node_location);                    \
526     ___n->val = ast_get_expr_string(___n, string_str);     \
527     AST_NODE_OF(___n);                                  \
528 })
529
530 String ast_module_string(Const_String initial);
531
532 // Module name (package.name).
533 AST_NODE_STRUCT_BEGIN(Ast_Module_String)
534     String module;
535     int dep_idx;
536 AST_NODE_STRUCT_END(Ast_Module_String)
537
538 #define AST_MODULE_STRING_ALLOC(node_type, node_location, module_str) ({ \
539     Ast_Module_String *___n = AST_NODE_ALLOC(Ast_Module_String,    \
540           node_type, node_location);                      \
541     ___n->module = ast_module_string(module_str);         \
542     AST_NODE_OF(___n);                                    \
543 })
544
545 // For nodes without any contents.
546 AST_NODE_STRUCT_BEGIN(Ast_Empty)
547 AST_NODE_STRUCT_END(Ast_Empty)
548
549 #define AST_EMPTY_ALLOC(node_type, node_location) ({ \
550     Ast_Empty *___n = AST_NODE_ALLOC(Ast_Empty,   \
551           node_type, node_location);       \
552     AST_NODE_OF(___n);                     \
553 })
554
555 // For null cunstant node.
556 AST_NODE_STRUCT_BEGIN(Ast_Expr_Null)
557 AST_NODE_STRUCT_END(Ast_Expr_Null)
558
559 #define AST_EXPR_NULL_ALLOC(node_type, node_location) ({ \
560     Ast_Expr_Null *___n = AST_NODE_ALLOC(Ast_Expr_Null,  \
561           node_type, node_location);          \
562     AST_NODE_OF(___n);                        \
563 })
564
565 // Node for typedefs type iden = something.
566 AST_NODE_STRUCT_BEGIN(Ast_Type_Iden)
567     String iden;
568 AST_NODE_STRUCT_END(Ast_Type_Iden)
569
570 #define AST_TYPE_IDEN_ALLOC(node_type, node_location, identifier) ({ \
```

```
571     Ast_Type_Iden *___n = AST_NODE_ALLOC(Ast_Type_Iden,     \
572           node_type, node_location);                        \
573     ___n->iden = string_duplicate(identifier);              \
574     AST_NODE_OF(___n);                                      \
575 })
576
577 // Nodes for complex types with one child. Only array curretly.
578 // (type a = array of something)
579 AST_NODE_STRUCT_BEGIN(Ast_Type)
580     Ast_Node *type;
581 AST_NODE_STRUCT_END(Ast_Type)
582
583 #define AST_TYPE_ALLOC(node_type, node_location, complex_type) ({  \
584     Ast_Type *___n = AST_NODE_ALLOC(Ast_Type,               \
585           node_type, node_location);                        \
586     ___n->type = complex_type;                              \
587     AST_NODE_OF(___n);                                      \
588 })
589
590 AST_NODE_STRUCT_BEGIN(Ast_Stmt_List)
591     Vector *statements;
592     Uns num_rec_ctor_stmts;
593 AST_NODE_STRUCT_END(Ast_Stmt_List)
594
595 #define AST_STMT_LIST_ALLOC(node_type, node_location, vec_stmts) ({  \
596     Ast_Stmt_List *___n = AST_NODE_ALLOC(Ast_Stmt_List,     \
597           node_type, node_location);                        \
598     ___n->statements = vec_stmts;                           \
599     ___n->num_rec_ctor_stmts = 0;                           \
600     AST_NODE_OF(___n);                                      \
601 })
602
603 // Function definition node
604 // (func foo():something ... end foo) also works as:
605 // Extern function declaration node
606 // (extern (C) func foo():something; )
607 AST_NODE_STRUCT_BEGIN(Ast_Func_Def)
608     Ast_Node *iden;
609     Ast_Node *extern_type;
610     Ast_Node *return_type;
611     Vector *parameters;
612     Ast_Node *statements;
613 AST_NODE_STRUCT_END(Ast_Func_Def)
614
615 #define AST_FUNC_DEF_ALLOC(node_type, node_location, ext_type, identifier, \
616       type, vec_params, stmts) ({                           \
617     Ast_Func_Def *___n = AST_NODE_ALLOC(Ast_Func_Def,       \
618           node_type, node_location);                        \
619     ___n->iden = identifier;                                \
620     ___n->extern_type = ext_type;                           \
621     ___n->return_type = type;                               \
622     ___n->parameters = vec_params;                          \
623     ___n->statements = stmts;                               \
624     AST_NODE_OF(___n);                                      \
625 })
626
627 typedef struct Symbol_Type_Struct Symbol_Type_Struct;
628
629 Ast_Expr_Type symbol_type_to_expr_type(Symbol_Type_Struct *st);
630
631 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_LOR);
632 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_LAND);
633 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_EQ);
634 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_NEQ);
635 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_GT);
636 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_LT);
637 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_GTEQ);
638 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_LTEQ);
639 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_PLUS);
640 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_MINUS);
641 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_MUL);
642 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_DIV);
643 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_CAST);
644 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_ARY_REF);
```

```
645 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_DOT_REF);
646 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_LNOT);
647 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_ABS);
648 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_FUNC_CALL);
649 AST_NODE_ACCEPT_VISITOR_DECL(AST_VARIABLE_IDEN);
650 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_INT);
651 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_BOOL);
652 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_NULL);
653 AST_NODE_ACCEPT_VISITOR_DECL(AST_SIMPLE_TYPE_INT);
654 AST_NODE_ACCEPT_VISITOR_DECL(AST_SIMPLE_TYPE_BOOL);
655 AST_NODE_ACCEPT_VISITOR_DECL(AST_TYPE_IDEN);
656 AST_NODE_ACCEPT_VISITOR_DECL(AST_VAR_DECL);
657 AST_NODE_ACCEPT_VISITOR_DECL(AST_TYPE_DEF);
658 AST_NODE_ACCEPT_VISITOR_DECL(AST_TYPE_ARY);
659 AST_NODE_ACCEPT_VISITOR_DECL(AST_TYPE_REC);
660 AST_NODE_ACCEPT_VISITOR_DECL(AST_STMT_LIST);
661 AST_NODE_ACCEPT_VISITOR_DECL(AST_FUNC_DEF);
662 AST_NODE_ACCEPT_VISITOR_DECL(AST_IF_STMT);
663 AST_NODE_ACCEPT_VISITOR_DECL(AST_IF_ELSE_STMT);
664 AST_NODE_ACCEPT_VISITOR_DECL(AST_ALLOC_REC);
665 AST_NODE_ACCEPT_VISITOR_DECL(AST_ALLOC_ARY);
666 AST_NODE_ACCEPT_VISITOR_DECL(AST_WHILE_STMT);
667 AST_NODE_ACCEPT_VISITOR_DECL(AST_RETURN_STMT);
668 AST_NODE_ACCEPT_VISITOR_DECL(AST_WRITE_STMT);
669 AST_NODE_ACCEPT_VISITOR_DECL(AST_ASSIGNMENT);
670 AST_NODE_ACCEPT_VISITOR_DECL(AST_FUNC_BODY);
671 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_CHAR);
672 AST_NODE_ACCEPT_VISITOR_DECL(AST_SIMPLE_TYPE_CHAR);
673 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_STRING);
674 AST_NODE_ACCEPT_VISITOR_DECL(AST_SIMPLE_TYPE_STRING);
675 AST_NODE_ACCEPT_VISITOR_DECL(AST_IMPORT_STRING);
676 AST_NODE_ACCEPT_VISITOR_DECL(AST_PACKAGE_STRING);
677 AST_NODE_ACCEPT_VISITOR_DECL(AST_REC_SELF_PTR);
678 AST_NODE_ACCEPT_VISITOR_DECL(AST_SIMPLE_TYPE_VOID);
679 AST_NODE_ACCEPT_VISITOR_DECL(AST_FIN_FUNC_DEF);
680 AST_NODE_ACCEPT_VISITOR_DECL(AST_DELETE);
681 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXT_FUNC_DECL);
682 AST_NODE_ACCEPT_VISITOR_DECL(AST_FIN_STMT_LIST);
683 AST_NODE_ACCEPT_VISITOR_DECL(AST_REC_FUNC_DEF);
684 AST_NODE_ACCEPT_VISITOR_DECL(AST_EXPR_DIRECT_REF);
685 AST_NODE_ACCEPT_VISITOR_DECL(AST_ALLOC_REC_CALL);
686
687 #endif // AST_H
```

:

A.3.3 src/ast/ast_string.c

```
1  #include "ast.h"
2  #include <errno.h>
3  #include "ast_string.h"
4
5  int32_t ast_string_to_int32(Ast_Expr_Int *n, String str)
6  {
7     errno = 0;
8     int32_t res = string_base10_to_int32(str);
9     if (errno) {
10       if (errno == EINVAL) {
11          /* Probably cannot happen. */
12          report_error_location(&n->ast_node.location,
13                S("unable to convert " QFY("%S") " to an integer.\n"),
14                str);
15       } else if (errno == ERANGE) {
16          report_error_location(&n->ast_node.location,
17                S("value " QFY("%S") " %s int\n"),
18                str,
19                res == INT32_MAX ? "overflows" : "underflows");
20       } else {
21          /* Probably cannot happen. */
22          fatal_error(S("unexpected error converting string "
23                "to integer.\n"));
```

```
24          }
25          res = 0;
26       }
27       return res;
28    }
29
30    /* Warning. Make sure string is dynamic before calling this function. */
31    bool ___ast_string_unescape(Ast_Node *n, String s)
32    {
33       bool ret = true;
34       char *cstr = s->str;
35       char *endstr = cstr;
36       for (; *endstr; endstr++, cstr++) {
37          if (*endstr == '\\') {
38             ++endstr;
39             switch (*endstr) {
40             case 'n':
41                *cstr = '\n';
42                break;
43             case 't':
44                *cstr = '\t';
45                break;
46             case '\\':
47                *cstr = '\\';
48                break;
49             case '"':
50                *cstr = '"';
51                break;
52             case '\'':
53                *cstr = '\'';
54                break;
55             default:
56                ret = false;
57                if (*endstr) {
58                   report_error_location(&n->location,
59                         S("Invalid escape character " QFY("%c") "\n"),
60                         *endstr);
61                } else {
62                   // Should never happen.
63                   report_error_location(&n->location,
64                         S("Invalid escape character " QFY("(null)") "\n"));
65                   goto out;
66                }
67                break;
68             }
69          } else {
70             *cstr = *endstr;
71          }
72       }
73    out:
74       *cstr = *endstr;
75       return ret;
76    }
77
78    #define STRING_ESCAPE_CHAR(c) (('\\' << 8) + (Int)c)
79
80    #include <debug.h>
81
82    void ast_string_escape(String s, String_Builder *sb)
83    {
84       string_builder_assign(sb, S(""));
85       char *cstr = s->str;
86       while (*cstr) {
87          switch (*cstr) {
88             case '\n':
89                string_builder_append_int16(sb, STRING_ESCAPE_CHAR('n'));
90                break;
91             case '\t':
92                string_builder_append_int16(sb, STRING_ESCAPE_CHAR('t'));
93                break;
94             case '\\':
95                string_builder_append_int16(sb, STRING_ESCAPE_CHAR('\\'));
96                break;
97             case '"':
```

```
98              string_builder_append_int16(sb, STRING_ESCAPE_CHAR('"'));
99              break;
100          case '\'':
101             string_builder_append_int16(sb, STRING_ESCAPE_CHAR('\''));
102             break;
103          default:
104             string_builder_append_char(sb, *cstr);
105             break;
106       }
107       ++cstr;
108    }
109 }
```

:

A.3.4 src/ast/ast_string.h

```
1  #ifndef AST_STRING_H
2  #define AST_STRING_H
3
4  #include <ast/ast.h>
5  #include <string_builder.h>
6
7  typedef struct String_Builder String_Builder;
8
9  int32_t ast_string_to_int32(Ast_Expr_Int *n, String str);
10
11 /* Warning. Make sure string is dynamic before calling this function. That is:
12  * s->dynamic == true. Use string_assign(s, s) to make a string (s) dynamic.
13  * Returns true if no error was reported. */
14 bool ___ast_string_unescape(Ast_Node *n, String s);
15
16 void ast_string_escape(String s, String_Builder *sb);
17
18 String ast_module_string(Const_String initial);
19
20 #endif // AST_STRING_H
```

:

A.3.5 src/ast/ast_visitor.h

```
1  #ifndef AST_VISITOR_H
2  #define AST_VISITOR_H
3
4  #include "ast.h"
5
6  typedef struct Ast_Visitor Ast_Visitor;
7
8  #define ___AST_VISITOR_FUNC(node_type) ___visit_ ## node_type
9  #define AST_VISITOR_FUNC(node_type) ___AST_VISITOR_FUNC(node_type)
10
11 #define AST_VISITOR_FUNC_DECL(node_type, visitor_param, node_param) \
12 static void AST_VISITOR_FUNC(node_type)(Ast_Visitor *visitor_param, \
13       Ast_Node *node_param)
14
15 #define AST_VISITOR_FUNC_UNUSED(node_type) \
16    AST_VISITOR_FUNC_DECL(node_type, v, n) { (void)v; (void)n; }
17
18 #define ___AST_VISITOR_FUNC_BEGIN(node_type,             \
19       visitor_type, visitor_param,                       \
20       node_struct_type, node_param)                      \
21 AST_VISITOR_FUNC_DECL(node_type, ___ ## visitor_param, ___ ## node_param) \
22 {                                                        \
23    visitor_type *visitor_param = CONTAINER_OF(___ ## visitor_param,  \
24          visitor_type, AST_VISITOR_FIELD);              \
25    node_struct_type *node_param = CONTAINER_OF(___ ## node_param,    \
```

```
26          node_struct_type, AST_NODE_FIELD);
27
28  #define AST_VISITOR_FUNC_BEGIN(node_type,             \
29          visitor_type, visitor_param,                  \
30          node_struct_type, node_param)                 \
31     ___AST_VISITOR_FUNC_BEGIN(node_type, visitor_type, visitor_param, \
32             node_struct_type, node_param)
33
34  #define AST_VISITOR_FUNC_END }
35
36  #define ASTVF_BEGIN  AST_VISITOR_FUNC_BEGIN
37  #define ASTVF_END  AST_VISITOR_FUNC_END
38  #define ASTVF_UNUSED AST_VISITOR_FUNC_UNUSED
39
40  #define AST_VISITOR_CONTAINER_OF(node, type) \
41     CONTAINER_OF(node, type, AST_VISITOR_FIELD)
42
43  typedef void (*Ast_Visitor_Method)(Ast_Visitor *, Ast_Node *);
44
45  struct Ast_Visitor {
46     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_LOR);
47     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_LAND);
48     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_EQ);
49     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_NEQ);
50     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_GT);
51     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_LT);
52     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_GTEQ);
53     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_LTEQ);
54     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_PLUS);
55     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_MINUS);
56     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_MUL);
57     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_DIV);
58     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_CAST);
59     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_LNOT);
60     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_ABS);
61     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_INT);
62     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_BOOL);
63     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_NULL);
64     Ast_Visitor_Method AST_VISITOR_FUNC(AST_VARIABLE_IDEN);
65     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_ARY_REF);
66     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_FUNC_CALL);
67     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_DOT_REF);
68     Ast_Visitor_Method AST_VISITOR_FUNC(AST_SIMPLE_TYPE_INT);
69     Ast_Visitor_Method AST_VISITOR_FUNC(AST_SIMPLE_TYPE_BOOL);
70     Ast_Visitor_Method AST_VISITOR_FUNC(AST_TYPE_IDEN);
71     Ast_Visitor_Method AST_VISITOR_FUNC(AST_VAR_DECL);
72     Ast_Visitor_Method AST_VISITOR_FUNC(AST_TYPE_DEF);
73     Ast_Visitor_Method AST_VISITOR_FUNC(AST_TYPE_ARY);
74     Ast_Visitor_Method AST_VISITOR_FUNC(AST_TYPE_REC);
75     Ast_Visitor_Method AST_VISITOR_FUNC(AST_STMT_LIST);
76     Ast_Visitor_Method AST_VISITOR_FUNC(AST_FUNC_DEF);
77     Ast_Visitor_Method AST_VISITOR_FUNC(AST_IF_STMT);
78     Ast_Visitor_Method AST_VISITOR_FUNC(AST_IF_ELSE_STMT);
79     Ast_Visitor_Method AST_VISITOR_FUNC(AST_ALLOC_REC);
80     Ast_Visitor_Method AST_VISITOR_FUNC(AST_ALLOC_ARY);
81     Ast_Visitor_Method AST_VISITOR_FUNC(AST_WHILE_STMT);
82     Ast_Visitor_Method AST_VISITOR_FUNC(AST_RETURN_STMT);
83     Ast_Visitor_Method AST_VISITOR_FUNC(AST_WRITE_STMT);
84     Ast_Visitor_Method AST_VISITOR_FUNC(AST_ASSIGNMENT);
85     Ast_Visitor_Method AST_VISITOR_FUNC(AST_FUNC_BODY);
86     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_CHAR);
87     Ast_Visitor_Method AST_VISITOR_FUNC(AST_SIMPLE_TYPE_CHAR);
88     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_STRING);
89     Ast_Visitor_Method AST_VISITOR_FUNC(AST_IMPORT_STRING);
90     Ast_Visitor_Method AST_VISITOR_FUNC(AST_SIMPLE_TYPE_STRING);
91     Ast_Visitor_Method AST_VISITOR_FUNC(AST_PACKAGE_STRING);
92     Ast_Visitor_Method AST_VISITOR_FUNC(AST_REC_SELF_PTR);
93     Ast_Visitor_Method AST_VISITOR_FUNC(AST_SIMPLE_TYPE_VOID);
94     Ast_Visitor_Method AST_VISITOR_FUNC(AST_FIN_FUNC_DEF);
95     Ast_Visitor_Method AST_VISITOR_FUNC(AST_DELETE);
96     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXT_FUNC_DECL);
97     Ast_Visitor_Method AST_VISITOR_FUNC(AST_FIN_STMT_LIST);
98     Ast_Visitor_Method AST_VISITOR_FUNC(AST_REC_FUNC_DEF);
99     Ast_Visitor_Method AST_VISITOR_FUNC(AST_EXPR_DIRECT_REF);
```

```
100     Ast_Visitor_Method AST_VISITOR_FUNC(AST_ALLOC_REC_CALL);
101  };
102
103  #define AST_VISITOR_STATIC_INIT() {        \
104     .AST_VISITOR_FUNC(AST_EXPR_LOR) =       \
105        AST_VISITOR_FUNC(AST_EXPR_LOR),      \
106     .AST_VISITOR_FUNC(AST_EXPR_LAND) =      \
107        AST_VISITOR_FUNC(AST_EXPR_LAND),     \
108     .AST_VISITOR_FUNC(AST_EXPR_EQ) =        \
109        AST_VISITOR_FUNC(AST_EXPR_EQ),       \
110     .AST_VISITOR_FUNC(AST_EXPR_NEQ) =       \
111        AST_VISITOR_FUNC(AST_EXPR_NEQ),      \
112     .AST_VISITOR_FUNC(AST_EXPR_GT) =        \
113        AST_VISITOR_FUNC(AST_EXPR_GT),       \
114     .AST_VISITOR_FUNC(AST_EXPR_LT) =        \
115        AST_VISITOR_FUNC(AST_EXPR_LT),       \
116     .AST_VISITOR_FUNC(AST_EXPR_GTEQ) =      \
117        AST_VISITOR_FUNC(AST_EXPR_GTEQ),     \
118     .AST_VISITOR_FUNC(AST_EXPR_LTEQ) =      \
119        AST_VISITOR_FUNC(AST_EXPR_LTEQ),     \
120     .AST_VISITOR_FUNC(AST_EXPR_PLUS) =      \
121        AST_VISITOR_FUNC(AST_EXPR_PLUS),     \
122     .AST_VISITOR_FUNC(AST_EXPR_MINUS) =      \
123        AST_VISITOR_FUNC(AST_EXPR_MINUS),    \
124     .AST_VISITOR_FUNC(AST_EXPR_MUL) =       \
125        AST_VISITOR_FUNC(AST_EXPR_MUL),      \
126     .AST_VISITOR_FUNC(AST_EXPR_DIV) =       \
127        AST_VISITOR_FUNC(AST_EXPR_DIV),      \
128     .AST_VISITOR_FUNC(AST_EXPR_CAST) =      \
129        AST_VISITOR_FUNC(AST_EXPR_CAST),     \
130     .AST_VISITOR_FUNC(AST_EXPR_LNOT) =      \
131        AST_VISITOR_FUNC(AST_EXPR_LNOT),     \
132     .AST_VISITOR_FUNC(AST_EXPR_ABS) =       \
133        AST_VISITOR_FUNC(AST_EXPR_ABS),      \
134     .AST_VISITOR_FUNC(AST_EXPR_INT) =       \
135        AST_VISITOR_FUNC(AST_EXPR_INT),      \
136     .AST_VISITOR_FUNC(AST_EXPR_BOOL) =      \
137        AST_VISITOR_FUNC(AST_EXPR_BOOL),     \
138     .AST_VISITOR_FUNC(AST_EXPR_NULL) =      \
139        AST_VISITOR_FUNC(AST_EXPR_NULL),     \
140     .AST_VISITOR_FUNC(AST_VARIABLE_IDEN) =    \
141        AST_VISITOR_FUNC(AST_VARIABLE_IDEN),   \
142     .AST_VISITOR_FUNC(AST_EXPR_ARY_REF) =    \
143        AST_VISITOR_FUNC(AST_EXPR_ARY_REF),    \
144     .AST_VISITOR_FUNC(AST_EXPR_FUNC_CALL) =    \
145        AST_VISITOR_FUNC(AST_EXPR_FUNC_CALL),   \
146     .AST_VISITOR_FUNC(AST_EXPR_DOT_REF) =    \
147        AST_VISITOR_FUNC(AST_EXPR_DOT_REF),    \
148     .AST_VISITOR_FUNC(AST_SIMPLE_TYPE_INT) =   \
149        AST_VISITOR_FUNC(AST_SIMPLE_TYPE_INT),   \
150     .AST_VISITOR_FUNC(AST_SIMPLE_TYPE_BOOL) =   \
151        AST_VISITOR_FUNC(AST_SIMPLE_TYPE_BOOL),   \
152     .AST_VISITOR_FUNC(AST_TYPE_IDEN) =      \
153        AST_VISITOR_FUNC(AST_TYPE_IDEN),     \
154     .AST_VISITOR_FUNC(AST_VAR_DECL) =       \
155        AST_VISITOR_FUNC(AST_VAR_DECL),      \
156     .AST_VISITOR_FUNC(AST_TYPE_DEF) =       \
157        AST_VISITOR_FUNC(AST_TYPE_DEF),      \
158     .AST_VISITOR_FUNC(AST_TYPE_ARY) =       \
159        AST_VISITOR_FUNC(AST_TYPE_ARY),      \
160     .AST_VISITOR_FUNC(AST_TYPE_REC) =       \
161        AST_VISITOR_FUNC(AST_TYPE_REC),      \
162     .AST_VISITOR_FUNC(AST_STMT_LIST) =      \
163        AST_VISITOR_FUNC(AST_STMT_LIST),     \
164     .AST_VISITOR_FUNC(AST_FUNC_DEF) =       \
165        AST_VISITOR_FUNC(AST_FUNC_DEF),      \
166     .AST_VISITOR_FUNC(AST_IF_STMT) =        \
167        AST_VISITOR_FUNC(AST_IF_STMT),       \
168     .AST_VISITOR_FUNC(AST_IF_ELSE_STMT) =    \
169        AST_VISITOR_FUNC(AST_IF_ELSE_STMT),    \
170     .AST_VISITOR_FUNC(AST_ALLOC_REC) =      \
171        AST_VISITOR_FUNC(AST_ALLOC_REC),     \
172     .AST_VISITOR_FUNC(AST_ALLOC_ARY) =      \
173        AST_VISITOR_FUNC(AST_ALLOC_ARY),     \
```

```
174     .AST_VISITOR_FUNC(AST_WHILE_STMT) =     \
175        AST_VISITOR_FUNC(AST_WHILE_STMT),    \
176     .AST_VISITOR_FUNC(AST_RETURN_STMT) =    \
177        AST_VISITOR_FUNC(AST_RETURN_STMT),    \
178     .AST_VISITOR_FUNC(AST_WRITE_STMT) =     \
179        AST_VISITOR_FUNC(AST_WRITE_STMT),    \
180     .AST_VISITOR_FUNC(AST_ASSIGNMENT) =     \
181        AST_VISITOR_FUNC(AST_ASSIGNMENT),    \
182     .AST_VISITOR_FUNC(AST_FUNC_BODY) =     \
183        AST_VISITOR_FUNC(AST_FUNC_BODY),    \
184     .AST_VISITOR_FUNC(AST_EXPR_CHAR) =     \
185        AST_VISITOR_FUNC(AST_EXPR_CHAR),    \
186     .AST_VISITOR_FUNC(AST_SIMPLE_TYPE_CHAR) =   \
187        AST_VISITOR_FUNC(AST_SIMPLE_TYPE_CHAR),   \
188     .AST_VISITOR_FUNC(AST_EXPR_STRING) =    \
189        AST_VISITOR_FUNC(AST_EXPR_STRING),    \
190     .AST_VISITOR_FUNC(AST_IMPORT_STRING) =    \
191        AST_VISITOR_FUNC(AST_IMPORT_STRING),   \
192     .AST_VISITOR_FUNC(AST_SIMPLE_TYPE_STRING) =   \
193        AST_VISITOR_FUNC(AST_SIMPLE_TYPE_STRING),  \
194     .AST_VISITOR_FUNC(AST_REC_SELF_PTR) =    \
195        AST_VISITOR_FUNC(AST_REC_SELF_PTR),    \
196     .AST_VISITOR_FUNC(AST_SIMPLE_TYPE_VOID) =   \
197        AST_VISITOR_FUNC(AST_SIMPLE_TYPE_VOID),   \
198     .AST_VISITOR_FUNC(AST_FIN_FUNC_DEF) =    \
199        AST_VISITOR_FUNC(AST_FIN_FUNC_DEF),    \
200     .AST_VISITOR_FUNC(AST_DELETE) =        \
201        AST_VISITOR_FUNC(AST_DELETE),       \
202     .AST_VISITOR_FUNC(AST_EXT_FUNC_DECL) =    \
203        AST_VISITOR_FUNC(AST_EXT_FUNC_DECL),   \
204     .AST_VISITOR_FUNC(AST_FIN_STMT_LIST) =    \
205        AST_VISITOR_FUNC(AST_FIN_STMT_LIST),   \
206     .AST_VISITOR_FUNC(AST_REC_FUNC_DEF) =    \
207        AST_VISITOR_FUNC(AST_REC_FUNC_DEF),    \
208     .AST_VISITOR_FUNC(AST_EXPR_DIRECT_REF) =   \
209        AST_VISITOR_FUNC(AST_EXPR_DIRECT_REF),   \
210     .AST_VISITOR_FUNC(AST_ALLOC_REC_CALL) =    \
211        AST_VISITOR_FUNC(AST_ALLOC_REC_CALL),   \
212     .AST_VISITOR_FUNC(AST_PACKAGE_STRING) =    \
213        AST_VISITOR_FUNC(AST_PACKAGE_STRING)   \
214 }
215
216 #define AST_VISITOR_INIT() ((Ast_Visitor)AST_VISITOR_STATIC_INIT())
217
218 #define AST_VISITOR_FIELD ast_visitor
219
220 #define AST_VISITOR_STRUCT_BEGIN(visitor_name) \
221    typedef struct visitor_name {    \
222       Ast_Visitor AST_VISITOR_FIELD;
223 #define AST_VISITOR_STRUCT_END(visitor_name) } visitor_name;
224
225 #define AST_VISITOR_OF(container) (&(container)->AST_VISITOR_FIELD)
226
227 #endif // AST_VISITOR_H
```

:

A.3.6 src/ast/ast_visitor_print.c

```
1  #include "ast_visitor_print.h"
2  #include "ast_string.h"
3  #include <std_define.h>
4  #include <std_include.h>
5
6  AST_VISITOR_STRUCT_BEGIN(Ast_Visitor_Print)
7     Uns indentation;
8     FILE *output_file;
9  AST_VISITOR_STRUCT_END(Ast_Visitor_Print)
10
11 #define INDENT_COUNT 4
12
```

```
13 #define PRINT_OPEN(stream, fmt, indent, ...) \
14 file_print_message(stream, S("%*s<" fmt ">\n"), indent, "", ## __VA_ARGS__)
15
16 #define PRINT_CLOSE(stream, fmt, indent, ...) \
17 file_print_message(stream, S("%*s</" fmt ">\n"), indent, "", ## __VA_ARGS__)
18
19 #define PRINT_SINGLE(stream, fmt, indent, ...) \
20 file_print_message(stream, S("%*s<" fmt " />\n"), indent, "", ## __VA_ARGS__)
21
22 static void stmt_list_action(Ast_Visitor_Print *v, Ast_Stmt_List *n,
23       const char *type)
24 {
25    Ast_Node *stmt;
26    Vector *vec = n->statements;
27
28    PRINT_OPEN(v->output_file, "%s line=\"%U\" column=\"%U\"",
29          v->indentation,
30          type,
31          n->ast_node.location.line,
32          n->ast_node.location.column);
33
34    v->indentation += INDENT_COUNT;
35    VECTOR_FOR_EACH_ENTRY(vec, stmt)
36       stmt->accept_visitor(stmt, AST_VISITOR_OF(v));
37    v->indentation -= INDENT_COUNT;
38
39    PRINT_CLOSE(v->output_file, "%s", v->indentation, type);
40 }
41
42 static void ternary_action(Ast_Visitor_Print *v, Ast_Node_Ternary *n,
43       const char *name)
44 {
45    PRINT_OPEN(v->output_file, "%s line=\"%U\" column=\"%U\"",
46          v->indentation,
47          name,
48          n->ast_node.location.line,
49          n->ast_node.location.column);
50
51    v->indentation += INDENT_COUNT;
52    n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
53    n->mid->accept_visitor(n->mid, AST_VISITOR_OF(v));
54    n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
55    v->indentation -= INDENT_COUNT;
56
57    PRINT_CLOSE(v->output_file, "%s", v->indentation, name);
58 }
59
60 static void binary_action(Ast_Visitor_Print *v, Ast_Node_Binary *n,
61       const char *name)
62 {
63    PRINT_OPEN(v->output_file, "%s line=\"%U\" column=\"%U\"",
64          v->indentation,
65          name,
66          n->ast_node.location.line,
67          n->ast_node.location.column);
68
69    v->indentation += INDENT_COUNT;
70    n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
71    n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
72    v->indentation -= INDENT_COUNT;
73
74    PRINT_CLOSE(v->output_file, "%s", v->indentation, name);
75 }
76
77 static void binary_op_action(Ast_Visitor_Print *v, Ast_Node_Binary *n,
78       const char *name)
79 {
80    Ast_Expr_Binary *bin = AST_EXPR_BINARY_OF(n);
81    PRINT_OPEN(v->output_file, "%s type=\"%S\" line=\"%U\" column=\"%U\"",
82          v->indentation,
83          name,
84          ast_expr_binary_get_expr_str(bin),
85          n->ast_node.location.line,
86          n->ast_node.location.column);
```

```
87
88     v->indentation += INDENT_COUNT;
89     if (n->lhs) // Because of DIRECT_REF
90        n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
91     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
92     v->indentation -= INDENT_COUNT;
93
94     PRINT_CLOSE(v->output_file, "%s", v->indentation, name);
95  }
96
97  static void unary_action(Ast_Visitor_Print *v, Ast_Node_Unary *n,
98        const char *name)
99  {
100    PRINT_OPEN(v->output_file, "%s line=\"%U\" column=\"%U\"",
101          v->indentation,
102          name,
103          n->ast_node.location.line,
104          n->ast_node.location.column);
105
106    v->indentation += INDENT_COUNT;
107    n->expr->accept_visitor(n->expr, AST_VISITOR_OF(v));
108    v->indentation -= INDENT_COUNT;
109
110    PRINT_CLOSE(v->output_file, "%s", v->indentation, name);
111 }
112
113 static void unary_op_action(Ast_Visitor_Print *v, Ast_Node_Unary *n,
114       const char *name)
115 {
116    Ast_Expr_Unary *una = AST_EXPR_UNARY_OF(n);
117    PRINT_OPEN(v->output_file, "%s type=\"%S\" line=\"%U\" column=\"%U\"",
118          v->indentation,
119          name,
120          ast_expr_unary_get_expr_str(una),
121          n->ast_node.location.line,
122          n->ast_node.location.column);
123
124    v->indentation += INDENT_COUNT;
125    n->expr->accept_visitor(n->expr, AST_VISITOR_OF(v));
126    v->indentation -= INDENT_COUNT;
127
128    PRINT_CLOSE(v->output_file, "%s", v->indentation, name);
129 }
130
131 static void simple_type_action(Ast_Visitor_Print *v, Ast_Empty *n,
132       const char *type)
133 {
134    PRINT_SINGLE(v->output_file, "simple_type type=\"%s\" "
135             "line=\"%U\" column=\"%U\"",
136          v->indentation,
137          type,
138          n->ast_node.location.line,
139          n->ast_node.location.column);
140 }
141
142 static void type_action(Ast_Visitor_Print *v, Ast_Type *n, const char *type)
143 {
144    PRINT_OPEN(v->output_file, "%s line=\"%U\" column=\"%U\"",
145          v->indentation,
146          type,
147          n->ast_node.location.line,
148          n->ast_node.location.column);
149
150    v->indentation += INDENT_COUNT;
151    n->type->accept_visitor(n->type, AST_VISITOR_OF(v));
152    v->indentation -= INDENT_COUNT;
153
154    PRINT_CLOSE(v->output_file, "%s", v->indentation, type);
155 }
156
157 ASTVF_BEGIN(AST_EXPR_LOR, Ast_Visitor_Print, v, Ast_Node_Binary, n)
158    binary_op_action(v, n, "expr_logic_or");
159 ASTVF_END
160
```

```
161 ASTVF_BEGIN(AST_EXPR_LAND, Ast_Visitor_Print, v, Ast_Node_Binary, n)
162    binary_op_action(v, n, "expr_logic_and");
163 ASTVF_END
164
165 ASTVF_BEGIN(AST_EXPR_EQ, Ast_Visitor_Print, v, Ast_Node_Binary, n)
166    binary_op_action(v, n, "expr_eq");
167 ASTVF_END
168
169 ASTVF_BEGIN(AST_EXPR_NEQ, Ast_Visitor_Print, v, Ast_Node_Binary, n)
170    binary_op_action(v, n, "expr_neq");
171 ASTVF_END
172
173 ASTVF_BEGIN(AST_EXPR_GT, Ast_Visitor_Print, v, Ast_Node_Binary, n)
174    binary_op_action(v, n, "expr_gt");
175 ASTVF_END
176
177 ASTVF_BEGIN(AST_EXPR_LT, Ast_Visitor_Print, v, Ast_Node_Binary, n)
178    binary_op_action(v, n, "expr_lt");
179 ASTVF_END
180
181 ASTVF_BEGIN(AST_EXPR_GTEQ, Ast_Visitor_Print, v, Ast_Node_Binary, n)
182    binary_op_action(v, n, "expr_gteq");
183 ASTVF_END
184
185 ASTVF_BEGIN(AST_EXPR_LTEQ, Ast_Visitor_Print, v, Ast_Node_Binary, n)
186    binary_op_action(v, n, "expr_lteq");
187 ASTVF_END
188
189 ASTVF_BEGIN(AST_EXPR_PLUS, Ast_Visitor_Print, v, Ast_Node_Binary, n)
190    binary_op_action(v, n, "expr_plus");
191 ASTVF_END
192
193 ASTVF_BEGIN(AST_EXPR_MINUS, Ast_Visitor_Print, v, Ast_Node_Binary, n)
194    binary_op_action(v, n, "expr_minus");
195 ASTVF_END
196
197 ASTVF_BEGIN(AST_EXPR_MUL, Ast_Visitor_Print, v, Ast_Node_Binary, n)
198    binary_op_action(v, n, "expr_mul");
199 ASTVF_END
200
201 ASTVF_BEGIN(AST_EXPR_DIV, Ast_Visitor_Print, v, Ast_Node_Binary, n)
202    binary_op_action(v, n, "expr_div");
203 ASTVF_END
204
205 ASTVF_BEGIN(AST_EXPR_CAST, Ast_Visitor_Print, v, Ast_Node_Binary, n)
206    binary_op_action(v, n, "expr_type_cast");
207 ASTVF_END
208
209 ASTVF_BEGIN(AST_EXPR_LNOT, Ast_Visitor_Print, v, Ast_Node_Unary, n)
210    unary_op_action(v, n, "expr_logic_not");
211 ASTVF_END
212
213 ASTVF_BEGIN(AST_EXPR_ABS, Ast_Visitor_Print, v, Ast_Node_Unary, n)
214    unary_op_action(v, n, "expr_abs");
215 ASTVF_END
216
217 ASTVF_BEGIN(AST_EXPR_INT, Ast_Visitor_Print, v, Ast_Expr_Int, n)
218    PRINT_SINGLE(v->output_file, "int_const value=\"%U\" "
219              "line=\"%U\" column=\"%U\"",
220          v->indentation,
221          n->val,
222          n->ast_node.location.line,
223          n->ast_node.location.column);
224 ASTVF_END
225
226 ASTVF_BEGIN(AST_EXPR_BOOL, Ast_Visitor_Print, v, Ast_Expr_Bool, n)
227    PRINT_SINGLE(v->output_file, "bool_const value=\"%s\" "
228              "line=\"%U\" column=\"%U\"",
229          v->indentation,
230          n->val ? "true" : "false",
231          n->ast_node.location.line,
232          n->ast_node.location.column);
233 ASTVF_END
234
```

```
235 ASTVF_BEGIN(AST_EXPR_NULL, Ast_Visitor_Print, v, Ast_Expr_Null, n)
236    PRINT_SINGLE(v->output_file, "null_const line=\"%U\" column=\"%U\"",
237          v->indentation,
238          n->ast_node.location.line,
239          n->ast_node.location.column);
240 ASTVF_END
241
242 ASTVF_BEGIN(AST_VARIABLE_IDEN, Ast_Visitor_Print, v, Ast_Variable_Iden, n)
243    PRINT_SINGLE(v->output_file, "identifier id=\"%S\" type=\"%S\" "
244               "line=\"%U\" column=\"%U\"",
245          v->indentation,
246          n->iden,
247          ast_variable_iden_get_expr_str(n),
248          n->ast_node.location.line,
249          n->ast_node.location.column);
250 ASTVF_END
251
252 ASTVF_BEGIN(AST_REC_SELF_PTR, Ast_Visitor_Print, v, Ast_Empty, n)
253    PRINT_SINGLE(v->output_file, "record_self "
254               "line=\"%U\" column=\"%U\"",
255          v->indentation,
256          n->ast_node.location.line,
257          n->ast_node.location.column);
258 ASTVF_END
259
260 ASTVF_BEGIN(AST_EXPR_ARY_REF, Ast_Visitor_Print, v, Ast_Node_Binary, n)
261    binary_op_action(v, n, "array_ref");
262 ASTVF_END
263
264 ASTVF_BEGIN(AST_EXPR_FUNC_CALL, Ast_Visitor_Print, v, Ast_Expr_Func_Call, n)
265    PRINT_OPEN(v->output_file, "func_call line=\"%U\" column=\"%U\"",
266          v->indentation,
267          n->ast_node.location.line,
268          n->ast_node.location.column);
269
270    v->indentation += INDENT_COUNT;
271
272    n->identifier->accept_visitor(n->identifier, AST_VISITOR_OF(v));
273
274    Ast_Node *arg;
275    Vector *vargs = n->arguments;
276    VECTOR_FOR_EACH_ENTRY(vargs, arg)
277       arg->accept_visitor(arg, AST_VISITOR_OF(v));
278
279    v->indentation -= INDENT_COUNT;
280
281    PRINT_CLOSE(v->output_file, "func_call", v->indentation);
282 ASTVF_END
283
284 ASTVF_BEGIN(AST_EXPR_DOT_REF, Ast_Visitor_Print, v, Ast_Node_Binary, n)
285    binary_op_action(v, n, "record_ref");
286 ASTVF_END
287
288 ASTVF_BEGIN(AST_EXPR_DIRECT_REF, Ast_Visitor_Print, v, Ast_Node_Binary, n)
289    binary_op_action(v, n, "direct_ref");
290 ASTVF_END
291
292 ASTVF_BEGIN(AST_SIMPLE_TYPE_INT, Ast_Visitor_Print, v, Ast_Empty, n)
293    simple_type_action(v, n, "int");
294 ASTVF_END
295
296 ASTVF_BEGIN(AST_SIMPLE_TYPE_VOID, Ast_Visitor_Print, v, Ast_Empty, n)
297    simple_type_action(v, n, "void");
298 ASTVF_END
299
300 ASTVF_BEGIN(AST_SIMPLE_TYPE_BOOL, Ast_Visitor_Print, v, Ast_Empty, n)
301    simple_type_action(v, n, "bool");
302 ASTVF_END
303
304 ASTVF_BEGIN(AST_TYPE_IDEN, Ast_Visitor_Print, v, Ast_Type_Iden, n)
305    PRINT_SINGLE(v->output_file, "type_iden id=\"%S\" "
306               "line=\"%U\" column=\"%U\"",
307          v->indentation,
308          n->iden,
```

```
309           n->ast_node.location.line,
310           n->ast_node.location.column);
311 ASTVF_END
312
313 ASTVF_BEGIN(AST_VAR_DECL, Ast_Visitor_Print, v, Ast_Node_Binary, n)
314    binary_action(v, n, "var_decl");
315 ASTVF_END
316
317 ASTVF_BEGIN(AST_TYPE_DEF, Ast_Visitor_Print, v, Ast_Node_Binary, n)
318    binary_action(v, n, "type_def");
319 ASTVF_END
320
321 ASTVF_BEGIN(AST_TYPE_ARY, Ast_Visitor_Print, v, Ast_Type, n)
322    type_action(v, n, "array_type");
323 ASTVF_END
324
325 ASTVF_BEGIN(AST_TYPE_REC, Ast_Visitor_Print, v, Ast_Type_Rec, n)
326    PRINT_OPEN(v->output_file, "record_type line=\"%U\" column=\"%U\"",
327          v->indentation,
328          n->ast_node.location.line,
329          n->ast_node.location.column);
330
331    v->indentation += INDENT_COUNT;
332
333    Ast_Node *arg;
334    Vector *vargs = n->extend_list;
335    VECTOR_FOR_EACH_ENTRY(vargs, arg)
336       arg->accept_visitor(arg, AST_VISITOR_OF(v));
337
338    vargs = n->body;
339    VECTOR_FOR_EACH_ENTRY(vargs, arg)
340       arg->accept_visitor(arg, AST_VISITOR_OF(v));
341
342    v->indentation -= INDENT_COUNT;
343
344    PRINT_CLOSE(v->output_file, "record_type", v->indentation);
345 ASTVF_END
346
347 ASTVF_BEGIN(AST_STMT_LIST, Ast_Visitor_Print, v, Ast_Stmt_List, n)
348    stmt_list_action(v, n, "statements");
349 ASTVF_END
350
351 ASTVF_BEGIN(AST_FIN_STMT_LIST, Ast_Visitor_Print, v, Ast_Stmt_List, n)
352    stmt_list_action(v, n, "finalize_stmt");
353 ASTVF_END
354
355 static void func_print(Ast_Visitor_Print *v, Ast_Func_Def *n)
356 {
357    Ast_Node *p;
358    Vector *vec = n->parameters;
359
360    PRINT_OPEN(v->output_file, "function line=\"%U\" column=\"%U\"",
361          v->indentation,
362          n->ast_node.location.line,
363          n->ast_node.location.column);
364
365    v->indentation += INDENT_COUNT;
366
367    n->iden->accept_visitor(n->iden, AST_VISITOR_OF(v));
368    n->return_type->accept_visitor(n->return_type, AST_VISITOR_OF(v));
369    VECTOR_FOR_EACH_ENTRY(vec, p)
370       p->accept_visitor(p, AST_VISITOR_OF(v));
371    n->statements->accept_visitor(n->statements, AST_VISITOR_OF(v));
372
373    v->indentation -= INDENT_COUNT;
374
375    PRINT_CLOSE(v->output_file, "function", v->indentation);
376 }
377
378 ASTVF_BEGIN(AST_EXT_FUNC_DECL, Ast_Visitor_Print, v, Ast_Func_Def, n)
379    Ast_Node *p;
380    Vector *vec = n->parameters;
381
382    PRINT_OPEN(v->output_file, "extern_func line=\"%U\" column=\"%U\"",
```

```
383             v->indentation,
384             n->ast_node.location.line,
385             n->ast_node.location.column);
386
387     v->indentation += INDENT_COUNT;
388
389     n->extern_type->accept_visitor(n->extern_type, AST_VISITOR_OF(v));
390     n->iden->accept_visitor(n->iden, AST_VISITOR_OF(v));
391     n->return_type->accept_visitor(n->return_type, AST_VISITOR_OF(v));
392
393     VECTOR_FOR_EACH_ENTRY(vec, p)
394        p->accept_visitor(p, AST_VISITOR_OF(v));
395
396     v->indentation -= INDENT_COUNT;
397
398     PRINT_CLOSE(v->output_file, "extern_func", v->indentation);
399 ASTVF_END
400
401 ASTVF_BEGIN(AST_FIN_FUNC_DEF, Ast_Visitor_Print, v, Ast_Func_Def, n)
402     func_print(v, n);
403 ASTVF_END
404
405 ASTVF_BEGIN(AST_REC_FUNC_DEF, Ast_Visitor_Print, v, Ast_Func_Def, n)
406     func_print(v, n);
407 ASTVF_END
408
409 ASTVF_BEGIN(AST_FUNC_DEF, Ast_Visitor_Print, v, Ast_Func_Def, n)
410     func_print(v, n);
411 ASTVF_END
412
413 ASTVF_BEGIN(AST_IF_STMT, Ast_Visitor_Print, v, Ast_Node_Binary, n)
414     binary_action(v, n, "if_stmt");
415 ASTVF_END
416
417 ASTVF_BEGIN(AST_IF_ELSE_STMT, Ast_Visitor_Print, v, Ast_Node_Ternary, n)
418     ternary_action(v, n, "if_else_stmt");
419 ASTVF_END
420
421 ASTVF_BEGIN(AST_ALLOC_ARY, Ast_Visitor_Print, v, Ast_Node_Binary, n)
422     binary_action(v, n, "allocate_array");
423 ASTVF_END
424
425 ASTVF_BEGIN(AST_ALLOC_REC, Ast_Visitor_Print, v, Ast_Node_Unary, n)
426     unary_action(v, n, "allocate_rec");
427 ASTVF_END
428
429 ASTVF_BEGIN(AST_ALLOC_REC_CALL, Ast_Visitor_Print, v, Ast_Node_Binary, n)
430     binary_action(v, n, "allocate_rec");
431 ASTVF_END
432
433 ASTVF_BEGIN(AST_DELETE, Ast_Visitor_Print, v, Ast_Node_Unary, n)
434     unary_action(v, n, "delete");
435 ASTVF_END
436
437 ASTVF_BEGIN(AST_WHILE_STMT, Ast_Visitor_Print, v, Ast_Node_Binary, n)
438     binary_action(v, n, "while_stmt");
439 ASTVF_END
440
441 ASTVF_BEGIN(AST_RETURN_STMT, Ast_Visitor_Print, v, Ast_Node_Unary, n)
442     unary_action(v, n, "return_stmt");
443 ASTVF_END
444
445 ASTVF_BEGIN(AST_WRITE_STMT, Ast_Visitor_Print, v, Ast_Node_Unary, n)
446     unary_action(v, n, "write_stmt");
447 ASTVF_END
448
449 ASTVF_BEGIN(AST_ASSIGNMENT, Ast_Visitor_Print, v, Ast_Node_Binary, n)
450     binary_action(v, n, "assignment");
451 ASTVF_END
452
453 ASTVF_BEGIN(AST_FUNC_BODY, Ast_Visitor_Print, v, Ast_Stmt_List, n)
454     stmt_list_action(v, n, "func_body");
455 ASTVF_END
456
```

```
457 ASTVF_BEGIN(AST_EXPR_CHAR, Ast_Visitor_Print, v, Ast_Expr_Char, n)
458    PRINT_SINGLE(v->output_file, "char_const value=\"%" PRIx32 "\" "
459              "line=\"%U\" column=\"%U\"",
460           v->indentation,
461           n->val,
462           n->ast_node.location.line,
463           n->ast_node.location.column);
464 ASTVF_END
465
466 ASTVF_BEGIN(AST_EXPR_STRING, Ast_Visitor_Print, v, Ast_Expr_String, n)
467    String_Builder sb = STRING_BUILDER_INIT();
468    ast_string_escape(n->val, &sb);
469    PRINT_SINGLE(v->output_file, "string_const value=\"%S\" "
470              "line=\"%U\" column=\"%U\"",
471           v->indentation,
472           string_builder_const_str(&sb),
473           n->ast_node.location.line,
474           n->ast_node.location.column);
475    string_builder_clear(&sb);
476 ASTVF_END
477
478 ASTVF_BEGIN(AST_IMPORT_STRING, Ast_Visitor_Print, v, Ast_Module_String, n)
479    PRINT_SINGLE(v->output_file, "import file=\"%S\" "
480              "line=\"%U\" column=\"%U\"",
481           v->indentation,
482           n->module,
483           n->ast_node.location.line,
484           n->ast_node.location.column);
485 ASTVF_END
486
487 ASTVF_BEGIN(AST_PACKAGE_STRING, Ast_Visitor_Print, v, Ast_Module_String, n)
488    PRINT_SINGLE(v->output_file, "package directory=\"%S\" "
489              "line=\"%U\" column=\"%U\"",
490           v->indentation,
491           n->module,
492           n->ast_node.location.line,
493           n->ast_node.location.column);
494 ASTVF_END
495
496 ASTVF_BEGIN(AST_SIMPLE_TYPE_CHAR, Ast_Visitor_Print, v, Ast_Empty, n)
497    simple_type_action(v, n, "char");
498 ASTVF_END
499
500 ASTVF_BEGIN(AST_SIMPLE_TYPE_STRING, Ast_Visitor_Print, v, Ast_Empty, n)
501    simple_type_action(v, n, "string");
502 ASTVF_END
503
504 static Ast_Visitor_Print print_visitor = {
505    .AST_VISITOR_FIELD = AST_VISITOR_STATIC_INIT(),
506    .indentation = 0,
507    .output_file = NULL
508 };
509
510 void ast_visitor_print_accept_visitor(Ast_Node *root,
511       Const_String file_name_prefix)
512 {
513    String file_name = string_from_format(S("%S.vitaly.parse-tree"),
514          file_name_prefix);
515    print_visitor.output_file = file_open(file_name, S("w"));
516
517    if (!print_visitor.output_file)
518       fatal_error(S("Unable to open file '%S' for parse tree dump"),
519             file_name);
520    string_destroy(file_name);
521
522    root->accept_visitor(root, AST_VISITOR_OF(&print_visitor));
523
524    file_close(print_visitor.output_file);
525 }
```

:

A.3.7 src/ast/ast_visitor_print.h

```
#ifndef AST_VISITOR_PRINT_H
#define AST_VISITOR_PRINT_H

#include "ast_visitor.h"

void ast_visitor_print_accept_visitor(Ast_Node *root,
      Const_String file_name_prefix);

#endif // AST_VISITOR_PRINT_H
```

:

A.3.8 src/ast/ast_visitor_print_graph.c

```
#include "ast_visitor_print_graph.h"
#include "ast_string.h"
#include <std_define.h>
#include <std_include.h>
#include <dot_printer.h>

#define ASTVF_G_END              \
   dot_printer_pop_current_id(v->printer); \
   ASTVF_END

AST_VISITOR_STRUCT_BEGIN(Ast_Visitor_Print_Graph)
   Dot_Printer *printer;
AST_VISITOR_STRUCT_END(Ast_Visitor_Print_Graph)

static void stmt_list_action(Ast_Visitor_Print_Graph *v, Ast_Stmt_List *n,
      const char *type)
{
   Ast_Node *stmt;
   Vector *vec = n->statements;

   String tmp_str = string_from_format(S("%s\\nlocation: %U:%U"),
         type,
         n->ast_node.location.line,
         n->ast_node.location.column);
   dot_printer_push_insert(v->printer, n,tmp_str);
   string_destroy(tmp_str);

   VECTOR_FOR_EACH_ENTRY(vec, stmt){
      stmt->accept_visitor(stmt, AST_VISITOR_OF(v));
   }
}

static void ternary_action(Ast_Visitor_Print_Graph *v, Ast_Node_Ternary *n,
      const char *name)
{
   String tmp_str = string_from_format(S("%s\\nlocation: %U:%U"),
         name,
         n->ast_node.location.line,
         n->ast_node.location.column);
   dot_printer_push_insert(v->printer, n,tmp_str);
   string_destroy(tmp_str);

   n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
   n->mid->accept_visitor(n->mid, AST_VISITOR_OF(v));
   n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
}

static void binary_action(Ast_Visitor_Print_Graph *v, Ast_Node_Binary *n,
      const char *name)
{
   String tmp_str = string_from_format(S("%s\\nlocation: %U:%U"),
         name,
         n->ast_node.location.line,
         n->ast_node.location.column);
```

```
55     dot_printer_push_insert(v->printer, n,tmp_str);
56     string_destroy(tmp_str);
57
58     if (n->lhs) // because of DIRECT_REF
59        n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
60     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
61  }
62
63  static void binary_op_action(Ast_Visitor_Print_Graph *v, Ast_Node_Binary *n,
64        const char *name)
65  {
66     Ast_Expr_Binary *bin = AST_EXPR_BINARY_OF(n);
67     String tmp_str = string_from_format(
68           S("%s\\ntype=\\\"%S\\\"\\nlocation: %U:%U"),
69           name,
70           ast_expr_binary_get_expr_str(bin),
71           n->ast_node.location.line,
72           n->ast_node.location.column);
73     dot_printer_push_insert(v->printer, n,tmp_str);
74     string_destroy(tmp_str);
75
76     n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
77     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
78  }
79
80  static void unary_action(Ast_Visitor_Print_Graph *v, Ast_Node_Unary *n,
81        const char *name)
82  {
83     String tmp_str = string_from_format(S("%s\\nlocation: %U:%U"),
84           name,
85           n->ast_node.location.line,
86           n->ast_node.location.column);
87     dot_printer_push_insert(v->printer, n,tmp_str);
88     string_destroy(tmp_str);
89
90     n->expr->accept_visitor(n->expr, AST_VISITOR_OF(v));
91  }
92
93  static void unary_op_action(Ast_Visitor_Print_Graph *v, Ast_Node_Unary *n,
94        const char *name)
95  {
96     Ast_Expr_Unary *una = AST_EXPR_UNARY_OF(n);
97     String tmp_str = string_from_format(
98           S("%s\\ntype=\\\"%S\\\"\\nlocation: %U:%U"),
99           name,
100          ast_expr_unary_get_expr_str(una),
101          n->ast_node.location.line,
102          n->ast_node.location.column);
103    dot_printer_push_insert(v->printer, n,tmp_str);
104    string_destroy(tmp_str);
105
106    n->expr->accept_visitor(n->expr, AST_VISITOR_OF(v));
107 }
108
109 static void simple_type_action(Ast_Visitor_Print_Graph *v, Ast_Empty *n,
110       const char *type)
111 {
112    String tmp_str = string_from_format(
113          S("simple_type\\ntype=\\\"%s\\\"\\nlocation: %U:%U"),
114          type,
115          n->ast_node.location.line,
116          n->ast_node.location.column);
117    dot_printer_push_insert(v->printer, n,tmp_str);
118    string_destroy(tmp_str);
119 }
120
121 static void type_action(Ast_Visitor_Print_Graph *v, Ast_Type *n,
122       const char *type)
123 {
124    String tmp_str = string_from_format(S("%s location: %U:%U"),
125          type,
126          n->ast_node.location.line,
127          n->ast_node.location.column);
128    dot_printer_push_insert(v->printer, n,tmp_str);
```

```
129     string_destroy(tmp_str);
130
131     n->type->accept_visitor(n->type, AST_VISITOR_OF(v));
132 }
133
134 ASTVF_BEGIN(AST_EXPR_LOR, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
135     binary_op_action(v, n, "expr_logic_or");
136 ASTVF_G_END
137
138 ASTVF_BEGIN(AST_EXPR_LAND, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
139     binary_op_action(v, n, "expr_logic_and");
140 ASTVF_G_END
141
142 ASTVF_BEGIN(AST_EXPR_EQ, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
143     binary_op_action(v, n, "expr_eq");
144 ASTVF_G_END
145
146 ASTVF_BEGIN(AST_EXPR_NEQ, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
147     binary_op_action(v, n, "expr_neq");
148 ASTVF_G_END
149
150 ASTVF_BEGIN(AST_EXPR_GT, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
151     binary_op_action(v, n, "expr_gt");
152 ASTVF_G_END
153
154 ASTVF_BEGIN(AST_EXPR_LT, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
155     binary_op_action(v, n, "expr_lt");
156 ASTVF_G_END
157
158 ASTVF_BEGIN(AST_EXPR_GTEQ, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
159     binary_op_action(v, n, "expr_gteq");
160 ASTVF_G_END
161
162 ASTVF_BEGIN(AST_EXPR_LTEQ, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
163     binary_op_action(v, n, "expr_lteq");
164 ASTVF_G_END
165
166 ASTVF_BEGIN(AST_EXPR_PLUS, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
167     binary_op_action(v, n, "expr_plus");
168 ASTVF_G_END
169
170 ASTVF_BEGIN(AST_EXPR_MINUS, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
171     binary_op_action(v, n, "expr_minus");
172 ASTVF_G_END
173
174 ASTVF_BEGIN(AST_EXPR_MUL, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
175     binary_op_action(v, n, "expr_mul");
176 ASTVF_G_END
177
178 ASTVF_BEGIN(AST_EXPR_DIV, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
179     binary_op_action(v, n, "expr_div");
180 ASTVF_G_END
181
182 ASTVF_BEGIN(AST_EXPR_CAST, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
183     binary_op_action(v, n, "expr_type_cast");
184 ASTVF_G_END
185
186 ASTVF_BEGIN(AST_EXPR_LNOT, Ast_Visitor_Print_Graph, v, Ast_Node_Unary, n)
187     unary_op_action(v, n, "expr_logic_not");
188 ASTVF_G_END
189
190 ASTVF_BEGIN(AST_EXPR_ABS, Ast_Visitor_Print_Graph, v, Ast_Node_Unary, n)
191     unary_op_action(v, n, "expr_abs");
192 ASTVF_G_END
193
194 ASTVF_BEGIN(AST_EXPR_INT, Ast_Visitor_Print_Graph, v, Ast_Expr_Int, n)
195     String tmp_str = string_from_format(S("int_const\\nvalue=\\\"%U\\\""
196               "\\nlocation: %U:%U"),
197           n->val,
198           n->ast_node.location.line,
199           n->ast_node.location.column);
200     dot_printer_push_insert(v->printer, n,tmp_str);
201     string_destroy(tmp_str);
202 ASTVF_G_END
```

```
203
204 ASTVF_BEGIN(AST_EXPR_BOOL, Ast_Visitor_Print_Graph, v, Ast_Expr_Bool, n)
205    String tmp_str = string_from_format(S("bool_const\\nvalue=\\\"%s\\\""
206              "\\nlocation: %U:%U"),
207           n->val ? "true" : "false",
208           n->ast_node.location.line,
209           n->ast_node.location.column);
210    dot_printer_push_insert(v->printer, n,tmp_str);
211    string_destroy(tmp_str);
212 ASTVF_G_END
213
214 ASTVF_BEGIN(AST_EXPR_NULL, Ast_Visitor_Print_Graph, v, Ast_Expr_Null, n)
215    String tmp_str = string_from_format(S("null_const"
216              "\\nlocation: %U:%U"),
217           n->ast_node.location.line,
218           n->ast_node.location.column);
219    dot_printer_push_insert(v->printer, n, tmp_str);
220    string_destroy(tmp_str);
221 ASTVF_G_END
222
223 ASTVF_BEGIN(AST_VARIABLE_IDEN, Ast_Visitor_Print_Graph, v,
224       Ast_Variable_Iden, n)
225    String tmp_str = string_from_format(S("identifier\\nid=\\\"%S\\\"\\n"
226              "type=\\\"%S\\\"\\nlocation: %U:%U"),
227           n->iden,
228           ast_variable_iden_get_expr_str(n),
229           n->ast_node.location.line,
230           n->ast_node.location.column);
231
232    dot_printer_push_insert(v->printer, n,tmp_str);
233    string_destroy(tmp_str);
234 ASTVF_G_END
235
236 ASTVF_BEGIN(AST_REC_SELF_PTR, Ast_Visitor_Print_Graph, v, Ast_Empty, n)
237    String tmp_str = string_from_format(S("record_self\\nlocation: %U:%U"),
238           n->ast_node.location.line,
239           n->ast_node.location.column);
240
241    dot_printer_push_insert(v->printer, n,tmp_str);
242    string_destroy(tmp_str);
243 ASTVF_END
244
245 ASTVF_BEGIN(AST_EXPR_ARY_REF, Ast_Visitor_Print_Graph, v,
246       Ast_Node_Binary, n)
247    binary_action(v, n, "array_ref");
248 ASTVF_G_END
249
250 ASTVF_BEGIN(AST_EXPR_FUNC_CALL, Ast_Visitor_Print_Graph, v,
251       Ast_Expr_Func_Call, n)
252    String tmp_str = string_from_format(S("func_call\\nlocation: %U:%U"),
253           n->ast_node.location.line,
254           n->ast_node.location.column);
255    dot_printer_push_insert(v->printer, n,tmp_str);
256    string_destroy(tmp_str);
257
258    n->identifier->accept_visitor(n->identifier, AST_VISITOR_OF(v));
259
260    Ast_Node *arg;
261
262    Vector *vargs = n->arguments;
263    VECTOR_FOR_EACH_ENTRY(vargs, arg)
264       arg->accept_visitor(arg, AST_VISITOR_OF(v));
265 ASTVF_G_END
266
267 ASTVF_BEGIN(AST_EXPR_DOT_REF, Ast_Visitor_Print_Graph, v,
268       Ast_Node_Binary, n)
269    binary_action(v, n, "record_ref");
270 ASTVF_G_END
271
272 ASTVF_BEGIN(AST_EXPR_DIRECT_REF, Ast_Visitor_Print_Graph, v,
273       Ast_Node_Binary, n)
274    binary_action(v, n, "direct_ref");
275 ASTVF_G_END
276
```

```
277 ASTVF_BEGIN(AST_SIMPLE_TYPE_INT, Ast_Visitor_Print_Graph, v,
278       Ast_Empty, n)
279    simple_type_action(v, n, "int");
280 ASTVF_G_END
281
282 ASTVF_BEGIN(AST_SIMPLE_TYPE_VOID, Ast_Visitor_Print_Graph, v,
283       Ast_Empty, n)
284    simple_type_action(v, n, "void");
285 ASTVF_G_END
286
287 ASTVF_BEGIN(AST_SIMPLE_TYPE_BOOL, Ast_Visitor_Print_Graph, v,
288       Ast_Empty, n)
289    simple_type_action(v, n, "bool");
290 ASTVF_G_END
291
292 ASTVF_BEGIN(AST_TYPE_IDEN, Ast_Visitor_Print_Graph, v, Ast_Type_Iden, n)
293    String tmp_str = string_from_format(
294          S("type_iden\\nid=\\\"%S\\\"\\nlocation: %U:%U"),
295          n->iden,
296          n->ast_node.location.line,
297          n->ast_node.location.column);
298    dot_printer_push_insert(v->printer, n,tmp_str);
299    string_destroy(tmp_str);
300 ASTVF_G_END
301
302 ASTVF_BEGIN(AST_VAR_DECL, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
303    binary_action(v, n, "var_decl");
304 ASTVF_G_END
305
306 ASTVF_BEGIN(AST_TYPE_DEF, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
307    binary_action(v, n, "type_def");
308 ASTVF_G_END
309
310 ASTVF_BEGIN(AST_TYPE_ARY, Ast_Visitor_Print_Graph, v, Ast_Type, n)
311    type_action(v, n, "array_type");
312 ASTVF_G_END
313
314 ASTVF_BEGIN(AST_TYPE_REC, Ast_Visitor_Print_Graph, v, Ast_Type_Rec, n)
315    String tmp_str = string_from_format(S("record_type\\nlocation: %U:%U"),
316          n->ast_node.location.line,
317          n->ast_node.location.column);
318    dot_printer_push_insert(v->printer, n,tmp_str);
319    string_destroy(tmp_str);
320
321    Ast_Node *arg;
322    Vector *vargs = n->extend_list;
323    VECTOR_FOR_EACH_ENTRY(vargs, arg)
324       arg->accept_visitor(arg, AST_VISITOR_OF(v));
325
326    vargs = n->body;
327    VECTOR_FOR_EACH_ENTRY(vargs, arg)
328       arg->accept_visitor(arg, AST_VISITOR_OF(v));
329
330 ASTVF_G_END
331
332 ASTVF_BEGIN(AST_STMT_LIST, Ast_Visitor_Print_Graph, v, Ast_Stmt_List, n)
333    stmt_list_action(v, n, "statements");
334 ASTVF_G_END
335
336 ASTVF_BEGIN(AST_FIN_STMT_LIST, Ast_Visitor_Print_Graph, v, Ast_Stmt_List, n)
337    stmt_list_action(v, n, "finalize_stmt");
338 ASTVF_G_END
339
340 static void func_print(Ast_Visitor_Print_Graph *v, Ast_Func_Def *n)
341 {
342    Ast_Node *p;
343    Vector *vec = n->parameters;
344
345    String tmp_str = string_from_format(S("function\\nlocation: %U:%U"),
346          n->ast_node.location.line,
347          n->ast_node.location.column);
348    dot_printer_push_insert(v->printer, n,tmp_str);
349    string_destroy(tmp_str);
350
```

```
351     n->iden->accept_visitor(n->iden, AST_VISITOR_OF(v));
352     n->return_type->accept_visitor(n->return_type, AST_VISITOR_OF(v));
353     VECTOR_FOR_EACH_ENTRY(vec, p)
354        p->accept_visitor(p, AST_VISITOR_OF(v));
355
356     n->statements->accept_visitor(n->statements, AST_VISITOR_OF(v));
357  }
358
359  ASTVF_BEGIN(AST_EXT_FUNC_DECL, Ast_Visitor_Print_Graph, v, Ast_Func_Def, n)
360     Ast_Node *p;
361     Vector *vec = n->parameters;
362
363     String tmp_str = string_from_format(S("extern_func\\nlocation: %U:%U"),
364           n->ast_node.location.line,
365           n->ast_node.location.column);
366     dot_printer_push_insert(v->printer, n,tmp_str);
367     string_destroy(tmp_str);
368
369     n->extern_type->accept_visitor(n->extern_type, AST_VISITOR_OF(v));
370     n->iden->accept_visitor(n->iden, AST_VISITOR_OF(v));
371     n->return_type->accept_visitor(n->return_type, AST_VISITOR_OF(v));
372
373     VECTOR_FOR_EACH_ENTRY(vec, p)
374        p->accept_visitor(p, AST_VISITOR_OF(v));
375  ASTVF_G_END
376
377  ASTVF_BEGIN(AST_FIN_FUNC_DEF, Ast_Visitor_Print_Graph, v, Ast_Func_Def, n)
378     func_print(v, n);
379  ASTVF_G_END
380
381  ASTVF_BEGIN(AST_REC_FUNC_DEF, Ast_Visitor_Print_Graph, v, Ast_Func_Def, n)
382     func_print(v, n);
383  ASTVF_G_END
384
385  ASTVF_BEGIN(AST_FUNC_DEF, Ast_Visitor_Print_Graph, v, Ast_Func_Def, n)
386     func_print(v, n);
387  ASTVF_G_END
388
389  ASTVF_BEGIN(AST_IF_STMT, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
390     binary_action(v, n, "if_stmt");
391  ASTVF_G_END
392
393  ASTVF_BEGIN(AST_IF_ELSE_STMT, Ast_Visitor_Print_Graph, v,
394        Ast_Node_Ternary, n)
395     ternary_action(v, n, "if_else_stmt");
396  ASTVF_G_END
397
398  ASTVF_BEGIN(AST_ALLOC_ARY, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
399     binary_action(v, n, "allocate_array");
400  ASTVF_G_END
401
402  ASTVF_BEGIN(AST_ALLOC_REC, Ast_Visitor_Print_Graph, v, Ast_Node_Unary, n)
403     unary_action(v, n, "allocate_rec");
404  ASTVF_G_END
405
406  ASTVF_BEGIN(AST_ALLOC_REC_CALL, Ast_Visitor_Print_Graph, v,
407        Ast_Node_Binary, n)
408     binary_action(v, n, "allocate_rec");
409  ASTVF_G_END
410
411  ASTVF_BEGIN(AST_DELETE, Ast_Visitor_Print_Graph, v, Ast_Node_Unary, n)
412     unary_action(v, n, "delete");
413  ASTVF_G_END
414
415  ASTVF_BEGIN(AST_WHILE_STMT, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
416     binary_action(v, n, "while_stmt");
417  ASTVF_G_END
418
419  ASTVF_BEGIN(AST_RETURN_STMT, Ast_Visitor_Print_Graph, v, Ast_Node_Unary, n)
420     unary_action(v, n, "return_stmt");
421  ASTVF_G_END
422
423  ASTVF_BEGIN(AST_WRITE_STMT, Ast_Visitor_Print_Graph, v, Ast_Node_Unary, n)
424     unary_action(v, n, "write_stmt");
```

```
425 ASTVF_G_END
426
427 ASTVF_BEGIN(AST_ASSIGNMENT, Ast_Visitor_Print_Graph, v, Ast_Node_Binary, n)
428    binary_action(v, n, "assignment");
429 ASTVF_G_END
430
431 ASTVF_BEGIN(AST_FUNC_BODY, Ast_Visitor_Print_Graph, v, Ast_Stmt_List, n)
432    stmt_list_action(v, n, "func_body");
433 ASTVF_G_END
434
435 ASTVF_BEGIN(AST_EXPR_CHAR, Ast_Visitor_Print_Graph, v, Ast_Expr_Char, n)
436    String tmp_str = string_from_format(
437          S("char_const\\nvalue=\\\"%" PRIx32 "\\\" "
438             "\\nlocation: %U:%U"),
439          n->val,
440          n->ast_node.location.line,
441          n->ast_node.location.column);
442    dot_printer_push_insert(v->printer, n,tmp_str);
443    string_destroy(tmp_str);
444 ASTVF_G_END
445
446 ASTVF_BEGIN(AST_EXPR_STRING, Ast_Visitor_Print_Graph, v, Ast_Expr_String, n)
447    String_Builder sb = STRING_BUILDER_INIT();
448    ast_string_escape(n->val, &sb);
449    String tmp_str = string_from_format(S("string_const\\nvalue=\\\"%S\\\" "
450             "\\nlocation: %U:%U"),
451          string_builder_const_str(&sb),
452          n->ast_node.location.line,
453          n->ast_node.location.column);
454    string_builder_clear(&sb);
455    dot_printer_push_insert(v->printer, n,tmp_str);
456    string_destroy(tmp_str);
457 ASTVF_G_END
458
459 ASTVF_BEGIN(AST_IMPORT_STRING, Ast_Visitor_Print_Graph, v,
460       Ast_Module_String, n)
461    String tmp_str = string_from_format(S("import\\nfile=\\\"%S\\\" "
462             "\\nlocation: %U:%U"),
463          n->module,
464          n->ast_node.location.line,
465          n->ast_node.location.column);
466    dot_printer_push_insert(v->printer, n,tmp_str);
467    string_destroy(tmp_str);
468 ASTVF_G_END
469
470 ASTVF_BEGIN(AST_PACKAGE_STRING, Ast_Visitor_Print_Graph, v,
471       Ast_Module_String, n)
472    String tmp_str = string_from_format(S("package \\ndirectory=\\\"%S\\\" "
473             "\\nlocation: %U:%U"),
474          n->module,
475          n->ast_node.location.line,
476          n->ast_node.location.column);
477    dot_printer_push_insert(v->printer, n,tmp_str);
478 ASTVF_G_END
479
480 ASTVF_BEGIN(AST_SIMPLE_TYPE_CHAR, Ast_Visitor_Print_Graph, v,
481       Ast_Empty, n)
482    simple_type_action(v, n, "char");
483 ASTVF_G_END
484
485 ASTVF_BEGIN(AST_SIMPLE_TYPE_STRING, Ast_Visitor_Print_Graph, v,
486       Ast_Empty, n)
487    simple_type_action(v, n, "string");
488 ASTVF_G_END
489
490 static Ast_Visitor_Print_Graph print_visitor = {
491    .AST_VISITOR_FIELD = AST_VISITOR_STATIC_INIT(),
492    .printer = NULL,
493 };
494
495 void ast_visitor_print_graph_accept_visitor(Ast_Node *root,
496       Const_String file_name_prefix)
497 {
498    print_visitor.printer = dot_printer_init(file_name_prefix,
```

```
499             S("vitaly.parse-tree"), S("LR"));
500
501     root->accept_visitor(root, AST_VISITOR_OF(&print_visitor));
502
503     dot_printer_fin_com_des(print_visitor.printer, S("pdf"));
504 }
```

:

A.3.9 src/ast/ast_visitor_print_graph.h

```
1 #ifndef AST_VISITOR_PRINT_GRAPH_H
2 #define AST_VISITOR_PRINT_GRAPH_H
3
4 #include "ast_visitor.h"
5
6 void ast_visitor_print_graph_accept_visitor(Ast_Node *root,
7       Const_String file_name_prefix);
8
9 #endif // AST_VISITOR_PRINT_GRAPH_H
```

:

A.3.10 src/ast/ast_visitor_symbol_table.c

```
1  #include "ast_visitor_symbol_table.h"
2  #include "symbol_table.h"
3  #include <errno.h>
4  #include <io.h>
5  #include <unistd.h>
6  #include <debug.h>
7  #if 0
8  #include <stdlib.h>
9  #endif
10
11 #undef DEBUG_TYPE
12 #define DEBUG_TYPE symbol-table
13
14 #define CSTR_REC_PREFIX   "R"
15 #define CSTR_FUNC_PREFIX  "F"
16 #define CSTR_TYPE_PREFIX  "T"
17 #define CSTR_VAR_PREFIX   "V"
18 #define CSTR_STMT_LIST_PREFIX "."
19
20 typedef enum Prev_Visited_Type {
21    PREV_VISITED_TYPE_FUNC,
22    PREV_VISITED_TYPE_VAR,
23    PREV_VISITED_TYPE_TYPE_DEF,
24    PREV_VISITED_TYPE_IMPORT
25 } Prev_Visited_Type;
26
27 AST_VISITOR_STRUCT_BEGIN(Ast_Visitor_Symbol_Table)
28    Ast *ast;
29    Ast_Variable_Iden *prev_variable_iden;
30    Symbol_Table *sym_table;
31    Symbol_Table_Node *current_node;
32    String current_unique_name;
33    Symbol_Type_Struct *prev_type;
34    Symbol_Type_Struct *curr_rec_struct;
35    String prev_iden;
36    Prev_Visited_Type prev_visited;
37    Symbol_Type prev_symbol_type;
38    Uns stmt_list_nest;
39    Uns array_nest;
40    Int next_unnamed_type_idx;
41    bool next_var_is_param;
42    bool next_type_in_func_signature;
```

```
43     bool next_type_is_numbered;
44 AST_VISITOR_STRUCT_END(Ast_Visitor_Symbol_Table)
45
46 static void unary_action(Ast_Visitor_Symbol_Table *v, Ast_Node_Unary *n)
47 {
48     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
49     n->expr->accept_visitor(n->expr, AST_VISITOR_OF(v));
50 }
51
52 static void binary_action(Ast_Visitor_Symbol_Table *v, Ast_Node_Binary *n)
53 {
54     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
55     n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
56     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
57 }
58
59 static void binary_stmt_action(Ast_Visitor_Symbol_Table *v, Ast_Node_Binary *n)
60 {
61     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
62     n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
63     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
64 }
65
66 ASTVF_BEGIN(AST_EXPR_LOR, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
67     binary_action(v, n);
68 ASTVF_END
69
70 ASTVF_BEGIN(AST_EXPR_LAND, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
71     binary_action(v, n);
72 ASTVF_END
73
74 ASTVF_BEGIN(AST_EXPR_EQ, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
75     binary_action(v, n);
76 ASTVF_END
77
78 ASTVF_BEGIN(AST_EXPR_NEQ, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
79     binary_action(v, n);
80 ASTVF_END
81
82 ASTVF_BEGIN(AST_EXPR_GT, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
83     binary_action(v, n);
84 ASTVF_END
85
86 ASTVF_BEGIN(AST_EXPR_LT, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
87     binary_action(v, n);
88 ASTVF_END
89
90 ASTVF_BEGIN(AST_EXPR_GTEQ, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
91     binary_action(v, n);
92 ASTVF_END
93
94 ASTVF_BEGIN(AST_EXPR_LTEQ, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
95     binary_action(v, n);
96 ASTVF_END
97
98 ASTVF_BEGIN(AST_EXPR_PLUS, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
99     binary_action(v, n);
100 ASTVF_END
101
102 ASTVF_BEGIN(AST_EXPR_MINUS, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
103     binary_action(v, n);
104 ASTVF_END
105
106 ASTVF_BEGIN(AST_EXPR_MUL, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
107     binary_action(v, n);
108 ASTVF_END
109
110 ASTVF_BEGIN(AST_EXPR_DIV, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
111     binary_action(v, n);
112 ASTVF_END
113
114 ASTVF_BEGIN(AST_EXPR_CAST, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
115     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
116
```

```
117     n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
118
119     symbol_table_insert_location(v->sym_table,
120           v->current_node,
121           v->current_unique_name,
122           v->prev_type,
123           ast_node_get_file_location(AST_NODE_OF(n)));
124
125     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
126  ASTVF_END
127
128  ASTVF_BEGIN(AST_EXPR_LNOT, Ast_Visitor_Symbol_Table, v, Ast_Node_Unary, n)
129     unary_action(v, n);
130  ASTVF_END
131
132  ASTVF_BEGIN(AST_EXPR_ABS, Ast_Visitor_Symbol_Table, v, Ast_Node_Unary, n)
133     unary_action(v, n);
134  ASTVF_END
135
136  ASTVF_BEGIN(AST_EXPR_INT, Ast_Visitor_Symbol_Table, v, Ast_Expr_Int, n)
137     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
138  ASTVF_END
139
140  ASTVF_BEGIN(AST_EXPR_BOOL, Ast_Visitor_Symbol_Table, v, Ast_Expr_Bool, n)
141     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
142  ASTVF_END
143
144  ASTVF_BEGIN(AST_EXPR_NULL, Ast_Visitor_Symbol_Table, v, Ast_Expr_Null, n)
145     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
146  ASTVF_END
147
148  ASTVF_BEGIN(AST_VARIABLE_IDEN, Ast_Visitor_Symbol_Table,
149        v, Ast_Variable_Iden, n)
150     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
151     v->prev_iden = n->iden;
152     v->prev_variable_iden = n;
153  ASTVF_END
154
155  ASTVF_BEGIN(AST_EXPR_ARY_REF, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
156     binary_action(v, n);
157  ASTVF_END
158
159  ASTVF_BEGIN(AST_EXPR_FUNC_CALL, Ast_Visitor_Symbol_Table, v,
160        Ast_Expr_Func_Call, n)
161     Ast_Node *expr;
162     Vector *vec;
163     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
164     n->identifier->accept_visitor(n->identifier, AST_VISITOR_OF(v));
165     vec = n->arguments;
166     VECTOR_FOR_EACH_ENTRY(vec, expr)
167        expr->accept_visitor(expr, AST_VISITOR_OF(v));
168  ASTVF_END
169
170  ASTVF_BEGIN(AST_EXPR_DOT_REF, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
171     binary_action(v, n);
172  ASTVF_END
173
174  ASTVF_BEGIN(AST_EXPR_DIRECT_REF, Ast_Visitor_Symbol_Table, v,
175        Ast_Node_Binary, n)
176     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
177     if (n->lhs) {
178        n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
179        symbol_table_insert_location(v->sym_table,
180              v->current_node,
181              v->current_unique_name,
182              v->prev_type,
183              ast_node_get_file_location(AST_NODE_OF(n)));
184     }
185     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
186  ASTVF_END
187
188  ASTVF_BEGIN(AST_SIMPLE_TYPE_INT, Ast_Visitor_Symbol_Table, v,
189        Ast_Empty, n)
190     v->prev_symbol_type = SYMBOL_TYPE_INT;
```

```
191     if (v->next_type_in_func_signature)
192        return;
193     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
194     v->prev_type = symbol_type_int_alloc(v->sym_table);
195  ASTVF_END
196
197  ASTVF_BEGIN(AST_SIMPLE_TYPE_VOID, Ast_Visitor_Symbol_Table, v,
198        Ast_Empty, n)
199     v->prev_symbol_type = SYMBOL_TYPE_VOID;
200     if (v->next_type_in_func_signature)
201        return;
202     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
203     v->prev_type = symbol_type_void_alloc(v->sym_table);
204  ASTVF_END
205
206  ASTVF_BEGIN(AST_SIMPLE_TYPE_BOOL, Ast_Visitor_Symbol_Table, v,
207        Ast_Empty, n)
208     v->prev_symbol_type = SYMBOL_TYPE_BOOL;
209     if (v->next_type_in_func_signature)
210        return;
211     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
212     v->prev_type = symbol_type_bool_alloc(v->sym_table);
213  ASTVF_END
214
215  ASTVF_BEGIN(AST_TYPE_IDEN, Ast_Visitor_Symbol_Table, v, Ast_Type_Iden, n)
216     Symbol_Type_Iden *tiden;
217
218     v->prev_symbol_type = SYMBOL_TYPE_IDEN;
219     v->prev_iden = n->iden;
220     if (v->next_type_in_func_signature)
221        return;
222
223     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
224     v->prev_type = symbol_type_iden_alloc(v->sym_table, n->iden);
225
226     tiden = SYMBOL_TYPE_STRUCT_CONTAINER(v->prev_type, Symbol_Type_Iden);
227     tiden->sym_node = v->current_node;
228     tiden->loc = ast_node_get_file_location(&n->ast_node);
229  ASTVF_END
230
231  ASTVF_BEGIN(AST_VAR_DECL, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
232     Symbol *duplicate;
233     String identifier;
234     Symbol_Table_Node *current_node;
235     String prev_unique_name;
236
237     if (v->next_type_in_func_signature) {
238        n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
239        return;
240     }
241
242     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
243
244     n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
245     identifier = v->prev_iden;
246
247     Uns hash = string_hash_code(identifier);
248
249     current_node = v->current_node;
250     if (v->next_var_is_param)
251        v->current_node = v->current_node->parent;
252
253     prev_unique_name = v->current_unique_name;
254     v->current_unique_name = string_from_format(S(CSTR_VAR_PREFIX "%S.%S"),
255           prev_unique_name, identifier);
256     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
257     v->current_node = current_node;
258
259     duplicate = symbol_table_node_get(v->current_node, identifier, hash,
260           SYMBOL_PROPERTY_VAR);
261
262     v->prev_iden = identifier;
263     if (!duplicate) {
264        String var_name = v->current_unique_name;
```

```
265         ___symbol_table_node_insert(
266               v->current_node,
267               identifier,
268               var_name,
269               hash,
270               v->prev_type,
271               SYMBOL_PROPERTY_VAR,
272               ast_node_get_file_location(n->lhs));
273      } else {
274         duplicate->resolved_type = symbol_type_unknown_alloc(v->sym_table);
275         v->prev_type = duplicate->resolved_type;
276         DLOG("Duplicate variable %S\n", identifier);
277         report_error_location(ast_node_get_file_location(n->lhs), S(
278                  "duplicate declaration of variable " QFY("%S")
279                  ", previous declaration was in:\n\t%F\n"),
280               identifier, duplicate->location);
281      }
282      string_destroy(v->current_unique_name);
283      v->prev_visited = PREV_VISITED_TYPE_VAR;
284      v->current_unique_name = prev_unique_name;
285   ASTVF_END
286
287   ASTVF_BEGIN(AST_TYPE_DEF, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
288      String identifier;
289      String prev_unique_name;
290
291      ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
292
293      n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
294      identifier = v->prev_iden;
295
296      Uns hash = string_hash_code(identifier);
297
298      prev_unique_name = v->current_unique_name;
299      v->current_unique_name = string_from_format(S(CSTR_TYPE_PREFIX "%S.%S"),
300            prev_unique_name, identifier);
301      n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
302
303      if (v->prev_symbol_type == SYMBOL_TYPE_REC) {
304         Symbol_Type_Rec *rec = SYMBOL_TYPE_STRUCT_CONTAINER(
305               v->prev_type, Symbol_Type_Rec);
306         symbol_type_rec_set_name(rec, identifier);
307      } else if (v->prev_symbol_type == SYMBOL_TYPE_ARY) {
308         Symbol_Type_Ary *ary = SYMBOL_TYPE_STRUCT_CONTAINER(
309               v->prev_type, Symbol_Type_Ary);
310         symbol_type_ary_set_name(ary, identifier);
311      }
312
313      String var_name = v->current_unique_name;
314      ___symbol_table_node_insert(v->current_node, identifier,
315            var_name, hash, v->prev_type,
316            SYMBOL_PROPERTY_TYPE_DEF, ast_node_get_file_location(n->lhs));
317
318      string_destroy(v->current_unique_name);
319      v->prev_iden = identifier;
320      v->prev_visited = PREV_VISITED_TYPE_TYPE_DEF;
321      v->current_unique_name = prev_unique_name;
322   ASTVF_END
323
324   ASTVF_BEGIN(AST_TYPE_ARY, Ast_Visitor_Symbol_Table, v, Ast_Type, n)
325      if (v->next_type_in_func_signature) {
326         ++v->array_nest;
327         n->type->accept_visitor(n->type, AST_VISITOR_OF(v));
328         return;
329      }
330      ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
331      n->type->accept_visitor(n->type, AST_VISITOR_OF(v));
332      v->prev_type = symbol_type_ary_alloc(v->sym_table, v->prev_type,
333            v->current_node->scope_id);
334      v->prev_symbol_type = SYMBOL_TYPE_ARY;
335   ASTVF_END
336
337   ASTVF_BEGIN(AST_TYPE_REC, Ast_Visitor_Symbol_Table, v, Ast_Type_Rec, n)
338      Ast_Node *tmp_node;
```

```
339     Symbol_Type_Struct *prev_rec;
340     Vector *node_vec, *trec_vec1;
341     bool saved_next_type_is_numbered;
342
343     if (v->next_type_in_func_signature) {
344        v->prev_symbol_type = SYMBOL_TYPE_REC;
345        return;
346     }
347
348     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
349
350     Symbol_Type_Rec *trec;
351     String prev_unique_name = v->current_unique_name;
352     if (v->next_type_is_numbered)
353        v->current_unique_name = string_from_format(S(CSTR_REC_PREFIX "%U%S"),
354              v->next_unnamed_type_idx++,
355              v->current_unique_name);
356     else
357        v->current_unique_name = string_from_format(S(CSTR_REC_PREFIX "%S"),
358              v->current_unique_name);
359
360     Symbol_Type_Struct *type = symbol_type_rec_alloc(v->sym_table,
361           v->current_node->scope_id, v->current_unique_name);
362     trec = SYMBOL_TYPE_STRUCT_CONTAINER(type, Symbol_Type_Rec);
363
364     Int prev_unnamed_type_idx = v->next_unnamed_type_idx;
365     v->next_unnamed_type_idx = 0;
366     saved_next_type_is_numbered = v->next_type_is_numbered;
367     v->next_type_is_numbered = true;
368
369     node_vec = n->extend_list;
370     trec_vec1 = &trec->extended_types;
371     VECTOR_FOR_EACH_ENTRY(node_vec, tmp_node) {
372        tmp_node->accept_visitor(tmp_node, AST_VISITOR_OF(v));
373        vector_append(trec_vec1, v->prev_type);
374     }
375     v->next_type_is_numbered = saved_next_type_is_numbered;
376     v->next_unnamed_type_idx = prev_unnamed_type_idx;
377
378     v->current_node = symbol_table_node_alloc_insert(v->current_node,
379           v->sym_table, SYMBOL_TABLE_NODE_REC, trec);
380     trec->rec_sym_node = v->current_node;
381
382     node_vec = n->body;
383     prev_rec = v->curr_rec_struct;
384     v->curr_rec_struct = type;
385
386     VECTOR_FOR_EACH_ENTRY(node_vec, tmp_node) {
387        tmp_node->accept_visitor(tmp_node, AST_VISITOR_OF(v));
388        if (v->prev_visited == PREV_VISITED_TYPE_FUNC)
389           symbol_type_rec_append_func_identifier(trec, v->prev_iden);
390        else if (v->prev_visited == PREV_VISITED_TYPE_VAR)
391           symbol_type_rec_append_var_identifier(trec, v->prev_iden);
392     }
393     v->curr_rec_struct = prev_rec;
394
395     n->body_node = v->current_node;
396     v->current_node = v->current_node->parent;
397     string_destroy(v->current_unique_name);
398     v->current_unique_name = prev_unique_name;
399     v->prev_symbol_type = SYMBOL_TYPE_REC;
400     v->prev_type = type;
401  ASTVF_END
402
403  static void stmt_list_action(Ast_Visitor_Symbol_Table *v, Ast_Stmt_List *n)
404  {
405     Vector *statements;
406     Ast_Node *stmt;
407
408     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
409
410     Symbol_Table_Node_Type ntype;
411     if (!v->current_node || v->current_node->type == SYMBOL_TABLE_NODE_GLOBAL)
412        ntype = SYMBOL_TABLE_NODE_GLOBAL;
```

```
413     else
414        ntype = SYMBOL_TABLE_NODE_INTERMEDIATE;
415     v->current_node = symbol_table_node_alloc_insert(v->current_node,
416           v->sym_table, ntype, NULL);
417
418     String prev_unique_name = v->current_unique_name;
419     if (!v->stmt_list_nest) {
420        v->current_unique_name = string_from_format(
421                  S(CSTR_STMT_LIST_PREFIX "%S"),
422              prev_unique_name);
423     } else {
424        v->current_unique_name = string_from_format(
425                  S(CSTR_STMT_LIST_PREFIX "%U%S"),
426              v->current_node->scope_id, prev_unique_name);
427     }
428
429     ++v->stmt_list_nest;
430     statements = n->statements;
431     VECTOR_FOR_EACH_ENTRY(statements, stmt)
432        stmt->accept_visitor(stmt, AST_VISITOR_OF(v));
433     --v->stmt_list_nest;
434
435     string_destroy(v->current_unique_name);
436     v->current_unique_name = prev_unique_name;
437     v->current_node = v->current_node->parent;
438  }
439
440  ASTVF_BEGIN(AST_STMT_LIST, Ast_Visitor_Symbol_Table, v, Ast_Stmt_List, n)
441     stmt_list_action(v, n);
442  ASTVF_END
443
444  ASTVF_BEGIN(AST_FIN_STMT_LIST, Ast_Visitor_Symbol_Table, v, Ast_Stmt_List, n)
445     stmt_list_action(v, n);
446  ASTVF_END
447
448  static void func_def_append_type_str(Ast_Visitor_Symbol_Table *v,
449        Symbol_Func_Map *func_map, String_Builder *sb)
450  {
451     Const_String rec_str;
452     if (v->array_nest) {
453        rec_str = S("a%D");
454        if (v->prev_symbol_type != SYMBOL_TYPE_REC) {
455           do
456              string_builder_append_char(sb, 'a');
457           while (--v->array_nest);
458        } else {
459           v->array_nest = 0;
460        }
461     } else {
462        rec_str = S("r%D");
463     }
464     switch (v->prev_symbol_type) {
465     case SYMBOL_TYPE_INT:
466        string_builder_append_char(sb, 'i');
467        break;
468     case SYMBOL_TYPE_BOOL:
469        string_builder_append_char(sb, 'b');
470        break;
471     case SYMBOL_TYPE_CHAR:
472        string_builder_append_char(sb, 'c');
473        break;
474     case SYMBOL_TYPE_STRING:
475        string_builder_append_char(sb, 's');
476        break;
477     case SYMBOL_TYPE_REC:;
478        String str = string_from_format(rec_str,
479              func_map ? func_map->unnamed_type_count++ : 0);
480        string_builder_append(sb, str);
481        string_destroy(str);
482        break;
483     case SYMBOL_TYPE_IDEN:
484        string_builder_append_char(sb, '$');
485        string_builder_append(sb, v->prev_iden);
486        string_builder_append_char(sb, '$');
```

```
487         break;
488      default:
489         assert(false);
490      }
491   }
492
493   static void func_symbol_table(Ast_Visitor_Symbol_Table *v, Ast_Func_Def *n)
494   {
495      Vector *param_node_vec;
496      Ast_Node *param;
497      Symbol_Type_Func *func_type;
498      String identifier;
499      String prev_unique_name;
500      Uns hash_code;
501      bool saved_next_var_isp;
502      bool saved_next_type_in_sig;
503      bool saved_next_type_is_numbered;
504      bool is_extern_c;
505      bool destroy_unique_name;
506      Ast_Variable_Iden *func_iden_node;
507
508      ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
509
510      destroy_unique_name = false;
511      is_extern_c = false;
512
513      if (n->extern_type) {
514         n->extern_type->accept_visitor(n->extern_type, AST_VISITOR_OF(v));
515         if (string_compare_nocase(v->prev_iden, S("c"))) {
516            report_error_location(ast_node_get_file_location(n->extern_type),
517                  S("unrecognized extern identifier " QFY("%S") "\n"),
518                  v->prev_iden);
519         } else {
520            is_extern_c = true;
521         }
522      }
523
524      n->iden->accept_visitor(n->iden, AST_VISITOR_OF(v));
525      identifier = v->prev_iden;
526      func_iden_node = v->prev_variable_iden;
527
528      hash_code = string_hash_code(identifier);
529      Symbol_Func_Map *func_map = symbol_table_node_get_func_map(v->current_node,
530            identifier, hash_code);
531
532      Int initial_unnamed_type_count;
533      if (func_map)
534         initial_unnamed_type_count = func_map->unnamed_type_count;
535      else
536         initial_unnamed_type_count = 0;
537
538      func_type = SYMBOL_TYPE_STRUCT_CONTAINER(
539            symbol_type_func_alloc(v->sym_table, is_extern_c),
540            Symbol_Type_Func);
541
542      prev_unique_name = v->current_unique_name;
543
544      String_Builder unique_name = STRING_BUILDER_INIT();
545      assert(!v->array_nest);
546
547      saved_next_type_is_numbered = v->next_type_is_numbered;
548      saved_next_type_in_sig = v->next_type_in_func_signature;
549      v->next_type_in_func_signature = true;
550      v->next_type_is_numbered = true;
551      param_node_vec = n->parameters;
552      VECTOR_FOR_EACH_ENTRY(param_node_vec, param) {
553         param->accept_visitor(param, AST_VISITOR_OF(v));
554         func_def_append_type_str(v, func_map, &unique_name);
555      }
556      v->next_type_in_func_signature = saved_next_type_in_sig;
557      v->next_type_is_numbered = saved_next_type_is_numbered;
558
559      Symbol_Table_Node *body_node = symbol_table_node_alloc_insert(
560            v->current_node, v->sym_table, SYMBOL_TABLE_NODE_FUNC, NULL);
```

```
561     v->current_node = body_node;
562
563     string_builder_append(&unique_name, prev_unique_name);
564     string_builder_append_char(&unique_name, '.');
565     string_builder_append(&unique_name, identifier);
566
567     v->current_unique_name = string_from_format(S(CSTR_FUNC_PREFIX "%S"),
568           string_builder_const_str(&unique_name));
569     string_builder_clear(&unique_name);
570
571
572     Int prev_unnamed_type_idx = v->next_unnamed_type_idx;
573     saved_next_type_is_numbered = v->next_type_is_numbered;
574
575     saved_next_var_isp = v->next_var_is_param;
576     v->next_type_is_numbered = true;
577     v->next_var_is_param = true;
578     v->next_unnamed_type_idx = initial_unnamed_type_count;
579     VECTOR_FOR_EACH_ENTRY(param_node_vec, param) {
580        param->accept_visitor(param, AST_VISITOR_OF(v));
581        symbol_type_func_append_param_identifier(func_type, v->prev_iden);
582     }
583     v->next_var_is_param = saved_next_var_isp;
584
585     v->current_node = body_node->parent;
586
587     Int ret_was_unique;
588     (void)ret_was_unique;
589     DEBUGT(def, ret_was_unique = v->next_unnamed_type_idx);
590
591     n->return_type->accept_visitor(n->return_type, AST_VISITOR_OF(v));
592     func_type->return_type = v->prev_type;
593     v->current_node = body_node;
594     v->next_type_is_numbered = saved_next_type_is_numbered;
595
596     DEBUGT(def,
597        ret_was_unique = v->next_unnamed_type_idx - ret_was_unique;
598     );
599
600     if (n->statements)
601        n->statements->accept_visitor(n->statements, AST_VISITOR_OF(v));
602
603     func_type->body_sym_node = v->current_node;
604     v->current_node = v->current_node->parent;
605
606     File_Location *loc = ast_node_get_file_location(AST_NODE_OF(n));
607
608     String var_name;
609     if (v->current_node->type == SYMBOL_TABLE_NODE_GLOBAL &&
610           v->stmt_list_nest == 1 &&
611           !string_compare(identifier, MAIN_FUNC_STR)) {
612        destroy_unique_name = true;
613        var_name = string_duplicate(MAIN_FUNC_STR);
614     } else if (is_extern_c) {
615        var_name = string_duplicate(identifier);
616        destroy_unique_name = true;
617     } else {
618        var_name = v->current_unique_name;
619     }
620     v->prev_type = SYMBOL_TYPE_STRUCT_OF_CONTAINER(func_type);
621     ___symbol_table_node_insert(v->current_node, identifier, var_name,
622           hash_code, v->prev_type, SYMBOL_PROPERTY_FUNC, loc);
623
624     if (!func_map) {
625        func_map = symbol_table_node_get_func_map(v->current_node, identifier,
626           hash_code);
627        assert(func_map);
628     } else {
629        assert(func_map->unnamed_type_count == v->next_unnamed_type_idx -
630              ret_was_unique);
631     }
632     func_map->unnamed_type_count = v->next_unnamed_type_idx;
633     if (is_extern_c)
634        func_map->has_extern_c = true;
```

```
635
636     string_destroy(func_iden_node->iden);
637     func_iden_node->iden = var_name;
638
639     if (destroy_unique_name)
640        string_destroy(v->current_unique_name);
641
642     v->next_unnamed_type_idx = prev_unnamed_type_idx;
643     v->prev_iden = var_name;
644     v->prev_visited = PREV_VISITED_TYPE_FUNC;
645     v->current_unique_name = prev_unique_name;
646 }
647
648 ASTVF_BEGIN(AST_EXT_FUNC_DECL, Ast_Visitor_Symbol_Table, v, Ast_Func_Def, n)
649     func_symbol_table(v, n);
650 ASTVF_END
651
652 ASTVF_BEGIN(AST_FIN_FUNC_DEF, Ast_Visitor_Symbol_Table, v, Ast_Func_Def, n)
653     /* Errors regarding finalize function is handled in type checker
654      * so we don't do much different here. */
655     if (v->current_node->type == SYMBOL_TABLE_NODE_REC)
656        v->current_node->has_finalize_func = true;
657     func_symbol_table(v, n);
658 ASTVF_END
659
660 ASTVF_BEGIN(AST_REC_FUNC_DEF, Ast_Visitor_Symbol_Table, v, Ast_Func_Def, n)
661     /* Errors regarding record function is handled in type checker
662      * so we don't do much different here. */
663     if (v->current_node->type == SYMBOL_TABLE_NODE_REC)
664        v->current_node->has_record_func = true;
665     func_symbol_table(v, n);
666 ASTVF_END
667
668 ASTVF_BEGIN(AST_FUNC_DEF, Ast_Visitor_Symbol_Table, v, Ast_Func_Def, n)
669     func_symbol_table(v, n);
670 ASTVF_END
671
672 ASTVF_BEGIN(AST_IF_STMT, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
673     binary_stmt_action(v, n);
674 ASTVF_END
675
676 ASTVF_BEGIN(AST_IF_ELSE_STMT, Ast_Visitor_Symbol_Table, v, Ast_Node_Ternary, n)
677     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
678     n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
679     n->mid->accept_visitor(n->mid, AST_VISITOR_OF(v));
680     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
681 ASTVF_END
682
683 ASTVF_BEGIN(AST_ALLOC_ARY, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
684     binary_action(v, n);
685 ASTVF_END
686
687 ASTVF_BEGIN(AST_ALLOC_REC, Ast_Visitor_Symbol_Table, v, Ast_Node_Unary, n)
688     unary_action(v, n);
689 ASTVF_END
690
691 ASTVF_BEGIN(AST_ALLOC_REC_CALL, Ast_Visitor_Symbol_Table, v,
692        Ast_Node_Binary, n)
693     binary_action(v, n);
694 ASTVF_END
695
696 ASTVF_BEGIN(AST_DELETE, Ast_Visitor_Symbol_Table, v, Ast_Node_Unary, n)
697     unary_action(v, n);
698 ASTVF_END
699
700 ASTVF_BEGIN(AST_WHILE_STMT, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
701     binary_stmt_action(v, n);
702 ASTVF_END
703
704 ASTVF_BEGIN(AST_RETURN_STMT, Ast_Visitor_Symbol_Table, v, Ast_Node_Unary, n)
705     unary_action(v, n);
706 ASTVF_END
707
708 ASTVF_BEGIN(AST_WRITE_STMT, Ast_Visitor_Symbol_Table, v, Ast_Node_Unary, n)
```

```
709     unary_action(v, n);
710  ASTVF_END
711
712  ASTVF_BEGIN(AST_ASSIGNMENT, Ast_Visitor_Symbol_Table, v, Ast_Node_Binary, n)
713     binary_action(v, n);
714  ASTVF_END
715
716  ASTVF_BEGIN(AST_EXPR_CHAR, Ast_Visitor_Symbol_Table, v, Ast_Expr_Char, n)
717     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
718  ASTVF_END
719
720  ASTVF_BEGIN(AST_EXPR_STRING, Ast_Visitor_Symbol_Table, v, Ast_Expr_String, n)
721     ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
722  ASTVF_END
723
724  ASTVF_BEGIN(AST_IMPORT_STRING, Ast_Visitor_Symbol_Table, v,
725        Ast_Module_String, n)
726     Symbol_Table_Node *node = v->current_node;
727     ast_node_set_symbol_table_node(AST_NODE_OF(n), node);
728     Const_String package = ast_get_package(v->ast);
729     String dependency;
730     DLOG("lookup real import name for '%S' ...", n->module);
731     if (package) {
732        String vit = string_from_format(S("%S.vit"), n->module);
733        String viti = string_from_format(S("%S.viti"), n->module);
734        char *cwd;
735        if (!(cwd = getcwd(NULL, 0)))
736           fatal_error(S("unable to get current working directory [%m]\n"));
737
738        if (chdir(string_to_cstr(ast_get_dirname(v->ast))))
739           fatal_error(S("unable to change working directory [%m]\n"));
740
741        if (file_access_read(vit) || file_access_read(viti)) {
742           dependency = string_dir_concat(package, n->module);
743           //vector_append(&node->import_dependencies,
744           //    string_dir_concat(package, n->module));
745        } else {
746           dependency = string_duplicate(n->module);
747           //vector_append(&node->import_dependencies,
748           // string_duplicate(n->module));
749        }
750
751
752        if (chdir(cwd))
753           fatal_error(S("unable to reset working directory [%m]\n"));
754
755        free_mem(cwd);
756        string_destroy(vit);
757        string_destroy(viti);
758     } else {
759        dependency = string_duplicate(n->module);
760        //vector_append(&node->import_dependencies,
761        // string_duplicate(n->module));
762     }
763
764     DLOG("result = '%S'\n", dependency);
765     //DLOG("result = '%S'\n", vector_peek_last(
766     //       &node->import_dependencies));
767
768  // n->dep_idx = vector_size(&v->current_node->import_dependencies_loc);
769  // vector_append(&ode->import_dependencies_loc,
770  //       ast_node_get_file_location(AST_NODE_OF(n)));
771     String str;
772     int idx = 0;
773     VECTOR_FOR_EACH_ENTRY(&node->import_dependencies, str) {
774        if (!string_compare(dependency, str)) {
775           string_destroy(dependency);
776           goto out;
777        }
778        idx++;
779     }
780     vector_append(&node->import_dependencies, dependency);
781     vector_append(&node->import_dependencies_loc,
782           ast_node_get_file_location(AST_NODE_OF(n)));
```

```
783 out:
784    n->dep_idx = idx;
785    v->prev_visited = PREV_VISITED_TYPE_IMPORT;
786 ASTVF_END
787
788 ASTVF_BEGIN(AST_PACKAGE_STRING, Ast_Visitor_Symbol_Table, v,
789       Ast_Module_String, n)
790    ast_node_set_symbol_table_node(AST_NODE_OF(n), v->current_node);
791
792    char *abs_path = realpath(string_to_cstr(ast_get_dirname(v->ast)), NULL);
793
794    if (!string_ends_with(S(abs_path), n->module)) {
795       String tmp_module = string_duplicate(n->module);
796       string_replace_all(tmp_module, '/', '.');
797       report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
798             S("expected file with package name " QFY("%S")
799                " inside directory structure " QFY("%S") "\n"),
800             tmp_module, n->module);
801       string_destroy(tmp_module);
802    } else {
803       String prev_unique = v->current_unique_name;
804       v->current_unique_name = string_from_format(S(".%S%S"),
805             n->module, prev_unique);
806       string_replace_all(v->current_unique_name, '/', '.');
807       string_destroy(prev_unique);
808       v->ast->package = n->module;
809    }
810    free_mem(abs_path);
811 ASTVF_END
812
813 ASTVF_BEGIN(AST_SIMPLE_TYPE_CHAR, Ast_Visitor_Symbol_Table,
814       v, Ast_Empty, n)
815    v->prev_symbol_type = SYMBOL_TYPE_CHAR;
816    if (v->next_type_in_func_signature)
817       return;
818    ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
819    v->prev_type = symbol_type_char_alloc(v->sym_table);
820 ASTVF_END
821
822 ASTVF_BEGIN(AST_SIMPLE_TYPE_STRING, Ast_Visitor_Symbol_Table,
823       v, Ast_Empty, n)
824    v->prev_symbol_type = SYMBOL_TYPE_STRING;
825    if (v->next_type_in_func_signature)
826       return;
827    ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
828    v->prev_type = symbol_type_string_alloc(v->sym_table);
829 ASTVF_END
830
831 ASTVF_BEGIN(AST_FUNC_BODY, Ast_Visitor_Symbol_Table, v, Ast_Stmt_List, n)
832    Vector *stmt_list;
833    ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
834
835    Ast_Node *stmt;
836    stmt_list = n->statements;
837    VECTOR_FOR_EACH_ENTRY(stmt_list, stmt)
838       stmt->accept_visitor(stmt, AST_VISITOR_OF(v));
839 ASTVF_END
840
841 ASTVF_BEGIN(AST_REC_SELF_PTR, Ast_Visitor_Symbol_Table, v, Ast_Empty, n)
842    ast_node_set_symbol_table_node(&n->ast_node, v->current_node);
843    if (v->curr_rec_struct) {
844       symbol_table_insert_location(v->sym_table,
845             v->current_node,
846             v->current_unique_name,
847             v->curr_rec_struct,
848             ast_node_get_file_location(AST_NODE_OF(n)));
849    }
850 ASTVF_END
851
852 static Ast_Visitor_Symbol_Table sym_table_visitor = {
853    .AST_VISITOR_FIELD = AST_VISITOR_STATIC_INIT()
854 };
855
856 void ___symbol_table_resolve(Symbol_Table *t);
```

```
857
858 Symbol_Table *ast_visitor_symbol_table_gen(Ast *ast)
859 {
860    if (!ast_is_valid(ast))
861       return NULL;
862
863    Ast_Node *root = ast_get_root(ast);
864
865    sym_table_visitor.sym_table = symbol_table_alloc(ast_get_file_name(ast));
866    sym_table_visitor.ast = ast;
867
868    String basename = string_basename(ast_get_file_name(ast));
869
870    assert(string_ends_with(basename, SOURCE_SUFFIX_STR) ||
871          string_ends_with(basename, INTERFACE_SUFFIX_STR));
872
873    sym_table_visitor.current_unique_name = string_to_module_name(basename);
874    string_destroy(basename);
875
876    root->accept_visitor(root, AST_VISITOR_OF(&sym_table_visitor));
877
878    string_destroy(sym_table_visitor.current_unique_name);
879
880    return sym_table_visitor.sym_table;
881 }
```

:

A.3.11 src/ast/ast_visitor_symbol_table.h

```
1  #ifndef AST_VISITOR_SYMBOL_TABLE_H
2  #define AST_VISITOR_SYMBOL_TABLE_H
3
4  #include "ast_visitor.h"
5
6  typedef struct Symbol_Table Symbol_Table;
7
8  /* Returns NULL is the Ast is invalid. */
9  Symbol_Table *ast_visitor_symbol_table_gen(Ast *ast);
10
11 #endif // AST_VISITOR_SYMBOL_TABLE_H
```

:

A.3.12 src/ast/symbol_table.c

```
1  #include "symbol_table.h"
2  #include <string_builder.h>
3  #include <pointer_hash.h>
4  #include <main.h>
5  #include <import_handler.h>
6
7  #undef DEBUG_TYPE
8  #define DEBUG_TYPE symbol-table
9
10 static inline bool symbol_type_names_equal(String lhs_name, Uns lhs_scope,
11       String rhs_name, Uns rhs_scope)
12 {
13    if (lhs_scope != rhs_scope)
14       return false;
15    return !string_compare(lhs_name, rhs_name);
16 }
17
18 static inline bool symbol_types_equal(Symbol_Type_Struct *lhs,
19       Symbol_Type_Struct *rhs)
20 {
21    return lhs->methods->same_type(lhs, rhs);
```

```
22  }
23
24  static inline bool symbol_type_vectors_same_type(Vector *lhs, Vector *rhs)
25  {
26     Uns size = vector_size(lhs);
27     if (size != vector_size(rhs))
28        return false;
29     while (size--) {
30        if (!symbol_types_equal(vector_get(lhs, size),
31                 vector_get(rhs, size)))
32           return false;
33     }
34     return true;
35  }
36
37  static inline bool symbol_type_vector_idens_identical(Vector *lhs,
38        Vector *rhs)
39  {
40     Uns size = vector_size(lhs);
41     if (size != vector_size(rhs))
42        return false;
43     while (size--) {
44        Const_String lhs_str = STRING_AFTER_LAST(vector_get(lhs, size), '.');
45        Const_String rhs_str = STRING_AFTER_LAST(vector_get(rhs, size), '.');
46  #if 0
47        Const_String lhs_str = vector_get(lhs, size);
48        Const_String rhs_str = vector_get(rhs, size);
49  #endif
50        if (string_compare(lhs_str, rhs_str))
51           return false;
52     }
53     return true;
54  }
55
56  bool ___symbol_var_is_in_scope(File_Location *var_loc,
57        Symbol *lookup_sym, Symbol_Table_Node *child_sym_node)
58  {
59     Symbol_Table_Node_Type nt = symbol_get_symbol_table_node_type(lookup_sym);
60     if (nt == SYMBOL_TABLE_NODE_REC)
61        return true;
62     if (nt == SYMBOL_TABLE_NODE_IMPORT)
63        return true;
64     if (file_location_cmp_lncol(var_loc, lookup_sym->location) >= 0)
65        return true;
66
67     Symbol_Table_Node *look_sym_func = lookup_sym->sym_node;
68     while (look_sym_func->type == SYMBOL_TABLE_NODE_INTERMEDIATE)
69        look_sym_func = look_sym_func->parent;
70     Symbol_Table_Node *child_func = child_sym_node;
71     while (child_func->type == SYMBOL_TABLE_NODE_INTERMEDIATE)
72        child_func = child_func->parent;
73
74  #ifdef NEST_FUNCS_ACCESS_LATER_DECL
75     if (child_func->scope_id != look_sym_func->scope_id) {
76        assert(child_func->scope_id > look_sym_func->scope_id);
77        return true;
78     }
79  #endif
80
81     return false;
82  }
83
84  static inline Type_Def_Symbol *symbol_table_node_lookup_type_def(
85        Symbol_Table_Node *sym_node, String iden, Uns hash_code)
86  {
87     Symbol *sym = ___symbol_table_node_lookup(sym_node, iden, hash_code,
88           SYMBOL_PROPERTY_TYPE_DEF);
89     if (sym)
90        return TYPE_DEF_SYMBOL_OF_SYMBOL(sym);
91     return NULL;
92  }
93
94  static inline Symbol_Type_Struct *___symbol_resolve(Symbol *sym,
95        Symbol_Table *t)
```

```
96  {
97     return sym->resolved_type->methods->resolve(sym->resolved_type, t);
98  }
99
100 static bool symbol_type_rec_structs_equal(Symbol_Type_Rec *rhs,
101       Symbol_Type_Rec *lhs)
102 {
103    bool ret = false;
104 #if 0
105    if (!vector_is_empty(&rhs->func_identifiers) ||
106          !vector_is_empty(&lhs->func_identifiers)) {
107       ret = rhs->rec_sym_node->scope_id == lhs->rec_sym_node->scope_id;
108       goto out;
109    }
110 #endif
111
112    if (!symbol_type_vector_idens_identical(&lhs->var_identifiers,
113             &rhs->var_identifiers))
114       goto out;
115
116    if (!symbol_type_vector_idens_identical(&lhs->func_identifiers,
117             &rhs->func_identifiers))
118       goto out;
119
120    if (!symbol_type_vectors_same_type(&lhs->var_types,
121             &rhs->var_types))
122       goto out;
123
124    if (!symbol_type_vectors_same_type(&lhs->func_types,
125             &rhs->func_types))
126       goto out;
127
128    if (!symbol_type_vectors_same_type(&lhs->extended_types,
129             &rhs->extended_types))
130       goto out;
131
132    ret = true;
133
134 out:
135    return ret;
136 }
137
138 static inline bool symbol_type_arys_equal(Symbol_Type_Ary *lhs_ary,
139       Symbol_Type_Ary *rhs_ary)
140 {
141    for (;;) {
142       Symbol_Type_Struct *lhs_tmp = lhs_ary->ary_type;
143       Symbol_Type_Struct *rhs_tmp = rhs_ary->ary_type;
144       Symbol_Type tmp_t = lhs_tmp->methods->get_type();
145
146       if (tmp_t == SYMBOL_TYPE_UNKNOWN)
147          return true;
148       Symbol_Type rhs_t = rhs_tmp->methods->get_type();
149       if (rhs_t == SYMBOL_TYPE_UNKNOWN)
150          return true;
151
152       if (rhs_t != tmp_t)
153          return false;
154
155       if (tmp_t != SYMBOL_TYPE_ARY) {
156          if (tmp_t == SYMBOL_TYPE_REC) {
157             Symbol_Type_Rec *lhs_rec, *rhs_rec;
158             lhs_rec = SYMBOL_TYPE_STRUCT_CONTAINER(lhs_tmp,
159                   Symbol_Type_Rec);
160             rhs_rec = SYMBOL_TYPE_STRUCT_CONTAINER(rhs_tmp,
161                   Symbol_Type_Rec);
162             if (!lhs_rec->rec_name || !rhs_rec->rec_name)
163                return false;
164             else
165                return lhs_tmp->methods->same_type(lhs_tmp, rhs_tmp);
166          } else {
167             return lhs_tmp->methods->same_type(lhs_tmp, rhs_tmp);
168          }
169
```

```
170         } else {
171            lhs_ary = SYMBOL_TYPE_STRUCT_CONTAINER(lhs_tmp,
172                  Symbol_Type_Ary);
173            rhs_ary = SYMBOL_TYPE_STRUCT_CONTAINER(rhs_tmp,
174                  Symbol_Type_Ary);
175         }
176      }
177   }
178
179   static inline bool symbol_type_rec_is_imported(Symbol_Type_Rec *rec)
180   {
181      assert(rec->rec_sym_node);
182      assert(rec->rec_sym_node->parent);
183      return rec->rec_sym_node->parent->type == SYMBOL_TABLE_NODE_IMPORT;
184   }
185
186   bool ___type_def_symbol_types_equal(Symbol_Type_Struct *lhs,
187         Symbol_Type_Struct *rhs)
188   {
189      Symbol_Type lhs_type = lhs->methods->get_type();
190      Symbol_Type rhs_type = rhs->methods->get_type();
191
192      if (lhs_type == rhs_type) {
193         switch (lhs_type) {
194         case SYMBOL_TYPE_ARY:
195            do {
196               Symbol_Type_Ary *lhs_ary = SYMBOL_TYPE_STRUCT_CONTAINER(lhs,
197                     Symbol_Type_Ary);
198               Symbol_Type_Ary *rhs_ary = SYMBOL_TYPE_STRUCT_CONTAINER(rhs,
199                     Symbol_Type_Ary);
200               lhs = lhs_ary->ary_type;
201               rhs = rhs_ary->ary_type;
202               lhs_type = lhs->methods->get_type();
203               rhs_type = rhs->methods->get_type();
204
205            } while (lhs_type == SYMBOL_TYPE_ARY &&
206                  rhs_type == SYMBOL_TYPE_ARY);
207            if (lhs_type != SYMBOL_TYPE_REC ||
208                  rhs_type != SYMBOL_TYPE_REC)
209               break;
210            /* Fall through */
211         case SYMBOL_TYPE_REC:;
212            Symbol_Type_Rec *lhs_rec = SYMBOL_TYPE_STRUCT_CONTAINER(lhs,
213                  Symbol_Type_Rec);
214            Symbol_Type_Rec *rhs_rec = SYMBOL_TYPE_STRUCT_CONTAINER(rhs,
215                  Symbol_Type_Rec);
216
217            if (vector_is_empty(&lhs_rec->func_identifiers) &&
218                  vector_is_empty(&rhs_rec->func_identifiers))
219               break;
220
221            if ((!symbol_type_rec_is_imported(lhs_rec) &&
222                  !symbol_type_rec_is_imported(rhs_rec))) {
223               return lhs_rec->rec_sym_node->scope_id ==
224                     rhs_rec->rec_sym_node->scope_id;
225            } else {
226               return !string_compare(lhs_rec->unique_name,
227                     rhs_rec->unique_name);
228            }
229
230         default:
231            break;
232         }
233      }
234
235      return lhs->methods->same_type(lhs, rhs);
236   }
237
238   static inline Symbol_Type_Struct *symbol_type_get_rec_cycle(Symbol *symbol,
239         Symbol_Table *t)
240   {
241      Symbol_Type_Struct *ret = NULL;
242
243      if (symbol->resolved_type->methods->get_type() == SYMBOL_TYPE_REC) {
```

```
244         Symbol_Type_Rec *rec = SYMBOL_TYPE_STRUCT_CONTAINER(
245               symbol->resolved_type, Symbol_Type_Rec);
246
247         assert(t->rec_cycle_type != SYMBOL_REC_CYCLE_MARK_NONE &&
248               rec->cycle_mark != SYMBOL_REC_CYCLE_MARK_NONE);
249
250         /* We have detected a record cycle.
251          * Find out whether the cycle is allowed. */
252         if (t->rec_cycle_type == SYMBOL_REC_CYCLE_ALLOWED ||
253               rec->cycle_mark == SYMBOL_REC_CYCLE_ALLOWED) {
254            /* Mark that this results in a cycle which
255             * is allowed and return. */
256            assert(rec->rec_name);
257            ret = symbol_type_cycle_alloc(t, rec->rec_name);
258         }
259      }
260
261      return ret;
262   }
263
264   static inline Symbol_Type_Struct *symbol_type_get_ary_cycle(Symbol *symbol,
265         Symbol_Table *t)
266   {
267      Symbol_Type_Ary *curr, *ary;
268      Symbol_Type_Struct *ret = NULL;
269      if (symbol->resolved_type->methods->get_type() ==
270            SYMBOL_TYPE_ARY) {
271
272         ary = SYMBOL_TYPE_STRUCT_CONTAINER(symbol->resolved_type,
273               Symbol_Type_Ary);
274         curr = ary;
275         do {
276            curr = SYMBOL_TYPE_STRUCT_CONTAINER(curr->ary_type,
277                  Symbol_Type_Ary);
278         } while (curr->sym_struct.methods->get_type() == SYMBOL_TYPE_ARY);
279
280         if (curr->sym_struct.methods->get_type() == SYMBOL_TYPE_REC)
281            ret = symbol_type_cycle_alloc(t, ary->ary_name);
282      }
283
284      return ret;
285   }
286
287   static inline void report_conflicting_type_definitios(Type_Def_Symbol *sym)
288   {
289      Double_List *list;
290      Double_List_Node *dbnode;
291      Type_Def_Symbol *tmp_sym;
292
293      if (!is_error_reported_here(sym->symbol.location)) {
294         if (sym->symbol.sym_node->type != SYMBOL_TABLE_NODE_IMPORT) {
295            String str = string_from_format(
296                  S("conflicting type definitions for type " QFY("%1$S")
297                        " which is also defined in:\n"),
298                  STRING_AFTER_LAST(sym->symbol.identifier, '.'));
299
300            list = &sym->dbnode;
301            DOUBLE_LIST_FOR_EACH(list, dbnode) {
302               tmp_sym = TYPE_DEF_SYMBOL_OF_DBNODE(dbnode);
303               string_append_format(str, S("\t%F\n"),
304                     tmp_sym->symbol.location);
305            }
306
307            report_error_location(sym->symbol.location, str);
308            string_destroy(str);
309         } else {
310            String str = string_from_format(
311                  S("conflicting imported type definitions for type "
312                        QFY("%S") " which is imported from:\n\t%S\n"),
313                  sym->symbol.identifier, sym->symbol.unique_name);
314
315            list = &sym->dbnode;
316            DOUBLE_LIST_FOR_EACH(list, dbnode) {
317               tmp_sym = TYPE_DEF_SYMBOL_OF_DBNODE(dbnode);
```

```
318             string_append_format(str, S("\t%S\n"),
319                   tmp_sym->symbol.unique_name);
320          }
321
322          report_error_location(sym->symbol.location, str);
323          string_destroy(str);
324       }
325    }
326 }
327
328 static Symbol_Type_Struct *___type_def_symbol_resolve(Type_Def_Symbol *symbol,
329       Symbol_Table *t)
330 {
331    Symbol_Type_Struct *ret;
332    Symbol_Type_Struct *tmp_type;
333    Type_Def_Symbol *next_sym = symbol;
334    Double_List *dblist;
335    Double_List_Node *dbnode;
336
337    bool report_cycle = symbol->report_cycle;
338    symbol->report_cycle = false;
339
340    if (symbol->cycle_marked) {
341       ret = symbol_type_get_rec_cycle(&symbol->symbol, t);
342       if (ret)
343          goto out;
344       ret = symbol_type_get_ary_cycle(&symbol->symbol, t);
345       if (ret)
346          goto out;
347
348       DOUBLE_LIST_FOR_EACH(&symbol->dbnode, dbnode) {
349          next_sym = TYPE_DEF_SYMBOL_OF_DBNODE(dbnode);
350          if (!next_sym->cycle_marked) {
351             goto no_cycle;
352          } else {
353             ret = symbol_type_get_rec_cycle(&next_sym->symbol, t);
354             if (ret)
355                goto out;
356             ret = symbol_type_get_ary_cycle(&next_sym->symbol, t);
357             if (ret)
358                goto out;
359          }
360       }
361
362       /* Cycle in type definitions is detected.
363        * Return NULL to notify about this. */
364       goto out;
365    }
366
367 no_cycle:
368    next_sym->cycle_marked = true;
369    ret = next_sym->symbol.resolved_type->methods->resolve(
370             next_sym->symbol.resolved_type, t);
371    next_sym->cycle_marked = false;
372
373    dblist = &next_sym->dbnode;
374    /* Loop through type symbols with identifier ==
375     *  symbol->symbol.identifier == next_sym->symbol.identifier. */
376    DOUBLE_LIST_FOR_EACH(dblist, dbnode) {
377       next_sym = TYPE_DEF_SYMBOL_OF_DBNODE(dbnode);
378
379       if (next_sym->cycle_marked) {
380          if (!ret) {
381             if ((ret = symbol_type_get_rec_cycle(&next_sym->symbol, t)))
382                break;
383             else
384                continue;
385          } else {
386             break;
387          }
388       }
389
390       next_sym->cycle_marked = true;
391       tmp_type = next_sym->symbol.resolved_type->methods->resolve(
```

```
392                 next_sym->symbol.resolved_type, t);
393         next_sym->cycle_marked = false;
394
395         if (!ret) {
396            ret = tmp_type;
397         } else if (t->last_resolve_pass &&
398               tmp_type && !___type_def_symbol_types_equal(tmp_type, ret)) {
399            ret = symbol_type_unknown_alloc(t);
400            report_conflicting_type_definitios(next_sym);
401         }
402
403      }
404
405      if (!ret && report_cycle) {
406         /* We were not able to resolve the symbol + we have found a cycle
407          * in the type definitions. We notify the user about this here. */
408
409         if (!is_error_reported_here(symbol->symbol.location)) {
410            if (symbol_get_symbol_table_node_type(&symbol->symbol) !=
411                  SYMBOL_TABLE_NODE_IMPORT)
412               report_error_location(symbol->symbol.location,
413                     S("cycle in type definitions invloving " QFY("%S") "\n"),
414                     STRING_AFTER_DOT(symbol->symbol.identifier));
415            else {
416               report_error_location(symbol->symbol.location,
417                     S("cycle in imported type definitions invloving "
418                        QFY("%S") "\n"),
419                     STRING_AFTER_DOT(symbol->symbol.identifier));
420            }
421         }
422         ret = symbol_type_unknown_alloc(t);
423      }
424
425   out:
426      return ret;
427   }
428
429   static inline Symbol_Type_Struct *symbol_resolve(Symbol *sym, Symbol_Table *t)
430   {
431      if (t->current_resolve_property == SYMBOL_PROPERTY_TYPE_DEF)
432         return ___type_def_symbol_resolve(TYPE_DEF_SYMBOL_OF_SYMBOL(sym), t);
433      return ___symbol_resolve(sym, t);
434   }
435
436   static inline Symbol_Type_Struct *symbol_type_struct_alloc_finalize(
437         Symbol_Type_Struct *s, Symbol_Type_Struct_Methods *methods,
438         Symbol_Table *t)
439   {
440      s->methods = methods;
441      double_list_append(&t->all_symbol_types, &s->dbnode);
442      return s;
443   }
444
445   static inline void symbol_type_struct_destroy_common(
446         Symbol_Type_Struct *s UNUSED)
447   {
448   }
449
450   static bool symbol_rec_ambiguous_ref_compare(String search,
451         Hash_Map_Slot *map_slot)
452   {
453      Symbol_Type_Rec_Ambiguous_Ref *map_ref =
454            SYMBOL_REC_AMBIGUOUS_REF_OF(map_slot);
455      return !string_compare(map_ref->field_name, search);
456   }
457
458   static inline Symbol_Type_Rec_Ambiguous_Ref *symbol_rec_ambiguous_ref_alloc(
459         Const_String field_name)
460   {
461      Symbol_Type_Rec_Ambiguous_Ref *r =
462            ALLOC_NEW(Symbol_Type_Rec_Ambiguous_Ref);
463      r->sym_locations = VECTOR_INIT_SIZE(PTR_SIZE);
464      r->field_name = field_name;
465      return r;
```

```
466 }
467
468 static inline void symbol_rec_ambiguous_ref_add_loc(
469       Symbol_Type_Rec_Ambiguous_Ref *r, File_Location *loc)
470 {
471    Vector *v = &r->sym_locations;
472    File_Location *tmp_loc;
473    VECTOR_FOR_EACH_ENTRY(v, tmp_loc) {
474       if (!file_location_cmp(loc, tmp_loc))
475          return;
476    }
477    vector_append(v, loc);
478 }
479
480 static void symbol_rec_ambiguous_ref_destroy(Hash_Map_Slot *slot)
481 {
482    Symbol_Type_Rec_Ambiguous_Ref *r = SYMBOL_REC_AMBIGUOUS_REF_OF(slot);
483    vector_clear(&r->sym_locations);
484    free_mem(r);
485 }
486
487 /*****************************************************************************/
488
489 static Symbol_Type symbol_type_void_get_type()
490 {
491    return SYMBOL_TYPE_VOID;
492 }
493
494 static Symbol_Type_Struct *symbol_type_void_resolve(Symbol_Type_Struct *self,
495       Symbol_Table *t UNUSED)
496 {
497    return self;
498 }
499
500 static bool symbol_type_void_same_type(Symbol_Type_Struct *self UNUSED,
501       Symbol_Type_Struct *oth)
502 {
503    Symbol_Type oth_t = oth->methods->get_type();
504    assert(oth_t != SYMBOL_TYPE_IDEN);
505    return oth_t == SYMBOL_TYPE_VOID || oth_t == SYMBOL_TYPE_UNKNOWN;
506 }
507
508 static void symbol_type_void_append_str(Symbol_Type_Struct *self UNUSED,
509       String_Builder *sb)
510 {
511    string_builder_append(sb, S("void"));
512 }
513
514 static void symbol_type_void_destroy(Symbol_Type_Struct *self)
515 {
516    symbol_type_struct_destroy_common(self);
517    free_mem(SYMBOL_TYPE_STRUCT_CONTAINER(self, Symbol_Type_Void));
518 }
519
520 static Symbol_Type_Struct_Methods symbol_type_void_methods = {
521    .get_type = symbol_type_void_get_type,
522    .resolve = symbol_type_void_resolve,
523    .append_str = symbol_type_void_append_str,
524    .destroy = symbol_type_void_destroy,
525    .same_type = symbol_type_void_same_type
526 };
527
528 Symbol_Type_Struct *symbol_type_void_alloc(Symbol_Table *t)
529 {
530    if (!t->symbol_type_struct_void) {
531       Symbol_Type_Void *s = ALLOC_NEW(Symbol_Type_Void);
532       t->symbol_type_struct_void = symbol_type_struct_alloc_finalize(
533             SYMBOL_TYPE_STRUCT_OF_CONTAINER(s),
534             &symbol_type_void_methods, t);
535    }
536    return t->symbol_type_struct_void;
537 }
538
539 /*****************************************************************************/
```

```
540
541 /*****************************************************************************/
542
543 static Symbol_Type symbol_type_int_get_type()
544 {
545    return SYMBOL_TYPE_INT;
546 }
547
548 static Symbol_Type_Struct *symbol_type_int_resolve(Symbol_Type_Struct *self,
549       Symbol_Table *t UNUSED)
550 {
551    return self;
552 }
553
554 static bool symbol_type_int_same_type(Symbol_Type_Struct *self UNUSED,
555       Symbol_Type_Struct *oth)
556 {
557    Symbol_Type oth_t = oth->methods->get_type();
558    assert(oth_t != SYMBOL_TYPE_IDEN);
559    return oth_t == SYMBOL_TYPE_INT || oth_t == SYMBOL_TYPE_UNKNOWN;
560 }
561
562 static void symbol_type_int_append_str(Symbol_Type_Struct *self UNUSED,
563       String_Builder *sb)
564 {
565    string_builder_append(sb, S("int"));
566 }
567
568 static void symbol_type_int_destroy(Symbol_Type_Struct *self)
569 {
570    symbol_type_struct_destroy_common(self);
571    free_mem(SYMBOL_TYPE_STRUCT_CONTAINER(self, Symbol_Type_Int));
572 }
573
574 static Symbol_Type_Struct_Methods symbol_type_int_methods = {
575    .get_type = symbol_type_int_get_type,
576    .resolve = symbol_type_int_resolve,
577    .append_str = symbol_type_int_append_str,
578    .destroy = symbol_type_int_destroy,
579    .same_type = symbol_type_int_same_type
580 };
581
582 Symbol_Type_Struct *symbol_type_int_alloc(Symbol_Table *t)
583 {
584    if (!t->symbol_type_struct_int) {
585       Symbol_Type_Int *s = ALLOC_NEW(Symbol_Type_Int);
586       t->symbol_type_struct_int = symbol_type_struct_alloc_finalize(
587             SYMBOL_TYPE_STRUCT_OF_CONTAINER(s),
588             &symbol_type_int_methods, t);
589    }
590    return t->symbol_type_struct_int;
591 }
592
593 /*****************************************************************************/
594
595 static Symbol_Type symbol_type_iden_get_type()
596 {
597    return SYMBOL_TYPE_IDEN;
598 }
599
600 static Symbol_Type_Struct *symbol_type_iden_resolve(Symbol_Type_Struct *self,
601       Symbol_Table *t)
602 {
603    Symbol *saved_sym;
604    Symbol_Type_Struct *ret;
605    Symbol_Type_Iden *tiden = SYMBOL_TYPE_STRUCT_CONTAINER(self,
606          Symbol_Type_Iden);
607
608    Symbol *lookup = ___symbol_table_node_lookup(tiden->sym_node, tiden->iden,
609          string_hash_code(tiden->iden), SYMBOL_PROPERTY_TYPE_DEF);
610    if (lookup) {
611       saved_sym = t->current_symbol;
612       t->current_symbol = lookup;
613       ret = symbol_resolve(lookup, t);
```

```
614         t->current_symbol = saved_sym;
615     } else {
616
617 #if 0
618         if (import_handler_is_merge_table(t))
619             return self;
620 #endif
621
622         ret = symbol_type_unknown_alloc(t);
623         if (!is_error_reported_here(tiden->loc)) {
624             report_error_location(tiden->loc, S("unable to resolve type "
625                     QFY("%S") "\n"),
626                     STRING_AFTER_DOT(tiden->iden));
627         }
628     }
629
630     return ret;
631 }
632
633 static bool symbol_type_iden_same_type(Symbol_Type_Struct *self UNUSED,
634         Symbol_Type_Struct *oth UNUSED)
635 {
636     DEBUGT(def,
637         fatal_error(S("Symbol table trying to compare identifier "
638                 "type with other type\n"))
639     );
640     return false;
641 }
642
643 static void symbol_type_iden_append_str(Symbol_Type_Struct *self,
644         String_Builder *sb)
645 {
646     Symbol_Type_Iden *tiden =
647             SYMBOL_TYPE_STRUCT_CONTAINER(self, Symbol_Type_Iden);
648     String s = string_from_format(S("identifier (%S)"), tiden->iden);
649     string_builder_append(sb, s);
650     string_destroy(s);
651 }
652
653 static void symbol_type_iden_destroy(Symbol_Type_Struct *self)
654 {
655     symbol_type_struct_destroy_common(self);
656     Symbol_Type_Iden *tiden = SYMBOL_TYPE_STRUCT_CONTAINER(self,
657             Symbol_Type_Iden);
658     string_destroy(tiden->iden);
659     free_mem(tiden);
660 }
661
662 static Symbol_Type_Struct_Methods symbol_type_iden_methods = {
663     .get_type = symbol_type_iden_get_type,
664     .resolve = symbol_type_iden_resolve,
665     .append_str = symbol_type_iden_append_str,
666     .destroy = symbol_type_iden_destroy,
667     .same_type = symbol_type_iden_same_type
668 };
669
670 Symbol_Type_Struct *symbol_type_iden_alloc(Symbol_Table *t, String iden)
671 {
672     Symbol_Type_Iden *s = ALLOC_NEW(Symbol_Type_Iden);
673     s->iden = string_duplicate(iden);
674     return symbol_type_struct_alloc_finalize(
675             SYMBOL_TYPE_STRUCT_OF_CONTAINER(s),
676             &symbol_type_iden_methods, t);
677 }
678
679 void symbol_type_iden_set_iden(Symbol_Type_Iden *self, String str)
680 {
681     string_destroy(self->iden);
682     self->iden = str;
683 }
684
685 /*****************************************************************************/
686
687 static Symbol_Type symbol_type_rec_get_type()
```

```
688 {
689    return SYMBOL_TYPE_REC;
690 }
691
692 static inline Symbol_Type_Struct *symbol_rec_get_extended_type(
693       Symbol_Type_Struct *extended_type, Symbol_Table *t)
694 {
695    Type_Def_Symbol *sym;
696    Symbol_Type_Cycle *cycle;
697    if (t->last_resolve_pass || t->current_resolve_property !=
698          SYMBOL_PROPERTY_TYPE_DEF) {
699       switch (extended_type->methods->get_type()) {
700       case SYMBOL_TYPE_REC:
701          break;
702       case SYMBOL_TYPE_CYCLE:
703          cycle = SYMBOL_TYPE_STRUCT_CONTAINER(extended_type,
704                Symbol_Type_Cycle);
705          sym = symbol_table_node_lookup_type_def(cycle->sym_node,
706                cycle->name, string_hash_code(cycle->name));
707          assert(sym);
708          if (sym->symbol.resolved_type->methods->get_type() ==
709                SYMBOL_TYPE_REC) {
710             extended_type = sym->symbol.resolved_type;
711             break;
712          }
713          /* Fall through. */
714       case SYMBOL_TYPE_UNKNOWN:
715          break;
716       default:
717          if (!is_error_reported_here(t->current_symbol->location))
718             report_error_location(t->current_symbol->location,
719                   S("record " QFY("%S") " is extending "
720                      "non-record type\n"),
721                   t->current_symbol->identifier);
722          extended_type = symbol_type_unknown_alloc(t);
723          break;
724       }
725    }
726    return extended_type;
727 }
728
729 static inline const char *get_current_record_type(Symbol_Table *t)
730 {
731    if (t->current_symbol->resolved_type->methods->get_type() ==
732          SYMBOL_TYPE_ARY)
733       return "array record";
734    return "record";
735 }
736
737 static inline void symbol_rec_append_remaps(Hash_Map *src,
738       Hash_Map *dest)
739 {
740    Hash_Map_Slot *src_slot;
741    HASH_MAP_FOR_EACH(src, src_slot) {
742       Symbol_Func_Remap *tmp = SYMBOL_FUNC_REMAP_OF(src_slot);
743       Uns hash = hash_map_slot_get_hash_code(&tmp->hash_slot);
744
745       if (!hash_map_contains(dest, tmp->initial_iden, hash)) {
746          Symbol_Func_Remap *new_map = symbol_func_remap_alloc(
747                tmp->initial_iden, tmp->new_iden);
748          hash_map_insert(dest, &new_map->hash_slot, hash);
749       }
750    }
751 }
752
753 static inline void symbol_rec_override_map(
754       Symbol_Table_Node *tmp_node,
755       Symbol_Func_Map *curr_idens,
756       Symbol *super_sym,
757       Symbol_Table_Node *curr_node)
758 {
759    Symbol *curr_sym;
760    Vector *curr_overloaded = &curr_idens->overload_idens;
761
```

```
762     DLOG("Vector is: %p\n", curr_overloaded);
763
764     VECTOR_FOR_EACH_ENTRY(curr_overloaded, curr_sym) {
765        if (curr_sym->resolved_type->methods->same_type(
766                 curr_sym->resolved_type,
767                 super_sym->resolved_type)) {
768           Uns hash = string_hash_code(super_sym->identifier);
769
770           DLOG("insert overloaded: %S to symbol %p\n",
771                 super_sym->identifier, curr_sym);
772
773           if (!hash_map_contains(&curr_node->func_remaps,
774                    super_sym->identifier, hash)) {
775              Symbol_Func_Remap *remap = symbol_func_remap_alloc(
776                    super_sym->identifier, curr_sym->identifier);
777              hash_map_insert(&curr_node->func_remaps,
778                    &remap->hash_slot, hash);
779           }
780           return;
781        }
782     }
783
784     symbol_table_node_insert(
785           tmp_node,
786           curr_idens->func_iden,
787           super_sym->unique_name,
788           super_sym->resolved_type,
789           SYMBOL_PROPERTY_FUNC,
790           super_sym->location);
791  }
792
793  static inline void symbol_rec_accumulate_super_funcs(
794        Symbol_Table_Node *tmp_node,
795        Symbol_Type_Rec *curr_rec,
796        Symbol_Type_Rec *curr_super,
797        Symbol_Table *t UNUSED)
798  {
799     Hash_Map *super_map;
800     Hash_Map *curr_map;
801     Hash_Map_Slot *super_slot;
802     Hash_Map_Slot *curr_slot;
803     Symbol *super_sym;
804
805     super_map = &curr_super->rec_sym_node->func_iden_map;
806     curr_map = &curr_rec->rec_sym_node->func_iden_map;
807
808     HASH_MAP_FOR_EACH(super_map, super_slot) {
809        Symbol_Func_Map *super_idens = SYMBOL_FUNC_MAP_OF(super_slot);
810
811        if (symbol_func_maps_ctor(super_idens))
812           continue;
813
814        DLOG("super idens: %S\n", super_idens->func_iden);
815        curr_slot = hash_map_get(curr_map, super_idens->func_iden,
816                  hash_map_slot_get_hash_code(&super_idens->hash_slot));
817        if (curr_slot) {
818           Symbol_Func_Map *curr_idens = SYMBOL_FUNC_MAP_OF(curr_slot);
819           DLOG("super size: %U\n", vector_size(&super_idens->overload_idens));
820           VECTOR_FOR_EACH_ENTRY(&super_idens->overload_idens, super_sym) {
821              DLOG("super sym: %S\n", super_sym->identifier);
822              symbol_rec_override_map(tmp_node, curr_idens,
823                    super_sym, curr_rec->rec_sym_node);
824           }
825        } else {
826           VECTOR_FOR_EACH_ENTRY(&super_idens->overload_idens, super_sym) {
827              symbol_table_node_insert(
828                    tmp_node,
829                    super_idens->func_iden,
830                    super_sym->unique_name,
831                    super_sym->resolved_type,
832                    SYMBOL_PROPERTY_FUNC,
833                    super_sym->location);
834           }
835        }
```

```
836         symbol_rec_append_remaps(&super_idens->sym_node->func_remaps,
837               &curr_rec->rec_sym_node->func_remaps);
838      }
839   }
840
841   static inline void symbol_rec_accumulate_super_vars(
842         Symbol_Table_Node *tmp_node,
843         Symbol_Type_Rec *curr_rec,
844         Symbol_Type_Rec *curr_super,
845         Symbol_Table *t)
846   {
847      Hash_Map *super_map;
848      Hash_Map_Slot *super_slot;
849      Symbol *base_sym, *tmp_sym, *super_sym;
850
851      super_map = &curr_super->rec_sym_node->symbol_maps[SYMBOL_PROPERTY_VAR];
852      HASH_MAP_FOR_EACH(super_map, super_slot) {
853         super_sym = SYMBOL_OF_SLOT(super_slot);
854         tmp_sym = symbol_table_node_get(tmp_node,
855               super_sym->identifier,
856               hash_map_slot_get_hash_code(&super_sym->hash_slot),
857               SYMBOL_PROPERTY_VAR);
858
859         if (!tmp_sym) {
860            symbol_table_node_insert(
861                  tmp_node,
862                  super_sym->identifier,
863                  super_sym->unique_name,
864                  super_sym->resolved_type,
865                  SYMBOL_PROPERTY_VAR,
866                  super_sym->location);
867         } else {
868            base_sym = symbol_table_node_get(
869                  curr_rec->rec_sym_node,
870                  super_sym->identifier,
871                  hash_map_slot_get_hash_code(&super_sym->hash_slot),
872                  SYMBOL_PROPERTY_VAR);
873
874            if (!base_sym) {
875               Symbol_Type_Rec_Ambiguous_Ref *r =
876                     symbol_type_rec_get_ambiguous_ref(curr_rec,
877                           super_sym->identifier);
878               if (r) {
879                  symbol_rec_ambiguous_ref_add_loc(r, super_sym->location);
880               } else {
881                  r = symbol_rec_ambiguous_ref_alloc(super_sym->identifier);
882                  symbol_rec_ambiguous_ref_add_loc(r, tmp_sym->location);
883                  symbol_rec_ambiguous_ref_add_loc(r, super_sym->location);
884
885                  symbol_type_rec_add_ambiguous_ref(curr_rec, r);
886
887                  symbol_table_node_insert(
888                        curr_rec->rec_sym_node,
889                        super_sym->identifier,
890                        super_sym->unique_name,
891                        symbol_type_unknown_alloc(t),
892                        SYMBOL_PROPERTY_VAR,
893                        t->current_symbol->location);
894               }
895            }
896
897         }
898      }
899   }
900
901   static inline void symbol_type_rec_append_super_vars(Symbol_Type_Rec *rec,
902         Symbol_Table_Node *tmp_node)
903   {
904      Hash_Map *map;
905      Hash_Map_Slot *slot;
906      Symbol *sym;
907      Symbol_Table_Node *rec_node;
908
909      rec_node = rec->rec_sym_node;
```

```
910
911      map = &tmp_node->symbol_maps[SYMBOL_PROPERTY_VAR];
912      HASH_MAP_FOR_EACH(map, slot) {
913         sym = SYMBOL_OF_SLOT(slot);
914         if (!symbol_table_node_get(rec_node, sym->identifier,
915               hash_map_slot_get_hash_code(&sym->hash_slot),
916               SYMBOL_PROPERTY_VAR)) {
917            symbol_table_node_insert(rec_node,
918                  sym->identifier,
919                  sym->unique_name,
920                  sym->resolved_type,
921                  SYMBOL_PROPERTY_VAR,
922                  sym->location);
923         }
924      }
925   }
926
927   static inline void symbol_type_rec_append_super_funcs(Symbol_Type_Rec *rec,
928         Symbol_Table_Node *tmp_node)
929   {
930      Hash_Map_Slot *slot;
931      Symbol_Table_Node *rec_node = rec->rec_sym_node;
932      Hash_Map *map = &tmp_node->func_iden_map;
933
934      HASH_MAP_FOR_EACH(map, slot) {
935         Symbol_Func_Map *func_map = SYMBOL_FUNC_MAP_OF(slot);
936         Symbol *fsym;
937         VECTOR_FOR_EACH_ENTRY(&func_map->overload_idens, fsym) {
938            symbol_table_node_insert(rec_node,
939                  func_map->func_iden,
940                  fsym->identifier,
941                  fsym->resolved_type,
942                  SYMBOL_PROPERTY_FUNC,
943                  fsym->location);
944         }
945      }
946   }
947
948   bool ___symbol_type_rec_ambiguous_cast(Symbol_Type_Rec *cast,
949         Symbol_Type_Rec *rec)
950   {
951      Vector *extend_vec;
952      Symbol_Type_Struct *super_type;
953      Uns count = 0;
954
955      extend_vec = &rec->extended_types;
956      VECTOR_FOR_EACH_ENTRY(extend_vec, super_type) {
957         if (symbol_type_rec_assignment_compatible(
958               SYMBOL_TYPE_STRUCT_OF_CONTAINER(cast), super_type)) {
959            if (++count > 1)
960               return true;
961         }
962      }
963
964      return false;
965   }
966
967   #if 0
968   static bool symbol_type_rec_ambiguous_extend(Symbol_Type_Struct *cast_st,
969         Symbol_Type_Struct *rec_st)
970   {
971      Vector *extend_vec;
972      Symbol_Type_Struct *super_type;
973      Symbol_Type_Rec *super_rec;
974      Uns count = 0;
975
976      if (cast_st->methods->same_type(cast_st, rec_st))
977         return true;
978
979      Symbol_Type_Rec *cast = SYMBOL_TYPE_STRUCT_CONTAINER(cast_st,
980            Symbol_Type_Rec);
981      Symbol_Type_Rec *rec = SYMBOL_TYPE_STRUCT_CONTAINER(rec_st,
982            Symbol_Type_Rec);
983
```

```
984     extend_vec = &rec->extended_types;
985     VECTOR_FOR_EACH_ENTRY(extend_vec, super_type) {
986        super_rec = SYMBOL_TYPE_STRUCT_CONTAINER(super_type, Symbol_Type_Rec);
987        if (symbol_type_rec_assignment_compatible(
988                  SYMBOL_TYPE_STRUCT_OF_CONTAINER(cast),
989                  SYMBOL_TYPE_STRUCT_OF_CONTAINER(super_rec)) &&
990              symbol_type_rec_assignment_compatible(
991                    SYMBOL_TYPE_STRUCT_OF_CONTAINER(super_rec),
992                    SYMBOL_TYPE_STRUCT_OF_CONTAINER(cast))) {
993           if (++count > 1)
994              return true;
995        }
996     }
997
998     return false;
999  }
1000 #endif
1001
1002 static void symbol_table_node_destroy(Double_List_Node *dnnode);
1003
1004 static inline Symbol_Type_Struct *symbol_type_finalize(Symbol_Type_Struct *s,
1005       Symbol_Table *t);
1006
1007 static void symbol_table_node_merge_remap(Symbol_Table_Node *src,
1008       Symbol_Table_Node *dest);
1009
1010 static void report_missing_finalize(File_Location *loc, const char *curr_type,
1011       Const_String curr_rec, Const_String base_reg_name)
1012 {
1013    if (!cmdopts.warn_no_finalize)
1014       return;
1015
1016    if (base_reg_name) {
1017       report_warning_location(loc, S("record " QFY("%S")
1018                " inherited by %s " QFY("%S")
1019                " does not have a " QFY("finalize") " function\n"),
1020             STRING_AFTER_DOT(base_reg_name),
1021             curr_type,
1022             STRING_AFTER_DOT(curr_rec));
1023    } else {
1024       report_warning_location(loc, S("record inherited by %s " QFY("%S")
1025                " is not defining " QFY("finalize") " function\n"),
1026             curr_type,
1027             STRING_AFTER_DOT(curr_rec));
1028    }
1029 }
1030
1031 static void symbol_type_rec_insert_void_func(Symbol_Type_Rec *rec,
1032       Const_String func_name, String unique_name,
1033       Symbol_Table *t, bool is_concrete)
1034 {
1035    Symbol_Type_Struct *fstruct = symbol_type_func_alloc(t, false);
1036    Symbol_Type_Func *func = SYMBOL_TYPE_STRUCT_CONTAINER(fstruct,
1037          Symbol_Type_Func);
1038    func->return_type = symbol_type_void_alloc(t);
1039    func->body_sym_node = symbol_table_node_alloc_insert(rec->rec_sym_node,
1040          t, SYMBOL_TABLE_NODE_FUNC, NULL);
1041    func->is_resolved = true;
1042    func->is_concrete_func = is_concrete;
1043
1044    symbol_table_node_insert(rec->rec_sym_node, (String)func_name,
1045          unique_name, fstruct, SYMBOL_PROPERTY_FUNC,
1046          &t->null_location);
1047
1048    vector_append(&rec->func_identifiers, unique_name);
1049    vector_append(&rec->func_types, fstruct);
1050 }
1051
1052 static void symbol_type_rec_insert_finalize(Symbol_Type_Rec *rec,
1053       Symbol_Table *t)
1054 {
1055    String del_name = string_from_format(S("%S.finalize"),
1056          rec->unique_name);
1057    rec->missing_finalize_name = del_name;
```

```
1058
1059    symbol_type_rec_insert_void_func(rec, S("finalize"), del_name, t, true);
1060
1061    rec->rec_sym_node->has_finalize_func = true;
1062 }
1063
1064 static void symbol_type_rec_insert_record_func(Symbol_Type_Rec *rec,
1065       Symbol_Table *t, bool is_concrete)
1066 {
1067    String name = string_from_format(S("%S.record"), rec->unique_name);
1068    if (is_concrete)
1069       rec->missing_record_func_name = name;
1070
1071    symbol_type_rec_insert_void_func(rec, S("record"), name, t, is_concrete);
1072    rec->rec_sym_node->has_record_func = is_concrete;
1073 }
1074
1075 static bool symbol_type_rec_has_finalize(Symbol_Type_Rec *rec, Symbol_Table *t)
1076 {
1077    Vector *extend_vec;
1078    Symbol_Type_Struct *super_type;
1079    Symbol_Type_Rec *super_rec;
1080
1081    bool has_finalize = rec->rec_sym_node->has_finalize_func;
1082    if (!has_finalize) {
1083       extend_vec = &rec->extended_types;
1084       VECTOR_FOR_EACH_ENTRY(extend_vec, super_type) {
1085          super_rec = SYMBOL_TYPE_STRUCT_CONTAINER(super_type,
1086                Symbol_Type_Rec);
1087          if (symbol_type_rec_has_finalize(super_rec, t)) {
1088             /* Then we insert a default finalize function. */
1089             has_finalize = true;
1090             symbol_type_rec_insert_finalize(rec, t);
1091             break;
1092          }
1093       }
1094    }
1095
1096    return has_finalize;
1097 }
1098
1099 static bool symbol_type_rec_has_record_func(Symbol_Type_Rec *rec,
1100       Symbol_Table *t)
1101 {
1102    Vector *extend_vec;
1103    Symbol_Type_Struct *super_type;
1104    Symbol_Type_Rec *super_rec;
1105
1106    bool has = rec->rec_sym_node->has_record_func;
1107    if (!has) {
1108       extend_vec = &rec->extended_types;
1109       VECTOR_FOR_EACH_ENTRY(extend_vec, super_type) {
1110          super_rec = SYMBOL_TYPE_STRUCT_CONTAINER(super_type,
1111                Symbol_Type_Rec);
1112          if (symbol_type_rec_has_record_func(super_rec, t)) {
1113             /* Then we insert a default 'record' function. */
1114             has = true;
1115             symbol_type_rec_insert_record_func(rec, t, true);
1116             break;
1117          }
1118       }
1119    }
1120
1121    return has;
1122 }
1123
1124 static Symbol_Type_Struct *symbol_type_rec_insert_base_types(
1125       Symbol_Type_Rec *rec, Symbol_Table *t)
1126 {
1127    if (rec->super_fields_appended)
1128       return SYMBOL_TYPE_STRUCT_OF_CONTAINER(rec);
1129
1130    rec->super_fields_appended = true;
1131
```

```
1132     for (Uns i = 0; i < vector_size(&rec->extended_types); i++) {
1133        Symbol_Type_Struct *base_struct = vector_get(&rec->extended_types, i);
1134        base_struct = symbol_type_finalize(base_struct, t);
1135        vector_set(&rec->extended_types, i, base_struct);
1136     }
1137     for (Uns i = 0; i < vector_size(&rec->func_types); i++) {
1138        Symbol_Type_Struct *func_struct = vector_get(&rec->func_types, i);
1139        func_struct = symbol_type_finalize(func_struct, t);
1140        vector_set(&rec->func_types, i, func_struct);
1141     }
1142     for (Uns i = 0; i < vector_size(&rec->var_types); i++) {
1143        Symbol_Type_Struct *var_struct = vector_get(&rec->var_types, i);
1144        var_struct = symbol_type_finalize(var_struct, t);
1145        vector_set(&rec->var_types, i, var_struct);
1146     }
1147
1148     Vector *extend_vec;
1149     Symbol_Type_Struct *super_type;
1150     Symbol_Type_Rec *super_rec;
1151
1152     Vector parsed_recs = VECTOR_INIT_SIZE(4);
1153     Symbol_Type_Struct *ret = SYMBOL_TYPE_STRUCT_OF_CONTAINER(rec);
1154
1155     Symbol_Table_Node *tmp_node = ___symbol_table_node_alloc(t,
1156           SYMBOL_TABLE_NODE_REC, rec);
1157
1158     /* Insert default 'finalize' function if it's needed. */
1159     symbol_type_rec_has_finalize(rec, t);
1160
1161     /* Insert default function 'record' if it's missing. */
1162     symbol_type_rec_has_record_func(rec, t);
1163
1164     extend_vec = &rec->extended_types;
1165     VECTOR_FOR_EACH_ENTRY(extend_vec, super_type) {
1166        super_rec = SYMBOL_TYPE_STRUCT_CONTAINER(super_type, Symbol_Type_Rec);
1167
1168        bool super_has_finalize = symbol_type_rec_has_finalize(super_rec, t);
1169        if (symbol_type_rec_ambiguous_cast(super_type,
1170              SYMBOL_TYPE_STRUCT_OF_CONTAINER(rec))) {
1171
1172           bool exists = false;
1173           Symbol_Type_Rec *parsed_rec;
1174           VECTOR_FOR_EACH_ENTRY(&parsed_recs, parsed_rec) {
1175              if (parsed_rec == super_rec) {
1176                 exists = true;
1177                 break;
1178              }
1179           }
1180
1181           if (!exists) {
1182              const char *curr_type = get_current_record_type(t);
1183              bool is_merge_table = import_handler_is_merge_table(t);
1184              if (super_rec->rec_name && !is_merge_table) {
1185                 report_error_location(t->current_symbol->location,
1186                       S("%s " QFY("%S")
1187                          " is extending record " QFY("%S")
1188                          " which is inaccessible due to ambiguity\n"),
1189                       curr_type,
1190                       STRING_AFTER_DOT(t->current_symbol->identifier),
1191                       STRING_AFTER_DOT(super_rec->rec_name));
1192              } else if (!is_merge_table) {
1193                 report_error_location(t->current_symbol->location,
1194                       S("%s " QFY("%S")
1195                          " is extending a record "
1196                          " which is inaccessible due to ambiguity\n"),
1197                       curr_type,
1198                       STRING_AFTER_DOT(t->current_symbol->identifier));
1199              }
1200           }
1201        } else if (!super_has_finalize) {
1202           const char *curr_type = get_current_record_type(t);
1203           report_missing_finalize(t->current_symbol->location, curr_type,
1204                 t->current_symbol->identifier, super_rec->rec_name);
1205        }
```

```
1206
1207        if (symbol_type_rec_assignment_compatible(ret,
1208              SYMBOL_TYPE_STRUCT_OF_CONTAINER(super_rec))) {
1209           /* This actually should never happen. */
1210           const char *curr_type = get_current_record_type(t);
1211           Const_String msg;
1212           msg = S("%s " QFY("%S") " is ambiguously extending the "
1213                 "same record twice\n");
1214           report_error_location(t->current_symbol->location,
1215                 msg, curr_type,
1216                 STRING_AFTER_DOT(t->current_symbol->identifier));
1217           ret = symbol_type_unknown_alloc(t);
1218           goto out;
1219        }
1220
1221        symbol_rec_accumulate_super_vars(tmp_node, rec, super_rec, t);
1222        symbol_rec_accumulate_super_funcs(tmp_node, rec, super_rec, t);
1223
1224        vector_append(&parsed_recs, super_type);
1225     }
1226
1227     symbol_type_rec_append_super_vars(rec, tmp_node);
1228     symbol_type_rec_append_super_funcs(rec, tmp_node);
1229
1230  out:
1231     vector_clear(&parsed_recs);
1232     symbol_table_node_destroy(&tmp_node->dbnode);
1233
1234     Symbol_Table_Node *rec_node = rec->rec_sym_node;
1235     Symbol_Func_Map *fmap = symbol_table_node_get_func_map(rec_node,
1236           (String)S("record"), string_hash_code(S("record")));
1237     if (!fmap)
1238        symbol_type_rec_insert_record_func(rec, t, false);
1239
1240     return ret;
1241  }
1242
1243  static Symbol_Type_Struct *symbol_type_func_finalize(Symbol_Type_Func *f,
1244        Symbol_Table *t);
1245
1246  static inline Symbol_Type_Struct *symbol_type_finalize(Symbol_Type_Struct *s,
1247        Symbol_Table *t)
1248  {
1249     Symbol_Type_Ary *ary;
1250     Symbol_Type_Rec *rec;
1251     Symbol_Type_Func *func;
1252     Symbol_Type_Cycle *cycle;
1253     switch (s->methods->get_type()) {
1254     case SYMBOL_TYPE_REC:
1255        rec = SYMBOL_TYPE_STRUCT_CONTAINER(s, Symbol_Type_Rec);
1256        return symbol_type_rec_insert_base_types(rec, t);
1257
1258     case SYMBOL_TYPE_ARY:
1259        ary = SYMBOL_TYPE_STRUCT_CONTAINER(s, Symbol_Type_Ary);
1260        ary->ary_type = symbol_type_finalize(ary->ary_type, t);
1261        return s;
1262
1263     case SYMBOL_TYPE_FUNC:
1264        func = SYMBOL_TYPE_STRUCT_CONTAINER(s, Symbol_Type_Func);
1265        return symbol_type_func_finalize(func, t);
1266
1267     case SYMBOL_TYPE_CYCLE:
1268        cycle = SYMBOL_TYPE_STRUCT_CONTAINER(s, Symbol_Type_Cycle);
1269        return symbol_table_node_lookup(cycle->sym_node, cycle->name,
1270              SYMBOL_PROPERTY_TYPE_DEF)->resolved_type;
1271
1272     default:
1273        return s;
1274     }
1275  }
1276
1277  static Symbol_Type_Struct *symbol_type_func_finalize(Symbol_Type_Func *f,
1278        Symbol_Table *t)
1279  {
```

```
1280     f->return_type = symbol_type_finalize(f->return_type, t);
1281     for (Uns i = 0; i < vector_size(&f->param_types); i++) {
1282        Symbol_Type_Struct *p = vector_get(&f->param_types, i);
1283        p = symbol_type_finalize(p, t);
1284        vector_set(&f->param_types, i, p);
1285     }
1286     return SYMBOL_TYPE_STRUCT_OF_CONTAINER(f);
1287  }
1288
1289  static Symbol_Type_Struct *symbol_type_rec_resolve(Symbol_Type_Struct *self,
1290        Symbol_Table *t)
1291  {
1292     Vector *tmp_vec;
1293     String tmp_str;
1294     Symbol *saved_sym, *sym;
1295     Uns i;
1296     Symbol_Type_Struct *tmp_type;
1297     Symbol_Type_Rec *trec = SYMBOL_TYPE_STRUCT_CONTAINER(self,
1298           Symbol_Type_Rec);
1299
1300     /* Save cycle type such that we can reset it before returning. */
1301     Symbol_Rec_Cycle_Type prev_table_cycle_type = t->rec_cycle_type;
1302     Symbol_Rec_Cycle_Type prev_rec_cycle_type = trec->cycle_mark;
1303
1304     /* Cycle is not allowed in the extended records. */
1305     trec->cycle_mark = t->rec_cycle_type = SYMBOL_REC_CYCLE_NOT_ALLOWED;
1306     i = 0;
1307     tmp_vec = &trec->extended_types;
1308     VECTOR_FOR_EACH_ENTRY(tmp_vec, tmp_type) {
1309        tmp_type = tmp_type->methods->resolve(tmp_type, t);
1310        DEBUGT(def,
1311           if (t->last_resolve_pass)
1312              assert(tmp_type)
1313        );
1314        if (tmp_type) {
1315           tmp_type = symbol_rec_get_extended_type(tmp_type, t);
1316           if (tmp_type->methods->get_type() == SYMBOL_TYPE_UNKNOWN) {
1317              self = symbol_type_unknown_alloc(t);
1318              // goto out;
1319           }
1320           vector_set(tmp_vec, i++, tmp_type);
1321        } else {
1322           self = NULL;
1323           goto out;
1324        }
1325     }
1326
1327     if (self->methods->get_type() == SYMBOL_TYPE_UNKNOWN)
1328        goto out;
1329
1330     if (trec->body_resolved && !t->last_resolve_pass)
1331        goto out;
1332     trec->body_resolved = true;
1333
1334     if (trec->body_resolved_last)
1335        goto out;
1336
1337     if (t->last_resolve_pass)
1338        trec->body_resolved_last = true;
1339
1340     /* Cycle allowed in the functions and variables inside records. */
1341     trec->cycle_mark = t->rec_cycle_type = SYMBOL_REC_CYCLE_ALLOWED;
1342
1343     saved_sym = t->current_symbol;
1344     i = 0;
1345     tmp_vec = &trec->func_identifiers;
1346     VECTOR_FOR_EACH_ENTRY(tmp_vec, tmp_str) {
1347        DLOG("lookup func: %S\n", tmp_str);
1348        sym = symbol_table_node_get(trec->rec_sym_node,
1349              tmp_str, string_hash_code(tmp_str), SYMBOL_PROPERTY_FUNC);
1350        assert(sym);
1351        t->current_symbol = sym;
1352        tmp_type = sym->resolved_type->methods->resolve(
1353              sym->resolved_type, t);
```

```
1354        DEBUGT(def, if (trec->body_resolved_last) assert(tmp_type));
1355
1356        if (tmp_type)
1357           sym->resolved_type = tmp_type;
1358
1359        if (trec->body_resolved_last) {
1360           if (tmp_type->methods->get_type() == SYMBOL_TYPE_CYCLE) {
1361              Symbol_Type_Cycle *cycle = SYMBOL_TYPE_STRUCT_CONTAINER(
1362                    tmp_type, Symbol_Type_Cycle);
1363              sym->resolved_type = symbol_table_node_lookup(
1364                    cycle->sym_node, cycle->name,
1365                    SYMBOL_PROPERTY_TYPE_DEF)->resolved_type;
1366           }
1367           vector_append(&trec->func_types, sym->resolved_type);
1368        }
1369     }
1370
1371     i = 0;
1372     tmp_vec = &trec->var_identifiers;
1373     VECTOR_FOR_EACH_ENTRY(tmp_vec, tmp_str) {
1374        DLOG("lookup var: %S\n", tmp_str);
1375        sym = symbol_table_node_get(trec->rec_sym_node,
1376              tmp_str, string_hash_code(tmp_str), SYMBOL_PROPERTY_VAR);
1377        assert(sym);
1378        t->current_symbol = sym;
1379        tmp_type = sym->resolved_type->methods->resolve(
1380              sym->resolved_type, t);
1381        DEBUGT(def, if (trec->body_resolved_last) assert(tmp_type));
1382        if (tmp_type)
1383           sym->resolved_type = tmp_type;
1384        if (trec->body_resolved_last) {
1385           if (tmp_type->methods->get_type() == SYMBOL_TYPE_CYCLE) {
1386              Symbol_Type_Cycle *cycle = SYMBOL_TYPE_STRUCT_CONTAINER(
1387                    tmp_type, Symbol_Type_Cycle);
1388              sym->resolved_type = symbol_table_node_lookup(
1389                    cycle->sym_node, cycle->name,
1390                    SYMBOL_PROPERTY_TYPE_DEF)->resolved_type;
1391           }
1392           vector_append(&trec->var_types, sym->resolved_type);
1393        }
1394     }
1395
1396     t->current_symbol = saved_sym;
1397
1398  out:
1399     /* Restore the cycle type to whatever it was before this
1400      * function was called. */
1401     t->rec_cycle_type = prev_table_cycle_type;
1402     trec->cycle_mark = prev_rec_cycle_type;
1403     return self;
1404  }
1405
1406  static bool symbol_type_rec_same_type(Symbol_Type_Struct *self,
1407        Symbol_Type_Struct *oth)
1408  {
1409     Hash_Map *rec_comp_map;
1410     Symbol *oth_sym;
1411     Symbol_Type_Rec *oth_rec, *self_rec;
1412     Symbol_Type oth_t = oth->methods->get_type();
1413     bool ret = true;
1414
1415     assert(oth_t != SYMBOL_TYPE_IDEN);
1416
1417     if (oth == self || oth_t == SYMBOL_TYPE_UNKNOWN)
1418        goto out;
1419
1420     self_rec = SYMBOL_TYPE_STRUCT_CONTAINER(self, Symbol_Type_Rec);
1421
1422     if (oth_t == SYMBOL_TYPE_CYCLE) {
1423        Symbol_Type_Cycle *oth_cy =
1424           SYMBOL_TYPE_STRUCT_CONTAINER(oth, Symbol_Type_Cycle);
1425        oth_sym = symbol_table_node_lookup(oth_cy->sym_node,
1426              oth_cy->name, SYMBOL_PROPERTY_TYPE_DEF);
1427        ret = symbol_type_rec_same_type(self, oth_sym->resolved_type);
```

```
1428        goto out;
1429     }
1430
1431     if (oth_t != SYMBOL_TYPE_REC) {
1432        ret = false;
1433        goto out;
1434     }
1435     oth_rec = SYMBOL_TYPE_STRUCT_CONTAINER(oth, Symbol_Type_Rec);
1436
1437     rec_comp_map = self_rec->rec_sym_node->record_comparisons;
1438
1439     Symbol_Rec_Comp_Struct *comp = symbol_rec_comp_struct_alloc(
1440           self_rec, oth_rec);
1441     Symbol_Rec_Comp_Struct *map_comp = symbol_table_get_comp_result(
1442           rec_comp_map, comp);
1443
1444     if (map_comp) {
1445        symbol_rec_comp_struct_destroy(&comp->hash_slot);
1446        if (symbol_rec_comp_struct_get(map_comp) == REC_COMP_DIFFERENT)
1447           ret = false;
1448        else
1449           ret = true;
1450        goto out;
1451     }
1452     symbol_table_insert_comp_result(rec_comp_map, comp);
1453
1454     ret = symbol_type_rec_structs_equal(self_rec, oth_rec);
1455
1456     if (ret)
1457        symbol_rec_comp_struct_set(comp, REC_COMP_SAME);
1458     else
1459        symbol_rec_comp_struct_set(comp, REC_COMP_DIFFERENT);
1460
1461  out:
1462     return ret;
1463  }
1464
1465  static void symbol_type_rec_append_str(Symbol_Type_Struct *self,
1466        String_Builder *sb)
1467  {
1468     Uns vec_size, idx;
1469     Vector *tmp_vec;
1470     Symbol_Type_Struct *tmp_type;
1471     Symbol_Type_Rec *trec =
1472           SYMBOL_TYPE_STRUCT_CONTAINER(self, Symbol_Type_Rec);
1473
1474     string_builder_append(sb, S("record["));
1475     if (trec->rec_name)
1476        string_builder_append(sb, trec->rec_name);
1477
1478     if (trec->append_str_cycle_marked) {
1479        string_builder_append(sb, S("]"));
1480        goto out;
1481     }
1482
1483     trec->append_str_cycle_marked = true;
1484
1485     string_builder_append(sb, S("] "));
1486     string_builder_append(sb, S("of"));
1487
1488     tmp_vec = &trec->extended_types;
1489     vec_size = vector_size(tmp_vec);
1490     if (!vec_size)
1491        goto skip_extend;
1492
1493     string_builder_append(sb, S(" "));
1494     for (idx = 0; idx < vec_size - 1; idx++) {
1495        tmp_type = vector_get(tmp_vec, idx);
1496        tmp_type->methods->append_str(tmp_type, sb);
1497        string_builder_append(sb, S(", "));
1498     }
1499     tmp_type = vector_get(tmp_vec, idx);
1500     tmp_type->methods->append_str(tmp_type, sb);
1501
```

```
1502 skip_extend:
1503    string_builder_append(sb, S(" { "));
1504
1505    tmp_vec = &trec->func_types;
1506    vec_size = vector_size(tmp_vec);
1507    if (!vec_size)
1508       goto skip_funcs;
1509
1510    for (idx = 0; idx < vec_size - 1; idx++) {
1511       tmp_type = vector_get(tmp_vec, idx);
1512       tmp_type->methods->append_str(tmp_type, sb);
1513       string_builder_append(sb, S(", "));
1514    }
1515    tmp_type = vector_get(tmp_vec, idx);
1516    tmp_type->methods->append_str(tmp_type, sb);
1517
1518 skip_funcs:
1519    if (!vector_is_empty(tmp_vec))
1520       string_builder_append(sb, S(", "));
1521
1522    tmp_vec = &trec->var_types;
1523    vec_size = vector_size(tmp_vec);
1524    if (!vec_size)
1525       goto skip_vars;
1526
1527    for (idx = 0; idx < vec_size - 1; idx++) {
1528       tmp_type = vector_get(tmp_vec, idx);
1529       tmp_type->methods->append_str(tmp_type, sb);
1530       string_builder_append(sb, S(", "));
1531    }
1532    tmp_type = vector_get(tmp_vec, idx);
1533    tmp_type->methods->append_str(tmp_type, sb);
1534    string_builder_append(sb, S(" "));
1535
1536    trec->append_str_cycle_marked = false;
1537
1538 skip_vars:
1539    string_builder_append(sb, S("}"));
1540
1541 out:;
1542 }
1543
1544 void symbol_type_rec_append_func_identifier(Symbol_Type_Rec *self,
1545       Const_String iden)
1546 {
1547    DLOG("append: %S\n", iden);
1548    vector_append(&self->func_identifiers, string_duplicate(iden));
1549 }
1550
1551 void symbol_type_rec_append_var_identifier(Symbol_Type_Rec *self,
1552       Const_String iden)
1553 {
1554    vector_append(&self->var_identifiers, string_duplicate(iden));
1555 }
1556
1557 void symbol_type_rec_set_name(Symbol_Type_Rec *self, Const_String name)
1558 {
1559    self->rec_name = string_duplicate(name);
1560 }
1561
1562 void symbol_type_rec_set_unique_name(Symbol_Type_Rec *self,
1563       Const_String unique_name)
1564 {
1565    self->unique_name = string_duplicate(unique_name);
1566 }
1567
1568 static void symbol_type_rec_destroy(Symbol_Type_Struct *self)
1569 {
1570    Symbol_Type_Rec *trec = SYMBOL_TYPE_STRUCT_CONTAINER(self,
1571          Symbol_Type_Rec);
1572    symbol_type_struct_destroy_common(self);
1573
1574    if(trec->rec_name)
1575       string_destroy(trec->rec_name);
```

```
1576
1577     vector_clear(&trec->extended_types);
1578     vector_for_each_destroy(&trec->func_identifiers,
1579           (Vector_Destructor) string_destroy);
1580     vector_clear(&trec->func_types);
1581     vector_for_each_destroy(&trec->var_identifiers,
1582           (Vector_Destructor) string_destroy);
1583     vector_clear(&trec->var_types);
1584
1585     string_destroy(trec->unique_name);
1586
1587     hash_map_for_each_destroy(&trec->ambiguous_refs,
1588           symbol_rec_ambiguous_ref_destroy);
1589
1590     free_mem(trec);
1591 }
1592
1593 static Symbol_Type_Struct_Methods symbol_type_rec_methods = {
1594     .get_type = symbol_type_rec_get_type,
1595     .resolve = symbol_type_rec_resolve,
1596     .append_str = symbol_type_rec_append_str,
1597     .destroy = symbol_type_rec_destroy,
1598     .same_type = symbol_type_rec_same_type
1599 };
1600
1601 Symbol_Type_Struct *symbol_type_rec_alloc(Symbol_Table *t, Uns scope_id,
1602       Const_String unique_name)
1603 {
1604     Symbol_Type_Rec *s = ALLOC_NEW(Symbol_Type_Rec);
1605     s->extended_types = VECTOR_INIT_SIZE(PTR_SIZE);
1606     s->func_identifiers = VECTOR_INIT_SIZE(PTR_SIZE);
1607     s->func_types = VECTOR_INIT_SIZE(PTR_SIZE);
1608     s->var_identifiers = VECTOR_INIT_SIZE(PTR_SIZE);
1609     s->var_types = VECTOR_INIT_SIZE(PTR_SIZE);
1610     s->ambiguous_refs = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_5,
1611           (Hash_Map_Comparator)symbol_rec_ambiguous_ref_compare);
1612     s->rec_name = NULL;
1613     s->cycle_mark = SYMBOL_REC_CYCLE_MARK_NONE;
1614     s->unique_name = string_duplicate(unique_name);
1615     s->scope_id = scope_id;
1616     s->body_resolved = false;
1617     s->body_resolved_last = false;
1618     s->append_str_cycle_marked = false;
1619     s->super_fields_appended = false;
1620     s->imp_table_updated = false;
1621     s->imp_table_name_updated = false;
1622     s->missing_finalize_name = NULL;
1623     s->missing_record_func_name = NULL;
1624     return symbol_type_struct_alloc_finalize(
1625           SYMBOL_TYPE_STRUCT_OF_CONTAINER(s),
1626           &symbol_type_rec_methods, t);
1627 }
1628
1629 /*****************************************************************************/
1630
1631 static Symbol_Type symbol_type_unknown_get_type()
1632 {
1633     return SYMBOL_TYPE_UNKNOWN;
1634 }
1635
1636 static bool symbol_type_unknown_same_type(Symbol_Type_Struct *self UNUSED,
1637       Symbol_Type_Struct *oth UNUSED)
1638 {
1639     return true;
1640 }
1641
1642 static Symbol_Type_Struct *symbol_type_unknown_resolve(
1643       Symbol_Type_Struct *self, Symbol_Table *t UNUSED)
1644 {
1645     return self;
1646 }
1647
1648 static void symbol_type_unknown_append_str(Symbol_Type_Struct *self UNUSED,
1649       String_Builder *sb)
```

```
1650 {
1651    string_builder_append(sb, S("unknown"));
1652 }
1653
1654 static void symbol_type_unknown_destroy(Symbol_Type_Struct *self)
1655 {
1656    Symbol_Type_Unknown *utype = SYMBOL_TYPE_STRUCT_CONTAINER(self,
1657          Symbol_Type_Unknown);
1658    symbol_type_struct_destroy_common(self);
1659    free_mem(utype);
1660 }
1661
1662 static Symbol_Type_Struct_Methods symbol_type_unknown_methods = {
1663    .get_type = symbol_type_unknown_get_type,
1664    .resolve = symbol_type_unknown_resolve,
1665    .append_str = symbol_type_unknown_append_str,
1666    .destroy = symbol_type_unknown_destroy,
1667    .same_type = symbol_type_unknown_same_type
1668 };
1669
1670 Symbol_Type_Struct *symbol_type_unknown_alloc(Symbol_Table *t)
1671 {
1672    if (!t->symbol_type_struct_unknown) {
1673       Symbol_Type_Unknown *s = ALLOC_NEW(Symbol_Type_Unknown);
1674       t->symbol_type_struct_unknown = symbol_type_struct_alloc_finalize(
1675             SYMBOL_TYPE_STRUCT_OF_CONTAINER(s),
1676             &symbol_type_unknown_methods, t);
1677    }
1678    return t->symbol_type_struct_unknown;
1679 }
1680
1681 /*****************************************************************************/
1682
1683 static Symbol_Type symbol_type_bool_get_type()
1684 {
1685    return SYMBOL_TYPE_BOOL;
1686 }
1687
1688 static Symbol_Type_Struct *symbol_type_bool_resolve(
1689       Symbol_Type_Struct *self, Symbol_Table *t UNUSED)
1690 {
1691    return self;
1692 }
1693
1694 static bool symbol_type_bool_same_type(Symbol_Type_Struct *self UNUSED,
1695       Symbol_Type_Struct *oth)
1696 {
1697    Symbol_Type oth_t = oth->methods->get_type();
1698    return oth_t == SYMBOL_TYPE_BOOL || oth_t == SYMBOL_TYPE_UNKNOWN;
1699 }
1700
1701 static void symbol_type_bool_append_str(Symbol_Type_Struct *self UNUSED,
1702       String_Builder *sb)
1703 {
1704    string_builder_append(sb, S("bool"));
1705 }
1706
1707 static void symbol_type_bool_destroy(Symbol_Type_Struct *self)
1708 {
1709    Symbol_Type_Bool *t = SYMBOL_TYPE_STRUCT_CONTAINER(self,
1710          Symbol_Type_Bool);
1711    symbol_type_struct_destroy_common(self);
1712    free_mem(t);
1713 }
1714
1715 static Symbol_Type_Struct_Methods symbol_type_bool_methods = {
1716    .get_type = symbol_type_bool_get_type,
1717    .resolve = symbol_type_bool_resolve,
1718    .append_str = symbol_type_bool_append_str,
1719    .destroy = symbol_type_bool_destroy,
1720    .same_type = symbol_type_bool_same_type
1721 };
1722
1723 Symbol_Type_Struct *symbol_type_bool_alloc(Symbol_Table *t)
```

```
1724 {
1725    if (!t->symbol_type_struct_bool) {
1726       Symbol_Type_Bool *s = ALLOC_NEW(Symbol_Type_Bool);
1727       t->symbol_type_struct_bool = symbol_type_struct_alloc_finalize(
1728             SYMBOL_TYPE_STRUCT_OF_CONTAINER(s),
1729             &symbol_type_bool_methods, t);
1730    }
1731    return t->symbol_type_struct_bool;
1732 }
1733
1734 /*****************************************************************************/
1735
1736 static Symbol_Type symbol_type_char_get_type()
1737 {
1738    return SYMBOL_TYPE_CHAR;
1739 }
1740
1741 static Symbol_Type_Struct *symbol_type_char_resolve(
1742       Symbol_Type_Struct *self, Symbol_Table *t UNUSED)
1743 {
1744    return self;
1745 }
1746
1747 static bool symbol_type_char_same_type(Symbol_Type_Struct *self UNUSED,
1748       Symbol_Type_Struct *oth)
1749 {
1750    Symbol_Type oth_t = oth->methods->get_type();
1751    return oth_t == SYMBOL_TYPE_CHAR || oth_t == SYMBOL_TYPE_UNKNOWN;
1752 }
1753
1754 static void symbol_type_char_append_str(Symbol_Type_Struct *self UNUSED,
1755       String_Builder *sb)
1756 {
1757    string_builder_append(sb, S("char"));
1758 }
1759
1760 static void symbol_type_char_destroy(Symbol_Type_Struct *self)
1761 {
1762    Symbol_Type_Char *t = SYMBOL_TYPE_STRUCT_CONTAINER(self,
1763          Symbol_Type_Char);
1764    symbol_type_struct_destroy_common(self);
1765    free_mem(t);
1766 }
1767
1768 static Symbol_Type_Struct_Methods symbol_type_char_methods = {
1769    .get_type = symbol_type_char_get_type,
1770    .resolve = symbol_type_char_resolve,
1771    .append_str = symbol_type_char_append_str,
1772    .destroy = symbol_type_char_destroy,
1773    .same_type = symbol_type_char_same_type
1774 };
1775
1776 Symbol_Type_Struct *symbol_type_char_alloc(Symbol_Table *t)
1777 {
1778    if (!t->symbol_type_struct_char) {
1779       Symbol_Type_Char *s = ALLOC_NEW(Symbol_Type_Char);
1780       t->symbol_type_struct_char = symbol_type_struct_alloc_finalize(
1781             SYMBOL_TYPE_STRUCT_OF_CONTAINER(s),
1782             &symbol_type_char_methods, t);
1783    }
1784    return t->symbol_type_struct_char;
1785 }
1786
1787 Symbol_Type_Rec *symbol_type_rec_assignment_compatible(
1788       Symbol_Type_Struct *rec_struct, Symbol_Type_Struct *oth_struct)
1789 {
1790    Symbol_Type_Rec *ret = NULL;
1791    Vector *extended_records;
1792
1793    if (rec_struct->methods->same_type(rec_struct, oth_struct)) {
1794       ret = SYMBOL_TYPE_STRUCT_CONTAINER(oth_struct, Symbol_Type_Rec);
1795       goto out;
1796    }
1797
```

```
1798     extended_records = &SYMBOL_TYPE_STRUCT_CONTAINER(oth_struct,
1799           Symbol_Type_Rec)->extended_types;
1800     VECTOR_FOR_EACH_ENTRY(extended_records, oth_struct)
1801        if ((ret = symbol_type_rec_assignment_compatible(rec_struct,
1802                oth_struct)))
1803           break;
1804  out:
1805     return ret;
1806  }
1807
1808  /*****************************************************************************/
1809
1810  static Symbol_Type symbol_type_string_get_type()
1811  {
1812     return SYMBOL_TYPE_STRING;
1813  }
1814
1815  static Symbol_Type_Struct *symbol_type_string_resolve(
1816        Symbol_Type_Struct *self, Symbol_Table *t UNUSED)
1817  {
1818     return self;
1819  }
1820
1821  static bool symbol_type_string_same_type(Symbol_Type_Struct *self UNUSED,
1822        Symbol_Type_Struct *oth)
1823  {
1824     Symbol_Type oth_t = oth->methods->get_type();
1825     return oth_t == SYMBOL_TYPE_STRING || oth_t == SYMBOL_TYPE_UNKNOWN;
1826  }
1827
1828  static void symbol_type_string_append_str(Symbol_Type_Struct *self UNUSED,
1829        String_Builder *sb)
1830  {
1831     string_builder_append(sb, S("string"));
1832  }
1833
1834  static void symbol_type_string_destroy(Symbol_Type_Struct *self)
1835  {
1836     Symbol_Type_String *t = SYMBOL_TYPE_STRUCT_CONTAINER(self,
1837           Symbol_Type_String);
1838     symbol_type_struct_destroy_common(self);
1839     free_mem(t);
1840  }
1841
1842  static Symbol_Type_Struct_Methods symbol_type_string_methods = {
1843     .get_type = symbol_type_string_get_type,
1844     .resolve = symbol_type_string_resolve,
1845     .append_str = symbol_type_string_append_str,
1846     .destroy = symbol_type_string_destroy,
1847     .same_type = symbol_type_string_same_type
1848  };
1849
1850  Symbol_Type_Struct *symbol_type_string_alloc(Symbol_Table *t)
1851  {
1852     if (!t->symbol_type_struct_string) {
1853        Symbol_Type_String *s = ALLOC_NEW(Symbol_Type_String);
1854        t->symbol_type_struct_string = symbol_type_struct_alloc_finalize(
1855              SYMBOL_TYPE_STRUCT_OF_CONTAINER(s),
1856              &symbol_type_string_methods, t);
1857     }
1858     return t->symbol_type_struct_string;
1859  }
1860
1861  /*****************************************************************************/
1862
1863  static Symbol_Type symbol_type_ary_get_type()
1864  {
1865     return SYMBOL_TYPE_ARY;
1866  }
1867
1868  static Symbol_Type_Struct *symbol_type_ary_resolve(
1869        Symbol_Type_Struct *self, Symbol_Table *t)
1870  {
1871     Symbol_Type_Struct *tmp_t;
```

```
1872
1873        Symbol_Type_Ary *ary = SYMBOL_TYPE_STRUCT_CONTAINER(self, Symbol_Type_Ary);
1874
1875        tmp_t = ary->ary_type->methods->resolve(ary->ary_type, t);
1876        if (tmp_t) {
1877            ary->ary_type = tmp_t;
1878            if (tmp_t->methods->get_type() == SYMBOL_TYPE_UNKNOWN)
1879                self = symbol_type_unknown_alloc(t);
1880        } else {
1881            assert(!t->last_resolve_pass);
1882            self = NULL;
1883        }
1884
1885        return self;
1886    }
1887
1888    static bool symbol_type_ary_same_type(Symbol_Type_Struct *self,
1889            Symbol_Type_Struct *oth)
1890    {
1891        Symbol *oth_sym;
1892        Symbol_Type_Ary *self_ary, *oth_ary;
1893        Symbol_Type oth_t = oth->methods->get_type();
1894        bool ret = true;
1895
1896        if (self == oth || oth_t == SYMBOL_TYPE_UNKNOWN)
1897            goto out;
1898
1899        self_ary = SYMBOL_TYPE_STRUCT_CONTAINER(self, Symbol_Type_Ary);
1900
1901        if (oth_t == SYMBOL_TYPE_ARY) {
1902            oth_ary = SYMBOL_TYPE_STRUCT_CONTAINER(oth, Symbol_Type_Ary);
1903            ret = self_ary->ary_type->methods->same_type(self_ary->ary_type,
1904                    oth_ary->ary_type);
1905        } else if (oth_t == SYMBOL_TYPE_CYCLE) {
1906            Symbol_Type_Cycle *oth_cy =
1907                SYMBOL_TYPE_STRUCT_CONTAINER(oth, Symbol_Type_Cycle);
1908            oth_sym = symbol_table_node_lookup(oth_cy->sym_node,
1909                    oth_cy->name, SYMBOL_PROPERTY_TYPE_DEF);
1910            ret = symbol_type_ary_same_type(self, oth_sym->resolved_type);
1911        } else {
1912            ret = false;
1913        }
1914    out:
1915        return ret;
1916    }
1917
1918    static void symbol_type_ary_append_str(Symbol_Type_Struct *self,
1919            String_Builder *sb)
1920    {
1921        Symbol_Type_Ary *t = SYMBOL_TYPE_STRUCT_CONTAINER(self, Symbol_Type_Ary);
1922        if (t->dump_cycle_marked) {
1923            string_builder_append(sb, S("array cycle"));
1924        } else {
1925            t->dump_cycle_marked = true;
1926            string_builder_append(sb, S("array of "));
1927            t->ary_type->methods->append_str(t->ary_type, sb);
1928            t->dump_cycle_marked = false;
1929        }
1930    }
1931
1932    void symbol_type_ary_set_name(Symbol_Type_Ary *self, String name)
1933    {
1934        String new_name = NULL;
1935        if(name)
1936            new_name = string_duplicate(name);
1937
1938        if(self->ary_name)
1939            string_destroy(self->ary_name);
1940
1941        self->ary_name = new_name;
1942    }
1943
1944    static void symbol_type_ary_destroy(Symbol_Type_Struct *self)
1945    {
```

```
1946     Symbol_Type_Ary *t = SYMBOL_TYPE_STRUCT_CONTAINER(self,
1947           Symbol_Type_Ary);
1948     if(t->ary_name)
1949        string_destroy(t->ary_name);
1950
1951     symbol_type_struct_destroy_common(self);
1952     free_mem(t);
1953  }
1954
1955  static Symbol_Type_Struct_Methods symbol_type_ary_methods = {
1956     .get_type = symbol_type_ary_get_type,
1957     .resolve = symbol_type_ary_resolve,
1958     .append_str = symbol_type_ary_append_str,
1959     .destroy = symbol_type_ary_destroy,
1960     .same_type = symbol_type_ary_same_type
1961  };
1962
1963  Symbol_Type_Struct *symbol_type_ary_alloc(Symbol_Table *t,
1964        Symbol_Type_Struct *ary_type, Uns scope_id)
1965  {
1966     Symbol_Type_Ary *s = ALLOC_NEW(Symbol_Type_Ary);
1967     s->ary_type = ary_type;
1968     s->dump_cycle_marked = false;
1969     s->ary_name = NULL;
1970     s->scope_id = scope_id;
1971     s->imp_table_updated = false;
1972     return symbol_type_struct_alloc_finalize(
1973           SYMBOL_TYPE_STRUCT_OF_CONTAINER(s),
1974           &symbol_type_ary_methods, t);
1975  }
1976
1977  /*****************************************************************************/
1978
1979  static Symbol_Type symbol_type_func_get_type()
1980  {
1981     return SYMBOL_TYPE_FUNC;
1982  }
1983
1984  static Symbol_Type_Struct *symbol_type_func_resolve(
1985        Symbol_Type_Struct *self, Symbol_Table *t)
1986  {
1987     Vector *tmp_vec;
1988     String tmp_str;
1989     Symbol *saved_sym, *sym;
1990     Symbol_Type_Struct *tmp_type;
1991     Symbol_Type_Func *tfunc = SYMBOL_TYPE_STRUCT_CONTAINER(self,
1992           Symbol_Type_Func);
1993
1994     if (tfunc->is_resolved)
1995        goto out;
1996
1997     if (t->last_resolve_pass)
1998        tfunc->is_resolved = true;
1999
2000     tmp_type = tfunc->return_type->methods->resolve(tfunc->return_type, t);
2001     if (tmp_type)
2002        tfunc->return_type = tmp_type;
2003     else
2004        assert(!tfunc->is_resolved);
2005
2006     saved_sym = t->current_symbol;
2007
2008     tmp_vec = &tfunc->param_identifiers;
2009     VECTOR_FOR_EACH_ENTRY(tmp_vec, tmp_str) {
2010        DLOG("lookup param: %S\n", tmp_str);
2011        sym = symbol_table_node_get(tfunc->body_sym_node,
2012              tmp_str, string_hash_code(tmp_str), SYMBOL_PROPERTY_VAR);
2013        assert(sym);
2014
2015        t->current_symbol = sym;
2016
2017        tmp_type = sym->resolved_type->methods->resolve(
2018              sym->resolved_type, t);
2019
```

```
2020        DEBUGT(def,
2021           if (tfunc->is_resolved)
2022              assert(tmp_type)
2023        );
2024
2025        if (tmp_type) {
2026           sym->resolved_type = tmp_type;
2027           DLOG("parameter: %d\n", tmp_type->methods->get_type());
2028        }
2029
2030        if (tfunc->is_resolved) {
2031           if (tmp_type->methods->get_type() == SYMBOL_TYPE_CYCLE) {
2032              Symbol_Type_Cycle *cycle = SYMBOL_TYPE_STRUCT_CONTAINER(
2033                    tmp_type, Symbol_Type_Cycle);
2034              sym->resolved_type = symbol_table_node_lookup(
2035                    cycle->sym_node, cycle->name,
2036                    SYMBOL_PROPERTY_TYPE_DEF)->resolved_type;
2037           }
2038           vector_append(&tfunc->param_types, sym->resolved_type);
2039           DLOG("last func pass. Num params: %U\n",
2040                 vector_size(&tfunc->param_types));
2041        }
2042     }
2043     t->current_symbol = saved_sym;
2044
2045  out:
2046     return self;
2047  }
2048
2049  static bool symbol_type_func_same_type(Symbol_Type_Struct *self,
2050        Symbol_Type_Struct *oth)
2051  {
2052     Symbol_Type_Func *self_func, *oth_func;
2053     Symbol_Type oth_t = oth->methods->get_type();
2054     bool ret = true;
2055     if (oth_t == SYMBOL_TYPE_UNKNOWN)
2056        goto out;
2057     if (oth_t != SYMBOL_TYPE_FUNC) {
2058        ret = false;
2059        goto out;
2060     }
2061     self_func = SYMBOL_TYPE_STRUCT_CONTAINER(self, Symbol_Type_Func);
2062     oth_func = SYMBOL_TYPE_STRUCT_CONTAINER(oth, Symbol_Type_Func);
2063
2064     assert(self_func->is_resolved);
2065     assert(oth_func->is_resolved);
2066
2067     if (self_func->compare_return_type) {
2068        assert(oth_func->compare_return_type);
2069        if (!self_func->return_type->methods->same_type(self_func->return_type,
2070                  oth_func->return_type)) {
2071           ret = false;
2072           goto out;
2073        }
2074     }
2075
2076     /* No comparison of parameter names. */
2077     if (!symbol_type_vectors_same_type(&self_func->param_types,
2078           &oth_func->param_types)) {
2079        ret = false;
2080        goto out;
2081     }
2082
2083  out:
2084     return ret;
2085  }
2086
2087  static void symbol_type_func_append_str(Symbol_Type_Struct *self,
2088        String_Builder *sb)
2089  {
2090     Uns vec_size, idx;
2091     Vector *tmp_vec;
2092     Symbol_Type_Struct *tmp_type;
2093     Symbol_Type_Func *tfunc =
```

```
2094            SYMBOL_TYPE_STRUCT_CONTAINER(self, Symbol_Type_Func);
2095
2096    if (tfunc->is_extern_c)
2097        string_builder_append(sb, S("extern (C) func ( "));
2098    else
2099        string_builder_append(sb, S("func ( "));
2100
2101    tmp_vec = &tfunc->param_types;
2102    vec_size = vector_size(tmp_vec);
2103
2104    if (!vec_size)
2105        goto skip_params;
2106
2107    for (idx = 0; idx < vec_size - 1; idx++) {
2108        tmp_type = vector_get(tmp_vec, idx);
2109        tmp_type->methods->append_str(tmp_type, sb);
2110        string_builder_append(sb, S(", "));
2111    }
2112    tmp_type = vector_get(tmp_vec, idx);
2113    tmp_type->methods->append_str(tmp_type, sb);
2114
2115skip_params:
2116    string_builder_append(sb, S(" ) : "));
2117
2118    tfunc->return_type->methods->append_str(tfunc->return_type, sb);
2119}
2120
2121void symbol_type_func_append_param_identifier(Symbol_Type_Func *self,
2122        String iden)
2123{
2124    vector_append(&self->param_identifiers, string_duplicate(iden));
2125}
2126
2127static void symbol_type_func_destroy(Symbol_Type_Struct *self)
2128{
2129    Symbol_Type_Func *t = SYMBOL_TYPE_STRUCT_CONTAINER(self,
2130          Symbol_Type_Func);
2131    symbol_type_struct_destroy_common(self);
2132    vector_for_each_destroy(&t->param_identifiers,
2133          (Vector_Destructor) string_destroy);
2134    vector_clear(&t->param_types);
2135
2136    free_mem(t);
2137}
2138
2139static Symbol_Type_Struct_Methods symbol_type_func_methods = {
2140    .get_type = symbol_type_func_get_type,
2141    .resolve = symbol_type_func_resolve,
2142    .append_str = symbol_type_func_append_str,
2143    .destroy = symbol_type_func_destroy,
2144    .same_type = symbol_type_func_same_type
2145};
2146
2147Symbol_Type_Struct *symbol_type_func_alloc(Symbol_Table *t, bool is_extern_c)
2148{
2149    Symbol_Type_Func *s = ALLOC_NEW(Symbol_Type_Func);
2150    s->param_identifiers = VECTOR_INIT_SIZE(4);
2151    s->param_types = VECTOR_INIT_SIZE(4);
2152    s->is_resolved = false;
2153    s->compare_return_type = true;
2154    s->is_extern_c = is_extern_c;
2155    s->main_err_int_reported = false;
2156    s->main_param_err_reported = false;
2157    s->imp_table_updated = false;
2158    s->is_concrete_func = true;
2159    return symbol_type_struct_alloc_finalize(
2160          SYMBOL_TYPE_STRUCT_OF_CONTAINER(s),
2161          &symbol_type_func_methods, t);
2162}
2163
2164/*****************************************************************************/
2165
2166static Symbol_Type symbol_type_cycle_get_type()
2167{
```

```
2168     return SYMBOL_TYPE_CYCLE;
2169  }
2170
2171  static Symbol_Type_Struct *symbol_type_cycle_resolve(
2172        Symbol_Type_Struct *self, Symbol_Table *t UNUSED)
2173  {
2174     return self;
2175  }
2176
2177  static bool symbol_type_cycle_same_type(Symbol_Type_Struct *self,
2178        Symbol_Type_Struct *oth)
2179  {
2180     Symbol *oth_sym;
2181     Symbol_Type oth_t = oth->methods->get_type();
2182     bool ret = true;
2183
2184     if (oth_t == SYMBOL_TYPE_UNKNOWN)
2185        goto out;
2186
2187     if (oth_t == SYMBOL_TYPE_CYCLE) {
2188        Symbol_Type_Cycle *oth_cy =
2189           SYMBOL_TYPE_STRUCT_CONTAINER(oth, Symbol_Type_Cycle);
2190        oth_sym = symbol_table_node_lookup(oth_cy->sym_node,
2191              oth_cy->name, SYMBOL_PROPERTY_TYPE_DEF);
2192        ret = oth_sym->resolved_type->methods->same_type(
2193              oth_sym->resolved_type, self);
2194     } else {
2195        ret = oth->methods->same_type(oth, self);
2196     }
2197
2198  out:
2199     return ret;
2200  }
2201
2202  static void symbol_type_cycle_append_str(Symbol_Type_Struct *self UNUSED,
2203        String_Builder *sb)
2204  {
2205     Symbol_Type_Cycle *s = SYMBOL_TYPE_STRUCT_CONTAINER(self,
2206           Symbol_Type_Cycle);
2207     string_builder_append(sb, S("cycle["));
2208     string_builder_append(sb, s->name);
2209     string_builder_append(sb, S("]"));
2210  }
2211
2212  static void symbol_type_cycle_destroy(Symbol_Type_Struct *self)
2213  {
2214     Symbol_Type_Cycle *t = SYMBOL_TYPE_STRUCT_CONTAINER(self,
2215           Symbol_Type_Cycle);
2216     symbol_type_struct_destroy_common(self);
2217     free_mem(t);
2218  }
2219
2220  static Symbol_Type_Struct_Methods symbol_type_cycle_methods = {
2221     .get_type = symbol_type_cycle_get_type,
2222     .resolve = symbol_type_cycle_resolve,
2223     .append_str = symbol_type_cycle_append_str,
2224     .destroy = symbol_type_cycle_destroy,
2225     .same_type = symbol_type_cycle_same_type
2226  };
2227
2228  Symbol_Type_Struct *symbol_type_cycle_alloc(Symbol_Table *t, String name)
2229  {
2230     Symbol_Type_Cycle *s = ALLOC_NEW(Symbol_Type_Cycle);
2231     s->name = name;
2232     s->scope_id = t->current_sym_table_node->scope_id;
2233     s->sym_node = t->current_sym_table_node;
2234     return symbol_type_struct_alloc_finalize(
2235           SYMBOL_TYPE_STRUCT_OF_CONTAINER(s),
2236           &symbol_type_cycle_methods, t);
2237  }
2238
2239  /*****************************************************************************/
2240
2241  /*****************************************************************************/
```

```
2242
2243 bool symbol_rec_comp_struct_compare(Symbol_Rec_Comp_Struct *search_comp,
2244       Hash_Map_Slot *map_slot)
2245 {
2246    Symbol_Rec_Comp_Struct *map_comp = SYMBOL_REC_COMP_STRUCT_OF(map_slot);
2247    return (map_comp->rec1 == search_comp->rec1 &&
2248          map_comp->rec2 == search_comp->rec2) ||
2249
2250          (map_comp->rec2 == search_comp->rec1 &&
2251          (map_comp->rec1 == search_comp->rec2));
2252 }
2253
2254 void symbol_rec_comp_struct_destroy(Hash_Map_Slot *slot)
2255 {
2256    Symbol_Rec_Comp_Struct *c = SYMBOL_REC_COMP_STRUCT_OF(slot);
2257    free_mem(c);
2258 }
2259
2260 bool ___symbol_map_comparator(String search_iden, Hash_Map_Slot *slot)
2261 {
2262    Symbol *map_sym = SYMBOL_OF_SLOT(slot);
2263    return !string_compare(search_iden, map_sym->identifier);
2264 }
2265
2266 static inline void symbol_destroy(Symbol *sym)
2267 {
2268    if (sym->unique_name)
2269       string_destroy(sym->unique_name);
2270    string_destroy(sym->identifier);
2271    free_mem(sym);
2272 }
2273
2274 static void symbol_dblist_destroy(Double_List_Node *n)
2275 {
2276    symbol_destroy(&TYPE_DEF_SYMBOL_OF_DBNODE(n)->symbol);
2277 }
2278
2279 static void symbol_hash_destructor(Hash_Map_Slot *slot)
2280 {
2281    Symbol *sym = SYMBOL_OF_SLOT(slot);
2282    symbol_destroy(sym);
2283 }
2284
2285 static void type_def_symbol_hash_destructor(Hash_Map_Slot *slot)
2286 {
2287
2288    Symbol *sym = SYMBOL_OF_SLOT(slot);
2289    double_list_for_each_destroy(&TYPE_DEF_SYMBOL_OF_SYMBOL(sym)->dbnode,
2290          symbol_dblist_destroy);
2291    symbol_destroy(sym);
2292 }
2293
2294 static void symbol_type_destructor(Double_List_Node *n)
2295 {
2296    Symbol_Type_Struct *t = SYMBOL_TYPE_STRUCT_OF_DBNODE(n);
2297    t->methods->destroy(t);
2298 }
2299
2300 static void symbol_table_node_destroy(Double_List_Node *dbnode)
2301 {
2302    Hash_Map *map;
2303    Symbol_Table_Node *n = SYMBOL_TABLE_NODE_OF(dbnode);
2304    map = &n->symbol_maps[SYMBOL_PROPERTY_TYPE_DEF];
2305    hash_map_for_each_destroy(map, type_def_symbol_hash_destructor);
2306    map = &n->symbol_maps[SYMBOL_PROPERTY_FUNC];
2307    hash_map_for_each_destroy(map, symbol_hash_destructor);
2308    map = &n->symbol_maps[SYMBOL_PROPERTY_VAR];
2309    hash_map_for_each_destroy(map, symbol_hash_destructor);
2310    vector_for_each_destroy(&n->import_dependencies,
2311          (Vector_Destructor) string_destroy);
2312    vector_clear(&n->import_dependencies_loc);
2313    hash_map_for_each_destroy(&n->func_iden_map, symbol_func_map_hash_destroy);
2314    hash_map_for_each_destroy(&n->func_remaps, symbol_func_remap_hash_destroy);
2315    free_mem(n);
```

```
2316 }
2317
2318 void symbol_table_clear(Symbol_Table *t)
2319 {
2320    double_list_for_each_destroy(&t->all_nodes, symbol_table_node_destroy);
2321    double_list_for_each_destroy(&t->all_symbol_types, symbol_type_destructor);
2322    vector_for_each_destroy(&t->location_names,
2323          (Vector_Destructor)string_destroy);
2324    hash_map_for_each_destroy(&t->record_comparisons,
2325          (Hash_Map_Destructor)symbol_rec_comp_struct_destroy);
2326    t->symbol_type_struct_bool = NULL;
2327    t->symbol_type_struct_char = NULL;
2328    t->symbol_type_struct_int = NULL;
2329    t->symbol_type_struct_string = NULL;
2330    t->symbol_type_struct_unknown = NULL;
2331 }
2332
2333
2334 void symbol_table_dump(Symbol_Table *t, Const_String prefix)
2335 {
2336    Double_List *list;
2337    Double_List_Node *dbnode;
2338    Symbol_Table_Node *n;
2339    Hash_Map_Slot *slot;
2340    Hash_Map *map;
2341    Symbol *sym;
2342    String_Builder sb;
2343
2344    String dumpf = string_from_format(S("%S.vitaly.symbol-table"), prefix);
2345    FILE *stream = file_open(dumpf, S("w"));
2346    if (!stream) {
2347       report_error(prefix, S("Unable to open file %S for symbol "
2348             "table dump [%m]\n"), dumpf);
2349       goto out_dumpf;
2350    }
2351
2352    sb = STRING_BUILDER_INIT();
2353    list = &t->all_nodes;
2354
2355    DOUBLE_LIST_FOR_EACH(list, dbnode) {
2356       n = SYMBOL_TABLE_NODE_OF(dbnode);
2357
2358       map = &n->symbol_maps[SYMBOL_PROPERTY_TYPE_DEF];
2359       file_print_message(stream, S("--------------------------------"
2360             "------------------------------------------------\n"));
2361       file_print_message(stream, S("Node: %p | Parent: %p\n"),
2362             n, n->parent);
2363       file_print_message(stream, S("--------------------------------"
2364             "------------------------------------------------\n\n"));
2365       HASH_MAP_FOR_EACH(map, slot) {
2366          sym = SYMBOL_OF_SLOT(slot);
2367          string_builder_assign(&sb, S("type "));
2368          string_builder_append(&sb, sym->identifier);
2369          string_builder_append(&sb, S(" => "));
2370          sym->resolved_type->methods->append_str(
2371                sym->resolved_type, &sb);
2372          string_builder_append(&sb, S("\n"));
2373          file_print_message(stream, S("%S\n"),
2374                string_builder_const_str(&sb));
2375       }
2376       map = &n->symbol_maps[SYMBOL_PROPERTY_FUNC];
2377       HASH_MAP_FOR_EACH(map, slot) {
2378          sym = SYMBOL_OF_SLOT(slot);
2379          string_builder_assign(&sb, S("func "));
2380          string_builder_append(&sb, sym->identifier);
2381          string_builder_append(&sb, S(" => "));
2382          sym->resolved_type->methods->append_str(
2383                sym->resolved_type, &sb);
2384          string_builder_append(&sb, S("\n"));
2385          file_print_message(stream, S("%S\n"),
2386                string_builder_const_str(&sb));
2387       }
2388       map = &n->symbol_maps[SYMBOL_PROPERTY_VAR];
2389       HASH_MAP_FOR_EACH(map, slot) {
```

```
2390            sym = SYMBOL_OF_SLOT(slot);
2391            string_builder_assign(&sb, S("var "));
2392            string_builder_append(&sb, sym->identifier);
2393            string_builder_append(&sb, S(" => "));
2394            sym->resolved_type->methods->append_str(
2395                  sym->resolved_type, &sb);
2396            string_builder_append(&sb, S("\n"));
2397            file_print_message(stream, S("%S\n"),
2398                  string_builder_const_str(&sb));
2399         }
2400      }
2401      file_print_message(stream, S("--------------------------------"
2402            "--------------------------------------------------\n"));
2403      string_builder_clear(&sb);
2404
2405      file_close(stream);
2406
2407   out_dumpf:
2408      string_destroy(dumpf);
2409   }
2410
2411   void symbol_table_dump_graph(Symbol_Table *t, Const_String file_prefix)
2412   {
2413      Dot_Printer *printer = dot_printer_init(file_prefix,
2414            S("vitaly.symbol-table"), S("BT"));
2415      Symbol_Table_Node *n;
2416      Hash_Map_Slot *slot;
2417      Hash_Map *map;
2418      Symbol *sym;
2419      String tmp_str;
2420      Const_String node_type;
2421      String_Builder sb = STRING_BUILDER_INIT();
2422      Double_List_Node *dbnode;
2423      Double_List *list = &t->all_nodes;
2424      DOUBLE_LIST_FOR_EACH(list, dbnode) {
2425         n = SYMBOL_TABLE_NODE_OF(dbnode);
2426
2427         switch (n->type) {
2428         case SYMBOL_TABLE_NODE_GLOBAL:
2429            node_type = S("GLOBAL SCOPE");
2430            break;
2431         case SYMBOL_TABLE_NODE_IMPORT:
2432            node_type = S("IMPORT SCOPE");
2433            break;
2434         case SYMBOL_TABLE_NODE_FUNC:
2435            node_type = S("FUNCTION SCOPE");
2436            break;
2437         case SYMBOL_TABLE_NODE_INTERMEDIATE:
2438            node_type = S("INTERMEDIATE SCOPE");
2439            break;
2440         case SYMBOL_TABLE_NODE_REC:
2441            node_type = S("RECORD SCOPE");
2442            break;
2443         default:
2444            fatal_error(S("unexpected symbol table node type for "
2445                  "symbol table graph dump\n"));
2446         }
2447
2448         dot_printer_insert_relation(printer, n, n->parent);
2449         dot_printer_begin_table(printer, n, 2);
2450         map = &n->symbol_maps[SYMBOL_PROPERTY_TYPE_DEF];
2451         dot_printer_insert_merge_row(printer, node_type);
2452         dot_printer_insert_merge_row(printer, S("Type definitions:"));
2453         HASH_MAP_FOR_EACH(map, slot) {
2454            string_builder_assign(&sb, S(""));
2455            sym = SYMBOL_OF_SLOT(slot);
2456            sym->resolved_type->methods->append_str(
2457                  sym->resolved_type, &sb);
2458            tmp_str = string_from_format(S("type %S"), sym->identifier);
2459            dot_printer_insert_row(printer, 2,
2460                  tmp_str, string_builder_const_str(&sb));
2461            string_destroy(tmp_str);
2462
2463            Double_List_Node *dbnode;
```

```
2464            Type_Def_Symbol *td_sym = TYPE_DEF_SYMBOL_OF_SYMBOL(sym);
2465            DOUBLE_LIST_FOR_EACH(&td_sym->dbnode, dbnode) {
2466               sym = (Symbol *) TYPE_DEF_SYMBOL_OF_DBNODE(dbnode);
2467               if (sym->resolved_type) {
2468                  string_builder_assign(&sb, S(""));
2469                  sym->resolved_type->methods->append_str(
2470                        sym->resolved_type, &sb);
2471                  tmp_str = string_from_format(S("type %S"), sym->identifier);
2472                  dot_printer_insert_row(printer, 2,
2473                        tmp_str, string_builder_const_str(&sb));
2474                  string_destroy(tmp_str);
2475               }
2476            }
2477         }
2478         map = &n->symbol_maps[SYMBOL_PROPERTY_FUNC];
2479         dot_printer_insert_merge_row(printer, S("Functions:"));
2480         HASH_MAP_FOR_EACH(map, slot) {
2481            string_builder_assign(&sb, S(""));
2482            sym = SYMBOL_OF_SLOT(slot);
2483            sym->resolved_type->methods->append_str(
2484                  sym->resolved_type, &sb);
2485            tmp_str = string_from_format(S("func %S"), sym->identifier);
2486            dot_printer_insert_row(printer, 2,
2487                 tmp_str, string_builder_const_str(&sb));
2488            string_destroy(tmp_str);
2489         }
2490         map = &n->symbol_maps[SYMBOL_PROPERTY_VAR];
2491         dot_printer_insert_merge_row(printer, S("Variables:"));
2492         HASH_MAP_FOR_EACH(map, slot) {
2493            string_builder_assign(&sb, S(""));
2494            sym = SYMBOL_OF_SLOT(slot);
2495            sym->resolved_type->methods->append_str(
2496                  sym->resolved_type, &sb);
2497            tmp_str = string_from_format(S("var %S"), sym->identifier);
2498            dot_printer_insert_row(printer, 2,
2499                  tmp_str, string_builder_const_str(&sb));
2500            string_destroy(tmp_str);
2501         }
2502         dot_printer_end_table(printer);
2503      }
2504      string_builder_clear(&sb);
2505      dot_printer_fin_com_des(printer, S("pdf"));
2506   }
2507
2508   static void symbol_table_node_resolve_type_def(Symbol_Table_Node *n,
2509         Symbol_Table *t)
2510   {
2511      Hash_Map_Slot *slot;
2512      Hash_Map *map;
2513      Symbol *sym;
2514      Type_Def_Symbol *td_sym;
2515
2516      map = &n->symbol_maps[SYMBOL_PROPERTY_TYPE_DEF];
2517      t->current_resolve_property = SYMBOL_PROPERTY_TYPE_DEF;
2518      HASH_MAP_FOR_EACH(map, slot) {
2519         sym = SYMBOL_OF_SLOT(slot);
2520         t->current_symbol = sym;
2521         td_sym = TYPE_DEF_SYMBOL_OF_SYMBOL(sym);
2522         td_sym->report_cycle = true;
2523         sym->resolved_type = ___type_def_symbol_resolve(td_sym, t);
2524         td_sym->report_cycle = false;
2525      }
2526
2527      t->last_resolve_pass = true;
2528      HASH_MAP_FOR_EACH(map, slot) {
2529         sym = SYMBOL_OF_SLOT(slot);
2530         t->current_symbol = sym;
2531         td_sym = TYPE_DEF_SYMBOL_OF_SYMBOL(sym);
2532         td_sym->report_cycle = true;
2533         sym->resolved_type = ___type_def_symbol_resolve(td_sym, t);
2534         td_sym->report_cycle = false;
2535
2536         /* We are not destroying all of the type def symbols.
2537          * The first element of the list (td_sym) is not destroyed. */
```

```
2538        double_list_for_each_destroy(&td_sym->dbnode,
2539              symbol_dblist_destroy);
2540        sym->resolved_type = symbol_type_finalize(sym->resolved_type, t);
2541     }
2542     t->last_resolve_pass = false;
2543  }
2544
2545  static inline bool symbol_func_same(Symbol *lhs, Symbol *rhs)
2546  {
2547     Symbol_Type_Struct *tmp;
2548     Symbol_Type_Func *lhs_f, *rhs_f;
2549
2550     if (lhs->resolved_type->methods->get_type() == SYMBOL_TYPE_UNKNOWN ||
2551           rhs->resolved_type->methods->get_type() == SYMBOL_TYPE_UNKNOWN)
2552        return false;
2553
2554     lhs_f = SYMBOL_TYPE_STRUCT_CONTAINER(lhs->resolved_type, Symbol_Type_Func);
2555     rhs_f = SYMBOL_TYPE_STRUCT_CONTAINER(rhs->resolved_type, Symbol_Type_Func);
2556
2557     Vector *v = &lhs_f->param_types;
2558     VECTOR_FOR_EACH_ENTRY(v, tmp) {
2559        if (tmp->methods->get_type() == SYMBOL_TYPE_UNKNOWN)
2560           return false;
2561     }
2562
2563     v = &rhs_f->param_types;
2564     VECTOR_FOR_EACH_ENTRY(v, tmp) {
2565        if (tmp->methods->get_type() == SYMBOL_TYPE_UNKNOWN)
2566           return false;
2567     }
2568
2569  #if 0
2570     if (lhs_f->is_extern_c && rhs_f->is_extern_c)
2571        return true;
2572  #endif
2573
2574     lhs_f->compare_return_type = false;
2575     rhs_f->compare_return_type = false;
2576
2577     bool ret = lhs->resolved_type->methods->same_type(lhs->resolved_type,
2578              rhs->resolved_type);
2579
2580     lhs_f->compare_return_type = true;
2581     rhs_f->compare_return_type = true;
2582
2583     return ret;
2584  }
2585
2586  static void symbol_func_report_errors(Vector *err, bool is_main)
2587  {
2588     if (vector_is_empty(err))
2589        return;
2590
2591     Symbol *fsym = vector_peek_first(err);
2592     STRING(loc_str, "");
2593
2594     Const_String func_name = STRING_AFTER_LAST(fsym->identifier, '.');
2595     assert(func_name);
2596
2597     File_Location *err_location;
2598
2599     inline void import_report_main()
2600     {
2601        report_error_location(err_location,
2602              S("multiple declarations of " QFY("%S")
2603                 " function imported from:\n%S"),
2604              func_name, loc_str);
2605     }
2606
2607     inline void import_report_vit()
2608     {
2609        if (!string_is_empty(loc_str))
2610           report_error_location(err_location,
2611                 S("conflicting declarations of function " QFY("%S")
```

```
2612                    " imported from:\n%S"),
2613                func_name, loc_str);
2614    }
2615
2616    inline void import_report_c()
2617    {
2618       report_error_location(err_location,
2619             S("conflicting declarations of " QFY("extern(C)")
2620                " function " QFY("%S") " imported from:\n%S"),
2621             func_name, loc_str);
2622    }
2623
2624    inline void report_main()
2625    {
2626       report_error_location(err_location,
2627             S("conflicting declarations of " QFY("%S") " function"
2628                " here:\n%S"),
2629             func_name, loc_str);
2630    }
2631
2632    inline void report_vit()
2633    {
2634       report_error_location(err_location,
2635             S("conflicting declarations of function " QFY("%S")
2636                " involving:\n%S"),
2637             func_name, loc_str);
2638    }
2639
2640    inline void report_c()
2641    {
2642       report_error_location(err_location,
2643             S("conflicting declarations of " QFY("extern(C)")
2644                " function " QFY("%S") " here:\n%S"),
2645             func_name, loc_str);
2646    }
2647
2648    bool is_extern_c_report = true;
2649
2650    inline void set_error_strings(bool use_location) {
2651       VECTOR_FOR_EACH_ENTRY(err, fsym) {
2652          assert(fsym->resolved_type->methods->get_type() ==
2653                SYMBOL_TYPE_FUNC);
2654
2655          Symbol_Type_Func *func = SYMBOL_TYPE_STRUCT_CONTAINER(
2656                fsym->resolved_type, Symbol_Type_Func);
2657
2658          assert(fsym->resolved_type->methods->get_type() ==
2659                SYMBOL_TYPE_FUNC);
2660          if (!func->is_extern_c)
2661             is_extern_c_report = false;
2662
2663          err_location = fsym->location;
2664
2665          if (use_location) {
2666             string_append_format(loc_str, S("\t%F\n"), fsym->location);
2667          } else {
2668             String s = string_between_alloc(fsym->unique_name, '.');
2669             string_append_format(loc_str, S("\t%S\n"), s);
2670             string_destroy(s);
2671          }
2672       }
2673    }
2674
2675    if (symbol_get_symbol_table_node_type(fsym) ==
2676          SYMBOL_TABLE_NODE_IMPORT) {
2677       set_error_strings(false);
2678       if (is_main) {
2679          import_report_main();
2680       } else {
2681          if (is_extern_c_report)
2682             import_report_c();
2683          else
2684             import_report_vit();
2685       }
```

```
2686     } else {
2687        set_error_strings(true);
2688        if (is_main) {
2689           report_main();
2690        } else {
2691           if (is_extern_c_report)
2692              report_c();
2693           else
2694              report_vit();
2695        }
2696     }
2697     string_clear(loc_str);
2698  }
2699
2700  static void symbol_func_append_errors(Symbol_Func_Map *func_map,
2701        Vector *errors)
2702  {
2703     Vector *vec = &func_map->overload_idens;
2704
2705     inline void append_symbols(Symbol *lhs, Symbol *rhs)
2706     {
2707        Symbol_Type_Func *lhs_f = SYMBOL_TYPE_STRUCT_CONTAINER(
2708              lhs->resolved_type, Symbol_Type_Func);
2709        Symbol_Type_Func *rhs_f = SYMBOL_TYPE_STRUCT_CONTAINER(
2710              rhs->resolved_type, Symbol_Type_Func);
2711
2712        Vector *err;
2713        Symbol *tmp;
2714        Symbol_Type_Func *tmp_f;
2715
2716  #if 0
2717        if (lhs_f->is_extern_c && rhs_f->is_extern_c)
2718           return;
2719  #endif
2720
2721        if (lhs_f->is_extern_c && rhs_f->is_extern_c) {
2722           if (lhs_f->return_type->methods->same_type(
2723                 lhs_f->return_type, rhs_f->return_type))
2724              return;
2725
2726           VECTOR_FOR_EACH_ENTRY(errors, err) {
2727              tmp = vector_get(err, 0);
2728              tmp_f = SYMBOL_TYPE_STRUCT_CONTAINER(
2729                    tmp->resolved_type, Symbol_Type_Func);
2730              if (tmp_f->is_extern_c) {
2731                 if (!vector_contains_ptr(err, lhs))
2732                    vector_append(err, lhs);
2733                 if (!vector_contains_ptr(err, rhs))
2734                    vector_append(err, rhs);
2735                 return;
2736              }
2737           }
2738        } else {
2739           VECTOR_FOR_EACH_ENTRY(errors, err) {
2740              tmp = vector_get(err, 0);
2741              if (symbol_func_same(tmp, lhs)) {
2742                 if (!vector_contains_ptr(err, lhs))
2743                    vector_append(err, lhs);
2744                 if (!vector_contains_ptr(err, rhs))
2745                    vector_append(err, rhs);
2746                 return;
2747              }
2748           }
2749        }
2750        err = vector_alloc_size(4);
2751        vector_append(errors, err);
2752        vector_append(err, lhs);
2753        vector_append(err, rhs);
2754     }
2755
2756     Uns size = vector_size(vec);
2757     for (Uns i = 0; i < size; i++) {
2758        Symbol *lhs = vector_get(vec, i);
2759
```

```
2760        if (lhs->resolved_type->methods->get_type() == SYMBOL_TYPE_UNKNOWN)
2761           continue;
2762        assert(lhs->resolved_type->methods->get_type() == SYMBOL_TYPE_FUNC);
2763
2764        for (Uns j = i + 1; j < size; j++) {
2765           Symbol *rhs = vector_get(vec, j);
2766           if (rhs->resolved_type->methods->get_type() == SYMBOL_TYPE_UNKNOWN)
2767              continue;
2768
2769           assert(rhs->resolved_type->methods->get_type() ==
2770                 SYMBOL_TYPE_FUNC);
2771
2772           Symbol_Type_Func *lhs_f, *rhs_f;
2773           lhs_f = SYMBOL_TYPE_STRUCT_CONTAINER(lhs->resolved_type,
2774                 Symbol_Type_Func);
2775           rhs_f = SYMBOL_TYPE_STRUCT_CONTAINER(rhs->resolved_type,
2776                 Symbol_Type_Func);
2777
2778           if (lhs_f->body_sym_node->parent != rhs_f->body_sym_node->parent)
2779              continue;
2780
2781           if (!file_location_cmp(lhs->location, rhs->location))
2782              continue;
2783
2784           if (symbol_func_same(lhs, rhs))
2785              append_symbols(lhs, rhs);
2786        }
2787     }
2788  }
2789
2790  void symbol_func_map_compare(Symbol_Func_Map *func_map, Symbol_Table *t)
2791  {
2792     if (func_map->is_verified)
2793        return;
2794     if (import_handler_is_merge_table(t))
2795        return;
2796     func_map->is_verified = true;
2797
2798     VECTOR(errors); // Vector of vectors
2799
2800     Vector *vec = &func_map->overload_idens;
2801     if (!string_compare(MAIN_FUNC_STR, func_map->func_iden)) {
2802        assert(!vector_is_empty(vec));
2803        Symbol *sym = vector_get(vec, 0);
2804        if (vector_size(vec) > 1 &&
2805              !string_compare(MAIN_FUNC_STR, sym->identifier)) {
2806           symbol_func_report_errors(&func_map->overload_idens, true);
2807           goto out;
2808        }
2809     }
2810
2811     symbol_func_append_errors(func_map, &errors);
2812
2813     Vector *err;
2814     VECTOR_FOR_EACH_ENTRY(&errors, err)
2815        symbol_func_report_errors(err, false);
2816
2817     void symbol_error_func_destructor(void *vec)
2818     {
2819        Vector *v = vec;
2820        Symbol *fsym;
2821        VECTOR_FOR_EACH_ENTRY(v, fsym)
2822           fsym->resolved_type = symbol_type_unknown_alloc(t);
2823        vector_destroy(v, NULL);
2824     }
2825
2826  out:
2827     vector_for_each_destroy(&errors, symbol_error_func_destructor);
2828  }
2829
2830  static void symbol_table_node_resolve_func(Symbol_Table_Node *n,
2831        Symbol_Table *t)
2832  {
2833     Hash_Map_Slot *slot;
```

```
2834     Hash_Map *map;
2835     Symbol *sym;
2836
2837     t->current_resolve_property = SYMBOL_PROPERTY_FUNC;
2838     map = &n->symbol_maps[SYMBOL_PROPERTY_FUNC];
2839     HASH_MAP_FOR_EACH(map, slot) {
2840        sym = SYMBOL_OF_SLOT(slot);
2841        t->current_symbol = sym;
2842        sym->resolved_type = ___symbol_resolve(sym, t);
2843     }
2844
2845     t->last_resolve_pass = true;
2846     map = &n->symbol_maps[SYMBOL_PROPERTY_FUNC];
2847     HASH_MAP_FOR_EACH(map, slot) {
2848        sym = SYMBOL_OF_SLOT(slot);
2849        t->current_symbol = sym;
2850        sym->resolved_type = ___symbol_resolve(sym, t);
2851        sym->resolved_type = symbol_type_finalize(sym->resolved_type, t);
2852     }
2853
2854     t->last_resolve_pass = false;
2855
2856     if (n->type == SYMBOL_TABLE_NODE_IMPORT)
2857        return;
2858
2859     map = &n->func_iden_map;
2860     HASH_MAP_FOR_EACH(map, slot) {
2861        Symbol_Func_Map *func_map = SYMBOL_FUNC_MAP_OF(slot);
2862        symbol_func_map_compare(func_map, t);
2863     }
2864  }
2865
2866  static void symbol_table_node_resolve_var(Symbol_Table_Node *n,
2867        Symbol_Table *t)
2868  {
2869     Hash_Map_Slot *slot;
2870     Hash_Map *map;
2871     Symbol *sym;
2872
2873     t->current_resolve_property = SYMBOL_PROPERTY_VAR;
2874     map = &n->symbol_maps[SYMBOL_PROPERTY_VAR];
2875     HASH_MAP_FOR_EACH(map, slot) {
2876        sym = SYMBOL_OF_SLOT(slot);
2877        t->current_symbol = sym;
2878        sym->resolved_type = ___symbol_resolve(sym, t);
2879     }
2880
2881     t->last_resolve_pass = true;
2882     map = &n->symbol_maps[SYMBOL_PROPERTY_VAR];
2883     HASH_MAP_FOR_EACH(map, slot) {
2884        sym = SYMBOL_OF_SLOT(slot);
2885        t->current_symbol = sym;
2886        sym->resolved_type = ___symbol_resolve(sym, t);
2887        sym->resolved_type = symbol_type_finalize(sym->resolved_type, t);
2888     }
2889
2890     t->last_resolve_pass = false;
2891  }
2892
2893  static void symbol_table_node_resolve(Symbol_Table_Node *n, Symbol_Table *t)
2894  {
2895     t->current_sym_table_node = n;
2896
2897     symbol_table_node_resolve_type_def(n, t);
2898     symbol_table_node_resolve_func(n, t);
2899     symbol_table_node_resolve_var(n, t);
2900  }
2901
2902  void symbol_table_resolve(Symbol_Table *t)
2903  {
2904     Double_List_Node *n;
2905     Double_List *list = &t->all_nodes;
2906     DOUBLE_LIST_FOR_EACH(list, n)
2907        symbol_table_node_resolve(SYMBOL_TABLE_NODE_OF(n), t);
```

```
2908 }
2909
2910 static void symbol_init(Symbol *sym,
2911       File_Location *loc,
2912       Symbol_Type_Struct *type,
2913       Const_String iden,
2914       Const_String unique_name,
2915       Symbol_Table_Node *sym_node)
2916 {
2917    sym->location = loc;
2918    sym->resolved_type = type;
2919    if(unique_name)
2920       sym->unique_name = string_duplicate(unique_name);
2921    else
2922       sym->unique_name = NULL;
2923    sym->sym_node = sym_node;
2924    sym->identifier = string_duplicate(iden);
2925 }
2926
2927 void ___symbol_table_node_insert(Symbol_Table_Node *node,
2928       Const_String iden, Const_String unique_name, Uns hash_code,
2929       Symbol_Type_Struct *type, Symbol_Property property,
2930       File_Location *loc)
2931 {
2932    Symbol *symbol;
2933    if (property == SYMBOL_PROPERTY_TYPE_DEF) {
2934       Type_Def_Symbol *type_def_sym = ALLOC_NEW(Type_Def_Symbol);
2935       type_def_sym->cycle_marked = false;
2936       type_def_sym->report_cycle = false;
2937
2938       symbol = &type_def_sym->symbol;
2939
2940       Symbol *dup = symbol_table_node_get(node,
2941             (String)iden, hash_code, property);
2942
2943       if (!dup) {
2944          type_def_sym->dbnode = DOUBLE_LIST_INIT(type_def_sym->dbnode);
2945          hash_map_insert(&node->symbol_maps[property],
2946                &symbol->hash_slot, hash_code);
2947       } else {
2948          double_list_append(&TYPE_DEF_SYMBOL_OF_SYMBOL(dup)->dbnode,
2949                &type_def_sym->dbnode);
2950       }
2951
2952    } else if (property == SYMBOL_PROPERTY_FUNC) {
2953       Symbol_Func_Map *fmap;
2954       Hash_Map_Slot *fslot = hash_map_get(&node->func_iden_map,
2955             (String)iden, hash_code);
2956
2957       if (fslot) {
2958          fmap = SYMBOL_FUNC_MAP_OF(fslot);
2959       } else {
2960          fmap = symbol_func_map_alloc(iden, node);
2961          hash_map_insert(&node->func_iden_map, &fmap->hash_slot, hash_code);
2962       }
2963
2964       symbol = ALLOC_NEW(Symbol);
2965       vector_append(&fmap->overload_idens, symbol);
2966       iden = unique_name;
2967       hash_code = string_hash_code(iden);
2968       hash_map_insert(&node->symbol_maps[property],
2969             &symbol->hash_slot, hash_code);
2970    } else {
2971       if (symbol_table_node_get(node, (String)iden,
2972                hash_code, property))
2973          assert(!symbol_table_node_get(node, (String)iden,
2974                   hash_code, property));
2975       symbol = ALLOC_NEW(Symbol);
2976       hash_map_insert(&node->symbol_maps[property],
2977             &symbol->hash_slot, hash_code);
2978    }
2979
2980    symbol_init(symbol, loc, type, iden, unique_name, node);
2981 }
```

```
2982
2983  static inline String symbol_table_get_name_from(File_Location *loc)
2984  {
2985     return string_from_format(S("%U.%U"), loc->line, loc->column);
2986  }
2987
2988  static inline String symbol_table_get_unique_name_from(Const_String prefix,
2989        File_Location *loc)
2990  {
2991     return string_from_format(S("%S.%U.%U"), prefix, loc->line, loc->column);
2992  }
2993
2994  void ___symbol_table_insert_location(Symbol_Table *t, Symbol_Table_Node *node,
2995        Const_String prefix, Symbol_Type_Struct *type, File_Location *loc,
2996        Symbol_Property property)
2997  {
2998     assert(property != SYMBOL_PROPERTY_FUNC);
2999
3000     String name = symbol_table_get_name_from(loc);
3001     Uns hash = string_hash_code(name);
3002
3003     assert(!symbol_table_node_get(node, name, string_hash_code(name),
3004           property));
3005
3006     String unique_name = symbol_table_get_unique_name_from(prefix, loc);
3007     vector_append(&t->location_names, name);
3008     DLOG("insert %S in %p\n", name, node);
3009     ___symbol_table_node_insert(node, name, unique_name, hash, type,
3010           property, loc);
3011     string_destroy(unique_name);
3012  }
3013
3014  void symbol_table_insert_location(Symbol_Table *t, Symbol_Table_Node *node,
3015        Const_String prefix, Symbol_Type_Struct *type, File_Location *loc)
3016  {
3017     ___symbol_table_insert_location(t, node, prefix, type, loc,
3018           SYMBOL_PROPERTY_VAR);
3019  }
3020
3021  Symbol *___symbol_table_get_from_location(Symbol_Table_Node *node,
3022        File_Location *loc, Symbol_Property property)
3023  {
3024     String name = symbol_table_get_name_from(loc);
3025     DLOG("get %S in %p\n", name, node);
3026     Symbol *sym = symbol_table_node_get(node, name, string_hash_code(name),
3027           property);
3028     assert(sym);
3029     string_destroy(name);
3030     return sym;
3031  }
3032
3033  Symbol *symbol_table_get_from_location(Symbol_Table_Node *node,
3034        File_Location *loc)
3035  {
3036     return ___symbol_table_get_from_location(node, loc, SYMBOL_PROPERTY_VAR);
3037  }
3038
3039  void symbol_table_node_insert(Symbol_Table_Node *node,
3040        Const_String iden, Const_String unique_name,
3041        Symbol_Type_Struct *type, Symbol_Property property,
3042        File_Location *loc)
3043  {
3044     Uns hash = string_hash_code(iden);
3045     DLOG("insert: %S\n", iden);
3046     assert(!hash_map_contains(&node->symbol_maps[property],
3047              (String)iden, hash));
3048     ___symbol_table_node_insert(node, iden, unique_name,
3049           hash, type, property, loc);
3050  }
3051
3052  Symbol_Func_Map *___symbol_table_node_lookup_func_map(
3053        Symbol_Table_Node *sym_node, String iden, Uns hash_code)
3054  {
3055     Symbol_Func_Map *fmap;
```

```
3056     for (;;) {
3057        fmap = symbol_table_node_get_func_map(sym_node, iden, hash_code);
3058        if (fmap)
3059           break;
3060        sym_node = sym_node->parent;
3061        if (!sym_node)
3062           goto out;
3063     }
3064
3065  out:
3066     return fmap;
3067  }
3068
3069  Symbol *___symbol_table_node_lookup(Symbol_Table_Node *sym_node,
3070        String iden, Uns hash_code, Symbol_Property property)
3071  {
3072     Symbol *sym;
3073     for (;;) {
3074        sym = symbol_table_node_get(sym_node, iden, hash_code, property);
3075        if (sym)
3076           break;
3077        sym_node = sym_node->parent;
3078        if (!sym_node)
3079           goto out;
3080     }
3081
3082     if (sym->resolved_type->methods->get_type() == SYMBOL_TYPE_CYCLE) {
3083        Symbol_Type_Cycle *cycle = SYMBOL_TYPE_STRUCT_CONTAINER(
3084              sym->resolved_type, Symbol_Type_Cycle);
3085        Symbol *tmp = ___symbol_table_node_lookup(cycle->sym_node, cycle->name,
3086              string_hash_code(cycle->name), SYMBOL_PROPERTY_TYPE_DEF);
3087        sym->resolved_type = tmp->resolved_type;
3088     }
3089
3090  out:
3091     return sym;
3092  }
3093
3094  static HASH_MAP(hash_map, pointer_hash_map_compare);
3095
3096  static Symbol_Table_Node *symbol_table_node_copy_hash_insert_node(
3097        Symbol_Table *table, Symbol_Table_Node *old_node, Vector *needed_nodes)
3098  {
3099     Pointer_Slot *ps, *lookup;
3100     Hash_Map_Slot *slot = hash_map_get(&hash_map, old_node,
3101           hash_map_aligned_ptr_hash(old_node));
3102
3103     if (!slot) {
3104        slot = hash_map_get(&hash_map, old_node->parent,
3105              hash_map_aligned_ptr_hash(old_node->parent));
3106        assert(slot);
3107        lookup = POINTER_SLOT_OF(slot);
3108        ps = ALLOC_NEW(Pointer_Slot);
3109        ps->key = old_node;
3110        ps->val = symbol_table_node_alloc_insert(lookup->val, table,
3111              old_node->type, old_node->node_rec);
3112        hash_map_insert(&hash_map, &ps->slot,
3113              hash_map_aligned_ptr_hash(ps->key));
3114        vector_append(needed_nodes, ps->key);
3115        return ps->val;
3116     } else {
3117        lookup = POINTER_SLOT_OF(slot);
3118        return lookup->val;
3119     }
3120  }
3121
3122  static HASH_MAP(type_hash, pointer_hash_map_compare);
3123
3124  static void type_hash_insert(void *key, void *val)
3125  {
3126     Pointer_Slot *ps = ALLOC_NEW(Pointer_Slot);
3127     ps->key = key;
3128     ps->val = val;
3129     hash_map_insert(&type_hash, &ps->slot, hash_map_aligned_ptr_hash(ps->key));
```

```
3130 }
3131
3132 static void *type_hash_get(void *key)
3133 {
3134    Hash_Map_Slot *slot;
3135    slot = hash_map_get(&type_hash, key, hash_map_aligned_ptr_hash(key));
3136    if (!slot)
3137       return NULL;
3138    Pointer_Slot *ps = POINTER_SLOT_OF(slot);
3139    return ps->val;
3140 }
3141
3142 static void type_hash_clear()
3143 {
3144    hash_map_for_each_destroy(&type_hash, pointer_hash_map_destructor);
3145 }
3146
3147 Symbol_Type_Struct *symbol_table_insert_symbol_type(Symbol_Table *table,
3148       Symbol_Type_Struct *type_struct, Vector *needed_nodes,
3149       bool use_unique_name)
3150 {
3151    Vector *tmp_vec;
3152    Symbol_Type_Struct *ret = NULL, *tmp_type;
3153    Symbol_Type type = type_struct->methods->get_type();
3154    String tmp_str;
3155    Pointer_Slot *ps;
3156    Hash_Map_Slot *slot;
3157    switch (type) {
3158       case SYMBOL_TYPE_VOID:
3159          ret = symbol_type_void_alloc(table);
3160          break;
3161       case SYMBOL_TYPE_INT:
3162          ret = symbol_type_int_alloc(table);
3163          break;
3164       case SYMBOL_TYPE_BOOL:
3165          ret = symbol_type_bool_alloc(table);
3166          break;
3167       case SYMBOL_TYPE_CHAR:
3168          ret = symbol_type_char_alloc(table);
3169          break;
3170       case SYMBOL_TYPE_STRING:
3171          ret = symbol_type_string_alloc(table);
3172          break;
3173       case SYMBOL_TYPE_UNKNOWN:
3174          ret = symbol_type_unknown_alloc(table);
3175          break;
3176       case SYMBOL_TYPE_ARY:;
3177          Symbol_Type_Ary *old_ary, *new_ary;
3178          old_ary = SYMBOL_TYPE_STRUCT_CONTAINER(type_struct,
3179                Symbol_Type_Ary);
3180          if ((ret = type_hash_get(old_ary)))
3181             break;
3182          Symbol_Type_Struct *ary_type = symbol_table_insert_symbol_type(
3183                table, old_ary->ary_type, needed_nodes, use_unique_name);
3184          ret = symbol_type_ary_alloc(table, ary_type, old_ary->scope_id);
3185          new_ary = SYMBOL_TYPE_STRUCT_CONTAINER(ret, Symbol_Type_Ary);
3186          type_hash_insert(old_ary, new_ary);
3187          symbol_type_ary_set_name(new_ary, old_ary->ary_name);
3188          break;
3189       case SYMBOL_TYPE_REC:;
3190          Symbol_Type_Rec *old_rec, *new_rec;
3191          old_rec = SYMBOL_TYPE_STRUCT_CONTAINER(type_struct,
3192                Symbol_Type_Rec);
3193
3194          if ((ret = type_hash_get(old_rec)))
3195             break;
3196
3197          ret = symbol_type_rec_alloc(table, old_rec->scope_id,
3198                old_rec->unique_name);
3199          new_rec = SYMBOL_TYPE_STRUCT_CONTAINER(ret, Symbol_Type_Rec);
3200
3201          type_hash_insert(old_rec, new_rec);
3202
3203          if (old_rec->rec_name) {
```

```
3204            if (use_unique_name) {
3205               Const_String uname = SYMBOL_TYPE_REC_TYPE_NAME(old_rec);
3206               symbol_type_rec_set_name(new_rec, uname);
3207            } else {
3208               symbol_type_rec_set_name(new_rec, old_rec->rec_name);
3209            }
3210         }
3211
3212         new_rec->rec_sym_node = symbol_table_node_copy_hash_insert_node(
3213               table, old_rec->rec_sym_node, needed_nodes);
3214
3215         new_rec->super_fields_appended = old_rec->super_fields_appended;
3216
3217         new_rec->body_resolved = old_rec->body_resolved;
3218         new_rec->body_resolved_last = old_rec->body_resolved_last;
3219
3220         tmp_vec = &old_rec->extended_types;
3221         VECTOR_FOR_EACH_ENTRY(tmp_vec, tmp_type)
3222            vector_append(&new_rec->extended_types,
3223                  symbol_table_insert_symbol_type(table, tmp_type,
3224                     needed_nodes, use_unique_name));
3225
3226         tmp_vec = &old_rec->func_identifiers;
3227         VECTOR_FOR_EACH_ENTRY(tmp_vec, tmp_str)
3228            symbol_type_rec_append_func_identifier(new_rec, tmp_str);
3229
3230         tmp_vec = &old_rec->var_identifiers;
3231         VECTOR_FOR_EACH_ENTRY(tmp_vec, tmp_str)
3232            symbol_type_rec_append_var_identifier(new_rec, tmp_str);
3233
3234         tmp_vec = &old_rec->var_types;
3235         VECTOR_FOR_EACH_ENTRY(tmp_vec, tmp_type)
3236            vector_append(&new_rec->var_types,
3237                  symbol_table_insert_symbol_type(table, tmp_type,
3238                        needed_nodes, use_unique_name));
3239
3240         tmp_vec = &old_rec->func_types;
3241         VECTOR_FOR_EACH_ENTRY(tmp_vec, tmp_type)
3242            vector_append(&new_rec->func_types,
3243                  symbol_table_insert_symbol_type(table, tmp_type,
3244                        needed_nodes, use_unique_name));
3245
3246         break;
3247
3248      case SYMBOL_TYPE_FUNC:;
3249         Symbol_Type_Func *new_func, *old_func;
3250         old_func = SYMBOL_TYPE_STRUCT_CONTAINER(type_struct,
3251               Symbol_Type_Func);
3252
3253         if ((ret = type_hash_get(old_func)))
3254            break;
3255
3256         ret = symbol_type_func_alloc(table, old_func->is_extern_c);
3257         new_func = SYMBOL_TYPE_STRUCT_CONTAINER(ret,
3258               Symbol_Type_Func);
3259
3260         type_hash_insert(old_func, new_func);
3261
3262         new_func->body_sym_node =
3263            symbol_table_node_copy_hash_insert_node(table,
3264                  old_func->body_sym_node, needed_nodes);
3265
3266         new_func->is_resolved = old_func->is_resolved;
3267         new_func->is_concrete_func = old_func->is_concrete_func;
3268
3269         tmp_vec = &old_func->param_identifiers;
3270         VECTOR_FOR_EACH_ENTRY(tmp_vec, tmp_str)
3271            symbol_type_func_append_param_identifier(new_func, tmp_str);
3272
3273         tmp_vec = &old_func->param_types;
3274         VECTOR_FOR_EACH_ENTRY(tmp_vec, tmp_type)
3275            vector_append(&new_func->param_types,
3276                  symbol_table_insert_symbol_type(table, tmp_type,
3277                        needed_nodes, use_unique_name));
```

```
3278
3279            new_func->return_type = symbol_table_insert_symbol_type(table,
3280                  old_func->return_type, needed_nodes, use_unique_name);
3281            break;
3282         case SYMBOL_TYPE_CYCLE:;
3283            assert(0);
3284            Symbol_Type_Cycle *old_cycle = SYMBOL_TYPE_STRUCT_CONTAINER(
3285                  type_struct, Symbol_Type_Cycle);
3286            ret = symbol_type_cycle_alloc(table, old_cycle->name);
3287            Symbol_Type_Cycle *new_cycle = SYMBOL_TYPE_STRUCT_CONTAINER(ret,
3288                  Symbol_Type_Cycle);
3289            new_cycle->sym_node = symbol_table_node_copy_hash_insert_node(
3290                  table, old_cycle->sym_node, needed_nodes);
3291            new_cycle->scope_id = new_cycle->sym_node->scope_id;
3292            break;
3293         case SYMBOL_TYPE_IDEN:;
3294            Symbol_Type_Iden *new_iden;
3295            Symbol_Type_Iden *old_iden = SYMBOL_TYPE_STRUCT_CONTAINER(
3296                  type_struct, Symbol_Type_Iden);
3297
3298            ret = symbol_type_iden_alloc(table, old_iden->iden);
3299
3300            new_iden = SYMBOL_TYPE_STRUCT_CONTAINER(ret, Symbol_Type_Iden);
3301
3302            slot = hash_map_get(&hash_map, old_iden->sym_node,
3303                  hash_map_aligned_ptr_hash(old_iden->sym_node));
3304            assert(slot);
3305            ps = POINTER_SLOT_OF(slot);
3306            new_iden->sym_node = ps->val;
3307
3308            new_iden->loc = old_iden->loc;
3309            break;
3310         default:
3311            assert(false);
3312      }
3313      return ret;
3314   }
3315
3316   bool symbol_table_node_insert_symbol(Symbol_Table *table,
3317         Symbol_Table_Node *node, Symbol *sym, bool use_unique_name,
3318         Symbol_Property property)
3319   {
3320      bool ret;
3321      Vector needed_nodes = VECTOR_INIT();
3322      ret = ___symbol_table_node_insert_symbol(table, node, sym, use_unique_name,
3323            property, &needed_nodes);
3324      symbol_table_node_copy_needed_nodes(table, &needed_nodes, use_unique_name);
3325      symbol_table_node_copy_hash_clear();
3326      vector_for_each_destroy(&needed_nodes, NULL);
3327      return ret;
3328   }
3329
3330   /* Tries to insert symbol, returns true on success otherwise */
3331   bool ___symbol_table_node_insert_symbol(Symbol_Table *table,
3332         Symbol_Table_Node *node, Symbol *sym, bool use_unique_name,
3333         Symbol_Property property, Vector *needed_nodes)
3334   {
3335      Uns hash;
3336      bool ret;
3337      Symbol_Type_Struct *type = NULL;
3338      String new_sym_name;
3339      Symbol *dup;
3340
3341      if (property == SYMBOL_PROPERTY_FUNC)
3342         new_sym_name = string_duplicate(STRING_AFTER_DOT(sym->identifier));
3343      else if (use_unique_name)
3344         new_sym_name = string_duplicate(sym->unique_name);
3345      else
3346         new_sym_name = string_duplicate(sym->identifier);
3347
3348      hash = string_hash_code(new_sym_name);
3349      if (hash_map_contains(&node->symbol_maps[property], new_sym_name, hash)
3350            && property == SYMBOL_PROPERTY_VAR) {
3351         ret = false;
```

```
3352        assert(false);
3353        goto out;
3354     }
3355
3356     if (property == SYMBOL_PROPERTY_TYPE_DEF) {
3357        Type_Def_Symbol *tsym = TYPE_DEF_SYMBOL_OF_SYMBOL(sym);
3358        Double_List *list = &tsym->dbnode;
3359        Double_List_Node *dbnode;
3360        DOUBLE_LIST_FOR_EACH(list, dbnode) {
3361           dup = (Symbol *) TYPE_DEF_SYMBOL_OF_DBNODE(dbnode);
3362           assert(dup->resolved_type);
3363           type = symbol_table_insert_symbol_type(table,
3364                 dup->resolved_type, needed_nodes, use_unique_name);
3365
3366           ___symbol_table_node_insert(node, new_sym_name, dup->unique_name,
3367                 hash, type, property, dup->location);
3368        }
3369
3370     }
3371
3372     assert(sym->resolved_type);
3373     type = symbol_table_insert_symbol_type(table, sym->resolved_type,
3374           needed_nodes, use_unique_name);
3375
3376     ___symbol_table_node_insert(node, new_sym_name, sym->unique_name,
3377           hash, type, property, sym->location);
3378
3379     ret = true;
3380  out:
3381     string_destroy(new_sym_name);
3382     return ret;
3383  }
3384
3385  static void symbol_table_node_merge_remap(Symbol_Table_Node *src,
3386        Symbol_Table_Node *dest)
3387  {
3388     Symbol_Func_Remap *src_map;
3389     Symbol_Func_Remap *dest_map;
3390     Hash_Map_Slot *slot, *dest_slot;
3391     HASH_MAP_FOR_EACH(&src->func_remaps, slot) {
3392        src_map = SYMBOL_FUNC_REMAP_OF(slot);
3393        dest_slot = hash_map_get(&dest->func_remaps, src_map->initial_iden,
3394                 hash_map_slot_get_hash_code(slot));
3395        if (!dest_slot) {
3396           DLOG("cpy remap %S => %S\n", src_map->initial_iden,
3397                 src_map->new_iden);
3398           dest_map = symbol_func_remap_alloc(src_map->initial_iden,
3399                 src_map->new_iden);
3400           hash_map_insert(&dest->func_remaps, &dest_map->hash_slot,
3401                 hash_map_slot_get_hash_code(slot));
3402        } else {
3403           DEBUGT(def,
3404              dest_map = SYMBOL_FUNC_REMAP_OF(dest_slot);
3405              assert(!string_compare(dest_map->new_iden, src_map->new_iden));
3406           );
3407        }
3408     }
3409  }
3410
3411  Symbol *___symbol_table_node_copy_func_symbols(Symbol_Table *table,
3412        Symbol_Table_Node *node1, Symbol_Table_Node *node2,
3413        bool use_unique_name, Symbol_Table_Node *cond, Vector *needed_nodes)
3414  {
3415     Symbol *sym = NULL, *sym2;
3416     Hash_Map_Slot *slot;
3417     Symbol_Func_Map *map, *map2;
3418     if (cond) {
3419        HASH_MAP_FOR_EACH(&cond->func_iden_map, slot) {
3420           map = SYMBOL_FUNC_MAP_OF(slot);
3421           VECTOR_FOR_EACH_ENTRY(&map->overload_idens, sym2) {
3422              map2 = symbol_table_node_lookup_func_map(node2,
3423                    (String)STRING_AFTER_DOT(sym2->identifier));
3424              assert(map2);
3425              VECTOR_FOR_EACH_ENTRY(&map2->overload_idens, sym) {
```

```
3426                if (!file_location_cmp(sym->location, sym2->location))
3427                   break;
3428                DEBUGT(def, sym = NULL);
3429             }
3430             assert(sym);
3431             if (!___symbol_table_node_insert_symbol(table, node1, sym,
3432                      false, SYMBOL_PROPERTY_FUNC, needed_nodes))
3433                goto out;
3434          }
3435       }
3436    } else {
3437       HASH_MAP_FOR_EACH(&node2->func_iden_map, slot) {
3438          map = SYMBOL_FUNC_MAP_OF(slot);
3439          VECTOR_FOR_EACH_ENTRY(&map->overload_idens, sym) {
3440             if (!___symbol_table_node_insert_symbol(table, node1, sym,
3441                      use_unique_name, SYMBOL_PROPERTY_FUNC,
3442                      needed_nodes))
3443                goto out;
3444          }
3445       }
3446    }
3447    symbol_table_node_merge_remap(node2, node1);
3448
3449    sym = NULL;
3450 out:
3451    return sym;
3452 }
3453
3454 Symbol *___symbol_table_node_copy_symbols(Symbol_Table *table,
3455       Symbol_Table_Node *node1, Symbol_Table_Node *node2,
3456       bool use_unique_name, Symbol_Table_Node *cond, Vector *needed_nodes,
3457       Symbol_Property property)
3458 {
3459    if (property == SYMBOL_PROPERTY_FUNC)
3460       return ___symbol_table_node_copy_func_symbols(table, node1, node2,
3461             use_unique_name, cond, needed_nodes);
3462
3463    Symbol *sym = NULL, *tmp_sym;
3464    Hash_Map_Slot *slot;
3465    if (cond) {
3466       SYMBOL_TABLE_NODE_FOR_EACH_SYMBOL(cond, slot, tmp_sym, property) {
3467          DLOG("cpy_sym: %S\n", tmp_sym->unique_name);
3468          sym = symbol_table_node_lookup(node2,
3469                tmp_sym->unique_name, property);
3470          assert(sym);
3471          if (!___symbol_table_node_insert_symbol(table, node1, sym, false,
3472                   property, needed_nodes))
3473             goto out;
3474       }
3475    } else {
3476       SYMBOL_TABLE_NODE_FOR_EACH_SYMBOL(node2, slot, sym, property) {
3477          DLOG("cpy_sym: %S\n", sym->unique_name);
3478          if(!___symbol_table_node_insert_symbol(table, node1, sym,
3479                   use_unique_name, property, needed_nodes))
3480             goto out;
3481       }
3482    }
3483    sym = NULL;
3484 out:
3485    return sym;
3486 }
3487
3488 Symbol *symbol_table_node_copy_symbols(Symbol_Table *table,
3489       Symbol_Table_Node *node1, Symbol_Table_Node *node2,
3490       bool use_unique_name, Symbol_Table_Node *cond, Vector *needed_nodes)
3491 {
3492    bool has_finalize = node1->has_finalize_func || node2->has_finalize_func;
3493    node1->has_finalize_func = has_finalize;
3494    bool has_rec_func = node1->has_record_func || node2->has_record_func;
3495    node1->has_record_func = has_rec_func;
3496
3497    Symbol *sym;
3498    sym = ___symbol_table_node_copy_symbols(table, node1, node2,
3499                use_unique_name, cond, needed_nodes,
```

```
3500                SYMBOL_PROPERTY_TYPE_DEF);
3501    assert(!sym);
3502    sym = ___symbol_table_node_copy_symbols(table, node1, node2,
3503                use_unique_name, cond, needed_nodes,
3504                SYMBOL_PROPERTY_FUNC);
3505    assert(!sym);
3506    sym = ___symbol_table_node_copy_symbols(table, node1, node2,
3507                use_unique_name, cond, needed_nodes,
3508                SYMBOL_PROPERTY_VAR);
3509    (void)sym;
3510    assert(!sym);
3511
3512    return NULL;
3513 }
3514
3515
3516
3517 Symbol *symbol_table_node_copy_needed_nodes(Symbol_Table *table,
3518       Vector *needed_nodes, bool use_unique_name UNUSED)
3519 {
3520    Symbol *sym = NULL;
3521    Symbol_Table_Node *node1, *node2;
3522    Hash_Map_Slot *tmp_slot;
3523
3524    while (vector_size(needed_nodes) > 0) {
3525       node2 = vector_pop_last(needed_nodes);
3526
3527       assert(hash_map_contains(&hash_map, node2->parent,
3528             hash_map_aligned_ptr_hash(node2->parent)));
3529
3530       tmp_slot = hash_map_get(&hash_map, node2,
3531             hash_map_aligned_ptr_hash(node2));
3532       assert(tmp_slot);
3533       node1 = POINTER_SLOT_OF(tmp_slot)->val;
3534
3535       if ((sym = symbol_table_node_copy_symbols(table, node1, node2,
3536                   false, NULL, needed_nodes)))
3537          goto error_out;
3538    }
3539
3540 error_out:
3541    return sym;
3542 }
3543
3544 Symbol *symbol_table_node_copy_node(Symbol_Table *table,
3545       Symbol_Table_Node *node1, Symbol_Table_Node *node2,
3546       bool use_unique_name, Symbol_Table_Node *cond, Vector *needed_nodes)
3547 {
3548    Symbol *sym = NULL;
3549    sym = symbol_table_node_copy_symbols(table, node1, node2,
3550                use_unique_name, cond, needed_nodes);
3551    assert(!sym);
3552
3553    if (node1->type != SYMBOL_TABLE_NODE_IMPORT) {
3554       Vector *dep = &node2->import_dependencies;
3555       Vector *dep_loc = & node2->import_dependencies_loc;
3556       Uns size = vector_size(dep);
3557       for (Uns i = 0; i < size; i++) {
3558          vector_append(&node1->import_dependencies,
3559                string_duplicate(vector_get(dep, i)));
3560          vector_append(&node1->import_dependencies_loc, vector_get(dep_loc, i));
3561       }
3562    }
3563
3564    sym = symbol_table_node_copy_needed_nodes(table, needed_nodes,
3565          use_unique_name);
3566
3567    assert(!sym);
3568
3569    return sym;
3570 }
3571
3572 /* n1 is the sym node n2 copied to */
3573 void symbol_table_node_copy_hash_link(Symbol_Table_Node *n1,
```

```
3574        Symbol_Table_Node *n2)
3575  {
3576     Pointer_Slot *ps = ALLOC_NEW(Pointer_Slot);
3577     ps->key = n2;
3578     ps->val = n1;
3579     hash_map_insert(&hash_map, &ps->slot, hash_map_aligned_ptr_hash(ps->key));
3580  }
3581
3582  void symbol_table_node_copy_hash_clear()
3583  {
3584     hash_map_for_each_destroy(&hash_map, pointer_hash_map_destructor);
3585  }
3586
3587  /*node1 must be a node in table1 and node2 must be a node in table2*/
3588  Symbol *symbol_table_node_merge_cond(
3589        Symbol_Table *table1, Symbol_Table_Node *n1,
3590        Symbol_Table *table2, Symbol_Table_Node *n2,
3591        bool use_unique_name, Symbol_Table_Node *cond)
3592  {
3593     Double_List *list;
3594     Double_List_Node *dbnode;
3595     Symbol_Table_Node *node1 = n1;
3596     Symbol_Table_Node *node2 = n2;
3597     Symbol *sym = NULL;
3598
3599     if (double_list_is_empty(&table2->all_nodes) && !node2)
3600        goto out;
3601     else if (!double_list_is_empty(&table2->all_nodes) && !node2)
3602        node2 = SYMBOL_TABLE_NODE_OF(
3603              double_list_peek_first(&table2->all_nodes));
3604
3605     if (double_list_is_empty(&table1->all_nodes) && !node1)
3606        node1 = symbol_table_node_alloc_insert(NULL, table1,
3607              SYMBOL_TABLE_NODE_GLOBAL, NULL);
3608     else if (!double_list_is_empty(&table2->all_nodes) && !node1)
3609        node1 = SYMBOL_TABLE_NODE_OF(
3610              double_list_peek_first(&table1->all_nodes));
3611     else if (double_list_is_empty(&table1->all_nodes) && node1) {
3612        assert(false);
3613        goto out;
3614     }
3615
3616     list = &table2->all_nodes;
3617     DOUBLE_LIST_FOR_EACH(list, dbnode) {
3618        if (SYMBOL_TABLE_NODE_OF(dbnode) == node2)
3619           goto node2_found;
3620     }
3621
3622     assert(false);
3623
3624  node2_found:;
3625     Vector *needed_nodes = vector_alloc();
3626
3627     symbol_table_node_copy_hash_link(node1, node2);
3628
3629     sym = symbol_table_node_copy_node(table1, node1, node2,
3630                 use_unique_name, cond, needed_nodes);
3631
3632     vector_destroy(needed_nodes, NULL);
3633  out:
3634     hash_map_for_each_destroy(&hash_map, pointer_hash_map_destructor);
3635     type_hash_clear();
3636     return sym;
3637  }
3638
3639  inline Symbol *symbol_table_node_merge(
3640        Symbol_Table *table1, Symbol_Table_Node *n1,
3641        Symbol_Table *table2, Symbol_Table_Node *n2,
3642        bool use_unique_name)
3643  {
3644     return symbol_table_node_merge_cond(table1, n1, table2, n2,
3645           use_unique_name, NULL);
3646  }
3647
```

```
3648 /* Merges two symbol tables.
3649  * The result of the merge is table1.
3650  * returns NULL on succes, the conflicting symbol on failure. */
3651 inline Symbol *symbol_table_merge(Symbol_Table *table1, Symbol_Table *table2,
3652       bool use_unique_name)
3653 {
3654    return symbol_table_node_merge(table1, NULL, table2, NULL,
3655          use_unique_name);
3656 }
3657
3658 void symbol_func_map_hash_destroy(Hash_Map_Slot *slot)
3659 {
3660    symbol_func_map_destroy(SYMBOL_FUNC_MAP_OF(slot));
3661 }
3662
3663 bool ___symbol_func_map_comparator(String func_iden, Hash_Map_Slot *slot)
3664 {
3665    Symbol_Func_Map *m = SYMBOL_FUNC_MAP_OF(slot);
3666    return !string_compare(m->func_iden, func_iden);
3667 }
3668
3669 void symbol_func_remap_hash_destroy(Hash_Map_Slot *slot)
3670 {
3671    symbol_func_remap_destroy(SYMBOL_FUNC_REMAP_OF(slot));
3672 }
3673
3674 bool ___symbol_func_remap_comparator(String func_iden, Hash_Map_Slot *slot)
3675 {
3676    Symbol_Func_Remap *r = SYMBOL_FUNC_REMAP_OF(slot);
3677    return !string_compare(r->initial_iden, func_iden);
3678 }
```

:

A.3.13 src/ast/symbol_table.h

```
1  #ifndef SYMBOL_TABLE_H
2  #define SYMBOL_TABLE_H
3
4  #include <hash_map.h>
5  #include <std_include.h>
6  #include <vector.h>
7  #include <debug.h>
8  #include <double_list.h>
9  #include <dot_printer.h>
10
11 #undef DEBUG_TYPE
12 #define DEBUG_TYPE symbol-table
13
14 typedef struct Symbol_Table_Node Symbol_Table_Node;
15
16 typedef struct Symbol_Table Symbol_Table;
17
18 typedef struct Symbol Symbol;
19
20 typedef struct Type_Def_Symbol Type_Def_Symbol;
21
22 typedef struct Symbol_Return Symbol_Return;
23
24 typedef struct Symbol_Type_Struct Symbol_Type_Struct;
25
26 typedef struct String_Builder String_Builder;
27
28 typedef struct Symbol_Type_String Symbol_Type_String;
29
30 void symbol_table_clear(Symbol_Table *t);
31
32 typedef enum Symbol_Property {
33    SYMBOL_PROPERTY_VAR,
34    SYMBOL_PROPERTY_FUNC,
35    SYMBOL_PROPERTY_TYPE_DEF // Must be last
```

```
36  } Symbol_Property;
37
38  #define SYMBOL_PROPERTY_COUNT (SYMBOL_PROPERTY_TYPE_DEF + 1)
39
40  typedef enum Symbol_Type {
41     SYMBOL_TYPE_VOID,     // Symbol has type void
42     SYMBOL_TYPE_INT,      // Symbol has type int
43     SYMBOL_TYPE_BOOL,     // Symbol has type bool
44     SYMBOL_TYPE_CHAR,     // Symbol has type char
45     SYMBOL_TYPE_STRING,    // Symbol has type string
46     SYMBOL_TYPE_ARY,      // Symbol has type array
47     SYMBOL_TYPE_REC,      // Symbol has type record
48     SYMBOL_TYPE_FUNC,     // Symbol has type function
49
50     /* This symbol type is used when a record or array cycle has been detected.
51      * An example of a record cycle is:
52      *  type R = record of {r:R, ...};
53      * The following is also a cycle:
54      *  type R = record of R {...};
55      * However this last one is an error and will cause R to become an
56      * unknown type instead of a record type. */
57     SYMBOL_TYPE_CYCLE,
58
59     /* Used internaly to represent types which are not yet resolved.
60      * I.e. The type is defined by some identifier. Examples:
61      * type T = A; (here symbol T has type A which have not yet been resolved).
62      * var a:A; (here symbol a has type A which have not yet been resloved). */
63     SYMBOL_TYPE_IDEN,
64
65     /* Symbol has unknown type. This might be because a symbol was
66      * initially defined to be some identifier type which we were
67      * not able to resolve. Most likely because the user never
68      * defined the identifier type.
69      * A symbol will also have unknown type when the user has
70      * defined the same symbol with different types. */
71     SYMBOL_TYPE_UNKNOWN  // Must be last
72  } Symbol_Type;
73
74  #define SYMBOL_RETURN_TYPE_COUNT (SYMBOL_RETURN_TYPE_UNKNOWN + 1)
75
76  struct Symbol {
77     String identifier;
78     String unique_name;
79     Symbol_Type_Struct *resolved_type;
80     File_Location *location;
81     Symbol_Table_Node *sym_node;
82     Hash_Map_Slot hash_slot;
83  };
84
85  inline static File_Location *symbol_get_location(Symbol *sym)
86  {
87     return sym->location;
88  }
89
90  #define SYMBOL_LOCATION(symbol_ptr) symbol_ptr->location
91
92  #define SYMBOL_OF_SLOT(slot) HASH_MAP_ENTRY(slot, Symbol, hash_slot)
93
94  struct Type_Def_Symbol {
95     Symbol symbol;     // Must be first.
96     Double_List_Node dbnode;
97     bool cycle_marked;
98     bool report_cycle;
99  };
100
101 #define TYPE_DEF_SYMBOL_OF_SYMBOL(sym) ((Type_Def_Symbol *)(sym))
102
103 #define TYPE_DEF_SYMBOL_OF_DBNODE(node) \
104    CONTAINER_OF(node, Type_Def_Symbol, dbnode)
105
106 /*****************************************************************************/
107
108 typedef struct Symbol_Type_Struct_Methods {
109    Symbol_Type (*get_type)();
```

```
110     Symbol_Type_Struct *(*resolve)(Symbol_Type_Struct *self, Symbol_Table *t);
111     void (*append_str)(Symbol_Type_Struct *self, String_Builder *sb);
112     void (*destroy)(Symbol_Type_Struct *self);
113     bool (*same_type)(Symbol_Type_Struct *self, Symbol_Type_Struct *oth);
114  } Symbol_Type_Struct_Methods;
115
116  struct Symbol_Type_Struct {
117     Symbol_Type_Struct_Methods *methods;
118     Double_List_Node dbnode;
119  };
120
121  #define SYMBOL_TYPE_STRUCT_FIELD sym_struct
122
123  #define SYMBOL_TYPE_STRUCT_BEGIN(name) \
124     typedef struct name { Symbol_Type_Struct SYMBOL_TYPE_STRUCT_FIELD;
125
126  #define SYMBOL_TYPE_STRUCT_END(name) } name;
127
128  #define SYMBOL_TYPE_STRUCT_CONTAINER(sym_struct, container_type) \
129     CONTAINER_OF(sym_struct, container_type, SYMBOL_TYPE_STRUCT_FIELD)
130
131  #define SYMBOL_TYPE_STRUCT_OF_CONTAINER(container) \
132     (&(container)->SYMBOL_TYPE_STRUCT_FIELD)
133
134  #define SYMBOL_TYPE_STRUCT_OF_DBNODE(node) \
135     DOUBLE_LIST_ENTRY(node, Symbol_Type_Struct, dbnode)
136
137  SYMBOL_TYPE_STRUCT_BEGIN(Symbol_Type_Void)
138  SYMBOL_TYPE_STRUCT_END(Symbol_Type_Void)
139
140  SYMBOL_TYPE_STRUCT_BEGIN(Symbol_Type_Int)
141  SYMBOL_TYPE_STRUCT_END(Symbol_Type_Int)
142
143  Symbol_Type_Struct *symbol_type_int_alloc(Symbol_Table *t);
144
145  Symbol_Type_Struct *symbol_type_void_alloc(Symbol_Table *t);
146
147  SYMBOL_TYPE_STRUCT_BEGIN(Symbol_Type_Bool)
148  SYMBOL_TYPE_STRUCT_END(Symbol_Type_Bool)
149
150  Symbol_Type_Struct *symbol_type_bool_alloc(Symbol_Table *t);
151
152  SYMBOL_TYPE_STRUCT_BEGIN(Symbol_Type_Char)
153  SYMBOL_TYPE_STRUCT_END(Symbol_Type_Char)
154
155  Symbol_Type_Struct *symbol_type_char_alloc(Symbol_Table *t);
156
157  SYMBOL_TYPE_STRUCT_BEGIN(Symbol_Type_String)
158  SYMBOL_TYPE_STRUCT_END(Symbol_Type_String)
159
160  Symbol_Type_Struct *symbol_type_string_alloc(Symbol_Table *t);
161
162  SYMBOL_TYPE_STRUCT_BEGIN(Symbol_Type_Ary)
163     Symbol_Type_Struct *ary_type;
164     String ary_name;
165     Uns scope_id;
166     struct {
167        bool dump_cycle_marked : 1;
168        bool imp_table_updated : 1;
169     };
170  SYMBOL_TYPE_STRUCT_END(Symbol_Type_Ary)
171
172  void symbol_type_ary_set_name(Symbol_Type_Ary *self, String name);
173
174  Symbol_Type_Struct *symbol_type_ary_alloc(Symbol_Table *t,
175        Symbol_Type_Struct *ary_type, Uns scope_id);
176
177  SYMBOL_TYPE_STRUCT_BEGIN(Symbol_Type_Iden)
178     String iden;
179     Symbol_Table_Node *sym_node;
180     File_Location *loc;
181  SYMBOL_TYPE_STRUCT_END(Symbol_Type_Iden)
182
183  Symbol_Type_Struct *symbol_type_iden_alloc(Symbol_Table *t, String iden);
```

```
184
185 typedef struct Symbol_Type_Rec_Ambiguous_Ref {
186    Vector sym_locations;
187    Const_String field_name;
188    Hash_Map_Slot hash_slot;
189 } Symbol_Type_Rec_Ambiguous_Ref;
190
191 #define SYMBOL_REC_AMBIGUOUS_REF_OF(slot) \
192    HASH_MAP_ENTRY(slot, Symbol_Type_Rec_Ambiguous_Ref, hash_slot)
193
194 void symbol_type_iden_set_iden(Symbol_Type_Iden *self, String str);
195
196 typedef enum Symbol_Rec_Cycle_Type {
197    SYMBOL_REC_CYCLE_MARK_NONE,
198    SYMBOL_REC_CYCLE_ALLOWED,
199    SYMBOL_REC_CYCLE_NOT_ALLOWED
200 } Symbol_Rec_Cycle_Type;
201
202 SYMBOL_TYPE_STRUCT_BEGIN(Symbol_Type_Rec)
203    Symbol_Table_Node *rec_sym_node;
204    Vector extended_types;
205    Vector func_identifiers;
206    Vector func_types;
207    Vector var_identifiers;
208    Vector var_types;
209    String rec_name;
210    String unique_name;
211    String missing_finalize_name;
212    String missing_record_func_name;
213    Hash_Map ambiguous_refs;
214    Uns scope_id;
215    Symbol_Rec_Cycle_Type cycle_mark;
216    struct {
217       bool body_resolved      : 1;
218       bool body_resolved_last   : 1;
219       bool append_str_cycle_marked : 1;
220       bool super_fields_appended  : 1;
221       bool imp_table_updated   : 1;
222       bool imp_table_name_updated  : 1;
223    };
224 SYMBOL_TYPE_STRUCT_END(Symbol_Type_Rec)
225
226 #define SYMBOL_TYPE_REC_TYPE_NAME(rec) ({       \
227    const char *___cstr = string_to_cstr(rec->unique_name);  \
228    S(___cstr + 1);                              \
229 })
230
231 static inline void ___symbol_type_rec_reset_unique_name(Symbol_Type_Rec *rec,
232       String new_unique)
233 {
234    string_destroy(rec->unique_name);
235    rec->unique_name = new_unique;
236 }
237
238 static inline void symbol_type_rec_add_ambiguous_ref(
239       Symbol_Type_Rec *rec, Symbol_Type_Rec_Ambiguous_Ref *r)
240 {
241    Uns hash = string_hash_code(r->field_name);
242    hash_map_insert(&rec->ambiguous_refs, &r->hash_slot, hash);
243 }
244
245 static inline Symbol_Type_Rec_Ambiguous_Ref *symbol_type_rec_get_ambiguous_ref(
246       Symbol_Type_Rec *rec, String field_name)
247 {
248    Hash_Map_Slot *slot = hash_map_get(&rec->ambiguous_refs, field_name,
249          string_hash_code(field_name));
250    if (LIKELY(!slot))
251       return NULL;
252    return SYMBOL_REC_AMBIGUOUS_REF_OF(slot);
253 }
254
255 Symbol_Type_Struct *symbol_type_rec_alloc(Symbol_Table *t, Uns scope_id,
256       Const_String unique_name);
257
```

```
258 void symbol_type_rec_append_func_identifier(Symbol_Type_Rec *self,
259       Const_String iden);
260
261 void symbol_type_rec_append_var_identifier(Symbol_Type_Rec *self,
262       Const_String iden);
263
264 void symbol_type_rec_set_name(Symbol_Type_Rec *self, Const_String name);
265
266 Symbol_Type_Rec *symbol_type_rec_assignment_compatible(
267       Symbol_Type_Struct *dest, Symbol_Type_Struct *src);
268
269 static inline Symbol_Type_Rec *symbol_type_rec_cast_compatible(
270       Symbol_Type_Struct *lhs, Symbol_Type_Struct *rhs)
271 {
272    Symbol_Type_Rec *ret = symbol_type_rec_assignment_compatible(lhs, rhs);
273    if (ret)
274       goto out;
275    ret = symbol_type_rec_assignment_compatible(rhs, lhs);
276 out:
277    return ret;
278 }
279
280 bool ___symbol_type_rec_ambiguous_cast(Symbol_Type_Rec *cast,
281       Symbol_Type_Rec *rec);
282
283 static inline bool symbol_type_rec_ambiguous_cast(Symbol_Type_Struct *cast,
284       Symbol_Type_Struct *rec)
285 {
286    Symbol_Type_Rec *lhs = SYMBOL_TYPE_STRUCT_CONTAINER(cast, Symbol_Type_Rec);
287    Symbol_Type_Rec *rhs = SYMBOL_TYPE_STRUCT_CONTAINER(rec, Symbol_Type_Rec);
288    return ___symbol_type_rec_ambiguous_cast(lhs, rhs);
289 }
290
291 SYMBOL_TYPE_STRUCT_BEGIN(Symbol_Type_Cycle)
292    String name;
293    Uns scope_id;
294    Symbol_Table_Node *sym_node;
295 SYMBOL_TYPE_STRUCT_END(Symbol_Type_Cycle)
296
297 Symbol_Type_Struct *symbol_type_cycle_alloc(Symbol_Table *t, String name);
298
299 SYMBOL_TYPE_STRUCT_BEGIN(Symbol_Type_Unknown)
300 SYMBOL_TYPE_STRUCT_END(Symbol_Type_Unknown)
301
302 Symbol_Type_Struct *symbol_type_unknown_alloc(Symbol_Table *t);
303
304 SYMBOL_TYPE_STRUCT_BEGIN(Symbol_Type_Func)
305    Symbol_Table_Node *body_sym_node;
306    Symbol_Type_Struct *return_type;
307    Vector param_identifiers;
308    Vector param_types;
309    struct {
310       bool is_resolved        : 1;
311       bool compare_return_type  : 1;
312       bool is_extern_c        : 1;
313       bool main_err_int_reported  : 1;
314       bool main_param_err_reported : 1;
315       bool imp_table_updated   : 1;
316       bool is_concrete_func   : 1;
317    };
318 SYMBOL_TYPE_STRUCT_END(Symbol_Type_Func)
319
320 typedef struct Symbol_Func_Map {
321    Symbol_Table_Node *sym_node;
322    String func_iden;
323    Int unnamed_type_count;
324    Vector overload_idens;
325    Hash_Map_Slot hash_slot;
326    bool is_verified;
327    bool has_extern_c;
328 } Symbol_Func_Map;
329
330 static inline Symbol_Func_Map *symbol_func_map_alloc(Const_String func_iden,
331       Symbol_Table_Node *sym_node)
```

```
332 {
333    Symbol_Func_Map *ret = ALLOC_NEW(Symbol_Func_Map);
334    ret->func_iden = string_duplicate(func_iden);
335    ret->overload_idens = VECTOR_INIT();
336    ret->sym_node = sym_node;
337    ret->unnamed_type_count = 0;
338    ret->is_verified = false;
339    ret->has_extern_c = false;
340    return ret;
341 }
342
343 static inline bool string_is_ctor(Const_String s)
344 {
345    return !string_compare(STRING_AFTER_DOT(s), S("record"));
346 }
347
348 static inline bool symbol_func_maps_ctor(Symbol_Func_Map *map)
349 {
350    return string_is_ctor(map->func_iden);
351 }
352
353 static inline void symbol_func_map_destroy(Symbol_Func_Map *fmap)
354 {
355    string_destroy(fmap->func_iden);
356    vector_clear(&fmap->overload_idens);
357    free_mem(fmap);
358 }
359
360 typedef struct Symbol_Func_Remap {
361    String initial_iden;
362    String new_iden;
363    Hash_Map_Slot hash_slot;
364 } Symbol_Func_Remap;
365
366 #define SYMBOL_FUNC_REMAP_OF(slot) \
367    HASH_MAP_ENTRY(slot, Symbol_Func_Remap, hash_slot)
368
369 static inline Symbol_Func_Remap *symbol_func_remap_alloc(
370       Const_String initial_iden, Const_String new_iden)
371 {
372    Symbol_Func_Remap *ret = ALLOC_NEW(Symbol_Func_Remap);
373    ret->initial_iden = string_duplicate(initial_iden);
374    ret->new_iden = string_duplicate(new_iden);
375    return ret;
376 }
377
378 static inline void symbol_func_remap_destroy(Symbol_Func_Remap *r)
379 {
380    string_destroy(r->initial_iden);
381    string_destroy(r->new_iden);
382    free_mem(r);
383 }
384
385 void symbol_func_remap_hash_destroy(Hash_Map_Slot *slot);
386
387 void symbol_func_map_hash_destroy(Hash_Map_Slot *slot);
388
389 #define SYMBOL_FUNC_MAP_OF(slot) \
390    HASH_MAP_ENTRY(slot, Symbol_Func_Map, hash_slot)
391
392 void symbol_type_func_append_param_identifier(Symbol_Type_Func *self,
393       String iden);
394
395 Symbol_Type_Struct *symbol_type_func_alloc(Symbol_Table *t, bool is_extern_c);
396
397 /*****************************************************************************/
398
399 typedef enum Symbol_Rec_Comp {
400    REC_COMP_DIFFERENT,
401    REC_COMP_SAME,
402    REC_COMP_IN_PROGRESS
403 } Symbol_Rec_Comp;
404
405 /* Iserted in Symbol_Table hash map when 2 records (rec1, and rec2)
```

```
406  * have been compared, or are in progress of being compared. */
407 typedef struct Symbol_Rec_Comp_Struct {
408    Hash_Map_Slot hash_slot;
409    Symbol_Type_Rec *rec1, *rec2;
410    Symbol_Rec_Comp comp_result;
411 } ALIGNED(PTR_SIZE) Symbol_Rec_Comp_Struct;
412
413 static inline Uns symbol_rec_comp_struct_hash_code(Symbol_Rec_Comp_Struct *c)
414 {
415    return hash_map_aligned_ptr_hash(c->rec1) +
416          hash_map_aligned_ptr_hash(c->rec2);
417 }
418
419 static inline void symbol_rec_comp_struct_set(Symbol_Rec_Comp_Struct *c,
420       Symbol_Rec_Comp comp_res)
421 {
422    c->comp_result = comp_res;
423 }
424
425 static inline Symbol_Rec_Comp symbol_rec_comp_struct_get(
426       Symbol_Rec_Comp_Struct *c)
427 {
428    return c->comp_result;
429 }
430
431 static inline Symbol_Rec_Comp_Struct *___symbol_rec_comp_struct_alloc(
432       Symbol_Type_Rec *rec1, Symbol_Type_Rec *rec2)
433 {
434    Symbol_Rec_Comp_Struct *c = ALLOC_NEW(Symbol_Rec_Comp_Struct);
435    c->rec1 = rec1;
436    c->rec2 = rec2;
437    return c;
438 }
439
440 /* Initially the comp_result is initialized to REC_COMP_IN_PROGRESS. */
441 static inline Symbol_Rec_Comp_Struct *symbol_rec_comp_struct_alloc(
442       Symbol_Type_Rec *rec1, Symbol_Type_Rec *rec2)
443 {
444    Symbol_Rec_Comp_Struct *c = ___symbol_rec_comp_struct_alloc(rec1, rec2);
445    c->comp_result = REC_COMP_IN_PROGRESS;
446    return c;
447 }
448
449 #define SYMBOL_REC_COMP_STRUCT_OF(slot) \
450    HASH_MAP_ENTRY(slot, Symbol_Rec_Comp_Struct, hash_slot)
451
452 bool symbol_rec_comp_struct_compare(Symbol_Rec_Comp_Struct *search_comp,
453       Hash_Map_Slot *map_slot);
454
455 void symbol_rec_comp_struct_destroy(Hash_Map_Slot *slot);
456
457 struct Symbol_Table {
458    Symbol *current_symbol;
459    Symbol_Table_Node *current_sym_table_node;
460    Symbol_Type_Struct *symbol_type_struct_void;
461    Symbol_Type_Struct *symbol_type_struct_int;
462    Symbol_Type_Struct *symbol_type_struct_bool;
463    Symbol_Type_Struct *symbol_type_struct_char;
464    Symbol_Type_Struct *symbol_type_struct_string;
465    Symbol_Type_Struct *symbol_type_struct_unknown;
466    File_Location null_location;
467    Vector location_names;
468    Double_List all_nodes;
469    Double_List all_symbol_types;
470    Hash_Map record_comparisons;
471    Symbol_Property current_resolve_property;
472    Uns next_node_id;
473    Symbol_Rec_Cycle_Type rec_cycle_type;
474    bool last_resolve_pass;
475 };
476
477 static inline void symbol_table_insert_comp_result(Hash_Map *m,
478       Symbol_Rec_Comp_Struct *c)
479 {
```

```
480     Uns hash = symbol_rec_comp_struct_hash_code(c);
481     assert(!hash_map_contains(m, c, hash));
482     hash_map_insert(m, &c->hash_slot, hash);
483  }
484
485  static inline Symbol_Rec_Comp_Struct *symbol_table_get_comp_result(Hash_Map *m,
486        Symbol_Rec_Comp_Struct *search_struct)
487  {
488     Hash_Map_Slot *slot = hash_map_get(m, search_struct,
489           symbol_rec_comp_struct_hash_code(search_struct));
490     if (!slot)
491        return NULL;
492     return SYMBOL_REC_COMP_STRUCT_OF(slot);
493  }
494
495  #define SYMBOL_TABLE_INIT(name, curr_file) \
496     ((Symbol_Table)SYMBOL_TABLE_STATIC_INIT(name, curr_file))
497
498  #define SYMBOL_TABLE_STATIC_INIT(name, curr_file) {       \
499     .all_nodes = DOUBLE_LIST_STATIC_INIT((name).all_nodes),     \
500     .all_symbol_types = DOUBLE_LIST_STATIC_INIT((name).all_symbol_types), \
501     .next_node_id = 0,                                        \
502     .last_resolve_pass = false,                               \
503     .location_names = VECTOR_STATIC_INIT(),                   \
504     .record_comparisons = HASH_MAP_STATIC_INIT(               \
505           (Hash_Map_Comparator)symbol_rec_comp_struct_compare),   \
506     .rec_cycle_type = SYMBOL_REC_CYCLE_MARK_NONE,             \
507     .null_location = FILE_LOCATION_STATIC_INIT(curr_file, 0, 0)    \
508  }
509
510  inline static Symbol_Table *symbol_table_alloc(Const_String curr_file_name)
511  {
512     Symbol_Table *ret = ALLOC_NEW(Symbol_Table);
513     *ret = SYMBOL_TABLE_INIT(*ret, curr_file_name);
514     return ret;
515  }
516
517  inline static void symbol_table_destroy(Symbol_Table *table)
518  {
519     symbol_table_clear(table);
520     free_mem(table);
521  }
522
523  typedef enum Symbol_Table_Node_Type {
524     SYMBOL_TABLE_NODE_GLOBAL,
525     SYMBOL_TABLE_NODE_REC,
526     SYMBOL_TABLE_NODE_FUNC,
527     SYMBOL_TABLE_NODE_INTERMEDIATE,
528     SYMBOL_TABLE_NODE_IMPORT
529  } Symbol_Table_Node_Type;
530
531  struct Symbol_Table_Node {
532     Double_List_Node dbnode;
533     Symbol_Table_Node *parent;
534     Symbol_Type_Rec *node_rec;
535     Hash_Map *record_comparisons;
536     Hash_Map symbol_maps[SYMBOL_PROPERTY_COUNT];
537     Hash_Map func_iden_map;
538     Hash_Map func_remaps;
539     Vector import_dependencies;
540     Vector import_dependencies_loc;
541     Uns scope_id;
542     Symbol_Table_Node_Type type;
543     Uns finalize_func_count;
544     bool has_finalize_func;
545     bool has_record_func;
546  };
547
548  inline static Uns symbol_table_node_get_scope_id(Symbol_Table_Node *node)
549  {
550     return node->scope_id;
551  }
552
553  #define SYMBOL_TABLE_FOR_EACH_NODE(table, node, dbnode) \
```

```
554     DOUBLE_LIST_FOR_EACH(&((table)->all_nodes), dbnode) \
555     if ((node = SYMBOL_TABLE_NODE_OF(dbnode)))
556
557  #define SYMBOL_TABLE_FOR_EACH_NODE_REVERSED(table, node, dbnode) \
558     DOUBLE_LIST_FOR_EACH_REVERSED(&((table)->all_nodes), dbnode) \
559     if ((node = SYMBOL_TABLE_NODE_OF(dbnode)))
560
561  #define SYMBOL_TABLE_NODE_FOR_EACH_SYMBOL(node, slot, sym, property) \
562        HASH_MAP_FOR_EACH(&((node)->symbol_maps[property]), slot)   \
563        if ((sym = SYMBOL_OF_SLOT(slot)))
564
565  static inline Symbol_Table_Node_Type symbol_get_symbol_table_node_type(
566        Symbol *sym)
567  {
568     return sym->sym_node->type;
569  }
570
571  static inline Symbol_Func_Map *symbol_table_node_get_func_map(
572        Symbol_Table_Node *node, String iden, Uns hash_code)
573  {
574     Hash_Map_Slot *slot = hash_map_get(&node->func_iden_map, iden, hash_code);
575     if (!slot)
576        return NULL;
577     return SYMBOL_FUNC_MAP_OF(slot);
578  }
579
580  static inline Symbol *symbol_table_node_get(Symbol_Table_Node *node,
581        String iden, Uns hash_code, Symbol_Property property)
582  {
583     Hash_Map_Slot *slot;
584     if (property == SYMBOL_PROPERTY_FUNC) {
585        slot = hash_map_get(&node->func_remaps, iden, hash_code);
586        if (slot) {
587           Symbol_Func_Remap *remap = SYMBOL_FUNC_REMAP_OF(slot);
588           return symbol_table_node_get(node,
589                 remap->new_iden,
590                 string_hash_code(remap->new_iden),
591                 SYMBOL_PROPERTY_FUNC);
592        }
593     }
594     slot = hash_map_get(&node->symbol_maps[property], iden, hash_code);
595     if (!slot)
596        return NULL;
597     return SYMBOL_OF_SLOT(slot);
598  }
599
600  static inline Type_Def_Symbol *symbol_table_node_get_type_def(
601        Symbol_Table_Node *node, String iden, Uns hash_code,
602        Symbol_Property property)
603  {
604     Symbol *sym = symbol_table_node_get(node, iden, hash_code, property);
605     if (sym)
606        return TYPE_DEF_SYMBOL_OF_SYMBOL(sym);
607     return NULL;
608  }
609
610  Symbol *___symbol_table_node_lookup(Symbol_Table_Node *sym_node,
611        String iden, Uns hash_code, Symbol_Property property);
612
613  static inline Symbol *symbol_table_node_lookup(Symbol_Table_Node *sym_node,
614        String iden, Symbol_Property property)
615  {
616     Uns hash = string_hash_code(iden);
617     return ___symbol_table_node_lookup(sym_node, iden, hash, property);
618  }
619
620  bool ___symbol_var_is_in_scope(File_Location *var_loc,
621        Symbol *lookup_sym, Symbol_Table_Node *child_sym_node);
622
623  static inline Symbol *symbol_table_node_lookup_var(
624        Symbol_Table_Node *sym_node,
625        String iden,
626        File_Location *var_loc)
627  {
```

```
628     Symbol_Table_Node *child_sym_node = sym_node;
629
630     Symbol *ret;
631
632     Uns hash = string_hash_code(iden);
633     for (;;) {
634        ret = ___symbol_table_node_lookup(sym_node, iden, hash,
635              SYMBOL_PROPERTY_VAR);
636        if (!ret || ___symbol_var_is_in_scope(var_loc, ret, child_sym_node))
637           break;
638        sym_node = ret->sym_node->parent;
639        if (!sym_node) {
640           ret = NULL;
641           break;
642        }
643     }
644
645     return ret;
646  }
647
648  Symbol_Func_Map *___symbol_table_node_lookup_func_map(
649        Symbol_Table_Node *sym_node, String iden, Uns hash_code);
650
651  static inline Symbol_Func_Map *symbol_table_node_lookup_func_map(
652        Symbol_Table_Node *sym_node, String iden)
653  {
654     Uns hash = string_hash_code(iden);
655     return ___symbol_table_node_lookup_func_map(sym_node, iden, hash);
656  }
657
658  void ___symbol_table_node_insert(Symbol_Table_Node *node,
659        Const_String iden, Const_String unique_name, Uns hash_code,
660        Symbol_Type_Struct *type, Symbol_Property property,
661        File_Location *loc);
662
663  /* Warning. Assumes that iden is not in the symbol table node
664   * with property 'property'. */
665  void symbol_table_node_insert(Symbol_Table_Node *node, Const_String iden,
666        Const_String unique_name, Symbol_Type_Struct *type,
667        Symbol_Property property, File_Location *loc);
668
669  /* Warning. Assumes that iden is not in the symbol table node
670   * with property 'property'. */
671  static inline void symbol_table_node_insert_unknown(Symbol_Table_Node *node,
672        Symbol_Table *t, String iden, Symbol_Property property,
673        File_Location *loc)
674  {
675     Uns hash = string_hash_code(iden);
676     if (!symbol_table_node_get(node, iden, hash, property)) {
677        ___symbol_table_node_insert(node, iden, NULL, hash,
678              symbol_type_unknown_alloc(t), property, loc);
679     }
680  }
681
682  static inline void symbol_table_node_insert_unknown_var(
683        Symbol_Table_Node *node, Symbol_Table *t, String iden,
684        File_Location *loc)
685  {
686     symbol_table_node_insert_unknown(node, t, iden,
687           SYMBOL_PROPERTY_VAR, loc);
688  }
689
690  static inline void symbol_table_node_insert_unknown_func(
691        Symbol_Table_Node *node, Symbol_Table *t, String iden,
692        File_Location *loc)
693  {
694     Uns hash = string_hash_code(iden);
695     if (!symbol_table_node_get(node, iden, hash, SYMBOL_PROPERTY_FUNC)) {
696        ___symbol_table_node_insert(node, iden, iden, hash,
697              symbol_type_unknown_alloc(t), SYMBOL_PROPERTY_FUNC, loc);
698     }
699  }
700
701  bool ___symbol_map_comparator(String search_iden, Hash_Map_Slot *slot);
```

```
702
703 bool ___symbol_func_map_comparator(String func_iden, Hash_Map_Slot *slot);
704
705 bool ___symbol_func_remap_comparator(String func_iden, Hash_Map_Slot *slot);
706
707 static inline Symbol_Table_Node *___symbol_table_node_alloc(Symbol_Table *t,
708       Symbol_Table_Node_Type type, Symbol_Type_Rec *node_rec)
709 {
710    Symbol_Table_Node *n = ALLOC_NEW(Symbol_Table_Node);
711    n->record_comparisons = &t->record_comparisons;
712    n->import_dependencies = VECTOR_INIT_SIZE(4);
713    n->import_dependencies_loc = VECTOR_INIT_SIZE(4);
714    for (Uns i = 0; i < SYMBOL_PROPERTY_COUNT; i++)
715       n->symbol_maps[i] = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_11,
716             (Hash_Map_Comparator)___symbol_map_comparator);
717    n->func_iden_map = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_11,
718          (Hash_Map_Comparator)___symbol_func_map_comparator);
719    n->func_remaps = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_11,
720          (Hash_Map_Comparator)___symbol_func_remap_comparator);
721    n->type = type;
722    n->finalize_func_count = 0;
723    n->has_finalize_func = false;
724    n->has_record_func = false;
725    n->node_rec = node_rec;
726    DEBUGT(def,
727       if (type == SYMBOL_TABLE_NODE_REC) {
728          assert(node_rec);
729       } else {
730          assert(!node_rec);
731       }
732    );
733
734    return n;
735 }
736
737 static inline Symbol_Table_Node *symbol_table_node_alloc_insert(
738       Symbol_Table_Node *parent, Symbol_Table *t,
739       Symbol_Table_Node_Type type, Symbol_Type_Rec *node_rec)
740 {
741    Symbol_Table_Node *n = ___symbol_table_node_alloc(t, type, node_rec);
742    n->parent = parent;
743    n->scope_id = t->next_node_id++;
744    double_list_append(&t->all_nodes, &n->dbnode);
745    return n;
746 }
747
748 void ___symbol_table_insert_location(Symbol_Table *t, Symbol_Table_Node *node,
749       Const_String prefix, Symbol_Type_Struct *type, File_Location *loc,
750       Symbol_Property property);
751
752 void symbol_table_insert_location(Symbol_Table *t, Symbol_Table_Node *node,
753       Const_String prefix, Symbol_Type_Struct *type, File_Location *loc);
754
755 Symbol *symbol_table_get_from_location(Symbol_Table_Node *node,
756       File_Location *loc);
757
758 void symbol_table_dump(Symbol_Table *t, Const_String prefix);
759
760 void symbol_table_dump_graph(Symbol_Table *t, Const_String file_prefix);
761
762 void symbol_table_resolve(Symbol_Table *t);
763
764 void symbol_table_node_copy_hash_link(Symbol_Table_Node * n1,
765       Symbol_Table_Node *n2);
766
767 void symbol_table_node_copy_hash_clear();
768
769 Symbol *symbol_table_node_copy_needed_nodes(Symbol_Table *table,
770       Vector *needed_nodes, bool use_unique_name);
771
772 bool symbol_table_node_insert_symbol(Symbol_Table *table,
773       Symbol_Table_Node *node, Symbol *sym, bool use_unique_name,
774       Symbol_Property property);
775
```

```
776 bool ___symbol_table_node_insert_symbol(Symbol_Table *table,
777       Symbol_Table_Node *node, Symbol *sym, bool use_unique_name,
778       Symbol_Property property, Vector *needed_nodes);
779
780 Symbol *symbol_table_merge(Symbol_Table *table1, Symbol_Table *table2,
781       bool use_unique_name);
782
783 Symbol *symbol_table_node_merge(
784       Symbol_Table *table1, Symbol_Table_Node *n1,
785       Symbol_Table *table2, Symbol_Table_Node *n2,
786       bool use_unique_name);
787
788 Symbol *symbol_table_node_merge_cond(
789       Symbol_Table *table1, Symbol_Table_Node *n1,
790       Symbol_Table *table2, Symbol_Table_Node *n2,
791       bool use_unique_name, Symbol_Table_Node *cond);
792
793 #define SYMBOL_TABLE_NODE_OF(node) \
794    DOUBLE_LIST_ENTRY(node, Symbol_Table_Node, dbnode)
795
796 inline static Symbol_Table_Node *symbol_table_get_root(Symbol_Table *t)
797 {
798    Symbol_Table_Node *node = SYMBOL_TABLE_NODE_OF(
799          double_list_peek_first(&t->all_nodes));
800    return node;
801 }
802
803 #undef DEBUG_TYPE
804 #define DEBUG_TYPE def
805
806 #endif // SYMBOL_TABLE_H
```

:

A.3.14 src/parser.c

```
1  #include <parser.h>
2  #include <main.h>
3  #include <std_include.h>
4
5  extern FILE *yyin;
6
7  void scanner_finalize();
8  void parser_finalize();
9  Ast *parser_parse(Const_String file);
10
11 Ast *parse(Const_String file)
12 {
13    Ast *ast;
14    yyin = file_open(file, S("r"));
15    if (!yyin) {
16       report_error(file, S("cannot open file [%m]\n"), file);
17       ast = NULL;
18    } else {
19       ast = parser_parse(file);
20       file_close(yyin);
21    }
22    return ast;
23 }
24
25 void parse_cleanup()
26 {
27    parser_finalize();
28    scanner_finalize();
29 }
```

:

A.3.15 src/parser.h

```
1  #ifndef PARSER_H
2  #define PARSER_H
3
4  #include <std_define.h>
5  #include <ast/ast.h>
6
7  typedef enum yytokentype Parser_Token_Type;
8
9  /* Parse the file with name 'current_file_name' and return root of
10  * the parse tree. If NULL then the parse tree could not be created
11  * and parsing failed. */
12 Ast *parse(Const_String file);
13
14 /* Free memory used by parser and scanner. Call this function once
15  * when parsing of all input files are done. */
16 void parse_cleanup();
17
18 void parser_report_error(Uns line, Uns column, Const_String format, ...);
19
20 #endif // PARSER_H
```

A.3.16 src/parser/parser.y

```
1  %{
2
3  #include <parser.h>
4  #include <std_include.h>
5  #include <vector.h>
6  #include <debug.h>
7  #include <main.h>
8  #include <ast/ast_visitor_delete.h>
9
10 int yylex();
11 int yyparse();
12 void scanner_restart();
13 void scanner_push_back_token();
14
15 static Uns func_nest;
16 static Uns curl_nest;
17 static VECTOR(curl_nest_stack);
18
19 static bool same_as_prev_node(Uns line, Uns col);
20 static void func_head_recover();
21 static void extern_func_recover();
22 static void decl_stmt_recover();
23 static void record_body_recover();
24
25 static Uns last_err_line;
26 static Uns last_err_column;
27 static Const_String last_err_text;
28
29 static VECTOR(decl_stmt_stack);
30 static Uns consistent_stmt_decl_top;
31
32 static VECTOR(extend_stack);
33 static VECTOR(extend_nest_stack);
34 static Uns extend_nest;
35
36 static VECTOR(func_head_stack);
37
38 static VECTOR(expr_stack);
39
40 static Ast *current_ast;
41
42 static Const_String current_file_name;
43
44 void yyerror(const char *str);
```

```
45
46  #define EXPECTED_STRING_START '@'
47  #define EXPECTED_STRING_END '#'
48  static STRING_EMPTY(expect_string);
49
50  #define GET_UNEXPEC_STRING(unexpec) ({ \
51     Const_String ___ret;        \
52     if (string_is_empty(unexpec))  \
53        ___ret = S("end of input");  \
54     else                        \
55        ___ret = unexpec;        \
56     ___ret;                     \
57  })
58
59  #define RECOVER(func, line, col, format, ...)      \
60  do {                                               \
61     if (!same_as_prev_node(line, col)) {            \
62        parser_report_error(line, col,               \
63              S(format), ## __VA_ARGS__);            \
64        func();                                      \
65     }                                               \
66     yyerrok;                                        \
67     yyclearin;                                      \
68  } while (false)
69
70  #define RECOVER_UNEXPEC(func, line, col, unexpec)    \
71  do {                                                 \
72     RECOVER(func, line, col, "unexpected " QFY("%S") "\n", \
73           GET_UNEXPEC_STRING(unexpec));         \
74  } while (false)
75
76  #define RECOVER_EXPEC(func, line, col, unexpec)           \
77  do {                                                      \
78     if (!string_is_empty(expect_string)) {                 \
79        RECOVER(func, line, col, "unexpected " QFY("%S") ", expected %S\n", \
80              GET_UNEXPEC_STRING(unexpec), expect_string);     \
81     } else {                                               \
82        RECOVER_UNEXPEC(func, line, col, unexpec);          \
83     }                                                      \
84  } while (false)
85
86  #define RECOVER_EXPEC_SCOLON(func, line, col, unexpec) \
87  do {                                                   \
88     string_assign(expect_string, S(QFY(";")));    \
89     RECOVER_EXPEC(func, line, col, unexpec);    \
90  } while (false)
91
92  #undef DEBUG_TYPE
93  #define DEBUG_TYPE parser-recover:parser-parse
94
95  void parser_report_error(Uns line, Uns column, Const_String format, ...)
96  {
97     VA_SETUP(vl, format);
98     File_Location loc = FILE_LOCATION_INIT(current_ast->file, line, column);
99     report_vaerror_location(&loc, format, vl);
100    VA_END(vl);
101 }
102
103 static inline void push_curl_nest()
104 {
105    DLOG("PARSER PUSH CURL NEST\n");
106    vector_append(&curl_nest_stack, INT_TO_PTR(curl_nest));
107    curl_nest = 0;
108 }
109
110 static inline void pop_curl_nest()
111 {
112    if (!vector_is_empty(&curl_nest_stack)) {
113       DLOG("PARSER POP CURL NEST\n");
114       curl_nest = PTR_TO_INT(vector_pop_last(&curl_nest_stack));
115    }
116 }
117
118 static inline void inc_curl_nest()
```

```
119 {
120    DLOG("PARSER INC CURL NEST\n");
121    ++curl_nest;
122 }
123
124 static inline void dec_curl_nest()
125 {
126    if (curl_nest) {
127       DLOG("PARSER DEC CURL NEST\n");
128       --curl_nest;
129    }
130 }
131
132 static inline Uns get_curl_nest()
133 {
134    return curl_nest;
135 }
136
137 static inline void inc_func_nest()
138 {
139    ++func_nest;
140 }
141
142 static inline void dec_func_nest()
143 {
144    if (func_nest)
145       --func_nest;
146 }
147
148 static inline void enter_func()
149 {
150    inc_func_nest();
151    push_curl_nest();
152 }
153
154 static inline void leave_func()
155 {
156    dec_func_nest();
157    pop_curl_nest();
158 }
159
160 static inline Uns get_func_nest()
161 {
162    return func_nest;
163 }
164
165 static inline void inc_extend_nest()
166 {
167    ++extend_nest;
168 }
169
170 static inline void dec_extend_nest()
171 {
172    assert(extend_nest);
173    --extend_nest;
174 }
175
176 static inline Uns get_extend_nest()
177 {
178    return extend_nest;
179 }
180
181 static inline void push_extend_nest()
182 {
183    vector_append(&extend_nest_stack, INT_TO_PTR(extend_nest));
184    extend_nest = 0;
185 }
186
187 static inline void pop_extend_nest()
188 {
189    assert(!vector_is_empty(&extend_nest_stack));
190    extend_nest = PTR_TO_INT(vector_pop_last(&extend_nest_stack));
191 }
192
```

```
193 static void clear_vector_stack(Vector *stack)
194 {
195    Ast_Node *n;
196    Vector *v;
197    VECTOR_FOR_EACH_ENTRY(stack, v) {
198       VECTOR_FOR_EACH_ENTRY(v, n)
199          ast_visitor_delete_accept_visitor(n);
200       vector_destroy(v, NULL);
201    }
202    vector_clear(stack);
203 }
204
205 static inline Uns vector_stack_size(Vector *stack)
206 {
207    return vector_size(stack);
208 }
209
210 static inline bool vector_stack_is_empty(Vector *stack)
211 {
212    return vector_is_empty(stack);
213 }
214
215 static inline void push_vector_stack(Vector *stack)
216 {
217    Vector *v = vector_alloc();
218    vector_append(stack, v);
219 }
220
221 static inline Vector *peek_vector_stack(Vector *stack)
222 {
223    assert(!vector_stack_is_empty(stack));
224    return vector_peek_last(stack);
225 }
226
227 static inline Vector *pop_vector_stack(Vector *stack)
228 {
229    assert(!vector_stack_is_empty(stack));
230    return vector_pop_last(stack);
231 }
232
233 static inline void push_ast_node(Vector *stack, Ast_Node *n)
234 {
235    vector_append(peek_vector_stack(stack), n);
236 }
237
238 static inline Ast_Node *pop_ast_node(Vector *stack)
239 {
240    assert(!vector_is_empty(peek_vector_stack(stack)));
241    return vector_pop_last(peek_vector_stack(stack));
242 }
243
244 static inline Ast_Node *peek_ast_node(Vector *stack)
245 {
246    assert(!vector_is_empty(peek_vector_stack(stack)));
247    return vector_peek_last(peek_vector_stack(stack));
248 }
249
250 static inline void commit_decl_stmt()
251 {
252    consistent_stmt_decl_top =
253          vector_size(peek_vector_stack(&decl_stmt_stack));
254 }
255
256 static inline Uns get_consistent_stmt_decl_top()
257 {
258    return consistent_stmt_decl_top;
259 }
260
261 static inline File_Location get_node_location(Uns start_line, Uns start_column)
262 {
263    return FILE_LOCATION_INIT(current_file_name, start_line, start_column);
264 }
265
266 #define PARSER_BINARY_NODE(node_type, first_line, first_column)  \
```

```
267 do {                                                \
268    Ast_Node *___rhs = pop_ast_node(&decl_stmt_stack);    \
269    Ast_Node *___lhs = pop_ast_node(&decl_stmt_stack);    \
270    Ast_Node *___n = AST_NODE_BINARY_ALLOC(node_type,    \
271          get_node_location(first_line, first_column),   \
272          ___lhs, ___rhs);                               \
273    push_ast_node(&decl_stmt_stack, ___n);          \
274 } while (false)
275
276 #define PARSER_BINARY_NODE_REVERSED(node_type, first_line, first_column) \
277 do {                                                    \
278    Ast_Node *___lhs = pop_ast_node(&decl_stmt_stack);      \
279    Ast_Node *___rhs = pop_ast_node(&decl_stmt_stack);      \
280    Ast_Node *___n = AST_NODE_BINARY_ALLOC(node_type,      \
281          get_node_location(first_line, first_column),     \
282          ___lhs, ___rhs);                                 \
283    push_ast_node(&decl_stmt_stack, ___n);                \
284 } while (false)
285
286 #define PARSER_BINARY_EXPR(node_type, first_line, first_column)  \
287 do {                                                    \
288    Ast_Node *___rhs = pop_ast_node(&decl_stmt_stack);    \
289    Ast_Node *___lhs = pop_ast_node(&decl_stmt_stack);    \
290    Ast_Node *___n = AST_EXPR_BINARY_ALLOC(node_type,    \
291          get_node_location(first_line, first_column),   \
292          ___lhs, ___rhs);                               \
293    push_ast_node(&decl_stmt_stack, ___n);          \
294 } while (false)
295
296 #define PARSER_BINARY_EXPR_REVERSED(node_type, first_line, first_column) \
297 do {                                                    \
298    Ast_Node *___lhs = pop_ast_node(&decl_stmt_stack);      \
299    Ast_Node *___rhs = pop_ast_node(&decl_stmt_stack);      \
300    Ast_Node *___n = AST_EXPR_BINARY_ALLOC(node_type,      \
301          get_node_location(first_line, first_column),     \
302          ___lhs, ___rhs);                                 \
303    push_ast_node(&decl_stmt_stack, ___n);                \
304 } while (false)
305
306 #define PARSER_UNARY_NODE(node_type, first_line, first_column)  \
307 do {                                                    \
308    Ast_Node *___expr = pop_ast_node(&decl_stmt_stack);    \
309    Ast_Node *___n = AST_NODE_UNARY_ALLOC(node_type,    \
310          get_node_location(                             \
311             first_line, first_column),                  \
312          ___expr);                                      \
313    push_ast_node(&decl_stmt_stack, ___n);          \
314 } while (false)
315
316 #define PARSER_UNARY_EXPR(node_type, first_line, first_column)  \
317 do {                                                    \
318    Ast_Node *___expr = pop_ast_node(&decl_stmt_stack);    \
319    Ast_Node *___n = AST_EXPR_UNARY_ALLOC(node_type,    \
320          get_node_location(                             \
321             first_line, first_column),                  \
322          ___expr);                                      \
323    push_ast_node(&decl_stmt_stack, ___n);          \
324 } while (false)
325
326 #define PARSER_VAR_IDEN(node_type, first_line, first_column, text) \
327 do {                                                    \
328    Ast_Node *___n = AST_VARIABLE_IDEN_ALLOC(node_type,    \
329          get_node_location(first_line, first_column),   \
330          text);                                         \
331    push_ast_node(&decl_stmt_stack, ___n);          \
332 } while (false)
333
334 #define GET_STMT_LIST(node_type, vec_stmts) ({      \
335    Uns ___first_line, ___first_column;          \
336    if (!vector_is_empty(vec_stmts)) {           \
337       Ast_Node *___tmp_node = vector_peek_first(vec_stmts); \
338       ___first_line = ___tmp_node->location.line;    \
339       ___first_column = ___tmp_node->location.column;   \
340    } else {                                     \
```

```
341         ___first_line = yylval.token.lineno;      \
342         ___first_column = yylval.token.startcol;    \
343      }                                              \
344      AST_STMT_LIST_ALLOC(node_type,                 \
345            get_node_location(                       \
346               ___first_line, ___first_column), vec_stmts); \
347   })
348
349   static void report_further_errors()
350   {
351      File_Location tmp_loc = FILE_LOCATION_INIT(current_file_name,
352            last_err_line, last_err_column);
353      if (last_err_line == 0 || last_err_column == 0 ||
354            is_error_reported_here(&tmp_loc))
355         return;
356
357      if (!string_is_empty(last_err_text)) {
358         if (!string_is_empty(expect_string)) {
359            parser_report_error(last_err_line, last_err_column,
360               S("unexpected " QFY("%S") ", expected %S\n"),
361               last_err_text, expect_string);
362         } else if (!was_error_reported()) {
363            parser_report_error(last_err_line, last_err_column,
364                  S("unexpected " QFY("%S") "\n"), last_err_text);
365         }
366      } else if (!string_is_empty(expect_string)) {
367         parser_report_error(last_err_line, last_err_column,
368               S("expected " QFY("%S") " before " QFY("end of input") "\n"),
369               expect_string);
370      } else if (get_curl_nest()) {
371         parser_report_error(last_err_line, last_err_column,
372               S("expected " QFY("}") " before " QFY("end of input") "\n"));
373      } else if (get_func_nest()) {
374         parser_report_error(last_err_line, last_err_column,
375               S("expected end of function before " QFY("end of input") "\n"),
376               expect_string);
377      } else if (!was_error_reported()) {
378         parser_report_error(last_err_line, last_err_column,
379               S("unexpected " QFY("end of input") "\n"));
380      }
381   }
382
383   void parser_finalize()
384   {
385   }
386
387   #undef DEBUG_TYPE
388   #define DEBUG_TYPE parser-parse
389
390   %}
391
392   %code requires {
393      #include <str.h>
394      #include <parser.h>
395   }
396
397   %union {
398      struct {
399         String text;
400         Parser_Token_Type type;
401         Uns lineno;
402         Uns startcol;
403      } token;
404   }
405
406   %token <token> TKN_PLUS_OP  "@'+'#"
407   %token <token> TKN_MINUS_OP  "@'-'#"
408   %token <token> TKN_MUL_OP  "@'*'#"
409   %token <token> TKN_DIV_OP  "@'/'#"
410   %token <token> TKN_EQ_OP  "@'=='#"
411   %token <token> TKN_NEQ_OP  "@'!='#"
412   %token <token> TKN_GT_OP  "@'>'#"
413   %token <token> TKN_LT_OP  "@'<'#"
414   %token <token> TKN_GTEQ_OP  "@'>='#"
```

```
415 %token <token> TKN_LTEQ_OP  "@'<='#"
416 %token <token> TKN_LAND_OP  "@'&&'#"
417 %token <token> TKN_LOR_OP  "@'||'#"
418 %token <token> TKN_ASSIGN_OP "@'='#"
419 %token <token> TKN_DOT_OP  "@'.'#"
420 %token <token> TKN_COMMA_OP  "@','#"
421 %token <token> TKN_LSQUARE_OP "@'['#"
422 %token <token> TKN_RSQUARE_OP "@']'#"
423 %token <token> TKN_LPAREN_OP "@'('#"
424 %token <token> TKN_RPAREN_OP "@')'#"
425 %token <token> TKN_BANG_OP  "@'!'#"
426 %token <token> TKN_HLINE_OP  "@'|'#"
427 %token <token> TKN_COLON_OP  "@':'#"
428 %token <token> TKN_SCOLON_OP "@';'#"
429 %token <token> TKN_LCURLY_OP "@'{'#"
430 %token <token> TKN_RCURLY_OP "@'}'#"
431
432 %token <token> TKN_EXTERN_KEY "@'extern'#"
433 %token <token> TKN_FUNC_KEY  "@'func'#"
434 %token <token> TKN_END_KEY  "@'end'#"
435 %token <token> TKN_INT_KEY  "@'int'#"
436 %token <token> TKN_VOID_KEY  "@'void'#"
437 %token <token> TKN_BOOL_KEY  "@'bool'#"
438 %token <token> TKN_ARRAY_KEY "@'array'#"
439 %token <token> TKN_OF_KEY  "@'of'#"
440 %token <token> TKN_RECORD_KEY "@'record'#"
441 %token <token> TKN_FINALIZE_KEY "@'finalize'#"
442 %token <token> TKN_TYPE_KEY  "@'type'#"
443 %token <token> TKN_VAR_KEY  "@'var'#"
444 %token <token> TKN_IMPORT_KEY "@'import'#"
445 %token <token> TKN_PACKAGE_KEY "@'package'#"
446
447 %token <token> TKN_CHAR_KEY  "@'char'#"
448 %token <token> TKN_STRING_KEY "@'string'#"
449
450 %token <token> TKN_RETURN_KEY "@'return'#"
451 %token <token> TKN_WRITE_KEY "@'write'#"
452 %token <token> TKN_IF_KEY  "@'if'#"
453 %token <token> TKN_ALLOCATE_KEY "@'allocate'#"
454 %token <token> TKN_DELETE_KEY "@'delete'#"
455 %token <token> TKN_THEN_KEY  "@'then'#"
456 %token <token> TKN_WHILE_KEY "@'while'#"
457 %token <token> TKN_DO_KEY  "@'do'#"
458 %token <token> TKN_LENGTH_KEY "@'length'#"
459 %token <token> TKN_ELSE_KEY  "@'else'#"
460 %token <token> TKN_TRUE_KEY  "@'true'#"
461 %token <token> TKN_FALSE_KEY "@'false'#"
462 %token <token> TKN_NULL_KEY  "@'null'#"
463 %token <token> TKN_CAST_KEY  "@'cast'#"
464
465 %token <token> TKN_IDENTIFIER "@identifier#"
466 %token <token> TKN_INT_CONST "@integer constant#"
467 %token <token> TKN_CHAR_CONST "@char constant#"
468 %token <token> TKN_STRING_CONST "@string constant#"
469 %token <token> TKN_MODULE_CONST "@module literal#"
470
471 %token <token> TKN_UNEXPECTED "@unexpected character#"
472 %token <token> TKN_EOF    "@'end of input'#"
473
474 %token <token> error
475
476 %type <token> start
477 %type <token> start_body
478 %type <token> lcurly_op
479 %type <token> rcurly_op
480 %type <token> function
481 %type <token> extern_function
482 %type <token> func_head
483 %type <token> func_head_iden
484 %type <token> func_tail
485 %type <token> type_def
486 %type <token> type
487 %type <token> void_type
488 %type <token> record_decl
```

```
489 %type <token> type_cast
490 %type <token> var_type
491 %type <token> declaration
492 %type <token> decl_stmt_list
493 %type <token> statement
494 %type <token> variable
495 %type <token> direct_record_ref
496 %type <token> identifier
497 %type <token> record_identifier
498 %type <token> variable_identifier
499 %type <token> expression
500 %type <token> var_decl_list
501 %type <token> term
502 %type <token> term_no_var
503 %type <token> exp_list
504 %type <token> record_head
505 %type <token> decl_stmt
506 %type <token> errors
507 %type <token> record_member_last
508 %type <token> record_member_first
509 %type <token> record_seperator
510 %type <token> record_var
511 %type <token> curly_decl_stmt_list
512 %type <token> finalize_decl_stmt
513 %type <token> record_decl_list_last
514 %type <token> record_decl_list_first
515 %type <token> func_key
516 %type <token> func_key_enter
517 %type <token> end_key_leave
518 %type <token> if_stmt
519 %type <token> var_decl_type
520 %type <token> import_start
521 %type <token> package
522 %type <token> scolon_list
523
524 /* Expression precedence. */
525 %left TKN_LOR_OP
526 %left TKN_LAND_OP
527 %left TKN_EQ_OP TKN_NEQ_OP TKN_GT_OP TKN_LT_OP TKN_GTEQ_OP TKN_LTEQ_OP
528 %left TKN_PLUS_OP TKN_MINUS_OP
529 %left TKN_MUL_OP TKN_DIV_OP
530
531 /* Precedence to handle if-then-else shift/reduce conflicts. */
532 %right if_stmt_prec
533 %right TKN_ELSE_KEY
534
535 /* Precedence to handle variable shift/reduce conflicts. */
536 %right term_prec
537 %right variable_prec
538
539 /* Handle func tail shift/reduce. */
540 %right func_tail_prec
541
542 /* Handle shift/reducec for package statement errors. */
543 %right package_prec
544
545 /* Precedence to handle type cast shift/reduce conflicts. */
546 %right TKN_IDENTIFIER
547 %right TKN_RPAREN_OP
548 %right TKN_DOT_OP
549 %right TKN_RECORD_KEY
550 %right TKN_LSQUARE_OP
551
552 /* Precedence to handle record seperator shift/reduce conflicts. */
553 %right TKN_SCOLON_OP
554 %right TKN_COMMA_OP
555
556 /* Precedence to handle shift/reduce conflicts related to error recovery
557  * in decl_stmt and record_decl . */
558 %right decl_stmt_prec
559 %right record_member_prec
560 %right TKN_FUNC_KEY
561 %right error
562
```

```
563 %start start
564
565 %define parse.lac full
566 %error-verbose
567
568 %%
569
570 lcurly_op
571    : TKN_LCURLY_OP {
572       inc_curl_nest();
573    }
574    ;
575
576 rcurly_op
577    : TKN_RCURLY_OP {
578       dec_curl_nest();
579    }
580    ;
581
582 func_key
583    : TKN_FUNC_KEY {
584       push_vector_stack(&func_head_stack);
585    }
586    ;
587
588 func_key_enter
589    : func_key {
590       enter_func();
591    }
592
593 end_key_leave
594    : TKN_END_KEY {
595       leave_func();
596    }
597    ;
598
599 errors
600    : errors error
601    | error
602    ;
603
604 start
605    : {
606       push_vector_stack(&decl_stmt_stack);
607    } opt_package start_body {
608       Vector *statements = pop_vector_stack(&decl_stmt_stack);
609       assert(vector_stack_is_empty(&decl_stmt_stack));
610       current_ast->root = GET_STMT_LIST(AST_STMT_LIST, statements);
611    }
612    ;
613
614 start_body
615    : decl_stmt_list TKN_EOF
616    | TKN_EOF
617    ;
618
619 opt_package
620    : opt_scolon_list package %prec package_prec
621    | opt_scolon_list %prec package_prec
622    ;
623
624 opt_scolon_list
625    : scolon_list %prec package_prec
626    | %prec package_prec
627    ;
628
629 scolon_list
630    : scolon_list TKN_SCOLON_OP
631    | TKN_SCOLON_OP
632    ;
633
634 package
635    : TKN_PACKAGE_KEY TKN_MODULE_CONST TKN_SCOLON_OP {
636       Ast_Node *n = AST_MODULE_STRING_ALLOC(AST_PACKAGE_STRING,
```

```
637             get_node_location($2.lineno, $2.startcol), $2.text);
638       push_ast_node(&decl_stmt_stack, n);
639    }
640    | errors %prec package_prec {
641       RECOVER_EXPEC(decl_stmt_recover, $errors.lineno,
642             $errors.startcol, $errors.text);
643    }
644    ;
645
646 function
647    : func_head {
648       push_vector_stack(&decl_stmt_stack);
649    } func_body func_tail[t] {
650       Ast_Variable_Iden *head_iden = AST_CONTAINER_OF(
651             pop_ast_node(&func_head_stack), Ast_Variable_Iden);
652
653       Ast_Node *ret_type = pop_ast_node(&func_head_stack);
654       Vector *params = pop_vector_stack(&func_head_stack);
655       Vector *statements = pop_vector_stack(&decl_stmt_stack);
656       Ast_Node *body = GET_STMT_LIST(AST_FUNC_BODY, statements);
657
658       if ($t.text) {
659          if (string_compare($t.text, head_iden->iden))
660             parser_report_error($t.lineno, $t.startcol,
661                   S("unexpected identifier " QFY("%S")
662                      " after " QFY("end") " of function, "
663                      "expected " QFY("%S") "\n"),
664                   $t.text, head_iden->iden);
665       }
666
667       Ast_Node *n;
668       if (!string_compare(head_iden->iden, S("finalize"))) {
669          n = AST_FUNC_DEF_ALLOC(AST_FIN_FUNC_DEF,
670                get_node_location($1.lineno, $1.startcol), NULL,
671                AST_NODE_OF(head_iden), ret_type, params, body);
672       } else if (!string_compare(head_iden->iden, S("record"))) {
673          n = AST_FUNC_DEF_ALLOC(AST_REC_FUNC_DEF,
674                get_node_location($1.lineno, $1.startcol), NULL,
675                AST_NODE_OF(head_iden), ret_type, params, body);
676       } else {
677          n = AST_FUNC_DEF_ALLOC(AST_FUNC_DEF,
678                get_node_location($1.lineno, $1.startcol), NULL,
679                AST_NODE_OF(head_iden), ret_type, params, body);
680       }
681
682       push_ast_node(&decl_stmt_stack, n);
683    }
684    | func_key_enter func_head_iden TKN_LPAREN_OP opt_par_decl_list
685        TKN_RPAREN_OP error {
686       RECOVER_EXPEC(func_head_recover, $error.lineno,
687             $error.startcol, $error.text);
688    } func_body func_tail
689    | func_key_enter func_head_iden TKN_LPAREN_OP error {
690       RECOVER_UNEXPEC(func_head_recover, $error.lineno,
691             $error.startcol, $error.text);
692    } func_body func_tail
693    | func_key_enter error {
694       RECOVER_EXPEC(func_head_recover, $error.lineno,
695             $error.startcol, $error.text);
696    } func_body func_tail
697    ;
698
699 func_head_iden
700    : TKN_IDENTIFIER
701    | TKN_FINALIZE_KEY
702    | TKN_RECORD_KEY
703    ;
704
705 func_head
706    : func_key_enter func_head_iden[i] TKN_LPAREN_OP opt_par_decl_list
707        TKN_RPAREN_OP TKN_COLON_OP void_type {
708       push_ast_node(&func_head_stack, pop_ast_node(&decl_stmt_stack));
709       Ast_Node *iden = AST_VARIABLE_IDEN_ALLOC(AST_VARIABLE_IDEN,
710                get_node_location($i.lineno, $i.startcol),
```

```
711             $i.text);
712       push_ast_node(&func_head_stack, iden);
713    }
714    ;
715
716 func_body
717    : opt_decl_stmt_list
718    ;
719
720 func_tail
721    : end_key_leave func_head_iden[i] {
722       $$ = $i;
723    }
724    | end_key_leave error %prec func_tail_prec {
725       RECOVER_EXPEC(decl_stmt_recover, $error.lineno,
726             $error.startcol, $error.text);
727       $$.text = NULL;
728    }
729    ;
730
731 extern_function
732    : TKN_EXTERN_KEY TKN_LPAREN_OP TKN_IDENTIFIER[t] TKN_RPAREN_OP func_key
733          TKN_IDENTIFIER[i] TKN_LPAREN_OP opt_par_decl_list TKN_RPAREN_OP
734          TKN_COLON_OP void_type {
735       Ast_Node *ret_type = pop_ast_node(&decl_stmt_stack);
736       Vector *params = pop_vector_stack(&func_head_stack);
737       Ast_Node *func_iden = AST_VARIABLE_IDEN_ALLOC(AST_VARIABLE_IDEN,
738                get_node_location($i.lineno, $i.startcol),
739             $i.text);
740       Ast_Node *ext_iden = AST_TYPE_IDEN_ALLOC(AST_TYPE_IDEN,
741                get_node_location($t.lineno, $t.startcol),
742             $t.text);
743       Ast_Node *n = AST_FUNC_DEF_ALLOC(AST_EXT_FUNC_DECL,
744                get_node_location($1.lineno, $1.startcol),
745             ext_iden, func_iden, ret_type, params, NULL);
746       push_ast_node(&decl_stmt_stack, n);
747    }
748    | TKN_EXTERN_KEY TKN_LPAREN_OP TKN_IDENTIFIER[t] TKN_RPAREN_OP func_key
749          error {
750       RECOVER_EXPEC(extern_func_recover, $error.lineno,
751             $error.startcol, $error.text);
752    }
753
754 opt_par_decl_list
755    : par_decl_list
756    |
757    ;
758
759 par_decl_list
760    : par_decl_list TKN_COMMA_OP var_type {
761       push_ast_node(&func_head_stack, pop_ast_node(&decl_stmt_stack));
762    }
763    | var_type {
764       push_ast_node(&func_head_stack, pop_ast_node(&decl_stmt_stack));
765    }
766    ;
767
768 type
769    : TKN_IDENTIFIER {
770       Ast_Node *n = AST_TYPE_IDEN_ALLOC(AST_TYPE_IDEN,
771             get_node_location(
772                $TKN_IDENTIFIER.lineno, $TKN_IDENTIFIER.startcol),
773             $TKN_IDENTIFIER.text);
774       push_ast_node(&decl_stmt_stack, n);
775    }
776    | TKN_INT_KEY {
777       Ast_Node *n = AST_EMPTY_ALLOC(AST_SIMPLE_TYPE_INT,
778             get_node_location($1.lineno, $1.startcol));
779       push_ast_node(&decl_stmt_stack, n);
780    }
781    | TKN_BOOL_KEY {
782       Ast_Node *n = AST_EMPTY_ALLOC(AST_SIMPLE_TYPE_BOOL,
783             get_node_location($1.lineno, $1.startcol));
784       push_ast_node(&decl_stmt_stack, n);
```

```
785     }
786     | TKN_ARRAY_KEY TKN_OF_KEY type[t] {
787        Ast_Node *n = AST_TYPE_ALLOC(AST_TYPE_ARY,
788              get_node_location($1.lineno, $1.startcol),
789              pop_ast_node(&decl_stmt_stack));
790        push_ast_node(&decl_stmt_stack, n);
791     }
792     | TKN_CHAR_KEY {
793        Ast_Node *n = AST_EMPTY_ALLOC(AST_SIMPLE_TYPE_CHAR,
794              get_node_location($1.lineno, $1.startcol));
795        push_ast_node(&decl_stmt_stack, n);
796     }
797     | TKN_STRING_KEY {
798        Ast_Node *n = AST_EMPTY_ALLOC(AST_SIMPLE_TYPE_STRING,
799              get_node_location($1.lineno, $1.startcol));
800        push_ast_node(&decl_stmt_stack, n);
801     }
802     | record_decl
803     ;
804
805  void_type
806     : type
807     | TKN_VOID_KEY {
808        Ast_Node *n = AST_EMPTY_ALLOC(AST_SIMPLE_TYPE_VOID,
809              get_node_location($1.lineno, $1.startcol));
810        push_ast_node(&decl_stmt_stack, n);
811     }
812     ;
813
814  record_decl
815     : record_head lcurly_op {
816        dec_extend_nest();
817        push_extend_nest();
818        push_vector_stack(&decl_stmt_stack);
819     } opt_record_decl_list rcurly_op[r] {
820        DLOG("POP extend_stack\n");
821        Vector *extend = pop_vector_stack(&extend_stack);
822        Vector *body = pop_vector_stack(&decl_stmt_stack);
823        Ast_Node *n = AST_TYPE_REC_ALLOC(AST_TYPE_REC,
824              get_node_location($1.lineno, $1.startcol),
825              extend, body);
826        push_ast_node(&decl_stmt_stack, n);
827        pop_extend_nest();
828     }
829     ;
830
831  record_head
832     : TKN_RECORD_KEY TKN_OF_KEY {
833        DLOG("PUSH extend_stack\n");
834        inc_extend_nest();
835        push_vector_stack(&extend_stack);
836     } opt_extend
837     ;
838
839  opt_extend
840     : record_extend_list
841     |
842     ;
843
844  opt_record_decl_list
845     : record_decl_list_first
846     |
847     ;
848
849  record_extend_list
850     : record_extend_list TKN_COMMA_OP record_var {
851        push_ast_node(&extend_stack, pop_ast_node(&decl_stmt_stack));
852     }
853     | record_var {
854        push_ast_node(&extend_stack, pop_ast_node(&decl_stmt_stack));
855     }
856     ;
857
858  record_var
```

```
859     : TKN_IDENTIFIER {
860        Ast_Node *n = AST_TYPE_IDEN_ALLOC(AST_TYPE_IDEN,
861              get_node_location(
862              $TKN_IDENTIFIER.lineno, $TKN_IDENTIFIER.startcol),
863              $TKN_IDENTIFIER.text);
864        push_ast_node(&decl_stmt_stack, n);
865     }
866  /*
867     | record_decl
868  */
869     ;
870
871  record_decl_list_first
872     : record_decl_list_last record_member_first
873     | record_member_first
874     ;
875
876  record_decl_list_last
877     : record_decl_list_last record_member_last
878     | record_member_last
879     ;
880
881  record_member_first
882     : function {
883        commit_decl_stmt();
884     }
885     | var_type {
886        commit_decl_stmt();
887     }
888     | var_type record_seperator {
889        commit_decl_stmt();
890     }
891     | TKN_VAR_KEY var_type {
892        commit_decl_stmt();
893     }
894     | TKN_VAR_KEY var_type record_seperator {
895        commit_decl_stmt();
896     }
897     | type_def {
898        commit_decl_stmt();
899     }
900     | type_def record_seperator {
901        commit_decl_stmt();
902     }
903     | import_start {
904        Ast_Node *n = AST_MODULE_STRING_ALLOC(AST_IMPORT_STRING,
905              get_node_location($1.lineno, $1.startcol), $1.text);
906        push_ast_node(&decl_stmt_stack, n);
907        commit_decl_stmt();
908     }
909     | import_start record_seperator {
910        Ast_Node *n = AST_MODULE_STRING_ALLOC(AST_IMPORT_STRING,
911              get_node_location($1.lineno, $1.startcol), $1.text);
912        push_ast_node(&decl_stmt_stack, n);
913        commit_decl_stmt();
914     }
915     | record_seperator
916     | errors %prec record_member_prec {
917        RECOVER_UNEXPEC(record_body_recover, $errors.lineno, $errors.startcol,
918              $errors.text);
919     }
920     | errors TKN_LCURLY_OP {
921        RECOVER_UNEXPEC(record_body_recover, $errors.lineno, $errors.startcol,
922              $errors.text);
923     }
924     | errors TKN_FUNC_KEY %prec record_member_prec {
925        RECOVER_UNEXPEC(record_body_recover, $errors.lineno, $errors.startcol,
926              $errors.text);
927     }
928     ;
929
930  record_member_last
931     : function {
932        commit_decl_stmt();
```

```
933     }
934     | var_type record_seperator {
935        commit_decl_stmt();
936     }
937     | TKN_VAR_KEY var_type record_seperator {
938        commit_decl_stmt();
939     }
940     | type_def record_seperator {
941        commit_decl_stmt();
942     }
943     | import_start record_seperator {
944        Ast_Node *n = AST_MODULE_STRING_ALLOC(AST_IMPORT_STRING,
945              get_node_location($1.lineno, $1.startcol), $1.text);
946        push_ast_node(&decl_stmt_stack, n);
947        commit_decl_stmt();
948     }
949     | record_seperator
950     | errors %prec record_member_prec {
951        RECOVER_UNEXPEC(record_body_recover, $errors.lineno, $errors.startcol,
952              $errors.text);
953     }
954     | errors TKN_LCURLY_OP {
955        RECOVER_UNEXPEC(record_body_recover, $errors.lineno, $errors.startcol,
956              $errors.text);
957     }
958     | errors TKN_FUNC_KEY %prec record_member_prec {
959        RECOVER_UNEXPEC(record_body_recover, $errors.lineno, $errors.startcol,
960              $errors.text);
961     }
962     ;
963
964  record_seperator
965     : TKN_COMMA_OP
966     | TKN_SCOLON_OP
967     ;
968
969  var_decl_list
970     : var_decl_list TKN_COMMA_OP var_decl_type
971     | var_decl_type
972     ;
973
974  var_decl_type
975     : var_type
976     | var_type[i] TKN_ASSIGN_OP[a] expression {
977        Ast_Node *expr = pop_ast_node(&decl_stmt_stack);
978
979        Ast_Node *iden_n = AST_VARIABLE_IDEN_ALLOC(AST_VARIABLE_IDEN,
980           get_node_location($i.lineno, $i.startcol),
981           $i.text);
982
983        Ast_Node *n = AST_NODE_BINARY_ALLOC(AST_ASSIGNMENT,
984              get_node_location($a.lineno, $a.startcol),
985              iden_n, expr);
986        push_ast_node(&decl_stmt_stack, n);
987     }
988     ;
989
990  var_type
991     : TKN_IDENTIFIER[i] TKN_COLON_OP type {
992        PARSER_VAR_IDEN(AST_VARIABLE_IDEN, $i.lineno, $i.startcol, $i.text);
993        PARSER_BINARY_NODE_REVERSED(AST_VAR_DECL, $1.lineno, $1.startcol);
994     }
995     ;
996
997  opt_decl_stmt_list
998     : decl_stmt_list
999     |
1000    ;
1001
1002 decl_stmt_list
1003    : decl_stmt_list decl_stmt
1004    | decl_stmt
1005    ;
1006
```

```
1007 decl_stmt
1008    : declaration {
1009       commit_decl_stmt();
1010    }
1011    | statement {
1012       commit_decl_stmt();
1013    }
1014    | errors %prec decl_stmt_prec {
1015       RECOVER_EXPEC(decl_stmt_recover, $errors.lineno,
1016             $errors.startcol, $errors.text);
1017    }
1018    ;
1019
1020 curly_decl_stmt_list
1021    : lcurly_op {
1022       push_vector_stack(&decl_stmt_stack);
1023    } opt_decl_stmt_list rcurly_op {
1024       Vector *statements = pop_vector_stack(&decl_stmt_stack);
1025       push_ast_node(&decl_stmt_stack,
1026             GET_STMT_LIST(AST_STMT_LIST, statements));
1027    }
1028    ;
1029
1030 finalize_decl_stmt
1031    : TKN_FINALIZE_KEY {
1032       push_vector_stack(&decl_stmt_stack);
1033    } decl_stmt {
1034       Vector *statements = pop_vector_stack(&decl_stmt_stack);
1035       push_ast_node(&decl_stmt_stack,
1036             GET_STMT_LIST(AST_FIN_STMT_LIST, statements));
1037    }
1038    ;
1039
1040 declaration
1041    : function
1042    | extern_function TKN_SCOLON_OP
1043    | type_def TKN_SCOLON_OP
1044    | TKN_VAR_KEY var_decl_list TKN_SCOLON_OP /* Ignore. */
1045    | var_decl_list TKN_SCOLON_OP /* Ignore. */
1046    ;
1047
1048 type_def
1049    : TKN_TYPE_KEY TKN_IDENTIFIER TKN_ASSIGN_OP type {
1050       PARSER_VAR_IDEN(AST_VARIABLE_IDEN,
1051             $TKN_IDENTIFIER.lineno, $TKN_IDENTIFIER.startcol,
1052             $TKN_IDENTIFIER.text);
1053       PARSER_BINARY_NODE_REVERSED(AST_TYPE_DEF, $1.lineno, $1.startcol);
1054    }
1055    ;
1056
1057 statement
1058    : TKN_SCOLON_OP      /* Ignore. */
1059    | import_start TKN_SCOLON_OP {
1060       Ast_Node *n = AST_MODULE_STRING_ALLOC(AST_IMPORT_STRING,
1061             get_node_location($1.lineno, $1.startcol), $1.text);
1062       push_ast_node(&decl_stmt_stack, n);
1063    }
1064    | TKN_ALLOCATE_KEY variable TKN_SCOLON_OP {
1065       PARSER_UNARY_NODE(AST_ALLOC_REC, $1.lineno, $1.startcol);
1066    }
1067    | TKN_ALLOCATE_KEY variable[v] TKN_OF_KEY TKN_RECORD_KEY[r] TKN_LPAREN_OP {
1068       push_vector_stack(&expr_stack);
1069    } arg_list TKN_RPAREN_OP {
1070       Vector *v = pop_vector_stack(&expr_stack);
1071
1072       if (vector_is_empty(v)) {
1073          vector_destroy(v, NULL);
1074          PARSER_UNARY_NODE(AST_ALLOC_REC, $1.lineno, $1.startcol);
1075       } else {
1076          Ast_Node *rec_iden = pop_ast_node(&decl_stmt_stack);
1077
1078          Ast_Node *func_iden = AST_VARIABLE_IDEN_ALLOC(AST_VARIABLE_IDEN,
1079                get_node_location($r.lineno, $r.startcol), S("record"));
1080
```

```
1081            Ast_Node *func_call = AST_EXPR_FUNC_CALL_ALLOC(AST_EXPR_FUNC_CALL,
1082                  get_node_location($r.lineno, $r.startcol), func_iden, v);
1083
1084            Ast_Node *n = AST_NODE_BINARY_ALLOC(AST_ALLOC_REC_CALL,
1085                  get_node_location($1.lineno, $1.startcol),
1086                  rec_iden, func_call);
1087            push_ast_node(&decl_stmt_stack, n);
1088          }
1089      }
1090      | TKN_ALLOCATE_KEY variable TKN_OF_KEY TKN_LENGTH_KEY
1091            expression TKN_SCOLON_OP {
1092          PARSER_BINARY_NODE(AST_ALLOC_ARY, $1.lineno, $1.startcol);
1093      }
1094      | TKN_DELETE_KEY variable TKN_SCOLON_OP {
1095          PARSER_UNARY_NODE(AST_DELETE, $1.lineno, $1.startcol);
1096      }
1097      | TKN_RETURN_KEY expression TKN_SCOLON_OP {
1098          PARSER_UNARY_NODE(AST_RETURN_STMT, $1.lineno, $1.startcol);
1099      }
1100      | TKN_RETURN_KEY TKN_SCOLON_OP {
1101          Ast_Node *vnode = AST_EMPTY_ALLOC(AST_SIMPLE_TYPE_VOID,
1102                get_node_location($1.lineno, $1.startcol));
1103          push_ast_node(&decl_stmt_stack, vnode);
1104          PARSER_UNARY_NODE(AST_RETURN_STMT, $1.lineno, $1.startcol);
1105      }
1106      | TKN_WRITE_KEY expression TKN_SCOLON_OP {
1107          PARSER_UNARY_NODE(AST_WRITE_STMT, $1.lineno, $1.startcol);
1108      }
1109      | variable TKN_ASSIGN_OP[a] expression TKN_SCOLON_OP {
1110          PARSER_BINARY_NODE(AST_ASSIGNMENT, $a.lineno, $a.startcol);
1111      }
1112      | if_stmt %prec if_stmt_prec {
1113          Vector *statements = pop_vector_stack(&decl_stmt_stack);
1114          Ast_Node *s = GET_STMT_LIST(AST_STMT_LIST, statements);
1115          push_ast_node(&decl_stmt_stack, s);
1116          PARSER_BINARY_NODE(AST_IF_STMT, $1.lineno, $1.startcol);
1117      }
1118      | if_stmt TKN_ELSE_KEY {
1119          push_vector_stack(&decl_stmt_stack);
1120      } decl_stmt {
1121          Vector *if_statements = pop_vector_stack(&decl_stmt_stack);
1122          Vector *else_statements = pop_vector_stack(&decl_stmt_stack);
1123          Ast_Node *rhs = GET_STMT_LIST(AST_STMT_LIST, if_statements);
1124          Ast_Node *mid = GET_STMT_LIST(AST_STMT_LIST, else_statements);
1125          Ast_Node *lhs = pop_ast_node(&decl_stmt_stack);
1126          Ast_Node *n = AST_NODE_TERNARY_ALLOC(AST_IF_ELSE_STMT,
1127                get_node_location($1.lineno, $1.startcol),
1128                lhs, mid, rhs);
1129          push_ast_node(&decl_stmt_stack, n);
1130      }
1131      | TKN_WHILE_KEY expression TKN_DO_KEY {
1132          push_vector_stack(&decl_stmt_stack);
1133      } decl_stmt {
1134          Vector *statements = pop_vector_stack(&decl_stmt_stack);
1135          Ast_Node *s = GET_STMT_LIST(AST_STMT_LIST, statements);
1136          push_ast_node(&decl_stmt_stack, s);
1137          PARSER_BINARY_NODE(AST_WHILE_STMT, $1.lineno, $1.startcol);
1138      }
1139      | expression TKN_SCOLON_OP  /* Ignore. */
1140      | curly_decl_stmt_list   /* Ignore. */
1141      | finalize_decl_stmt
1142      ;
1143
1144  import_start
1145      : TKN_IMPORT_KEY TKN_MODULE_CONST {
1146          $$ = $2;
1147      }
1148      ;
1149
1150  if_stmt
1151      : TKN_IF_KEY expression TKN_THEN_KEY {
1152          push_vector_stack(&decl_stmt_stack);
1153      } decl_stmt
1154      ;
```

```
1155
1156  expression
1157      : expression TKN_LOR_OP expression {
1158          PARSER_BINARY_EXPR(AST_EXPR_LOR, $2.lineno, $2.startcol);
1159      }
1160      | expression TKN_LAND_OP expression {
1161          PARSER_BINARY_EXPR(AST_EXPR_LAND, $2.lineno, $2.startcol);
1162      }
1163      | expression TKN_EQ_OP expression {
1164          PARSER_BINARY_EXPR(AST_EXPR_EQ, $2.lineno, $2.startcol);
1165      }
1166      | expression TKN_NEQ_OP expression {
1167          PARSER_BINARY_EXPR(AST_EXPR_NEQ, $2.lineno, $2.startcol);
1168      }
1169      | expression TKN_GT_OP expression {
1170          PARSER_BINARY_EXPR(AST_EXPR_GT, $2.lineno, $2.startcol);
1171      }
1172      | expression TKN_LT_OP expression {
1173          PARSER_BINARY_EXPR(AST_EXPR_LT, $2.lineno, $2.startcol);
1174      }
1175      | expression TKN_GTEQ_OP expression {
1176          PARSER_BINARY_EXPR(AST_EXPR_GTEQ, $2.lineno, $2.startcol);
1177      }
1178      | expression TKN_LTEQ_OP expression {
1179          PARSER_BINARY_EXPR(AST_EXPR_LTEQ, $2.lineno, $2.startcol);
1180      }
1181      | expression TKN_PLUS_OP expression {
1182          PARSER_BINARY_EXPR(AST_EXPR_PLUS, $2.lineno, $2.startcol);
1183      }
1184      | expression TKN_MINUS_OP expression {
1185          PARSER_BINARY_EXPR(AST_EXPR_MINUS, $2.lineno, $2.startcol);
1186      }
1187      | expression TKN_MUL_OP expression {
1188          PARSER_BINARY_EXPR(AST_EXPR_MUL, $2.lineno, $2.startcol);
1189      }
1190      | expression TKN_DIV_OP expression {
1191          PARSER_BINARY_EXPR(AST_EXPR_DIV, $2.lineno, $2.startcol);
1192      }
1193      | term   /* Ignore. */
1194      ;
1195
1196  term
1197      : variable %prec term_prec       /* Ignore. */
1198      | term_no_var
1199      ;
1200
1201  term_no_var
1202      : TKN_LPAREN_OP expression TKN_RPAREN_OP /* Ignore. */
1203      | type_cast term_no_var {
1204          PARSER_BINARY_EXPR(AST_EXPR_CAST, $1.lineno, $1.startcol);
1205      }
1206      | TKN_BANG_OP term {
1207          PARSER_UNARY_EXPR(AST_EXPR_LNOT, $1.lineno, $1.startcol);
1208      }
1209      | TKN_INT_CONST {
1210          Ast_Node *n = AST_EXPR_INT_ALLOC(AST_EXPR_INT,
1211                get_node_location($1.lineno, $1.startcol), $1.text);
1212          push_ast_node(&decl_stmt_stack, n);
1213      }
1214      | TKN_TRUE_KEY {
1215          Ast_Node *n = AST_EXPR_BOOL_ALLOC(AST_EXPR_BOOL,
1216                get_node_location($1.lineno, $1.startcol), true);
1217          push_ast_node(&decl_stmt_stack, n);
1218      }
1219      | TKN_FALSE_KEY {
1220          Ast_Node *n = AST_EXPR_BOOL_ALLOC(AST_EXPR_BOOL,
1221                get_node_location($1.lineno, $1.startcol), false);
1222          push_ast_node(&decl_stmt_stack, n);
1223      }
1224      | TKN_NULL_KEY {
1225          Ast_Node *n = AST_EXPR_NULL_ALLOC(AST_EXPR_NULL,
1226                get_node_location($1.lineno, $1.startcol));
1227          push_ast_node(&decl_stmt_stack, n);
1228      }
```

```
1229      | TKN_CHAR_CONST {
1230         Ast_Node *n = AST_EXPR_CHAR_ALLOC(AST_EXPR_CHAR,
1231               get_node_location($1.lineno, $1.startcol), $1.text);
1232         push_ast_node(&decl_stmt_stack, n);
1233      }
1234      | TKN_STRING_CONST {
1235         Ast_Node *n = AST_EXPR_STRING_ALLOC(AST_EXPR_STRING,
1236               get_node_location($1.lineno, $1.startcol), $1.text);
1237         push_ast_node(&decl_stmt_stack, n);
1238      }
1239      | TKN_HLINE_OP expression TKN_HLINE_OP {
1240         PARSER_UNARY_EXPR(AST_EXPR_ABS, $1.lineno, $1.startcol);
1241      }
1242      ;
1243
1244   variable
1245      : variable TKN_DOT_OP variable_identifier[v] {
1246         PARSER_BINARY_EXPR(AST_EXPR_DOT_REF, $1.lineno, $1.startcol);
1247         $$ = $v;
1248      }
1249      | TKN_LPAREN_OP TKN_IDENTIFIER TKN_RPAREN_OP
1250            TKN_DOT_OP variable_identifier[v] {
1251         PARSER_VAR_IDEN(AST_VARIABLE_IDEN,
1252               $TKN_IDENTIFIER.lineno, $TKN_IDENTIFIER.startcol,
1253               $TKN_IDENTIFIER.text);
1254         PARSER_BINARY_EXPR_REVERSED(AST_EXPR_DOT_REF, $1.lineno, $1.startcol);
1255         $$ = $v;
1256      }
1257      | TKN_LPAREN_OP TKN_IDENTIFIER TKN_RPAREN_OP
1258            TKN_LSQUARE_OP expression TKN_RSQUARE_OP[s] {
1259         PARSER_VAR_IDEN(AST_VARIABLE_IDEN,
1260               $TKN_IDENTIFIER.lineno, $TKN_IDENTIFIER.startcol,
1261               $TKN_IDENTIFIER.text);
1262         PARSER_BINARY_EXPR_REVERSED(AST_EXPR_ARY_REF, $1.lineno, $1.startcol);
1263         $$ = $s;
1264      }
1265      | variable TKN_LSQUARE_OP expression TKN_RSQUARE_OP[s] {
1266         PARSER_BINARY_EXPR(AST_EXPR_ARY_REF, $1.lineno, $1.startcol);
1267         $$ = $s;
1268      }
1269      | type_cast[c] variable %prec variable_prec {
1270         PARSER_BINARY_EXPR(AST_EXPR_CAST, $1.lineno, $1.startcol);
1271         $$ = $c;
1272      }
1273      | TKN_LPAREN_OP variable[v] TKN_RPAREN_OP {
1274         $$ = $v;
1275      }
1276      | record_identifier[v] %prec variable_prec {
1277         $$ = $v;
1278      }
1279      | TKN_LPAREN_OP record_identifier[v] TKN_RPAREN_OP {
1280         $$ = $v;
1281      }
1282      | TKN_LPAREN_OP TKN_IDENTIFIER[t] TKN_RPAREN_OP {
1283         PARSER_VAR_IDEN(AST_VARIABLE_IDEN, $1.lineno, $1.startcol, $2.text);
1284         $$ = $t;
1285      }
1286      | direct_record_ref TKN_DOT_OP variable_identifier[v] {
1287         PARSER_BINARY_EXPR(AST_EXPR_DIRECT_REF, $1.lineno, $1.startcol);
1288      }
1289      | direct_record_ref TKN_LPAREN_OP[p] {
1290         push_vector_stack(&expr_stack);
1291      } arg_list TKN_RPAREN_OP[r] {
1292         Vector *v = pop_vector_stack(&expr_stack);
1293
1294         Ast_Node *iden = AST_VARIABLE_IDEN_ALLOC(AST_VARIABLE_IDEN,
1295               get_node_location($p.lineno, $p.startcol), S("record"));
1296
1297         Ast_Node *n = AST_EXPR_FUNC_CALL_ALLOC(AST_EXPR_FUNC_CALL,
1298               get_node_location($1.lineno, $1.startcol), iden, v);
1299         push_ast_node(&decl_stmt_stack, n);
1300
1301         PARSER_BINARY_EXPR(AST_EXPR_DIRECT_REF, $1.lineno, $1.startcol);
1302         $$ = $r;
```

```
1303     }
1304     ;
1305
1306  direct_record_ref
1307     : TKN_RECORD_KEY TKN_LSQUARE_OP record_var TKN_RSQUARE_OP
1308     | TKN_RECORD_KEY TKN_LSQUARE_OP TKN_RSQUARE_OP {
1309        push_ast_node(&decl_stmt_stack, NULL);
1310     }
1311     ;
1312
1313  variable_identifier
1314     : identifier
1315     | TKN_IDENTIFIER[i] TKN_LPAREN_OP {
1316        push_vector_stack(&expr_stack);
1317     } arg_list TKN_RPAREN_OP[p] {
1318        Vector *v = pop_vector_stack(&expr_stack);
1319
1320        Ast_Node *iden = AST_VARIABLE_IDEN_ALLOC(AST_VARIABLE_IDEN,
1321              get_node_location($i.lineno, $i.startcol),
1322              $i.text);
1323
1324        Ast_Node *n = AST_EXPR_FUNC_CALL_ALLOC(AST_EXPR_FUNC_CALL,
1325              get_node_location($1.lineno, $1.startcol), iden, v);
1326        push_ast_node(&decl_stmt_stack, n);
1327        $$ = $p;
1328     }
1329     ;
1330
1331  record_identifier
1332     : identifier
1333     | TKN_RECORD_KEY[r] {
1334        Ast_Node *n = AST_EMPTY_ALLOC(AST_REC_SELF_PTR,
1335              get_node_location($1.lineno, $1.startcol));
1336        push_ast_node(&decl_stmt_stack, n);
1337     }
1338     | TKN_IDENTIFIER[i] TKN_LPAREN_OP {
1339        push_vector_stack(&expr_stack);
1340     } arg_list TKN_RPAREN_OP[p] {
1341        Vector *v = pop_vector_stack(&expr_stack);
1342
1343        Ast_Node *iden = AST_VARIABLE_IDEN_ALLOC(AST_VARIABLE_IDEN,
1344              get_node_location($i.lineno, $i.startcol),
1345              $i.text);
1346
1347        Ast_Node *n = AST_EXPR_FUNC_CALL_ALLOC(AST_EXPR_FUNC_CALL,
1348              get_node_location($1.lineno, $1.startcol), iden, v);
1349        push_ast_node(&decl_stmt_stack, n);
1350        $$ = $p;
1351     }
1352     ;
1353
1354  identifier
1355     : TKN_IDENTIFIER[t] {
1356        PARSER_VAR_IDEN(AST_VARIABLE_IDEN, $1.lineno, $1.startcol, $1.text);
1357        $$ = $t;
1358     }
1359     ;
1360
1361  arg_list
1362     : exp_list
1363     |
1364     ;
1365
1366  exp_list
1367     : exp_list TKN_COMMA_OP expression {
1368        push_ast_node(&expr_stack, pop_ast_node(&decl_stmt_stack));
1369     }
1370     | expression {
1371        push_ast_node(&expr_stack, pop_ast_node(&decl_stmt_stack));
1372     }
1373     ;
1374
1375  type_cast
1376     : TKN_CAST_KEY TKN_LPAREN_OP type TKN_RPAREN_OP
```

```
1377     ;
1378 %%
1379
1380 static Uns prev_err_line, prev_err_col;
1381
1382 static bool same_as_prev_node(Uns line, Uns col)
1383 {
1384     bool ret;
1385     if (prev_err_line == line && prev_err_col == col) {
1386         ret = true;
1387     } else {
1388         prev_err_line = line;
1389         prev_err_col = col;
1390         ret = false;
1391     }
1392     return ret;
1393 }
1394
1395 static void finish_recover()
1396 {
1397     Ast_Node *n;
1398     Vector *v = peek_vector_stack(&decl_stmt_stack);
1399     while (vector_size(v) > get_consistent_stmt_decl_top()) {
1400         n = vector_pop_last(v);
1401         ast_visitor_delete_accept_visitor(n);
1402     }
1403     for (; get_extend_nest(); dec_extend_nest()) {
1404         v = pop_vector_stack(&extend_stack);
1405         VECTOR_FOR_EACH_ENTRY(v, n)
1406             ast_visitor_delete_accept_visitor(n);
1407         vector_destroy(v, NULL);
1408     }
1409     clear_vector_stack(&expr_stack);
1410 }
1411
1412 static void finish_func_head_stack()
1413 {
1414     Ast_Node *n;
1415     Vector *head = pop_vector_stack(&func_head_stack);
1416     VECTOR_FOR_EACH_ENTRY(head, n)
1417         ast_visitor_delete_accept_visitor(n);
1418     vector_destroy(head, NULL);
1419 }
1420
1421 #undef DEBUG_TYPE
1422 #define DEBUG_TYPE parser-recover:parser-func-recover
1423 static void func_head_recover()
1424 {
1425     Parser_Token_Type tt = yylval.token.type;
1426     Int recover_func_nest = 0, recover_curl_nest = 0;
1427     DLOG(" - START TOKEN: %d\n", tt);
1428     switch (tt) {
1429     case TKN_END_KEY:
1430         goto out;
1431     default:
1432         break;
1433     }
1434     while (tt) {
1435         switch (tt) {
1436         case TKN_FUNC_KEY:
1437             DLOG("INC FUNC NEST\n");
1438             ++recover_func_nest;
1439             break;
1440         case TKN_LCURLY_OP:
1441             DLOG("INC CURL NEST\n");
1442             ++recover_curl_nest;
1443             break;
1444         case TKN_END_KEY:
1445             if (!recover_func_nest) {
1446                 if (!recover_curl_nest)
1447                     goto out;
1448             } else {
1449                 DLOG("DEC FUNC NEST\n");
1450                 --recover_func_nest;
```

```
1451            }
1452            break;
1453         case TKN_RCURLY_OP:
1454            if (recover_curl_nest) {
1455               DLOG("DEC CURL NEST\n");
1456               --recover_curl_nest;
1457            }
1458            break;
1459         case TKN_EOF:
1460            if (recover_curl_nest)
1461               inc_curl_nest();
1462            if (recover_func_nest)
1463               inc_func_nest();
1464            goto out;
1465         default:
1466            break;
1467         }
1468         tt = yylex();
1469      };
1470   out:
1471      scanner_push_back_token();
1472      finish_func_head_stack();
1473      finish_recover();
1474   }
1475
1476   static void extern_func_recover()
1477   {
1478      decl_stmt_recover();
1479      finish_func_head_stack();
1480   }
1481
1482   #undef DEBUG_TYPE
1483   #define DEBUG_TYPE parser-recover:parser-stmt-recover
1484   static void decl_stmt_recover()
1485   {
1486      Parser_Token_Type tt = yylval.token.type;
1487      Int recover_func_nest = 0, recover_curl_nest = 0;
1488      DLOG("START TOKEN: %u\n", tt);
1489      switch (tt) {
1490      case TKN_RCURLY_OP:
1491         if (get_curl_nest())
1492            goto out;
1493         tt = yylex();
1494         break;
1495      default:
1496         break;
1497      }
1498      while (tt) {
1499         DLOG("TOKEN VAL: %d\n", tt);
1500         switch (tt) {
1501         case TKN_IMPORT_KEY:
1502         case TKN_ALLOCATE_KEY:
1503         case TKN_IF_KEY:
1504         case TKN_WRITE_KEY:
1505         case TKN_RETURN_KEY:
1506         case TKN_TYPE_KEY:
1507         case TKN_VAR_KEY:
1508         case TKN_WHILE_KEY:
1509         case TKN_SCOLON_OP:
1510            if (!recover_func_nest && !recover_curl_nest)
1511               goto out;
1512            break;
1513         case TKN_FUNC_KEY:
1514            DLOG("INC FUNC NEST\n");
1515            ++recover_func_nest;
1516            break;
1517         case TKN_LCURLY_OP:
1518            DLOG("INC CURL NEST\n");
1519            ++recover_curl_nest;
1520            break;
1521         case TKN_END_KEY:
1522            if (!recover_func_nest) {
1523               if (!recover_curl_nest) {
1524                  DLOG("END TOKEN PUSH\n");
```

```
1525                goto out;
1526             }
1527          } else {
1528             DLOG("DEC FUNC NEST\n");
1529             if (!--recover_func_nest && !recover_curl_nest) {
1530                tt = yylex();
1531                if (tt != TKN_IDENTIFIER)
1532                   goto out;
1533                tt = yylex();
1534                if (tt != TKN_COMMA_OP)
1535                   goto out;
1536                continue;
1537             }
1538          }
1539          break;
1540       case TKN_RCURLY_OP:
1541          DLOG("FOUND '}' CURL NEST IS CURRENTLY: %U\n", recover_curl_nest);
1542          if (!recover_curl_nest) {
1543             if (!recover_func_nest) {
1544                if (!get_curl_nest()) {
1545                   DLOG("OUT NO PUSH '}'\n");
1546                   goto out_no_push;
1547                }
1548                DLOG("OUT PUSH '}'\n");
1549                goto out;
1550             }
1551          } else {
1552             DLOG("DEC CURL NEST\n");
1553             --recover_curl_nest;
1554          }
1555          break;
1556       case TKN_EOF:
1557          if (recover_curl_nest)
1558             inc_curl_nest();
1559          if (recover_func_nest)
1560             inc_func_nest();
1561          goto out;
1562       default:
1563          break;
1564       }
1565       tt = yylex();
1566    };
1567 out:
1568    scanner_push_back_token();
1569 out_no_push:
1570    finish_recover();
1571 }
1572
1573 #undef DEBUG_TYPE
1574 #define DEBUG_TYPE parser-recover:parser-record-recover
1575 static void record_body_recover()
1576 {
1577    Parser_Token_Type tt = yylval.token.type;
1578    Int recover_func_nest = 0, recover_curl_nest = 0;
1579    DLOG("--- START TOKEN: %d\n", tt);
1580    while (tt) {
1581       DLOG("TOKEN VAL: %d\n", tt);
1582       switch (tt) {
1583       case TKN_IMPORT_KEY:
1584       case TKN_TYPE_KEY:
1585       case TKN_SCOLON_OP:
1586          /* Fall through. */
1587       case TKN_COMMA_OP:
1588          if (!recover_func_nest && !recover_curl_nest)
1589             goto out;
1590          break;
1591       case TKN_FUNC_KEY:
1592          DLOG("INC FUNC NEST\n");
1593          ++recover_func_nest;
1594          break;
1595       case TKN_LCURLY_OP:
1596          DLOG("INC CURL NEST\n");
1597          ++recover_curl_nest;
1598          break;
```

```
1599        case TKN_END_KEY:
1600           if (!recover_func_nest) {
1601              if (!recover_curl_nest) {
1602                 DLOG("END TOKEN BREAK\n");
1603                 goto out;
1604              }
1605           } else {
1606              DLOG("DEC FUNC NEST\n");
1607              --recover_func_nest;
1608           }
1609           break;
1610        case TKN_RCURLY_OP:
1611           DLOG("FOUND '}' CURL NEST IS CURRENTLY: %U\n", recover_curl_nest);
1612           if (!recover_curl_nest) {
1613              if (!recover_func_nest) {
1614                 if (!get_curl_nest()) {
1615                    DLOG("OUT NO PUSH '}'\n");
1616                    goto out_no_push;
1617                 }
1618                 DLOG("OUT PUSH '}'\n");
1619                 goto out;
1620              }
1621           } else {
1622              DLOG("DEC CURL NEST\n");
1623              --recover_curl_nest;
1624           }
1625           break;
1626        case TKN_EOF:
1627           if (recover_curl_nest)
1628              inc_curl_nest();
1629           if (recover_func_nest)
1630              inc_func_nest();
1631           goto out;
1632        default:
1633           break;
1634        }
1635        tt = yylex();
1636     };
1637  out:
1638     scanner_push_back_token();
1639  out_no_push:
1640     finish_recover();
1641  }
1642
1643  Ast *parser_parse(Const_String file)
1644  {
1645     current_ast = ast_alloc(file);
1646     current_file_name = file;
1647     last_err_line = 0;
1648     last_err_column = 0;
1649     extend_nest = 0;
1650     consistent_stmt_decl_top = 0;
1651
1652     scanner_restart();
1653     int ret = yyparse();
1654     (void)ret;
1655
1656     report_further_errors();
1657
1658     string_clear(expect_string);
1659
1660     assert(vector_is_empty(&curl_nest_stack) || ret);
1661     vector_clear(&curl_nest_stack);
1662
1663     assert(vector_stack_is_empty(&expr_stack) || ret);
1664     clear_vector_stack(&expr_stack);
1665
1666     assert(vector_stack_is_empty(&decl_stmt_stack) || ret);
1667     clear_vector_stack(&decl_stmt_stack);
1668
1669     assert(vector_stack_is_empty(&extend_stack) || ret);
1670     clear_vector_stack(&extend_stack);
1671
1672     assert(vector_is_empty(&extend_nest_stack) || ret);
```

```
1673     vector_clear(&extend_nest_stack);
1674
1675     assert(vector_stack_is_empty(&func_head_stack) || ret);
1676     clear_vector_stack(&func_head_stack);
1677
1678     return current_ast;
1679 }
1680
1681 static void create_expect_string(const char *str)
1682 {
1683     const char *nchr, *chr = strchr(str, EXPECTED_STRING_START);
1684     string_clear(expect_string);
1685     if (!chr)
1686         return; /* Should never happen. */
1687     /* Go past unexexpected token. */
1688     chr = strchr(chr + 1, EXPECTED_STRING_START);
1689     if (chr) {
1690         ++chr;
1691         string_append(expect_string, S(chr));
1692         string_search_replace_char(expect_string, EXPECTED_STRING_END, '\0');
1693         chr = strchr(chr, EXPECTED_STRING_START);
1694         for (; chr; chr = nchr) {
1695             nchr = strchr(++chr, EXPECTED_STRING_START);
1696             if (nchr)
1697                 string_append_format(expect_string, S(", %s"), chr);
1698             else
1699                 string_append_format(expect_string, S(" or %s"), chr);
1700             string_search_replace_char(expect_string,
1701                     EXPECTED_STRING_END, '\0');
1702         }
1703     }
1704 }
1705
1706 void yyerror(const char *str)
1707 {
1708     last_err_line = yylval.token.lineno;
1709     last_err_column = yylval.token.startcol;
1710     last_err_text = yylval.token.text;
1711     create_expect_string(str);
1712 }
```

:

A.3.17 src/parser/scanner.l

```
1  %{
2
3  #include "parser.tab.h"
4  #include <parser.h>
5  #include <std_include.h>
6  #include <vector.h>
7
8  static Uns block_comment_nest;
9  static Uns column = 1;
10 static Uns eof_count;
11 static bool at_eof;
12
13 /* Used to free memory allocated for token text later on. */
14 static VECTOR(token_text_list);
15
16 static inline void newline_action()
17 {
18     column = 1;
19 }
20
21 static inline void text_read_action()
22 {
23     column += yyleng;
24 }
25
26 static Parser_Token_Type token_action(Parser_Token_Type token_type)
```

```
27  {
28     yylval.token.text = string_duplicate(S(yytext));
29     vector_append(&token_text_list, yylval.token.text);
30     yylval.token.type = token_type;
31     yylval.token.lineno = yylineno;
32     yylval.token.startcol = column;
33     text_read_action();
34     return token_type;
35  }
36
37  %}
38
39  %option noinput
40  %option nounput
41  %option noyywrap
42  %option yylineno
43  %option align
44
45  %s IN_COMMENT
46  %s IN_MODULE
47
48  ID    [a-zA-Z_][a-zA-Z_0-9]*
49  STR   \"(\\.|[^\\"\n])*[\"\n]
50  CHAR  \'(\\.|[^\\'\n])*[\'\n]
51  MODULE ({ID}\.?)*{ID}
52
53  %%
54
55  <INITIAL>{
56     \(\*     text_read_action(); ++block_comment_nest; BEGIN(IN_COMMENT);
57     \#.*\n   newline_action();
58     [ \t\r]  text_read_action();
59     \n       newline_action();
60
61     \+       return token_action(TKN_PLUS_OP);
62     \-       return token_action(TKN_MINUS_OP);
63     \*       return token_action(TKN_MUL_OP);
64     \/       return token_action(TKN_DIV_OP);
65     ==       return token_action(TKN_EQ_OP);
66     !=       return token_action(TKN_NEQ_OP);
67     \>       return token_action(TKN_GT_OP);
68     \<       return token_action(TKN_LT_OP);
69     \>=      return token_action(TKN_GTEQ_OP);
70     \<=      return token_action(TKN_LTEQ_OP);
71     &&       return token_action(TKN_LAND_OP);
72     \|\|     return token_action(TKN_LOR_OP);
73     =        return token_action(TKN_ASSIGN_OP);
74     \.       return token_action(TKN_DOT_OP);
75     ,        return token_action(TKN_COMMA_OP);
76     \[       return token_action(TKN_LSQUARE_OP);
77     \]       return token_action(TKN_RSQUARE_OP);
78     \(       return token_action(TKN_LPAREN_OP);
79     \)       return token_action(TKN_RPAREN_OP);
80     \{       return token_action(TKN_LCURLY_OP);
81     \}       return token_action(TKN_RCURLY_OP);
82     !        return token_action(TKN_BANG_OP);
83     \|       return token_action(TKN_HLINE_OP);
84     :        return token_action(TKN_COLON_OP);
85     ;        return token_action(TKN_SCOLON_OP);
86
87     extern   return token_action(TKN_EXTERN_KEY);
88     func     return token_action(TKN_FUNC_KEY);
89     end      return token_action(TKN_END_KEY);
90     int      return token_action(TKN_INT_KEY);
91     void     return token_action(TKN_VOID_KEY);
92     bool     return token_action(TKN_BOOL_KEY);
93     char     return token_action(TKN_CHAR_KEY);
94     string   return token_action(TKN_STRING_KEY);
95     array    return token_action(TKN_ARRAY_KEY);
96     of       return token_action(TKN_OF_KEY);
97     record   return token_action(TKN_RECORD_KEY);
98     finalize return token_action(TKN_FINALIZE_KEY);
99     type     return token_action(TKN_TYPE_KEY);
100    var      return token_action(TKN_VAR_KEY);
```

```
101     return   return token_action(TKN_RETURN_KEY);
102     write    return token_action(TKN_WRITE_KEY);
103     if       return token_action(TKN_IF_KEY);
104     allocate return token_action(TKN_ALLOCATE_KEY);
105     delete   return token_action(TKN_DELETE_KEY);
106     then     return token_action(TKN_THEN_KEY);
107     while    return token_action(TKN_WHILE_KEY);
108     do       return token_action(TKN_DO_KEY);
109     length   return token_action(TKN_LENGTH_KEY);
110     else     return token_action(TKN_ELSE_KEY);
111     true     return token_action(TKN_TRUE_KEY);
112     false    return token_action(TKN_FALSE_KEY);
113     null     return token_action(TKN_NULL_KEY);
114     cast     return token_action(TKN_CAST_KEY);
115     import   BEGIN(IN_MODULE); return token_action(TKN_IMPORT_KEY);
116     package  BEGIN(IN_MODULE); return token_action(TKN_PACKAGE_KEY);
117
118     [0-9]+   return token_action(TKN_INT_CONST);
119     {ID}     return token_action(TKN_IDENTIFIER);
120
121     {CHAR}   return token_action(TKN_CHAR_CONST);
122     {STR}    return token_action(TKN_STRING_CONST);
123
124     .        return token_action(TKN_UNEXPECTED);
125
126     <<eof>> {
127              if (at_eof) {
128                 return 0;
129              } else {
130                 at_eof = true;
131                 return token_action(TKN_EOF);
132              }
133           }
134 }
135
136 <IN_COMMENT>{
137     \(\*  text_read_action(); ++block_comment_nest;
138     \*\)  text_read_action(); if (!--block_comment_nest) BEGIN(INITIAL);
139     \n    newline_action();
140     .     text_read_action();
141
142     <<eof>> {
143              if (at_eof) {
144                 return 0;
145              } else {
146                 at_eof = true;
147                 if (!eof_count++)
148                    parser_report_error(yylineno, column, S(
149                          "unterminated block comment, "
150                          "missing " QFY("*)") "\n"));
151                 return token_action(TKN_EOF);
152              }
153           }
154 }
155
156 <IN_MODULE>{
157     [ \t\r]  text_read_action();
158     \n       newline_action();
159     {MODULE} BEGIN(INITIAL); return token_action(TKN_MODULE_CONST);
160     .        BEGIN(INITIAL); return token_action(TKN_UNEXPECTED);
161     <<eof>>  BEGIN(INITIAL); return token_action(TKN_MODULE_CONST);
162 }
163
164 %%
165
166 int yylex_destroy();
167 void yyrestart(FILE *in);
168
169 void scanner_push_back_token()
170 {
171     if (!*yytext) {
172        --column;
173        at_eof = false;
174     } else {
```

```
175         if (!strcmp(yytext, "import"))
176            BEGIN(INITIAL);
177         column -= yyleng;
178         yyless(0);
179      }
180   }
181
182   void scanner_restart()
183   {
184      vector_for_each_destroy(&token_text_list,
185            (Vector_Destructor)string_destroy);
186      yylineno = 1;
187      column = 1;
188      block_comment_nest = 0;
189      eof_count = 0;
190      at_eof = false;
191      BEGIN(INITIAL);
192      yyrestart(yyin);
193   }
194
195   void scanner_finalize()
196   {
197      vector_for_each_destroy(&token_text_list,
198         (Vector_Destructor)string_destroy);
199      if (yylex_destroy())
200         fatal_error(S("error deallocating scanner memory.\n"));
201   }
```

A.4 Imports

:

A.4.1 src/ast/ast_visitor_import.c

```
1   #include "ast_visitor_import.h"
2   #include <import_handler.h>
3   #include "symbol_table.h"
4   #include <debug.h>
5   #include <main.h>
6
7   #undef DEBUG_TYPE
8   #define DEBUG_TYPE import
9
10  AST_VISITOR_STRUCT_BEGIN(Ast_Visitor_Import)
11     Ast *ast;
12     Symbol_Table *sym_table;
13     Symbol_Property next_property;
14     String prev_iden;
15     bool in_def_or_decl;
16     Hash_Map imported_hash;
17  AST_VISITOR_STRUCT_END(Ast_Visitor_Import)
18
19  static void unary_action(Ast_Visitor_Import *v, Ast_Node_Unary *n)
20  {
21     n->expr->accept_visitor(n->expr, AST_VISITOR_OF(v));
22  }
23
24  static void binary_action(Ast_Visitor_Import *v, Ast_Node_Binary *n)
25  {
26     n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
27     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
28  }
29
30  #include <unistd.h>
31
32  static void set_project_root(Ast *ast)
33  {
34     Const_String package = ast_get_package(ast);
```

```
35     cd_working_dir();
36     Uns cnt = 0;
37
38     String tmp_str, cur_dir;
39     char *cstr = realpath(string_to_cstr(ast_get_dirname(ast)), NULL);
40     if (!cstr)
41        fatal_error(S("Unable to locate project root [%m]\n"));
42
43     cur_dir = string_alloc(S(cstr));
44     free_mem(cstr);
45     if (package) {
46        cnt = string_count(package, S("/"));
47        for (Uns i = 0; i < cnt+1; i++ ) {
48           tmp_str = string_dirname(cur_dir);
49           string_destroy(cur_dir);
50           cur_dir = tmp_str;
51        }
52     }
53
54     import_handler_set_project_root(cur_dir);
55     string_destroy(cur_dir);
56  }
57
58  static void func_call_import(Vector *args, Ast_Visitor *v)
59  {
60     Ast_Node *expr;
61     VECTOR_FOR_EACH_ENTRY(args, expr)
62        expr->accept_visitor(expr, v);
63  }
64
65  typedef struct Imported {
66     Symbol_Table_Node *node;
67     Const_String dep;
68     Hash_Map_Slot slot;
69  } Imported;
70
71  #define IMPORTED_OF_SLOT(s) CONTAINER_OF(s, Imported, slot)
72
73  static bool imported_hash_comparator(Imported *search, Hash_Map_Slot *slot)
74  {
75     Imported *imp = IMPORTED_OF_SLOT(slot);
76     if (search->node != imp->node)
77        return false;
78     if (string_compare(search->dep, imp->dep))
79        return false;
80     return true;
81  }
82
83  static bool imported_hash_insert(Hash_Map *map, Symbol_Table_Node *node,
84        Const_String dep)
85  {
86     Imported *imp = alloc_mem(sizeof(Imported));
87     imp->dep = dep;
88     imp->node = node;
89     Uns hash = string_hash_code(dep);
90     if (!hash_map_contains(map, imp, hash)) {
91        hash_map_insert(map, &imp->slot, hash);
92        return true;
93     } else {
94        free_mem(imp);
95        return false;
96     }
97  }
98
99  static void imported_hash_destructor(Hash_Map_Slot *slot)
100 {
101    free_mem(IMPORTED_OF_SLOT(slot));
102 }
103
104 ASTVF_BEGIN(AST_EXPR_LOR, Ast_Visitor_Import, v, Ast_Node_Binary, n)
105    binary_action(v, n);
106 ASTVF_END
107
108 ASTVF_BEGIN(AST_EXPR_LAND, Ast_Visitor_Import, v, Ast_Node_Binary, n)
```

```
109     binary_action(v, n);
110 ASTVF_END
111
112 ASTVF_BEGIN(AST_EXPR_EQ, Ast_Visitor_Import, v, Ast_Node_Binary, n)
113     binary_action(v, n);
114 ASTVF_END
115
116 ASTVF_BEGIN(AST_EXPR_NEQ, Ast_Visitor_Import, v, Ast_Node_Binary, n)
117     binary_action(v, n);
118 ASTVF_END
119
120 ASTVF_BEGIN(AST_EXPR_GT, Ast_Visitor_Import, v, Ast_Node_Binary, n)
121     binary_action(v, n);
122 ASTVF_END
123
124 ASTVF_BEGIN(AST_EXPR_LT, Ast_Visitor_Import, v, Ast_Node_Binary, n)
125     binary_action(v, n);
126 ASTVF_END
127
128 ASTVF_BEGIN(AST_EXPR_GTEQ, Ast_Visitor_Import, v, Ast_Node_Binary, n)
129     binary_action(v, n);
130 ASTVF_END
131
132 ASTVF_BEGIN(AST_EXPR_LTEQ, Ast_Visitor_Import, v, Ast_Node_Binary, n)
133     binary_action(v, n);
134 ASTVF_END
135
136 ASTVF_BEGIN(AST_EXPR_PLUS, Ast_Visitor_Import, v, Ast_Node_Binary, n)
137     binary_action(v, n);
138 ASTVF_END
139
140 ASTVF_BEGIN(AST_EXPR_MINUS, Ast_Visitor_Import, v, Ast_Node_Binary, n)
141     binary_action(v, n);
142 ASTVF_END
143
144 ASTVF_BEGIN(AST_EXPR_MUL, Ast_Visitor_Import, v, Ast_Node_Binary, n)
145     binary_action(v, n);
146 ASTVF_END
147
148 ASTVF_BEGIN(AST_EXPR_DIV, Ast_Visitor_Import, v, Ast_Node_Binary, n)
149     binary_action(v, n);
150 ASTVF_END
151
152 ASTVF_BEGIN(AST_EXPR_CAST, Ast_Visitor_Import, v, Ast_Node_Binary, n)
153     Symbol_Table_Node *node = ast_node_get_symbol_table_node(AST_NODE_OF(n));
154     Symbol_Property saved_property = v->next_property;
155
156     v->in_def_or_decl = true;
157     v->next_property = SYMBOL_PROPERTY_TYPE_DEF;
158     n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
159     v->in_def_or_decl = false;
160
161     DLOG("Check update type of CAST '%S'\n", v->prev_iden);
162     v->next_property = SYMBOL_PROPERTY_VAR;
163     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
164     v->next_property = saved_property;
165
166     File_Location *loc = ast_node_get_file_location(AST_NODE_OF(n));
167     Symbol *symbol = symbol_table_get_from_location(node, loc);
168     assert(symbol);
169     import_table_update_symbol_type(false, ast_get_symbol_table(v->ast), node,
170             symbol->resolved_type, true);
171 ASTVF_END
172
173 ASTVF_BEGIN(AST_EXPR_LNOT, Ast_Visitor_Import, v, Ast_Node_Unary, n)
174     unary_action(v, n);
175 ASTVF_END
176
177 ASTVF_BEGIN(AST_EXPR_ABS, Ast_Visitor_Import, v, Ast_Node_Unary, n)
178     unary_action(v, n);
179 ASTVF_END
180
181 ASTVF_BEGIN(AST_EXPR_INT, Ast_Visitor_Import, v, Ast_Expr_Int, n)
182     (void) v; (void) n;
```

```
183 ASTVF_END
184
185 ASTVF_BEGIN(AST_EXPR_BOOL, Ast_Visitor_Import, v, Ast_Expr_Bool, n)
186     (void) v; (void) n;
187 ASTVF_END
188
189 ASTVF_BEGIN(AST_EXPR_NULL, Ast_Visitor_Import, v, Ast_Expr_Null, n)
190     (void) v; (void) n;
191 ASTVF_END
192
193 ASTVF_BEGIN(AST_VARIABLE_IDEN, Ast_Visitor_Import, v, Ast_Variable_Iden, n)
194     (void) v; (void) n;
195     Ast_Node *ast_node = AST_NODE_OF(n);
196     Symbol_Table_Node *node = ast_node_get_symbol_table_node(ast_node);
197     File_Location *location = ast_node_get_file_location(ast_node);
198     Vector *sym_vec;
199     Dependency_Symbols *dep_sym = NULL;
200     Symbol *sym;
201     String new_iden = NULL;
202     switch (v->next_property) {
203     case SYMBOL_PROPERTY_TYPE_DEF:
204         DLOG("%S - Found variable iden (type def): %S",
205               ast_get_file_name(v->ast), n->iden);
206         dep_sym = import_table_build_iden_loc(false, node,
207               v->next_property, n->iden, location);
208         break;
209     case SYMBOL_PROPERTY_VAR:
210         DLOG("%S - Found variable iden (var): %S",
211               ast_get_file_name(v->ast), n->iden);
212         dep_sym = import_table_build_iden_loc(false, node,
213               SYMBOL_PROPERTY_VAR, n->iden, location);
214         break;
215     case SYMBOL_PROPERTY_FUNC:
216         DLOG("%S - Found variable iden (func): %S",
217               ast_get_file_name(v->ast), n->iden);
218         dep_sym = import_table_build_iden_loc(false, node,
219               SYMBOL_PROPERTY_FUNC, n->iden, location);
220         break;
221     }
222     if (dep_sym) {
223         sym_vec = dep_sym->sym_vec;
224         if (sym_vec && vector_size(sym_vec) == 1) {
225             sym = vector_pop_last(sym_vec);
226             new_iden = string_duplicate(sym->unique_name);
227         }
228         assert(!sym_vec || vector_size(sym_vec) <= 1);
229         dependency_symbols_destroy(dep_sym);
230     }
231     if (new_iden) {
232         DLOG("\n\treplaced with '%S'\n", new_iden);
233         string_destroy(n->iden);
234         n->iden = new_iden;
235     } else {
236         DLOG("\n\t(ignored)\n");
237     }
238     v->prev_iden = n->iden;
239 ASTVF_END
240
241 ASTVF_BEGIN(AST_REC_SELF_PTR, Ast_Visitor_Import, v, Ast_Empty, n)
242     (void)v; (void)n;
243 ASTVF_END
244
245 ASTVF_BEGIN(AST_EXPR_ARY_REF, Ast_Visitor_Import, v, Ast_Node_Binary, n)
246     binary_action(v, n);
247 ASTVF_END
248
249 ASTVF_BEGIN(AST_EXPR_FUNC_CALL, Ast_Visitor_Import, v, Ast_Expr_Func_Call, n)
250     func_call_import(n->arguments, AST_VISITOR_OF(v));
251 ASTVF_END
252
253 ASTVF_BEGIN(AST_EXPR_DOT_REF, Ast_Visitor_Import, v, Ast_Node_Binary, n)
254     binary_action(v, n);
255 ASTVF_END
256
```

```
257 ASTVF_BEGIN(AST_EXPR_DIRECT_REF, Ast_Visitor_Import, v, Ast_Node_Binary, n)
258    if (n->lhs) {
259       Symbol_Table_Node *node = ast_node_get_symbol_table_node(AST_NODE_OF(n));
260       Symbol_Property saved_property = v->next_property;
261       v->next_property = SYMBOL_PROPERTY_TYPE_DEF;
262       n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
263       v->next_property = SYMBOL_PROPERTY_VAR;
264
265       File_Location *loc = ast_node_get_file_location(AST_NODE_OF(n));
266       Symbol *symbol = symbol_table_get_from_location(node, loc);
267       assert(symbol);
268       import_table_update_symbol_type(false, ast_get_symbol_table(v->ast), node,
269             symbol->resolved_type, true);
270       v->next_property = saved_property;
271    }
272    n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
273 ASTVF_END
274
275 ASTVF_BEGIN(AST_SIMPLE_TYPE_INT, Ast_Visitor_Import, v, Ast_Empty, n)
276    (void) v; (void) n;
277 ASTVF_END
278
279 ASTVF_BEGIN(AST_SIMPLE_TYPE_VOID, Ast_Visitor_Import, v, Ast_Empty, n)
280    (void) v; (void) n;
281 ASTVF_END
282
283 ASTVF_BEGIN(AST_SIMPLE_TYPE_BOOL, Ast_Visitor_Import, v, Ast_Empty, n)
284    (void) v; (void) n;
285 ASTVF_END
286
287 ASTVF_BEGIN(AST_TYPE_IDEN, Ast_Visitor_Import, v, Ast_Type_Iden, n)
288    DLOG("%S - TYPE_IDEN: %S", ast_get_file_name(v->ast), n->iden);
289    Ast_Node *ast_node = AST_NODE_OF(n);
290    Symbol_Table_Node *node = ast_node_get_symbol_table_node(ast_node);
291    File_Location *location = ast_node_get_file_location(ast_node);
292    Dependency_Symbols *dep_sym;
293    String new_iden = NULL;
294    dep_sym = import_table_build_iden_loc(false, node,
295          SYMBOL_PROPERTY_TYPE_DEF, n->iden, location);
296    if (dep_sym) {
297       Vector *sym_vec = dep_sym->sym_vec;
298       Symbol *sym;
299       if (sym_vec && vector_size(sym_vec) == 1) {
300          sym = vector_pop_last(sym_vec);
301          new_iden = string_duplicate(sym->unique_name);
302       }
303       assert(!sym_vec || vector_size(sym_vec) <= 1);
304       dependency_symbols_destroy(dep_sym);
305    }
306    if (new_iden) {
307       DLOG("\n\treplaced with " QFY("%S") "\n", new_iden);
308       string_destroy(n->iden);
309       n->iden = new_iden;
310    } else {
311       DLOG("\n\t(ignored)\n");
312    }
313    v->prev_iden = n->iden;
314 ASTVF_END
315
316 ASTVF_BEGIN(AST_VAR_DECL, Ast_Visitor_Import, v, Ast_Node_Binary, n)
317    Symbol_Property saved_property;
318    Symbol *symbol;
319    Symbol_Table_Node *node;
320    String iden;
321
322    node = ast_node_get_symbol_table_node(AST_NODE_OF(n));
323    saved_property = v->next_property;
324    v->next_property = SYMBOL_PROPERTY_VAR;
325    v->in_def_or_decl = true;
326    n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
327    iden = v->prev_iden;
328    v->prev_iden = NULL;
329
330    v->next_property = SYMBOL_PROPERTY_TYPE_DEF;
```

```
331     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
332     v->next_property = saved_property;
333
334     DLOG("Check update type of variable '%S'\n", iden);
335     Uns hash = string_hash_code(iden);
336     symbol = symbol_table_node_get(node, iden, hash, SYMBOL_PROPERTY_VAR);
337     assert(symbol);
338     import_table_update_symbol_type(false, ast_get_symbol_table(v->ast), node,
339           symbol->resolved_type, true);
340     File_Location *loc = ast_node_get_file_location(AST_NODE_OF(n));
341
342     import_handler_search_dependencies(node, SYMBOL_PROPERTY_VAR, iden, hash,
343        loc, loc);
344
345     v->in_def_or_decl = false;
346 ASTVF_END
347
348 ASTVF_BEGIN(AST_TYPE_DEF, Ast_Visitor_Import, v, Ast_Node_Binary, n)
349     Symbol_Table_Node *node = ast_node_get_symbol_table_node(AST_NODE_OF(n));
350     Symbol_Property saved_property = v->next_property;
351     v->next_property = SYMBOL_PROPERTY_TYPE_DEF;
352     v->in_def_or_decl = true;
353     n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
354     v->in_def_or_decl = false;
355     String iden = v->prev_iden;
356     v->prev_iden = NULL;
357     v->next_property = saved_property;
358
359     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
360
361     DLOG("Check update type of type def '%S'\n", iden);
362     Uns hash = string_hash_code(iden);
363     Symbol *symbol = symbol_table_node_get(node, iden, hash,
364           SYMBOL_PROPERTY_TYPE_DEF);
365     assert(symbol);
366     import_table_update_symbol_type(false, ast_get_symbol_table(v->ast), node,
367           symbol->resolved_type, true);
368     Double_List *dblist;
369     dblist = &TYPE_DEF_SYMBOL_OF_SYMBOL(symbol)->dbnode;
370     Double_List_Node *dbnode;
371     DOUBLE_LIST_FOR_EACH(dblist, dbnode) {
372        symbol = (Symbol *) TYPE_DEF_SYMBOL_OF_DBNODE(dbnode);
373        import_table_update_symbol_type(false, ast_get_symbol_table(v->ast),
374              node, symbol->resolved_type, true);
375     }
376 ASTVF_END
377
378 ASTVF_BEGIN(AST_TYPE_ARY, Ast_Visitor_Import, v, Ast_Type, n)
379     n->type->accept_visitor(n->type, AST_VISITOR_OF(v));
380 ASTVF_END
381
382 ASTVF_BEGIN(AST_TYPE_REC, Ast_Visitor_Import, v, Ast_Type_Rec, n)
383     Ast_Node *arg;
384     Vector *vargs = n->extend_list;
385     VECTOR_FOR_EACH_ENTRY(vargs, arg)
386        arg->accept_visitor(arg, AST_VISITOR_OF(v));
387     vargs = n->body;
388     VECTOR_FOR_EACH_ENTRY(vargs, arg)
389        arg->accept_visitor(arg, AST_VISITOR_OF(v));
390 ASTVF_END
391
392 static void stmt_list_action(Ast_Visitor_Import *v, Ast_Stmt_List *n)
393 {
394     Vector *statements;
395     Ast_Node *stmt;
396     statements = n->statements;
397     VECTOR_FOR_EACH_ENTRY(statements, stmt)
398        stmt->accept_visitor(stmt, AST_VISITOR_OF(v));
399 }
400
401 ASTVF_BEGIN(AST_STMT_LIST, Ast_Visitor_Import, v, Ast_Stmt_List, n)
402     stmt_list_action(v, n);
403 ASTVF_END
404
```

```
405 ASTVF_BEGIN(AST_FIN_STMT_LIST, Ast_Visitor_Import, v, Ast_Stmt_List, n)
406    stmt_list_action(v, n);
407 ASTVF_END
408
409 static void func_import(Ast_Visitor_Import *v, Ast_Func_Def *n)
410 {
411    Ast_Node *p;
412    Symbol *symbol;
413    Symbol_Table_Node *node = ast_node_get_symbol_table_node(AST_NODE_OF(n));
414    Symbol_Property saved_property = v->next_property;
415
416    /* Really no need to visit n->extern_type when it's != NULL */
417
418    v->in_def_or_decl = true;
419    v->next_property = SYMBOL_PROPERTY_FUNC;
420    n->iden->accept_visitor(n->iden, AST_VISITOR_OF(v));
421    DLOG("import lookup: %S\n", v->prev_iden);
422    Uns hash = string_hash_code(v->prev_iden);
423    symbol = symbol_table_node_get(node, v->prev_iden, hash,
424          SYMBOL_PROPERTY_FUNC);
425    assert(symbol);
426    import_table_update_symbol_type(false, ast_get_symbol_table(v->ast), node,
427          symbol->resolved_type, true);
428    v->next_property = saved_property;
429
430    n->return_type->accept_visitor(n->return_type, AST_VISITOR_OF(v));
431    v->in_def_or_decl = false;
432
433    Vector *vec = n->parameters;
434    VECTOR_FOR_EACH_ENTRY(vec, p)
435       p->accept_visitor(p, AST_VISITOR_OF(v));
436
437    if (n->statements)
438       n->statements->accept_visitor(n->statements, AST_VISITOR_OF(v));
439 }
440
441 ASTVF_BEGIN(AST_EXT_FUNC_DECL, Ast_Visitor_Import, v, Ast_Func_Def, n)
442    func_import(v, n);
443 ASTVF_END
444
445 ASTVF_BEGIN(AST_FIN_FUNC_DEF, Ast_Visitor_Import, v, Ast_Func_Def, n)
446    func_import(v, n);
447 ASTVF_END
448
449 ASTVF_BEGIN(AST_REC_FUNC_DEF, Ast_Visitor_Import, v, Ast_Func_Def, n)
450    func_import(v, n);
451 ASTVF_END
452
453 ASTVF_BEGIN(AST_FUNC_DEF, Ast_Visitor_Import, v, Ast_Func_Def, n)
454    func_import(v, n);
455 ASTVF_END
456
457 ASTVF_BEGIN(AST_IF_STMT, Ast_Visitor_Import, v, Ast_Node_Binary, n)
458    binary_action(v, n);
459 ASTVF_END
460
461 ASTVF_BEGIN(AST_IF_ELSE_STMT, Ast_Visitor_Import, v, Ast_Node_Ternary, n)
462    n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
463    n->mid->accept_visitor(n->mid, AST_VISITOR_OF(v));
464    n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
465 ASTVF_END
466
467 ASTVF_BEGIN(AST_ALLOC_ARY, Ast_Visitor_Import, v, Ast_Node_Binary, n)
468    binary_action(v, n);
469 ASTVF_END
470
471 ASTVF_BEGIN(AST_ALLOC_REC, Ast_Visitor_Import, v, Ast_Node_Unary, n)
472    unary_action(v, n);
473 ASTVF_END
474
475 ASTVF_BEGIN(AST_ALLOC_REC_CALL, Ast_Visitor_Import, v, Ast_Node_Binary, n)
476    binary_action(v, n);
477 ASTVF_END
478
```

```
479 ASTVF_BEGIN(AST_DELETE, Ast_Visitor_Import, v, Ast_Node_Unary, n)
480    unary_action(v, n);
481 ASTVF_END
482
483 ASTVF_BEGIN(AST_WHILE_STMT, Ast_Visitor_Import, v, Ast_Node_Binary, n)
484    binary_action(v, n);
485 ASTVF_END
486
487 ASTVF_BEGIN(AST_RETURN_STMT, Ast_Visitor_Import, v, Ast_Node_Unary, n)
488    unary_action(v, n);
489 ASTVF_END
490
491 ASTVF_BEGIN(AST_WRITE_STMT, Ast_Visitor_Import, v, Ast_Node_Unary, n)
492    assert(v->next_property == SYMBOL_PROPERTY_VAR);
493    unary_action(v, n);
494 ASTVF_END
495
496 ASTVF_BEGIN(AST_ASSIGNMENT, Ast_Visitor_Import, v, Ast_Node_Binary, n)
497    binary_action(v, n);
498 ASTVF_END
499
500 ASTVF_BEGIN(AST_EXPR_CHAR, Ast_Visitor_Import, v, Ast_Expr_Char, n)
501    (void) v; (void) n;
502 ASTVF_END
503
504 ASTVF_BEGIN(AST_EXPR_STRING, Ast_Visitor_Import, v, Ast_Expr_String, n)
505    (void) v; (void) n;
506 ASTVF_END
507
508 ASTVF_BEGIN(AST_IMPORT_STRING, Ast_Visitor_Import, v, Ast_Module_String, n)
509    Ast_Node *ast_node = AST_NODE_OF(n);
510    File_Location *loc = ast_node_get_file_location(ast_node);
511    Symbol_Table *table = ast_get_symbol_table(v->ast);
512    Symbol_Table_Node *node = ast_node_get_symbol_table_node(AST_NODE_OF(n));
513    String real_dep = vector_get(&node->import_dependencies, n->dep_idx);
514    if (imported_hash_insert(&v->imported_hash, node, real_dep))
515       import_handler_import(table, node, real_dep, loc);
516 ASTVF_END
517
518 ASTVF_BEGIN(AST_PACKAGE_STRING, Ast_Visitor_Import, v, Ast_Module_String, n)
519    (void) v; (void) n;
520 ASTVF_END
521
522 ASTVF_BEGIN(AST_SIMPLE_TYPE_CHAR, Ast_Visitor_Import, v, Ast_Empty, n)
523    (void) v; (void) n;
524 ASTVF_END
525
526 ASTVF_BEGIN(AST_SIMPLE_TYPE_STRING, Ast_Visitor_Import, v, Ast_Empty, n)
527    (void) v; (void) n;
528 ASTVF_END
529
530 ASTVF_BEGIN(AST_FUNC_BODY, Ast_Visitor_Import, v, Ast_Stmt_List, n)
531    Vector *stmt_list;
532    Ast_Node *stmt;
533    stmt_list = n->statements;
534    VECTOR_FOR_EACH_ENTRY(stmt_list, stmt)
535       stmt->accept_visitor(stmt, AST_VISITOR_OF(v));
536 ASTVF_END
537
538 bool ast_visitor_import_handle(Ast *ast, bool is_import)
539 {
540    String file_prefix = NULL;
541    char *cur_work_dir = NULL;
542    if (!is_import) {
543       if (!(cur_work_dir = getcwd(NULL, 0)))
544          fatal_error(S("unable to obtain current working directoy [%m]\n"));
545
546       ast_get_symbol_table(ast); // generate package name
547       set_project_root(ast);
548       import_handler_cd_project_root();
549
550       String file_name = string_basename(ast_get_file_name(ast));
551       Const_String package = ast_get_package(ast);
552       if (package)
```

```
553            file_prefix = string_dir_concat(ast_get_package(ast),
554                  STRING_AFTER_LAST(file_name, '/'));
555         else
556            file_prefix = string_duplicate(file_name);
557         string_destroy(file_name);
558
559         string_replace_from(file_prefix, '.', S(""));
560         DLOG("Insert AST for %S\n", file_prefix);
561         import_handler_insert_ast(ast, file_prefix);
562      }
563
564      Ast_Node *root;
565      if (ast_is_valid(ast)) {
566         Ast_Visitor_Import import_visitor = {
567            .AST_VISITOR_FIELD = AST_VISITOR_STATIC_INIT(),
568            .next_property = SYMBOL_PROPERTY_VAR,
569            .in_def_or_decl = false,
570            .ast = ast,
571            .sym_table = ast_get_symbol_table(ast),
572            .imported_hash = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_5,
573                  (Hash_Map_Comparator) imported_hash_comparator),
574         };
575
576         root = ast_get_root(ast);
577         root->accept_visitor(root, AST_VISITOR_OF(&import_visitor));
578         assert(import_visitor.next_property == SYMBOL_PROPERTY_VAR);
579         symbol_table_resolve(import_visitor.sym_table);
580         symbol_table_node_copy_hash_clear();
581
582         hash_map_for_each_destroy(&import_visitor.imported_hash,
583               (Hash_Map_Destructor) imported_hash_destructor);
584
585         if (!was_error_reported() && cmdopts.recursive_compile) {
586            import_handler_compile_imports();
587         }
588      }
589
590      if (!is_import) {
591         string_destroy(file_prefix);
592         assert(cur_work_dir);
593         if (chdir(cur_work_dir))
594            fatal_error(S("cannot switch back to directory %s [%m]\n"),
595                  cur_work_dir);
596         free_mem(cur_work_dir);
597      }
598      return !import_handler_is_error_reported();
599   }
```

:

A.4.2 src/ast/ast_visitor_import.h

```
1  #ifndef AST_VISITOR_IMPORT_H
2  #define AST_VISITOR_IMPORT_H
3
4  #include "ast_visitor.h"
5
6  bool ast_visitor_import_handle(Ast *ast, bool is_import);
7
8  #endif // AST_VISITOR_IMPORT_H
```

:

A.4.3 src/import_handler.c

```
1  #include <stdio.h>
2  #include <import_handler.h>
```

```
3  #include <parser.h>
4  #include <hash_map.h>
5  #include <vector.h>
6  #include <pointer_hash.h>
7  #include <stdlib.h>
8  #include <errno.h>
9  #include <unistd.h>
10 #include <main.h>
11 #include <ast/ast_visitor_import.h>
12
13 #undef DEBUG_TYPE
14 #define DEBUG_TYPE import-handler
15
16 void import_table_destroy(Import_Table *it);
17
18 static void import_table_init_ast(Import_Table *it, File_Location *loc);
19
20 void import_table_dump_viti(Import_Table *it);
21
22 static void import_handler_merge_in(Import_Table *it);
23
24 void import_handler_merge_tables();
25
26 void import_table_viti_append(String_Builder *sb,
27       Symbol_Type_Struct *type_struct);
28
29 static String project_root = NULL;
30
31 static Symbol_Table *import_merge_table;
32
33 bool import_handler_is_merge_table(Symbol_Table* t) {
34    return import_merge_table == t;
35 }
36
37 Symbol *import_handler_get_merge_sym(String iden, Symbol_Property property)
38 {
39    Symbol_Table_Node *node = symbol_table_get_root(import_merge_table);
40    assert(node);
41    return symbol_table_node_get(node, iden, string_hash_code(iden), property);
42 }
43
44 // hashmap containing all currently loaded interface tables.
45 struct Import_Table {
46    Hash_Map_Slot slot;
47    Const_String file_prefix;
48    String file_name;
49    Ast *ast;
50    Symbol_Table *cpy_sym_table;
51    bool merged_in;
52    bool is_viti;
53    bool is_compiled;
54    bool in_project;
55    bool is_symbols_updated;
56    bool is_main_file;
57 };
58
59 static bool import_handler_error_reported;
60
61 bool import_handler_is_error_reported()
62 {
63    return import_handler_error_reported;
64 }
65
66 #define IMPORT_TABLE_OF(s) CONTAINER_OF(s, Import_Table, slot)
67
68 bool import_hash_compare(void *search_obj, Hash_Map_Slot *map_slot)
69 {
70    Import_Table *it = IMPORT_TABLE_OF(map_slot);
71    return !string_compare(search_obj, it->file_prefix);
72 }
73
74 void import_table_destructor(Hash_Map_Slot *slot)
75 {
76    import_table_destroy(IMPORT_TABLE_OF(slot));
```

```
77  }
78
79  static HASH_MAP(import_hash, import_hash_compare);
80  // End of hash map.
81
82  Dependency_Symbols *dependency_symbols_alloc(Vector *sym_vec, Vector *dep_vec)
83  {
84     Dependency_Symbols *ret = ALLOC_NEW(Dependency_Symbols);
85     ret->sym_vec = sym_vec;
86     ret->dep_vec = dep_vec;
87     return ret;
88  }
89
90  void dependency_symbols_destroy(Dependency_Symbols *dep_sym)
91  {
92     if (dep_sym->sym_vec)
93        vector_destroy(dep_sym->sym_vec, NULL);
94     if (dep_sym->dep_vec)
95        vector_destroy(dep_sym->dep_vec, (Vector_Destructor) string_destroy);
96     free_mem(dep_sym);
97  }
98
99
100 void import_handler_set_project_root(Const_String root)
101 {
102    DLOG("set project root: %S\n", root);
103    string_destroy(project_root);
104    char *abs_path = realpath(string_to_cstr(root), NULL);
105    project_root = string_alloc(S(abs_path));
106    free_mem(abs_path);
107 }
108
109 void import_handler_cd_project_root()
110 {
111    if (project_root && chdir(string_to_cstr(project_root)))
112       fatal_error(S("unable to change working directory to " QFY("%S")
113                " [%m]\n"), project_root);
114    if (project_root)
115       DLOG("CD to project root: %S\n", project_root);
116 }
117
118 Import_Table *import_table_init(Const_String file_prefix, Uns hash)
119 {
120    Import_Table *it = ALLOC_NEW(Import_Table);
121    it->file_prefix = file_prefix;
122    it->file_name = NULL;
123    it->is_compiled = false;
124    it->in_project = true;
125    it->is_symbols_updated = false;
126    it->is_main_file = false;
127    it->is_viti = false;
128    it->merged_in = false;
129    it->ast = NULL;
130    it->cpy_sym_table = NULL;
131
132    assert(!hash_map_get(&import_hash, (void *)file_prefix, hash));
133
134    hash_map_insert(&import_hash, &it->slot, hash);
135
136    return it;
137 }
138
139 Import_Table *___import_table_get(Const_String file_prefix,
140       File_Location * loc)
141 {
142    Uns hash = string_hash_code(file_prefix);
143    Import_Table *it = IMPORT_TABLE_OF(hash_map_get(&import_hash,
144             (void *)file_prefix, hash));
145    if (it) {
146       goto out;
147    }
148
149    it = import_table_init(file_prefix, hash);
150
```

```
151     import_table_init_ast(it, loc);
152
153     if (cmdopts.generate_viti)
154        import_table_dump_viti(it);
155  out:
156     return it;
157  }
158
159  Import_Table *import_table_get(Const_String file_prefix, File_Location *loc)
160  {
161     Import_Table *ret;
162     int32_t init_num_errors = get_error_count();
163     ret = ___import_table_get(file_prefix, loc);
164     import_handler_error_reported |= init_num_errors != get_error_count();
165     return ret;
166  }
167
168  void import_table_destroy(Import_Table *it)
169  {
170     if (it->ast && !it->is_main_file) {
171        ast_destroy(it->ast);
172     }
173
174     string_destroy(it->file_name);
175
176     if (it->cpy_sym_table) {
177        symbol_table_destroy(it->cpy_sym_table);
178     }
179
180     free_mem(it);
181  }
182
183  Ast *import_symbol_table_parse(Const_String file_name, File_Location *loc)
184  {
185     int32_t err_count = get_error_count();
186     Ast *ast = parse(file_name);
187     if (!ast)
188        goto out;
189
190     if (!ast_is_valid(ast))
191        goto error_out;
192
193     ast_get_symbol_table(ast);
194
195     if (err_count == get_error_count()) {
196        Uns cnt = string_count(file_name, S("/"));
197        Const_String package = ast_get_package(ast);
198        if (package) {
199           char *abs_path = realpath(string_to_cstr(ast_get_dirname(ast)), NULL);
200           if (!string_ends_with(S(abs_path), package)) {
201              free(abs_path);
202              goto error_out;
203           }
204           free(abs_path);
205        } else if (!package && cnt > 0) {
206           Vector *split = string_split(file_name, S("."));
207           report_error_location(loc, S("import " QFY("%S") " does not "
208                    "specify a package\n"), vector_peek_first(split));
209           vector_destroy(split, (Vector_Destructor) string_destroy);
210           goto error_out;
211        }
212        goto out;
213     }
214
215  error_out:
216     ast_destroy(ast);
217     ast = NULL;
218  out:
219     return ast;
220  }
221
222  static void import_table_include_imports(Import_Table *it)
223  {
224     Symbol_Table *sym_table = ast_get_symbol_table(it->ast);
```

```
225     Symbol_Table_Node *global_node = symbol_table_get_root(sym_table);
226     assert(global_node->type == SYMBOL_TABLE_NODE_GLOBAL);
227     Const_String dependency;
228     File_Location *loc;
229     for (Uns i = 0; i < vector_size(&global_node->import_dependencies); i++) {
230        dependency = vector_get(&global_node->import_dependencies, i);
231        loc = vector_get(&global_node->import_dependencies_loc, i);
232        import_table_get(dependency, loc);
233     }
234  }
235
236  static void search_viti(Import_Table *it, File_Location *loc)
237  {
238     Const_String file_prefix = it->file_prefix;
239     String file_name_viti = string_from_format(S("%S.viti"), file_prefix);
240
241     it->is_viti = true;
242     if (file_access_read(file_name_viti)) {
243        DLOG("Use " QFY("%S") "\n", file_name_viti);
244        it->ast = import_symbol_table_parse(file_name_viti, loc);
245        if (!ast_is_valid(it->ast))
246           goto err_out;
247        it->file_name = file_name_viti;
248        goto out;
249     }
250  err_out:
251     string_destroy(file_name_viti);
252  out:;
253
254
255  #if 0
256     String dependency, tmp_str;
257     Const_String file_prefix = it->file_prefix;
258     Symbol_Table *sym_table;
259     Symbol_Table_Node *tmp_node;
260     time_t this_time, other_time;
261     String file_name_viti = string_from_format(S("%S.viti"), file_prefix);
262     String file_name_vit = string_from_format(S("%S.vit"), file_prefix);
263
264     if (file_access_read(file_name_viti)) {
265        this_time = file_get_mtime(file_name_viti);
266        if (this_time == -1) {
267           fatal_error(S("unable to access modification time for file "
268                    QFY("%S") " [%m]\n"), file_name_viti);
269        }
270        other_time = file_get_mtime(file_name_vit);
271        if (this_time < other_time || other_time == -1) {
272           if (other_time == -1 && errno == ENOENT) {
273              DLOG("Viti file " QFY("%S") " does not exist.\n",
274                    file_name_viti);
275              goto out;
276           } else if (other_time == -1) {
277              fatal_error(S("unable to access modification time for file "
278                       QFY("%S") " [%m]\n"), file_name_viti);
279           }
280           DLOG("Viti file " QFY("%S") " is older than corresponding .vit "
281                 "file. Use .vit file\n", file_name_viti);
282           goto out;
283        }
284
285        it->ast = import_symbol_table_parse(file_name_viti, loc);
286        if (!ast_is_valid(it->ast))
287           goto out;
288
289        sym_table = ast_get_symbol_table(it->ast);
290        tmp_node = symbol_table_get_root(sym_table);
291        VECTOR_FOR_EACH_ENTRY(&tmp_node->import_dependencies, dependency){
292           tmp_str = string_from_format(S("%S.vit"), dependency);
293           if (file_access_read(tmp_str)){
294              other_time = file_get_mtime(tmp_str);
295              if (other_time == -1) {
296                 fatal_error(S("unable to access modification time for "
297                          "file " QFY("%S") " [%m]\n"), tmp_str);
298              } else if (this_time < other_time) {
```

```
299                 DLOG(QFY("%S") " outdated since " QFY("%S") " has been "
300                       "updated\n", file_name_viti, tmp_str);
301                 string_destroy(tmp_str);
302                 goto err_out;
303              }
304           } else {
305              string_destroy(tmp_str);
306              goto err_out;
307           }
308           string_destroy(tmp_str);
309        }
310
311        DLOG("Viti file " QFY("%S") " is up to date.\n", file_name_viti);
312        it->is_viti = true;
313        it->file_name = file_name_viti;
314        goto out;
315     }
316
317  err_out:
318     ast_destroy(it->ast);
319     it->ast = NULL;
320     string_destroy(file_name_viti);
321  out:
322     string_destroy(file_name_vit);
323  #endif
324  }
325
326  static void search_vit(Import_Table *it, File_Location *loc)
327  {
328     Const_String file_prefix = it->file_prefix;
329     String file_name_vit = string_from_format(S("%S.vit"), file_prefix);
330
331     it->is_viti = false;
332     if (file_access_read(file_name_vit)) {
333        DLOG("Use " QFY("%S") "\n", file_name_vit);
334        it->ast = import_symbol_table_parse(file_name_vit, loc);
335        if (!ast_is_valid(it->ast))
336           goto err_out;
337        it->file_name = file_name_vit;
338        goto out;
339     }
340  err_out:
341     string_destroy(file_name_vit);
342  out:;
343  }
344
345  static void ___import_table_init_ast(Import_Table *it, File_Location *loc)
346  {
347     if (cmdopts.recursive_compile) {
348        search_vit(it, loc);
349        if (!ast_is_valid(it->ast))
350           search_viti(it, loc);
351     } else {
352        search_viti(it, loc);
353        if(!ast_is_valid(it->ast))
354           search_vit(it, loc);
355     }
356     if (!ast_is_valid(it->ast)) {
357        it->ast = NULL;
358     } else {
359        /* Get all needed import files */
360        import_table_include_imports(it);
361     }
362
363  }
364
365
366  void import_table_init_ast(Import_Table *it, File_Location *loc)
367  {
368     /* Lookup in project root */
369     import_handler_cd_project_root();
370     DLOG("Init ast for: %S\n", it->file_prefix);
371     ___import_table_init_ast(it, loc);
372
```

```
373     /* Else lookup in include paths */
374     if (!ast_is_valid(it->ast)) {
375        it->in_project = false;
376        Const_String path;
377        VECTOR_FOR_EACH_ENTRY(&cmdopts.import_search_paths, path){
378           DLOG("Search include path: %S\n", path);
379           assert(path);
380           if (chdir(string_to_cstr(path)))
381              fatal_error(S("unable to change working directory to "
382                       QFY("%S") " [%m]\n"), path);
383           ___import_table_init_ast(it, loc);
384           if (ast_is_valid(it->ast)) {
385              break;
386           }
387        }
388     }
389
390     if (!ast_is_valid(it->ast)) {
391        report_error_location(loc, S("unable to import " QFY("%S") "\n"),
392              it->file_prefix);
393     } else {
394        it->cpy_sym_table = symbol_table_alloc(ast_get_file_name(it->ast));
395        symbol_table_merge(it->cpy_sym_table, ast_get_symbol_table(it->ast),
396              false);
397     }
398  }
399
400  static bool import_table_dependency_string_append(String_Builder *sb,
401        Import_Table *it)
402  {
403     bool ret = false;
404     String import_dependency, tmp_module_path;
405     if (ast_is_valid(it->ast)) {
406        Symbol_Table *sym_table = ast_get_symbol_table(it->ast);
407        Symbol_Table_Node *node = symbol_table_get_root(sym_table);
408        VECTOR_FOR_EACH_ENTRY(&node->import_dependencies, import_dependency) {
409           string_builder_append(sb, S("import "));
410           tmp_module_path = string_duplicate(import_dependency);
411           string_replace_all(tmp_module_path, '/', '.');
412           string_builder_append(sb, tmp_module_path);
413           string_destroy(tmp_module_path);
414           string_builder_append(sb, S(";\n"));
415           ret = true;
416        }
417     }
418     return ret;
419  }
420
421  static void ___import_table_dump_viti(Import_Table *it)
422  {
423     Symbol_Table *sym_table = ast_get_symbol_table(it->ast);
424     Symbol_Table_Node *node = symbol_table_get_root(sym_table);
425
426     bool inserted_something = false;
427     String file_name = string_from_format(S("%S.viti"), it->file_prefix);
428     FILE *output_file = file_open(file_name, S("w"));
429     if (!output_file)
430        fatal_error(S("unable to open file " QFY("%S")
431                    " for interface dump [%m]\n"),
432              file_name);
433
434     String_Builder sb = STRING_BUILDER_INIT();
435
436     string_builder_assign(&sb, S(""));
437     if (ast_get_package(it->ast)) {
438        string_builder_append(&sb, S("package "));
439        String tmp = string_duplicate(ast_get_package(it->ast));
440        string_replace_all(tmp, '/', '.');
441        string_builder_append(&sb, tmp);
442        string_destroy(tmp);
443        string_builder_append(&sb, S(";\n"));
444     }
445
446     inserted_something = import_table_dependency_string_append(&sb, it);
```

```
447
448     if (string_compare(S(""), string_builder_const_str(&sb)))
449        file_print_message(output_file, S("%S\n"),
450              string_builder_const_str(&sb));
451
452     inserted_something = false;
453     Symbol *tmp_sym;
454     Hash_Map_Slot *slot;
455     SYMBOL_TABLE_NODE_FOR_EACH_SYMBOL(node, slot, tmp_sym,
456           SYMBOL_PROPERTY_TYPE_DEF) {
457        string_builder_assign(&sb, S("type "));
458        string_builder_append(&sb, tmp_sym->identifier);
459        string_builder_append(&sb, S(" = "));
460        import_table_viti_append(&sb, tmp_sym->resolved_type);
461        string_builder_append(&sb, S(";\n"));
462        file_print_message(output_file, string_builder_const_str(&sb));
463        inserted_something = true;
464     }
465     if (inserted_something)
466        file_print_message(output_file, S("\n"));
467     inserted_something = false;
468
469     SYMBOL_TABLE_NODE_FOR_EACH_SYMBOL(node, slot, tmp_sym,
470           SYMBOL_PROPERTY_VAR) {
471        string_builder_assign(&sb, S("var "));
472        string_builder_append(&sb, tmp_sym->identifier);
473        string_builder_append(&sb, S(":"));
474        import_table_viti_append(&sb, tmp_sym->resolved_type);
475        string_builder_append(&sb, S(";\n"));
476        file_print_message(output_file, string_builder_const_str(&sb));
477        inserted_something = true;
478     }
479     if (inserted_something)
480        file_print_message(output_file, S("\n"));
481     inserted_something = false;
482
483     SYMBOL_TABLE_NODE_FOR_EACH_SYMBOL(node, slot, tmp_sym,
484           SYMBOL_PROPERTY_FUNC) {
485        Symbol_Type_Func *func = SYMBOL_TYPE_STRUCT_CONTAINER(
486              tmp_sym->resolved_type, Symbol_Type_Func);
487
488        if (func->is_extern_c)
489           string_builder_assign(&sb, S("extern(C) func "));
490        else
491           string_builder_assign(&sb, S("func "));
492
493        string_builder_append(&sb,
494              STRING_AFTER_LAST(tmp_sym->identifier, '.'));
495        import_table_viti_append(&sb, tmp_sym->resolved_type);
496
497        if (func->is_extern_c) {
498           string_builder_append(&sb, S(";\n"));
499        } else {
500           string_builder_append(&sb, S(" end "));
501           string_builder_append(&sb, STRING_AFTER_LAST(tmp_sym->identifier,
502                 '.'));
503           string_builder_append(&sb, S("\n"));
504        }
505
506        file_print_message(output_file, string_builder_const_str(&sb));
507     }
508
509     string_builder_clear(&sb);
510     file_close(output_file);
511     string_destroy(file_name);
512  }
513
514  void import_table_dump_viti(Import_Table *it)
515  {
516     if (!it->in_project)
517        return;
518
519     import_handler_cd_project_root();
520
```

```
521     ___import_table_dump_viti(it);
522  }
523
524  static void import_table_update_func_sym_types(Import_Table *it,
525        Symbol_Table_Node *node)
526  {
527     Symbol_Func_Map *map;
528     Hash_Map_Slot *slot;
529     Symbol *sym;
530     HASH_MAP_FOR_EACH(&node->func_iden_map, slot) {
531        map = SYMBOL_FUNC_MAP_OF(slot);
532        VECTOR_FOR_EACH_ENTRY(&map->overload_idens, sym) {
533           import_table_update_symbol_type(true, it->cpy_sym_table,
534                 node, sym->resolved_type, false);
535        }
536     }
537
538  }
539
540  static void import_table_update_symbol_types(Import_Table *it,
541        Symbol_Table_Node *node, Symbol_Property prop)
542  {
543     if (prop == SYMBOL_PROPERTY_FUNC) {
544        import_table_update_func_sym_types(it, node);
545        return;
546     }
547
548     Hash_Map_Slot *tmp_slot;
549     Symbol *sym;
550     Symbol_Table *sym_table = it->cpy_sym_table;
551
552     SYMBOL_TABLE_NODE_FOR_EACH_SYMBOL(node, tmp_slot, sym, prop) {
553        import_table_update_symbol_type(true, sym_table, node,
554              sym->resolved_type, false);
555
556        if(prop == SYMBOL_PROPERTY_TYPE_DEF) {
557           Double_List *dblist;
558           dblist = &TYPE_DEF_SYMBOL_OF_SYMBOL(sym)->dbnode;
559           Double_List_Node *dbnode;
560           DOUBLE_LIST_FOR_EACH(dblist, dbnode) {
561              sym = (Symbol *) TYPE_DEF_SYMBOL_OF_DBNODE(dbnode);
562              import_table_update_symbol_type(true, sym_table, node,
563                    sym->resolved_type, false);
564           }
565        }
566     }
567  }
568
569  static void import_handler_merge_in(Import_Table *it)
570  {
571     Symbol_Table *sym_table = it->cpy_sym_table;
572
573     if (!it->is_symbols_updated) {
574        Symbol_Table_Node *tmp_node;
575        Double_List_Node *dbnode;
576        SYMBOL_TABLE_FOR_EACH_NODE(sym_table, tmp_node, dbnode) {
577           import_table_update_symbol_types(it, tmp_node,
578                 SYMBOL_PROPERTY_FUNC);
579           import_table_update_symbol_types(it, tmp_node,
580                 SYMBOL_PROPERTY_VAR);
581           import_table_update_symbol_types(it, tmp_node,
582                 SYMBOL_PROPERTY_TYPE_DEF);
583        }
584        it->is_symbols_updated = true;
585     }
586
587     symbol_table_merge(import_merge_table, sym_table, true);
588  }
589
590  void import_handler_merge_tables()
591  {
592     Hash_Map_Slot *slot;
593     Import_Table *it;
594     HASH_MAP_FOR_EACH(&import_hash, slot) {
```

```
595         it = IMPORT_TABLE_OF(slot);
596         if (ast_is_valid(it->ast) && !it->merged_in) {
597            DLOG("Merging in: %S\n", it->file_prefix);
598            import_handler_merge_in(it);
599            it->merged_in = true;
600         }
601      }
602   }
603
604   void import_handler_compile_imports()
605   {
606      Hash_Map_Slot *slot;
607      Import_Table *it;
608      import_handler_cd_project_root();
609      HASH_MAP_FOR_EACH(&import_hash, slot) {
610         it = IMPORT_TABLE_OF(slot);
611         if (ast_is_valid(it->ast) && !it->is_viti) {
612            if (it->in_project && !it->is_compiled &&
613                  cmdopts.recursive_compile) {
614               it->is_compiled = true;
615               String obj = ___compile(it->ast, true);
616               add_gen_object_file(obj);
617            }
618         }
619      }
620      cd_working_dir();
621   }
622
623   Dependency_Symbols *import_handler_search_dependencies(Symbol_Table_Node *node,
624         Symbol_Property property, String iden, Uns hash,
625         File_Location *local_loc, File_Location *err_loc UNUSED)
626   {
627      Symbol *sym = NULL, *sym_dup;
628      Import_Table *tmp_it;
629      Symbol_Table *tmp_table;
630      Symbol_Table_Node *tmp_node;
631      Vector *found_in_dep = NULL, *sym_vec = NULL;
632      String dependency;
633      Dependency_Symbols *ret = NULL;
634
635      if (!local_loc)
636         sym_vec = vector_alloc();
637
638      Uns n = vector_size(&node->import_dependencies);
639      if (n > 0)
640         found_in_dep = vector_alloc_size(n);
641
642      Const_String type_str;
643      switch (property){
644         case SYMBOL_PROPERTY_TYPE_DEF:
645            type_str = S("type definitions");
646            break;
647         case SYMBOL_PROPERTY_VAR:
648            type_str = S("variable declarations");
649            break;
650         default:
651            return NULL;
652      }
653
654      VECTOR_FOR_EACH_ENTRY(&node->import_dependencies, dependency) {
655         tmp_it = ___import_table_get(dependency, NULL);
656         if (ast_is_valid(tmp_it->ast)) {
657            tmp_table = tmp_it->cpy_sym_table;
658            tmp_node = symbol_table_get_root(tmp_table);
659            if (!local_loc && (!sym || property == SYMBOL_PROPERTY_TYPE_DEF)) {
660               sym = symbol_table_node_get(tmp_node, iden, hash, property);
661               if (sym) {
662                  String str = string_duplicate(dependency);
663                  string_replace_all(str, '/', '.');
664                  vector_append(found_in_dep, str);
665                  vector_append(sym_vec, sym);
666               }
667            } else {
668               sym_dup = symbol_table_node_get(tmp_node, iden, hash,
```

```
669                     property);
670             if (sym_dup) {
671                String str = string_duplicate(dependency);
672                string_replace_all(str, '/', '.');
673                vector_append(found_in_dep, str);
674                sym_dup = NULL;
675             }
676          }
677       }
678    }
679
680    if (found_in_dep && vector_size(found_in_dep) > 0) {
681       String str;
682       if (!local_loc && vector_size(found_in_dep) > 1 &&
683             property != SYMBOL_PROPERTY_TYPE_DEF) {
684          str = string_from_format(S("ambiguous imported %S of " QFY("%S")
685                ", %1$S is imported from:\n"),
686                type_str, iden);
687          VECTOR_FOR_EACH_ENTRY(found_in_dep, dependency)
688             string_append_format(str, S("\t%S\n"), dependency);
689
690          report_error_location(err_loc, str);
691          string_destroy(str);
692       }
693    }
694
695    if (!local_loc) {
696       ret = dependency_symbols_alloc(sym_vec, found_in_dep);
697    } else if (found_in_dep){
698       vector_destroy(found_in_dep, (Vector_Destructor) string_destroy);
699    }
700
701    return ret;
702 }
703
704 Dependency_Symbols *import_table_build_iden_loc(bool use_unique_name,
705       Symbol_Table_Node *node, Symbol_Property property, String iden,
706       File_Location *err_loc)
707 {
708    Symbol *local_sym;
709    Vector *sym_vec = NULL;
710    Uns hash = string_hash_code(iden);
711    Dependency_Symbols *ret;
712
713    do {
714       if (property == SYMBOL_PROPERTY_VAR)
715          local_sym = symbol_table_node_lookup_var(node, iden, err_loc);
716       else
717          local_sym = symbol_table_node_get(node, iden, hash, property);
718       if (local_sym) {
719          sym_vec = vector_alloc();
720          if (use_unique_name) {
721             vector_append(sym_vec, local_sym);
722          }
723          ret = dependency_symbols_alloc(sym_vec, NULL);
724          break;
725       } else {
726          ret = import_handler_search_dependencies(node, property, iden,
727                hash, NULL, err_loc);
728          if (ret) {
729            if (vector_size(ret->sym_vec) > 0) {
730               break;
731            }
732            dependency_symbols_destroy(ret);
733            ret = NULL;
734          }
735       }
736    } while (node->parent && (node = node->parent));
737
738    return ret;
739 }
740
741 #if 0
742 Dependency_Symbols *import_table_build_iden(bool use_unique_name,
```

```
743         Symbol_Table_Node *node, Symbol_Property property, String iden)
744 {
745    File_Location loc = FILE_LOCATION_INIT(NULL, 0, 0);
746    return import_table_build_iden_loc(use_unique_name, node,
747          property, iden, &loc);
748 }
749 #endif
750
751 void import_table_update_symbol_type(bool use_unique_name, Symbol_Table *table,
752       Symbol_Table_Node *node, Symbol_Type_Struct *type_struct,
753       bool as_import)
754 {
755    Uns vec_size, idx;
756    Vector *tmp_vec;
757    Symbol *tmp_sym;
758    Symbol_Type_Struct *tmp_type;
759    Symbol_Type type = type_struct->methods->get_type();
760    Dependency_Symbols *dep_sym;
761
762    switch (type) {
763       case SYMBOL_TYPE_VOID:
764       case SYMBOL_TYPE_INT:
765       case SYMBOL_TYPE_BOOL:
766       case SYMBOL_TYPE_CHAR:
767       case SYMBOL_TYPE_STRING:
768       case SYMBOL_TYPE_CYCLE:
769       case SYMBOL_TYPE_UNKNOWN:
770          break;
771       case SYMBOL_TYPE_ARY:;
772          Symbol_Type_Ary *type_ary;
773          type_ary = SYMBOL_TYPE_STRUCT_CONTAINER(type_struct,
774                Symbol_Type_Ary);
775          if (type_ary->imp_table_updated)
776             break;
777          type_ary->imp_table_updated = true;
778
779          import_table_update_symbol_type(use_unique_name, table, node,
780                type_ary->ary_type, as_import);
781          break;
782       case SYMBOL_TYPE_REC:;
783          Symbol_Type_Rec *type_rec;
784          type_rec = SYMBOL_TYPE_STRUCT_CONTAINER(type_struct,
785                Symbol_Type_Rec);
786
787          if (type_rec->imp_table_updated)
788             break;
789          type_rec->imp_table_updated = true;
790
791          tmp_vec = &type_rec->extended_types;
792          vec_size = vector_size(tmp_vec);
793          for (idx = 0; idx < vec_size; idx++) {
794             tmp_type = vector_get(tmp_vec, idx);
795             import_table_update_symbol_type(use_unique_name, table, node,
796                   tmp_type, as_import);
797          }
798          tmp_vec = &type_rec->var_types;
799          vec_size = vector_size(tmp_vec);
800          for (idx = 0; idx < vec_size; idx++) {
801             tmp_type = vector_get(tmp_vec, idx);
802             import_table_update_symbol_type(use_unique_name, table, node,
803                   tmp_type, as_import);
804          }
805          tmp_vec = &type_rec->func_types;
806          vec_size = vector_size(tmp_vec);
807          for (idx = 0; idx < vec_size; idx++) {
808             tmp_type = vector_get(tmp_vec, idx);
809             import_table_update_symbol_type(use_unique_name, table, node,
810                   tmp_type, as_import);
811          }
812          break;
813       case SYMBOL_TYPE_FUNC:;
814          Symbol_Type_Func *func_type;
815          func_type = SYMBOL_TYPE_STRUCT_CONTAINER(type_struct,
816                Symbol_Type_Func);
```

```
817           if (func_type->imp_table_updated)
818              break;
819           func_type->imp_table_updated = true;
820
821           tmp_vec = &func_type->param_identifiers;
822           vec_size = vector_size(tmp_vec);
823           for (idx = 0; idx < vec_size; idx++) {
824              String par_iden = vector_get(tmp_vec, idx);
825              tmp_sym = symbol_table_node_get(func_type->body_sym_node,
826                    par_iden, string_hash_code(par_iden),
827                    SYMBOL_PROPERTY_VAR);
828              assert(tmp_sym);
829              import_table_update_symbol_type(use_unique_name, table,
830                    tmp_sym->sym_node, tmp_sym->resolved_type, as_import);
831           }
832
833           import_table_update_symbol_type(use_unique_name, table, node,
834                 func_type->return_type, as_import);
835           break;
836        case SYMBOL_TYPE_IDEN:;
837           Symbol_Type_Iden *iden_type = SYMBOL_TYPE_STRUCT_CONTAINER(
838                 type_struct, Symbol_Type_Iden);
839
840           dep_sym = import_table_build_iden_loc(use_unique_name,
841                 iden_type->sym_node, SYMBOL_PROPERTY_TYPE_DEF,
842                 iden_type->iden, iden_type->loc);
843
844           if (dep_sym && dep_sym->sym_vec) {
845              tmp_vec = dep_sym->sym_vec;
846              Uns size = vector_size(tmp_vec);
847
848              if (!dep_sym->dep_vec) {
849                 assert(size <= 1);
850                 if (size == 1) {
851                    tmp_sym = vector_peek_first(dep_sym->sym_vec);
852                    if (tmp_sym->sym_node->type !=
853                          SYMBOL_TABLE_NODE_GLOBAL) {
854                       dependency_symbols_destroy(dep_sym);
855                       break;
856                    }
857                 }
858              }
859
860              if (size == 1) {
861                 tmp_sym = vector_pop_last(tmp_vec);
862                 DLOG("update sigle iden: %S => %S\n", iden_type->iden,
863                       tmp_sym->unique_name);
864                 symbol_type_iden_set_iden(iden_type,
865                       string_duplicate(tmp_sym->unique_name));
866                 Symbol_Type_Struct *tstruct = tmp_sym->resolved_type;
867                 if (tstruct->methods->get_type() == SYMBOL_TYPE_REC) {
868                    Symbol_Type_Rec *trec =
869                       SYMBOL_TYPE_STRUCT_CONTAINER(tstruct,
870                             Symbol_Type_Rec);
871                    if (!trec->imp_table_name_updated) {
872                       string_destroy(trec->rec_name);
873                       trec->rec_name = string_duplicate(iden_type->iden);
874                       trec->imp_table_name_updated = true;
875                    }
876                 }
877              } else if (size > 1) {
878                 Uns hash = string_hash_code(iden_type->iden);
879                 /*
880                 String local_unique = string_from_format(S(".%U.%S"),
881                       unique_import_no++, iden_type->iden);
882                 */
883                 String local_unique = string_duplicate(iden_type->iden);
884
885                 if (as_import && node->type != SYMBOL_TABLE_NODE_IMPORT) {
886                    if (!node->parent ||
887                       node->parent->type != SYMBOL_TABLE_NODE_IMPORT){
888                       Symbol_Table_Node *tmp_node = node;
889                       node = symbol_table_node_alloc_insert(node->parent,
890                             table, SYMBOL_TABLE_NODE_IMPORT, NULL);
```

```
891                     tmp_node->parent = node;
892                  } else {
893                     node = node->parent;
894                  }
895               }
896
897               for (Uns i = 0; i < vector_size(tmp_vec); i++) {
898                  tmp_sym = vector_get(tmp_vec, i);
899                  Symbol_Type_Struct *ts = symbol_type_iden_alloc(table,
900                           tmp_sym->unique_name);
901                  Symbol_Type_Iden *tiden = SYMBOL_TYPE_STRUCT_CONTAINER(
902                        ts, Symbol_Type_Iden);
903                  tiden->sym_node = node;
904
905                  DLOG("\tupdate iden: %S => %S\n", local_unique,
906                     tiden->iden);
907
908                  Symbol_Type_Struct *tstruct = tmp_sym->resolved_type;
909                  if (tstruct->methods->get_type() == SYMBOL_TYPE_REC) {
910                     Symbol_Type_Rec *trec =
911                        SYMBOL_TYPE_STRUCT_CONTAINER(tstruct,
912                              Symbol_Type_Rec);
913                     if (!trec->imp_table_name_updated) {
914                        string_destroy(trec->rec_name);
915                        trec->rec_name = string_duplicate(
916                              iden_type->iden);
917                        trec->imp_table_name_updated = true;
918                     }
919                  }
920
921                  if (as_import) {
922                     ___symbol_table_node_insert(node, local_unique,
923                           vector_get(dep_sym->dep_vec, i), hash, ts,
924                           SYMBOL_PROPERTY_TYPE_DEF,
925                           iden_type->loc);
926                  } else {
927                     ___symbol_table_node_insert(node, local_unique,
928                           local_unique, hash, ts,
929                           SYMBOL_PROPERTY_TYPE_DEF,
930                           iden_type->loc);
931                  }
932               }
933               symbol_type_iden_set_iden(iden_type, local_unique);
934            }
935            dependency_symbols_destroy(dep_sym);
936         }
937         break;
938      default:
939         assert(false);
940   }
941 }
942
943 void import_table_viti_append(String_Builder *sb,
944       Symbol_Type_Struct *type_struct)
945 {
946    Uns vec_size, tmp_vec_size, idx;
947    Vector *tmp_vec;
948    Symbol *tmp_sym;
949    Symbol_Type_Struct *tmp_type;
950    Symbol_Type type = type_struct->methods->get_type();
951    switch (type) {
952       case SYMBOL_TYPE_INT:
953       case SYMBOL_TYPE_BOOL:
954       case SYMBOL_TYPE_CHAR:
955       case SYMBOL_TYPE_STRING:
956       case SYMBOL_TYPE_CYCLE:
957       case SYMBOL_TYPE_VOID:
958       case SYMBOL_TYPE_UNKNOWN:
959          type_struct->methods->append_str(type_struct, sb);
960          break;
961       case SYMBOL_TYPE_ARY:;
962          Symbol_Type_Ary *type_ary;
963          type_ary = SYMBOL_TYPE_STRUCT_CONTAINER(type_struct,
964                Symbol_Type_Ary);
```

```
965            string_builder_append(sb, S("array of "));
966            import_table_viti_append(sb, type_ary->ary_type);
967            break;
968         case SYMBOL_TYPE_REC:;
969            Symbol_Type_Rec *type_rec;
970            type_rec = SYMBOL_TYPE_STRUCT_CONTAINER(type_struct,
971                  Symbol_Type_Rec);
972
973            string_builder_append(sb, S("record of "));
974            tmp_vec = &type_rec->extended_types;
975            vec_size = vector_size(&type_rec->extended_types);
976            if (vec_size) {
977               for (idx = 0; idx < vec_size-1; idx++) {
978                  tmp_type = vector_get(tmp_vec, idx);
979                  import_table_viti_append(sb, tmp_type);
980                  string_builder_append(sb, S(", "));
981               }
982               tmp_type = vector_get(tmp_vec, idx);
983               import_table_viti_append(sb, tmp_type);
984               string_builder_append(sb, S(" "));
985            }
986
987            string_builder_append(sb, S("{ "));
988            tmp_vec = &type_rec->func_identifiers;
989            vec_size = vector_size(tmp_vec);
990            String fname;
991            if (vec_size) {
992               for (idx = 0; idx < vec_size-1; idx++) {
993                  string_builder_append(sb, S("func "));
994                  fname = vector_get(tmp_vec, idx);
995                  string_builder_append(sb, STRING_AFTER_LAST(fname, '.'));
996                  tmp_sym = symbol_table_node_get(type_rec->rec_sym_node,
997                        fname, string_hash_code(fname),
998                        SYMBOL_PROPERTY_FUNC);
999                  import_table_viti_append(sb, tmp_sym->resolved_type);
1000                 string_builder_append(sb, S(" end "));
1001                 string_builder_append(sb, STRING_AFTER_LAST(fname, '.'));
1002                 string_builder_append(sb, S(", "));
1003              }
1004              string_builder_append(sb, S("func "));
1005              fname = vector_get(tmp_vec, idx);
1006              string_builder_append(sb, STRING_AFTER_LAST(fname, '.'));
1007              tmp_sym = symbol_table_node_get(type_rec->rec_sym_node,
1008                    fname, string_hash_code(fname), SYMBOL_PROPERTY_FUNC);
1009              import_table_viti_append(sb, tmp_sym->resolved_type);
1010              string_builder_append(sb, S(" end "));
1011              string_builder_append(sb, STRING_AFTER_LAST(fname, '.'));
1012
1013           }
1014
1015           tmp_vec = &type_rec->var_identifiers;
1016           tmp_vec_size = vector_size(tmp_vec);
1017           if (vec_size && tmp_vec_size)
1018              string_builder_append(sb, S(", "));
1019
1020           String var_name;
1021           vec_size = tmp_vec_size;
1022           if (vec_size) {
1023              for (idx = 0; idx < vec_size-1; idx++) {
1024                 var_name = vector_get(tmp_vec, idx);
1025                 string_builder_append(sb, var_name);
1026                 string_builder_append(sb, S(":"));
1027                 tmp_sym = symbol_table_node_get(type_rec->rec_sym_node,
1028                       var_name, string_hash_code(var_name),
1029                       SYMBOL_PROPERTY_VAR);
1030                 import_table_viti_append(sb, tmp_sym->resolved_type);
1031                 string_builder_append(sb, S(", "));
1032              }
1033              var_name = vector_get(tmp_vec, idx);
1034              string_builder_append(sb, var_name);
1035              string_builder_append(sb, S(":"));
1036              tmp_sym = symbol_table_node_get(type_rec->rec_sym_node,
1037                    var_name, string_hash_code(var_name),
1038                    SYMBOL_PROPERTY_VAR);
```

```
1039             import_table_viti_append(sb, tmp_sym->resolved_type);
1040          }
1041          string_builder_append(sb, S(" }"));
1042
1043          break;
1044       case SYMBOL_TYPE_FUNC:;
1045          Symbol_Type_Func *func_type;
1046          func_type = SYMBOL_TYPE_STRUCT_CONTAINER(type_struct,
1047                Symbol_Type_Func);
1048          tmp_vec = &func_type->param_identifiers;
1049          vec_size = vector_size(tmp_vec);
1050          string_builder_append(sb, S("("));
1051          if (vec_size) {
1052             for (idx = 0; idx < vec_size-1; idx++) {
1053                string_builder_append(sb, vector_get(tmp_vec, idx));
1054                string_builder_append(sb, S(":"));
1055                tmp_sym = symbol_table_node_get(func_type->body_sym_node,
1056                      vector_get(tmp_vec, idx),
1057                      string_hash_code(vector_get(tmp_vec, idx)),
1058                      SYMBOL_PROPERTY_VAR);
1059                assert(tmp_sym);
1060                import_table_viti_append(sb, tmp_sym->resolved_type);
1061                string_builder_append(sb, S(", "));
1062             }
1063             string_builder_append(sb, vector_get(tmp_vec, idx));
1064             string_builder_append(sb, S(":"));
1065             tmp_sym = symbol_table_node_get(func_type->body_sym_node,
1066                   vector_get(tmp_vec, idx),
1067                   string_hash_code(vector_get(tmp_vec, idx)),
1068                   SYMBOL_PROPERTY_VAR);
1069             assert(tmp_sym);
1070             import_table_viti_append(sb, tmp_sym->resolved_type);
1071          }
1072
1073          string_builder_append(sb, S("):"));
1074          import_table_viti_append(sb, func_type->return_type);
1075          break;
1076       case SYMBOL_TYPE_IDEN:;
1077          Symbol_Type_Iden *type_iden = SYMBOL_TYPE_STRUCT_CONTAINER(
1078                type_struct, Symbol_Type_Iden);
1079          string_builder_append(sb, type_iden->iden);
1080          break;
1081       default:
1082          assert(false);
1083    }
1084 }
1085
1086 void import_handler_insert_ast(Ast* ast, Const_String file_prefix)
1087 {
1088    Uns hash = string_hash_code(file_prefix);
1089    Import_Table *it = import_table_init(file_prefix, hash);
1090
1091    it->is_main_file = true;
1092    it->is_compiled = true;
1093
1094    if (ast_is_valid(ast)) {
1095       it->ast = ast;
1096
1097       cd_working_dir();
1098
1099       it->cpy_sym_table = symbol_table_alloc(ast_get_file_name(it->ast));
1100       symbol_table_merge(it->cpy_sym_table, ast_get_symbol_table(it->ast),
1101             false);
1102
1103       import_table_include_imports(it);
1104
1105       if (cmdopts.generate_viti)
1106          import_table_dump_viti(it);
1107    }
1108 }
1109
1110 void import_handler_import(Symbol_Table *table, Symbol_Table_Node *local_node,
1111       Const_String file_prefix, File_Location *from_loc)
1112 {
```

```
1113     Import_Table *it;
1114     Symbol_Table *import_table;
1115     Symbol_Table_Node *import_node;
1116     Symbol_Table_Node *local_import_node;
1117
1118     char *cur_work_dir;
1119     if (!(cur_work_dir = getcwd(NULL, 0)))
1120        fatal_error(S("unable to obtain current working directoy [%m]\n"));
1121
1122     it = import_table_get(file_prefix, from_loc);
1123
1124     if (!symbol_table_get_root(import_merge_table))
1125        symbol_table_node_alloc_insert(NULL, import_merge_table,
1126              SYMBOL_TABLE_NODE_GLOBAL, NULL);
1127
1128     import_handler_merge_tables();
1129     symbol_table_dump_graph(import_merge_table, S("MERGE"));
1130     symbol_table_resolve(import_merge_table);
1131
1132     if (ast_is_valid(it->ast)) {
1133        import_table = ast_get_symbol_table(it->ast);
1134        import_node = symbol_table_get_root(import_table);
1135
1136        if (local_node->parent &&
1137              local_node->parent->type == SYMBOL_TABLE_NODE_IMPORT)
1138           local_import_node = local_node->parent;
1139        else {
1140           local_import_node = symbol_table_node_alloc_insert(
1141                 local_node->parent, table, SYMBOL_TABLE_NODE_IMPORT, NULL);
1142           local_node->parent = local_import_node;
1143        }
1144
1145        symbol_table_node_merge_cond(table, local_import_node,
1146              import_merge_table, NULL, it->file_prefix, import_node);
1147     }
1148
1149     if (chdir(cur_work_dir))
1150        fatal_error(S("cannot switch back to directory %s [%m]\n"),
1151              cur_work_dir);
1152     free_mem(cur_work_dir);
1153  }
1154
1155  void import_handler_init()
1156  {
1157     import_merge_table = symbol_table_alloc(NULL);
1158  }
1159
1160  void import_handler_clear()
1161  {
1162     if (project_root)
1163        string_destroy(project_root);
1164     project_root = NULL;
1165
1166     hash_map_for_each_destroy(&import_hash, import_table_destructor);
1167     symbol_table_destroy(import_merge_table);
1168     import_merge_table = NULL;
1169  }
```

:

A.4.4 src/import_handler.h

```
1  #ifndef IMPORT_HANDLER_H
2  #define IMPORT_HANDLER_H
3
4  #include <std_include.h>
5  #include <ast/symbol_table.h>
6  #include <ast/ast.h>
7
8  typedef struct Import_Table Import_Table;
9
```

```
10 typedef struct Dependency_Symbols {
11    Vector *sym_vec;
12    Vector *dep_vec;
13 } Dependency_Symbols;
14
15 Dependency_Symbols *dependency_symbols_alloc(Vector *sym_vec, Vector *dep_vec);
16
17 void dependency_symbols_destroy(Dependency_Symbols *dep_sym);
18
19 void import_handler_import(Symbol_Table *table, Symbol_Table_Node *local_node,
20       Const_String file_prefix, File_Location *from_loc);
21
22 bool import_handler_is_merge_table(Symbol_Table* t);
23
24 Import_Table *import_table_get(Const_String file_prefix, File_Location *loc);
25
26 Dependency_Symbols *import_table_build_iden(bool use_unique_name,
27       Symbol_Table_Node *node, Symbol_Property property, String iden);
28
29 Dependency_Symbols *import_table_build_iden_loc(bool use_unique_name,
30       Symbol_Table_Node *node, Symbol_Property property, String iden,
31       File_Location *err_loc);
32
33 Dependency_Symbols *import_handler_search_dependencies(Symbol_Table_Node *node,
34       Symbol_Property property, String iden, Uns hash,
35       File_Location *local_loc, File_Location *err_loc);
36
37 void import_table_update_symbol_type(bool use_unique_name, Symbol_Table *table,
38       Symbol_Table_Node *node, Symbol_Type_Struct *type_struct,
39       bool as_import);
40
41 Symbol *import_handler_get_merge_sym(String iden, Symbol_Property property);
42
43 void import_handler_compile_imports();
44
45 void import_handler_init();
46
47 void import_handler_clear();
48
49 void import_handler_insert_ast(Ast* ast, Const_String file_prefix);
50
51 /* Set the project root, searched before include paths */
52 void import_handler_set_project_root(Const_String path);
53
54 void import_handler_cd_project_root();
55
56 bool import_handler_is_error_reported();
57
58 #endif
```

A.5 Type Checking

:

A.5.1 src/ast/ast_visitor_type_check.c

```
1  #include "ast_visitor_type_check.h"
2  #include "symbol_table.h"
3  #include <main.h>
4
5  #undef DEBUG_TYPE
6  #define DEBUG_TYPE type-check
7
8  typedef enum Type_Check_Func_Type {
9     TT_FUNC_TYPE_NORMAL,
10    TT_FUNC_TYPE_FINALIZE,
11    TT_FUNC_TYPE_RECORD
12 } Type_Check_Func_Type;
```

```
13
14  AST_VISITOR_STRUCT_BEGIN(Ast_Visitor_Type_Check)
15     Symbol_Table *sym_table;
16     Symbol_Type_Struct *prev_sym_type;
17     Symbol_Func_Map *prev_func_map;
18     /* Variable is set in VARIABLE_IDEN and used by REC_ALLOCATE */
19     Symbol_Type_Struct *prev_variable_sym_type;
20     /* Variable is set in VARIABLE_IDEN and used by REC_ALLOCATE */
21     Symbol_Table_Node *rec_body_sym_node;
22     Symbol_Table_Node *dot_ref_sym_node;
23     /* Symbol_Type_Rec *lookup_rec; */
24     Symbol_Type_Struct *prev_direct_ref_rec;
25     Symbol_Type_Struct *prev_direct_ref_func;
26     Symbol_Property next_property;
27     String prev_iden;
28     Const_String prev_func_call_iden;
29     String curr_func_iden;
30     String prev_var_decl_iden;
31     Ast_Expr_Type prev_expr_type;
32     Ast_Expr_Type func_return_type;
33     Symbol_Type_Struct *func_return_sym;
34     Ast_Visitor_Method prev_method;
35     Uns stmt_list_nest;
36     Type_Check_Func_Type current_func_type;
37     bool lhs_of_assign_is_string_ref;
38     bool next_func_iden_is_decl;
39     bool in_beginning_of_ctor;
40     bool in_allocate_stmt;
41  AST_VISITOR_STRUCT_END(Ast_Visitor_Type_Check)
42
43  #define ASTVF_TC_BEGIN ASTVF_BEGIN
44
45  #define ASTVF_TC_RETURN(node_type, vis)     \
46  do {                                        \
47     (vis)->prev_method = AST_VISITOR_FUNC(node_type); \
48     return;                                  \
49  } while (0)
50
51  #define ASTVF_TC_END(node_type, vis) ASTVF_TC_RETURN(node_type, vis); ASTVF_END
52
53  Ast_Expr_Type symbol_type_to_expr_type(Symbol_Type_Struct *st)
54  {
55     Ast_Expr_Type ret;
56     Symbol *tmp_sym;
57     Symbol_Type_Cycle *tmp_cycle;
58     Symbol_Type_Iden *tmp_iden;
59
60  try_again:
61     switch (st->methods->get_type()) {
62     case SYMBOL_TYPE_VOID:
63        ret = AST_EXPR_TYPE_VOID;
64        break;
65     case SYMBOL_TYPE_INT:
66        ret = AST_EXPR_TYPE_INT;
67        break;
68     case SYMBOL_TYPE_BOOL:
69        ret = AST_EXPR_TYPE_BOOL;
70        break;
71     case SYMBOL_TYPE_CHAR:
72        ret = AST_EXPR_TYPE_CHAR;
73        break;
74     case SYMBOL_TYPE_STRING:
75        ret = AST_EXPR_TYPE_STRING;
76        break;
77     case SYMBOL_TYPE_ARY:
78        ret = AST_EXPR_TYPE_ARY;
79        break;
80     case SYMBOL_TYPE_REC:
81        ret = AST_EXPR_TYPE_REC;
82        break;
83     case SYMBOL_TYPE_FUNC:
84        st = SYMBOL_TYPE_STRUCT_CONTAINER(st, Symbol_Type_Func)->return_type;
85        goto try_again;
86     case SYMBOL_TYPE_CYCLE:
```

```
87          tmp_cycle = SYMBOL_TYPE_STRUCT_CONTAINER(st, Symbol_Type_Cycle);
88          tmp_sym = symbol_table_node_lookup(tmp_cycle->sym_node,
89                tmp_cycle->name, SYMBOL_PROPERTY_TYPE_DEF);
90          assert(tmp_sym);
91          st = tmp_sym->resolved_type;
92          goto try_again;
93       case SYMBOL_TYPE_IDEN:
94          tmp_iden = SYMBOL_TYPE_STRUCT_CONTAINER(st, Symbol_Type_Iden);
95          fatal_error(S("unexpected unresolved symbol '%S'. Aborting...\n"),
96                tmp_iden->iden);
97          break;
98
99       default:
100         ret = AST_EXPR_TYPE_UNKNOWN;
101         break;
102      }
103      return ret;
104   }
105
106   static inline void error_not_compatible_types(Ast_Node *n,
107         Ast_Expr_Type lhs_t, Ast_Expr_Type rhs_t)
108   {
109      if (lhs_t != rhs_t)
110         report_error_location(ast_node_get_file_location(n),
111               S("type " QFY("%S") " is incompatible with " QFY("%S") "\n"),
112               ast_expr_type_to_string(lhs_t),
113               ast_expr_type_to_string(rhs_t));
114      else
115         report_error_location(ast_node_get_file_location(n),
116               S("incompatible " QFY("%S") " types\n"),
117               ast_expr_type_to_string(lhs_t));
118   }
119
120   static inline void warn_implicit_cast(File_Location *loc, Ast_Expr_Type from,
121         Ast_Expr_Type to)
122   {
123      if (cmdopts.warn_implicit_cast) {
124         report_warning_location(loc,
125               S("implicit cast from " QFY("%S") " to " QFY("%S") "\n"),
126               ast_expr_type_to_string(from),
127               ast_expr_type_to_string(to));
128      }
129   }
130
131   static inline void warn_implicit_expr_cast(Ast_Node *n, Ast_Expr_Type from,
132         Ast_Expr_Type to, const char *expr_type)
133   {
134      if (cmdopts.warn_implicit_cast) {
135         report_warning_location(ast_node_get_file_location(n),
136               S(QFY("%s") "-expression implicitly casted from " QFY("%S")
137                  " to " QFY("%S") "\n"),
138               expr_type,
139               ast_expr_type_to_string(from),
140               ast_expr_type_to_string(to));
141      }
142   }
143
144   static inline void warn_implicit_cast_lhs(Ast_Node *n, Ast_Expr_Type from,
145         Ast_Expr_Type to, const char *operator)
146   {
147      if (cmdopts.warn_implicit_cast) {
148         report_warning_location(ast_node_get_file_location(n),
149               S("implicit cast from " QFY("%S") " to " QFY("%S")
150                  " left of " QFY("%s") "\n"),
151               ast_expr_type_to_string(from),
152               ast_expr_type_to_string(to),
153               operator);
154      }
155   }
156
157   static inline void warn_implicit_cast_rhs(Ast_Node *n, Ast_Expr_Type from,
158         Ast_Expr_Type to, const char *operator)
159   {
160      if (cmdopts.warn_implicit_cast) {
```

```
161         report_warning_location(ast_node_get_file_location(n),
162               S("implicit cast from " QFY("%S") " to " QFY("%S")
163                  " right of " QFY("%s") "\n"),
164               ast_expr_type_to_string(from),
165               ast_expr_type_to_string(to),
166               operator);
167      }
168   }
169
170   typedef enum Assign_Comatibility_Type {
171      ASSIGN_COMPATIBILITY_TRUE,
172      ASSIGN_COMPATIBILITY_FALSE,
173      ASSIGN_COMPATIBILITY_IMPLICIT,
174      ASSIGN_COMPATIBILITY_AMBIGUOUS
175   } Assign_Comatibility_Type;
176
177   static Assign_Comatibility_Type types_are_assignment_compatible(
178         Symbol_Type_Struct *dest,
179         Ast_Expr_Type dest_type,
180         Symbol_Type_Struct *src,
181         Ast_Expr_Type src_type)
182   {
183      if (dest_type == AST_EXPR_TYPE_UNKNOWN ||
184            src_type == AST_EXPR_TYPE_UNKNOWN)
185         return ASSIGN_COMPATIBILITY_TRUE;
186
187      if (dest_type != src_type) {
188         switch (dest_type) {
189         case AST_EXPR_TYPE_VOID:
190            return ASSIGN_COMPATIBILITY_FALSE;
191
192         case AST_EXPR_TYPE_INT:
193            switch (src_type) {
194            case AST_EXPR_TYPE_CHAR:
195               // return ASSIGN_COMPATIBILITY_IMPLICIT;
196               return ASSIGN_COMPATIBILITY_TRUE;
197
198            case AST_EXPR_TYPE_BOOL:
199               return ASSIGN_COMPATIBILITY_IMPLICIT;
200
201            default:
202               return ASSIGN_COMPATIBILITY_FALSE;
203            }
204
205         case AST_EXPR_TYPE_CHAR:
206            switch (src_type) {
207            case AST_EXPR_TYPE_INT:
208               // return ASSIGN_COMPATIBILITY_IMPLICIT;
209               return ASSIGN_COMPATIBILITY_TRUE;
210
211            case AST_EXPR_TYPE_BOOL:
212               return ASSIGN_COMPATIBILITY_IMPLICIT;
213
214            default:
215               return ASSIGN_COMPATIBILITY_FALSE;
216            }
217
218         case AST_EXPR_TYPE_STRING:
219            /* Fall through. */
220         case AST_EXPR_TYPE_ARY:
221            /* Fall through. */
222         case AST_EXPR_TYPE_REC:
223            if (src_type != AST_EXPR_TYPE_NULL)
224               return ASSIGN_COMPATIBILITY_FALSE;
225            return ASSIGN_COMPATIBILITY_TRUE;
226
227         case AST_EXPR_TYPE_BOOL:
228            return ASSIGN_COMPATIBILITY_IMPLICIT;
229
230         default:
231            return ASSIGN_COMPATIBILITY_FALSE;
232         }
233      }
234
```

```
235     switch (dest_type) {
236     case AST_EXPR_TYPE_REC:
237        if (symbol_type_rec_assignment_compatible(dest, src)) {
238           if (!symbol_type_rec_ambiguous_cast(dest, src))
239              return ASSIGN_COMPATIBILITY_TRUE;
240           return ASSIGN_COMPATIBILITY_AMBIGUOUS;
241        }
242        return ASSIGN_COMPATIBILITY_FALSE;
243
244     case AST_EXPR_TYPE_ARY:
245        if (dest->methods->same_type(dest, src))
246           return ASSIGN_COMPATIBILITY_TRUE;
247        return ASSIGN_COMPATIBILITY_FALSE;
248
249     case AST_EXPR_TYPE_VOID:
250        return ASSIGN_COMPATIBILITY_FALSE;
251
252     default:
253        return ASSIGN_COMPATIBILITY_TRUE;
254     }
255  }
256
257  static inline NORETURN void unexpected_operand()
258  {
259     fatal_error(S("unexpected operand. Aborting...\n"));
260  }
261
262  static inline void invalid_bin_operands(Ast_Node *n,
263        Ast_Expr_Type lhs_t, Ast_Expr_Type rhs_t, const char *operator)
264  {
265     if (lhs_t != rhs_t)
266        report_error_location(ast_node_get_file_location(n),
267              S("incompatible " QFY("%S") " and " QFY("%S") " operands"
268                 " for " QFY("%s") " operator\n"),
269              ast_expr_type_to_string(lhs_t),
270              ast_expr_type_to_string(rhs_t),
271              operator);
272     else
273        report_error_location(ast_node_get_file_location(n),
274              S("operator " QFY("%s") " is incompatible with "
275                 QFY("%S") " operands\n"),
276              operator,
277              ast_expr_type_to_string(lhs_t));
278  }
279
280  static inline void invalid_ary_operands(Ast_Node *n, const char *operator)
281  {
282     report_error_location(ast_node_get_file_location(n),
283           S("incompatible array types for binary operator " QFY("%s") "\n"),
284           operator);
285  }
286
287  static void pure_logic_binop(Ast_Visitor_Type_Check *v, Ast_Node_Binary *n,
288        const char *operator)
289  {
290     Ast_Expr_Type lhs_t, rhs_t;
291     n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
292     lhs_t = v->prev_expr_type;
293     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
294     rhs_t = v->prev_expr_type;
295
296     switch (lhs_t) {
297     case AST_EXPR_TYPE_UNKNOWN:
298        v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
299        goto out;
300
301     case AST_EXPR_TYPE_BOOL:
302        break;
303
304     case AST_EXPR_TYPE_VOID:
305        invalid_bin_operands(AST_NODE_OF(n), lhs_t, rhs_t, operator);
306        v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
307        goto out;
308
```

```
309     default:
310        warn_implicit_cast_lhs(AST_NODE_OF(n), lhs_t,
311              AST_EXPR_TYPE_BOOL, operator);
312        break;
313     }
314
315     switch (rhs_t) {
316     case AST_EXPR_TYPE_UNKNOWN:
317        v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
318        goto out;
319
320     case AST_EXPR_TYPE_BOOL:
321        break;
322
323     case AST_EXPR_TYPE_VOID:
324        invalid_bin_operands(AST_NODE_OF(n), lhs_t, rhs_t, operator);
325        v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
326        goto out;
327
328     default:
329        warn_implicit_cast_rhs(AST_NODE_OF(n), rhs_t,
330              AST_EXPR_TYPE_BOOL, operator);
331        break;
332     }
333
334     if (v->prev_expr_type != AST_EXPR_TYPE_UNKNOWN)
335        v->prev_expr_type = AST_EXPR_TYPE_BOOL;
336
337  out:
338     ast_expr_binary_set_expr_type(AST_EXPR_BINARY_OF(n), v->prev_expr_type);
339  }
340
341  static inline void invalid_una_operand(Ast_Node *n, Const_String op,
342        const char *operator)
343  {
344     report_error_location(ast_node_get_file_location(n),
345           S("incompatible " QFY("%S") " operand "
346              " for unary " QFY("%s") " operator\n"),
347           op, operator);
348  }
349
350  static inline void warn_from_to_una(Ast_Node *n, Ast_Expr_Type from,
351        Ast_Expr_Type to, const char *operator)
352  {
353     if (cmdopts.warn_implicit_cast)
354        report_warning_location(ast_node_get_file_location(n),
355              S("implicit cast from " QFY("%S") " to " QFY("%S")
356                 " for unary " QFY("%s") " operator\n"),
357              ast_expr_type_to_string(from),
358              ast_expr_type_to_string(to),
359              operator);
360  }
361
362  static void equality_binop(Ast_Visitor_Type_Check *v, Ast_Node_Binary *n,
363        const char *operator)
364  {
365     Ast_Expr_Type lhs_t, rhs_t;
366     n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
367     lhs_t = v->prev_expr_type;
368     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
369     rhs_t = v->prev_expr_type;
370
371     if (lhs_t == AST_EXPR_TYPE_UNKNOWN || rhs_t == AST_EXPR_TYPE_UNKNOWN) {
372        v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
373        goto out;
374     }
375     if (lhs_t == rhs_t)
376        goto out_bool;
377
378     switch (lhs_t) {
379     case AST_EXPR_TYPE_INT:
380        /* Fall through. */
381     case AST_EXPR_TYPE_CHAR:
382        switch (rhs_t) {
```

```
383         case AST_EXPR_TYPE_INT:
384            /* Fall through. */
385         case AST_EXPR_TYPE_CHAR:
386            break;
387         case AST_EXPR_TYPE_BOOL:
388            warn_implicit_cast(ast_node_get_file_location(n->rhs),
389                  rhs_t, lhs_t);
390            break;
391         default:
392            invalid_bin_operands(AST_NODE_OF(n), lhs_t, rhs_t, operator);
393            v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
394            goto out;
395         }
396         break;
397
398      case AST_EXPR_TYPE_BOOL:
399         switch (rhs_t) {
400         case AST_EXPR_TYPE_INT:
401            /* Fall through. */
402         case AST_EXPR_TYPE_CHAR:
403            warn_implicit_cast(ast_node_get_file_location(n->lhs),
404                  lhs_t, rhs_t);
405            break;
406         case AST_EXPR_TYPE_BOOL:
407            break;
408         default:
409            invalid_bin_operands(AST_NODE_OF(n), lhs_t, rhs_t, operator);
410            v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
411            goto out;
412
413         }
414         break;
415
416      case AST_EXPR_TYPE_STRING:
417         /* Fall through. */
418      case AST_EXPR_TYPE_REC:
419         /* Fall through. */
420      case AST_EXPR_TYPE_ARY:
421         switch (rhs_t) {
422         case AST_EXPR_TYPE_NULL:
423            /* Fall. */
424         case AST_EXPR_TYPE_STRING:
425            /* Fall. */
426         case AST_EXPR_TYPE_ARY:
427            /* Fall. */
428         case AST_EXPR_TYPE_REC:
429            break;
430         default:
431            invalid_bin_operands(AST_NODE_OF(n), lhs_t, rhs_t, operator);
432            v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
433            goto out;
434         }
435         break;
436
437      case AST_EXPR_TYPE_NULL:
438         switch (rhs_t) {
439         case AST_EXPR_TYPE_VOID:
440            invalid_bin_operands(AST_NODE_OF(n), lhs_t, rhs_t, operator);
441            v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
442            goto out;
443
444         case AST_EXPR_TYPE_INT:
445            /* Fall through. */
446         case AST_EXPR_TYPE_BOOL:
447            /* Fall through. */
448         case AST_EXPR_TYPE_CHAR:
449            invalid_bin_operands(AST_NODE_OF(n), lhs_t, rhs_t, operator);
450            v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
451            goto out;
452
453         case AST_EXPR_TYPE_STRING:
454            /* Fall through. */
455         case AST_EXPR_TYPE_REC:
456            /* Fall through. */
```

```
457         case AST_EXPR_TYPE_ARY:
458            break;
459
460         default:
461            unexpected_operand();
462         }
463
464      case AST_EXPR_TYPE_VOID:
465         invalid_bin_operands(AST_NODE_OF(n), lhs_t, rhs_t, operator);
466         v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
467         goto out;
468
469      default:
470         unexpected_operand();
471      }
472
473   out_bool:
474      v->prev_expr_type = AST_EXPR_TYPE_BOOL;
475
476   out:
477      ast_expr_binary_set_expr_type(AST_EXPR_BINARY_OF(n), v->prev_expr_type);
478   }
479
480   static void compare_binop(Ast_Visitor_Type_Check *v, Ast_Node_Binary *n,
481         const char *operator)
482   {
483      Ast_Expr_Type lhs_t, rhs_t;
484      n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
485      lhs_t = v->prev_expr_type;
486      n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
487      rhs_t = v->prev_expr_type;
488
489      if (lhs_t == AST_EXPR_TYPE_UNKNOWN || rhs_t == AST_EXPR_TYPE_UNKNOWN) {
490         v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
491         goto out;
492      }
493
494      switch (lhs_t) {
495      case AST_EXPR_TYPE_INT:
496         /* Fall through. */
497      case AST_EXPR_TYPE_CHAR:
498         switch (rhs_t) {
499         case AST_EXPR_TYPE_INT:
500            /* Fall through. */
501         case AST_EXPR_TYPE_CHAR:
502            break;
503         case AST_EXPR_TYPE_BOOL:
504            warn_implicit_cast(ast_node_get_file_location(n->rhs),
505                  rhs_t, lhs_t);
506            break;
507         default:
508            invalid_bin_operands(AST_NODE_OF(n), lhs_t, rhs_t, operator);
509            v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
510            goto out;
511         }
512         break;
513
514      case AST_EXPR_TYPE_VOID:
515         invalid_bin_operands(AST_NODE_OF(n), lhs_t, rhs_t, operator);
516         v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
517         goto out;
518
519      case AST_EXPR_TYPE_BOOL:
520         switch (rhs_t) {
521         case AST_EXPR_TYPE_INT:
522            /* Fall through. */
523         case AST_EXPR_TYPE_CHAR:
524            warn_implicit_cast(ast_node_get_file_location(n->lhs),
525                  lhs_t, rhs_t);
526            break;
527         case AST_EXPR_TYPE_BOOL:
528            break;
529
530         default:
```

```
531             invalid_bin_operands(AST_NODE_OF(n), lhs_t, rhs_t, operator);
532             v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
533             goto out;
534
535          }
536          break;
537
538       case AST_EXPR_TYPE_STRING:
539          /* Fall through. */
540       case AST_EXPR_TYPE_REC:
541          /* Fall through. */
542       case AST_EXPR_TYPE_ARY:
543          /* Fall through. */
544       case AST_EXPR_TYPE_NULL:
545          switch (rhs_t) {
546          case AST_EXPR_TYPE_STRING:
547             /* Fall through. */
548          case AST_EXPR_TYPE_REC:
549             /* Fall through. */
550          case AST_EXPR_TYPE_ARY:
551             /* Fall through. */
552          case AST_EXPR_TYPE_NULL:
553             if (cmdopts.warn_ref_compare) {
554                if (lhs_t != rhs_t) {
555                   report_warning_location(
556                         ast_node_get_file_location(AST_NODE_OF(n)),
557                         S(QFY("%s")"-comparison between " QFY("%S")
558                            " and " QFY("%S") " reference operands\n"),
559                         operator,
560                         ast_expr_type_to_string(lhs_t),
561                         ast_expr_type_to_string(rhs_t));
562                } else {
563                   report_warning_location(
564                         ast_node_get_file_location(AST_NODE_OF(n)),
565                         S(QFY("%s")"-comparison between " QFY("%S")
566                            " reference operands\n"),
567                         operator,
568                         ast_expr_type_to_string(lhs_t),
569                         ast_expr_type_to_string(rhs_t));
570                }
571             }
572             break;
573
574          default:
575             invalid_bin_operands(AST_NODE_OF(n), lhs_t, rhs_t, operator);
576             v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
577             goto out;
578          }
579          break;
580
581       default:
582          unexpected_operand();
583       }
584
585       v->prev_expr_type = AST_EXPR_TYPE_BOOL;
586
587    out:
588       ast_expr_binary_set_expr_type(AST_EXPR_BINARY_OF(n), v->prev_expr_type);
589    }
590
591    static void arith_binop(Ast_Visitor_Type_Check *v, Ast_Node_Binary *n,
592          const char *operator, bool is_ary_operator UNUSED)
593    {
594       //Symbol_Type_Struct *lhs_s, *rhs_s;
595       Ast_Expr_Type lhs_t, rhs_t;
596       n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
597       //lhs_s = v->prev_sym_type;
598       lhs_t = v->prev_expr_type;
599       n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
600       //rhs_s = v->prev_sym_type;
601       rhs_t = v->prev_expr_type;
602
603       if (lhs_t == AST_EXPR_TYPE_UNKNOWN || rhs_t == AST_EXPR_TYPE_UNKNOWN) {
604          v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
```

```
605         goto out;
606      }
607
608      switch (lhs_t) {
609      case AST_EXPR_TYPE_INT:
610         switch (rhs_t) {
611         case AST_EXPR_TYPE_INT:
612            /* Fall through. */
613         case AST_EXPR_TYPE_CHAR:
614            break;
615         case AST_EXPR_TYPE_BOOL:
616            warn_implicit_cast(ast_node_get_file_location(n->rhs),
617                  rhs_t, AST_EXPR_TYPE_INT);
618            break;
619         default:
620            invalid_bin_operands(AST_NODE_OF(n), lhs_t, rhs_t, operator);
621            v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
622            goto out;
623         }
624         v->prev_expr_type = AST_EXPR_TYPE_INT;
625         goto out;
626
627      case AST_EXPR_TYPE_CHAR:
628         switch (rhs_t) {
629         case AST_EXPR_TYPE_INT:
630            /* Fall through. */
631         case AST_EXPR_TYPE_CHAR:
632            break;
633         case AST_EXPR_TYPE_BOOL:
634            warn_implicit_cast(ast_node_get_file_location(n->rhs),
635                  rhs_t, AST_EXPR_TYPE_INT);
636            break;
637         default:
638            invalid_bin_operands(AST_NODE_OF(n), lhs_t, rhs_t, operator);
639            v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
640            goto out;
641         }
642         v->prev_expr_type = AST_EXPR_TYPE_INT;
643         goto out;
644
645      case AST_EXPR_TYPE_ARY:
646         /* Fall. */
647      case AST_EXPR_TYPE_STRING:
648         invalid_bin_operands(AST_NODE_OF(n), lhs_t, rhs_t, operator);
649         v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
650         goto out;
651
652      case AST_EXPR_TYPE_BOOL:
653         switch (rhs_t) {
654         case AST_EXPR_TYPE_INT:
655            /* Fall through. */
656         case AST_EXPR_TYPE_CHAR:
657            warn_implicit_cast(ast_node_get_file_location(n->lhs),
658                  lhs_t, AST_EXPR_TYPE_INT);
659            break;
660         case AST_EXPR_TYPE_BOOL:
661            if (cmdopts.warn_implicit_cast) {
662               report_warning_location(
663                     ast_node_get_file_location(AST_NODE_OF(n)),
664                     S( QFY("bool") " operands for " QFY("%s") " operator "
665                        "implicitly casted to " QFY("int") "\n"),
666                     operator);
667            }
668            break;
669         default:
670            invalid_bin_operands(AST_NODE_OF(n), lhs_t, rhs_t, operator);
671            v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
672            goto out;
673
674         }
675         v->prev_expr_type = AST_EXPR_TYPE_INT;
676         break;
677
678      case AST_EXPR_TYPE_VOID:
```

```
679         /* Fall through. */
680     case AST_EXPR_TYPE_REC:
681         /* Fall through. */
682     case AST_EXPR_TYPE_NULL:
683         invalid_bin_operands(AST_NODE_OF(n), lhs_t, rhs_t, operator);
684         v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
685         goto out;
686 
687     default:
688         unexpected_operand();
689     }
690 
691 out:
692     ast_expr_binary_set_expr_type(AST_EXPR_BINARY_OF(n), v->prev_expr_type);
693 }
694 
695 static void pure_logic_unaop(Ast_Visitor_Type_Check *v, Ast_Node_Unary *n,
696         const char *operator)
697 {
698     Ast_Expr_Type t;
699     n->expr->accept_visitor(n->expr, AST_VISITOR_OF(v));
700     t = v->prev_expr_type;
701 
702     if (t == AST_EXPR_TYPE_UNKNOWN)
703         goto out;
704 
705     if (t == AST_EXPR_TYPE_VOID) {
706         invalid_una_operand(AST_NODE_OF(n),
707                 ast_expr_type_to_string(AST_EXPR_TYPE_VOID), operator);
708         v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
709         goto out;
710     }
711 
712     if (t != AST_EXPR_TYPE_BOOL)
713         warn_from_to_una(AST_NODE_OF(n), t, AST_EXPR_TYPE_BOOL, operator);
714 
715     v->prev_expr_type = AST_EXPR_TYPE_BOOL;
716 
717 out:
718     ast_expr_unary_set_expr_type(AST_EXPR_UNARY_OF(n), v->prev_expr_type);
719 }
720 
721 ASTVF_TC_BEGIN(AST_EXPR_LOR, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
722     pure_logic_binop(v, n, "||");
723 ASTVF_TC_END(AST_EXPR_LOR, v)
724 
725 ASTVF_TC_BEGIN(AST_EXPR_LAND, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
726     pure_logic_binop(v, n, "&&");
727 ASTVF_TC_END(AST_EXPR_LAND, v)
728 
729 ASTVF_TC_BEGIN(AST_EXPR_EQ, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
730     equality_binop(v, n, "==");
731 ASTVF_TC_END(AST_EXPR_EQ, v)
732 
733 ASTVF_TC_BEGIN(AST_EXPR_NEQ, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
734     equality_binop(v, n, "!=");
735 ASTVF_TC_END(AST_EXPR_NEQ, v)
736 
737 ASTVF_TC_BEGIN(AST_EXPR_GT, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
738     compare_binop(v, n, ">");
739 ASTVF_TC_END(AST_EXPR_GT, v)
740 
741 ASTVF_TC_BEGIN(AST_EXPR_LT, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
742     compare_binop(v, n, "<");
743 ASTVF_TC_END(AST_EXPR_LT, v)
744 
745 ASTVF_TC_BEGIN(AST_EXPR_GTEQ, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
746     compare_binop(v, n, ">=");
747 ASTVF_TC_END(AST_EXPR_GTEQ, v)
748 
749 ASTVF_TC_BEGIN(AST_EXPR_LTEQ, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
750     compare_binop(v, n, "<=");
751 ASTVF_TC_END(AST_EXPR_LTEQ, v)
752 
```

```
753 ASTVF_TC_BEGIN(AST_EXPR_PLUS, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
754    arith_binop(v, n, "+", false);
755 ASTVF_TC_END(AST_EXPR_PLUS, v)
756
757 ASTVF_TC_BEGIN(AST_EXPR_MINUS, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
758    arith_binop(v, n, "-", false);
759 ASTVF_TC_END(AST_EXPR_MINUS, v)
760
761 ASTVF_TC_BEGIN(AST_EXPR_MUL, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
762    arith_binop(v, n, "*", false);
763 ASTVF_TC_END(AST_EXPR_MUL, v)
764
765 ASTVF_TC_BEGIN(AST_EXPR_DIV, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
766    arith_binop(v, n, "/", false);
767 ASTVF_TC_END(AST_EXPR_DIV, v)
768
769 static void invalid_cast_from_to(Ast_Node *n, Ast_Expr_Type lhs_t,
770       Ast_Expr_Type rhs_t, Ast_Visitor_Type_Check *v)
771 {
772    report_error_location(ast_node_get_file_location(n),
773          S("invalid cast from " QFY("%S") " to " QFY("%S") "\n"),
774          ast_expr_type_to_string(lhs_t),
775          ast_expr_type_to_string(rhs_t));
776    v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
777 }
778
779 static void invalid_cast_between(Ast_Node *n, Ast_Expr_Type t,
780       Ast_Visitor_Type_Check *v)
781 {
782    report_error_location(ast_node_get_file_location(n),
783          S("invalid cast between " QFY("%S") " types\n"),
784          ast_expr_type_to_string(t));
785    v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
786 }
787
788 ASTVF_TC_BEGIN(AST_EXPR_CAST, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
789    Ast_Expr_Type lhs_t, rhs_t;
790    Symbol_Type_Struct *lhs_s, *rhs_s;
791
792    Symbol_Property saved_property = v->next_property;
793    v->next_property = SYMBOL_PROPERTY_TYPE_DEF;
794    n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
795    v->next_property = saved_property;
796
797    Symbol *lhs_sym = symbol_table_get_from_location(
798          AST_NODE_OF(n)->sym_table_node,
799          ast_node_get_file_location(AST_NODE_OF(n)));
800
801    lhs_s = lhs_sym->resolved_type;
802    lhs_t = symbol_type_to_expr_type(lhs_s);
803
804    n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
805    rhs_t = v->prev_expr_type;
806    rhs_s = v->prev_sym_type;
807
808    switch (lhs_t) {
809    case AST_EXPR_TYPE_UNKNOWN:
810       v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
811       break;
812
813    case AST_EXPR_TYPE_BOOL:
814       if (rhs_t == AST_EXPR_TYPE_VOID) {
815          v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
816          invalid_cast_from_to(n->lhs, rhs_t, lhs_t, v);
817       } else if (rhs_t == AST_EXPR_TYPE_UNKNOWN) {
818          v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
819       } else {
820          v->prev_sym_type = lhs_s;
821       }
822       break;
823
824    case AST_EXPR_TYPE_INT:
825       /* Fall through. */
826    case AST_EXPR_TYPE_CHAR:
```

```
827         switch (rhs_t) {
828         case AST_EXPR_TYPE_UNKNOWN:
829            v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
830            break;
831
832         case AST_EXPR_TYPE_INT:
833            /* Fall through. */
834         case AST_EXPR_TYPE_CHAR:
835            /* Fall through. */
836         case AST_EXPR_TYPE_BOOL:
837            v->prev_expr_type = lhs_t;
838            goto out;
839
840         default:
841            invalid_cast_from_to(n->lhs, rhs_t, lhs_t, v);
842            break;
843         }
844         break;
845
846      case AST_EXPR_TYPE_STRING:
847         if (rhs_t == AST_EXPR_TYPE_UNKNOWN) {
848            v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
849            break;
850         }
851         if (rhs_t == AST_EXPR_TYPE_ARY) {
852            Symbol_Type_Ary *rhs_ary = SYMBOL_TYPE_STRUCT_CONTAINER(rhs_s,
853                  Symbol_Type_Ary);
854            if (rhs_ary->ary_type->methods->get_type() != SYMBOL_TYPE_CHAR) {
855               Const_String ary_str = ast_expr_type_to_string(
856                     symbol_type_to_expr_type(rhs_ary->ary_type));
857               report_error_location(ast_node_get_file_location(n->rhs),
858                     S("invalid type cast from " QFY("array of %S")
859                        " to " QFY("string") "\n"),
860                     ary_str);
861               v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
862               break;
863            } else {
864               v->prev_expr_type = AST_EXPR_TYPE_STRING;
865               goto out;
866            }
867         } else if (rhs_t == AST_EXPR_TYPE_STRING ||
868               rhs_t == AST_EXPR_TYPE_NULL) {
869            v->prev_expr_type = AST_EXPR_TYPE_STRING;
870            goto out;
871         } else {
872            invalid_cast_from_to(n->lhs, rhs_t, lhs_t, v);
873         }
874         break;
875
876      case AST_EXPR_TYPE_REC:
877         if (rhs_t == AST_EXPR_TYPE_UNKNOWN) {
878            v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
879            break;
880         }
881         if (rhs_t == AST_EXPR_TYPE_NULL) {
882            v->prev_sym_type = lhs_s;
883            v->prev_expr_type = lhs_t;
884            goto out;
885         } else if (rhs_t != AST_EXPR_TYPE_REC) {
886            invalid_cast_from_to(n->lhs, rhs_t, lhs_t, v);
887         } else {
888            if (symbol_type_rec_cast_compatible(rhs_s, lhs_s)) {
889               if (!symbol_type_rec_ambiguous_cast(lhs_s, rhs_s)) {
890                  v->prev_sym_type = lhs_s;
891                  v->prev_expr_type = lhs_t;
892                  goto out;
893               } else {
894                  v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
895                  report_error_location(
896                        ast_node_get_file_location(n->lhs),
897                        S("Ambiguous cast, "
898                           "type casted record is directly or "
899                           "indirectly extending multiple records "
900                           "with that structure\n"));
```

```
901                  break;
902               }
903            }
904            invalid_cast_between(n->lhs, lhs_t, v);
905         }
906         break;
907
908      case AST_EXPR_TYPE_ARY:
909         if (rhs_t == AST_EXPR_TYPE_UNKNOWN) {
910            v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
911            break;
912         }
913         if (rhs_t == AST_EXPR_TYPE_NULL) {
914            v->prev_expr_type = lhs_t;
915            v->prev_sym_type = lhs_s;
916            goto out;
917         } else if (rhs_t != AST_EXPR_TYPE_ARY) {
918            invalid_cast_from_to(n->lhs, rhs_t, lhs_t, v);
919         } else {
920            if (!lhs_s->methods->same_type(lhs_s, rhs_s)) {
921               invalid_cast_between(n->lhs, lhs_t, v);
922            } else {
923               v->prev_expr_type = lhs_t;
924               v->prev_sym_type = lhs_s;
925               goto out;
926            }
927         }
928         break;
929
930      default:
931         invalid_cast_from_to(n->lhs, rhs_t, lhs_t, v);
932         break;
933      }
934
935      v->prev_expr_type = symbol_type_to_expr_type(v->prev_sym_type);
936
937   out:
938      ast_expr_binary_set_expr_type(AST_EXPR_BINARY_OF(n), v->prev_expr_type);
939   ASTVF_TC_END(AST_EXPR_CAST, v)
940
941   ASTVF_TC_BEGIN(AST_EXPR_LNOT, Ast_Visitor_Type_Check, v, Ast_Node_Unary, n)
942      pure_logic_unaop(v, n, "!");
943   ASTVF_TC_END(AST_EXPR_LNOT, v)
944
945   ASTVF_TC_BEGIN(AST_EXPR_ABS, Ast_Visitor_Type_Check, v, Ast_Node_Unary, n)
946      Ast_Expr_Type t;
947      n->expr->accept_visitor(n->expr, AST_VISITOR_OF(v));
948      t = v->prev_expr_type;
949
950      switch (t) {
951      case AST_EXPR_TYPE_UNKNOWN:
952         /* Fall through. */
953      case AST_EXPR_TYPE_INT:
954         /* Fall through. */
955      case AST_EXPR_TYPE_CHAR:
956         break;
957      case AST_EXPR_TYPE_BOOL:
958         if (cmdopts.warn_implicit_cast)
959               report_warning_location(
960                     ast_node_get_file_location(AST_NODE_OF(n)),
961                     S( QFY("bool") " operand for " QFY("| |") " operator "
962                        "implicitly casted to " QFY("int") "\n"));
963         break;
964
965      case AST_EXPR_TYPE_VOID:
966         /* Fall through. */
967      case AST_EXPR_TYPE_STRING:
968         /* Fall through. */
969      case AST_EXPR_TYPE_REC:
970         /* Fall through. */
971      case AST_EXPR_TYPE_NULL:
972         v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
973         report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
974               S("invalid " QFY("%S") " expression as " QFY("| |")
```

```
975                  " argument\n"),
976               ast_expr_type_to_string(t));
977          break;
978
979       case AST_EXPR_TYPE_ARY:
980          v->prev_expr_type = AST_EXPR_TYPE_INT;
981          break;
982
983       default:
984          fatal_error(S("unexpected operand for abs operator. Aborting...\n"));
985       }
986
987       ast_expr_unary_set_expr_type(AST_EXPR_UNARY_OF(n), v->prev_expr_type);
988    ASTVF_TC_END(AST_EXPR_ABS, v)
989
990    ASTVF_TC_BEGIN(AST_EXPR_INT, Ast_Visitor_Type_Check, v, Ast_Expr_Int, n)
991       (void)n;
992       v->prev_expr_type = AST_EXPR_TYPE_INT;
993    ASTVF_TC_END(AST_EXPR_INT, v)
994
995    ASTVF_TC_BEGIN(AST_EXPR_BOOL, Ast_Visitor_Type_Check, v, Ast_Expr_Bool, n)
996       (void)n;
997       v->prev_expr_type = AST_EXPR_TYPE_BOOL;
998    ASTVF_TC_END(AST_EXPR_BOOL, v)
999
1000   ASTVF_TC_BEGIN(AST_EXPR_NULL, Ast_Visitor_Type_Check, v, Ast_Expr_Null, n)
1001      (void)n;
1002      v->prev_expr_type = AST_EXPR_TYPE_NULL;
1003   ASTVF_TC_END(AST_EXPR_NULL, v)
1004
1005   static inline bool symbol_var_in_scope(Symbol *tmp_sym UNUSED,
1006         Ast_Node *ast_node UNUSED, Symbol_Table_Node *lookup_node UNUSED)
1007   {
1008      if (!tmp_sym)
1009         return false;
1010      return true;
1011   }
1012
1013   static inline bool type_visitor_record_field_invalid(Ast_Visitor_Type_Check *v,
1014         Symbol_Table_Node *tmp_sym_node)
1015   {
1016      if (v->dot_ref_sym_node)
1017         return false;
1018
1019      if (!v->rec_body_sym_node)
1020         return false;
1021
1022      Symbol_Table_Node_Type tnt = tmp_sym_node->type;
1023      if (v->rec_body_sym_node->scope_id > tmp_sym_node->scope_id &&
1024            (tnt == SYMBOL_TABLE_NODE_REC || tnt == SYMBOL_TABLE_NODE_FUNC))
1025         return true;
1026
1027      return false;
1028   }
1029
1030   static void symbol_property_var_iden_report(Symbol_Table_Node *sym_node,
1031         Symbol *tmp_sym, Ast_Variable_Iden *n, Ast_Visitor_Type_Check *v)
1032   {
1033      Ast_Node *ast_node = AST_NODE_OF(n);
1034
1035      if (symbol_var_in_scope(tmp_sym, ast_node, sym_node)) {
1036         if (type_visitor_record_field_invalid(v, tmp_sym->sym_node)) {
1037
1038            report_error_location(ast_node_get_file_location(ast_node),
1039                  S("record function " QFY("%S")
1040                     " unable to access variable " QFY("%S") "\n"),
1041                  STRING_AFTER_LAST(v->curr_func_iden, '.'), n->iden);
1042
1043            symbol_table_node_insert_unknown_var(v->rec_body_sym_node,
1044                  v->sym_table,
1045                  n->iden,
1046                  ast_node_get_file_location(AST_NODE_OF(n)));
1047            v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1048         } else {
```

```
1049            v->prev_sym_type = tmp_sym->resolved_type;
1050         }
1051
1052      } else {
1053         if (!tmp_sym)
1054            symbol_table_node_insert_unknown_var(sym_node, v->sym_table,
1055                  n->iden, ast_node_get_file_location(ast_node));
1056         else
1057            tmp_sym->resolved_type = symbol_type_unknown_alloc(v->sym_table);
1058         report_error_location(ast_node_get_file_location(ast_node),
1059               S("undeclared %svariable " QFY("%S") "\n"),
1060               v->dot_ref_sym_node ? "record " : "",
1061               n->iden);
1062         v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1063      }
1064   }
1065
1066   static bool type_check_rec_construct_valid_access(Ast_Visitor_Type_Check *v,
1067         Symbol *lookup_sym, File_Location *loc)
1068   {
1069      if (!lookup_sym || !v->rec_body_sym_node || !v->in_beginning_of_ctor)
1070         return true;
1071
1072      if (lookup_sym->sym_node->scope_id == v->rec_body_sym_node->scope_id) {
1073         v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1074         report_error_location(loc,
1075               S("record fields inaccessible before invocation of "
1076                  "constructors\n"));
1077         return false;
1078      }
1079
1080      return true;
1081   }
1082
1083   static void symbol_property_var_iden(Symbol_Table_Node *sym_node,
1084         Ast_Variable_Iden *n, Ast_Visitor_Type_Check *v,
1085         Symbol_Table_Node *dot_ref_node)
1086   {
1087      Symbol *tmp_sym;
1088      if (!dot_ref_node)
1089         tmp_sym = symbol_table_node_lookup_var(sym_node, n->iden,
1090               ast_node_get_file_location(AST_NODE_OF(n)));
1091      else
1092         tmp_sym = symbol_table_node_get(sym_node, n->iden,
1093               string_hash_code(n->iden), SYMBOL_PROPERTY_VAR);
1094
1095      DEBUGT(def,
1096         if (tmp_sym)
1097            assert(tmp_sym->resolved_type->methods->get_type() !=
1098               SYMBOL_TYPE_CYCLE);
1099      );
1100
1101      if (!type_check_rec_construct_valid_access(v, tmp_sym,
1102               ast_node_get_file_location(AST_NODE_OF(n))))
1103         goto out;
1104
1105      symbol_property_var_iden_report(sym_node, tmp_sym, n, v);
1106   out:;
1107   }
1108
1109   /* Will really only insert an unknown type if the symbol was not found.
1110    * This is because the error has been reported by symbol table. */
1111   static void symbol_property_type_def_iden_report(Symbol *tmp_sym,
1112         Ast_Visitor_Type_Check *v)
1113   {
1114      if (tmp_sym)
1115         v->prev_sym_type = tmp_sym->resolved_type;
1116      else
1117         v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1118   }
1119
1120   static void symbol_property_type_def_iden(Symbol_Table_Node *sym_node,
1121         String iden, Ast_Visitor_Type_Check *v)
1122   {
```

```
1123     Symbol *tmp_sym = symbol_table_node_lookup(sym_node, iden,
1124           SYMBOL_PROPERTY_TYPE_DEF);
1125     symbol_property_type_def_iden_report(tmp_sym, v);
1126  }
1127
1128  static void symbol_property_func_iden_report(
1129        Symbol_Table_Node *sym_node,
1130        Symbol_Func_Map *func_map,
1131        Ast_Variable_Iden *n,
1132        Ast_Visitor_Type_Check *v)
1133  {
1134     Ast_Node *ast_node = AST_NODE_OF(n);
1135
1136     if (func_map) {
1137        if (type_visitor_record_field_invalid(v, func_map->sym_node)) {
1138           report_error_location(ast_node_get_file_location(ast_node),
1139                 S("record function " QFY("%S") " unable to access "
1140                    "function " QFY("%S") "\n"),
1141                 STRING_AFTER_LAST(v->curr_func_iden, '.'), n->iden);
1142
1143           symbol_table_node_insert_unknown_func(v->rec_body_sym_node,
1144                 v->sym_table, n->iden,
1145                 ast_node_get_file_location(AST_NODE_OF(n)));
1146           v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1147           v->prev_func_map = NULL;
1148        } else {
1149           v->prev_sym_type = NULL;
1150           v->prev_func_map = func_map;
1151        }
1152     } else {
1153        symbol_table_node_insert_unknown_func(sym_node, v->sym_table,
1154              n->iden, ast_node_get_file_location(ast_node));
1155        report_error_location(ast_node_get_file_location(ast_node),
1156              S("undefined %sfunction " QFY("%S") "\n"),
1157              v->dot_ref_sym_node ? "record " : "",
1158              STRING_AFTER_DOT(n->iden));
1159        v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1160        v->prev_func_map = NULL;
1161     }
1162  }
1163
1164  static void symbol_property_func_iden(Symbol_Table_Node *sym_node,
1165        Ast_Variable_Iden *n, Ast_Visitor_Type_Check *v,
1166        Symbol_Table_Node *dot_ref_node)
1167  {
1168     Symbol_Func_Map *func_map;
1169     if (!dot_ref_node)
1170        func_map = symbol_table_node_lookup_func_map(sym_node, n->iden);
1171     else
1172        func_map = symbol_table_node_get_func_map(sym_node, n->iden,
1173              string_hash_code(n->iden));
1174
1175     if (func_map) {
1176        File_Location *loc = ast_node_get_file_location(AST_NODE_OF(n));
1177        bool maps_ctor = symbol_func_maps_ctor(func_map);
1178        if (!v->in_beginning_of_ctor && maps_ctor && !v->in_allocate_stmt) {
1179           report_error_location(loc,
1180                 S("call to constructor not allowed here\n"));
1181           v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1182           goto out;
1183        } else if (!maps_ctor) {
1184           Symbol *tmp_sym = vector_get(&func_map->overload_idens, 0);
1185           if (!type_check_rec_construct_valid_access(v, tmp_sym, loc))
1186              goto out;
1187        }
1188     }
1189
1190     symbol_property_func_iden_report(sym_node, func_map, n, v);
1191
1192  out:;
1193  }
1194
1195  ASTVF_TC_BEGIN(AST_VARIABLE_IDEN, Ast_Visitor_Type_Check, v,
1196        Ast_Variable_Iden, n)
```

```
1197     Ast_Node *ast_node = AST_NODE_OF(n);
1198
1199     Symbol_Table_Node *sym_node = v->dot_ref_sym_node ? v->dot_ref_sym_node :
1200           ast_node_get_symbol_table_node(ast_node);
1201
1202     DEBUGT(def, v->prev_func_map = NULL);
1203
1204     switch (v->next_property) {
1205     case SYMBOL_PROPERTY_VAR:
1206        symbol_property_var_iden(sym_node, n, v, v->dot_ref_sym_node);
1207        v->prev_variable_sym_type = v->prev_sym_type;
1208        break;
1209
1210     case SYMBOL_PROPERTY_TYPE_DEF:
1211        assert(!v->dot_ref_sym_node);
1212        symbol_property_type_def_iden(sym_node, n->iden, v);
1213        break;
1214
1215     case SYMBOL_PROPERTY_FUNC:
1216        if (!v->next_func_iden_is_decl)
1217           symbol_property_func_iden(sym_node, n, v, v->dot_ref_sym_node);
1218        break;
1219     }
1220
1221     Symbol_Table_Node *ref_node;
1222     if (v->next_property == SYMBOL_PROPERTY_FUNC && v->next_func_iden_is_decl)
1223        ref_node = NULL;
1224     else if (v->dot_ref_sym_node)
1225        ref_node = v->dot_ref_sym_node;
1226     else if (v->rec_body_sym_node)
1227        ref_node = v->rec_body_sym_node;
1228     else
1229        ref_node = NULL;
1230
1231     if (ref_node) {
1232        assert(ref_node->node_rec);
1233        Symbol_Type_Rec_Ambiguous_Ref *r =
1234              symbol_type_rec_get_ambiguous_ref(ref_node->node_rec, n->iden);
1235        if (r) {
1236           STRING(locations, "");
1237           File_Location *loc;
1238           VECTOR_FOR_EACH_ENTRY(&r->sym_locations, loc)
1239              string_append_format(locations, S("\t%F\n"), loc);
1240
1241           if (ref_node->node_rec->rec_name) {
1242              report_error_location(ast_node_get_file_location(ast_node),
1243                    S("referencing field " QFY("%2$S")
1244                       " of record " QFY("%1$S")
1245                       " is ambiguous, " QFY("%2$S")
1246                       " is declared here:\n%3$S"),
1247                    STRING_AFTER_DOT(ref_node->node_rec->rec_name),
1248                    n->iden,
1249                    locations);
1250           } else {
1251              report_error_location(ast_node_get_file_location(ast_node),
1252                    S("referencing field " QFY("%1$S")
1253                       " is ambiguous, " QFY("%1$S")
1254                       " is declared here:\n%2$S"),
1255                    n->iden,
1256                    locations);
1257           }
1258
1259           string_clear(locations);
1260        }
1261     }
1262
1263     v->prev_iden = n->iden;
1264     v->dot_ref_sym_node = NULL;
1265     /* v->lookup_rec = NULL; */
1266     if (v->prev_sym_type) {
1267        assert(!v->prev_func_map);
1268        v->prev_expr_type = symbol_type_to_expr_type(v->prev_sym_type);
1269        ast_variable_iden_set_expr_type(n, v->prev_expr_type);
1270     } else {
```

```
1271        DEBUGT(def,
1272           if (!v->next_func_iden_is_decl)
1273              assert(v->prev_func_map)
1274        );
1275     }
1276  ASTVF_TC_END(AST_VARIABLE_IDEN, v)
1277
1278  ASTVF_BEGIN(AST_REC_SELF_PTR, Ast_Visitor_Type_Check, v, Ast_Empty, n)
1279     if (!v->rec_body_sym_node) {
1280        report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
1281              S("unexpected " QFY("record") " self-reference "
1282                    "outside of record declaration\n"));
1283        v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1284        v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
1285     } else if (v->in_beginning_of_ctor) {
1286        report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
1287              S(QFY("record") " self-reference inaccessible "
1288                    "before invocation of constructors\n"));
1289        v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1290        v->prev_expr_type = AST_EXPR_TYPE_UNKNOWN;
1291     } else {
1292        Symbol *sym = symbol_table_get_from_location(
1293              ast_node_get_symbol_table_node(AST_NODE_OF(n)),
1294              ast_node_get_file_location(AST_NODE_OF(n)));
1295        assert(sym);
1296        v->prev_sym_type = sym->resolved_type;
1297        v->prev_expr_type = symbol_type_to_expr_type(v->prev_sym_type);
1298        if (v->prev_expr_type == AST_EXPR_TYPE_UNKNOWN)
1299           v->prev_variable_sym_type = v->prev_sym_type;
1300        else
1301           v->prev_variable_sym_type = NULL;
1302     }
1303  ASTVF_END
1304
1305  static inline void variable_unexpected_type(Ast_Node *n, Const_String type,
1306        Const_String expected)
1307  {
1308     report_error_location(ast_node_get_file_location(n),
1309           S("expected " QFY("%S")
1310              ", expression evaluates into " QFY("%S") "\n"),
1311           expected, type);
1312  }
1313
1314  ASTVF_TC_BEGIN(AST_EXPR_ARY_REF, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
1315     Symbol_Type_Ary *ary;
1316     Ast_Expr_Type lhs_t;
1317     Symbol_Type_Struct *lhs_s;
1318     n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
1319     lhs_s = v->prev_variable_sym_type;
1320
1321     lhs_t = v->prev_expr_type;
1322     if (lhs_t == AST_EXPR_TYPE_UNKNOWN)
1323        goto out;
1324
1325     if (lhs_t != AST_EXPR_TYPE_ARY && lhs_t != AST_EXPR_TYPE_STRING) {
1326        report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
1327              S("expected " QFY("array") " or " QFY("string")
1328                 " expression before " QFY("[") ","
1329                 " found " QFY("%S") "\n"),
1330              ast_expr_type_to_string(v->prev_expr_type));
1331        v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1332        goto out;
1333     }
1334
1335     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
1336     switch (v->prev_expr_type) {
1337     case AST_EXPR_TYPE_BOOL:
1338        warn_implicit_cast(ast_node_get_file_location(n->rhs),
1339              AST_EXPR_TYPE_BOOL, AST_EXPR_TYPE_INT);
1340        /* Fall through. */
1341     case AST_EXPR_TYPE_INT:
1342        /* Fall through. */
1343     case AST_EXPR_TYPE_CHAR:
1344        switch (lhs_s->methods->get_type()) {
```

```
1345        case SYMBOL_TYPE_STRING:
1346           v->prev_sym_type = symbol_type_char_alloc(v->sym_table);
1347           v->lhs_of_assign_is_string_ref = true;
1348           break;
1349        case SYMBOL_TYPE_FUNC:
1350           lhs_s = SYMBOL_TYPE_STRUCT_CONTAINER(lhs_s,
1351                 Symbol_Type_Func)->return_type;
1352           /* Fall through. */
1353        case SYMBOL_TYPE_ARY:
1354           assert(lhs_s->methods->get_type() == SYMBOL_TYPE_ARY);
1355           ary = SYMBOL_TYPE_STRUCT_CONTAINER(lhs_s, Symbol_Type_Ary);
1356           v->prev_sym_type = ary->ary_type;
1357           break;
1358        default:
1359           assert(false);
1360           break;
1361        }
1362        break;
1363
1364     case AST_EXPR_TYPE_UNKNOWN:
1365        goto out;
1366
1367     default:
1368        report_error_location(ast_node_get_file_location(n->rhs),
1369              S("referencing " QFY("%S") " with " QFY("%S")
1370                 " expression, expected integral expression\n"),
1371              ast_expr_type_to_string(lhs_t),
1372              ast_expr_type_to_string(v->prev_expr_type));
1373        v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1374        goto out;
1375     }
1376
1377  out:
1378     v->prev_expr_type = symbol_type_to_expr_type(v->prev_sym_type);
1379     v->prev_variable_sym_type = v->prev_sym_type;
1380     ast_expr_binary_set_expr_type(AST_EXPR_BINARY_OF(n), v->prev_expr_type);
1381  ASTVF_TC_END(AST_EXPR_ARY_REF, v)
1382
1383  static Int func_call_get_compatibility_score(Vector *arg_struct_expr_pairs,
1384        Vector *param_structs)
1385  {
1386     Symbol_Type_Struct *arg, *param;
1387     Uns num_args = vector_size(param_structs);
1388
1389     if (vector_size(arg_struct_expr_pairs) / 2 != num_args)
1390        return 0;
1391
1392     Uns score = 1;
1393
1394     Uns exact = num_args + 1;
1395     Uns rec_cast = num_args;
1396
1397     for (Uns i = 0; i < num_args; i++) {
1398        arg = vector_get(arg_struct_expr_pairs, i * 2);
1399        param = vector_get(param_structs, i);
1400
1401        Ast_Expr_Type arg_t = PTR_TO_INT(
1402              vector_get(arg_struct_expr_pairs, i * 2 + 1));
1403        Ast_Expr_Type par_t = symbol_type_to_expr_type(param);
1404
1405        Assign_Comatibility_Type assign_t =
1406              types_are_assignment_compatible(param, par_t, arg, arg_t);
1407
1408        switch (assign_t) {
1409        case ASSIGN_COMPATIBILITY_TRUE:
1410           switch (arg_t) {
1411           case AST_EXPR_TYPE_REC:
1412              if (par_t == AST_EXPR_TYPE_NULL ||
1413                    param->methods->same_type(param, arg))
1414                 score += exact;
1415              else
1416                 score += rec_cast;
1417              break;
1418
```

```
1419            case AST_EXPR_TYPE_STRING:
1420               /* Fall through. */
1421            case AST_EXPR_TYPE_ARY:
1422               if (par_t == AST_EXPR_TYPE_NULL) {
1423                  score += exact;
1424                  break;
1425               }
1426               /* Fall through. */
1427            default:
1428               if (par_t == arg_t)
1429                  score += rec_cast;
1430               break;
1431            }
1432            break;
1433
1434         case ASSIGN_COMPATIBILITY_FALSE:
1435            return 0;
1436
1437         case ASSIGN_COMPATIBILITY_AMBIGUOUS:
1438            if (arg_t == par_t && par_t == AST_EXPR_TYPE_REC)
1439               score += rec_cast;
1440            break;
1441
1442         case ASSIGN_COMPATIBILITY_IMPLICIT:
1443            break;
1444         }
1445      }
1446
1447      return score;
1448   }
1449
1450   // Return score of best match
1451   static Uns func_call_append_best_match(Vector *func_symbols,
1452         Vector *arg_struct_expr_pairs, Vector *result)
1453   {
1454      Uns current_score = 0;
1455
1456      Symbol *fsym;
1457      VECTOR_FOR_EACH_ENTRY(func_symbols, fsym) {
1458         Symbol_Type func_symbol_type =
1459               fsym->resolved_type->methods->get_type();
1460         assert(func_symbol_type == SYMBOL_TYPE_FUNC ||
1461            func_symbol_type == SYMBOL_TYPE_UNKNOWN);
1462
1463         if (func_symbol_type == SYMBOL_TYPE_UNKNOWN) {
1464            vector_clear(result);
1465            current_score = UNSIGNED_MAX;
1466            goto out;
1467         }
1468
1469         Symbol_Type_Func *func = SYMBOL_TYPE_STRUCT_CONTAINER(
1470               fsym->resolved_type, Symbol_Type_Func);
1471         Vector *params = &func->param_types;
1472
1473         Uns score =
1474            func_call_get_compatibility_score(arg_struct_expr_pairs, params);
1475
1476         if (score) {
1477            if (score > current_score) {
1478               vector_clear(result);
1479               vector_append(result, fsym);
1480               current_score = score;
1481            } else if (score == current_score) {
1482               vector_append(result, fsym);
1483            }
1484         }
1485      }
1486
1487   out:
1488      return current_score;
1489   }
1490
1491   static Vector *func_call_get_best_match(Ast_Visitor_Type_Check *v,
1492         Symbol_Func_Map *curr_map, Vector *arg_struct_expr_pairs)
```

```
1493 {
1494    extern void symbol_func_map_compare(Symbol_Func_Map *func_map,
1495          Symbol_Table *t);
1496
1497    Vector *ret = vector_alloc();
1498    VECTOR(tmp);
1499
1500    VECTOR(func_symbols);
1501
1502    Uns best_score = 0;
1503
1504    do {
1505       symbol_func_map_compare(curr_map, v->sym_table);
1506
1507       Symbol *fsym = NULL;
1508       VECTOR_FOR_EACH_ENTRY(&curr_map->overload_idens, fsym)
1509          vector_append(&func_symbols, fsym);
1510
1511       Uns score = func_call_append_best_match(&func_symbols,
1512             arg_struct_expr_pairs, &tmp);
1513       vector_clear(&func_symbols);
1514
1515       if (score == UNSIGNED_MAX) {
1516          vector_destroy(ret, NULL);
1517          ret = NULL;
1518          break;
1519       }
1520
1521       if (score > best_score) {
1522          best_score = score;
1523          vector_clear(ret);
1524          VECTOR_FOR_EACH_ENTRY(&tmp, fsym)
1525             vector_append(ret, fsym);
1526       }
1527
1528       Symbol *sym = vector_get(&curr_map->overload_idens, 0);
1529       assert(sym->resolved_type->methods->get_type() == SYMBOL_TYPE_FUNC);
1530
1531       Symbol_Type_Func *func = SYMBOL_TYPE_STRUCT_CONTAINER(
1532             sym->resolved_type, Symbol_Type_Func);
1533       Symbol_Table_Node *real_parent = func->body_sym_node->parent;
1534       while (real_parent && real_parent->type == SYMBOL_TABLE_NODE_IMPORT)
1535          real_parent = real_parent->parent;
1536       Symbol_Table_Node *next_node;
1537       if(real_parent)
1538          next_node = real_parent->parent;
1539       else
1540          next_node = func->body_sym_node->parent->parent;
1541
1542       if (next_node)
1543          curr_map = symbol_table_node_lookup_func_map(next_node,
1544                curr_map->func_iden);
1545       else
1546          curr_map = NULL;
1547
1548       vector_clear(&tmp);
1549    } while (curr_map);
1550
1551    vector_clear(&tmp);
1552
1553    return ret;
1554 }
1555
1556 ASTVF_TC_BEGIN(AST_EXPR_FUNC_CALL, Ast_Visitor_Type_Check, v,
1557       Ast_Expr_Func_Call, n)
1558    Uns num_args;
1559    Symbol_Type_Struct *tmp_type;
1560    Ast_Node *arg;
1561    String func_iden;
1562    Symbol_Type_Func *func = NULL;
1563
1564    Symbol_Property saved_property = v->next_property;
1565    v->next_property = SYMBOL_PROPERTY_FUNC;
1566    n->identifier->accept_visitor(n->identifier, AST_VISITOR_OF(v));
```

```
1567     v->next_property = saved_property;
1568     func_iden = v->prev_iden;
1569
1570     Vector *sym_results = NULL;
1571     VECTOR(arg_struct_expr_pairs);
1572     VECTOR(arg_locations);
1573
1574     if (v->prev_sym_type) {
1575        assert(v->prev_expr_type == AST_EXPR_TYPE_UNKNOWN);
1576        goto out;
1577     }
1578     assert(v->prev_func_map);
1579     Symbol_Func_Map *func_map = v->prev_func_map;
1580
1581     bool args_are_valid = true;
1582     VECTOR_FOR_EACH_ENTRY(n->arguments, arg) {
1583        arg->accept_visitor(arg, AST_VISITOR_OF(v));
1584        if (v->prev_expr_type == AST_EXPR_TYPE_VOID) {
1585           args_are_valid = false;
1586           report_error_location(ast_node_get_file_location(arg),
1587                 S("invalid " QFY("void") " function argument\n"));
1588        }
1589        if (v->prev_expr_type == AST_EXPR_TYPE_UNKNOWN) {
1590           v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1591           goto out;
1592        }
1593        vector_append(&arg_struct_expr_pairs, v->prev_sym_type);
1594        vector_append(&arg_struct_expr_pairs, INT_TO_PTR(v->prev_expr_type));
1595        vector_append(&arg_locations, ast_node_get_file_location(arg));
1596     }
1597
1598     if (args_are_valid)
1599        sym_results =
1600           func_call_get_best_match(v, func_map, &arg_struct_expr_pairs);
1601
1602     if (!sym_results) {
1603        v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1604        goto out;
1605     }
1606
1607     Symbol *fsym = vector_is_empty(sym_results) ?
1608           NULL : vector_get(sym_results, 0);
1609
1610     switch (vector_size(sym_results)) {
1611     case 0:
1612        report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
1613              S("unable to locate function " QFY("%S")
1614                 " with parameter list that matches arguments\n"),
1615              func_iden);
1616        v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1617        goto out;
1618     case 1:
1619        break;
1620     default:;
1621
1622        bool all_extern_c = true;
1623        Symbol *tmp_sym;
1624        VECTOR_FOR_EACH_ENTRY(sym_results, tmp_sym) {
1625           Symbol_Type_Func *tmp_func = SYMBOL_TYPE_STRUCT_CONTAINER(
1626                 tmp_sym->resolved_type, Symbol_Type_Func);
1627           if (!tmp_func->is_extern_c) {
1628              all_extern_c = false;
1629              break;
1630           }
1631        }
1632        if (all_extern_c)
1633           break;
1634
1635        STRING(loc, "");
1636        if (symbol_get_symbol_table_node_type(fsym) ==
1637              SYMBOL_TABLE_NODE_IMPORT) {
1638
1639           VECTOR(imp_modules);
1640           VECTOR_FOR_EACH_ENTRY(sym_results, fsym) {
```

```
1641              String tmp = string_between_alloc(fsym->unique_name, '.');
1642              if (vector_contains(&imp_modules,
1643                        (Vector_Comparator)string_compare, tmp)) {
1644                 string_destroy(tmp);
1645              } else {
1646                 string_append_format(loc, S("\t%S\n"), tmp);
1647                 vector_append(&imp_modules, tmp);
1648              }
1649           }
1650           vector_for_each_destroy(&imp_modules,
1651                 (Vector_Destructor)string_destroy);
1652
1653           report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
1654                 S("call of function " QFY("%1$S") " is ambiguous"
1655                    ", equally matching declarations imported from:\n%2$S"),
1656                 func_iden, loc);
1657        } else {
1658
1659           int num_unique = 0;
1660           VECTOR(func_locations);
1661           VECTOR_FOR_EACH_ENTRY(sym_results, fsym) {
1662              String tmp = fsym->unique_name;
1663              if (vector_contains(&func_locations,
1664                        (Vector_Comparator)string_compare, tmp)) {
1665              } else {
1666                 ++num_unique;
1667                 string_append_format(loc, S("\t%F\n"), fsym->location);
1668                 vector_append(&func_locations, tmp);
1669              }
1670           }
1671           vector_clear(&func_locations);
1672
1673  #if 0
1674           VECTOR_FOR_EACH_ENTRY(sym_results, fsym)
1675              string_append_format(loc, S("\t%F\n"), fsym->location);
1676  #endif
1677
1678           report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
1679                 S("call of function " QFY("%S") " is ambiguous"
1680                    ", equally matching declarations located here:\n%S"),
1681                 func_iden, loc);
1682        }
1683        string_clear(loc);
1684        v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1685        goto out;
1686     }
1687
1688     func = SYMBOL_TYPE_STRUCT_CONTAINER(fsym->resolved_type, Symbol_Type_Func);
1689
1690     num_args = vector_size(&func->param_types);
1691     assert(vector_size(&arg_struct_expr_pairs) / 2 == num_args);
1692
1693     for (Uns i = 0; i < num_args; i++) {
1694        Symbol_Type_Struct *arg_struct = vector_get(
1695              &arg_struct_expr_pairs, i * 2);
1696        tmp_type = vector_get(&func->param_types, i);
1697
1698        Ast_Expr_Type par_t = symbol_type_to_expr_type(tmp_type);
1699        Ast_Expr_Type arg_t = PTR_TO_INT(
1700              vector_get(&arg_struct_expr_pairs, i * 2 + 1));
1701        Assign_Comatibility_Type assign_t =
1702              types_are_assignment_compatible(tmp_type, par_t,
1703                    arg_struct, arg_t);
1704
1705        switch (assign_t) {
1706        case ASSIGN_COMPATIBILITY_TRUE:
1707           break;
1708
1709        case ASSIGN_COMPATIBILITY_FALSE:
1710           assert(false);
1711           break;
1712
1713        case ASSIGN_COMPATIBILITY_AMBIGUOUS:
1714           report_error_location(
```

```
1715                 vector_get(&arg_locations, i),
1716                 S("passing argument %U to function " QFY("%S")
1717                    " is ambiguous, record is extending multiple "
1718                    "records with the required structure\n"),
1719                 i + 1, func_iden);
1720           v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1721           goto out;
1722
1723        case ASSIGN_COMPATIBILITY_IMPLICIT:
1724           /* Implicit cast from par_t to arg_t. */
1725           warn_implicit_cast(vector_get(&arg_locations, i), arg_t, par_t);
1726           break;
1727        }
1728     }
1729     Ast_Variable_Iden *iden_node =
1730           AST_CONTAINER_OF(n->identifier, Ast_Variable_Iden);
1731     string_destroy(iden_node->iden);
1732     iden_node->iden = string_duplicate(fsym->identifier);
1733     func_iden = fsym->identifier;
1734
1735     n->func = func;
1736     v->prev_sym_type = func->return_type;
1737  out:
1738     v->prev_expr_type = symbol_type_to_expr_type(v->prev_sym_type);
1739     v->prev_func_call_iden = func_iden;
1740
1741     if (v->prev_expr_type != AST_EXPR_TYPE_UNKNOWN)
1742        v->prev_variable_sym_type = symbol_table_node_lookup(
1743              func->body_sym_node->parent,
1744              func_iden,
1745              SYMBOL_PROPERTY_FUNC)->resolved_type;
1746
1747     vector_clear(&arg_locations);
1748     vector_clear(&arg_struct_expr_pairs);
1749     if (sym_results)
1750        vector_destroy(sym_results, NULL);
1751
1752     ast_expr_func_call_set_expr_type(n, v->prev_expr_type);
1753  ASTVF_TC_END(AST_EXPR_FUNC_CALL, v)
1754
1755
1756  ASTVF_TC_BEGIN(AST_EXPR_DOT_REF, Ast_Visitor_Type_Check, v,
1757        Ast_Node_Binary, n)
1758     Symbol_Type_Rec *rec;
1759     n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
1760     if (v->prev_expr_type == AST_EXPR_TYPE_UNKNOWN)
1761        goto out;
1762
1763     if (v->prev_expr_type != AST_EXPR_TYPE_REC) {
1764        variable_unexpected_type(AST_NODE_OF(n),
1765              ast_expr_type_to_string(v->prev_expr_type), S("record"));
1766        v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1767        goto out;
1768     }
1769
1770     rec = SYMBOL_TYPE_STRUCT_CONTAINER(v->prev_sym_type, Symbol_Type_Rec);
1771
1772     /* v->lookup_rec = rec; */
1773     v->dot_ref_sym_node = rec->rec_sym_node;
1774     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
1775
1776  out:
1777     v->prev_expr_type = symbol_type_to_expr_type(v->prev_sym_type);
1778     ast_expr_binary_set_expr_type(AST_EXPR_BINARY_OF(n), v->prev_expr_type);
1779  ASTVF_TC_END(AST_EXPR_DOT_REF, v)
1780
1781  /* Defined in symbol table. */
1782  bool ___type_def_symbol_types_equal(Symbol_Type_Struct *lhs,
1783        Symbol_Type_Struct *rhs);
1784
1785  static bool type_check_rec_extends(Symbol_Type_Rec *rec,
1786        Symbol_Type_Struct *base)
1787  {
1788     Symbol_Type_Struct *ext;
```

```
1789     VECTOR_FOR_EACH_ENTRY(&rec->extended_types, ext) {
1790        if (___type_def_symbol_types_equal(ext, base))
1791           return true;
1792     }
1793     return false;
1794  }
1795
1796  ASTVF_TC_BEGIN(AST_EXPR_DIRECT_REF, Ast_Visitor_Type_Check, v,
1797        Ast_Node_Binary, n)
1798     Symbol_Type_Struct *ref_rec_result =
1799           symbol_type_unknown_alloc(v->sym_table);
1800     Symbol_Type_Struct *ref_func_result =
1801           symbol_type_unknown_alloc(v->sym_table);
1802
1803     Symbol_Type_Rec *ref_rec;
1804     Symbol_Type_Rec *curr_rec;
1805
1806     if (!v->rec_body_sym_node) {
1807        report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
1808              S("direct record reference outside record scope\n"));
1809        v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1810        goto out;
1811     }
1812     curr_rec = v->rec_body_sym_node->node_rec;
1813     assert(curr_rec);
1814
1815     if (n->lhs) {
1816        n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
1817        if (v->prev_expr_type == AST_EXPR_TYPE_UNKNOWN)
1818           goto out;
1819
1820        if (v->prev_expr_type != AST_EXPR_TYPE_REC) {
1821           report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
1822                 S("expected type " QFY("record")
1823                    ", found type " QFY("%S") "\n"),
1824                 ast_expr_type_to_string(v->prev_expr_type));
1825           v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1826           goto out;
1827        }
1828
1829        ref_rec = SYMBOL_TYPE_STRUCT_CONTAINER(v->prev_sym_type, Symbol_Type_Rec);
1830     } else {
1831        ref_rec = v->rec_body_sym_node->node_rec;
1832     }
1833
1834     Symbol_Type_Struct *ref_struct =
1835        SYMBOL_TYPE_STRUCT_OF_CONTAINER(ref_rec);
1836     Symbol_Type_Struct *curr_struct =
1837        SYMBOL_TYPE_STRUCT_OF_CONTAINER(curr_rec);
1838
1839     bool compatible;
1840     if (ref_struct->methods->same_type(ref_struct, curr_struct))
1841        compatible = ___type_def_symbol_types_equal(ref_struct,
1842              curr_struct);
1843     else
1844        compatible = type_check_rec_extends(
1845              curr_rec, ref_struct);
1846
1847     if (!compatible) {
1848        String ref_str;
1849        if (ref_rec->rec_name)
1850           ref_str = string_from_format(S("record " QFY("%S")),
1851                 STRING_AFTER_DOT(ref_rec->rec_name));
1852        else
1853           ref_str = string_alloc(S("the given record type"));
1854
1855        String curr_str;
1856        if (curr_rec->rec_name)
1857           curr_str = string_from_format(S("record " QFY("%S")),
1858                 STRING_AFTER_DOT(curr_rec->rec_name));
1859        else
1860           curr_str = string_alloc(S("current record"));
1861
1862        report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
```

```
1863                S("%S cannot directly reference %S\n"),
1864                curr_str, ref_str);
1865          string_destroy(curr_str);
1866          string_destroy(ref_str);
1867          v->prev_sym_type = symbol_type_unknown_alloc(v->sym_table);
1868          goto out;
1869       }
1870
1871       bool in_ctor_list = v->in_beginning_of_ctor;
1872       if (n->rhs->accept_visitor ==
1873             AST_NODE_ACCEPT_VISITOR_FUNC(AST_EXPR_FUNC_CALL)) {
1874          Ast_Expr_Func_Call *call =
1875                AST_CONTAINER_OF(n->rhs, Ast_Expr_Func_Call);
1876          Ast_Variable_Iden *iden = AST_CONTAINER_OF(call->identifier,
1877                Ast_Variable_Iden);
1878          if (!string_is_ctor(iden->iden))
1879             v->in_beginning_of_ctor = false;
1880       } else {
1881          v->in_beginning_of_ctor = false;
1882       }
1883
1884       /* v->lookup_rec = ref_rec; */
1885       v->dot_ref_sym_node = ref_rec->rec_sym_node;
1886       n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
1887
1888       v->in_beginning_of_ctor = in_ctor_list;
1889
1890       if (n->rhs->accept_visitor ==
1891             AST_NODE_ACCEPT_VISITOR_FUNC(AST_EXPR_FUNC_CALL)) {
1892          Ast_Expr_Func_Call *fnode =
1893             AST_CONTAINER_OF(n->rhs, Ast_Expr_Func_Call);
1894          Symbol_Type_Func *func = fnode->func;
1895          if (func)
1896             ref_func_result = SYMBOL_TYPE_STRUCT_OF_CONTAINER(func);
1897       }
1898       ref_rec_result = SYMBOL_TYPE_STRUCT_OF_CONTAINER(ref_rec);
1899
1900    out:
1901       v->prev_direct_ref_rec = ref_rec_result;
1902       v->prev_direct_ref_func = ref_func_result;
1903       v->prev_expr_type = symbol_type_to_expr_type(v->prev_sym_type);
1904       ast_expr_binary_set_expr_type(AST_EXPR_BINARY_OF(n), v->prev_expr_type);
1905    ASTVF_TC_END(AST_EXPR_DIRECT_REF, v)
1906
1907    ASTVF_TC_BEGIN(AST_SIMPLE_TYPE_INT, Ast_Visitor_Type_Check, v, Ast_Empty, n)
1908       (void)n;
1909       v->prev_expr_type = AST_EXPR_TYPE_INT;
1910    ASTVF_TC_END(AST_SIMPLE_TYPE_INT, v)
1911
1912    ASTVF_TC_BEGIN(AST_SIMPLE_TYPE_BOOL, Ast_Visitor_Type_Check, v, Ast_Empty, n)
1913       (void)n;
1914       v->prev_expr_type = AST_EXPR_TYPE_BOOL;
1915    ASTVF_TC_END(AST_SIMPLE_TYPE_BOOL, v)
1916
1917    ASTVF_TC_BEGIN(AST_TYPE_IDEN, Ast_Visitor_Type_Check, v, Ast_Type_Iden, n)
1918       Ast_Node *ast_node = AST_NODE_OF(n);
1919
1920       Symbol_Table_Node *sym_node = ast_node_get_symbol_table_node(ast_node);
1921
1922       symbol_property_type_def_iden(sym_node, n->iden, v);
1923
1924       v->prev_iden = n->iden;
1925       v->prev_expr_type = symbol_type_to_expr_type(v->prev_sym_type);
1926    ASTVF_TC_END(AST_TYPE_IDEN, v)
1927
1928    ASTVF_TC_BEGIN(AST_VAR_DECL, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
1929       Symbol_Property saved_property = v->next_property;
1930       v->next_property = SYMBOL_PROPERTY_VAR;
1931       DEBUGT(def, v->prev_iden = NULL);
1932       n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
1933       assert(v->prev_iden);
1934       String iden = v->prev_iden;
1935       v->next_property = saved_property;
1936       /* Identifiers should be resolved.
```

```
1937        * So no need to modify v->prev_property. */
1938       n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
1939       v->prev_var_decl_iden = iden;
1940    ASTVF_TC_END(AST_VAR_DECL, v)
1941
1942    ASTVF_TC_BEGIN(AST_TYPE_DEF, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
1943       Symbol_Property saved_property = v->next_property;
1944       v->next_property = SYMBOL_PROPERTY_TYPE_DEF;
1945       n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
1946       v->next_property = saved_property;
1947       /* Identifiers should be resolved.
1948        * So no need to modify v->prev_property. */
1949       n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
1950    ASTVF_TC_END(AST_TYPE_DEF, v)
1951
1952    ASTVF_TC_BEGIN(AST_TYPE_ARY, Ast_Visitor_Type_Check, v, Ast_Type, n)
1953       n->type->accept_visitor(n->type, AST_VISITOR_OF(v));
1954       v->prev_expr_type = AST_EXPR_TYPE_ARY;
1955    ASTVF_TC_END(AST_TYPE_ARY, v)
1956
1957    static void type_check_rec_default_constructor(Symbol_Type_Rec *rec,
1958          File_Location *loc);
1959
1960    ASTVF_TC_BEGIN(AST_TYPE_REC, Ast_Visitor_Type_Check, v, Ast_Type_Rec, n)
1961       Symbol_Table_Node *prev_body_node;
1962       Ast_Node *arg;
1963       Vector *vargs = n->extend_list;
1964       VECTOR_FOR_EACH_ENTRY(vargs, arg)
1965          arg->accept_visitor(arg, AST_VISITOR_OF(v));
1966
1967       type_check_rec_default_constructor(n->body_node->node_rec,
1968             ast_node_get_file_location(AST_NODE_OF(n)));
1969
1970       vargs = n->body;
1971       if (!vector_is_empty(vargs)) {
1972          prev_body_node = v->rec_body_sym_node;
1973
1974          arg = vector_get(vargs, 0);
1975          v->rec_body_sym_node = ast_node_get_symbol_table_node(arg);
1976          type_check_rec_default_constructor(v->rec_body_sym_node->node_rec,
1977                ast_node_get_file_location(AST_NODE_OF(n)));
1978
1979          arg->accept_visitor(arg, AST_VISITOR_OF(v));
1980
1981          for (Uns i = 1; i < vector_size(vargs); i++) {
1982             arg = vector_get(vargs, i);
1983             arg->accept_visitor(arg, AST_VISITOR_OF(v));
1984          }
1985
1986          v->rec_body_sym_node = prev_body_node;
1987       }
1988
1989       v->prev_expr_type = AST_EXPR_TYPE_REC;
1990    ASTVF_TC_END(AST_TYPE_REC, v)
1991
1992    static void stmt_list_action(Ast_Visitor_Type_Check *v, Ast_Stmt_List *n)
1993    {
1994       ++v->stmt_list_nest;
1995       Ast_Node *stmt;
1996       Vector *statements = n->statements;
1997       VECTOR_FOR_EACH_ENTRY(statements, stmt)
1998          stmt->accept_visitor(stmt, AST_VISITOR_OF(v));
1999       --v->stmt_list_nest;
2000    }
2001
2002    ASTVF_TC_BEGIN(AST_STMT_LIST, Ast_Visitor_Type_Check, v, Ast_Stmt_List, n)
2003       stmt_list_action(v, n);
2004    ASTVF_TC_END(AST_STMT_LIST, v)
2005
2006    ASTVF_TC_BEGIN(AST_FIN_STMT_LIST, Ast_Visitor_Type_Check, v, Ast_Stmt_List, n)
2007       if (v->stmt_list_nest > 1) {
2008          report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
2009                S(QFY("finalize") " statement only valid in "
2010                   "outermost scope\n"));
```

```
2011     }
2012     stmt_list_action(v, n);
2013  ASTVF_TC_END(AST_STMT_LIST, v)
2014
2015  static void func_type_check(Ast_Visitor_Type_Check *v, Ast_Func_Def *n,
2016        Symbol_Table_Node *rec_body_sym_node, Type_Check_Func_Type tt_ftype)
2017  {
2018     Ast_Node *p;
2019     Symbol_Type_Struct *saved_return_sym;
2020     Ast_Expr_Type saved_return_type;
2021     String func_iden;
2022     String prev_func_iden;
2023
2024     Type_Check_Func_Type saved_func_type = v->current_func_type;
2025     v->current_func_type = tt_ftype;
2026
2027     Vector *vec = n->parameters;
2028
2029     Symbol_Property saved_property = v->next_property;
2030     v->next_property = SYMBOL_PROPERTY_FUNC;
2031     v->next_func_iden_is_decl = true;
2032     n->iden->accept_visitor(n->iden, AST_VISITOR_OF(v));
2033     v->next_func_iden_is_decl = false;
2034     func_iden = v->prev_iden;
2035     v->next_property = saved_property;
2036
2037     n->return_type->accept_visitor(n->return_type, AST_VISITOR_OF(v));
2038
2039     Symbol *sym = symbol_table_node_get(
2040           ast_node_get_symbol_table_node(AST_NODE_OF(n)),
2041           func_iden,
2042           string_hash_code(func_iden),
2043           SYMBOL_PROPERTY_FUNC);
2044     assert(sym);
2045     Symbol_Type_Func *func = SYMBOL_TYPE_STRUCT_CONTAINER(
2046           sym->resolved_type, Symbol_Type_Func);
2047
2048     if (tt_ftype == TT_FUNC_TYPE_FINALIZE) {
2049        if (v->prev_expr_type != AST_EXPR_TYPE_VOID &&
2050              v->prev_expr_type != AST_EXPR_TYPE_UNKNOWN) {
2051           report_error_location(ast_node_get_file_location(n->return_type),
2052                 S(QFY("finalize") " function expected to have " QFY("void")
2053                    " return type, found " QFY("%S") "\n"),
2054                 ast_expr_type_to_string(v->prev_expr_type));
2055        }
2056        if (rec_body_sym_node->finalize_func_count == 1) {
2057           report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
2058                 S("multiple definitions of " QFY("finalize")
2059                    " function inside record\n"));
2060        }
2061        ++rec_body_sym_node->finalize_func_count;
2062     } else if (tt_ftype == TT_FUNC_TYPE_RECORD) {
2063        if (v->prev_expr_type != AST_EXPR_TYPE_VOID &&
2064              v->prev_expr_type != AST_EXPR_TYPE_UNKNOWN) {
2065           report_error_location(ast_node_get_file_location(n->return_type),
2066                 S(QFY("record") " function expected to have " QFY("void")
2067                    " return type, found " QFY("%S") "\n"),
2068                 ast_expr_type_to_string(v->prev_expr_type));
2069        }
2070     }
2071
2072     bool func_is_main = false;
2073     if (!rec_body_sym_node && !string_compare(func_iden, MAIN_FUNC_STR)) {
2074        if (vector_size(vec) > 1 && !func->main_param_err_reported) {
2075           report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
2076                 S(QFY(MAIN_FUNC_CSTR) " function expected to have at "
2077                    "most one parameter, " QFY("array of string") "\n"));
2078           func->main_param_err_reported = true;
2079        }
2080        func_is_main = true;
2081     }
2082
2083     saved_return_sym = v->func_return_sym;
2084     saved_return_type = v->func_return_type;
```

```
2085
2086        if (sym->resolved_type->methods->get_type() == SYMBOL_TYPE_UNKNOWN) {
2087           v->func_return_sym = symbol_type_unknown_alloc(v->sym_table);
2088           v->func_return_type = AST_EXPR_TYPE_UNKNOWN;
2089        } else {
2090           if (func_is_main &&
2091                 func->return_type->methods->get_type() != SYMBOL_TYPE_INT) {
2092              if (!func->main_err_int_reported) {
2093                 report_error_location(
2094                       ast_node_get_file_location(AST_NODE_OF(n)),
2095                       S(QFY(MAIN_FUNC_CSTR) " function must have "
2096                          QFY("int") " return type\n"));
2097                 func->main_err_int_reported = true;
2098              }
2099           }
2100
2101           v->func_return_sym = SYMBOL_TYPE_STRUCT_CONTAINER(sym->resolved_type,
2102                 Symbol_Type_Func)->return_type;
2103           v->func_return_type = symbol_type_to_expr_type(v->func_return_sym);
2104
2105           if (func_is_main && vector_size(vec)) {
2106              p = vector_get(vec, 0);
2107              p->accept_visitor(p, AST_VISITOR_OF(v));
2108
2109              Symbol_Type_Ary *ary;
2110              Symbol *par_sym = symbol_table_node_get(
2111                    func->body_sym_node,
2112                    v->prev_var_decl_iden,
2113                    string_hash_code(v->prev_var_decl_iden),
2114                    SYMBOL_PROPERTY_VAR);
2115              /* This might be so if there are multiple
2116               * definitions of main in the same scope. */
2117              if (par_sym) {
2118                 ary = SYMBOL_TYPE_STRUCT_CONTAINER(par_sym->resolved_type,
2119                       Symbol_Type_Ary);
2120                 if ((v->prev_expr_type != AST_EXPR_TYPE_ARY ||
2121                       ary->ary_type->methods->get_type() !=
2122                       SYMBOL_TYPE_STRING) &&
2123                       !func->main_param_err_reported) {
2124                    report_error_location(ast_node_get_file_location(p),
2125                          S(QFY(MAIN_FUNC_CSTR) " function expected to have "
2126                                QFY("array of string") " parameter\n"));
2127                    func->main_param_err_reported = true;
2128                 }
2129              }
2130           } else {
2131              VECTOR_FOR_EACH_ENTRY(vec, p)
2132                 p->accept_visitor(p, AST_VISITOR_OF(v));
2133           }
2134
2135           if (n->statements) {
2136              prev_func_iden = v->curr_func_iden;
2137              v->curr_func_iden = func_iden;
2138              n->statements->accept_visitor(n->statements, AST_VISITOR_OF(v));
2139              v->curr_func_iden = prev_func_iden;
2140           }
2141
2142           v->func_return_sym = saved_return_sym;
2143           v->func_return_type = saved_return_type;
2144        }
2145        v->current_func_type = saved_func_type;
2146     }
2147
2148     ASTVF_BEGIN(AST_EXT_FUNC_DECL, Ast_Visitor_Type_Check, v, Ast_Func_Def, n)
2149        func_type_check(v, n, NULL, TT_FUNC_TYPE_NORMAL);
2150     ASTVF_END
2151
2152     ASTVF_TC_BEGIN(AST_FIN_FUNC_DEF, Ast_Visitor_Type_Check, v, Ast_Func_Def, n)
2153        Symbol_Table_Node *rec_sym_node = v->rec_body_sym_node;
2154        Type_Check_Func_Type tt;
2155        if (!rec_sym_node) {
2156           tt = TT_FUNC_TYPE_NORMAL;
2157           report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
2158                 S("definition of " QFY("finalize")
```

```
2159                " function outside record scope\n"));
2160    } else if (ast_node_get_symbol_table_node(AST_NODE_OF(n))->scope_id !=
2161          rec_sym_node->scope_id) {
2162       tt = TT_FUNC_TYPE_NORMAL;
2163       report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
2164             S("nested " QFY("finalize") " function definition\n"));
2165    } else {
2166       tt = TT_FUNC_TYPE_FINALIZE;
2167       if (!vector_is_empty(n->parameters)) {
2168          report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
2169                S(QFY("finalize")
2170                   " function expected to have empty parameter list\n"));
2171       }
2172    }
2173    func_type_check(v, n, rec_sym_node, tt);
2174 ASTVF_TC_END(AST_FIN_FUNC_DEF, v)
2175
2176 ASTVF_TC_BEGIN(AST_REC_FUNC_DEF, Ast_Visitor_Type_Check, v, Ast_Func_Def, n)
2177    Symbol_Table_Node *rec_sym_node = v->rec_body_sym_node;
2178    Type_Check_Func_Type tt;
2179    if (!rec_sym_node) {
2180       tt = TT_FUNC_TYPE_NORMAL;
2181       report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
2182             S("definition of " QFY("record")
2183                " function outside record scope\n"));
2184    } else if (ast_node_get_symbol_table_node(AST_NODE_OF(n))->scope_id !=
2185          rec_sym_node->scope_id) {
2186       tt = TT_FUNC_TYPE_NORMAL;
2187       report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
2188             S("nested definition of function " QFY("record") "\n"));
2189    } else {
2190       tt = TT_FUNC_TYPE_RECORD;
2191    }
2192    func_type_check(v, n, rec_sym_node, tt);
2193 ASTVF_TC_END(AST_REC_FUNC_DEF, v)
2194
2195 ASTVF_TC_BEGIN(AST_FUNC_DEF, Ast_Visitor_Type_Check, v, Ast_Func_Def, n)
2196    func_type_check(v, n, NULL, TT_FUNC_TYPE_NORMAL);
2197 ASTVF_TC_END(AST_FUNC_DEF, v)
2198
2199 static void stmt_expr_error_report(Ast_Expr_Type expr_type,
2200       const char *stmt_name, Ast_Node *stmt_node)
2201 {
2202    if (expr_type == AST_EXPR_TYPE_VOID) {
2203       report_error_location(ast_node_get_file_location(stmt_node),
2204             S("invalid " QFY("void") " type in "
2205                QFY("%s") "-expression\n"),
2206             stmt_name);
2207    } else if (expr_type != AST_EXPR_TYPE_BOOL &&
2208          expr_type != AST_EXPR_TYPE_UNKNOWN) {
2209       warn_implicit_expr_cast(stmt_node, expr_type,
2210             AST_EXPR_TYPE_BOOL, "if");
2211    }
2212 }
2213
2214 ASTVF_TC_BEGIN(AST_IF_STMT, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
2215    n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
2216    stmt_expr_error_report(v->prev_expr_type, "if", AST_NODE_OF(n));
2217    n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
2218 ASTVF_TC_END(AST_IF_STMT, v)
2219
2220 ASTVF_TC_BEGIN(AST_IF_ELSE_STMT, Ast_Visitor_Type_Check, v,
2221       Ast_Node_Ternary, n)
2222    n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
2223    stmt_expr_error_report(v->prev_expr_type, "if", AST_NODE_OF(n));
2224    n->mid->accept_visitor(n->mid, AST_VISITOR_OF(v));
2225    n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
2226 ASTVF_TC_END(AST_IF_ELSE_STMT, v)
2227
2228 ASTVF_TC_BEGIN(AST_ALLOC_ARY, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
2229    n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
2230    switch (v->prev_expr_type) {
2231    case AST_EXPR_TYPE_UNKNOWN:
2232       /* Fall through. */
```

```
2233     case AST_EXPR_TYPE_ARY:
2234        if (v->prev_variable_sym_type->methods->get_type() ==
2235                  SYMBOL_TYPE_FUNC) {
2236           report_error_location(ast_node_get_file_location(n->lhs),
2237              S("invalid " QFY("allocate") " of function result,"
2238                 " expected variable of type " QFY("array") "\n"));
2239        }
2240        break;
2241
2242     default:
2243        report_error_location(ast_node_get_file_location(n->lhs),
2244              S("expected variable of type " QFY("array")
2245                 ", found " QFY("%S") "\n"),
2246              ast_expr_type_to_string(v->prev_expr_type));
2247        break;
2248     }
2249
2250     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
2251     switch (v->prev_expr_type) {
2252     case AST_EXPR_TYPE_UNKNOWN:
2253        /* Fall through. */
2254     case AST_EXPR_TYPE_INT:
2255        /* Fall through. */
2256     case AST_EXPR_TYPE_CHAR:
2257        break;
2258     case AST_EXPR_TYPE_BOOL:
2259        warn_implicit_cast(ast_node_get_file_location(n->rhs),
2260              AST_EXPR_TYPE_BOOL, AST_EXPR_TYPE_INT);
2261        break;
2262
2263     default:
2264        report_error_location(ast_node_get_file_location(n->rhs),
2265              S("expression of integral type expected,"
2266                 " found " QFY("%S") "\n"),
2267              ast_expr_type_to_string(v->prev_expr_type));
2268        break;
2269     }
2270  ASTVF_TC_END(AST_ALLOC_ARY, v)
2271
2272  static bool type_check_rec_has_default_rec_func(Symbol_Type_Rec *rec);
2273
2274  static bool type_check_rec_alloc(Ast_Visitor_Type_Check *v, Ast_Node *rec)
2275  {
2276     rec->accept_visitor(rec, AST_VISITOR_OF(v));
2277     if (!v->prev_variable_sym_type) {
2278        report_error_location(ast_node_get_file_location(rec),
2279              S("invalid " QFY("allocate") " of " QFY("record")
2280                 " self-reference\n"));
2281        return false;
2282     } else if (v->prev_expr_type != AST_EXPR_TYPE_REC &&
2283           v->prev_expr_type != AST_EXPR_TYPE_UNKNOWN) {
2284        report_error_location(ast_node_get_file_location(rec),
2285              S("expected variable of type " QFY("record")
2286                 ", found " QFY("%S") "\n"),
2287              ast_expr_type_to_string(v->prev_expr_type));
2288        return false;
2289     } else if (v->prev_variable_sym_type->methods->get_type() ==
2290              SYMBOL_TYPE_FUNC) {
2291        report_error_location(ast_node_get_file_location(rec),
2292              S("invalid " QFY("allocate")
2293                 " of expression returned from function,"
2294                 " expected variable of type " QFY("record") "\n"));
2295        return false;
2296     } else if (v->prev_variable_sym_type->methods->get_type() !=
2297           SYMBOL_TYPE_UNKNOWN) {
2298        assert(v->prev_variable_sym_type->methods->get_type() ==
2299              SYMBOL_TYPE_REC);
2300        if (!symbol_type_rec_assignment_compatible(v->prev_variable_sym_type,
2301                 v->prev_sym_type)) {
2302           report_error_location(ast_node_get_file_location(rec),
2303                 S("type cast to invalid record "
2304                    "type in " QFY("allocate") " statement\n"));
2305           return false;
2306        } else if (!v->prev_sym_type->methods->same_type(v->prev_sym_type,
```

```
                  v->prev_variable_sym_type)) {
#if 0
         Symbol_Type_Rec *var_rec = SYMBOL_TYPE_STRUCT_CONTAINER(
               v->prev_variable_sym_type, Symbol_Type_Rec);
         if (cmdopts.warn_no_finalize &
               !symbol_table_node_get_func_map(var_rec->rec_sym_node,
               (String)S("finalize"), string_hash_code(S("finalize")))) {

            report_warning_location(ast_node_get_file_location(rec),
                  S("type cast of record without " QFY("finalize")
                     " function in " QFY("allocate") " statement\n"));
            /* Only warning. */
         }
#endif
      }
   }

   return true;
}

ASTVF_TC_BEGIN(AST_ALLOC_REC, Ast_Visitor_Type_Check, v, Ast_Node_Unary, n)
   if (!type_check_rec_alloc(v, n->expr))
      goto out;
   if (v->prev_sym_type->methods->get_type() == SYMBOL_TYPE_UNKNOWN)
      goto out;

   assert(v->prev_sym_type->methods->get_type() == SYMBOL_TYPE_REC);

   Symbol_Type_Rec *rec_sym = SYMBOL_TYPE_STRUCT_CONTAINER(
         v->prev_sym_type, Symbol_Type_Rec);
   if (!type_check_rec_has_default_rec_func(rec_sym)) {
      if (rec_sym->rec_name)
         report_error_location(ast_node_get_file_location(n->expr),
               S("record " QFY("%S") " does not have a default "
               "constructor\n"),
               STRING_AFTER_DOT(rec_sym->rec_name));
      else
         report_error_location(ast_node_get_file_location(n->expr),
               S("record does not have a default constructor\n"));
   }
out:;
ASTVF_TC_END(AST_ALLOC_REC, v)

ASTVF_TC_BEGIN(AST_ALLOC_REC_CALL, Ast_Visitor_Type_Check, v,
      Ast_Node_Binary, n)
   if (!type_check_rec_alloc(v, n->lhs))
      goto out;
   if (v->prev_expr_type == AST_EXPR_TYPE_UNKNOWN)
      goto out;
   assert(v->prev_expr_type == AST_EXPR_TYPE_REC);

   bool prev = v->in_allocate_stmt;
   v->in_allocate_stmt = true;

   Symbol_Type_Rec *rec = SYMBOL_TYPE_STRUCT_CONTAINER(v->prev_sym_type,
         Symbol_Type_Rec);
   v->dot_ref_sym_node = rec->rec_sym_node;
   n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
   v->in_allocate_stmt = prev;
out:;
ASTVF_TC_END(AST_ALLOC_REC, v)

ASTVF_TC_BEGIN(AST_DELETE, Ast_Visitor_Type_Check, v, Ast_Node_Unary, n)
   n->expr->accept_visitor(n->expr, AST_VISITOR_OF(v));
   if (v->prev_expr_type != AST_EXPR_TYPE_REC &&
         v->prev_expr_type != AST_EXPR_TYPE_ARY &&
         v->prev_expr_type != AST_EXPR_TYPE_UNKNOWN) {
      report_error_location(ast_node_get_file_location(n->expr),
            S("expected variable of type " QFY("record")
               " or " QFY("array") ", found " QFY("%S") "\n"),
            ast_expr_type_to_string(v->prev_expr_type));
   }
ASTVF_TC_END(AST_DELETE, v)
```

```
2381 ASTVF_TC_BEGIN(AST_WHILE_STMT, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
2382    n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
2383    stmt_expr_error_report(v->prev_expr_type, "while", AST_NODE_OF(n));
2384    n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
2385 ASTVF_TC_END(AST_WHILE_STMT, v)
2386
2387 static bool type_check_void_return(Ast_Visitor_Type_Check *v, Ast_Node *n)
2388 {
2389    if (v->prev_expr_type == AST_EXPR_TYPE_VOID) {
2390       if (v->func_return_type != AST_EXPR_TYPE_VOID &&
2391             v->func_return_type != AST_EXPR_TYPE_UNKNOWN)
2392          report_error_location(ast_node_get_file_location(n),
2393                S("returning " QFY("void") " from " QFY("%S")
2394                   " function\n"),
2395                ast_expr_type_to_string(v->func_return_type));
2396       return true;
2397    } else {
2398       if (v->func_return_type == AST_EXPR_TYPE_VOID) {
2399          report_error_location(ast_node_get_file_location(n),
2400                S("returning " QFY("%S") " from " QFY("void")
2401                   " function\n"),
2402                ast_expr_type_to_string(v->prev_expr_type));
2403          return true;
2404       }
2405    }
2406
2407    return false;
2408 }
2409
2410 ASTVF_TC_BEGIN(AST_RETURN_STMT, Ast_Visitor_Type_Check, v, Ast_Node_Unary, n)
2411    n->expr->accept_visitor(n->expr, AST_VISITOR_OF(v));
2412
2413    Ast_Node *ast_node = AST_NODE_OF(n);
2414    Symbol_Table_Node *sym_node = ast_node_get_symbol_table_node(ast_node);
2415
2416    if (v->sym_table) {
2417       if (sym_node->type == SYMBOL_TABLE_NODE_GLOBAL) {
2418          report_error_location(ast_node_get_file_location(ast_node),
2419                S("invalid " QFY("return")
2420                   " statement in global scope\n"));
2421          return;
2422       }
2423    }
2424
2425    if (type_check_void_return(v, AST_NODE_OF(n)))
2426       return;
2427
2428    Assign_Comatibility_Type assign_t =
2429          types_are_assignment_compatible(
2430                v->func_return_sym, v->func_return_type,
2431                v->prev_sym_type, v->prev_expr_type);
2432
2433    switch (assign_t) {
2434    case ASSIGN_COMPATIBILITY_TRUE:
2435       break;
2436    case ASSIGN_COMPATIBILITY_FALSE:
2437       if (v->prev_expr_type != v->func_return_type)
2438          report_error_location(ast_node_get_file_location(n->expr),
2439                S("return expression of incompatible type " QFY("%S")
2440                   ", expected " QFY("%S") "\n"),
2441                ast_expr_type_to_string(v->prev_expr_type),
2442                ast_expr_type_to_string(v->func_return_type));
2443       else
2444          report_error_location(ast_node_get_file_location(n->expr),
2445                S("return expression of incompatible " QFY("%S")
2446                   " type\n"),
2447                ast_expr_type_to_string(v->prev_expr_type));
2448       break;
2449
2450    case ASSIGN_COMPATIBILITY_AMBIGUOUS:
2451       report_error_location(
2452             ast_node_get_file_location(n->expr),
2453             S("return expression of ambiguous record type, "
2454                "record is directly or "
```

```
2455                "indirectly extending multiple records "
2456                "with the required structure\n"));
2457       break;
2458
2459    case ASSIGN_COMPATIBILITY_IMPLICIT:
2460       warn_implicit_cast(ast_node_get_file_location(n->expr),
2461             v->prev_expr_type, v->func_return_type);
2462       break;
2463    }
2464 ASTVF_TC_END(AST_RETURN_STMT, v)
2465
2466 ASTVF_TC_BEGIN(AST_WRITE_STMT, Ast_Visitor_Type_Check, v, Ast_Node_Unary, n)
2467    n->expr->accept_visitor(n->expr, AST_VISITOR_OF(v));
2468    if (v->prev_expr_type == AST_EXPR_TYPE_VOID) {
2469       report_error_location(ast_node_get_file_location(n->expr),
2470             S("invalid " QFY("write") " of "
2471                QFY("void") " expression\n"));
2472    }
2473 ASTVF_TC_END(AST_WRITE_STMT, v)
2474
2475 static inline bool type_check_prev_was_cast(Ast_Visitor_Type_Check *v)
2476 {
2477    return v->prev_method == AST_VISITOR_FUNC(AST_EXPR_CAST);
2478 }
2479
2480 ASTVF_TC_BEGIN(AST_ASSIGNMENT, Ast_Visitor_Type_Check, v, Ast_Node_Binary, n)
2481    Ast_Expr_Type lhs_t, rhs_t;
2482    Symbol_Type_Struct *lhs_struct, *rhs_struct;
2483    v->lhs_of_assign_is_string_ref = false;
2484    n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
2485    if (!type_check_prev_was_cast(v)) {
2486       if (!v->prev_variable_sym_type) {
2487          report_error_location(ast_node_get_file_location(n->lhs),
2488             S("invalid assignment of " QFY("record")
2489                " self-reference\n"));
2490          lhs_struct = symbol_type_unknown_alloc(v->sym_table);
2491          lhs_t = symbol_type_to_expr_type(lhs_struct);
2492       } else if (v->prev_variable_sym_type->methods->get_type() ==
2493                   SYMBOL_TYPE_FUNC) {
2494          report_error_location(ast_node_get_file_location(n->lhs),
2495             S("invalid function call on left hand side of assignment\n"));
2496          lhs_struct = symbol_type_unknown_alloc(v->sym_table);
2497          lhs_t = symbol_type_to_expr_type(lhs_struct);
2498       } else if (v->lhs_of_assign_is_string_ref) {
2499          report_error_location(ast_node_get_file_location(n->lhs),
2500                S("invalid assignment of immutable string element\n"));
2501          lhs_struct = symbol_type_unknown_alloc(v->sym_table);
2502          lhs_t = symbol_type_to_expr_type(lhs_struct);
2503       } else {
2504          lhs_struct = v->prev_sym_type;
2505          lhs_t = v->prev_expr_type;
2506       }
2507    } else {
2508       lhs_struct = symbol_type_unknown_alloc(v->sym_table);
2509       lhs_t = symbol_type_to_expr_type(lhs_struct);
2510       report_error_location(ast_node_get_file_location(n->lhs),
2511             S("invalid type cast on left hand side of assignment\n"));
2512    }
2513
2514    n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
2515    rhs_struct = v->prev_sym_type;
2516    rhs_t = v->prev_expr_type;
2517
2518    Assign_Comatibility_Type assign_t =
2519          types_are_assignment_compatible(lhs_struct, lhs_t,
2520                rhs_struct, rhs_t);
2521    switch (assign_t) {
2522    case ASSIGN_COMPATIBILITY_TRUE:
2523       break;
2524
2525    case ASSIGN_COMPATIBILITY_FALSE:
2526       if (lhs_t != rhs_t)
2527          report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
2528                S("incompatible assignment of " QFY("%S") " type from "
```

```
2529                    QFY("%S") " type\n"),
2530                ast_expr_type_to_string(lhs_t),
2531                ast_expr_type_to_string(rhs_t));
2532       else
2533          report_error_location(ast_node_get_file_location(AST_NODE_OF(n)),
2534                S("assignment with incompatible " QFY("%S") " types\n"),
2535                ast_expr_type_to_string(lhs_t));
2536       break;
2537
2538    case ASSIGN_COMPATIBILITY_AMBIGUOUS:
2539       report_error_location(
2540             ast_node_get_file_location(AST_NODE_OF(n)),
2541             S("ambiguous record assigmnent, "
2542                "right hand side record is directly or "
2543                "indirectly extending multiple records "
2544                "with the same structure as the left hand side\n"));
2545       break;
2546
2547    case ASSIGN_COMPATIBILITY_IMPLICIT:
2548       /* Implicit cast from rhs to lhs. */
2549       warn_implicit_cast(ast_node_get_file_location(AST_NODE_OF(n)),
2550             rhs_t, lhs_t);
2551       break;
2552    }
2553 ASTVF_TC_END(AST_ASSIGNMENT, v)
2554
2555 static void type_check_func_body(Ast_Visitor_Type_Check *v,
2556       Vector *statements, Uns start_idx)
2557 {
2558    Ast_Node *stmt;
2559    for (; start_idx < vector_size(statements); start_idx++) {
2560       stmt = vector_get(statements, start_idx);
2561       stmt->accept_visitor(stmt, AST_VISITOR_OF(v));
2562    }
2563 }
2564
2565 typedef struct Tt_Extend_Mapping {
2566    Symbol_Type_Struct *extended_rec;
2567    Uns call_count;
2568    bool constructor_called;
2569 } Tt_Extend_Mapping;
2570
2571 static UNUSED bool type_check_extend_maps_all_called(Vector *ext_maps)
2572 {
2573    Tt_Extend_Mapping *m;
2574    VECTOR_FOR_EACH_ENTRY(ext_maps, m) {
2575       if (!m->constructor_called)
2576          return false;
2577    }
2578    return true;
2579 }
2580
2581 static bool type_check_rec_has_default_rec_func(Symbol_Type_Rec *rec)
2582 {
2583    Symbol_Func_Map *map = symbol_table_node_get_func_map(rec->rec_sym_node,
2584          (String)S("record"), string_hash_code(S("record")));
2585    if (!map)
2586       return true;
2587
2588    Symbol_Type_Func *func;
2589    Symbol *sym;
2590    VECTOR_FOR_EACH_ENTRY(&map->overload_idens, sym) {
2591       if (sym->resolved_type->methods->get_type() == SYMBOL_TYPE_UNKNOWN)
2592          return true;
2593       assert(sym->resolved_type->methods->get_type() == SYMBOL_TYPE_FUNC);
2594
2595       func = SYMBOL_TYPE_STRUCT_CONTAINER(
2596             sym->resolved_type, Symbol_Type_Func);
2597       if (!vector_size(&func->param_identifiers))
2598          return true;
2599    }
2600
2601    return false;
2602 }
```

```
2603
2604 static inline void type_check_init_extend_maps(Symbol_Type_Rec *rec,
2605       Vector *ext_maps)
2606 {
2607    Symbol_Type_Struct *ext_s;
2608    Symbol_Type_Rec *ext_r;
2609    VECTOR_FOR_EACH_ENTRY(&rec->extended_types, ext_s) {
2610       if (ext_s->methods->get_type() == SYMBOL_TYPE_UNKNOWN)
2611          continue;
2612       assert(ext_s->methods->get_type() == SYMBOL_TYPE_REC);
2613       ext_r = SYMBOL_TYPE_STRUCT_CONTAINER(ext_s, Symbol_Type_Rec);
2614       if (ext_r->rec_sym_node->has_record_func) {
2615          Tt_Extend_Mapping *m = ALLOC_NEW(Tt_Extend_Mapping);
2616          m->extended_rec = ext_s;
2617          m->call_count = 0;
2618          m->constructor_called = type_check_rec_has_default_rec_func(ext_r);
2619          vector_append(ext_maps, m);
2620       }
2621    }
2622 }
2623
2624 static inline void type_check_extend_maps_report(Vector *ext_maps,
2625       Uns num_unnamed_bases, File_Location *loc)
2626 {
2627    if (num_unnamed_bases) {
2628       report_error_location(loc, S("missing call to base record "
2629                "constructor%s\n"),
2630             num_unnamed_bases > 1 ? "s" : "");
2631       return;
2632    }
2633
2634    Symbol_Type_Rec *rec;
2635    Tt_Extend_Mapping *m;
2636    VECTOR_FOR_EACH_ENTRY(ext_maps, m) {
2637       if (m->constructor_called)
2638          continue;
2639       rec = SYMBOL_TYPE_STRUCT_CONTAINER(m->extended_rec, Symbol_Type_Rec);
2640       report_error_location(loc, S("missing call to constructor"
2641                " of base record " QFY("%S") "\n"),
2642             STRING_AFTER_DOT(rec->rec_name));
2643    }
2644 }
2645
2646 static inline void type_check_finalize_extend_map_report(Vector *ext_maps,
2647       File_Location *final_loc)
2648 {
2649    Uns num_unnamed = 0;
2650    bool has_uncalled_ctor = false;
2651
2652    Symbol_Type_Rec *rec;
2653    Tt_Extend_Mapping *m;
2654    VECTOR_FOR_EACH_ENTRY(ext_maps, m) {
2655       rec = SYMBOL_TYPE_STRUCT_CONTAINER(m->extended_rec, Symbol_Type_Rec);
2656       if (!m->constructor_called) {
2657          if (!rec->rec_name)
2658             ++num_unnamed;
2659          has_uncalled_ctor = true;
2660       }
2661    }
2662
2663    if (has_uncalled_ctor)
2664       type_check_extend_maps_report(ext_maps, num_unnamed, final_loc);
2665 }
2666
2667 static bool type_check_extend_maps_mark_called(Vector *ext_maps,
2668       Symbol_Type_Struct *base, File_Location *loc)
2669 {
2670    assert(base->methods->get_type() == SYMBOL_TYPE_REC);
2671
2672    bool ret = false;
2673    Tt_Extend_Mapping *m;
2674    VECTOR_FOR_EACH_ENTRY(ext_maps, m) {
2675       if (___type_def_symbol_types_equal(base, m->extended_rec)) {
2676          ret = true;
```

```
2677            ++m->call_count;
2678            m->constructor_called = true;
2679            break;
2680         }
2681      }
2682
2683      if (ret && m->call_count == 2) {
2684         Symbol_Type_Rec *base_r = SYMBOL_TYPE_STRUCT_CONTAINER(base,
2685               Symbol_Type_Rec);
2686         Const_String rec_name;
2687         if (base_r->rec_name)
2688            rec_name = base_r->rec_name;
2689         else
2690            rec_name = S("record");
2691         report_error_location(loc, S("multiple calls to constructor of base "
2692                  QFY("%S") "\n"),
2693               rec_name);
2694      }
2695
2696      return ret;
2697   }
2698
2699   enum {
2700      TC_NOT_RECORD_CALL,
2701      TC_BASE_RECORD_CALL,
2702      TC_FORWARD_RECORD_CALL
2703   };
2704
2705   static inline int type_check_extend_maps_is_base_call(Vector *ext_maps,
2706         Symbol_Type_Struct *rec, Symbol_Type_Struct *base,
2707         Const_String func_iden, File_Location *loc)
2708   {
2709      if (string_compare(STRING_AFTER_DOT(func_iden), S("record")))
2710         return TC_NOT_RECORD_CALL;
2711
2712      if (type_check_extend_maps_mark_called(ext_maps, base, loc))
2713         return TC_BASE_RECORD_CALL;
2714
2715      if (___type_def_symbol_types_equal(rec, base))
2716         return TC_FORWARD_RECORD_CALL;
2717
2718      return TC_NOT_RECORD_CALL;
2719   }
2720
2721   static void type_check_direct_ctor_error(Symbol_Type_Rec *rec,
2722         File_Location *loc)
2723   {
2724      if (rec->rec_name)
2725         report_error_location(loc, S("forwarding call to constructor of "
2726                  "record " QFY("%S")
2727                  " should be first statement of function\n"),
2728               rec->rec_name);
2729      else
2730         report_error_location(loc, S("forwarding call to constructor of "
2731                  "record should be first statement of function\n"),
2732               rec->rec_name);
2733   }
2734
2735   static Uns type_check_func_constructors(Ast_Visitor_Type_Check *v,
2736         Vector *statements, Ast_Stmt_List *n)
2737   {
2738      Ast_Node *stmt;
2739      Uns idx = 0;
2740
2741      VECTOR(ext_maps);
2742
2743      if (!v->rec_body_sym_node)
2744         goto unknown_out;
2745
2746      File_Location *loc = ast_node_get_file_location(AST_NODE_OF(n));
2747
2748      Symbol_Type_Struct *curr_rec = SYMBOL_TYPE_STRUCT_OF_CONTAINER(
2749            v->rec_body_sym_node->node_rec);
2750
```

```
2751     bool do_finalize = true;
2752
2753     type_check_init_extend_maps(v->rec_body_sym_node->node_rec, &ext_maps);
2754
2755     while (idx < vector_size(statements)) {
2756        stmt = vector_get(statements, idx);
2757        loc = ast_node_get_file_location(stmt);
2758
2759        if (stmt->accept_visitor !=
2760              AST_NODE_ACCEPT_VISITOR_FUNC(AST_EXPR_DIRECT_REF))
2761           break;
2762
2763        v->prev_direct_ref_func = NULL;
2764        v->prev_direct_ref_rec = NULL;
2765        stmt->accept_visitor(stmt, AST_VISITOR_OF(v));
2766        ++idx;
2767
2768        if (v->prev_direct_ref_func && v->prev_direct_ref_rec) {
2769           Symbol_Type_Struct *base = v->prev_direct_ref_rec;
2770           Symbol_Type_Struct *func = v->prev_direct_ref_func;
2771           if (base->methods->get_type() == SYMBOL_TYPE_UNKNOWN ||
2772                 func->methods->get_type() == SYMBOL_TYPE_UNKNOWN) {
2773              goto unknown_out;
2774           }
2775           int res = type_check_extend_maps_is_base_call(&ext_maps,
2776                 curr_rec, base, v->prev_func_call_iden, loc);
2777           if (res == TC_NOT_RECORD_CALL)
2778              break;
2779           if (res == TC_FORWARD_RECORD_CALL) {
2780              if (idx != 1) {
2781                 type_check_direct_ctor_error(SYMBOL_TYPE_STRUCT_CONTAINER(
2782                           base, Symbol_Type_Rec), loc);
2783              } else {
2784                 do_finalize = false;
2785                 break;
2786              }
2787           }
2788        } else {
2789           break;
2790        }
2791     }
2792
2793     n->num_rec_ctor_stmts = idx;
2794
2795     if (do_finalize)
2796        type_check_finalize_extend_map_report(&ext_maps, loc);
2797
2798  unknown_out:
2799     vector_for_each_destroy(&ext_maps, free_mem);
2800     return idx;
2801  }
2802
2803  static void type_check_rec_default_constructor(Symbol_Type_Rec *rec,
2804        File_Location *loc)
2805  {
2806     if (!rec->missing_record_func_name)
2807        return;
2808
2809     VECTOR(ext_maps);
2810     type_check_init_extend_maps(rec, &ext_maps);
2811     type_check_finalize_extend_map_report(&ext_maps, loc);
2812     vector_for_each_destroy(&ext_maps, free_mem);
2813  }
2814
2815  ASTVF_TC_BEGIN(AST_FUNC_BODY, Ast_Visitor_Type_Check, v, Ast_Stmt_List, n)
2816     Vector *statements = n->statements;
2817     Uns idx;
2818
2819     bool prev = v->in_beginning_of_ctor;
2820     v->in_beginning_of_ctor = true;
2821     if (v->current_func_type == TT_FUNC_TYPE_RECORD)
2822        idx = type_check_func_constructors(v, statements, n);
2823     else
2824        idx = 0;
```

```
2825     v->in_beginning_of_ctor = prev;
2826     type_check_func_body(v, statements, idx);
2827 ASTVF_TC_END(AST_FUNC_BODY, v)
2828
2829 ASTVF_TC_BEGIN(AST_EXPR_CHAR, Ast_Visitor_Type_Check, v, Ast_Expr_Char, n)
2830     (void)n;
2831     v->prev_expr_type = AST_EXPR_TYPE_CHAR;
2832 ASTVF_TC_END(AST_EXPR_CHAR, v)
2833
2834 ASTVF_TC_BEGIN(AST_EXPR_STRING, Ast_Visitor_Type_Check, v,
2835        Ast_Expr_String, n)
2836     (void)n;
2837     v->prev_expr_type = AST_EXPR_TYPE_STRING;
2838 ASTVF_TC_END(AST_EXPR_STRING, v)
2839
2840 ASTVF_TC_BEGIN(AST_IMPORT_STRING, Ast_Visitor_Type_Check, v,
2841        Ast_Module_String, n)
2842     (void)n; (void)v;
2843 ASTVF_TC_END(AST_IMPORT_STRING, v)
2844
2845 ASTVF_TC_BEGIN(AST_PACKAGE_STRING, Ast_Visitor_Type_Check, v,
2846        Ast_Module_String, n)
2847     (void)n; (void)v;
2848 ASTVF_TC_END(AST_IMPORT_STRING, v)
2849
2850 ASTVF_TC_BEGIN(AST_SIMPLE_TYPE_CHAR, Ast_Visitor_Type_Check, v, Ast_Empty, n)
2851     (void)n;
2852     v->prev_expr_type = AST_EXPR_TYPE_CHAR;
2853 ASTVF_TC_END(AST_SIMPLE_TYPE_CHAR, v)
2854
2855 ASTVF_TC_BEGIN(AST_SIMPLE_TYPE_VOID, Ast_Visitor_Type_Check, v, Ast_Empty, n)
2856     (void)n;
2857     v->prev_expr_type = AST_EXPR_TYPE_VOID;
2858 ASTVF_TC_END(AST_SIMPLE_TYPE_CHAR, v)
2859
2860 ASTVF_TC_BEGIN(AST_SIMPLE_TYPE_STRING, Ast_Visitor_Type_Check, v, Ast_Empty, n)
2861     (void)n;
2862     v->prev_expr_type = AST_EXPR_TYPE_STRING;
2863 ASTVF_TC_END(AST_SIMPLE_TYPE_STRING, v)
2864
2865 static Ast_Visitor_Type_Check type_check_visitor = {
2866     .AST_VISITOR_FIELD = AST_VISITOR_STATIC_INIT(),
2867     .next_property = SYMBOL_PROPERTY_VAR
2868 };
2869
2870 void ast_visitor_type_check(Ast *ast)
2871 {
2872     Ast_Node *root;
2873     if (ast_is_valid(ast)) {
2874         type_check_visitor.sym_table = ast_get_symbol_table(ast);
2875         type_check_visitor.prev_sym_type = NULL;
2876         root = ast_get_root(ast);
2877         root->accept_visitor(root, AST_VISITOR_OF(&type_check_visitor));
2878         assert(!type_check_visitor.rec_body_sym_node);
2879         assert(type_check_visitor.next_property == SYMBOL_PROPERTY_VAR);
2880     }
2881 }
```

:

A.5.2 src/ast/ast_visitor_type_check.h

```
1 #ifndef AST_VISITOR_TYPE_CHECK_H
2 #define AST_VISITOR_TYPE_CHECK_H
3
4 #include "ast_visitor.h"
5
6 void ast_visitor_type_check(Ast *ast);
7
8 #endif // AST_VISITOR_TYPE_CHECK_H
```

A.6 Generate AIA

:

A.6.1 src/ast/ast_visitor_aia.c

```
1  #include "ast_visitor_aia.h"
2  #include "ast_visitor_dependency.h"
3  #include "symbol_table.h"
4  #include <main.h>
5  #include <debug.h>
6  #include <hash_map.h>
7  #include <aia/aia.h>
8
9  /* let DEBUG=aia-gen:aia-gen-full
10  * for more debug info. */
11 #undef DEBUG_TYPE
12 #define DEBUG_TYPE aia-gen
13
14 #define BYTE_ALIGNMENT ((Uns)1)
15 #define LONG_ALIGNMENT ((Uns)4)
16 #define LONG_ALIGN_MASK (LONG_ALIGNMENT - 1)
17
18 typedef enum Aia_Expr_Type {
19    AIA_EXPR_DEBUG,
20    AIA_EXPR_SHORT_CIRCUIT,
21    AIA_EXPR_STANDARD
22 } Aia_Expr_Type;
23
24 typedef enum Aia_Visitor_Func_Type {
25    AIAV_FUNC_TYPE_NORMAL,
26    AIAV_FUNC_TYPE_FINALIZE,
27    AIAV_FUNC_TYPE_RECORD
28 } Aia_Visitor_Func_Type;
29
30 AST_VISITOR_STRUCT_BEGIN(Ast_Visitor_Aia)
31    Symbol_Table *sym_table;
32    Aia *aia;
33    Aia_Operand *prev_result;
34    Aia_Operand *func_call_selfptr;
35    Aia_Operand *prev_variable_result;
36    Aia_Operand *bool_true_label;
37    Aia_Operand *bool_false_label;
38    Symbol_Type_Struct *prev_sym_type;
39    Symbol_Type_Struct *func_ret_sym_type;
40    Symbol_Type_Rec *dot_ref_record;
41    Symbol_Type_Rec *curr_record_selfptr;
42    Symbol_Type_Rec *alloc_record_selfptr;
43    Symbol_Type_Rec *prev_dot_ref_record;
44    Stn_Display_Preserve *curr_display;
45    Symbol *curr_symbol;
46    String prev_iden;
47    Hash_Map record_map;
48    Hash_Map vmt_map;
49    Hash_Map trampolines;
50    Symbol_Property next_property;
51    File_Location null_location;
52    File_Location *curr_loc;
53    Uns stmt_list_nest;
54    Ast_Expr_Type prev_expr_type;
55    Aia_Expr_Type aia_expr_type;
56    Aia_Visitor_Func_Type curr_func_type;
57    int32_t allocated_record_offset;
58    /* Used to determine whether a variable identifier is used as a variable
59     * or whether it is just declared. */
60    bool next_variable_iden_is_operand;
61    bool dot_ref_is_direct;
62    bool next_var_decl_is_param;
63    bool allocating_record;
64 AST_VISITOR_STRUCT_END(Ast_Visitor_Aia)
65
```

```
66  typedef enum Vit_Field_Type {
67     VIT_RECORD_FIELD_BYTE,
68     VIT_RECORD_FIELD_LONG,
69     VIT_RECORD_FIELD_RECORD
70  } Vit_Field_Type;
71
72  typedef struct Vit_Record_Field {
73     String field_name;
74     Hash_Map_Slot hash_slot;
75     Int field_offset;
76     Vit_Field_Type field_type;
77     String field_type_name;
78     Symbol_Type sym_type;
79  } Vit_Record_Field;
80
81  typedef struct Vit_Vmt_Trampoline {
82     String tramp_name;
83     String func_name;
84     Int rec_offset;
85  } Vit_Vmt_Trampoline;
86
87  #define VIT_RECORD_FIELD_OF(slot) \
88     HASH_MAP_ENTRY(slot, Vit_Record_Field, hash_slot);
89
90  typedef struct Vit_Vmt_Trampoline_Entry {
91     Hash_Map_Slot hash_slot;
92     Vector trampolines;
93  } Vit_Vmt_Trampoline_Entry;
94
95  #define VIT_VMT_TRAMPOLINE_ENTRY_OF(slot) \
96     HASH_MAP_ENTRY(slot, Vit_Vmt_Trampoline_Entry, hash_slot)
97
98  typedef struct Vit_Func_Off_Entry {
99     String func_name;
100    Hash_Map_Slot hash_slot;
101    Uns func_offset;
102    Uns cast_offset;
103 } Vit_Func_Off_Entry;
104
105 #define VIT_FUNC_OFF_ENTRY_OF(slot) \
106    HASH_MAP_ENTRY(slot, Vit_Func_Off_Entry, hash_slot)
107
108 typedef struct Vit_Record_Initializer {
109    String initializer_name;
110    /* Vector containing record offsets. See comment for vmt_offsets.*/
111    Vector rec_offsets;
112    /* Vector containing offsets into this VMT.
113     * rec_offset[1] contains the offset to record with name 'record_name'
114     * which should get initialized with vmt: this VMT + vmt_offsets[1]. */
115    Vector vmt_offsets;
116 } Vit_Record_Initializer;
117
118 typedef struct Vit_Vmt {
119    /* Name of the record containing this VMT. */
120    String record_name;
121    /* Names of functions and function trampolines in the VMT. */
122    Vector func_names;
123    /* Offsets to functions in the VMT from the owning record's perspective. */
124    Hash_Map func_off_map;
125    /* struct to generate function to initialize record VMT's. */
126    Vit_Record_Initializer initializer;
127    Hash_Map_Slot hash_slot;
128    /* Offset to next function which will get inserted.
129     * After all funcs are inserted it can be used to
130     * determine the size if the vmt. */
131    Uns current_func_offset;
132    bool is_imported;
133 } Vit_Vmt;
134
135 #define VIT_VMT_OF(slot) HASH_MAP_ENTRY(slot, Vit_Vmt, hash_slot)
136
137 typedef struct Vit_Record {
138    String identifier;
139    Const_String initializer_name;
```

```
140     Symbol_Type_Rec *rec;
141     Vector extended_sym_types;
142     Vector field_vector;
143     Hash_Map field_map;
144     Hash_Map_Slot hash_slot;
145     Uns byte_size;
146     Uns alignment;
147     bool is_c_header_printed;
148  } Vit_Record;
149
150  #define VIT_RECORD_OF(slot) HASH_MAP_ENTRY(slot, Vit_Record, hash_slot)
151
152  typedef struct Vit_Record_Func_Entry {
153     String func_name;
154     String long_func_name;
155     Hash_Map_Slot hash_slot;
156     bool is_inserted;
157     Symbol_Type_Rec *owner;
158  } Vit_Record_Func_Entry;
159
160  #define VIT_RECORD_FUNC_ENTRY_OF(slot) \
161     HASH_MAP_ENTRY(slot, Vit_Record_Func_Entry, hash_slot)
162
163  static Const_String vit_field_type_strings[] = {
164     [VIT_RECORD_FIELD_BYTE]   = S(".byte"),
165     [VIT_RECORD_FIELD_LONG]   = S(".long"),
166     [VIT_RECORD_FIELD_RECORD] = NULL
167  };
168
169  static NORETURN void aia_visitor_unexpected_symbol()
170  {
171     fatal_error(S("AIA code generator encountered unexpected "
172              "symbol type. Aborting...\n"));
173  }
174
175  static inline Const_String vit_simple_field_type_to_string(Vit_Field_Type t)
176  {
177     Const_String ret = vit_field_type_strings[t];
178     assert(ret);
179     return ret;
180  }
181
182  static inline Vit_Record_Field *vit_record_get_field(Vit_Record *r,
183        String field_name)
184  {
185     Hash_Map_Slot *s = hash_map_get(&r->field_map, field_name,
186           string_hash_code(field_name));
187     if (s)
188        return VIT_RECORD_FIELD_OF(s);
189     return NULL;
190  }
191
192  static inline Const_String vit_record_field_get_type_name(Vit_Record_Field *f)
193  {
194     if (f->field_type == VIT_RECORD_FIELD_RECORD)
195        return f->field_type_name;
196     return vit_simple_field_type_to_string(f->field_type);
197  }
198
199  static bool vit_record_field_comparator(String search_name,
200        Hash_Map_Slot *map_slot)
201  {
202     Vit_Record_Field *f = VIT_RECORD_FIELD_OF(map_slot);
203     return !string_compare(search_name, f->field_name);
204  }
205
206  static Vit_Record_Field *___vit_record_field_alloc(
207        String field_type_name, Vit_Field_Type t,
208        Symbol_Type sym_type, Const_String field_name)
209  {
210     Vit_Record_Field *f = ALLOC_NEW(Vit_Record_Field);
211     f->field_type_name = field_type_name;
212     f->field_name = string_duplicate(field_name);
213     f->field_type = t;
```

```
214     f->sym_type = sym_type;
215     return f;
216  }
217
218  static void vit_record_field_destroy(Vit_Record_Field *f)
219  {
220     string_destroy(f->field_name);
221     free_mem(f);
222  }
223
224  static Vit_Record_Field *vit_record_field_alloc_simple(Vit_Field_Type t,
225        Symbol_Type sym_type, Const_String field_name)
226  {
227     return ___vit_record_field_alloc(NULL, t, sym_type, field_name);
228  }
229
230  static Vit_Record_Field *vit_record_field_alloc_record(String type_name,
231        Const_String field_name)
232  {
233     return ___vit_record_field_alloc(type_name, VIT_RECORD_FIELD_RECORD,
234           SYMBOL_TYPE_IDEN, field_name);
235  }
236
237  static inline Vit_Vmt_Trampoline *vit_vmt_trampoline_alloc(String func_name,
238        Const_String unique_rec_name, Int rec_offset)
239  {
240     Vit_Vmt_Trampoline *t = ALLOC_NEW(Vit_Vmt_Trampoline);
241     t->func_name = func_name;
242     t->tramp_name = string_from_format(S("%S$%S"), unique_rec_name,
243           func_name);
244     t->rec_offset = rec_offset;
245     return t;
246  }
247
248  static inline void vit_vmt_trampoline_destroy(Vit_Vmt_Trampoline *t)
249  {
250     string_destroy(t->tramp_name);
251     free_mem(t);
252  }
253
254  static UNUSED void vit_vmt_trampoline_dump(Vit_Vmt_Trampoline *t)
255  {
256     print_message(S("trampoline %S subtracts %U from thisptr\n\n"),
257           t->tramp_name, t->rec_offset);
258  }
259
260  static inline Vit_Vmt_Trampoline_Entry *vit_vmt_trampoline_entry_alloc()
261  {
262     Vit_Vmt_Trampoline_Entry *e = ALLOC_NEW(Vit_Vmt_Trampoline_Entry);
263     e->trampolines = VECTOR_INIT_SIZE(4);
264     return e;
265  }
266
267  static inline void vit_vmt_trampoline_entry_destroy(
268        Vit_Vmt_Trampoline_Entry *e)
269  {
270     vector_for_each_destroy(&e->trampolines,
271           (Vector_Destructor)vit_vmt_trampoline_destroy);
272     free_mem(e);
273  }
274
275  static void vit_vmt_trampoline_entry_hash_destroy(Hash_Map_Slot *s)
276  {
277     vit_vmt_trampoline_entry_destroy(VIT_VMT_TRAMPOLINE_ENTRY_OF(s));
278  }
279
280  static bool vit_vmt_trampoline_entry_comparator(String search_func,
281     Hash_Map_Slot *map_slot)
282  {
283     Vit_Vmt_Trampoline_Entry *e = VIT_VMT_TRAMPOLINE_ENTRY_OF(map_slot);
284     Vit_Vmt_Trampoline *t = vector_get(&e->trampolines, 0);
285     return !string_compare(t->func_name, search_func);
286  }
287
```

```
288 /* Does not matter whether the tramoline is already inserted.
289  * This function will detect it.
290  * Returns the name of the trampoline. */
291 static inline String aia_visitor_insert_trampoline(Ast_Visitor_Aia *v,
292       Vit_Vmt_Trampoline *t)
293 {
294    Uns hash = string_hash_code(t->func_name);
295    Hash_Map_Slot *s = hash_map_get(&v->trampolines, t->func_name, hash);
296    Vit_Vmt_Trampoline_Entry *e;
297    if (!s) {
298       e = vit_vmt_trampoline_entry_alloc();
299       hash_map_insert(&v->trampolines, &e->hash_slot,
300             string_hash_code(t->func_name));
301    } else {
302       e = VIT_VMT_TRAMPOLINE_ENTRY_OF(s);
303       Vector *tramps = &e->trampolines;
304       Vit_Vmt_Trampoline *existing;
305       VECTOR_FOR_EACH_ENTRY(tramps, existing) {
306          if (!string_compare(existing->tramp_name, t->tramp_name)) {
307             vit_vmt_trampoline_destroy(t);
308             return existing->tramp_name;
309          }
310       }
311    }
312    DEBUGT(aia-gen-full, vit_vmt_trampoline_dump(t));
313    vector_append(&e->trampolines, t);
314    return t->tramp_name;
315 }
316
317 static inline Vit_Func_Off_Entry *vit_func_off_entry_alloc(String func_name,
318       Uns func_off, Uns cast_off)
319 {
320    Vit_Func_Off_Entry *e = ALLOC_NEW(Vit_Func_Off_Entry);
321    e->func_name = func_name;
322    e->func_offset = func_off;
323    e->cast_offset = cast_off;
324    return e;
325 }
326
327 static inline void vit_func_off_entry_destroy(Vit_Func_Off_Entry *e)
328 {
329    free_mem(e);
330 }
331
332 static void vit_func_off_entry_hash_destroy(Hash_Map_Slot *s)
333 {
334    vit_func_off_entry_destroy(VIT_FUNC_OFF_ENTRY_OF(s));
335 }
336
337 static bool vit_func_off_entry_comparator(String search_func,
338       Hash_Map_Slot *map_slot)
339 {
340    Vit_Func_Off_Entry *f = VIT_FUNC_OFF_ENTRY_OF(map_slot);
341    return !string_compare(search_func, f->func_name);
342 }
343
344 static UNUSED void vit_vmt_dump(Vit_Vmt *vmt)
345 {
346    print_message(S("initializer %S {\n"), vmt->initializer.initializer_name);
347    for (Uns i = 0; i < vector_size(&vmt->initializer.rec_offsets); i++) {
348       Uns roff = PTR_TO_INT(vector_get(&vmt->initializer.rec_offsets, i));
349       Uns voff = PTR_TO_INT(vector_get(&vmt->initializer.vmt_offsets, i));
350       print_message(S("\trecord offset %U is initialized with "
351                "vmt offset %U\n"),
352             roff, voff);
353    }
354    print_message(S("}\n\n"));
355
356    print_message(S("vmt %S {\n"), vmt->record_name);
357
358    Hash_Map_Slot *slot;
359    HASH_MAP_FOR_EACH(&vmt->func_off_map, slot) {
360       Vit_Func_Off_Entry *e = VIT_FUNC_OFF_ENTRY_OF(slot);
361       print_message(S("\tfunc %S has offset %U add thisptr "
```

```
362                "with %U before call\n"),
363             e->func_name, e->func_offset, e->cast_offset);
364    }
365    print_message(S("\n"));
366
367    String fname;
368    Uns off = 0;
369    VECTOR_FOR_EACH_ENTRY(&vmt->func_names, fname) {
370       print_message(S("\t%U: .long %S\n"), off, fname);
371       off += LONG_ALIGNMENT;
372    }
373
374    print_message(S("}\n\n"));
375 }
376
377
378 static inline void vit_vmt_append_rec_vmt_offset(Vit_Vmt *v,
379       Uns rec_off, Uns vmt_off)
380 {
381    if (vector_is_empty(&v->initializer.rec_offsets) ||
382          PTR_TO_UINT(vector_peek_last(&v->initializer.rec_offsets)) !=
383          rec_off) {
384       vector_append(&v->initializer.rec_offsets, INT_TO_PTR(rec_off));
385       vector_append(&v->initializer.vmt_offsets, INT_TO_PTR(vmt_off));
386    }
387 }
388
389 static inline bool rec_has_vmt_func(Symbol_Type_Rec *rec);
390
391 static inline Vit_Vmt *vit_vmt_alloc(Symbol_Type_Rec *rec)
392 {
393    if (!rec_has_vmt_func(rec))
394       return NULL;
395
396    Vit_Vmt *v = ALLOC_NEW(Vit_Vmt);
397    v->record_name = rec->unique_name;
398    v->func_names = VECTOR_INIT_SIZE(4);
399    v->initializer.rec_offsets = VECTOR_INIT_SIZE(4);
400    v->initializer.vmt_offsets = VECTOR_INIT_SIZE(4);
401    v->initializer.initializer_name = string_from_format(S("%S.init"),
402          rec->unique_name);
403    v->func_off_map = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_11,
404          (Hash_Map_Comparator)vit_func_off_entry_comparator);
405    v->current_func_offset = 0;
406    v->is_imported = rec->rec_sym_node->parent->type == SYMBOL_TABLE_NODE_IMPORT;
407    return v;
408 }
409
410 static inline void vit_vmt_destroy(Vit_Vmt *v)
411 {
412    vector_clear(&v->func_names);
413    vector_clear(&v->initializer.rec_offsets);
414    vector_clear(&v->initializer.vmt_offsets);
415    string_destroy(v->initializer.initializer_name);
416    hash_map_for_each_destroy(&v->func_off_map,
417          vit_func_off_entry_hash_destroy);
418    free_mem(v);
419 }
420
421 /* Does not matter whether the func is already appended. */
422 static inline void vit_vmt_append_func(Vit_Vmt *v,
423       String unique_func_name, String short_func_name, Uns rec_offset)
424 {
425    vector_append(&v->func_names, unique_func_name);
426    Uns hash = string_hash_code(short_func_name);
427    if (!hash_map_contains(&v->func_off_map, short_func_name, hash)) {
428       Vit_Func_Off_Entry *e = vit_func_off_entry_alloc(short_func_name,
429             v->current_func_offset, rec_offset);
430       hash_map_insert(&v->func_off_map, &e->hash_slot, hash);
431    }
432    v->current_func_offset += LONG_ALIGNMENT;
433 }
434
435 static bool vit_vmt_comparator(String search_rec, Hash_Map_Slot *map_slot)
```

```
436 {
437    Vit_Vmt *v = VIT_VMT_OF(map_slot);
438    return !string_compare(search_rec, v->record_name);
439 }
440
441 static void vit_vmt_hash_destroy(Hash_Map_Slot *s)
442 {
443    vit_vmt_destroy(VIT_VMT_OF(s));
444 }
445
446 static UNUSED void vit_record_dump(Vit_Record *r)
447 {
448    Vit_Record_Field *f;
449    print_message(S("record %S {\n"), r->identifier);
450    VECTOR_FOR_EACH_ENTRY(&r->field_vector, f)
451       print_message(S("\t%U: %S of type %S\n"), f->field_offset,
452             f->field_name, vit_record_field_get_type_name(f));
453    if (r->initializer_name)
454       print_message(S("} of size %U, initializer: %S\n\n"), r->byte_size,
455             r->initializer_name);
456    else
457       print_message(S("} of size %U, initializer: (null)\n\n"),
458             r->byte_size);
459 }
460
461 static inline Vit_Record *vit_record_alloc(Symbol_Type_Rec *rec)
462 {
463    Vit_Record *vrec = ALLOC_NEW(Vit_Record);
464    vrec->identifier = rec->unique_name;
465    vrec->initializer_name = NULL;
466    vrec->rec = rec;
467    vrec->extended_sym_types = VECTOR_INIT_SIZE(2);
468    vrec->field_vector = VECTOR_INIT();
469    vrec->field_map = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_23,
470          (Hash_Map_Comparator)vit_record_field_comparator);
471    vrec->byte_size = 0;
472    vrec->is_c_header_printed = false;
473    return vrec;
474 }
475
476 static inline void vit_record_destroy(Vit_Record *r)
477 {
478    vector_clear(&r->extended_sym_types);
479    vector_for_each_destroy(&r->field_vector,
480          (Vector_Destructor)vit_record_field_destroy);
481    hash_map_clear(&r->field_map);
482    free_mem(r);
483 }
484
485 static inline void vit_record_hash_destroy(Hash_Map_Slot *s)
486 {
487    vit_record_destroy(VIT_RECORD_OF(s));
488 }
489
490 static inline Vit_Record *aia_visitor_get_record(Ast_Visitor_Aia *v,
491       String iden);
492
493 static bool aia_visitor_get_rec_base_offset(Ast_Visitor_Aia *v, Vit_Record *r,
494       Symbol_Type_Struct *base_rec, int32_t *result)
495 {
496    Vit_Record_Field *f;
497    Symbol_Type_Struct *ext_s;
498    Vector *ext_vec = &r->extended_sym_types;
499    VECTOR_FOR_EACH_ENTRY(ext_vec, ext_s) {
500       Symbol_Type_Rec *ext_r = SYMBOL_TYPE_STRUCT_CONTAINER(ext_s,
501             Symbol_Type_Rec);
502       f = vit_record_get_field(r, ext_r->unique_name);
503       if (base_rec->methods->same_type(base_rec, ext_s)) {
504          *result = f->field_offset;
505          return true;
506       }
507       Vit_Record *base = aia_visitor_get_record(v, ext_r->unique_name);
508       assert(base);
509       if (aia_visitor_get_rec_base_offset(v, base, base_rec, result)) {
```

```
510             *result += f->field_offset;
511             return true;
512          }
513       }
514       return false;
515    }
516
517    /* Assumes it is possible to cast record with name 'rec_from' to the record
518     * with name 'rec_to'. */
519    static int32_t aia_visitor_get_rec_cast_offset(Ast_Visitor_Aia *v,
520          Symbol_Type_Struct *from, Symbol_Type_Struct *to)
521    {
522       int32_t result;
523
524       Symbol_Type_Rec *rec_from, *rec_to;
525       rec_from = SYMBOL_TYPE_STRUCT_CONTAINER(from, Symbol_Type_Rec);
526       rec_to = SYMBOL_TYPE_STRUCT_CONTAINER(to, Symbol_Type_Rec);
527
528       if (from->methods->same_type(from, to)) {
529          result = 0;
530          goto out;
531       }
532
533       Vit_Record *r = aia_visitor_get_record(v, rec_from->unique_name);
534       assert(r);
535       if (aia_visitor_get_rec_base_offset(v, r, to, &result))
536          goto out;
537       r = aia_visitor_get_record(v, rec_to->unique_name);
538       assert(r);
539       bool ret = aia_visitor_get_rec_base_offset(v, r, from, &result);
540       (void)ret;
541       assert(ret);
542       result = -result;
543
544    out:
545       return result;
546    }
547
548    static int32_t aia_visitor_get_rec_field_offset(Ast_Visitor_Aia *v,
549          Symbol_Type_Rec *rec, String field_name)
550    {
551       if (!symbol_table_node_get(rec->rec_sym_node, field_name,
552                string_hash_code(field_name), SYMBOL_PROPERTY_VAR))
553          return -1;
554
555       Vit_Record *r = aia_visitor_get_record(v, rec->unique_name);
556       assert(r);
557       Vit_Record_Field *f = vit_record_get_field(r, field_name);
558       if (f)
559          return f->field_offset;
560
561       Vector *ext = &rec->extended_types;
562       Symbol_Type_Struct *tmp;
563       VECTOR_FOR_EACH_ENTRY(ext, tmp) {
564          Symbol_Type_Rec *tmp_r = SYMBOL_TYPE_STRUCT_CONTAINER(tmp,
565                Symbol_Type_Rec);
566          int32_t ret = aia_visitor_get_rec_field_offset(v, tmp_r, field_name);
567          if (ret > -1) {
568             f = vit_record_get_field(r, tmp_r->unique_name);
569             assert(f);
570             return ret + f->field_offset;
571          }
572       }
573
574       fatal_error(S("Unexpected query for record field '%S'. Aborting...\n"));
575    }
576
577    static inline Uns vit_record_get_record_padding(Uns current_offset,
578          Vit_Record *oth_rec)
579    {
580       assert(oth_rec->alignment);
581       if (oth_rec->alignment == BYTE_ALIGNMENT) {
582          return 0;
583       } else { // allignment == LONG_ALIGNMENT
```

```
584         if (current_offset & LONG_ALIGN_MASK)
585            return LONG_ALIGNMENT - (current_offset & LONG_ALIGN_MASK);
586         else
587            return 0;
588      }
589   }
590
591   static inline void vit_record_insert_field(Vit_Record *r, Vit_Record_Field *f,
592         Ast_Visitor_Aia *v)
593   {
594      Vit_Record *oth;
595      Uns hash = string_hash_code(f->field_name);
596      assert(!hash_map_contains(&r->field_map, f->field_name, hash));
597      hash_map_insert(&r->field_map, &f->hash_slot, hash);
598      vector_append(&r->field_vector, f);
599      switch (f->field_type) {
600      case VIT_RECORD_FIELD_BYTE:
601         f->field_offset = r->byte_size;
602         r->byte_size += BYTE_ALIGNMENT;
603         break;
604      case VIT_RECORD_FIELD_LONG:
605         if (r->byte_size & LONG_ALIGN_MASK)
606            f->field_offset =
607                  (r->byte_size & ~LONG_ALIGN_MASK) + LONG_ALIGNMENT;
608         else
609            f->field_offset = r->byte_size;
610         r->byte_size = f->field_offset + LONG_ALIGNMENT;
611         break;
612      case VIT_RECORD_FIELD_RECORD:
613         oth = aia_visitor_get_record(v, f->field_type_name);
614         assert(oth);
615         Uns padding = vit_record_get_record_padding(r->byte_size, oth);
616         f->field_offset = r->byte_size + padding;
617         r->byte_size = f->field_offset + oth->byte_size;
618         break;
619      }
620   }
621
622   static bool vit_record_comparator(String search_rec_name,
623         Hash_Map_Slot *map_slot)
624   {
625      Vit_Record *map_rec = VIT_RECORD_OF(map_slot);
626      return !string_compare(search_rec_name, map_rec->identifier);
627   }
628
629   static inline void aia_visitor_insert_record(Ast_Visitor_Aia *v, Vit_Record *r,
630         Hash_Map *map)
631   {
632      Vit_Record_Field *tmp;
633      Vit_Record *ext;
634      Uns hash = string_hash_code(r->identifier);
635      assert(!hash_map_contains(map, r->identifier, hash));
636      if (vector_is_empty(&r->field_vector)) {
637         r->alignment = BYTE_ALIGNMENT;
638      } else {
639         tmp = vector_get(&r->field_vector, 0);
640         switch (tmp->field_type) {
641         case VIT_RECORD_FIELD_BYTE:
642            r->alignment = BYTE_ALIGNMENT;
643            break;
644         case VIT_RECORD_FIELD_LONG:
645            r->alignment = LONG_ALIGNMENT;
646            break;
647         case VIT_RECORD_FIELD_RECORD:
648            ext = aia_visitor_get_record(v, tmp->field_type_name);
649            r->alignment = ext->alignment;
650            break;
651         }
652      }
653      hash_map_insert(map, &r->hash_slot, hash);
654   }
655
656   static inline Vit_Record *aia_visitor_get_record(Ast_Visitor_Aia *v,
657         String iden)
```

```
658 {
659    Uns hash = string_hash_code(iden);
660    Hash_Map_Slot *slot;
661    slot = hash_map_get(&v->record_map, iden, hash);
662    if (slot)
663       return VIT_RECORD_OF(slot);
664    return NULL;
665 }
666
667 bool aia_struct_comparator(Vit_Record *search_struct, Hash_Map_Slot *map_slot);
668
669 static void rec_generate_record(Symbol_Type_Rec *rec,
670       Ast_Visitor_Aia *v);
671
672 static void rec_generate_extended_records(Symbol_Type_Rec *rec,
673       Ast_Visitor_Aia *v)
674 {
675    Symbol_Type_Rec *ext_r;
676    Symbol_Type_Struct *ext_s;
677    Vector *extended = &rec->extended_types;
678    VECTOR_FOR_EACH_ENTRY(extended, ext_s) {
679       ext_r = SYMBOL_TYPE_STRUCT_CONTAINER(ext_s, Symbol_Type_Rec);
680       rec_generate_record(ext_r, v);
681    }
682 }
683
684 static inline bool rec_has_vmt_func(Symbol_Type_Rec *rec)
685 {
686    Const_String iden;
687    VECTOR_FOR_EACH_ENTRY(&rec->func_identifiers, iden) {
688       if (!string_is_ctor(iden))
689          return true;
690    }
691
692    Vector *ext = &rec->extended_types;
693    Symbol_Type_Struct *tmp;
694    VECTOR_FOR_EACH_ENTRY(ext, tmp) {
695       if (rec_has_vmt_func(
696                SYMBOL_TYPE_STRUCT_CONTAINER(tmp, Symbol_Type_Rec)))
697          return true;
698    }
699    return false;
700 }
701
702 static inline bool rec_has_own_vmt(Symbol_Type_Rec *rec)
703 {
704    Symbol_Type_Struct *tmp;
705    Vector *ext = &rec->extended_types;
706    VECTOR_FOR_EACH_ENTRY(ext, tmp) {
707       if (rec_has_vmt_func(
708                SYMBOL_TYPE_STRUCT_CONTAINER(tmp, Symbol_Type_Rec)))
709          return false;
710    }
711
712    Const_String iden;
713    VECTOR_FOR_EACH_ENTRY(&rec->func_identifiers, iden) {
714       if (!string_is_ctor(iden))
715          return true;
716    }
717
718    return false;
719 }
720
721 /* Called to make sure that if some extended record is defining a function then
722  * the first extended record is defining a functon. */
723 static bool rec_order_extended(Symbol_Type_Rec *rec)
724 {
725    Uns size;
726    Symbol_Type_Rec *ext_r;
727    Symbol_Type_Struct *ext_s;
728    Vector *extended = &rec->extended_types;
729    size = vector_size(extended);
730    for (Uns i = 0; i < size; i++) {
731       ext_s = vector_get(extended, i);
```

```
732         ext_r = SYMBOL_TYPE_STRUCT_CONTAINER(ext_s, Symbol_Type_Rec);
733         if (rec_has_vmt_func(ext_r)) {
734            vector_swap(extended, 0, i);
735            return true;
736         }
737      }
738      return false;
739   }
740
741   static inline void rec_insert_vmt(Symbol_Type_Rec *rec, Vit_Record *r,
742         Ast_Visitor_Aia *v)
743   {
744      if (rec_has_own_vmt(rec)) {
745         Vit_Record_Field *field =
746               vit_record_field_alloc_simple(VIT_RECORD_FIELD_LONG,
747                     SYMBOL_TYPE_REC, VMT_STR);
748         vit_record_insert_field(r, field, v);
749      }
750   }
751
752   static void rec_insert_extended(Symbol_Type_Rec *rec, Vit_Record *r,
753         Ast_Visitor_Aia *v)
754   {
755      Vit_Record_Field *f;
756      Symbol_Type_Rec *ext_r;
757      Symbol_Type_Struct *ext_s;
758      Vector *extended = &rec->extended_types;
759      VECTOR_FOR_EACH_ENTRY(extended, ext_s) {
760         ext_r = SYMBOL_TYPE_STRUCT_CONTAINER(ext_s, Symbol_Type_Rec);
761         f = vit_record_field_alloc_record(ext_r->unique_name,
762               ext_r->unique_name);
763         vit_record_insert_field(r, f, v);
764         vector_append(&r->extended_sym_types, ext_s);
765      }
766   }
767
768   static void rec_insert_field(String iden, Symbol_Type_Struct *s,
769         Vit_Record *r, Ast_Visitor_Aia *v)
770   {
771      Vit_Record_Field *f;
772      Symbol_Type t = s->methods->get_type();
773      switch (t) {
774      case SYMBOL_TYPE_INT:
775      case SYMBOL_TYPE_STRING:
776      case SYMBOL_TYPE_ARY:
777      case SYMBOL_TYPE_REC:
778         f = vit_record_field_alloc_simple(VIT_RECORD_FIELD_LONG, t, iden);
779         break;
780      case SYMBOL_TYPE_BOOL:
781      case SYMBOL_TYPE_CHAR:
782         f = vit_record_field_alloc_simple(VIT_RECORD_FIELD_BYTE, t, iden);
783         break;
784      default:
785         aia_visitor_unexpected_symbol();
786      }
787      vit_record_insert_field(r, f, v);
788   }
789
790   static void rec_insert_fields(Symbol_Type_Rec *rec, Vit_Record *r,
791         Ast_Visitor_Aia *v)
792   {
793      Vector *ftype_vec = &rec->var_types;
794      Vector *fname_vec = &rec->var_identifiers;
795      Uns size = vector_size(fname_vec);
796      for (Uns i = 0; i < size; i++)
797         rec_insert_field(vector_get(fname_vec, i),
798               vector_get(ftype_vec, i), r, v);
799   }
800
801   static inline String get_func_long_name(Symbol_Table_Node *n, String func_iden)
802   {
803      Symbol *sym = symbol_table_node_lookup(n, func_iden, SYMBOL_PROPERTY_FUNC);
804      assert(sym);
805      return sym->unique_name;
```

```
806 }
807
808 static Vit_Record_Func_Entry *vit_record_func_entry_alloc(
809       Symbol_Type_Rec *rec, String func_name)
810 {
811    Vit_Record_Func_Entry *e = ALLOC_NEW(Vit_Record_Func_Entry);
812    e->func_name = func_name;
813    e->long_func_name = get_func_long_name(rec->rec_sym_node, func_name);
814    e->is_inserted = false;
815    e->owner = rec;
816    return e;
817 }
818
819 static inline void vit_record_func_entry_destroy(Vit_Record_Func_Entry *e)
820 {
821    free_mem(e);
822 }
823
824 static bool vit_record_func_entry_comparator(String search_func,
825       Hash_Map_Slot *map_slot)
826 {
827    Vit_Record_Func_Entry *fentry = VIT_RECORD_FUNC_ENTRY_OF(map_slot);
828    return !string_compare(fentry->func_name, search_func);
829 }
830
831 static inline String rec_get_func_iden(Symbol_Table_Node *orig_node,
832       String first_iden)
833 {
834    DLOG("\nAIA get func symbol: %S from node %p\n", first_iden, orig_node);
835    DEBUG(
836       Hash_Map_Slot *slot;
837       HASH_MAP_FOR_EACH(&orig_node->symbol_maps[SYMBOL_PROPERTY_FUNC],
838             slot) {
839          Symbol *func_sym = SYMBOL_OF_SLOT(slot);
840          DLOG("exisitng sym: %S\n", func_sym->identifier);
841       }
842    );
843
844    Symbol *func_sym = symbol_table_node_get(
845          orig_node,
846          first_iden,
847          string_hash_code(first_iden),
848          SYMBOL_PROPERTY_FUNC);
849    assert(func_sym);
850    return func_sym->identifier;
851 }
852
853 static void rec_insert_missing_vmt_funcs(Vit_Vmt *vmt,
854       Symbol_Table_Node *orig_node,
855       Hash_Map *func_map,
856       Symbol_Type_Rec *rec,
857       Ast_Visitor_Aia *v,
858       Uns byte_offset,
859       bool is_first_extended)
860 {
861    DLOG("insert missing vmts in %S\n", rec->rec_name);
862    Hash_Map_Slot *slot;
863    Vit_Record_Func_Entry *e;
864    String func_iden;
865    Vector *funcs = &rec->func_identifiers;
866    VECTOR_FOR_EACH_ENTRY(funcs, func_iden) {
867       if (string_is_ctor(func_iden))
868          continue;
869       func_iden = rec_get_func_iden(orig_node, func_iden);
870       slot = hash_map_get(func_map, func_iden, string_hash_code(func_iden));
871       assert(slot);
872       e = VIT_RECORD_FUNC_ENTRY_OF(slot);
873
874       if (is_first_extended) {
875          if (e->is_inserted)
876             continue;
877          vit_vmt_append_func(vmt, e->long_func_name, e->func_name,
878                byte_offset);
879          e->is_inserted = true;
```

```
880         } else if (e->owner != rec) {
881            Vit_Vmt_Trampoline *tramp = vit_vmt_trampoline_alloc(
882                  e->long_func_name, rec->unique_name, byte_offset);
883            String tname = aia_visitor_insert_trampoline(v, tramp);
884            vit_vmt_append_func(vmt, tname, e->func_name, byte_offset);
885         } else {
886            vit_vmt_append_func(vmt, e->long_func_name, e->func_name,
887                  byte_offset);
888            e->is_inserted = true;
889         }
890      }
891   }
892
893   static void rec_append_vmt(Vit_Vmt *vmt,
894         Symbol_Table_Node *orig_node,
895         Hash_Map *func_map,
896         Symbol_Type_Rec *rec,
897         Ast_Visitor_Aia *v,
898         Uns curr_offset,
899         bool is_first_extended)
900   {
901      Vector *vec;
902      String func_iden;
903      Uns hash;
904      Hash_Map_Slot *slot;
905
906      vec = &rec->func_identifiers;
907      VECTOR_FOR_EACH_ENTRY(vec, func_iden) {
908         if (string_is_ctor(func_iden))
909            continue;
910         func_iden = rec_get_func_iden(orig_node, func_iden);
911         hash = string_hash_code(func_iden);
912         if (hash_map_contains(func_map, func_iden, hash))
913            continue;
914         Vit_Record_Func_Entry *e = vit_record_func_entry_alloc(rec,
915               func_iden);
916         hash_map_insert(func_map, &e->hash_slot, hash);
917      }
918
919      vec = &rec->extended_types;
920      Uns size = vector_size(vec);
921      if (size) {
922         Symbol_Type_Rec *tmp = vector_get(vec, 0);
923
924         Vit_Record *tmp_vit = aia_visitor_get_record(v, tmp->unique_name);
925         curr_offset += vit_record_get_record_padding(curr_offset, tmp_vit);
926
927         vit_vmt_append_rec_vmt_offset(vmt, curr_offset,
928               vmt->current_func_offset);
929         rec_append_vmt(vmt, orig_node, func_map, tmp, v,
930               curr_offset, is_first_extended);
931         rec_insert_missing_vmt_funcs(vmt, orig_node, func_map, rec, v,
932               curr_offset, is_first_extended);
933
934         curr_offset += tmp_vit->byte_size;
935         for (Uns i = 1; i < size; i++) {
936            tmp = vector_get(vec, i);
937
938            tmp_vit = aia_visitor_get_record(v, tmp->unique_name);
939            curr_offset += vit_record_get_record_padding(curr_offset, tmp_vit);
940
941            if (rec_has_vmt_func(tmp))
942               vit_vmt_append_rec_vmt_offset(vmt, curr_offset,
943                     vmt->current_func_offset);
944            rec_append_vmt(vmt, orig_node, func_map, tmp, v,
945                  curr_offset, false);
946            curr_offset += tmp_vit->byte_size;
947         }
948      } else {
949         Vit_Record *tmp_vit = aia_visitor_get_record(v, rec->unique_name);
950         curr_offset += vit_record_get_record_padding(curr_offset, tmp_vit);
951
952         if (rec_has_vmt_func(rec))
953            vit_vmt_append_rec_vmt_offset(vmt, curr_offset,
```

```
954                 vmt->current_func_offset);
955         rec_insert_missing_vmt_funcs(vmt, orig_node, func_map, rec, v,
956               curr_offset, is_first_extended);
957     }
958
959     vec = &rec->func_identifiers;
960     VECTOR_FOR_EACH_ENTRY(vec, func_iden) {
961        if (string_is_ctor(func_iden))
962           continue;
963        func_iden = rec_get_func_iden(orig_node, func_iden);
964        hash = string_hash_code(func_iden);
965        slot = hash_map_get(func_map, func_iden, hash);
966        assert(slot);
967        Vit_Record_Func_Entry *e = VIT_RECORD_FUNC_ENTRY_OF(slot);
968        if (e->owner == rec) {
969           hash_map_remove(func_map, func_iden, hash);
970           vit_record_func_entry_destroy(e);
971        }
972     }
973 }
974
975 static void rec_generate_vmt(Symbol_Type_Rec *rec, Ast_Visitor_Aia *v,
976       Vit_Record *r)
977 {
978     if (vector_is_empty(&rec->func_types)) {
979        if (vector_is_empty(&rec->extended_types))
980           goto out;
981        Symbol_Type_Rec *tmp = SYMBOL_TYPE_STRUCT_CONTAINER(
982              vector_get(&rec->extended_types, 0), Symbol_Type_Rec);
983        if (vector_is_empty(&tmp->func_types))
984           goto out;
985     }
986
987
988     Vit_Vmt *vmt = vit_vmt_alloc(rec);
989     if (!vmt)
990        goto out;
991
992     HASH_MAP(func_map, (Hash_Map_Comparator)vit_record_func_entry_comparator);
993     rec_append_vmt(vmt, rec->rec_sym_node, &func_map, rec, v, 0, true);
994     Uns hash = string_hash_code(vmt->record_name);
995     assert(!hash_map_contains(&v->vmt_map, vmt->record_name, hash));
996     hash_map_insert(&v->vmt_map, &vmt->hash_slot, hash);
997
998     DEBUGT(aia-gen-full, vit_vmt_dump(vmt));
999
1000    hash_map_clear(&func_map);
1001
1002    r->initializer_name = vmt->initializer.initializer_name;
1003 out:;
1004 }
1005
1006 static void rec_generate_record(Symbol_Type_Rec *rec, Ast_Visitor_Aia *v)
1007 {
1008    Vit_Record *r;
1009    UNUSED Symbol_Type_Rec *ext_r;
1010
1011    /* Needed to handle case where the SAME record is declared and imported */
1012    if ((r = aia_visitor_get_record(v, rec->unique_name))) {
1013       if (rec->rec_sym_node->parent->type == SYMBOL_TABLE_NODE_IMPORT)
1014          return;
1015       Hash_Map_Slot *slot = hash_map_get(&v->vmt_map, rec->unique_name,
1016                string_hash_code(rec->unique_name));
1017       if (slot)
1018          VIT_VMT_OF(slot)->is_imported = false;
1019
1020       return;
1021    }
1022
1023    bool insert_vmt_field;
1024    if (rec_order_extended(rec))
1025       insert_vmt_field = false;
1026    else
1027       insert_vmt_field = true;
```

```
1028
1029        rec_generate_extended_records(rec, v);
1030
1031        r = vit_record_alloc(rec);
1032        if (insert_vmt_field)
1033           rec_insert_vmt(rec, r, v);
1034    #if 0
1035        if (vector_is_empty(&rec->extended_types)) {
1036           rec_insert_vmt(rec, r, v);
1037        } else {
1038           ext_r = SYMBOL_TYPE_STRUCT_CONTAINER(
1039                 vector_get(&rec->extended_types, 0), Symbol_Type_Rec);
1040           if (vector_is_empty(&ext_r->func_types))
1041              rec_insert_vmt(rec, r, v);
1042        }
1043    #endif
1044
1045        rec_insert_extended(rec, r, v);
1046        rec_insert_fields(rec, r, v);
1047
1048        aia_visitor_insert_record(v, r, &v->record_map);
1049
1050        rec_generate_vmt(rec, v, r);
1051
1052        DEBUGT(aia-gen-full, vit_record_dump(r));
1053    }
1054
1055    static Symbol_Type_Struct *on_symbol_type_ary_get_struct(
1056           Symbol_Type_Struct *ary)
1057    {
1058        while (ary->methods->get_type() == SYMBOL_TYPE_ARY)
1059           ary = SYMBOL_TYPE_STRUCT_CONTAINER(ary, Symbol_Type_Ary)->ary_type;
1060        return ary;
1061    }
1062
1063    static inline void on_symrec_gen_vitrec(Symbol_Type_Struct *sym_s,
1064           Ast_Visitor_Aia *v)
1065    {
1066        sym_s = on_symbol_type_ary_get_struct(sym_s);
1067
1068        Symbol_Type_Rec *rec;
1069        if (sym_s->methods->get_type() == SYMBOL_TYPE_REC) {
1070           rec = SYMBOL_TYPE_STRUCT_CONTAINER(sym_s, Symbol_Type_Rec);
1071           rec_generate_record(rec, v);
1072        }
1073    }
1074
1075    static inline uint8_t ast_expr_type_to_aia_operand_size(Ast_Expr_Type t)
1076    {
1077        switch (t) {
1078        case AST_EXPR_TYPE_CHAR:
1079        case AST_EXPR_TYPE_BOOL:
1080           return AIA_BYTE;
1081        default:
1082           return AIA_LONG;
1083        }
1084    }
1085
1086    static inline uint8_t symbol_type_struct_to_aia_operand_size(
1087           Symbol_Type_Struct *s)
1088    {
1089        switch (s->methods->get_type()) {
1090        case SYMBOL_TYPE_CHAR:
1091        case SYMBOL_TYPE_BOOL:
1092           return AIA_BYTE;
1093        default:
1094           return AIA_LONG;
1095        }
1096    }
1097
1098    static inline Aia_Operand *get_tmp_op(Ast_Visitor_Aia *v)
1099    {
1100        return aia_operand_tmp_reg_alloc(v->aia);
1101    }
```

```
1102
1103 static void mov_instr(Ast_Visitor_Aia *v, uint16_t instr_t, Aia_Operand *dest,
1104       Aia_Operand *src, uint8_t dest_type, uint8_t src_type)
1105 {
1106    Aia_Instr *instr = ___aia_1op_instr(v->aia, instr_t, dest_type, src_type,
1107          v->curr_loc);
1108    aia_instr_set_src_op(instr, 0, src);
1109    aia_instr_set_dest_op(instr, dest);
1110 }
1111
1112 static Aia_Operand *movs_tmp_instr(Ast_Visitor_Aia *v, Aia_Operand *op)
1113 {
1114    Aia_Operand *tmp_op = get_tmp_op(v);
1115    mov_instr(v, AIA_MOVS, tmp_op, op, AIA_LONG, AIA_BYTE);
1116    return tmp_op;
1117 }
1118
1119 static Aia_Operand *movz_tmp_instr(Ast_Visitor_Aia *v, Aia_Operand *op)
1120 {
1121    Aia_Operand *tmp_op = get_tmp_op(v);
1122    mov_instr(v, AIA_MOVZ, tmp_op, op, AIA_LONG, AIA_BYTE);
1123    return tmp_op;
1124 }
1125
1126 #define EXPRESSION_SETUP(v)                              \
1127    bool ___saved_next_iden_is_op = (v)->next_variable_iden_is_operand; \
1128    (v)->next_variable_iden_is_operand = true;
1129
1130 #define EXPRESSION_END(v) \
1131    (v)->next_variable_iden_is_operand = ___saved_next_iden_is_op;
1132
1133 #define EXPRESSION_ACCEPT_VISITOR(node, v)     \
1134    DEBUG(v->prev_result = NULL);              \
1135    DEBUG(v->aia_expr_type = AIA_EXPR_DEBUG);    \
1136    (node)->accept_visitor((node), AST_VISITOR_OF(v));  \
1137    assert(v->aia_expr_type != AIA_EXPR_DEBUG);    \
1138    assert(v->prev_result || v->aia_expr_type == AIA_EXPR_SHORT_CIRCUIT);
1139
1140 /* Possible operand types are int or char. */
1141 static void arith_binop(Ast_Visitor_Aia *v, Ast_Node_Binary *n,
1142       uint16_t op_type)
1143 {
1144    v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
1145
1146    Aia_Operand *lhs_r, *rhs_r;
1147
1148    EXPRESSION_SETUP(v);
1149
1150    Ast_Expr_Type res_type = ast_expr_binary_get_expr_type(
1151          AST_EXPR_BINARY_OF(n));
1152    DEBUG(
1153       switch (res_type) {
1154       case AST_EXPR_TYPE_INT:
1155       case AST_EXPR_TYPE_CHAR:
1156          break;
1157       default:
1158          assert(false);
1159       }
1160    );
1161
1162    EXPRESSION_ACCEPT_VISITOR(n->lhs, v);
1163    lhs_r = v->prev_result;
1164    if (v->prev_expr_type == AST_EXPR_TYPE_CHAR)
1165       lhs_r = movs_tmp_instr(v, lhs_r);
1166    else if (v->prev_expr_type == AST_EXPR_TYPE_BOOL)
1167       lhs_r = movz_tmp_instr(v, lhs_r);
1168
1169    EXPRESSION_ACCEPT_VISITOR(n->rhs, v);
1170    rhs_r = v->prev_result;
1171    if (v->prev_expr_type == AST_EXPR_TYPE_CHAR)
1172       rhs_r = movs_tmp_instr(v, rhs_r);
1173    else if (v->prev_expr_type == AST_EXPR_TYPE_BOOL)
1174       rhs_r = movz_tmp_instr(v, rhs_r);
1175
```

```
1176     uint8_t op_sizes = ast_expr_type_to_aia_operand_size(res_type);
1177
1178     Aia_Operand *tmp_op = get_tmp_op(v);
1179     Aia_Instr *add_instr = ___aia_2op_instr(v->aia, op_type,
1180           op_sizes, op_sizes, v->curr_loc);
1181     aia_instr_set_src_op(add_instr, 0, lhs_r);
1182     aia_instr_set_src_op(add_instr, 1, rhs_r);
1183     aia_instr_set_dest_op(add_instr, tmp_op);
1184
1185     v->prev_result = tmp_op;
1186     v->prev_expr_type = res_type;
1187     v->aia_expr_type = AIA_EXPR_STANDARD;
1188
1189     EXPRESSION_END(v);
1190 }
1191
1192 /* Get index of the function display with index_display_node as
1193  * body symbol table node.
1194  * func_node is the symbol table node of the function
1195  * which sets up the display. */
1196 static Int stn_display_index(Symbol_Table_Node *func_node,
1197       Symbol_Table_Node *index_display_node,
1198       Const_String *display_func_name_out)
1199 {
1200     while (func_node->type != SYMBOL_TABLE_NODE_FUNC) {
1201        assert(func_node->type == SYMBOL_TABLE_NODE_INTERMEDIATE ||
1202             func_node->type == SYMBOL_TABLE_NODE_REC);
1203        func_node = func_node->parent;
1204     }
1205
1206     Stn_Display_Preserve *p = stn_display_preserve_get(func_node);
1207
1208     Vector *v = &p->stn_displays;
1209     Int size = (Int)vector_size(v);
1210     for (Int i = 0; i < size; i++) {
1211        if (vector_get(v, i) == index_display_node) {
1212           Stn_Display_Preserve *tmp = stn_display_preserve_get(
1213                 index_display_node);
1214           assert(tmp);
1215           assert(tmp->func_name);
1216           *display_func_name_out = tmp->func_name;
1217           return i;
1218        }
1219     }
1220     assert(false);
1221     *display_func_name_out = NULL;
1222     return -1;
1223 }
1224
1225 static inline String generate_display_str(Uns display_idx)
1226 {
1227     return string_from_format(S(DISP_CSTR_PREFIX "%U"), display_idx);
1228 }
1229
1230 static inline void ___type_cast_byte_to_long(Ast_Visitor_Aia *v,
1231       Aia_Operand *char_op, Ast_Expr_Type long_type, uint32_t mov_type)
1232 {
1233     assert(long_type != AST_EXPR_TYPE_CHAR && long_type != AST_EXPR_TYPE_BOOL);
1234     Aia_Operand *tmp_op = get_tmp_op(v);
1235     mov_instr(v, mov_type, tmp_op, char_op, AIA_LONG, AIA_BYTE);
1236     v->prev_result = tmp_op;
1237     v->prev_expr_type = long_type;
1238     v->aia_expr_type = AIA_EXPR_STANDARD;
1239 }
1240
1241 static inline void type_cast_char_to_long(Ast_Visitor_Aia *v,
1242       Aia_Operand *char_op, Ast_Expr_Type long_type)
1243 {
1244     ___type_cast_byte_to_long(v, char_op, long_type, AIA_MOVS);
1245 }
1246
1247 static inline void type_cast_prev_char_to_long(Ast_Visitor_Aia *v,
1248       Ast_Expr_Type long_type)
1249 {
```

```
1250    type_cast_char_to_long(v, v->prev_result, long_type);
1251 }
1252
1253 static inline void type_cast_bool_to_long(Ast_Visitor_Aia *v,
1254       Aia_Operand *bool_op, Ast_Expr_Type long_type)
1255 {
1256    ___type_cast_byte_to_long(v, bool_op, long_type, AIA_MOVZ);
1257 }
1258
1259 static inline void type_cast_prev_bool_to_long(Ast_Visitor_Aia *v,
1260       Ast_Expr_Type long_type)
1261 {
1262    type_cast_bool_to_long(v, v->prev_result, long_type);
1263 }
1264
1265 static inline void type_cast_prev_long_to_char(Ast_Visitor_Aia *v)
1266 {
1267    assert(v->prev_expr_type != AST_EXPR_TYPE_CHAR &&
1268          v->prev_expr_type != AST_EXPR_TYPE_BOOL);
1269
1270    Aia_Operand *tmp_op = get_tmp_op(v);
1271    mov_instr(v, AIA_MOV, tmp_op, v->prev_result,
1272          AIA_BYTE, AIA_BYTE);
1273    v->prev_result = tmp_op;
1274    v->prev_expr_type = AST_EXPR_TYPE_CHAR;
1275    v->aia_expr_type = AIA_EXPR_STANDARD;
1276 }
1277
1278 static inline void type_cast_prev_to_bool(Ast_Visitor_Aia *v,
1279       uint8_t prev_op_size)
1280 {
1281    assert(v->prev_expr_type != AST_EXPR_TYPE_BOOL);
1282
1283    Aia_Instr *cmp_in = ___aia_2op_instr(v->aia, AIA_CMP, 0, prev_op_size,
1284          v->curr_loc);
1285    Aia_Operand *iconst0 = aia_operand_const_int_alloc(v->aia, 0);
1286    aia_instr_set_src_op(cmp_in, 0, v->prev_result);
1287    aia_instr_set_src_op(cmp_in, 1, iconst0);
1288
1289    Aia_Operand *tmp = get_tmp_op(v);
1290    Aia_Instr *setne_in = ___aia_0op_instr(v->aia, AIA_SETNE, AIA_BYTE,
1291          v->curr_loc);
1292    aia_instr_set_dest_op(setne_in, tmp);
1293
1294    v->prev_result = tmp;
1295    v->prev_expr_type = AST_EXPR_TYPE_BOOL;
1296    v->aia_expr_type = AIA_EXPR_STANDARD;
1297 }
1298
1299 static void ___if_stmt_expr(Ast_Visitor_Aia *v, uint8_t cmp_size,
1300       Aia_Operand *then_lbl, Aia_Operand *skip_lbl);
1301
1302 /* Assumes v->prev_result contains from record operand.
1303  * If opt_dest != NULL the result is moved to opt_dest operand. */
1304 static inline void type_cast_rec_rec(Ast_Visitor_Aia *v,
1305       Symbol_Type_Struct *to_s, Symbol_Type_Struct *from_s,
1306       Aia_Operand *opt_dest, bool null_check)
1307 {
1308    int32_t off = aia_visitor_get_rec_cast_offset(v, from_s, to_s);
1309    if (v->allocating_record) {
1310       v->allocated_record_offset += off;
1311       return;
1312    }
1313
1314    if (!off) {
1315       if (opt_dest)
1316          mov_instr(v, AIA_MOV, opt_dest, v->prev_result,
1317                AIA_LONG, AIA_LONG);
1318       return;
1319    }
1320
1321    Aia_Operand *result;
1322    if (!opt_dest)
1323       result = get_tmp_op(v);
```

```
1324     else
1325        result = opt_dest;
1326
1327     if (null_check) {
1328        /* AIA block structure:
1329         *      ( )
1330         *      / \
1331         *    (n) (d)
1332         *      \ /
1333         *      (e)   */
1334
1335        Aia_Operand *do_cast =
1336           aia_operand_tmp_label_alloc(v->aia, S("CAST.do"));
1337        Aia_Operand *is_null =
1338           aia_operand_tmp_label_alloc(v->aia, S("CAST.null"));
1339        Aia_Operand *end_lbl =
1340           aia_operand_tmp_label_alloc(v->aia, S("CAST.end"));
1341
1342        ___if_stmt_expr(v, AIA_LONG, do_cast, is_null);
1343
1344        ___aia_block(v->aia);
1345        ___aia_insert_jmp_label_instr(v->aia,
1346              aia_operand_label_get_name(do_cast));
1347
1348        Aia_Instr *add_in = ___aia_2op_instr(v->aia, AIA_ADD,
1349              AIA_LONG, AIA_LONG, v->curr_loc);
1350        aia_instr_set_dest_op(add_in, result);
1351        aia_instr_set_src_op(add_in, 0, v->prev_result);
1352        aia_instr_set_src_op(add_in, 1, aia_operand_const_int_alloc(v->aia, off));
1353
1354        Aia_Instr *jmp = ___aia_1op_instr(v->aia, ___AIA_JMP, -1, AIA_LONG,
1355              v->curr_loc);
1356        aia_instr_set_src_op(jmp, 0, end_lbl);
1357
1358        ___aia_block(v->aia);
1359        ___aia_insert_jmp_label_instr(v->aia,
1360              aia_operand_label_get_name(is_null));
1361
1362        Aia_Operand *iconst0 = aia_operand_const_int_alloc(v->aia, 0);
1363        mov_instr(v, AIA_MOV, result, iconst0, AIA_LONG, AIA_LONG);
1364
1365        jmp = ___aia_1op_instr(v->aia, ___AIA_JMP, -1, AIA_LONG, v->curr_loc);
1366        aia_instr_set_src_op(jmp, 0, end_lbl);
1367
1368        ___aia_block(v->aia);
1369        ___aia_insert_jmp_label_instr(v->aia,
1370              aia_operand_label_get_name(end_lbl));
1371
1372     } else {
1373        Aia_Instr *add_in = ___aia_2op_instr(v->aia, AIA_ADD,
1374              AIA_LONG, AIA_LONG, v->curr_loc);
1375
1376        aia_instr_set_dest_op(add_in, result);
1377        aia_instr_set_src_op(add_in, 0, v->prev_result);
1378        aia_instr_set_src_op(add_in, 1,
1379              aia_operand_const_int_alloc(v->aia, off));
1380     }
1381
1382     v->prev_result = result;
1383  }
1384
1385  static inline void cmp_to_bool_result(Ast_Visitor_Aia *v, uint8_t src_op_size,
1386        Aia_Operand *lhs, Aia_Operand *rhs, Aia_Operand *result_op,
1387        uint32_t set_instr)
1388  {
1389     DEBUG(
1390        switch (set_instr) {
1391        case AIA_SETE:
1392        case AIA_SETNE:
1393        case AIA_SETL:
1394        case AIA_SETG:
1395        case AIA_SETLE:
1396        case AIA_SETGE:
1397           break;
```

```
1398        default:
1399           fatal_error(S("Unexpecetd cmp_to_bool set instruction\n"));
1400        };
1401     );
1402     Aia_Instr *cmp_in = ___aia_2op_instr(v->aia, AIA_CMP, 0, src_op_size,
1403           v->curr_loc);
1404     aia_instr_set_src_op(cmp_in, 0, lhs);
1405     aia_instr_set_src_op(cmp_in, 1, rhs);
1406
1407     Aia_Instr *set_in = ___aia_0op_instr(v->aia, set_instr, AIA_BYTE,
1408           v->curr_loc);
1409     aia_instr_set_dest_op(set_in, result_op);
1410  }
1411
1412  static inline void mov_prev_to_bool(Ast_Visitor_Aia *v,
1413        uint8_t prev_op_size, Aia_Operand *result_op)
1414  {
1415     Aia_Operand *iconst0 = aia_operand_const_int_alloc(v->aia, 0);
1416     cmp_to_bool_result(v, prev_op_size, v->prev_result, iconst0,
1417           result_op, AIA_SETNE);
1418  }
1419
1420  /* Default AIA block structure:
1421   *    (p)
1422   *    / \
1423   *   | (c)
1424   *   | / \
1425   *  (t) (f)
1426   *    \ /
1427   *    (e)   */
1428  ASTVF_BEGIN(AST_EXPR_LOR, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
1429     uint8_t src_size;
1430     Aia_Instr *test_instr;
1431     Aia_Instr *jmp_instr;
1432
1433     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
1434
1435     EXPRESSION_SETUP(v);
1436
1437     Aia_Operand *lort;
1438     Aia_Operand *lorf;
1439
1440     Aia_Operand *lor_rhs = aia_operand_tmp_label_alloc(v->aia, S("LOR.rhs"));
1441
1442     Aia_Operand *prev_true = v->bool_true_label;
1443     Aia_Operand *prev_false = v->bool_false_label;
1444
1445     if (v->bool_true_label) {
1446        assert(v->bool_false_label);
1447        lort = v->bool_true_label;
1448        lorf = v->bool_false_label;
1449     } else {
1450        lort = aia_operand_tmp_label_alloc(v->aia, S("LOR.true"));
1451        lorf = aia_operand_tmp_label_alloc(v->aia, S("LOR.false"));
1452     }
1453
1454     v->bool_true_label = lort;
1455
1456     Aia_Operand *int_const0 = NULL;
1457
1458     v->bool_false_label = lor_rhs;
1459     EXPRESSION_ACCEPT_VISITOR(n->lhs, v);
1460     if (v->aia_expr_type == AIA_EXPR_STANDARD) {
1461        int_const0 = aia_operand_const_int_alloc(v->aia, 0);
1462        src_size = ast_expr_type_to_aia_operand_size(v->prev_expr_type);
1463
1464        test_instr = ___aia_2op_instr(v->aia, AIA_CMP, 0, src_size, v->curr_loc);
1465        aia_instr_set_src_op(test_instr, 0, v->prev_result);
1466        aia_instr_set_src_op(test_instr, 1, int_const0);
1467        jmp_instr = ___aia_2op_instr(v->aia, ___AIA_JNE, -1, AIA_LONG,
1468              v->curr_loc);
1469        aia_instr_set_src_op(jmp_instr, 0, lort);
1470        aia_instr_set_src_op(jmp_instr, 1, lor_rhs);
1471
```

```
1472     }
1473
1474     ___aia_block(v->aia);
1475     ___aia_insert_jmp_label_instr(v->aia,
1476           aia_operand_label_get_name(lor_rhs));
1477
1478     v->bool_false_label = lorf;
1479     EXPRESSION_ACCEPT_VISITOR(n->rhs, v);
1480     if (v->aia_expr_type == AIA_EXPR_STANDARD) {
1481        if (!int_const0)
1482           int_const0 = aia_operand_const_int_alloc(v->aia, 0);
1483        src_size = ast_expr_type_to_aia_operand_size(v->prev_expr_type);
1484
1485        test_instr = ___aia_2op_instr(v->aia, AIA_CMP, 0, src_size, v->curr_loc);
1486        aia_instr_set_src_op(test_instr, 0, v->prev_result);
1487        aia_instr_set_src_op(test_instr, 1, int_const0);
1488
1489        jmp_instr = ___aia_2op_instr(v->aia, ___AIA_JE, -1,
1490              AIA_LONG, v->curr_loc);
1491        aia_instr_set_src_op(jmp_instr, 0, lorf);
1492        aia_instr_set_src_op(jmp_instr, 1, lort);
1493     }
1494
1495     Aia_Operand *result_op = NULL;
1496     if (!prev_true) {
1497        if (!int_const0)
1498           int_const0 = aia_operand_const_int_alloc(v->aia, 0);
1499        Aia_Operand *int_const1 = aia_operand_const_int_alloc(v->aia, 1);
1500        Aia_Operand *lore = aia_operand_tmp_label_alloc(v->aia, S("LOR.end"));
1501
1502        result_op = get_tmp_op(v);
1503
1504        ___aia_block(v->aia);
1505        ___aia_insert_jmp_label_instr(v->aia,
1506              aia_operand_label_get_name(lort));
1507
1508        Aia_Instr *mov_instr = ___aia_1op_instr(v->aia, AIA_MOV,
1509              AIA_BYTE, AIA_BYTE, v->curr_loc);
1510        aia_instr_set_src_op(mov_instr, 0, int_const1);
1511        aia_instr_set_dest_op(mov_instr, result_op);
1512        jmp_instr = ___aia_1op_instr(v->aia, ___AIA_JMP, -1, AIA_LONG,
1513              v->curr_loc);
1514        aia_instr_set_src_op(jmp_instr, 0, lore);
1515
1516        ___aia_block(v->aia);
1517        ___aia_insert_jmp_label_instr(v->aia,
1518              aia_operand_label_get_name(lorf));
1519
1520        mov_instr = ___aia_1op_instr(v->aia, AIA_MOV, AIA_BYTE, AIA_BYTE,
1521              v->curr_loc);
1522        aia_instr_set_src_op(mov_instr, 0, int_const0);
1523        aia_instr_set_dest_op(mov_instr, result_op);
1524        jmp_instr = ___aia_1op_instr(v->aia, ___AIA_JMP, -1, AIA_LONG,
1525              v->curr_loc);
1526        aia_instr_set_src_op(jmp_instr, 0, lore);
1527
1528        ___aia_block(v->aia);
1529        ___aia_insert_jmp_label_instr(v->aia,
1530              aia_operand_label_get_name(lore));
1531     }
1532
1533     v->bool_true_label = prev_true;
1534     v->bool_false_label = prev_false;
1535
1536     v->prev_expr_type = AST_EXPR_TYPE_BOOL;
1537     v->aia_expr_type = AIA_EXPR_SHORT_CIRCUIT;
1538     v->prev_result = result_op;
1539
1540     EXPRESSION_END(v);
1541  ASTVF_END
1542
1543  /* Default AIA block structure:
1544   *    (p)
1545   *    / \
```

```
1546  *   | (c)
1547  *   | / \
1548  *  (f) (t)
1549  *    \ /
1550  *    (e)   */
1551 ASTVF_BEGIN(AST_EXPR_LAND, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
1552    uint8_t src_size;
1553    Aia_Instr *test_instr;
1554    Aia_Instr *jmp_instr;
1555
1556    v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
1557
1558    EXPRESSION_SETUP(v);
1559
1560    Aia_Operand *landf;
1561    Aia_Operand *landt;
1562
1563    Aia_Operand *land_rhs = aia_operand_tmp_label_alloc(v->aia, S("LAND.rhs"));
1564
1565    Aia_Operand *prev_true = v->bool_true_label;
1566    Aia_Operand *prev_false = v->bool_false_label;
1567
1568    if (v->bool_true_label) {
1569       assert(v->bool_false_label);
1570       landt = v->bool_true_label;
1571       landf = v->bool_false_label;
1572    } else {
1573       landt = aia_operand_tmp_label_alloc(v->aia, S("LAND.true"));
1574       landf = aia_operand_tmp_label_alloc(v->aia, S("LAND.false"));
1575    }
1576    v->bool_false_label = landf;
1577
1578    Aia_Operand *int_const0 = NULL;
1579
1580    v->bool_true_label = land_rhs;
1581    EXPRESSION_ACCEPT_VISITOR(n->lhs, v);
1582    if (v->aia_expr_type == AIA_EXPR_STANDARD) {
1583       int_const0 = aia_operand_const_int_alloc(v->aia, 0);
1584       src_size = ast_expr_type_to_aia_operand_size(v->prev_expr_type);
1585
1586       test_instr = ___aia_2op_instr(v->aia, AIA_CMP, 0, src_size,
1587             v->curr_loc);
1588       aia_instr_set_src_op(test_instr, 0, v->prev_result);
1589       aia_instr_set_src_op(test_instr, 1, int_const0);
1590       jmp_instr = ___aia_2op_instr(v->aia, ___AIA_JE, -1, AIA_LONG,
1591             v->curr_loc);
1592       aia_instr_set_src_op(jmp_instr, 0, landf);
1593       aia_instr_set_src_op(jmp_instr, 1, land_rhs);
1594    }
1595
1596    ___aia_block(v->aia);
1597    ___aia_insert_jmp_label_instr(v->aia,
1598          aia_operand_label_get_name(land_rhs));
1599
1600    v->bool_true_label = landt;
1601    EXPRESSION_ACCEPT_VISITOR(n->rhs, v);
1602    if (v->aia_expr_type == AIA_EXPR_STANDARD) {
1603       if (!int_const0)
1604          int_const0 = aia_operand_const_int_alloc(v->aia, 0);
1605       src_size = ast_expr_type_to_aia_operand_size(v->prev_expr_type);
1606
1607       test_instr = ___aia_2op_instr(v->aia, AIA_CMP, 0, src_size,
1608             v->curr_loc);
1609       aia_instr_set_src_op(test_instr, 0, v->prev_result);
1610       aia_instr_set_src_op(test_instr, 1, int_const0);
1611       jmp_instr = ___aia_2op_instr(v->aia, ___AIA_JNE, -1, AIA_LONG,
1612             v->curr_loc);
1613       aia_instr_set_src_op(jmp_instr, 0, landt);
1614       aia_instr_set_src_op(jmp_instr, 1, landf);
1615    }
1616
1617    Aia_Operand *result_op = NULL;
1618
1619    if (!prev_true) {
```

```
1620        if (!int_const0)
1621           int_const0 = aia_operand_const_int_alloc(v->aia, 0);
1622        Aia_Operand *int_const1 = aia_operand_const_int_alloc(v->aia, 1);
1623        Aia_Operand *lande = aia_operand_tmp_label_alloc(v->aia, S("LOR.end"));
1624
1625        result_op = get_tmp_op(v);
1626
1627        ___aia_block(v->aia);
1628        ___aia_insert_jmp_label_instr(v->aia,
1629              aia_operand_label_get_name(landf));
1630
1631        Aia_Instr *mov_instr = ___aia_lop_instr(v->aia, AIA_MOV,
1632              AIA_BYTE, AIA_BYTE, v->curr_loc);
1633        aia_instr_set_src_op(mov_instr, 0, int_const0);
1634        aia_instr_set_dest_op(mov_instr, result_op);
1635        jmp_instr = ___aia_lop_instr(v->aia, ___AIA_JMP, -1, AIA_LONG,
1636              v->curr_loc);
1637        aia_instr_set_src_op(jmp_instr, 0, lande);
1638
1639        ___aia_block(v->aia);
1640        ___aia_insert_jmp_label_instr(v->aia,
1641              aia_operand_label_get_name(landt));
1642
1643        mov_instr = ___aia_lop_instr(v->aia, AIA_MOV, AIA_BYTE, AIA_BYTE,
1644              v->curr_loc);
1645        aia_instr_set_src_op(mov_instr, 0, int_const1);
1646        aia_instr_set_dest_op(mov_instr, result_op);
1647        jmp_instr = ___aia_lop_instr(v->aia, ___AIA_JMP, -1, AIA_LONG,
1648              v->curr_loc);
1649        aia_instr_set_src_op(jmp_instr, 0, lande);
1650
1651        ___aia_block(v->aia);
1652        ___aia_insert_jmp_label_instr(v->aia,
1653              aia_operand_label_get_name(lande));
1654     }
1655
1656     v->bool_true_label = prev_true;
1657     v->bool_false_label = prev_false;
1658
1659     v->prev_expr_type = AST_EXPR_TYPE_BOOL;
1660     v->aia_expr_type = AIA_EXPR_SHORT_CIRCUIT;
1661     v->prev_result = result_op;
1662
1663     EXPRESSION_END(v);
1664  ASTVF_END
1665
1666  static inline void comparison_binop(Ast_Visitor_Aia *v, Ast_Node_Binary *n,
1667        uint32_t set_instr)
1668  {
1669     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
1670
1671     EXPRESSION_SETUP(v);
1672     Ast_Expr_Type lhs_t, rhs_t;
1673     Aia_Operand *lhs_r, *rhs_r;
1674
1675     EXPRESSION_ACCEPT_VISITOR(n->lhs, v);
1676     lhs_t = v->prev_expr_type;
1677     lhs_r = v->prev_result;
1678
1679     EXPRESSION_ACCEPT_VISITOR(n->rhs, v);
1680     rhs_t = v->prev_expr_type;
1681     rhs_r = v->prev_result;
1682
1683     Aia_Operand *tmp = get_tmp_op(v);
1684     switch (lhs_t) {
1685     case AST_EXPR_TYPE_CHAR:
1686        switch (rhs_t) {
1687        case AST_EXPR_TYPE_BOOL:
1688        case AST_EXPR_TYPE_CHAR:
1689           cmp_to_bool_result(v, AIA_BYTE, lhs_r, rhs_r, tmp, set_instr);
1690           break;
1691        default:
1692           type_cast_char_to_long(v, lhs_r, rhs_t);
1693           cmp_to_bool_result(v, AIA_LONG, v->prev_result,
```

```
1694                rhs_r, tmp, set_instr);
1695          break;
1696       }
1697       break;
1698
1699    case AST_EXPR_TYPE_BOOL:
1700       switch (rhs_t) {
1701       case AST_EXPR_TYPE_CHAR:
1702          /* Fall through. */
1703       case AST_EXPR_TYPE_BOOL:
1704          cmp_to_bool_result(v, AIA_BYTE, lhs_r, rhs_r, tmp, set_instr);
1705          break;
1706       default:
1707          type_cast_bool_to_long(v, lhs_r, rhs_t);
1708          cmp_to_bool_result(v, AIA_LONG, v->prev_result,
1709                rhs_r, tmp, set_instr);
1710          break;
1711       }
1712       break;
1713
1714    default:
1715       switch (rhs_t) {
1716       case AST_EXPR_TYPE_BOOL:
1717          type_cast_bool_to_long(v, v->prev_result, lhs_t);
1718          cmp_to_bool_result(v, AIA_LONG, lhs_r,
1719                v->prev_result, tmp, set_instr);
1720          break;
1721       case AST_EXPR_TYPE_CHAR:
1722          type_cast_char_to_long(v, rhs_r, lhs_t);
1723          cmp_to_bool_result(v, AIA_LONG, lhs_r,
1724                v->prev_result, tmp, set_instr);
1725          break;
1726
1727       default:
1728          cmp_to_bool_result(v, AIA_LONG, lhs_r, rhs_r, tmp, set_instr);
1729          break;
1730       }
1731       break;
1732    }
1733    v->prev_result = tmp;
1734
1735    EXPRESSION_END(v);
1736    v->prev_expr_type = ast_expr_binary_get_expr_type(AST_EXPR_BINARY_OF(n));
1737    v->aia_expr_type = AIA_EXPR_STANDARD;
1738 }
1739
1740 ASTVF_BEGIN(AST_EXPR_EQ, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
1741    comparison_binop(v, n, AIA_SETE);
1742 ASTVF_END
1743
1744 ASTVF_BEGIN(AST_EXPR_NEQ, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
1745    comparison_binop(v, n, AIA_SETNE);
1746 ASTVF_END
1747
1748 ASTVF_BEGIN(AST_EXPR_GT, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
1749    comparison_binop(v, n, AIA_SETG);
1750 ASTVF_END
1751
1752 ASTVF_BEGIN(AST_EXPR_LT, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
1753    comparison_binop(v, n, AIA_SETL);
1754 ASTVF_END
1755
1756 ASTVF_BEGIN(AST_EXPR_GTEQ, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
1757    comparison_binop(v, n, AIA_SETGE);
1758 ASTVF_END
1759
1760 ASTVF_BEGIN(AST_EXPR_LTEQ, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
1761    comparison_binop(v, n, AIA_SETLE);
1762 ASTVF_END
1763
1764 ASTVF_BEGIN(AST_EXPR_PLUS, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
1765    arith_binop(v, n, AIA_ADD);
1766 ASTVF_END
1767
```

```
1768 ASTVF_BEGIN(AST_EXPR_MINUS, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
1769    arith_binop(v, n, AIA_SUB);
1770 ASTVF_END
1771
1772 ASTVF_BEGIN(AST_EXPR_MUL, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
1773    arith_binop(v, n, AIA_IMUL);
1774 ASTVF_END
1775
1776 ASTVF_BEGIN(AST_EXPR_DIV, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
1777    arith_binop(v, n, AIA_IDIV);
1778 ASTVF_END
1779
1780 static NORETURN void type_cast_unexpected()
1781 {
1782    fatal_error(S("Unexpected type cast. Aborting...\n"));
1783 }
1784
1785 ASTVF_BEGIN(AST_EXPR_CAST, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
1786    v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
1787
1788    Ast_Expr_Type lhs_t;
1789    Symbol_Type_Struct *lhs_s, *rhs_s;
1790
1791    Symbol *prev_curr_sym = v->curr_symbol;
1792    Symbol *lhs_sym = symbol_table_get_from_location(
1793          ast_node_get_symbol_table_node(AST_NODE_OF(n)),
1794          ast_node_get_file_location(AST_NODE_OF(n)));
1795    v->curr_symbol = lhs_sym;
1796
1797    Symbol_Property saved_property = v->next_property;
1798    v->next_property = SYMBOL_PROPERTY_TYPE_DEF;
1799    n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
1800    v->next_property = saved_property;
1801
1802    lhs_s = lhs_sym->resolved_type;
1803    lhs_t = symbol_type_to_expr_type(lhs_s);
1804
1805    on_symrec_gen_vitrec(lhs_s, v);
1806
1807    EXPRESSION_SETUP(v);
1808    EXPRESSION_ACCEPT_VISITOR(n->rhs, v);
1809    rhs_s = v->prev_sym_type;
1810
1811    DEBUGT(def,
1812       if (v->allocating_record) {
1813          assert(v->prev_expr_type == AST_EXPR_TYPE_REC);
1814          assert(lhs_t == AST_EXPR_TYPE_REC);
1815       }
1816    );
1817
1818    switch (lhs_t) {
1819    case AST_EXPR_TYPE_INT:
1820       switch (v->prev_expr_type) {
1821       case AST_EXPR_TYPE_INT:
1822          break;
1823       case AST_EXPR_TYPE_CHAR:
1824          type_cast_prev_char_to_long(v, AST_EXPR_TYPE_INT);
1825          break;
1826       case AST_EXPR_TYPE_BOOL:
1827          type_cast_prev_bool_to_long(v, AST_EXPR_TYPE_INT);
1828          break;
1829       default:
1830          type_cast_unexpected();
1831       }
1832       break;
1833
1834    case AST_EXPR_TYPE_CHAR:
1835       switch (v->prev_expr_type) {
1836       case AST_EXPR_TYPE_INT:
1837          type_cast_prev_long_to_char(v);
1838          break;
1839       case AST_EXPR_TYPE_CHAR:
1840          break;
1841       case AST_EXPR_TYPE_BOOL:
```

```
1842            break;
1843         default:
1844            type_cast_unexpected();
1845         }
1846         break;
1847
1848      case AST_EXPR_TYPE_BOOL:
1849         switch (v->prev_expr_type) {
1850         case AST_EXPR_TYPE_CHAR:
1851            type_cast_prev_to_bool(v, AIA_BYTE);
1852            break;
1853         case AST_EXPR_TYPE_BOOL:
1854            break;
1855         default:
1856            type_cast_prev_to_bool(v, AIA_LONG);
1857            break;
1858         }
1859         break;
1860
1861      case AST_EXPR_TYPE_STRING:
1862         switch (v->prev_expr_type) {
1863         case AST_EXPR_TYPE_NULL:
1864            break;
1865         case AST_EXPR_TYPE_STRING:
1866            break;
1867         case AST_EXPR_TYPE_ARY:
1868            break;
1869         default:
1870            type_cast_unexpected();
1871            break;
1872         }
1873         break;
1874
1875      case AST_EXPR_TYPE_REC:
1876         switch (v->prev_expr_type) {
1877         case AST_EXPR_TYPE_NULL:
1878            break;
1879         case AST_EXPR_TYPE_REC:
1880            type_cast_rec_rec(v, lhs_s, rhs_s, NULL, true);
1881            break;
1882         default:
1883            type_cast_unexpected();
1884            break;
1885         }
1886         break;
1887
1888      case AST_EXPR_TYPE_ARY:
1889         switch (v->prev_expr_type) {
1890         case AST_EXPR_TYPE_NULL:
1891            break;
1892         case AST_EXPR_TYPE_ARY:
1893            break;
1894         default:
1895            type_cast_unexpected();
1896            break;
1897         }
1898         break;
1899
1900      default:
1901         type_cast_unexpected();
1902      }
1903
1904      EXPRESSION_END(v);
1905      v->prev_expr_type = ast_expr_binary_get_expr_type(AST_EXPR_BINARY_OF(n));
1906      v->aia_expr_type = AIA_EXPR_STANDARD;
1907      v->prev_sym_type = lhs_s;
1908      v->curr_symbol = prev_curr_sym;
1909   ASTVF_END
1910
1911   ASTVF_BEGIN(AST_EXPR_LNOT, Ast_Visitor_Aia, v, Ast_Node_Unary, n)
1912      v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
1913
1914      n->expr->accept_visitor(n->expr, AST_VISITOR_OF(v));
1915
```

```
1916     uint8_t src_size = ast_expr_type_to_aia_operand_size(v->prev_expr_type);
1917
1918     Aia_Instr *cmp_in = ___aia_2op_instr(v->aia, AIA_CMP, 0, src_size,
1919           v->curr_loc);
1920     Aia_Operand *iconst0 = aia_operand_const_int_alloc(v->aia, 0);
1921     aia_instr_set_src_op(cmp_in, 0, v->prev_result);
1922     aia_instr_set_src_op(cmp_in, 1, iconst0);
1923
1924     Aia_Operand *tmp = get_tmp_op(v);
1925     Aia_Instr *sete_in = ___aia_0op_instr(v->aia, AIA_SETE, AIA_BYTE,
1926           v->curr_loc);
1927     aia_instr_set_dest_op(sete_in, tmp);
1928
1929     v->prev_result = tmp;
1930     v->prev_expr_type = AST_EXPR_TYPE_BOOL;
1931     v->aia_expr_type = AIA_EXPR_STANDARD;
1932 ASTVF_END
1933
1934 static void cmp0_skip_on_false(Ast_Visitor_Aia *v, uint8_t cmp_size,
1935       Aia_Operand *then_lbl, Aia_Operand *skip_lbl, uint16_t jmp_instr_type)
1936 {
1937     Aia_Operand *iconst0 = aia_operand_const_int_alloc(v->aia, 0);
1938     Aia_Instr *cmp = ___aia_2op_instr(v->aia, AIA_CMP, 0, cmp_size,
1939           v->curr_loc);
1940     aia_instr_set_src_op(cmp, 0, v->prev_result);
1941     aia_instr_set_src_op(cmp, 1, iconst0);
1942     Aia_Instr *jmp = ___aia_2op_instr(v->aia, jmp_instr_type, -1, AIA_LONG,
1943           v->curr_loc);
1944     aia_instr_set_src_op(jmp, 0, skip_lbl);
1945     aia_instr_set_src_op(jmp, 1, then_lbl);
1946 }
1947
1948 static void long_integer_abs(Ast_Visitor_Aia *v)
1949 {
1950     Aia_Operand *result = get_tmp_op(v);
1951
1952     /* AIA block structure:
1953      *      ( )
1954      *      / \
1955      *    (n) (p)
1956      *      \ /
1957      *      (e)   */
1958
1959     Aia_Operand *do_neg =
1960        aia_operand_tmp_label_alloc(v->aia, S("ABS.neg"));
1961     Aia_Operand *skip_neg =
1962        aia_operand_tmp_label_alloc(v->aia, S("ABS.pos"));
1963     Aia_Operand *end_lbl =
1964        aia_operand_tmp_label_alloc(v->aia, S("ABS.end"));
1965
1966     cmp0_skip_on_false(v, AIA_LONG, do_neg, skip_neg, ___AIA_JGE);
1967
1968     ___aia_block(v->aia);
1969     ___aia_insert_jmp_label_instr(v->aia,
1970           aia_operand_label_get_name(do_neg));
1971
1972     Aia_Instr *neg_in = ___aia_1op_instr(v->aia, AIA_NEG,
1973           AIA_LONG, AIA_LONG, v->curr_loc);
1974     aia_instr_set_dest_op(neg_in, result);
1975     aia_instr_set_src_op(neg_in, 0, v->prev_result);
1976
1977     Aia_Instr *jmp = ___aia_1op_instr(v->aia, ___AIA_JMP, -1, AIA_LONG,
1978           v->curr_loc);
1979     aia_instr_set_src_op(jmp, 0, end_lbl);
1980
1981     ___aia_block(v->aia);
1982     ___aia_insert_jmp_label_instr(v->aia,
1983           aia_operand_label_get_name(skip_neg));
1984
1985     mov_instr(v, AIA_MOV, result, v->prev_result, AIA_LONG, AIA_LONG);
1986
1987     jmp = ___aia_1op_instr(v->aia, ___AIA_JMP, -1, AIA_LONG, v->curr_loc);
1988     aia_instr_set_src_op(jmp, 0, end_lbl);
1989
```

```
1990     ___aia_block(v->aia);
1991     ___aia_insert_jmp_label_instr(v->aia,
1992           aia_operand_label_get_name(end_lbl));
1993
1994     v->prev_result = result;
1995  }
1996
1997  ASTVF_BEGIN(AST_EXPR_ABS, Ast_Visitor_Aia, v, Ast_Node_Unary, n)
1998     Aia_Operand *iconst;
1999     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
2000
2001     n->expr->accept_visitor(n->expr, AST_VISITOR_OF(v));
2002
2003     switch (v->prev_expr_type) {
2004     case AST_EXPR_TYPE_BOOL:
2005        v->prev_result = movz_tmp_instr(v, v->prev_result);
2006        long_integer_abs(v);
2007        break;
2008
2009     case AST_EXPR_TYPE_CHAR:
2010        v->prev_result = movs_tmp_instr(v, v->prev_result);
2011        /* Fall through. */
2012     case AST_EXPR_TYPE_INT:
2013        long_integer_abs(v);
2014        break;
2015
2016     case AST_EXPR_TYPE_ARY:
2017        iconst = aia_operand_const_int_alloc(v->aia, -4);
2018        v->prev_result = aia_operand_addr_ref_alloc(v->aia,
2019              NULL,
2020              iconst,
2021              v->prev_result,
2022              NULL,
2023              NULL);
2024        break;
2025     default:
2026        fatal_error(S("Unexpected " QFY("| |") "-operator operand\n"));
2027     }
2028
2029     v->prev_expr_type = AST_EXPR_TYPE_INT;
2030     v->aia_expr_type = AIA_EXPR_STANDARD;
2031  ASTVF_END
2032
2033  ASTVF_BEGIN(AST_EXPR_INT, Ast_Visitor_Aia, v, Ast_Expr_Int, n)
2034     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
2035     v->prev_result = aia_operand_const_int_alloc(v->aia, n->val);
2036     v->prev_expr_type = AST_EXPR_TYPE_INT;
2037     v->aia_expr_type = AIA_EXPR_STANDARD;
2038  ASTVF_END
2039
2040  ASTVF_BEGIN(AST_EXPR_BOOL, Ast_Visitor_Aia, v, Ast_Expr_Bool, n)
2041     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
2042     v->prev_result = aia_operand_const_int_alloc(v->aia, n->val);
2043     v->prev_expr_type = AST_EXPR_TYPE_BOOL;
2044     v->aia_expr_type = AIA_EXPR_STANDARD;
2045  ASTVF_END
2046
2047  ASTVF_BEGIN(AST_EXPR_NULL, Ast_Visitor_Aia, v, Ast_Expr_Null, n)
2048     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
2049     v->prev_result = aia_operand_const_int_alloc(v->aia, 0);
2050     v->prev_expr_type = AST_EXPR_TYPE_NULL;
2051     v->aia_expr_type = AIA_EXPR_STANDARD;
2052  ASTVF_END
2053
2054  static void variable_iden_record_field_ref(Ast_Visitor_Aia *v,
2055        String field_name, Symbol_Type_Rec *selfrec, Aia_Operand *selfop)
2056  {
2057     int32_t field_offset;
2058     Aia_Operand *off_op, *ref_op;
2059     field_offset = aia_visitor_get_rec_field_offset(v,
2060           selfrec, field_name);
2061     off_op = aia_operand_const_int_alloc(v->aia,
2062           field_offset);
2063     ref_op = aia_operand_addr_ref_alloc(v->aia,
```

```
2064            NULL, off_op, selfop, NULL, NULL);
2065    v->prev_result = ref_op;
2066 }
2067
2068 static void variable_iden_record_vmt_mov(Ast_Visitor_Aia *v,
2069       Aia_Operand *selfop)
2070 {
2071    Aia_Operand *ref_op, *tmp;
2072    tmp = get_tmp_op(v);
2073    ref_op = aia_operand_addr_ref_alloc(v->aia,
2074          NULL, NULL, selfop, NULL, NULL);
2075    mov_instr(v, AIA_MOV, tmp, ref_op, AIA_LONG, AIA_LONG);
2076    v->prev_result = tmp;
2077 }
2078
2079 static Aia_Operand *get_curr_display_selfptr(Ast_Visitor_Aia *v)
2080 {
2081    Aia_Operand *selfptr;
2082
2083    Symbol_Table_Node *tmp = v->curr_display->sym_node;
2084    while (tmp->parent->type != SYMBOL_TABLE_NODE_REC)
2085       tmp = tmp->parent;
2086
2087    if (tmp == v->curr_display->sym_node) {
2088       selfptr = v->aia->record_self_ptr;
2089    } else {
2090       Int display;
2091       Const_String display_func_name;
2092       display = stn_display_index(
2093             v->curr_display->sym_node->parent,
2094             tmp,
2095             &display_func_name);
2096
2097       Aia_Operand *tmp_disp = ___aia_operand_local_ref_alloc(
2098             v->aia, generate_display_str(display) /*, AIA_LONG */);
2099       Aia_Operand *tmp_reg = aia_operand_tmp_reg_alloc(v->aia);
2100       mov_instr(v, AIA_MOV, tmp_reg, tmp_disp, AIA_LONG,
2101             AIA_LONG);
2102       selfptr = aia_operand_display_ref_alloc(v->aia,
2103             tmp_reg, SELF_STR, display_func_name /*, AIA_LONG */);
2104    }
2105
2106    return selfptr;
2107 }
2108
2109 ASTVF_BEGIN(AST_VARIABLE_IDEN, Ast_Visitor_Aia, v, Ast_Variable_Iden, n)
2110    v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
2111
2112    Symbol_Table_Node *sym_node;
2113    if (v->dot_ref_record) {
2114       sym_node = v->dot_ref_record->rec_sym_node;
2115    } else {
2116       sym_node = ast_node_get_symbol_table_node(AST_NODE_OF(n));
2117    }
2118
2119    Symbol *prev_curr_sym = v->curr_symbol;
2120    Symbol *sym;
2121    if (v->next_property != SYMBOL_PROPERTY_VAR) {
2122       sym = symbol_table_node_lookup(sym_node, n->iden, v->next_property);
2123    } else {
2124       DLOG("var iden: %S from node %p\n", n->iden, sym_node);
2125       sym = symbol_table_node_lookup_var(sym_node, n->iden,
2126             ast_node_get_file_location(AST_NODE_OF(n)));
2127    }
2128    assert(sym);
2129    v->curr_symbol = sym;
2130
2131    on_symrec_gen_vitrec(sym->resolved_type, v);
2132
2133    if (v->next_variable_iden_is_operand) {
2134       Symbol_Table_Node *var_root = sym->sym_node;
2135       while (var_root->type == SYMBOL_TABLE_NODE_INTERMEDIATE)
2136          var_root = var_root->parent;
2137
```

```
2138        if (var_root->type == SYMBOL_TABLE_NODE_GLOBAL ||
2139              var_root->type == SYMBOL_TABLE_NODE_IMPORT) {
2140           assert(!v->dot_ref_record);
2141           v->prev_result = aia_operand_label_alloc(v->aia,
2142                 sym->unique_name, 0);
2143
2144        } else if (var_root->type == SYMBOL_TABLE_NODE_FUNC) {
2145           assert(!v->dot_ref_record);
2146
2147           if (sym->resolved_type->methods->get_type() == SYMBOL_TYPE_FUNC) {
2148              v->prev_result = aia_operand_label_alloc(v->aia,
2149                    sym->unique_name, 0);
2150           } else {
2151              UNUSED uint8_t var_size = symbol_type_struct_to_aia_operand_size(
2152                    sym->resolved_type);
2153
2154              if (var_root == v->curr_display->sym_node) {
2155                 v->prev_result = aia_operand_local_ref_alloc(v->aia,
2156                       sym->unique_name /* , var_size */);
2157              } else {
2158                 Const_String func_name;
2159                 Int idx = stn_display_index(
2160                       v->curr_display->sym_node->parent,
2161                       var_root,
2162                       &func_name);
2163                 Aia_Operand *tmp_disp = ___aia_operand_local_ref_alloc(
2164                       v->aia, generate_display_str(idx) /*, AIA_LONG */);
2165                 /*
2166                 Aia_Operand *tmp_reg = aia_operand_tmp_reg_alloc(v->aia);
2167                 mov_instr(v, AIA_MOV, tmp_reg, tmp_disp, AIA_LONG,
2168                       AIA_LONG);
2169                 */
2170                 v->prev_result = aia_operand_display_ref_alloc(v->aia,
2171                       tmp_disp, sym->unique_name, func_name
2172                       /*, var_size */);
2173              }
2174           }
2175        } else { // SYMBOL_TABLE_NODE_REC
2176           assert(v->dot_ref_record || v->curr_record_selfptr);
2177           assert(v->curr_record_selfptr || v->prev_result);
2178
2179           Symbol_Type_Struct *field = sym->resolved_type;
2180
2181           Aia_Operand *selfptr;
2182           Symbol_Type_Rec *selfrec;
2183
2184           bool is_direct_ref;
2185           if (v->dot_ref_record) {
2186              selfptr = v->prev_result;
2187              is_direct_ref = v->dot_ref_is_direct;
2188              if (is_direct_ref) {
2189                 if (v->alloc_record_selfptr) {
2190                    selfrec = v->alloc_record_selfptr;
2191                    v->alloc_record_selfptr = NULL;
2192                 } else {
2193                    selfrec = v->curr_record_selfptr;
2194                 }
2195              } else {
2196                 selfrec = v->dot_ref_record;
2197              }
2198           } else {
2199              is_direct_ref = false;
2200              selfptr = get_curr_display_selfptr(v);
2201              selfrec = v->curr_record_selfptr;
2202           }
2203
2204           switch (field->methods->get_type()) {
2205           case SYMBOL_TYPE_FUNC:;
2206              int32_t cast_offset;
2207              if (!is_direct_ref) {
2208                 variable_iden_record_vmt_mov(v, selfptr);
2209                 // v->prev_result is pointing at VMT at the moment.
2210
2211                 Hash_Map_Slot *vmt_slot = hash_map_get(&v->vmt_map,
```

```
2212                     selfrec->unique_name,
2213                     string_hash_code(selfrec->unique_name));
2214                Vit_Vmt *vmt = VIT_VMT_OF(vmt_slot);
2215                Hash_Map_Slot *fe_slot = hash_map_get(&vmt->func_off_map,
2216                     sym->identifier,
2217                     string_hash_code(sym->identifier));
2218                Vit_Func_Off_Entry *fe = VIT_FUNC_OFF_ENTRY_OF(fe_slot);
2219
2220                Aia_Operand *disp = aia_operand_const_int_alloc(v->aia,
2221                     fe->func_offset);
2222                v->prev_result = aia_operand_addr_ref_alloc(v->aia,
2223                     NULL, disp, v->prev_result, NULL, NULL);
2224                cast_offset = (int32_t)fe->cast_offset;
2225             } else {
2226                v->prev_result = aia_operand_label_alloc(v->aia,
2227                     sym->unique_name, 0);
2228                cast_offset = aia_visitor_get_rec_cast_offset(v,
2229                     SYMBOL_TYPE_STRUCT_OF_CONTAINER(selfrec),
2230                     SYMBOL_TYPE_STRUCT_OF_CONTAINER(v->dot_ref_record)
2231                     );
2232             }
2233
2234             if (cast_offset) {
2235                v->func_call_selfptr = get_tmp_op(v);
2236                Aia_Instr *add_in = ___aia_2op_instr(v->aia, AIA_ADD,
2237                     AIA_LONG, AIA_LONG, v->curr_loc);
2238                aia_instr_set_dest_op(add_in, v->func_call_selfptr);
2239                aia_instr_set_src_op(add_in, 0,
2240                     aia_operand_const_int_alloc(v->aia,
2241                        cast_offset));
2242                aia_instr_set_src_op(add_in, 1, selfptr);
2243             } else {
2244                v->func_call_selfptr = selfptr;
2245             }
2246             break;
2247
2248          default:
2249             variable_iden_record_field_ref(v, sym->identifier,
2250                   selfrec, selfptr);
2251             break;
2252          }
2253       }
2254
2255       v->dot_ref_record = NULL;
2256       v->prev_variable_result = v->prev_result;
2257       v->prev_sym_type = sym->resolved_type;
2258       v->prev_expr_type = ast_variable_iden_get_expr_type(n);
2259    } else {
2260       DEBUG(v->prev_sym_type = NULL; v->prev_result = NULL);
2261    }
2262
2263    v->aia_expr_type = AIA_EXPR_STANDARD;
2264    v->prev_iden = n->iden;
2265    v->curr_symbol = prev_curr_sym;
2266 ASTVF_END
2267
2268 ASTVF_BEGIN(AST_EXPR_ARY_REF, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
2269    Symbol_Type_Ary *ary;
2270    Aia_Operand *ary_op;
2271    Ast_Expr_Type result_type;
2272
2273    v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
2274
2275    EXPRESSION_SETUP(v);
2276
2277    EXPRESSION_ACCEPT_VISITOR(n->lhs, v);
2278    ary_op = v->prev_result;
2279    assert(v->prev_sym_type->methods->get_type() == SYMBOL_TYPE_ARY ||
2280          v->prev_sym_type->methods->get_type() == SYMBOL_TYPE_STRING);
2281
2282    if (v->prev_sym_type->methods->get_type() == SYMBOL_TYPE_ARY)
2283       ary = SYMBOL_TYPE_STRUCT_CONTAINER(v->prev_sym_type, Symbol_Type_Ary);
2284    else
2285       ary = NULL;
```

```
2286
2287        EXPRESSION_ACCEPT_VISITOR(n->rhs, v);
2288        if (v->prev_expr_type == AST_EXPR_TYPE_CHAR)
2289           type_cast_prev_char_to_long(v, AST_EXPR_TYPE_INT);
2290        else if (v->prev_expr_type == AST_EXPR_TYPE_BOOL)
2291           type_cast_prev_bool_to_long(v, AST_EXPR_TYPE_INT);
2292        // v->prev_result == long array index at the moment
2293
2294        result_type = ast_expr_binary_get_expr_type(AST_EXPR_BINARY_OF(n));
2295
2296        Aia_Operand *scale;
2297        if (ast_expr_type_to_aia_operand_size(result_type) == AIA_LONG)
2298           scale = aia_operand_const_int_alloc(v->aia, 4);
2299        else
2300           scale = NULL;
2301
2302        v->prev_result = aia_operand_addr_ref_alloc(v->aia,
2303              NULL, NULL, ary_op, v->prev_result, scale);
2304
2305        EXPRESSION_END(v);
2306        if (ary)
2307           v->prev_sym_type = ary->ary_type;
2308        v->prev_expr_type = result_type;
2309        v->aia_expr_type = AIA_EXPR_STANDARD;
2310     ASTVF_END
2311
2312     static NORETURN void func_call_unexpected_arg()
2313     {
2314        fatal_error(S("Unexpected function call argument. Aborting...\n"));
2315     }
2316
2317     static void func_call_set_prev_result(Ast_Visitor_Aia *v,
2318           Ast_Expr_Type param_type, Symbol_Type_Struct *param_s,
2319           Symbol_Type_Struct *arg_s)
2320     {
2321        switch (v->prev_expr_type) {
2322        case AST_EXPR_TYPE_INT:
2323           switch (param_type) {
2324           case AST_EXPR_TYPE_INT:
2325              break;
2326           case AST_EXPR_TYPE_BOOL:
2327              type_cast_prev_to_bool(v, AIA_LONG);
2328              type_cast_prev_bool_to_long(v, AST_EXPR_TYPE_INT);
2329              break;
2330           case AST_EXPR_TYPE_CHAR:
2331              break;
2332           default:
2333              func_call_unexpected_arg();
2334           }
2335           break;
2336
2337        case AST_EXPR_TYPE_BOOL:
2338           type_cast_prev_bool_to_long(v, AST_EXPR_TYPE_INT);
2339           break;
2340
2341        case AST_EXPR_TYPE_CHAR:
2342           switch (param_type) {
2343           case AST_EXPR_TYPE_BOOL:
2344              type_cast_prev_to_bool(v, AIA_BYTE);
2345              type_cast_prev_bool_to_long(v, AST_EXPR_TYPE_INT);
2346              break;
2347           case AST_EXPR_TYPE_CHAR:
2348              /* Fall. */
2349           case AST_EXPR_TYPE_INT:
2350              type_cast_prev_char_to_long(v, AST_EXPR_TYPE_INT);
2351              break;
2352           default:
2353              func_call_unexpected_arg();
2354           }
2355           break;
2356
2357        case AST_EXPR_TYPE_STRING:
2358           switch (param_type) {
2359           case AST_EXPR_TYPE_BOOL:
```

```
2360            type_cast_prev_to_bool(v, AIA_LONG);
2361            type_cast_prev_bool_to_long(v, AST_EXPR_TYPE_INT);
2362            break;
2363         case AST_EXPR_TYPE_STRING:
2364            break;
2365         default:
2366            func_call_unexpected_arg();
2367         }
2368         break;
2369
2370      case AST_EXPR_TYPE_ARY:
2371         switch (param_type) {
2372         case AST_EXPR_TYPE_BOOL:
2373            type_cast_prev_to_bool(v, AIA_LONG);
2374            type_cast_prev_bool_to_long(v, AST_EXPR_TYPE_INT);
2375            break;
2376         case AST_EXPR_TYPE_ARY:
2377            break;
2378         default:
2379            func_call_unexpected_arg();
2380         }
2381         break;
2382
2383      case AST_EXPR_TYPE_NULL:
2384         break;
2385
2386      case AST_EXPR_TYPE_REC:
2387         switch (param_type) {
2388         case AST_EXPR_TYPE_BOOL:
2389            type_cast_prev_to_bool(v, AIA_LONG);
2390            type_cast_prev_bool_to_long(v, AST_EXPR_TYPE_INT);
2391            break;
2392         case AST_EXPR_TYPE_REC:
2393            type_cast_rec_rec(v, param_s, arg_s, NULL, true);
2394            break;
2395         default:
2396            func_call_unexpected_arg();
2397         }
2398         break;
2399
2400      default:
2401         fatal_error(S("unexpected function call arg. Aborting...\n"));
2402      }
2403   }
2404
2405   ASTVF_BEGIN(AST_EXPR_FUNC_CALL, Ast_Visitor_Aia, v, Ast_Expr_Func_Call, n)
2406      v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
2407
2408      Vector *arguments, *parameters;
2409      Ast_Node *arg_node;
2410      Symbol_Type_Struct *param;
2411      Aia_Operand *call_operand;
2412
2413      EXPRESSION_SETUP(v);
2414
2415      Symbol_Property saved_property = v->next_property;
2416      v->next_property = SYMBOL_PROPERTY_FUNC;
2417      // We visit VARIABLE_IDEN node now. It might need v->prev_result
2418      // so we don't use EXPRESSION_ACCEPT_VISITOR() here.
2419      n->identifier->accept_visitor(n->identifier, AST_VISITOR_OF(v));
2420      v->next_property = saved_property;
2421      call_operand = v->prev_result;
2422
2423      Symbol_Type_Func *func = ast_expr_func_call_get_func(n);
2424
2425      uint8_t ret_size = symbol_type_struct_to_aia_operand_size(
2426            func->return_type);
2427
2428      arguments = n->arguments;
2429      parameters = &func->param_types;
2430      Uns size = vector_size(parameters);
2431      assert(vector_size(arguments) == size);
2432
2433      VECTOR(tmp_arg_ops);
```

```
2434
2435     Aia_Operand *tmp_arg;
2436     if (v->func_call_selfptr) {
2437        tmp_arg = aia_operand_tmp_reg_alloc(v->aia);
2438        mov_instr(v, AIA_MOV, tmp_arg, v->func_call_selfptr,
2439              AIA_LONG, AIA_LONG);
2440        vector_append(&tmp_arg_ops, tmp_arg);
2441     }
2442
2443     Aia_Operand *func_self = v->func_call_selfptr;
2444
2445     v->func_call_selfptr = NULL;
2446     for (Uns i = 0; i < size; i++) {
2447        arg_node = vector_get(arguments, i);
2448        param = vector_get(parameters, i);
2449
2450        EXPRESSION_ACCEPT_VISITOR(arg_node, v);
2451        Symbol_Type_Struct *arg = v->prev_sym_type;
2452
2453        Ast_Expr_Type ptype = symbol_type_to_expr_type(param);
2454
2455        func_call_set_prev_result(v, ptype, param, arg);
2456        tmp_arg = aia_operand_tmp_reg_alloc(v->aia);
2457        mov_instr(v, AIA_MOV, tmp_arg, v->prev_result, AIA_LONG, AIA_LONG);
2458        vector_append(&tmp_arg_ops, tmp_arg);
2459     }
2460     v->func_call_selfptr = func_self;
2461
2462     int32_t arg_idx = 0;
2463     VECTOR_FOR_EACH_ENTRY(&tmp_arg_ops, tmp_arg) {
2464        Aia_Operand *arg_op = aia_operand_arg_alloc(v->aia, arg_idx++);
2465        mov_instr(v, AIA_MOV, arg_op, tmp_arg, AIA_LONG, AIA_LONG);
2466     }
2467     vector_clear(&tmp_arg_ops);
2468
2469     Aia_Instr *call_in = ___aia_1op_instr(v->aia, AIA_CALL, ret_size,
2470           AIA_LONG, v->curr_loc);
2471
2472     v->prev_result = get_tmp_op(v);
2473     aia_instr_set_dest_op(call_in, v->prev_result);
2474     aia_instr_set_src_op(call_in, 0, call_operand);
2475
2476     v->func_call_selfptr = NULL;
2477     v->prev_expr_type = ast_expr_func_call_get_expr_type(n);
2478     v->aia_expr_type = AIA_EXPR_STANDARD;
2479     v->prev_sym_type = func->return_type;
2480     EXPRESSION_END(v);
2481  ASTVF_END
2482
2483  static bool direct_ref_is_concrete(Ast_Node *n)
2484  {
2485     assert(n->accept_visitor ==
2486           AST_NODE_ACCEPT_VISITOR_FUNC(AST_EXPR_DIRECT_REF));
2487     Ast_Node_Binary *bin = AST_CONTAINER_OF(n, Ast_Node_Binary);
2488
2489     if (bin->rhs->accept_visitor ==
2490           AST_NODE_ACCEPT_VISITOR_FUNC(AST_EXPR_FUNC_CALL)) {
2491        Ast_Expr_Func_Call *lhs = AST_CONTAINER_OF(bin->rhs,
2492              Ast_Expr_Func_Call);
2493        if (!lhs->func->is_concrete_func)
2494           return false;
2495     }
2496
2497     return true;
2498  }
2499
2500  static void rec_dot_ref(Ast_Visitor_Aia *v, Ast_Node_Binary *n,
2501        bool is_direct, Aia_Operand *rec_ptr, bool release_lhs_result)
2502  {
2503     Symbol_Type_Rec *rec;
2504
2505     EXPRESSION_SETUP(v);
2506
2507     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
```

```
2508
2509     bool prev_is_direct = v->dot_ref_is_direct;
2510     Symbol_Type_Rec *prev_dot_record = v->dot_ref_record;
2511
2512     v->prev_result = NULL;
2513
2514     if (n->lhs) {
2515        Ast_Node *lhs = n->lhs;
2516
2517        if (is_direct && lhs->accept_visitor ==
2518              AST_NODE_ACCEPT_VISITOR_FUNC(AST_EXPR_CAST)) {
2519           Ast_Node_Binary *tmp = AST_CONTAINER_OF(lhs, Ast_Node_Binary);
2520           lhs = tmp->lhs;
2521        }
2522
2523        lhs->accept_visitor(lhs, AST_VISITOR_OF(v));
2524        if (release_lhs_result && v->prev_result) {
2525           ___aia_operand_acquire(v->prev_result);
2526           ___aia_operand_release(v->prev_result);
2527        }
2528
2529        assert(v->prev_sym_type->methods->get_type() == SYMBOL_TYPE_REC);
2530        rec = SYMBOL_TYPE_STRUCT_CONTAINER(v->prev_sym_type, Symbol_Type_Rec);
2531     } else {
2532        rec = v->curr_record_selfptr;
2533     }
2534
2535     if (rec_ptr)
2536        v->prev_result = rec_ptr;
2537
2538     v->dot_ref_is_direct = is_direct;
2539     v->dot_ref_record = rec;
2540     // We visit VARIABLE_IDEN node now. It will need v->prev_result
2541     // so we don't use EXPRESSION_ACCEPT_VISITOR() here.
2542     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
2543
2544     v->prev_dot_ref_record = rec;
2545     v->dot_ref_is_direct = prev_is_direct;
2546     v->dot_ref_record = prev_dot_record;
2547
2548     EXPRESSION_END(v);
2549  }
2550
2551  ASTVF_BEGIN(AST_EXPR_DOT_REF, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
2552     rec_dot_ref(v, n, false, NULL, false);
2553  ASTVF_END
2554
2555  ASTVF_BEGIN(AST_EXPR_DIRECT_REF, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
2556     rec_dot_ref(v, n, true, v->aia->record_self_ptr, false);
2557  ASTVF_END
2558
2559  ASTVF_BEGIN(AST_SIMPLE_TYPE_INT, Ast_Visitor_Aia, v, Ast_Empty, n)
2560     (void)v;
2561     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
2562  ASTVF_END
2563
2564  ASTVF_BEGIN(AST_SIMPLE_TYPE_BOOL, Ast_Visitor_Aia, v, Ast_Empty, n)
2565     (void)n;
2566     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
2567  ASTVF_END
2568
2569  ASTVF_BEGIN(AST_TYPE_IDEN, Ast_Visitor_Aia, v, Ast_Type_Iden, n)
2570     Symbol *sym;
2571     sym = symbol_table_node_lookup(
2572           ast_node_get_symbol_table_node(AST_NODE_OF(n)),
2573           n->iden,
2574           SYMBOL_PROPERTY_TYPE_DEF);
2575     assert(sym);
2576     v->prev_sym_type = sym->resolved_type;
2577     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
2578  ASTVF_END
2579
2580  ASTVF_BEGIN(AST_VAR_DECL, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
2581     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
```

```
2582
2583     Symbol *sym;
2584
2585     assert(!v->next_variable_iden_is_operand);
2586
2587     Symbol_Property saved_property = v->next_property;
2588     v->next_property = SYMBOL_PROPERTY_VAR;
2589     n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
2590     v->next_property = saved_property;
2591
2592     Symbol *prev_curr_sym = v->curr_symbol;
2593     sym = symbol_table_node_lookup(
2594           ast_node_get_symbol_table_node(AST_NODE_OF(n)),
2595           v->prev_iden,
2596           SYMBOL_PROPERTY_VAR);
2597     assert(sym);
2598     v->curr_symbol = sym;
2599
2600     Symbol_Table_Node *node = ast_node_get_symbol_table_node(AST_NODE_OF(n));
2601     while (node->type == SYMBOL_TABLE_NODE_INTERMEDIATE)
2602        node = node->parent;
2603
2604     assert(node->type != SYMBOL_TABLE_NODE_IMPORT);
2605
2606     if (node->type == SYMBOL_TABLE_NODE_GLOBAL) {
2607        assert(!v->next_var_decl_is_param);
2608        Aia_Section_Type prev_sec = ___aia_get_curr_section_type(v->aia);
2609        Const_String prev_fun = ___aia_get_curr_func_name(v->aia);
2610        ___aia_switch_section(v->aia, AIA_SECTION_DATA);
2611
2612        uint8_t src_size = symbol_type_struct_to_aia_operand_size(
2613              sym->resolved_type);
2614        Aia_Linkage linkage;
2615        if (v->stmt_list_nest == 1)
2616           linkage = AIA_LINKAGE_GLOBAL;
2617        else
2618           linkage = AIA_LINKAGE_PRIVATE;
2619
2620        ___aia_insert_label_instr(v->aia,
2621              sym->unique_name,
2622              0,
2623              src_size ? 4 : 0,
2624              linkage,
2625              AIA_LABEL_TYPE_OBJ,
2626              src_size ? 4 : 1,
2627              v->curr_loc);
2628
2629        Aia_Operand *val = aia_operand_const_int_alloc(v->aia, 0);
2630        ___aia_insert_const_val_instr(v->aia, val, src_size, v->curr_loc);
2631
2632        ___aia_switch_section(v->aia, prev_sec);
2633        ___aia_switch_func(v->aia, prev_fun);
2634     } else if (v->next_var_decl_is_param) {
2635        aia_func_append_param(v->aia, sym->unique_name);
2636        v->next_var_decl_is_param = false;
2637     } else if (node->type == SYMBOL_TABLE_NODE_FUNC) {
2638        ___aia_func_append_local(v->aia, sym->unique_name);
2639     } else {
2640        // Ignore record variable declaration.
2641     }
2642
2643     on_symrec_gen_vitrec(sym->resolved_type, v);
2644     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
2645
2646     v->curr_symbol = prev_curr_sym;
2647     v->prev_sym_type = sym->resolved_type;
2648 ASTVF_END
2649
2650 ASTVF_BEGIN(AST_TYPE_DEF, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
2651     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
2652
2653     Symbol *sym;
2654
2655     Symbol_Property saved_property = v->next_property;
```

```
2656     v->next_property = SYMBOL_PROPERTY_TYPE_DEF;
2657     n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
2658     v->next_property = saved_property;
2659
2660     Symbol *prev_curr_sym = v->curr_symbol;
2661     sym = symbol_table_node_lookup(
2662           ast_node_get_symbol_table_node(AST_NODE_OF(n)),
2663           v->prev_iden,
2664           SYMBOL_PROPERTY_TYPE_DEF);
2665     assert(sym);
2666     v->curr_symbol = sym;
2667
2668     on_symrec_gen_vitrec(sym->resolved_type, v);
2669
2670     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
2671
2672     v->curr_symbol = prev_curr_sym;
2673     v->prev_sym_type = sym->resolved_type;
2674 ASTVF_END
2675
2676 ASTVF_BEGIN(AST_TYPE_ARY, Ast_Visitor_Aia, v, Ast_Type, n)
2677     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
2678     n->type->accept_visitor(n->type, AST_VISITOR_OF(v));
2679 ASTVF_END
2680
2681 ASTVF_BEGIN(AST_TYPE_REC, Ast_Visitor_Aia, v, Ast_Type_Rec, n)
2682     Vector *vec;
2683     Ast_Node *node;
2684     Symbol_Type tmp_type UNUSED;
2685     Symbol_Type_Struct *tmp_struct;
2686
2687     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
2688
2689     vec = n->extend_list;
2690     VECTOR_FOR_EACH_ENTRY(vec, node)
2691        node->accept_visitor(node, AST_VISITOR_OF(v));
2692
2693     Symbol_Type curr_type = v->curr_symbol->resolved_type->methods->get_type();
2694
2695     Symbol_Type_Rec *prev_rec_selfptr = v->curr_record_selfptr;
2696
2697     switch (curr_type) {
2698     case SYMBOL_TYPE_REC:
2699        v->curr_record_selfptr = SYMBOL_TYPE_STRUCT_CONTAINER(
2700              v->curr_symbol->resolved_type, Symbol_Type_Rec);
2701        break;
2702
2703     case SYMBOL_TYPE_FUNC:
2704        assert(v->func_ret_sym_type);
2705
2706        tmp_type = v->func_ret_sym_type->methods->get_type();
2707        assert(tmp_type == SYMBOL_TYPE_REC || tmp_type == SYMBOL_TYPE_ARY);
2708
2709        tmp_struct = on_symbol_type_ary_get_struct(
2710              v->func_ret_sym_type);
2711        assert(tmp_struct->methods->get_type() == SYMBOL_TYPE_REC);
2712
2713        v->curr_record_selfptr = SYMBOL_TYPE_STRUCT_CONTAINER(tmp_struct,
2714              Symbol_Type_Rec);
2715        break;
2716
2717     case SYMBOL_TYPE_ARY:
2718        tmp_struct = on_symbol_type_ary_get_struct(
2719              v->curr_symbol->resolved_type);
2720        assert(tmp_struct->methods->get_type() == SYMBOL_TYPE_REC);
2721
2722        v->curr_record_selfptr = SYMBOL_TYPE_STRUCT_CONTAINER(tmp_struct,
2723              Symbol_Type_Rec);
2724        break;
2725
2726     default:
2727        assert(false);
2728        break;
2729     }
```

```
2730
2731     vec = n->body;
2732     VECTOR_FOR_EACH_ENTRY(vec, node)
2733        node->accept_visitor(node, AST_VISITOR_OF(v));
2734
2735     v->curr_record_selfptr = prev_rec_selfptr;
2736  ASTVF_END
2737
2738  static void stmt_list_action(Ast_Visitor_Aia *v, Ast_Stmt_List *n)
2739  {
2740     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
2741
2742     Ast_Node *stmt;
2743     Vector *stmts = n->statements;
2744     ++v->stmt_list_nest;
2745     VECTOR_FOR_EACH_ENTRY(stmts, stmt) {
2746        stmt->accept_visitor(stmt, AST_VISITOR_OF(v));
2747        if (v->prev_result && v->prev_result->ref_count == 0) {
2748           ___aia_operand_destroy(v->prev_result);
2749           v->prev_result = NULL;
2750        }
2751     }
2752     --v->stmt_list_nest;
2753  }
2754
2755  ASTVF_BEGIN(AST_FIN_STMT_LIST, Ast_Visitor_Aia, v, Ast_Stmt_List, n)
2756     Aia_Section_Type prev_sec_type = ___aia_get_curr_section_type(v->aia);
2757     ___aia_switch_section(v->aia, AIA_SECTION_FINI);
2758     stmt_list_action(v, n);
2759     ___aia_switch_section(v->aia, prev_sec_type);
2760  ASTVF_END
2761
2762  ASTVF_BEGIN(AST_STMT_LIST, Ast_Visitor_Aia, v, Ast_Stmt_List, n)
2763     stmt_list_action(v, n);
2764  ASTVF_END
2765
2766  static bool func_def_insert_trampolines(Ast_Visitor_Aia *v,
2767        Const_String func_name, Vector *parameters)
2768  {
2769     Hash_Map_Slot *tr_slot = hash_map_get(&v->trampolines,
2770           (String)func_name, string_hash_code(func_name));
2771     if (tr_slot) {
2772        Vit_Vmt_Trampoline_Entry *tre = VIT_VMT_TRAMPOLINE_ENTRY_OF(tr_slot);
2773        Vit_Vmt_Trampoline *tr;
2774        Aia_Func *func = ___aia_get_curr_func(v->aia);
2775        ___aia_switch_func(v->aia, NULL);
2776
2777        VECTOR_FOR_EACH_ENTRY(&tre->trampolines, tr) {
2778           Aia_Func_Trampoline *func_tramp = ___aia_func_trampoline_alloc(
2779                 v->aia, tr->tramp_name, parameters, func);
2780
2781           ___aia_set_func_trampiline_block(v->aia, func_tramp);
2782
2783           ___aia_insert_label_instr(v->aia, tr->tramp_name, 0, 4,
2784                 aia_func_get_linkage(func), AIA_LABEL_TYPE_FUNC, 0,
2785                 aia_get_null_location(v->aia));
2786
2787           Aia_Operand *tmp = get_tmp_op(v);
2788           Aia_Instr *add_in = ___aia_2op_instr(v->aia, AIA_ADD,
2789                 AIA_LONG, AIA_LONG, aia_get_null_location(v->aia));
2790           aia_instr_set_dest_op(add_in, tmp);
2791           Aia_Operand *this_op = v->aia->record_self_ptr;
2792           Aia_Operand *iconst = aia_operand_const_int_alloc(v->aia,
2793                 -tr->rec_offset);
2794           aia_instr_set_src_op(add_in, 0, this_op);
2795           aia_instr_set_src_op(add_in, 1, iconst);
2796           this_op = v->aia->record_self_ptr;
2797           mov_instr(v, AIA_MOV, this_op, tmp, AIA_LONG, AIA_LONG);
2798
2799           Aia_Operand *func_lbl = aia_operand_label_alloc(v->aia,
2800                 func_name, 0);
2801           Aia_Instr *jmp_in = ___aia_1op_instr(v->aia, ___AIA_JMP, -1,
2802                 AIA_LONG, aia_get_null_location(v->aia));
2803           aia_instr_set_src_op(jmp_in, 0, func_lbl);
```

```
2804        }
2805        v->aia->curr_block = NULL;
2806        v->aia->curr_blist = NULL;
2807        return true;
2808     }
2809     return false;
2810  }
2811
2812  static Symbol *rec_get_finalize_func(Symbol_Type_Rec *rec)
2813  {
2814     Symbol_Func_Map *fmap = symbol_table_node_get_func_map(
2815           rec->rec_sym_node,
2816           (String)S("finalize"),
2817           string_hash_code(S("finalize")));
2818
2819     if (!fmap) // Then the record does not have finalize func
2820        return NULL;
2821
2822     /* Record must only have 1 finalize func. */
2823     assert(vector_size(&fmap->overload_idens) == 1);
2824     Symbol *sym = vector_get(&fmap->overload_idens, 0);
2825     return sym;
2826  }
2827
2828  static Symbol *rec_get_default_rec_func(Symbol_Type_Rec *rec)
2829  {
2830     Symbol_Func_Map *fmap = symbol_table_node_get_func_map(
2831           rec->rec_sym_node,
2832           (String)S("record"),
2833           string_hash_code(S("record")));
2834
2835     if (!fmap) // Then the record does not have record func
2836        return NULL;
2837
2838     Symbol_Type_Func *func = NULL;
2839     Symbol *sym = NULL;
2840     VECTOR_FOR_EACH_ENTRY(&fmap->overload_idens, sym) {
2841        assert(sym->resolved_type->methods->get_type() == SYMBOL_TYPE_FUNC);
2842        func = SYMBOL_TYPE_STRUCT_CONTAINER(sym->resolved_type,
2843              Symbol_Type_Func);
2844        if (vector_is_empty(&func->param_identifiers))
2845           break;
2846     }
2847
2848     assert(func);
2849     assert(sym);
2850
2851     return sym;
2852  }
2853
2854  static void default_func_call(Ast_Visitor_Aia *v, Vit_Record *vrec,
2855        Symbol_Type_Rec *rec, Symbol *func_sym, Aia_Operand *self_ptr)
2856  {
2857     if (!func_sym)
2858        return;
2859
2860     Vit_Record_Field *rec_field = vit_record_get_field(vrec, rec->unique_name);
2861     /* if (!rec_field) it's assumed it's the record itself. */
2862     DEBUGT(def,
2863        if (!rec_field) {
2864           Symbol_Type_Struct *rs = SYMBOL_TYPE_STRUCT_OF_CONTAINER(rec);
2865           Symbol_Type_Struct *fs = SYMBOL_TYPE_STRUCT_OF_CONTAINER(vrec->rec);
2866           assert(rs->methods->same_type(rs, fs));
2867        }
2868     );
2869
2870     Aia_Operand *arg = aia_operand_arg_alloc(v->aia, 0);
2871     if (rec_field && rec_field->field_offset) {
2872        Aia_Operand *tmp = get_tmp_op(v);
2873        Aia_Operand *off = aia_operand_const_int_alloc(v->aia,
2874              rec_field->field_offset);
2875        Aia_Instr *add_in = ___aia_2op_instr(v->aia, AIA_ADD,
2876              AIA_LONG, AIA_LONG, v->curr_loc);
2877        aia_instr_set_dest_op(add_in, tmp);
```

```
2878        aia_instr_set_src_op(add_in, 0, self_ptr);
2879        aia_instr_set_src_op(add_in, 1, off);
2880        mov_instr(v, AIA_MOV, arg, tmp, AIA_LONG, AIA_LONG);
2881     } else {
2882        mov_instr(v, AIA_MOV, arg, self_ptr, AIA_LONG, AIA_LONG);
2883     }
2884
2885     Aia_Instr *call_in = ___aia_1op_instr(v->aia, AIA_CALL, -1, AIA_LONG,
2886           v->curr_loc);
2887     Aia_Operand *call_op = aia_operand_label_alloc(v->aia,
2888           func_sym->unique_name, 0);
2889     aia_instr_set_src_op(call_in, 0, call_op);
2890  }
2891
2892  static void ___func_finalize_call(Ast_Visitor_Aia *v, Vit_Record *vrec,
2893        Symbol_Type_Rec *rec, Aia_Operand *self_ptr)
2894  {
2895     Symbol *fin_func_sym = rec_get_finalize_func(rec);
2896     default_func_call(v, vrec, rec, fin_func_sym, self_ptr);
2897  }
2898
2899  static void func_finalize_call(Ast_Visitor_Aia *v, Vit_Record *vrec,
2900        Symbol_Type_Rec *rec)
2901  {
2902     ___func_finalize_call(v, vrec, rec, v->aia->record_self_ptr);
2903  }
2904
2905  static void ___func_record_call(Ast_Visitor_Aia *v, Vit_Record *vrec,
2906        Symbol_Type_Rec *rec, Aia_Operand *self_ptr)
2907  {
2908     Symbol *rec_func_sym = rec_get_default_rec_func(rec);
2909     default_func_call(v, vrec, rec, rec_func_sym, self_ptr);
2910  }
2911
2912  static void func_record_call(Ast_Visitor_Aia *v, Vit_Record *vrec,
2913        Symbol_Type_Rec *rec)
2914  {
2915     ___func_record_call(v, vrec, rec, v->aia->record_self_ptr);
2916  }
2917
2918  static void func_finalize_setup_vit_rec(Ast_Visitor_Aia *v, Vit_Record *vrec)
2919  {
2920     Symbol_Type_Struct *etype;
2921     VECTOR_FOR_EACH_ENTRY(&vrec->extended_sym_types, etype)
2922        func_finalize_call(v, vrec,
2923              SYMBOL_TYPE_STRUCT_CONTAINER(etype, Symbol_Type_Rec));
2924  }
2925
2926  static void func_record_setup_vit_rec(Ast_Visitor_Aia *v, Vit_Record *vrec,
2927        Vector *bases_missing_call)
2928  {
2929     Symbol_Type_Struct *etype;
2930     VECTOR_FOR_EACH_ENTRY(bases_missing_call, etype)
2931        func_record_call(v, vrec,
2932              SYMBOL_TYPE_STRUCT_CONTAINER(etype, Symbol_Type_Rec));
2933  }
2934
2935  static void func_finalize_setup(Ast_Visitor_Aia *v, Symbol_Type_Rec *rec)
2936  {
2937     Hash_Map_Slot *slot = hash_map_get(&v->record_map, rec->unique_name,
2938           string_hash_code(rec->unique_name));
2939     assert(slot);
2940
2941     Vit_Record *vrec = VIT_RECORD_OF(slot);
2942     assert(!vrec->rec->missing_finalize_name);
2943
2944     func_finalize_setup_vit_rec(v, vrec);
2945  }
2946
2947  static void func_record_setup(Ast_Visitor_Aia *v, Symbol_Type_Rec *rec,
2948        Vector *bases_missing_call)
2949  {
2950     if (vector_is_empty(bases_missing_call))
2951        return;
```

```
2952
2953     Hash_Map_Slot *slot = hash_map_get(&v->record_map, rec->unique_name,
2954           string_hash_code(rec->unique_name));
2955     assert(slot);
2956
2957     Vit_Record *vrec = VIT_RECORD_OF(slot);
2958     assert(!vrec->rec->missing_record_func_name);
2959
2960     func_record_setup_vit_rec(v, vrec, bases_missing_call);
2961  }
2962
2963  static void func_aia(Ast_Visitor_Aia *v, Ast_Func_Def *n,
2964        Aia_Visitor_Func_Type func_type)
2965  {
2966     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
2967
2968     Vector *vec;
2969     Ast_Node *node;
2970     String func_iden;
2971     Symbol *sym;
2972     Vector *dpres_vec;
2973     Ast_Expr_Type func_ret_type;
2974
2975     Symbol_Type_Struct *prev_func_ret = v->func_ret_sym_type;
2976
2977     Symbol_Property saved_property = v->next_property;
2978     v->next_property = SYMBOL_PROPERTY_FUNC;
2979     n->iden->accept_visitor(n->iden, AST_VISITOR_OF(v));
2980     v->next_property = saved_property;
2981     func_iden = v->prev_iden;
2982
2983     Symbol_Table_Node *func_stn = ast_node_get_symbol_table_node(
2984           n->statements);
2985
2986     Stn_Display_Preserve *prev_display = v->curr_display;
2987     v->curr_display = stn_display_preserve_get(func_stn);
2988     dpres_vec = &v->curr_display->stn_displays;
2989
2990     Symbol *prev_curr_sym = v->curr_symbol;
2991     sym = symbol_table_node_lookup(
2992           ast_node_get_symbol_table_node(AST_NODE_OF(n)),
2993           func_iden,
2994           SYMBOL_PROPERTY_FUNC);
2995     assert(sym);
2996     v->curr_symbol = sym;
2997     v->func_ret_sym_type = SYMBOL_TYPE_STRUCT_CONTAINER(sym->resolved_type,
2998           Symbol_Type_Func)->return_type;
2999
3000     on_symrec_gen_vitrec(v->func_ret_sym_type, v);
3001
3002     v->aia_expr_type = AIA_EXPR_STANDARD;
3003     v->prev_expr_type = AST_EXPR_TYPE_INT;
3004     n->return_type->accept_visitor(n->return_type, AST_VISITOR_OF(v));
3005     func_ret_type = v->prev_expr_type;
3006
3007     Aia_Func *prev_func = ___aia_get_curr_func(v->aia);
3008     Const_String prev_func_name = ___aia_get_curr_func_name(v->aia);
3009
3010     Aia_Section_Type prev_sec = ___aia_get_curr_section_type(v->aia);
3011     ___aia_switch_section(v->aia, AIA_SECTION_TEXT);
3012
3013     bool func_needs_self_ptr = ast_node_get_symbol_table_node(
3014           AST_NODE_OF(n))->type == SYMBOL_TABLE_NODE_REC;
3015
3016     ___aia_switch_func(v->aia, sym->unique_name);
3017     aia_set_curr_func_location(v->aia,
3018           ast_node_get_file_location(AST_NODE_OF(n)));
3019
3020     Const_String func_name;
3021     Symbol_Table_Node *tmp_node;
3022     VECTOR_FOR_EACH_ENTRY(dpres_vec, tmp_node) {
3023        Int idx;
3024        if (tmp_node != func_stn) {
3025           idx = stn_display_index(func_stn->parent, tmp_node, &func_name);
```

```
3026            aia_func_append_preserve_display(v->aia, idx);
3027         } else {
3028            aia_func_append_preserve_display(v->aia, -1);
3029         }
3030      }
3031
3032      if (func_needs_self_ptr)
3033         aia_func_append_param(v->aia, SELF_STR);
3034
3035      vec = n->parameters;
3036      VECTOR_FOR_EACH_ENTRY(vec, node) {
3037         v->next_var_decl_is_param = true;
3038         node->accept_visitor(node, AST_VISITOR_OF(v));
3039      }
3040
3041      if (!prev_func) {
3042         aia_func_set_linkage(v->aia, AIA_LINKAGE_GLOBAL);
3043      } else {
3044         ___aia_set_curr_func_parent(v->aia, prev_func);
3045         ssize_t disp_num = vector_size(&prev_func->preserve_display_indices);
3046         while (--disp_num >= 0) {
3047            String disp_str = generate_display_str(disp_num);
3048            ___aia_func_append_display_param(v->aia, disp_str);
3049         }
3050      }
3051
3052      if (func_type == AIAV_FUNC_TYPE_FINALIZE) {
3053         Symbol_Type_Rec *container =
3054            ast_node_get_symbol_table_node(AST_NODE_OF(n))->node_rec;
3055         assert(container);
3056         func_finalize_setup(v, container);
3057      }
3058
3059      Aia_Visitor_Func_Type prev_func_type = v->curr_func_type;
3060      v->curr_func_type = func_type;
3061      n->statements->accept_visitor(n->statements, AST_VISITOR_OF(v));
3062      v->curr_func_type = prev_func_type;
3063
3064      if (func_type == AIAV_FUNC_TYPE_FINALIZE) {
3065         Aia_Instr *ret_in = ___aia_1op_instr(v->aia, AIA_RET, -1, AIA_LONG,
3066               v->curr_loc);
3067         Aia_Operand *selfptr = v->aia->record_self_ptr;
3068         aia_instr_set_src_op(ret_in, 0, selfptr);
3069      } else if (func_ret_type == AST_EXPR_TYPE_VOID) {
3070         ___aia_0op_instr(v->aia, AIA_RET, AIA_LONG,
3071               v->curr_loc);
3072      }
3073
3074      bool inserted_tramp = func_def_insert_trampolines(v, sym->identifier,
3075            &v->aia->curr_func->parameters);
3076      (void)inserted_tramp;
3077      DEBUGT(def, if (inserted_tramp) assert(func_needs_self_ptr));
3078
3079      ___aia_switch_section(v->aia, prev_sec);
3080      ___aia_switch_func(v->aia, prev_func_name);
3081      v->curr_symbol = prev_curr_sym;
3082      v->curr_display = prev_display;
3083      v->func_ret_sym_type = prev_func_ret;
3084   }
3085
3086   ASTVF_BEGIN(AST_EXT_FUNC_DECL, Ast_Visitor_Aia, v, Ast_Func_Def, n)
3087      (void)n;
3088      v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3089   ASTVF_END
3090
3091   ASTVF_BEGIN(AST_FIN_FUNC_DEF, Ast_Visitor_Aia, v, Ast_Func_Def, n)
3092      func_aia(v, n, AIAV_FUNC_TYPE_FINALIZE);
3093   ASTVF_END
3094
3095   ASTVF_BEGIN(AST_REC_FUNC_DEF, Ast_Visitor_Aia, v, Ast_Func_Def, n)
3096      func_aia(v, n, AIAV_FUNC_TYPE_RECORD);
3097   ASTVF_END
3098
3099   ASTVF_BEGIN(AST_FUNC_DEF, Ast_Visitor_Aia, v, Ast_Func_Def, n)
```

```
3100     func_aia(v, n, AIAV_FUNC_TYPE_NORMAL);
3101  ASTVF_END
3102
3103  static void ___if_stmt_expr(Ast_Visitor_Aia *v, uint8_t cmp_size,
3104        Aia_Operand *then_lbl, Aia_Operand *skip_lbl)
3105  {
3106     cmp0_skip_on_false(v, cmp_size, then_lbl, skip_lbl, ___AIA_JE);
3107  }
3108
3109  static void if_stmt_expr(Ast_Visitor_Aia *v, Ast_Node *exp_node,
3110        Aia_Operand *then_lbl, Aia_Operand *skip_lbl)
3111  {
3112     uint8_t cmp_size;
3113     EXPRESSION_SETUP(v);
3114
3115     assert(!v->bool_true_label);
3116     assert(!v->bool_false_label);
3117
3118     v->bool_true_label = then_lbl;
3119     v->bool_false_label = skip_lbl;
3120     EXPRESSION_ACCEPT_VISITOR(exp_node, v);
3121     v->bool_false_label = NULL;
3122     v->bool_true_label = NULL;
3123
3124     if (v->aia_expr_type == AIA_EXPR_STANDARD) {
3125        cmp_size = ast_expr_type_to_aia_operand_size(v->prev_expr_type);
3126        ___if_stmt_expr(v, cmp_size, then_lbl, skip_lbl);
3127     }
3128
3129     EXPRESSION_END(v);
3130  }
3131
3132  /* AIA block structure:
3133   *       (p)
3134   *       / \
3135   *      |  (i)
3136   *       \ /
3137   *       (l)   */
3138  ASTVF_BEGIN(AST_IF_STMT, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
3139     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3140
3141     Aia_Operand *if_thn = aia_operand_tmp_label_alloc(v->aia, S("IF.then"));
3142     Aia_Operand *ifend = aia_operand_tmp_label_alloc(v->aia, S("IF.end"));
3143
3144     if_stmt_expr(v, n->lhs, if_thn, ifend);
3145
3146     ___aia_block(v->aia);
3147     ___aia_insert_jmp_label_instr(v->aia,
3148           aia_operand_label_get_name(if_thn));
3149     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
3150     Aia_Instr *jmp = ___aia_1op_instr(v->aia, ___AIA_JMP, -1, AIA_LONG,
3151           v->curr_loc);
3152     aia_instr_set_src_op(jmp, 0, ifend);
3153
3154     ___aia_block(v->aia);
3155     ___aia_insert_jmp_label_instr(v->aia,
3156           aia_operand_label_get_name(ifend));
3157  ASTVF_END
3158
3159  /* AIA block structure:
3160   *       (p)
3161   *       / \
3162   *     (i) (e)
3163   *       \ /
3164   *       (l)   */
3165  ASTVF_BEGIN(AST_IF_ELSE_STMT, Ast_Visitor_Aia, v, Ast_Node_Ternary, n)
3166     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3167
3168     Aia_Operand *if_thn = aia_operand_tmp_label_alloc(v->aia, S("IF.then"));
3169     Aia_Operand *ifend = aia_operand_tmp_label_alloc(v->aia, S("IF.end"));
3170     Aia_Operand *else_body = aia_operand_tmp_label_alloc(v->aia, S("IF.else"));
3171
3172     if_stmt_expr(v, n->lhs, if_thn, else_body);
3173
```

```
3174     ___aia_block(v->aia);
3175     ___aia_insert_jmp_label_instr(v->aia,
3176           aia_operand_label_get_name(if_thn));
3177
3178     n->mid->accept_visitor(n->mid, AST_VISITOR_OF(v));
3179     Aia_Instr *jmp = ___aia_1op_instr(v->aia, ___AIA_JMP, -1, AIA_LONG,
3180           v->curr_loc);
3181     aia_instr_set_src_op(jmp, 0, ifend);
3182
3183     ___aia_block(v->aia);
3184     ___aia_insert_jmp_label_instr(v->aia,
3185           aia_operand_label_get_name(else_body));
3186
3187     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
3188     jmp = ___aia_1op_instr(v->aia, ___AIA_JMP, -1, AIA_LONG, v->curr_loc);
3189     aia_instr_set_src_op(jmp, 0, ifend);
3190
3191     ___aia_block(v->aia);
3192     ___aia_insert_jmp_label_instr(v->aia,
3193           aia_operand_label_get_name(ifend));
3194 ASTVF_END
3195
3196 /* AIA block structure:
3197  *      (p)
3198  *       | __
3199  *      (c) \
3200  *      / \ |
3201  *     /   \ |
3202  *    (l)  (b) */
3203 ASTVF_BEGIN(AST_WHILE_STMT, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
3204     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3205
3206     Aia_Operand *wend_lbl =
3207           aia_operand_tmp_label_alloc(v->aia, S("WHILE.end"));
3208     Aia_Operand *wcmp_lbl =
3209           aia_operand_tmp_label_alloc(v->aia, S("WHILE.cmp"));
3210     Aia_Operand *wtop_lbl =
3211           aia_operand_tmp_label_alloc(v->aia, S("WHILE.top"));
3212
3213     Aia_Instr *jmp = ___aia_1op_instr(v->aia, ___AIA_JMP, -1, AIA_LONG,
3214           v->curr_loc);
3215     aia_instr_set_src_op(jmp, 0, wcmp_lbl);
3216
3217     ___aia_block(v->aia);
3218     ___aia_insert_jmp_label_instr(v->aia,
3219           aia_operand_label_get_name(wtop_lbl));
3220
3221     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
3222     jmp = ___aia_1op_instr(v->aia, ___AIA_JMP, -1, AIA_LONG, v->curr_loc);
3223     aia_instr_set_src_op(jmp, 0, wcmp_lbl);
3224
3225     ___aia_block(v->aia);
3226     ___aia_insert_jmp_label_instr(v->aia,
3227           aia_operand_label_get_name(wcmp_lbl));
3228
3229     if_stmt_expr(v, n->lhs, wtop_lbl, wend_lbl);
3230
3231     ___aia_block(v->aia);
3232     ___aia_insert_jmp_label_instr(v->aia,
3233           aia_operand_label_get_name(wend_lbl));
3234 ASTVF_END
3235
3236 ASTVF_BEGIN(AST_ALLOC_ARY, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
3237     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3238
3239     EXPRESSION_SETUP(v);
3240
3241     Symbol_Type_Ary *ary_sym;
3242     Aia_Operand *ary_op;
3243     Aia_Operand *tmp;
3244
3245     EXPRESSION_ACCEPT_VISITOR(n->lhs, v);
3246     assert(v->prev_sym_type->methods->get_type() == SYMBOL_TYPE_ARY);
3247     ary_sym = SYMBOL_TYPE_STRUCT_CONTAINER(v->prev_sym_type, Symbol_Type_Ary);
```

```
3248     ary_op = v->prev_result;
3249
3250     EXPRESSION_ACCEPT_VISITOR(n->rhs, v);
3251     switch (v->prev_expr_type) {
3252     case AST_EXPR_TYPE_CHAR:
3253        tmp = get_tmp_op(v);
3254        mov_instr(v, AIA_MOVS, tmp, v->prev_result, AIA_LONG, AIA_BYTE);
3255        v->prev_result = tmp;
3256        break;
3257
3258     case AST_EXPR_TYPE_BOOL:
3259        tmp = get_tmp_op(v);
3260        mov_instr(v, AIA_MOVZ, tmp, v->prev_result, AIA_LONG, AIA_BYTE);
3261        v->prev_result = tmp;
3262        break;
3263
3264     default:
3265        assert(ast_expr_type_to_aia_operand_size(v->prev_expr_type) ==
3266              AIA_LONG);
3267        break;
3268     }
3269
3270     Const_String func_name;
3271     uint8_t elm_size = symbol_type_struct_to_aia_operand_size(
3272           ary_sym->ary_type);
3273     if (elm_size == AIA_LONG)
3274        func_name = AIA_FUNC_ALLOCATEAL;
3275     else
3276        func_name = AIA_FUNC_ALLOCATEAB;
3277
3278     Aia_Operand *arg_op = aia_operand_arg_alloc(v->aia, 0);
3279     mov_instr(v, AIA_MOV, arg_op, v->prev_result, AIA_LONG, AIA_LONG);
3280
3281     Aia_Instr *call_in = ___aia_lop_instr(v->aia, AIA_CALL, AIA_LONG,
3282           AIA_LONG, v->curr_loc);
3283     Aia_Operand *result = get_tmp_op(v);
3284     Aia_Operand *call_op = aia_operand_label_alloc(v->aia, func_name, 0);
3285     aia_instr_set_src_op(call_in, 0, call_op);
3286     aia_instr_set_dest_op(call_in, result);
3287     mov_instr(v, AIA_MOV, ary_op, result, AIA_LONG, AIA_LONG);
3288
3289     EXPRESSION_END(v);
3290  ASTVF_END
3291
3292  // Returns end label
3293  static Aia_Operand *record_alloc(Ast_Visitor_Aia *v, Ast_Node *rec_iden,
3294        bool call_default_ctor, Aia_Operand **alloc_result_out)
3295  {
3296     Symbol_Type_Rec *alloc_rec;
3297     EXPRESSION_SETUP(v);
3298
3299     v->allocating_record = true;
3300     v->allocated_record_offset = 0;
3301     EXPRESSION_ACCEPT_VISITOR(rec_iden, v);
3302     v->allocating_record = false;
3303     alloc_rec = SYMBOL_TYPE_STRUCT_CONTAINER(v->prev_sym_type,
3304           Symbol_Type_Rec);
3305
3306     Hash_Map_Slot *vit_slot = hash_map_get(&v->record_map,
3307           alloc_rec->unique_name, string_hash_code(alloc_rec->unique_name));
3308     assert(vit_slot);
3309     Vit_Record *vit_rec = VIT_RECORD_OF(vit_slot);
3310
3311     Aia_Operand *rec_size = aia_operand_const_int_alloc(v->aia,
3312           vit_rec->byte_size);
3313     Aia_Operand *arg_op = aia_operand_arg_alloc(v->aia, 0);
3314     mov_instr(v, AIA_MOV, arg_op, rec_size, AIA_LONG, AIA_LONG);
3315
3316     Aia_Instr *call_in = ___aia_lop_instr(v->aia, AIA_CALL,
3317           AIA_LONG, AIA_LONG, v->curr_loc);
3318
3319     Const_String func_name = AIA_FUNC_ALLOCATE;
3320
3321     Aia_Operand *alloc_result = get_tmp_op(v);
```

```
3322     Aia_Operand *call_op = aia_operand_label_alloc(v->aia, func_name, 0);
3323     aia_instr_set_src_op(call_in, 0, call_op);
3324     aia_instr_set_dest_op(call_in, alloc_result);
3325
3326     Aia_Operand *end_lbl = NULL;
3327     if (alloc_result_out ||
3328           vit_rec->initializer_name ||
3329           v->allocated_record_offset ||
3330           (call_default_ctor && alloc_rec->rec_sym_node->has_record_func)) {
3331
3332        Aia_Operand *saved_prev_result = v->prev_result;
3333        v->prev_result = alloc_result;
3334
3335        Aia_Operand *do_alloc_lbl;
3336        Aia_Operand *null_lbl;
3337        null_lbl = aia_operand_tmp_label_alloc(v->aia, S("ALOC.null"));
3338        do_alloc_lbl = aia_operand_tmp_label_alloc(v->aia, S("ALOC.do"));
3339        end_lbl = aia_operand_tmp_label_alloc(v->aia, S("ALOC.end"));
3340        cmp0_skip_on_false(v, AIA_LONG, null_lbl, do_alloc_lbl, ___AIA_JNE);
3341
3342        ___aia_block(v->aia);
3343        ___aia_insert_jmp_label_instr(v->aia,
3344              aia_operand_label_get_name(null_lbl));
3345
3346        v->prev_result = saved_prev_result;
3347        Aia_Operand *iconst0 = aia_operand_const_int_alloc(v->aia, 0);
3348        mov_instr(v, AIA_MOV, v->prev_result, iconst0,
3349              AIA_LONG, AIA_LONG);
3350
3351        Aia_Instr *jmp = ___aia_1op_instr(v->aia, ___AIA_JMP, -1, AIA_LONG,
3352              v->curr_loc);
3353        aia_instr_set_src_op(jmp, 0, end_lbl);
3354
3355        ___aia_block(v->aia);
3356        ___aia_insert_jmp_label_instr(v->aia,
3357              aia_operand_label_get_name(do_alloc_lbl));
3358     }
3359
3360     if (vit_rec->initializer_name) {
3361        arg_op = aia_operand_arg_alloc(v->aia, 0);
3362        mov_instr(v, AIA_MOV, arg_op, alloc_result, AIA_LONG, AIA_LONG);
3363     }
3364
3365     Aia_Operand *call_result;
3366     if (v->allocated_record_offset) {
3367        Aia_Instr *add_in = ___aia_2op_instr(v->aia, AIA_ADD,
3368              AIA_LONG, AIA_LONG, v->curr_loc);
3369        Aia_Operand *offset = aia_operand_const_int_alloc(v->aia,
3370              -v->allocated_record_offset);
3371        call_result = get_tmp_op(v);
3372        aia_instr_set_src_op(add_in, 0, alloc_result);
3373        aia_instr_set_src_op(add_in, 1, offset);
3374        aia_instr_set_dest_op(add_in, call_result);
3375     } else {
3376        call_result = alloc_result;
3377     }
3378     mov_instr(v, AIA_MOV, v->prev_result, call_result,
3379           AIA_LONG, AIA_LONG);
3380
3381     if (vit_rec->initializer_name) {
3382        call_in = ___aia_1op_instr(v->aia, AIA_CALL, -1, AIA_LONG,
3383              v->curr_loc);
3384        call_op = aia_operand_label_alloc(v->aia,
3385              vit_rec->initializer_name, 0);
3386        aia_instr_set_src_op(call_in, 0, call_op);
3387     }
3388
3389     if (call_default_ctor && alloc_rec->rec_sym_node->has_record_func)
3390        ___func_record_call(v, vit_rec, alloc_rec, alloc_result);
3391
3392     EXPRESSION_END(v);
3393
3394     if (alloc_result_out)
3395        *alloc_result_out = alloc_result;
```

```
3396
3397     return end_lbl;
3398  }
3399
3400  ASTVF_BEGIN(AST_ALLOC_REC, Ast_Visitor_Aia, v, Ast_Node_Unary, n)
3401     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3402     Aia_Operand *end_lbl = record_alloc(v, n->expr, true, NULL);
3403     if (end_lbl) {
3404        Aia_Instr *jmp = ___aia_1op_instr(v->aia, ___AIA_JMP, -1, AIA_LONG,
3405              v->curr_loc);
3406        aia_instr_set_src_op(jmp, 0, end_lbl);
3407        ___aia_block(v->aia);
3408        ___aia_insert_jmp_label_instr(v->aia,
3409              aia_operand_label_get_name(end_lbl));
3410     }
3411  ASTVF_END
3412
3413  ASTVF_BEGIN(AST_ALLOC_REC_CALL, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
3414     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3415
3416     Aia_Operand *alloc_res;
3417     Aia_Operand *end_lbl = record_alloc(v, n->lhs, false, &alloc_res);
3418     assert(end_lbl);
3419     Symbol_Type_Rec *rec = SYMBOL_TYPE_STRUCT_CONTAINER(v->prev_sym_type,
3420           Symbol_Type_Rec);
3421
3422     Symbol_Type_Rec *prev_rec = v->alloc_record_selfptr;
3423     v->alloc_record_selfptr = rec;
3424
3425     rec_dot_ref(v, n, true, alloc_res, true);
3426
3427     Aia_Instr *jmp = ___aia_1op_instr(v->aia, ___AIA_JMP, -1, AIA_LONG,
3428           v->curr_loc);
3429     aia_instr_set_src_op(jmp, 0, end_lbl);
3430     ___aia_block(v->aia);
3431     ___aia_insert_jmp_label_instr(v->aia,
3432           aia_operand_label_get_name(end_lbl));
3433
3434     v->alloc_record_selfptr = prev_rec;
3435
3436  ASTVF_END
3437
3438  static void finalize_call_prev_result(Ast_Visitor_Aia *v,
3439        Const_String func_name)
3440  {
3441     Aia_Operand *arg_op = aia_operand_arg_alloc(v->aia, 0);
3442     mov_instr(v, AIA_MOV, arg_op, v->prev_result, AIA_LONG, AIA_LONG);
3443
3444     Aia_Instr *call_in = ___aia_1op_instr(v->aia, AIA_CALL, -1, AIA_LONG,
3445           v->curr_loc);
3446
3447     Aia_Operand *call_op = aia_operand_label_alloc(v->aia, func_name, 0);
3448     aia_instr_set_src_op(call_in, 0, call_op);
3449  }
3450
3451  static void record_call_finalize(Ast_Visitor_Aia *v, Symbol_Type_Rec *rec,
3452        Const_String func_name)
3453  {
3454     Hash_Map_Slot *slot = hash_map_get(&v->vmt_map,
3455           rec->unique_name, string_hash_code(rec->unique_name));
3456     assert(slot);
3457
3458     Aia_Operand *selfptr = v->prev_result;
3459
3460     Vit_Vmt *vmt = VIT_VMT_OF(slot);
3461     slot = hash_map_get(&vmt->func_off_map, (String)func_name,
3462           string_hash_code(func_name));
3463     assert(slot);
3464     Vit_Func_Off_Entry *e = VIT_FUNC_OFF_ENTRY_OF(slot);
3465
3466     variable_iden_record_vmt_mov(v, selfptr);
3467
3468     Aia_Operand *disp = aia_operand_const_int_alloc(v->aia, e->func_offset);
3469     Aia_Operand *call_op = aia_operand_addr_ref_alloc(v->aia,
```

```
3470            NULL, disp, v->prev_result, NULL, NULL);
3471     Aia_Operand *arg = aia_operand_arg_alloc(v->aia, 0);
3472     mov_instr(v, AIA_MOV, arg, selfptr, AIA_LONG, AIA_LONG);
3473     Aia_Instr *call_in = ___aia_1op_instr(v->aia, AIA_CALL,
3474            AIA_LONG, AIA_LONG, v->curr_loc);
3475     aia_instr_set_src_op(call_in, 0, call_op);
3476     v->prev_result = get_tmp_op(v);
3477     aia_instr_set_dest_op(call_in, v->prev_result);
3478  }
3479
3480  /* AIA block structure:
3481   *      (p)
3482   *      / \
3483   *     |  (i)
3484   *      \ /
3485   *      (l)   */
3486  static void record_delete(Ast_Visitor_Aia *v, Symbol_Type_Rec *rec)
3487  {
3488     Aia_Operand *if_thn = aia_operand_tmp_label_alloc(v->aia, S("DEL.do"));
3489     Aia_Operand *ifend = aia_operand_tmp_label_alloc(v->aia, S("DEL.end"));
3490
3491     /* Dont't try to delete record if it's a null ptr.
3492      * Thus we insert an if-statement here. */
3493     cmp0_skip_on_false(v, AIA_LONG, if_thn, ifend, ___AIA_JE);
3494
3495     ___aia_block(v->aia);
3496     ___aia_insert_jmp_label_instr(v->aia,
3497            aia_operand_label_get_name(if_thn));
3498
3499     Symbol *fsym = rec_get_finalize_func(rec);
3500     if (fsym) // Then the record has a finalize function
3501        record_call_finalize(v, rec, fsym->identifier);
3502
3503     finalize_call_prev_result(v, AIA_FUNC_DELETE);
3504
3505     Aia_Instr *jmp = ___aia_1op_instr(v->aia, ___AIA_JMP, -1, AIA_LONG,
3506            v->curr_loc);
3507     aia_instr_set_src_op(jmp, 0, ifend);
3508
3509     ___aia_block(v->aia);
3510     ___aia_insert_jmp_label_instr(v->aia,
3511            aia_operand_label_get_name(ifend));
3512  }
3513
3514  static void array_delete(Ast_Visitor_Aia *v)
3515  {
3516     finalize_call_prev_result(v, AIA_FUNC_DELETEA);
3517  }
3518
3519  ASTVF_BEGIN(AST_DELETE, Ast_Visitor_Aia, v, Ast_Node_Unary, n)
3520     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3521
3522     EXPRESSION_SETUP(v);
3523
3524     EXPRESSION_ACCEPT_VISITOR(n->expr, v);
3525     switch (v->prev_expr_type) {
3526     case AST_EXPR_TYPE_REC:
3527        assert(v->prev_sym_type->methods->get_type() == SYMBOL_TYPE_REC);
3528        record_delete(v, SYMBOL_TYPE_STRUCT_CONTAINER(v->prev_sym_type,
3529               Symbol_Type_Rec));
3530        break;
3531     case AST_EXPR_TYPE_ARY:
3532        assert(v->prev_sym_type->methods->get_type() == SYMBOL_TYPE_ARY);
3533        array_delete(v);
3534        break;
3535     default:
3536        fatal_error(S("Delete of invalid type. Aborting...\n"));
3537     }
3538
3539     EXPRESSION_END(v);
3540  ASTVF_END
3541
3542  ASTVF_BEGIN(AST_WRITE_STMT, Ast_Visitor_Aia, v, Ast_Node_Unary, n)
3543     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
```

```
3544
3545     EXPRESSION_SETUP(v);
3546     EXPRESSION_ACCEPT_VISITOR(n->expr, v);
3547
3548     Const_String func_name;
3549     switch (v->prev_expr_type) {
3550     case AST_EXPR_TYPE_INT:
3551        func_name = AIA_FUNC_WRITELNI;
3552        break;
3553
3554     case AST_EXPR_TYPE_STRING:
3555        func_name = AIA_FUNC_WRITELNS;
3556        break;
3557
3558     case AST_EXPR_TYPE_REC:
3559        func_name = AIA_FUNC_WRITELNR;
3560        break;
3561
3562     case AST_EXPR_TYPE_ARY:
3563        func_name = AIA_FUNC_WRITELNA;
3564        break;
3565
3566     case AST_EXPR_TYPE_NULL:
3567        func_name = AIA_FUNC_WRITELNN;
3568        break;
3569
3570     case AST_EXPR_TYPE_CHAR:
3571        func_name = AIA_FUNC_WRITELNC;
3572        type_cast_char_to_long(v, v->prev_result, AST_EXPR_TYPE_INT);
3573        break;
3574
3575     case AST_EXPR_TYPE_BOOL:
3576        func_name = AIA_FUNC_WRITELNB;
3577        type_cast_bool_to_long(v, v->prev_result, AST_EXPR_TYPE_INT);
3578        break;
3579
3580     default:
3581        fatal_error(S("unexpected " QFY("write") " operand. Aborting...\n"));
3582     }
3583
3584     Aia_Operand *arg_op = aia_operand_arg_alloc(v->aia, 0);
3585     mov_instr(v, AIA_MOV, arg_op, v->prev_result, AIA_LONG, AIA_LONG);
3586
3587     Aia_Instr *call_in = ___aia_lop_instr(v->aia, AIA_CALL, -1,
3588           AIA_LONG, v->curr_loc);
3589     Aia_Operand *call_op = aia_operand_label_alloc(v->aia, func_name, 0);
3590     aia_instr_set_src_op(call_in, 0, call_op);
3591
3592     EXPRESSION_END(v);
3593  ASTVF_END
3594
3595  static void return_stmt_unexpected_lhs()
3596  {
3597     fatal_error(S("Unexpected return type. Aborting...\n"));
3598  }
3599
3600  ASTVF_BEGIN(AST_RETURN_STMT, Ast_Visitor_Aia, v, Ast_Node_Unary, n)
3601     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3602
3603     EXPRESSION_SETUP(v);
3604     EXPRESSION_ACCEPT_VISITOR(n->expr, v);
3605
3606     Aia_Operand *tmp;
3607     Ast_Expr_Type lhs_t = symbol_type_to_expr_type(v->func_ret_sym_type);
3608     Ast_Expr_Type rhs_t = v->prev_expr_type;
3609
3610     Aia_Instr *reti;
3611     switch (lhs_t) {
3612     case AST_EXPR_TYPE_BOOL:
3613        switch (rhs_t) {
3614        case AST_EXPR_TYPE_BOOL:
3615           break;
3616
3617        case AST_EXPR_TYPE_CHAR:
```

```
3618            tmp = get_tmp_op(v);
3619            mov_prev_to_bool(v, AIA_BYTE, tmp);
3620            v->prev_result = tmp;
3621            break;
3622
3623         default:
3624            tmp = get_tmp_op(v);
3625            mov_prev_to_bool(v, AIA_LONG, tmp);
3626            v->prev_result = tmp;
3627            break;
3628
3629         }
3630         break;
3631
3632      case AST_EXPR_TYPE_INT:
3633         switch (rhs_t) {
3634         case AST_EXPR_TYPE_INT:
3635            break;
3636         case AST_EXPR_TYPE_CHAR:
3637            tmp = get_tmp_op(v);
3638            mov_instr(v, AIA_MOVS, tmp, v->prev_result, AIA_LONG, AIA_BYTE);
3639            v->prev_result = tmp;
3640            break;
3641         case AST_EXPR_TYPE_BOOL:
3642            tmp = get_tmp_op(v);
3643            mov_instr(v, AIA_MOVZ, tmp, v->prev_result, AIA_LONG, AIA_BYTE);
3644            v->prev_result = tmp;
3645            break;
3646         default:
3647            return_stmt_unexpected_lhs();
3648         }
3649         break;
3650
3651      case AST_EXPR_TYPE_CHAR:
3652         switch (rhs_t) {
3653         case AST_EXPR_TYPE_INT:
3654            /* Fall. */
3655         case AST_EXPR_TYPE_BOOL:
3656            /* Fall. */
3657         case AST_EXPR_TYPE_CHAR:
3658            break;
3659         default:
3660            return_stmt_unexpected_lhs();
3661         }
3662         break;
3663
3664      case AST_EXPR_TYPE_STRING:
3665         break;
3666
3667      case AST_EXPR_TYPE_ARY:
3668         break;
3669
3670      case AST_EXPR_TYPE_REC:
3671         switch (rhs_t) {
3672         case AST_EXPR_TYPE_NULL:
3673            break;
3674         case AST_EXPR_TYPE_REC:
3675            type_cast_rec_rec(v, v->func_ret_sym_type, v->prev_sym_type,
3676                  NULL, true);
3677            break;
3678         default:
3679            return_stmt_unexpected_lhs();
3680         }
3681         break;
3682
3683      case AST_EXPR_TYPE_VOID:
3684         reti = ___aia_0op_instr(v->aia, AIA_RET, -1, v->curr_loc);
3685         goto out;
3686
3687      default:
3688         fatal_error(S("unexpected return type. Aborting...\n"));
3689      }
3690
3691      uint8_t val_size = symbol_type_struct_to_aia_operand_size(
```

```
3692            v->func_ret_sym_type);
3693
3694       reti = ___aia_lop_instr(v->aia, AIA_RET, -1, val_size,
3695            v->curr_loc);
3696       aia_instr_set_src_op(reti, 0, v->prev_result);
3697
3698    out:
3699       EXPRESSION_END(v);
3700    ASTVF_END
3701
3702    static void assignment_unexpected_lhs()
3703    {
3704       fatal_error(S("Unexpected assignment LHS. Aborting...\n"));
3705    }
3706
3707    ASTVF_BEGIN(AST_ASSIGNMENT, Ast_Visitor_Aia, v, Ast_Node_Binary, n)
3708       v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3709
3710       Aia_Operand *lhs_r, *rhs_r;
3711       Ast_Expr_Type lhs_t, rhs_t;
3712       Symbol_Type_Struct *lhs_s, *rhs_s;
3713
3714       EXPRESSION_SETUP(v);
3715
3716       EXPRESSION_ACCEPT_VISITOR(n->rhs, v);
3717       rhs_r = v->prev_result;
3718       rhs_t = v->prev_expr_type;
3719       rhs_s = v->prev_sym_type;
3720
3721       EXPRESSION_ACCEPT_VISITOR(n->lhs, v);
3722       lhs_r = v->prev_result;
3723       lhs_t = v->prev_expr_type;
3724       lhs_s = v->prev_sym_type;
3725
3726       v->prev_result = rhs_r;
3727
3728       switch (lhs_t) {
3729       case AST_EXPR_TYPE_BOOL:
3730          switch (rhs_t) {
3731          case AST_EXPR_TYPE_BOOL:
3732             mov_instr(v, AIA_MOV, lhs_r, rhs_r, AIA_BYTE, AIA_BYTE);
3733             break;
3734
3735          case AST_EXPR_TYPE_CHAR:
3736             mov_prev_to_bool(v, AIA_BYTE, lhs_r);
3737             break;
3738
3739          default:
3740             mov_prev_to_bool(v, AIA_LONG, lhs_r);
3741             break;
3742
3743          }
3744          break;
3745
3746       case AST_EXPR_TYPE_INT:
3747          switch (rhs_t) {
3748          case AST_EXPR_TYPE_INT:
3749             mov_instr(v, AIA_MOV, lhs_r, rhs_r, AIA_LONG, AIA_LONG);
3750             break;
3751          case AST_EXPR_TYPE_CHAR:
3752             if (!aia_operand_is_reg(lhs_r)) {
3753                rhs_r = movz_tmp_instr(v, rhs_r);
3754                mov_instr(v, AIA_MOV, lhs_r, rhs_r, AIA_LONG, AIA_LONG);
3755             } else {
3756                mov_instr(v, AIA_MOVS, lhs_r, rhs_r, AIA_LONG, AIA_BYTE);
3757             }
3758             break;
3759          case AST_EXPR_TYPE_BOOL:
3760             if (!aia_operand_is_reg(lhs_r)) {
3761                rhs_r = movz_tmp_instr(v, rhs_r);
3762                mov_instr(v, AIA_MOV, lhs_r, rhs_r, AIA_LONG, AIA_LONG);
3763             } else {
3764                mov_instr(v, AIA_MOVZ, lhs_r, rhs_r, AIA_LONG, AIA_BYTE);
3765             }
```

```
3766            break;
3767         default:
3768            assignment_unexpected_lhs();
3769         }
3770         break;
3771
3772      case AST_EXPR_TYPE_CHAR:
3773         switch (rhs_t) {
3774         case AST_EXPR_TYPE_INT:
3775            mov_instr(v, AIA_MOV, lhs_r, rhs_r, AIA_BYTE, AIA_BYTE);
3776            break;
3777         case AST_EXPR_TYPE_BOOL:
3778            /* Fall. */
3779         case AST_EXPR_TYPE_CHAR:
3780            mov_instr(v, AIA_MOV, lhs_r, rhs_r, AIA_BYTE, AIA_BYTE);
3781            break;
3782         default:
3783            assignment_unexpected_lhs();
3784         }
3785         break;
3786
3787      case AST_EXPR_TYPE_STRING:
3788         mov_instr(v, AIA_MOV, lhs_r, rhs_r, AIA_LONG, AIA_LONG);
3789         break;
3790
3791      case AST_EXPR_TYPE_ARY:
3792         mov_instr(v, AIA_MOV, lhs_r, rhs_r, AIA_LONG, AIA_LONG);
3793         break;
3794
3795      case AST_EXPR_TYPE_REC:
3796         switch (rhs_t) {
3797         case AST_EXPR_TYPE_NULL:
3798            mov_instr(v, AIA_MOV, lhs_r, rhs_r, AIA_LONG, AIA_LONG);
3799            break;
3800         case AST_EXPR_TYPE_REC:
3801            type_cast_rec_rec(v, lhs_s, rhs_s, lhs_r, true);
3802            break;
3803         default:
3804            assignment_unexpected_lhs();
3805         }
3806         break;
3807
3808      default:
3809         fatal_error(S("unexpected variable assignemnt. Aborting...\n"));
3810      }
3811
3812      EXPRESSION_END(v);
3813   ASTVF_END
3814
3815   static void rec_struct_vec_remove(Vector *recs, Symbol_Type_Rec *remove_rec)
3816   {
3817      Symbol_Type_Struct *rem = SYMBOL_TYPE_STRUCT_OF_CONTAINER(remove_rec);
3818      for (Uns i = 0; i < vector_size(recs); i++) {
3819         Symbol_Type_Struct *tmp = vector_get(recs, i);
3820         if (tmp->methods->same_type(tmp, rem)) {
3821            vector_remove(recs, i);
3822            return;
3823         }
3824      }
3825   }
3826
3827   static void record_func_stmt_startup(Ast_Visitor_Aia *v, Ast_Stmt_List *n)
3828   {
3829      inline bool recs_equal(Symbol_Type_Rec *lhs, Symbol_Type_Rec *rhs)
3830      {
3831         extern bool ___type_def_symbol_types_equal(Symbol_Type_Struct *lhs,
3832               Symbol_Type_Struct *rhs);
3833         Symbol_Type_Struct *lhs_s = SYMBOL_TYPE_STRUCT_OF_CONTAINER(lhs);
3834         Symbol_Type_Struct *rhs_s = SYMBOL_TYPE_STRUCT_OF_CONTAINER(rhs);
3835         return ___type_def_symbol_types_equal(lhs_s, rhs_s);
3836      }
3837
3838      assert(v->curr_record_selfptr);
3839      Symbol_Type_Rec *self = v->curr_record_selfptr;
```

```
3840
3841        VECTOR(bases);
3842
3843        Vector *extended = &v->curr_record_selfptr->extended_types;
3844        Symbol_Type_Struct *ext;
3845        Symbol_Type_Rec *ext_r;
3846        VECTOR_FOR_EACH_ENTRY(extended, ext) {
3847           ext_r = SYMBOL_TYPE_STRUCT_CONTAINER(ext, Symbol_Type_Rec);
3848           if (ext_r->rec_sym_node->has_record_func)
3849              vector_append(&bases, ext);
3850        }
3851
3852        Vector *stmts = n->statements;
3853        assert(n->num_rec_ctor_stmts <= vector_size(stmts));
3854
3855        Ast_Node *rec_call;
3856        for (Uns i = 0; i < n->num_rec_ctor_stmts; i++) {
3857           DEBUGT(def, v->prev_dot_ref_record = NULL);
3858           rec_call = vector_get(stmts, i);
3859           if (direct_ref_is_concrete(rec_call)) {
3860              rec_call->accept_visitor(rec_call, AST_VISITOR_OF(v));
3861              assert(v->prev_dot_ref_record);
3862              assert(recs_equal(self, v->curr_record_selfptr));
3863              if (recs_equal(v->prev_dot_ref_record, self)) {
3864                 assert(n->num_rec_ctor_stmts == 1);
3865                 vector_clear(&bases);
3866                 break;
3867              }
3868              rec_struct_vec_remove(&bases, v->prev_dot_ref_record);
3869           }
3870        }
3871        func_record_setup(v, v->curr_record_selfptr, &bases);
3872        vector_clear(&bases);
3873     }
3874
3875     ASTVF_BEGIN(AST_FUNC_BODY, Ast_Visitor_Aia, v, Ast_Stmt_List, n)
3876        Vector *stmts;
3877        Ast_Node *node;
3878
3879        v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3880
3881        if (v->curr_func_type == AIAV_FUNC_TYPE_RECORD)
3882           record_func_stmt_startup(v, n);
3883
3884        stmts = n->statements;
3885        for (Uns i = n->num_rec_ctor_stmts; i < vector_size(stmts); i++) {
3886           node = vector_get(stmts, i);
3887           node->accept_visitor(node, AST_VISITOR_OF(v));
3888           if (v->prev_result && v->prev_result->ref_count == 0) {
3889              ___aia_operand_destroy(v->prev_result);
3890              v->prev_result = NULL;
3891           }
3892        }
3893     ASTVF_END
3894
3895     ASTVF_BEGIN(AST_EXPR_CHAR, Ast_Visitor_Aia, v, Ast_Expr_Char, n)
3896        v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3897        v->prev_result = aia_operand_const_int_alloc(v->aia, n->val);
3898        v->prev_expr_type = AST_EXPR_TYPE_CHAR;
3899        v->aia_expr_type = AIA_EXPR_STANDARD;
3900     ASTVF_END
3901
3902     ASTVF_BEGIN(AST_EXPR_STRING, Ast_Visitor_Aia, v, Ast_Expr_String, n)
3903        v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3904
3905        Aia_Section_Type prev_sec = ___aia_get_curr_section_type(v->aia);
3906        Const_String prev_fun = ___aia_get_curr_func_name(v->aia);
3907
3908        ___aia_switch_section(v->aia, AIA_SECTION_RODATA);
3909
3910        Aia_Operand *lbl = aia_operand_tmp_label_alloc(v->aia, S("STR"));
3911        ___aia_insert_label_instr(v->aia,
3912              aia_operand_label_get_name(lbl),
3913              aia_operand_label_get_offset(lbl),
```

```
3914            0,
3915            AIA_LINKAGE_PRIVATE,
3916            AIA_LABEL_TYPE_OBJ,
3917            string_length(n->val) + 1,
3918            v->curr_loc);
3919
3920     Aia_Operand *str = aia_operand_const_string_alloc(v->aia, n->val);
3921     ___aia_insert_string_instr(v->aia, str, v->curr_loc);
3922
3923     v->prev_expr_type = AST_EXPR_TYPE_STRING;
3924     v->aia_expr_type = AIA_EXPR_STANDARD;
3925     v->prev_result = aia_operand_label_addr_alloc(v->aia,
3926           aia_operand_label_get_name(lbl), 0);
3927
3928     ___aia_operand_destroy(lbl);
3929
3930     ___aia_switch_section(v->aia, prev_sec);
3931     ___aia_switch_func(v->aia, prev_fun);
3932 ASTVF_END
3933
3934 ASTVF_BEGIN(AST_IMPORT_STRING, Ast_Visitor_Aia, v, Ast_Module_String, n)
3935     (void)n;
3936     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3937 ASTVF_END
3938
3939 ASTVF_BEGIN(AST_PACKAGE_STRING, Ast_Visitor_Aia, v, Ast_Module_String, n)
3940     (void)n;
3941     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3942 ASTVF_END
3943
3944 ASTVF_BEGIN(AST_SIMPLE_TYPE_CHAR, Ast_Visitor_Aia, v, Ast_Empty, n)
3945     (void)n;
3946     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3947 ASTVF_END
3948
3949 ASTVF_BEGIN(AST_SIMPLE_TYPE_VOID, Ast_Visitor_Aia, v, Ast_Empty, n)
3950     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3951     v->prev_expr_type = AST_EXPR_TYPE_VOID;
3952     v->aia_expr_type = AIA_EXPR_STANDARD;
3953 ASTVF_END
3954
3955 ASTVF_BEGIN(AST_SIMPLE_TYPE_STRING, Ast_Visitor_Aia, v, Ast_Empty, n)
3956     (void)n;
3957     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3958 ASTVF_END
3959
3960 ASTVF_BEGIN(AST_REC_SELF_PTR, Ast_Visitor_Aia, v, Ast_Empty, n)
3961     v->curr_loc = ast_node_get_file_location(AST_NODE_OF(n));
3962
3963     Symbol *sym = symbol_table_get_from_location(
3964           ast_node_get_symbol_table_node(AST_NODE_OF(n)),
3965           ast_node_get_file_location(AST_NODE_OF(n)));
3966
3967     v->prev_sym_type = sym->resolved_type;
3968     v->prev_expr_type = AST_EXPR_TYPE_REC;
3969     v->aia_expr_type = AIA_EXPR_STANDARD;
3970
3971     v->prev_iden = NULL;
3972     v->prev_variable_result = NULL;
3973     v->prev_result = get_curr_display_selfptr(v);
3974 ASTVF_END
3975
3976 static void ast_visitor_insert_initializer(Ast_Visitor_Aia *v,
3977       Vit_Vmt *vmt)
3978 {
3979     Vit_Record_Initializer *ini = &vmt->initializer;
3980     ___aia_switch_section(v->aia, AIA_SECTION_TEXT);
3981     ___aia_switch_func(v->aia, ini->initializer_name);
3982     aia_func_set_linkage(v->aia, AIA_LINKAGE_GLOBAL);
3983
3984     aia_func_append_param(v->aia, SELF_STR);
3985     Aia_Operand *self = v->aia->record_self_ptr;
3986
3987     Uns size = vector_size(&ini->vmt_offsets);
```

```
3988     assert(vector_size(&ini->rec_offsets) == size);
3989
3990     for (Uns i = 0; i < size; i++) {
3991        int32_t off = PTR_TO_INT(vector_get(&ini->vmt_offsets, i));
3992        Aia_Operand *vmt_op = aia_operand_label_addr_alloc(v->aia,
3993              vmt->record_name, off);
3994        off = PTR_TO_INT(vector_get(&ini->rec_offsets, i));
3995        Aia_Operand *disp = aia_operand_const_int_alloc(v->aia, off);
3996        Aia_Operand *addr_ref = aia_operand_addr_ref_alloc(v->aia,
3997              NULL, disp, self, NULL, NULL);
3998
3999        mov_instr(v, AIA_MOV, addr_ref, vmt_op, AIA_LONG, AIA_LONG);
4000     }
4001     ___aia_0op_instr(v->aia, AIA_RET, -1, v->curr_loc);
4002  }
4003
4004  static void ast_visitor_insert_vmt(Ast_Visitor_Aia *v, Vit_Vmt *vmt)
4005  {
4006     ___aia_switch_section(v->aia, AIA_SECTION_RODATA);
4007
4008     ___aia_insert_label_instr(v->aia,
4009           vmt->record_name,
4010           0,
4011           4,
4012           AIA_LINKAGE_GLOBAL,
4013           AIA_LABEL_TYPE_OBJ,
4014           vmt->current_func_offset,
4015           v->curr_loc);
4016
4017     Aia_Operand *lbl;
4018     String fname;
4019     VECTOR_FOR_EACH_ENTRY(&vmt->func_names, fname) {
4020        lbl = aia_operand_label_alloc(v->aia, fname, 0);
4021        ___aia_insert_const_val_instr(v->aia, lbl, AIA_LONG, v->curr_loc);
4022     }
4023  }
4024
4025  static void ast_visitor_default_finalize(Ast_Visitor_Aia *v, Vit_Record *r)
4026  {
4027     ___aia_switch_section(v->aia, AIA_SECTION_TEXT);
4028     ___aia_switch_func(v->aia, r->rec->missing_finalize_name);
4029     aia_set_curr_func_location(v->aia, v->curr_loc);
4030     aia_func_set_linkage(v->aia, AIA_LINKAGE_GLOBAL);
4031
4032     aia_func_append_param(v->aia, SELF_STR);
4033
4034     func_finalize_setup_vit_rec(v, r);
4035
4036     Aia_Operand *self = v->aia->record_self_ptr;
4037     Aia_Instr *ret_in = ___aia_1op_instr(v->aia, AIA_RET, -1, AIA_LONG,
4038           v->curr_loc);
4039     aia_instr_set_src_op(ret_in, 0, self);
4040
4041     func_def_insert_trampolines(v, r->rec->missing_finalize_name,
4042           &v->aia->curr_func->parameters);
4043  }
4044
4045  static void ast_visitor_default_rec_func(Ast_Visitor_Aia *v, Vit_Record *r)
4046  {
4047     ___aia_switch_section(v->aia, AIA_SECTION_TEXT);
4048     ___aia_switch_func(v->aia, r->rec->missing_record_func_name);
4049     aia_set_curr_func_location(v->aia, v->curr_loc);
4050     aia_func_set_linkage(v->aia, AIA_LINKAGE_GLOBAL);
4051
4052     aia_func_append_param(v->aia, SELF_STR);
4053
4054     func_record_setup_vit_rec(v, r, &r->rec->extended_types);
4055
4056     Aia_Operand *self = v->aia->record_self_ptr;
4057     Aia_Instr *ret_in = ___aia_1op_instr(v->aia, AIA_RET, -1, AIA_LONG,
4058           v->curr_loc);
4059     aia_instr_set_src_op(ret_in, 0, self);
4060
4061     func_def_insert_trampolines(v, r->rec->missing_record_func_name,
```

```
4062          &v->aia->curr_func->parameters);
4063  }
4064
4065  static void ast_visitor_insert_def_functions(Ast_Visitor_Aia *v)
4066  {
4067     File_Location *prev_loc = v->curr_loc;
4068     v->curr_loc = aia_get_null_location(v->aia);
4069     Hash_Map_Slot *slot;
4070     Hash_Map *m = &v->record_map;
4071     HASH_MAP_FOR_EACH(m, slot) {
4072        Vit_Record *r = VIT_RECORD_OF(slot);
4073        if (r->rec->missing_finalize_name)
4074           ast_visitor_default_finalize(v, r);
4075        if (r->rec->missing_record_func_name)
4076           ast_visitor_default_rec_func(v, r);
4077     }
4078     v->curr_loc = prev_loc;
4079  }
4080
4081  static void ast_visitor_insert_vmts(Ast_Visitor_Aia *v)
4082  {
4083     File_Location *prev_loc = v->curr_loc;
4084     v->curr_loc = aia_get_null_location(v->aia);
4085     Hash_Map_Slot *vmt_slot;
4086     Hash_Map *m = &v->vmt_map;
4087     HASH_MAP_FOR_EACH(m, vmt_slot) {
4088        Vit_Vmt *vmt = VIT_VMT_OF(vmt_slot);
4089        if (!vmt->is_imported) {
4090           ast_visitor_insert_vmt(v, vmt);
4091           ast_visitor_insert_initializer(v, vmt);
4092        }
4093     }
4094     v->curr_loc = prev_loc;
4095  }
4096
4097  static void ast_visitor_dump_vit_record(FILE *stream, Vit_Record *r)
4098  {
4099     file_print_message(stream, S("# record %S\n# align: %U\n"),
4100           r->identifier,
4101           r->alignment);
4102     if (r->initializer_name)
4103        file_print_message(stream, S("# initializer: %S\n"),
4104              r->initializer_name);
4105
4106     Vit_Record_Field *field;
4107     VECTOR_FOR_EACH_ENTRY(&r->field_vector, field) {
4108        file_print_message(stream, S("#\t%S offset(%U)\n"),
4109              field->field_name,
4110              field->field_offset);
4111     }
4112
4113     file_print_message(stream, S("# end record size(%U)\n\n"),
4114           r->byte_size, r->identifier);
4115  }
4116
4117  static void ast_visitor_dump_aia(Ast_Visitor_Aia *v,
4118        Const_String fname_prefix)
4119  {
4120     String fname = string_from_format(S("%S.vitaly.init-ic"), fname_prefix);
4121     FILE *stream = file_open(fname, S("w"));
4122     if (!stream)
4123        fatal_error(S("unable to create file %S for intermediate "
4124                  "code dump [%m]\n"), fname);
4125     string_destroy(fname);
4126
4127     Hash_Map_Slot *rec_slot;
4128     HASH_MAP_FOR_EACH(&v->record_map, rec_slot)
4129        ast_visitor_dump_vit_record(stream, VIT_RECORD_OF(rec_slot));
4130
4131     aia_dump(v->aia, stream);
4132
4133     file_close(stream);
4134  }
4135
```

```
4136 static String vit_name_to_c_name(Const_String rec_name)
4137 {
4138    String name = string_cpy_replace_all(rec_name, '.', '_');
4139    string_replace_all(name, '$', '_');
4140    return name;
4141 }
4142
4143 static void ast_visitor_dump_h_decl_rec(FILE *stream, Vit_Record *r)
4144 {
4145    String tmp = vit_name_to_c_name(r->identifier);
4146    file_print_message(stream, S("struct %S;\n"), tmp);
4147    string_destroy(tmp);
4148 }
4149
4150 static void ast_visitor_dump_h_def_vmt(FILE *stream, Vit_Vmt *vmt)
4151 {
4152    String name = vit_name_to_c_name(vmt->record_name);
4153    string_append(name, S("_vmt"));
4154
4155    file_print_message(stream, S("\nstruct %S {\n"), name);
4156    string_destroy(name);
4157
4158    Const_String func;
4159    VECTOR_FOR_EACH_ENTRY(&vmt->func_names, func) {
4160       String tmp = vit_name_to_c_name(func);
4161       file_print_message(stream,
4162             S("\tvoid *(*%S)(void *record, ...);\n"), tmp);
4163       string_destroy(tmp);
4164    }
4165
4166    file_print_message(stream, S("};\n"));
4167 }
4168
4169 static void ast_visitor_dump_h_def_rec(FILE *stream, Vit_Record *r,
4170       Ast_Visitor_Aia *v)
4171 {
4172    if (r->is_c_header_printed)
4173       return;
4174    r->is_c_header_printed = true;
4175
4176    Vit_Record_Field *field;
4177    VECTOR_FOR_EACH_ENTRY(&r->field_vector, field) {
4178       if (field->sym_type == SYMBOL_TYPE_IDEN) {
4179          Hash_Map_Slot *vit_slot = hash_map_get(&v->record_map,
4180                field->field_name, string_hash_code(field->field_name));
4181          assert(vit_slot);
4182          ast_visitor_dump_h_def_rec(stream, VIT_RECORD_OF(vit_slot), v);
4183       }
4184    }
4185
4186    String name = vit_name_to_c_name(r->identifier);
4187    file_print_message(stream, S("\nstruct %S {\n"), name);
4188    string_destroy(name);
4189
4190    String tn;
4191    String fn;
4192
4193    VECTOR_FOR_EACH_ENTRY(&r->field_vector, field) {
4194       switch (field->sym_type) {
4195       case SYMBOL_TYPE_IDEN:
4196          tn = vit_name_to_c_name(field->field_type_name);
4197          fn = vit_name_to_c_name(field->field_name);
4198          file_print_message(stream, S("\tstruct %S %S;\n"), tn, fn);
4199          string_destroy(tn);
4200          string_destroy(fn);
4201          break;
4202       case SYMBOL_TYPE_INT:
4203          file_print_message(stream, S("\tint %S;\n"), field->field_name);
4204          break;
4205       case SYMBOL_TYPE_BOOL:
4206          file_print_message(stream, S("\tbool %S;\n"), field->field_name);
4207          break;
4208       case SYMBOL_TYPE_CHAR:
4209          file_print_message(stream, S("\tchar %S;\n"), field->field_name);
```

```
4210            break;
4211         case SYMBOL_TYPE_STRING:
4212            file_print_message(stream, S("\tconst char *%S;\n"),
4213                  field->field_name);
4214            break;
4215         case SYMBOL_TYPE_ARY:
4216            file_print_message(stream, S("\tvoid *%S;\n"),
4217                  field->field_name);
4218            break;
4219         case SYMBOL_TYPE_REC:
4220            fn = vit_name_to_c_name(field->field_name);
4221            file_print_message(stream, S("\tvoid *%S;\n"), fn);
4222            string_destroy(fn);
4223            break;
4224         default:
4225            fatal_error(S("unexpected record filed type encountered "
4226                     "while printing C header. Aborting...\n"));
4227         }
4228      }
4229
4230      file_print_message(stream, S("};\n"));
4231   }
4232
4233   static void ast_visitor_dump_h(Ast_Visitor_Aia *v, Const_String src_fname)
4234   {
4235      String fname = string_from_format(S("%S.vitaly.h"), src_fname);
4236      FILE *stream = file_open(fname, S("w"));
4237      if (!stream)
4238         fatal_error(S("unable to create C header file %S [%m]\n"), fname);
4239
4240      String def = string_cpy_replace_all(fname, '.', '_');
4241      string_toupper(def);
4242      string_destroy(fname);
4243
4244      file_print_message(stream, S("#ifndef %1$S\n#define %1$S\n"
4245               "#include <stdbool.h>\n\n"), def);
4246
4247      Hash_Map_Slot *slot;
4248      HASH_MAP_FOR_EACH(&v->record_map, slot)
4249         ast_visitor_dump_h_decl_rec(stream, VIT_RECORD_OF(slot));
4250
4251      HASH_MAP_FOR_EACH(&v->vmt_map, slot)
4252         ast_visitor_dump_h_def_vmt(stream, VIT_VMT_OF(slot));
4253
4254      HASH_MAP_FOR_EACH(&v->record_map, slot)
4255         ast_visitor_dump_h_def_rec(stream, VIT_RECORD_OF(slot), v);
4256
4257      file_print_message(stream, S("\n#endif // %S\n"), def);
4258      string_destroy(def);
4259
4260      file_close(stream);
4261   }
4262
4263   static Ast_Visitor_Aia aia_visitor = {
4264      .AST_VISITOR_FIELD = AST_VISITOR_STATIC_INIT(),
4265      .next_property = SYMBOL_PROPERTY_VAR,
4266      .null_location = FILE_LOCATION_STATIC_INIT(NULL, 0, 0)
4267   };
4268
4269   Aia *ast_visitor_aia_create(Ast *ast, Const_String src_fname)
4270   {
4271      if (ast_is_valid(ast) && !was_error_reported()) {
4272         ast_visitor_dependency_accept(ast);
4273
4274         file_location_set_file_name(&aia_visitor.null_location,
4275               ast_get_file_name(ast));
4276         aia_visitor.sym_table = ast_get_symbol_table(ast);
4277         aia_visitor.prev_result = NULL;
4278
4279         aia_visitor.record_map = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_23,
4280               (Hash_Map_Comparator)vit_record_comparator);
4281         aia_visitor.vmt_map = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_23,
4282               (Hash_Map_Comparator)vit_vmt_comparator);
4283         aia_visitor.trampolines = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_23,
```

```
4284              (Hash_Map_Comparator)vit_vmt_trampoline_entry_comparator);
4285
4286        aia_visitor.aia = aia_alloc(ast_get_file_name(ast));
4287        ___aia_switch_section(aia_visitor.aia, AIA_SECTION_INIT);
4288
4289        ast->root->accept_visitor(ast->root, AST_VISITOR_OF(&aia_visitor));
4290
4291        assert(aia_visitor.next_property == SYMBOL_PROPERTY_VAR);
4292        assert(!aia_visitor.stmt_list_nest);
4293
4294        ast_visitor_insert_def_functions(&aia_visitor);
4295        ast_visitor_insert_vmts(&aia_visitor);
4296        ___aia_finish(aia_visitor.aia);
4297
4298        if (cmdopts.dump_init_ic)
4299           ast_visitor_dump_aia(&aia_visitor, src_fname);
4300        if (cmdopts.dump_c_header)
4301           ast_visitor_dump_h(&aia_visitor, src_fname);
4302
4303        hash_map_for_each_destroy(&aia_visitor.record_map,
4304              vit_record_hash_destroy);
4305        hash_map_for_each_destroy(&aia_visitor.vmt_map,
4306              vit_vmt_hash_destroy);
4307        hash_map_for_each_destroy(&aia_visitor.trampolines,
4308              vit_vmt_trampoline_entry_hash_destroy);
4309
4310        stn_display_preserve_destroy();
4311
4312        return aia_visitor.aia;
4313     }
4314     return NULL;
4315  }
```

:

A.6.2 src/ast/ast_visitor_aia.h

```
1  #ifndef AST_VISITOR_AIA_H
2  #define AST_VISITOR_AIA_H
3
4  #include "ast_visitor.h"
5  #include <aia/aia.h>
6
7  Aia *ast_visitor_aia_create(Ast *ast, Const_String src_fname);
8
9  #endif // AST_VISITOR_AIA_H
```

:

A.6.3 src/ast/ast_visitor_delete.c

```
1  #include "ast_visitor_delete.h"
2
3  AST_VISITOR_STRUCT_BEGIN(Ast_Visitor_Delete)
4  AST_VISITOR_STRUCT_END(Ast_Visitor_Delete)
5
6  static void stmt_list_action(Ast_Visitor_Delete *v, Ast_Stmt_List *n) {
7     Ast_Node *stmt;
8     Vector *vec = n->statements;
9     VECTOR_FOR_EACH_ENTRY(vec, stmt)
10       stmt->accept_visitor(stmt, AST_VISITOR_OF(v));
11    vector_destroy(vec, NULL);
12    free_mem(n);
13 }
14
15 static void ternary_action(Ast_Visitor_Delete *v, Ast_Node_Ternary *n)
16 {
```

```
17      n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
18      n->mid->accept_visitor(n->mid, AST_VISITOR_OF(v));
19      n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
20      free_mem(n);
21  }
22
23  static void binary_action(Ast_Visitor_Delete *v, Ast_Node_Binary *n)
24  {
25      n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
26      n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
27      free_mem(n);
28  }
29
30  static void unary_action(Ast_Visitor_Delete *v, Ast_Node_Unary *n)
31  {
32      n->expr->accept_visitor(n->expr, AST_VISITOR_OF(v));
33      free_mem(n);
34  }
35
36  static void type_action(Ast_Visitor_Delete *v, Ast_Type *n)
37  {
38      n->type->accept_visitor(n->type, AST_VISITOR_OF(v));
39      free_mem(n);
40  }
41
42  ASTVF_BEGIN(AST_EXPR_LOR, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
43      binary_action(v, n);
44  ASTVF_END
45
46  ASTVF_BEGIN(AST_EXPR_LAND, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
47      binary_action(v, n);
48  ASTVF_END
49
50  ASTVF_BEGIN(AST_EXPR_EQ, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
51      binary_action(v, n);
52  ASTVF_END
53
54  ASTVF_BEGIN(AST_EXPR_NEQ, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
55      binary_action(v, n);
56  ASTVF_END
57
58  ASTVF_BEGIN(AST_EXPR_GT, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
59      binary_action(v, n);
60  ASTVF_END
61
62  ASTVF_BEGIN(AST_EXPR_LT, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
63      binary_action(v, n);
64  ASTVF_END
65
66  ASTVF_BEGIN(AST_EXPR_GTEQ, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
67      binary_action(v, n);
68  ASTVF_END
69
70  ASTVF_BEGIN(AST_EXPR_LTEQ, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
71      binary_action(v, n);
72  ASTVF_END
73
74  ASTVF_BEGIN(AST_EXPR_PLUS, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
75      binary_action(v, n);
76  ASTVF_END
77
78  ASTVF_BEGIN(AST_EXPR_MINUS, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
79      binary_action(v, n);
80  ASTVF_END
81
82  ASTVF_BEGIN(AST_EXPR_MUL, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
83      binary_action(v, n);
84  ASTVF_END
85
86  ASTVF_BEGIN(AST_EXPR_DIV, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
87      binary_action(v, n);
88  ASTVF_END
89
90  ASTVF_BEGIN(AST_EXPR_CAST, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
```

```
91     binary_action(v, n);
92  ASTVF_END
93
94  ASTVF_BEGIN(AST_EXPR_LNOT, Ast_Visitor_Delete, v, Ast_Node_Unary, n)
95     unary_action(v, n);
96  ASTVF_END
97
98  ASTVF_BEGIN(AST_EXPR_ABS, Ast_Visitor_Delete, v, Ast_Node_Unary, n)
99     unary_action(v, n);
100 ASTVF_END
101
102 ASTVF_BEGIN(AST_EXPR_INT, Ast_Visitor_Delete, v, Ast_Expr_Int, n)
103    (void)v;
104    free_mem(n);
105 ASTVF_END
106
107 ASTVF_BEGIN(AST_EXPR_BOOL, Ast_Visitor_Delete, v, Ast_Expr_Bool, n)
108    (void)v;
109    free_mem(n);
110 ASTVF_END
111
112 ASTVF_BEGIN(AST_EXPR_NULL, Ast_Visitor_Delete, v, Ast_Expr_Null, n)
113    (void)v;
114    free_mem(n);
115 ASTVF_END
116
117 ASTVF_BEGIN(AST_VARIABLE_IDEN, Ast_Visitor_Delete, v, Ast_Variable_Iden, n)
118    (void)v;
119    string_destroy(n->iden);
120    free_mem(n);
121 ASTVF_END
122
123 ASTVF_BEGIN(AST_EXPR_ARY_REF, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
124    binary_action(v, n);
125 ASTVF_END
126
127 ASTVF_BEGIN(AST_EXPR_FUNC_CALL, Ast_Visitor_Delete, v, Ast_Expr_Func_Call, n)
128    n->identifier->accept_visitor(n->identifier, AST_VISITOR_OF(v));
129    Vector *vargs = n->arguments;
130    Ast_Node *arg;
131    VECTOR_FOR_EACH_ENTRY(vargs, arg)
132       arg->accept_visitor(arg, AST_VISITOR_OF(v));
133    vector_destroy(vargs, NULL);
134    free_mem(n);
135 ASTVF_END
136
137 ASTVF_BEGIN(AST_EXPR_DOT_REF, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
138    binary_action(v, n);
139 ASTVF_END
140
141 ASTVF_BEGIN(AST_EXPR_DIRECT_REF, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
142    if (n->lhs) {
143       binary_action(v, n);
144    } else {
145       n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
146       free_mem(n);
147    }
148 ASTVF_END
149
150 ASTVF_BEGIN(AST_SIMPLE_TYPE_INT, Ast_Visitor_Delete, v, Ast_Empty, n)
151    (void)v;
152    free_mem(n);
153 ASTVF_END
154
155 ASTVF_BEGIN(AST_SIMPLE_TYPE_BOOL, Ast_Visitor_Delete, v, Ast_Empty, n)
156    (void)v;
157    free_mem(n);
158 ASTVF_END
159
160 ASTVF_BEGIN(AST_TYPE_IDEN, Ast_Visitor_Delete, v, Ast_Type_Iden, n)
161    (void)v;
162    string_destroy(n->iden);
163    free_mem(n);
164 ASTVF_END
```

```
165
166 ASTVF_BEGIN(AST_VAR_DECL, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
167    binary_action(v, n);
168 ASTVF_END
169
170 ASTVF_BEGIN(AST_TYPE_DEF, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
171    binary_action(v, n);
172 ASTVF_END
173
174 ASTVF_BEGIN(AST_TYPE_ARY, Ast_Visitor_Delete, v, Ast_Type, n)
175    type_action(v, n);
176 ASTVF_END
177
178 ASTVF_BEGIN(AST_TYPE_REC, Ast_Visitor_Delete, v, Ast_Type_Rec, n)
179    Ast_Node *arg;
180    Vector *vargs = n->extend_list;
181    VECTOR_FOR_EACH_ENTRY(vargs, arg)
182       arg->accept_visitor(arg, AST_VISITOR_OF(v));
183    vector_destroy(vargs, NULL);
184
185    vargs = n->body;
186    VECTOR_FOR_EACH_ENTRY(vargs, arg)
187       arg->accept_visitor(arg, AST_VISITOR_OF(v));
188    vector_destroy(vargs, NULL);
189    free_mem(n);
190 ASTVF_END
191
192 ASTVF_BEGIN(AST_STMT_LIST, Ast_Visitor_Delete, v, Ast_Stmt_List, n)
193    stmt_list_action(v, n);
194 ASTVF_END
195
196 ASTVF_BEGIN(AST_FIN_STMT_LIST, Ast_Visitor_Delete, v, Ast_Stmt_List, n)
197    stmt_list_action(v, n);
198 ASTVF_END
199
200 static void delete_func(Ast_Visitor_Delete *v, Ast_Func_Def *n)
201 {
202    Ast_Node *p;
203    Vector *vec = n->parameters;
204    n->iden->accept_visitor(n->iden, AST_VISITOR_OF(v));
205    n->return_type->accept_visitor(n->return_type, AST_VISITOR_OF(v));
206    VECTOR_FOR_EACH_ENTRY(vec, p)
207       p->accept_visitor(p, AST_VISITOR_OF(v));
208    vector_destroy(vec, NULL);
209    n->statements->accept_visitor(n->statements, AST_VISITOR_OF(v));
210    free_mem(n);
211 }
212
213 ASTVF_BEGIN(AST_EXT_FUNC_DECL, Ast_Visitor_Delete, v, Ast_Func_Def, n)
214    Ast_Node *p;
215    n->iden->accept_visitor(n->iden, AST_VISITOR_OF(v));
216    n->return_type->accept_visitor(n->return_type, AST_VISITOR_OF(v));
217    n->extern_type->accept_visitor(n->extern_type, AST_VISITOR_OF(v));
218    Vector *vec = n->parameters;
219    VECTOR_FOR_EACH_ENTRY(vec, p)
220       p->accept_visitor(p, AST_VISITOR_OF(v));
221    vector_destroy(vec, NULL);
222    free_mem(n);
223 ASTVF_END
224
225 ASTVF_BEGIN(AST_FIN_FUNC_DEF, Ast_Visitor_Delete, v, Ast_Func_Def, n)
226    delete_func(v, n);
227 ASTVF_END
228
229 ASTVF_BEGIN(AST_REC_FUNC_DEF, Ast_Visitor_Delete, v, Ast_Func_Def, n)
230    delete_func(v, n);
231 ASTVF_END
232
233 ASTVF_BEGIN(AST_FUNC_DEF, Ast_Visitor_Delete, v, Ast_Func_Def, n)
234    delete_func(v, n);
235 ASTVF_END
236
237 ASTVF_BEGIN(AST_IF_STMT, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
238    binary_action(v, n);
```

```
239 ASTVF_END
240
241 ASTVF_BEGIN(AST_IF_ELSE_STMT, Ast_Visitor_Delete, v, Ast_Node_Ternary, n)
242     ternary_action(v, n);
243 ASTVF_END
244
245 ASTVF_BEGIN(AST_ALLOC_ARY, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
246     binary_action(v, n);
247 ASTVF_END
248
249 ASTVF_BEGIN(AST_ALLOC_REC, Ast_Visitor_Delete, v, Ast_Node_Unary, n)
250     unary_action(v, n);
251 ASTVF_END
252
253 ASTVF_BEGIN(AST_ALLOC_REC_CALL, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
254     binary_action(v, n);
255 ASTVF_END
256
257 ASTVF_BEGIN(AST_DELETE, Ast_Visitor_Delete, v, Ast_Node_Unary, n)
258     unary_action(v, n);
259 ASTVF_END
260
261 ASTVF_BEGIN(AST_WHILE_STMT, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
262     binary_action(v, n);
263 ASTVF_END
264
265 ASTVF_BEGIN(AST_RETURN_STMT, Ast_Visitor_Delete, v, Ast_Node_Unary, n)
266     unary_action(v, n);
267 ASTVF_END
268
269 ASTVF_BEGIN(AST_WRITE_STMT, Ast_Visitor_Delete, v, Ast_Node_Unary, n)
270     unary_action(v, n);
271 ASTVF_END
272
273 ASTVF_BEGIN(AST_ASSIGNMENT, Ast_Visitor_Delete, v, Ast_Node_Binary, n)
274     binary_action(v, n);
275 ASTVF_END
276
277 ASTVF_BEGIN(AST_FUNC_BODY, Ast_Visitor_Delete, v, Ast_Stmt_List, n)
278     stmt_list_action(v, n);
279 ASTVF_END
280
281 ASTVF_BEGIN(AST_EXPR_CHAR, Ast_Visitor_Delete, v, Ast_Expr_Char, n)
282     (void)v;
283     free_mem(n);
284 ASTVF_END
285
286 ASTVF_BEGIN(AST_EXPR_STRING, Ast_Visitor_Delete, v, Ast_Expr_String, n)
287     (void)v;
288     string_destroy(n->val);
289     free_mem(n);
290 ASTVF_END
291
292 ASTVF_BEGIN(AST_IMPORT_STRING, Ast_Visitor_Delete, v, Ast_Module_String, n)
293     (void)v;
294     string_destroy(n->module);
295     free_mem(n);
296 ASTVF_END
297
298 ASTVF_BEGIN(AST_PACKAGE_STRING, Ast_Visitor_Delete, v, Ast_Module_String, n)
299     (void)v;
300     string_destroy(n->module);
301     free_mem(n);
302 ASTVF_END
303
304 ASTVF_BEGIN(AST_SIMPLE_TYPE_CHAR, Ast_Visitor_Delete, v, Ast_Empty, n)
305     (void)v;
306     free_mem(n);
307 ASTVF_END
308
309 ASTVF_BEGIN(AST_SIMPLE_TYPE_STRING, Ast_Visitor_Delete, v, Ast_Empty, n)
310     (void)v;
311     free_mem(n);
312 ASTVF_END
```

```

ASTVF_BEGIN(AST_REC_SELF_PTR, Ast_Visitor_Delete, v, Ast_Empty, n)
    (void)v;
    free_mem(n);
ASTVF_END

ASTVF_BEGIN(AST_SIMPLE_TYPE_VOID, Ast_Visitor_Delete, v, Ast_Empty, n)
    (void)v;
    free_mem(n);
ASTVF_END

static Ast_Visitor_Delete delete_visitor = {
    .AST_VISITOR_FIELD = AST_VISITOR_STATIC_INIT()
};

void ast_visitor_delete_accept_visitor(Ast_Node *root)
{
    root->accept_visitor(root, AST_VISITOR_OF(&delete_visitor));
}
```

:

A.6.4 src/ast/ast_visitor_delete.h

```
#ifndef AST_VISITOR_DELETE_H
#define AST_VISITOR_DELETE_H

#include "ast_visitor.h"

void ast_visitor_delete_accept_visitor(Ast_Node *root);

#endif // AST_VISITOR_DELETE_H
```

:

A.6.5 src/ast/ast_visitor_dependency.c

```
#include "ast_visitor_dependency.h"
#include "symbol_table.h"

#undef DEBUG_TYPE
#define DEBUG_TYPE ast-dependency

typedef struct Stn_Dependency {
    Symbol_Table_Node *sym_node;
    Rb_Tree_Node rbnode;
    bool is_func;
    bool is_var;
} Stn_Dependency;

#define STN_DEPENDENCY_OF(node) RB_TREE_ENTRY(node, Stn_Dependency, rbnode)

static bool stn_display_preserve_comparator(Symbol_Table_Node *search_node,
        Hash_Map_Slot *map_slot)
{
    Stn_Display_Preserve *p = STN_DISPLAY_PRESERVE_OF(map_slot);
    return search_node == p->sym_node;
}

static void ___stn_display_preserve_destroy(Hash_Map_Slot *s)
{
    Stn_Display_Preserve *p = STN_DISPLAY_PRESERVE_OF(s);
    vector_clear(&p->stn_displays);
    vector_clear(&p->func_dependencies);
    free_mem(p);
}

```

```
31  static Hash_Map stn_display_map;
32
33  void stn_display_preserve_destroy()
34  {
35     hash_map_for_each_destroy(&stn_display_map,
36           ___stn_display_preserve_destroy);
37  }
38
39  void stn_display_add_dependency(Stn_Display_Preserve *p,
40        Stn_Dependency *dep)
41  {
42     assert(dep->sym_node->scope_id <= p->sym_node->scope_id);
43     if (dep->is_var)
44        vector_append(&p->stn_displays, dep->sym_node);
45     if (dep->is_func)
46        vector_append(&p->func_dependencies, dep->sym_node);
47  }
48
49  Stn_Display_Preserve *stn_display_preserve_get(Symbol_Table_Node *n)
50  {
51     Hash_Map_Slot *s = hash_map_get(&stn_display_map, n, n->scope_id);
52     if (s)
53        return STN_DISPLAY_PRESERVE_OF(s);
54     return NULL;
55  }
56
57  static inline Stn_Dependency *stn_dependency_alloc(Symbol_Table_Node *n,
58        bool is_func)
59  {
60     Stn_Dependency *d = ALLOC_NEW(Stn_Dependency);
61     d->sym_node = n;
62     if (is_func) {
63        d->is_func = true;
64        d->is_var = false;
65     } else {
66        d->is_func = false;
67        d->is_var = true;
68     }
69     return d;
70  }
71
72  static inline void stn_dependency_destroy(Stn_Dependency *d)
73  {
74     free_mem(d);
75  }
76
77  static Int stn_dependency_search_comparator(Symbol_Table_Node *search_node,
78        Rb_Tree_Node *tree_node)
79  {
80     Uns tree_id = STN_DEPENDENCY_OF(tree_node)->sym_node->scope_id;
81     if (search_node->scope_id < tree_id)
82        return -1;
83     else if (search_node->scope_id > tree_id)
84        return 1;
85     return 0;
86  }
87
88  static bool stn_dependency_comparator(Rb_Tree_Node *search_node,
89        Rb_Tree_Node *tree_node)
90  {
91     return STN_DEPENDENCY_OF(search_node)->sym_node->scope_id <=
92           STN_DEPENDENCY_OF(tree_node)->sym_node->scope_id;
93  }
94
95  AST_VISITOR_STRUCT_BEGIN(Ast_Visitor_Dependency)
96     Symbol_Table_Node *curr_func_node;
97     Rb_Tree *dependencies;
98     Vector *curr_dependencies;
99     Vector stn_display_vector;
100    String prev_iden;
101    Symbol_Property next_property;
102 AST_VISITOR_STRUCT_END(Ast_Visitor_Dependency)
103
104 static inline Stn_Display_Preserve *stn_display_preserve_alloc(
```

```
105         Symbol_Table_Node *n, Ast_Visitor_Dependency *v,
106         Const_String func_name)
107 {
108    Stn_Display_Preserve *p = ALLOC_NEW(Stn_Display_Preserve);
109    assert(func_name);
110    p->func_name = func_name;
111    p->sym_node = n;
112    p->stn_displays = VECTOR_INIT_SIZE(4);
113    p->func_dependencies = VECTOR_INIT_SIZE(4);
114    vector_append(&v->stn_display_vector, p);
115    p->next_vector_idx = vector_size(&v->stn_display_vector);
116    return p;
117 }
118
119 static inline void dep_visitor_add_dependency(Ast_Visitor_Dependency *v,
120       Symbol_Table_Node *dependency, bool is_func)
121 {
122    while (dependency->type == SYMBOL_TABLE_NODE_INTERMEDIATE)
123       dependency = dependency->parent;
124
125    if (!is_func && dependency->type == SYMBOL_TABLE_NODE_REC &&
126          v->curr_func_node) {
127       dependency = v->curr_func_node;
128       while (dependency->parent->type != SYMBOL_TABLE_NODE_REC)
129          dependency = dependency->parent;
130    }
131    if (dependency->type != SYMBOL_TABLE_NODE_FUNC ||
132          dependency == v->curr_func_node)
133       return;
134
135    Stn_Dependency *tmp;
136    VECTOR_FOR_EACH_ENTRY(v->curr_dependencies, tmp) {
137       if (tmp->sym_node == dependency) {
138          if (is_func)
139             tmp->is_func = true;
140          else
141             tmp->is_var = true;
142          return;
143       }
144    }
145
146    DLOG("found dependency %U is func? %d\n", dependency->scope_id, is_func);
147
148    Stn_Dependency *d = stn_dependency_alloc(dependency, is_func);
149    vector_append(v->curr_dependencies, d);
150 }
151
152 static inline void ternary_action(Ast_Visitor_Dependency *v,
153       Ast_Node_Ternary *n)
154 {
155    n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
156    n->mid->accept_visitor(n->mid, AST_VISITOR_OF(v));
157    n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
158 }
159
160 static inline void binary_action(Ast_Visitor_Dependency *v,
161       Ast_Node_Binary *n)
162 {
163    n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
164    n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
165 }
166
167 static inline void unary_action(Ast_Visitor_Dependency *v,
168       Ast_Node_Unary *n)
169 {
170    n->expr->accept_visitor(n->expr, AST_VISITOR_OF(v));
171 }
172
173 ASTVF_BEGIN(AST_EXPR_LOR, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
174    binary_action(v, n);
175 ASTVF_END
176
177 ASTVF_BEGIN(AST_EXPR_LAND, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
178    binary_action(v, n);
```

```
179 ASTVF_END
180
181 ASTVF_BEGIN(AST_EXPR_EQ, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
182    binary_action(v, n);
183 ASTVF_END
184
185 ASTVF_BEGIN(AST_EXPR_NEQ, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
186    binary_action(v, n);
187 ASTVF_END
188
189 ASTVF_BEGIN(AST_EXPR_GT, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
190    binary_action(v, n);
191 ASTVF_END
192
193 ASTVF_BEGIN(AST_EXPR_LT, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
194    binary_action(v, n);
195 ASTVF_END
196
197 ASTVF_BEGIN(AST_EXPR_GTEQ, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
198    binary_action(v, n);
199 ASTVF_END
200
201 ASTVF_BEGIN(AST_EXPR_LTEQ, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
202    binary_action(v, n);
203 ASTVF_END
204
205 ASTVF_BEGIN(AST_EXPR_PLUS, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
206    binary_action(v, n);
207 ASTVF_END
208
209 ASTVF_BEGIN(AST_EXPR_MINUS, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
210    binary_action(v, n);
211 ASTVF_END
212
213 ASTVF_BEGIN(AST_EXPR_MUL, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
214    binary_action(v, n);
215 ASTVF_END
216
217 ASTVF_BEGIN(AST_EXPR_DIV, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
218    binary_action(v, n);
219 ASTVF_END
220
221 ASTVF_BEGIN(AST_EXPR_CAST, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
222    Symbol_Property saved_property = v->next_property;
223    v->next_property = SYMBOL_PROPERTY_TYPE_DEF;
224    n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
225    v->next_property = saved_property;
226    n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
227 ASTVF_END
228
229 ASTVF_BEGIN(AST_EXPR_LNOT, Ast_Visitor_Dependency, v, Ast_Node_Unary, n)
230    unary_action(v, n);
231 ASTVF_END
232
233 ASTVF_BEGIN(AST_EXPR_ABS, Ast_Visitor_Dependency, v, Ast_Node_Unary, n)
234    unary_action(v, n);
235 ASTVF_END
236
237 ASTVF_BEGIN(AST_EXPR_INT, Ast_Visitor_Dependency, v, Ast_Expr_Int, n)
238    (void)v; (void)n;
239 ASTVF_END
240
241 ASTVF_BEGIN(AST_EXPR_BOOL, Ast_Visitor_Dependency, v, Ast_Expr_Bool, n)
242    (void)v; (void)n;
243 ASTVF_END
244
245 ASTVF_BEGIN(AST_EXPR_NULL, Ast_Visitor_Dependency, v, Ast_Expr_Null, n)
246    (void)v; (void)n;
247 ASTVF_END
248
249 ASTVF_BEGIN(AST_VARIABLE_IDEN, Ast_Visitor_Dependency, v, Ast_Variable_Iden, n)
250
251    Symbol *sym;
252    Symbol_Table_Node *sym_node = ast_node_get_symbol_table_node(
```

```
253           AST_NODE_OF(n));
254
255       switch (v->next_property) {
256       case SYMBOL_PROPERTY_VAR:
257          sym = symbol_table_node_lookup(sym_node, n->iden,
258                SYMBOL_PROPERTY_VAR);
259          assert(sym);
260          dep_visitor_add_dependency(v, sym->sym_node, false);
261          break;
262       case SYMBOL_PROPERTY_FUNC:
263          sym = symbol_table_node_lookup(sym_node, n->iden,
264                SYMBOL_PROPERTY_FUNC);
265          assert(sym);
266          dep_visitor_add_dependency(v, sym->sym_node, true);
267          break;
268
269       case SYMBOL_PROPERTY_TYPE_DEF:
270          break;
271       }
272       v->prev_iden = n->iden;
273    ASTVF_END
274
275    ASTVF_BEGIN(AST_EXPR_ARY_REF, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
276       binary_action(v, n);
277    ASTVF_END
278
279    ASTVF_BEGIN(AST_EXPR_FUNC_CALL, Ast_Visitor_Dependency, v,
280          Ast_Expr_Func_Call, n)
281       Symbol_Property saved_property = v->next_property;
282       v->next_property = SYMBOL_PROPERTY_FUNC;
283       n->identifier->accept_visitor(n->identifier, AST_VISITOR_OF(v));
284       v->next_property = saved_property;
285
286       Vector *args = n->arguments;
287       Ast_Node *a;
288       VECTOR_FOR_EACH_ENTRY(args, a)
289          a->accept_visitor(a, AST_VISITOR_OF(v));
290    ASTVF_END
291
292    ASTVF_BEGIN(AST_EXPR_DOT_REF, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
293       n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
294    ASTVF_END
295
296    ASTVF_BEGIN(AST_EXPR_DIRECT_REF, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
297       if (n->lhs)
298          n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
299    ASTVF_END
300
301    ASTVF_BEGIN(AST_SIMPLE_TYPE_INT, Ast_Visitor_Dependency, v, Ast_Empty, n)
302       (void)n; (void)v;
303    ASTVF_END
304
305    ASTVF_BEGIN(AST_SIMPLE_TYPE_BOOL, Ast_Visitor_Dependency, v, Ast_Empty, n)
306       (void)v; (void)n;
307    ASTVF_END
308
309    ASTVF_BEGIN(AST_TYPE_IDEN, Ast_Visitor_Dependency, v, Ast_Type_Iden, n)
310       (void)v; (void)n;
311    ASTVF_END
312
313    ASTVF_BEGIN(AST_VAR_DECL, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
314    #if 0
315       Symbol_Property saved_property = v->next_property;
316       v->next_property = SYMBOL_PROPERTY_VAR;
317       n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
318       v->next_property = saved_property;
319    #endif
320       n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
321    ASTVF_END
322
323    ASTVF_BEGIN(AST_TYPE_DEF, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
324    #if 0
325       Symbol_Property saved_property = v->next_property;
326       v->next_property = SYMBOL_PROPERTY_TYPE_DEF;
```

```
327     n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
328     v->next_property = saved_property;
329  #endif
330     n->rhs->accept_visitor(n->rhs, AST_VISITOR_OF(v));
331  ASTVF_END
332
333  ASTVF_BEGIN(AST_TYPE_ARY, Ast_Visitor_Dependency, v, Ast_Type, n)
334     (void)v;
335     n->type->accept_visitor(n->type, AST_VISITOR_OF(v));
336  ASTVF_END
337
338  ASTVF_BEGIN(AST_TYPE_REC, Ast_Visitor_Dependency, v, Ast_Type_Rec, n)
339     Vector *vec;
340     Ast_Node *node;
341     vec = n->extend_list;
342     VECTOR_FOR_EACH_ENTRY(vec, node)
343        node->accept_visitor(node, AST_VISITOR_OF(v));
344     vec = n->body;
345     VECTOR_FOR_EACH_ENTRY(vec, node)
346        node->accept_visitor(node, AST_VISITOR_OF(v));
347  ASTVF_END
348
349  static void stmt_list_action(Ast_Visitor_Dependency *v , Ast_Stmt_List *n)
350  {
351     Ast_Node *s;
352     Vector *stmts = n->statements;
353     VECTOR_FOR_EACH_ENTRY(stmts, s)
354        s->accept_visitor(s, AST_VISITOR_OF(v));
355  }
356
357  ASTVF_BEGIN(AST_STMT_LIST, Ast_Visitor_Dependency, v, Ast_Stmt_List, n)
358     stmt_list_action(v, n);
359  ASTVF_END
360
361  ASTVF_BEGIN(AST_FIN_STMT_LIST, Ast_Visitor_Dependency, v, Ast_Stmt_List, n)
362     stmt_list_action(v, n);
363  ASTVF_END
364
365  static void func_dependency(Ast_Visitor_Dependency *v, Ast_Func_Def *n)
366  {
367     n->return_type->accept_visitor(n->return_type, AST_VISITOR_OF(v));
368
369     Symbol_Property saved_property = v->next_property;
370     v->next_property = SYMBOL_PROPERTY_FUNC;
371     n->iden->accept_visitor(n->iden, AST_VISITOR_OF(v));
372     v->next_property = saved_property;
373     String func_iden;
374     func_iden = v->prev_iden;
375
376     Symbol_Table_Node *func_stn = ast_node_get_symbol_table_node(
377           n->statements);
378
379     Symbol *sym = symbol_table_node_lookup(
380           ast_node_get_symbol_table_node(AST_NODE_OF(n)),
381           func_iden, SYMBOL_PROPERTY_FUNC);
382     assert(sym);
383
384     Stn_Display_Preserve *p = stn_display_preserve_alloc(func_stn, v,
385           sym->unique_name);
386
387     hash_map_insert(&stn_display_map, &p->hash_slot, func_stn->scope_id);
388
389     Vector *prev_curr_dep = v->curr_dependencies;
390     v->curr_dependencies = vector_alloc_size(4);
391
392     Vector *vec;
393     Ast_Node *node;
394     vec = n->parameters;
395     VECTOR_FOR_EACH_ENTRY(vec, node)
396        node->accept_visitor(node, AST_VISITOR_OF(v));
397     n->statements->accept_visitor(n->statements, AST_VISITOR_OF(v));
398
399     DLOG("func %S has scope: %U\n", func_iden, func_stn->scope_id);
400
```

```
401     Stn_Dependency *tmp;
402     VECTOR_FOR_EACH_ENTRY(v->curr_dependencies, tmp) {
403        if (tmp->sym_node == func_stn)
404           continue;
405        if (tmp->is_func) {
406           Rb_Tree_Node *rbn =
407              rb_tree_search(v->dependencies, (Rb_Tree_Search_Comparator)
408                    stn_dependency_search_comparator, tmp->sym_node);
409           if (!rbn) {
410              rb_tree_insert(v->dependencies, &tmp->rbnode);
411           } else {
412              Stn_Dependency *curr = STN_DEPENDENCY_OF(rbn);
413              curr->is_func = true;
414           }
415        }
416     }
417
418     void stn_dependency_callback(Rb_Tree_Node *n)
419     {
420        Stn_Dependency *d = STN_DEPENDENCY_OF(n);
421        DLOG("add dependency with %U is func? %d\n", d->sym_node->scope_id,
422              (int)d->is_func);
423        stn_display_add_dependency(p, d);
424     }
425     rb_tree_for_each(v->dependencies, stn_dependency_callback);
426
427     Rb_Tree_Node *rbn = rb_tree_search_remove(v->dependencies,
428           (Rb_Tree_Search_Comparator)stn_dependency_search_comparator,
429           func_stn);
430
431     VECTOR_FOR_EACH_ENTRY(v->curr_dependencies, tmp) {
432        if (tmp->sym_node == func_stn) {
433           if (rbn && tmp != STN_DEPENDENCY_OF(rbn))
434              stn_dependency_destroy(tmp);
435           continue;
436        }
437        Rb_Tree_Node *tn = rb_tree_search(v->dependencies,
438              (Rb_Tree_Search_Comparator)stn_dependency_search_comparator,
439              tmp->sym_node);
440        if (tn) {
441           Stn_Dependency *dup = STN_DEPENDENCY_OF(tn);
442           if (!dup->is_func)
443              dup->is_func = tmp->is_func;
444           if (!dup->is_var)
445              dup->is_var = tmp->is_var;
446
447           if (tmp != STN_DEPENDENCY_OF(tn))
448              stn_dependency_destroy(tmp);
449        } else {
450           rb_tree_insert(v->dependencies, &tmp->rbnode);
451        }
452     }
453
454     if (rbn) {
455        Stn_Dependency *d = STN_DEPENDENCY_OF(rbn);
456        stn_dependency_destroy(d);
457     }
458
459     vector_destroy(v->curr_dependencies, NULL);
460     v->curr_dependencies = prev_curr_dep;
461  }
462
463  ASTVF_BEGIN(AST_EXT_FUNC_DECL, Ast_Visitor_Dependency, v, Ast_Func_Def, n)
464     //n->extern_type->accept_visitor(n->extern_type, AST_VISITOR_OF(v));
465     //n->iden->accept_visitor(n->iden, AST_VISITOR_OF(v));
466     n->return_type->accept_visitor(n->return_type, AST_VISITOR_OF(v));
467     Vector *vec = n->parameters;
468     Ast_Node *p;
469     VECTOR_FOR_EACH_ENTRY(vec, p)
470        p->accept_visitor(p, AST_VISITOR_OF(v));
471  ASTVF_END
472
473  ASTVF_BEGIN(AST_FIN_FUNC_DEF, Ast_Visitor_Dependency, v, Ast_Func_Def, n)
474     func_dependency(v, n);
```

```
475 ASTVF_END
476
477 ASTVF_BEGIN(AST_REC_FUNC_DEF, Ast_Visitor_Dependency, v, Ast_Func_Def, n)
478    func_dependency(v, n);
479 ASTVF_END
480
481 ASTVF_BEGIN(AST_FUNC_DEF, Ast_Visitor_Dependency, v, Ast_Func_Def, n)
482    func_dependency(v, n);
483 ASTVF_END
484
485 ASTVF_BEGIN(AST_IF_STMT, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
486    binary_action(v, n);
487 ASTVF_END
488
489 ASTVF_BEGIN(AST_IF_ELSE_STMT, Ast_Visitor_Dependency, v, Ast_Node_Ternary, n)
490    ternary_action(v, n);
491 ASTVF_END
492
493 ASTVF_BEGIN(AST_ALLOC_ARY, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
494    binary_action(v, n);
495 ASTVF_END
496
497 ASTVF_BEGIN(AST_ALLOC_REC, Ast_Visitor_Dependency, v, Ast_Node_Unary, n)
498    unary_action(v, n);
499 ASTVF_END
500
501 ASTVF_BEGIN(AST_ALLOC_REC_CALL, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
502    //binary_action(v, n);
503    n->lhs->accept_visitor(n->lhs, AST_VISITOR_OF(v));
504 ASTVF_END
505
506 ASTVF_BEGIN(AST_DELETE, Ast_Visitor_Dependency, v, Ast_Node_Unary, n)
507    unary_action(v, n);
508 ASTVF_END
509
510 ASTVF_BEGIN(AST_WHILE_STMT, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
511    binary_action(v, n);
512 ASTVF_END
513
514 ASTVF_BEGIN(AST_RETURN_STMT, Ast_Visitor_Dependency, v, Ast_Node_Unary, n)
515    unary_action(v, n);
516 ASTVF_END
517
518 ASTVF_BEGIN(AST_WRITE_STMT, Ast_Visitor_Dependency, v, Ast_Node_Unary, n)
519    unary_action(v, n);
520 ASTVF_END
521
522 ASTVF_BEGIN(AST_ASSIGNMENT, Ast_Visitor_Dependency, v, Ast_Node_Binary, n)
523    binary_action(v, n);
524 ASTVF_END
525
526 ASTVF_BEGIN(AST_FUNC_BODY, Ast_Visitor_Dependency, v, Ast_Stmt_List, n)
527    Vector *stmts;
528    Ast_Node *s;
529
530    Symbol_Table_Node *prev_n = v->curr_func_node;
531    v->curr_func_node = ast_node_get_symbol_table_node(AST_NODE_OF(n));
532    stmts = n->statements;
533
534    Rb_Tree *dep = v->dependencies;
535
536    VECTOR(depv);
537    void stn_dependency_append(Rb_Tree_Node *n)
538    {
539       vector_append(&depv, STN_DEPENDENCY_OF(n));
540    }
541
542    VECTOR_FOR_EACH_ENTRY(stmts, s) {
543       v->dependencies = rb_tree_alloc(stn_dependency_comparator);
544       s->accept_visitor(s, AST_VISITOR_OF(v));
545       rb_tree_for_each(v->dependencies, stn_dependency_append);
546       rb_tree_destroy(v->dependencies, NULL);
547    }
548
```

```
549     Stn_Dependency *d;
550     VECTOR_FOR_EACH_ENTRY(&depv, d) {
551        if (!rb_tree_contains(dep,
552              (Rb_Tree_Search_Comparator)stn_dependency_search_comparator,
553              d->sym_node))
554           rb_tree_insert(dep, &d->rbnode);
555        else
556           stn_dependency_destroy(d);
557     }
558
559     vector_clear(&depv);
560
561     v->dependencies = dep;
562     v->curr_func_node = prev_n;
563  ASTVF_END
564
565  ASTVF_BEGIN(AST_EXPR_CHAR, Ast_Visitor_Dependency, v, Ast_Expr_Char, n)
566     (void)v; (void)n;
567  ASTVF_END
568
569  ASTVF_BEGIN(AST_EXPR_STRING, Ast_Visitor_Dependency, v, Ast_Expr_String, n)
570     (void)v; (void)n;
571  ASTVF_END
572
573  ASTVF_BEGIN(AST_IMPORT_STRING, Ast_Visitor_Dependency, v, Ast_Module_String, n)
574     (void)v; (void)n;
575  ASTVF_END
576
577  ASTVF_BEGIN(AST_PACKAGE_STRING, Ast_Visitor_Dependency, v, Ast_Module_String, n)
578     (void)v; (void)n;
579  ASTVF_END
580
581  ASTVF_BEGIN(AST_SIMPLE_TYPE_CHAR, Ast_Visitor_Dependency, v, Ast_Empty, n)
582     (void)v; (void)n;
583  ASTVF_END
584
585  ASTVF_BEGIN(AST_SIMPLE_TYPE_STRING, Ast_Visitor_Dependency, v, Ast_Empty, n)
586     (void)v; (void)n;
587  ASTVF_END
588
589  ASTVF_BEGIN(AST_SIMPLE_TYPE_VOID, Ast_Visitor_Dependency, v, Ast_Empty, n)
590     (void)v; (void)n;
591  ASTVF_END
592
593  ASTVF_BEGIN(AST_REC_SELF_PTR, Ast_Visitor_Dependency, v, Ast_Empty, n)
594     (void)v; (void)n;
595  ASTVF_END
596
597  static Ast_Visitor_Dependency dep_visitor = {
598     .AST_VISITOR_FIELD = AST_VISITOR_STATIC_INIT(),
599     .next_property = SYMBOL_PROPERTY_VAR,
600     .stn_display_vector = VECTOR_STATIC_INIT()
601  };
602
603  static int symbol_table_node_comp(const Symbol_Table_Node *search_node,
604        const Symbol_Table_Node *vec_node)
605  {
606     if (search_node->scope_id < vec_node->scope_id)
607        return 1;
608     if (search_node->scope_id > vec_node->scope_id)
609        return -1;
610     return 0;
611  }
612
613  void ast_visitor_dependency_accept(Ast *ast)
614  {
615     if (!ast_is_valid(ast))
616        return;
617     dep_visitor.dependencies = rb_tree_alloc(stn_dependency_comparator);
618     stn_display_map = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_23,
619           (Hash_Map_Comparator)stn_display_preserve_comparator);
620     ast->root->accept_visitor(ast->root, AST_VISITOR_OF(&dep_visitor));
621     assert(dep_visitor.next_property == SYMBOL_PROPERTY_VAR);
622
```

```
623     Stn_Display_Preserve *p;
624     VECTOR_FOR_EACH_ENTRY(&dep_visitor.stn_display_vector, p) {
625        DLOG("find func dependency for %S\n", p->func_name);
626        Symbol_Table_Node *node;
627        VECTOR_FOR_EACH_ENTRY(&p->func_dependencies, node) {
628           DLOG("func dependency for node %U\n", node->scope_id);
629           Stn_Display_Preserve *tmp = stn_display_preserve_get(node);
630           Symbol_Table_Node *tmp_node;
631           VECTOR_FOR_EACH_ENTRY(&tmp->stn_displays, tmp_node) {
632              if (vector_contains_ptr(&p->stn_displays, tmp_node))
633                 continue;
634              vector_append(&p->stn_displays, tmp_node);
635           }
636        }
637        vector_sort(&p->stn_displays,
638              (Vector_Comparator)symbol_table_node_comp);
639     }
640
641     DEBUG(
642        DLOG("\n");
643        Stn_Display_Preserve *p;
644        VECTOR_FOR_EACH_ENTRY(&dep_visitor.stn_display_vector, p) {
645           DLOG("Scope %U preserves:\n", p->sym_node->scope_id);
646           Symbol_Table_Node *node;
647           VECTOR_FOR_EACH_ENTRY(&p->stn_displays, node) {
648              DLOG("\tdisplay for: %U\n", node->scope_id);
649           }
650        }
651        DLOG("\n");
652     );
653     DEBUGT(def,
654        Stn_Display_Preserve *p;
655        VECTOR_FOR_EACH_ENTRY(&dep_visitor.stn_display_vector, p) {
656           Uns i = UNSIGNED_MAX;
657           Symbol_Table_Node *node;
658           VECTOR_FOR_EACH_ENTRY(&p->stn_displays, node) {
659              if (i > node->scope_id)
660                 i = node->scope_id;
661              else
662                 fatal_error(S("AST visitor dependency detected "
663                       "unexpected scope dependency\n"));
664           }
665        }
666     );
667     rb_tree_destroy(dep_visitor.dependencies, NULL);
668     vector_clear(&dep_visitor.stn_display_vector);
669  }
```

:

A.6.6 src/ast/ast_visitor_dependency.h

```
1   #ifndef AST_VISITOR_DEPENDENCY_H
2   #define AST_VISITOR_DEPENDENCY_H
3
4   #include "ast_visitor.h"
5   #include <hash_map.h>
6   #include <rb_tree.h>
7
8   typedef struct Stn_Display_Preserve {
9      Const_String func_name;
10     Symbol_Table_Node *sym_node;
11     /* Symbol table node (function) displays to preserve
12      * when function with symbol table node sym_node is called. */
13     Vector stn_displays;
14     Vector func_dependencies;
15     Uns next_vector_idx;
16     Hash_Map_Slot hash_slot;
17  } Stn_Display_Preserve;
18
19  #define STN_DISPLAY_PRESERVE_OF(slot) \
```

```
20    HASH_MAP_ENTRY(slot, Stn_Display_Preserve, hash_slot)
21
22 /* Get stn dependencies for function with symbol table node n.
23  * Should always return != NULL if n is a symbol table node of a function. */
24 Stn_Display_Preserve *stn_display_preserve_get(Symbol_Table_Node *n);
25
26 void stn_display_preserve_destroy();
27
28 void ast_visitor_dependency_accept(Ast *ast);
29
30 #endif // AST_VISITOR_DEPENDENCY_H
```

A.7 Intermediate Representation

:

A.7.1 src/aia/aia.c

```
1  #include "aia.h"
2  #include <main.h>
3
4  Aia_Section *___aia_get_section(Aia *aia,
5        Aia_Section_Type sec)
6  {
7     Aia_Section *s;
8
9     if (aia->sections[sec])
10       return aia->sections[sec];
11
12    s = ALLOC_NEW(Aia_Section);
13    aia->sections[sec] = s;
14    ___aia_section_init(s, sec, aia);
15    ___aia_set_section(aia, sec, s);
16    String lbl_name = aia_tmp_name_gen(aia, S("SECT"));
17    ___aia_insert_jmp_label_instr(aia, lbl_name);
18    string_destroy(lbl_name);
19
20    return NULL;
21 }
22
23 Aia_Func_Trampoline *___aia_func_trampoline_alloc(Aia *aia,
24       Const_String tramp_name, Vector *params, Aia_Func *func)
25 {
26    Aia_Func_Trampoline *t = ALLOC_NEW(Aia_Func_Trampoline);
27    t->trampoline_name = string_duplicate(tramp_name);
28    t->func_name = func->func_name;
29    t->func_params = params;
30    t->block = ___aia_block_alloc_entry(
31          aia->sections[aia->curr_sec], NULL);
32    t->blist = DOUBLE_LIST_INIT(t->blist);
33    double_list_append(&t->blist, &t->block->blist_node);
34    vector_append(&func->trampolines, t);
35    return t;
36 }
37
38 void ___aia_func_destroy(Aia_Func *f)
39 {
40    string_destroy(f->func_name);
41    vector_for_each_destroy(&f->parameters,
42          (Vector_Destructor)string_destroy);
43    vector_for_each_destroy(&f->locals,
44          (Vector_Destructor)string_destroy);
45    vector_for_each_destroy(&f->trampolines,
46          (Vector_Destructor)___aia_func_trampoline_destroy);
47
48    vector_clear(&f->preserve_display_indices);
49
50    //___aia_block_for_each_sucessor_destroy(f->entry_block);
```

```
51     double_list_for_each_destroy(&f->blist, ___aia_block_lone_db_destroy);
52     free_mem(f);
53  }
54
55  void ___aia_func_hash_destroy(Hash_Map_Slot *s)
56  {
57     ___aia_func_destroy(AIA_FUNC_OF(s));
58  }
59
60  Aia_Func *___aia_func_alloc(Aia *aia, Const_String func_name)
61  {
62     Aia_Func *f = ALLOC_NEW(Aia_Func);
63     f->parameters = VECTOR_INIT_SIZE(4);
64     f->locals = VECTOR_INIT_SIZE(4);
65     f->preserve_display_indices = VECTOR_INIT_SIZE(2);
66     f->func_name = string_duplicate(func_name);
67     f->trampolines = VECTOR_INIT_SIZE(2);
68     Aia_Block *entry = ___aia_block_alloc_entry(
69           aia->sections[aia->curr_sec], f);
70     f->entry_block = f->exit_block = entry;
71     f->parent_func = NULL;
72     f->num_display_params = 0;
73     f->blist = DOUBLE_LIST_INIT(f->blist);
74     double_list_append(&f->blist, &f->entry_block->blist_node);
75     return f;
76  }
77
78  Aia_Func *___aia_get_func(Aia *aia, Const_String func_name)
79  {
80     Aia_Func *f;
81     Hash_Map_Slot *s;
82     Uns hash = string_hash_code(func_name);
83
84     s = hash_map_get(&aia->sections[aia->curr_sec]->functions,
85           (String)func_name, hash);
86     if (s)
87        return AIA_FUNC_OF(s);
88
89     f = ___aia_func_alloc(aia, func_name);
90     hash_map_insert(&aia->sections[aia->curr_sec]->functions,
91           &f->hash_slot, hash);
92     ___aia_set_func(aia, f);
93
94     /* Size of function is specified later. */
95     ___aia_insert_label_instr(aia, func_name, 0, 4, AIA_LINKAGE_PRIVATE,
96           AIA_LABEL_TYPE_FUNC, 0, aia_get_null_location(aia));
97
98     return NULL;
99  }
100
101 void ___aia_block_for_each_depth2_visit(Aia_Block *b,
102       Aia_Block_Callback start_callback,
103       Aia_Block_Callback ret_callback,
104       void *arg)
105 {
106    if (b->visit_count++)
107       goto out;
108
109    start_callback(b, arg);
110
111    Aia_Block *suc;
112    AIA_BLOCK_FOR_EACH_SUCESSOR(b, suc)
113       ___aia_block_for_each_depth2_visit(suc, start_callback,
114             ret_callback, arg);
115
116    if (ret_callback)
117       ret_callback(b, arg);
118
119 out:;
120 }
121
122 void ___aia_block_for_each_depth_visit(Aia_Block *b,
123       Aia_Block_Callback callback, void *arg)
124 {
```

```
125     ___aia_block_for_each_depth2_visit(b, callback, NULL, arg);
126  }
127
128  Aia_Block *aia_block_twin(Aia_Block *b, Aia *aia)
129  {
130     Aia_Block *twin_b = ___aia_block_alloc(b->section, b->function);
131     Aia_Instr *in;
132     AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in) {
133        Aia_Instr *twin_in = aia_instr_twin(in, twin_b);
134        ___aia_block_append_instr(twin_b, twin_in);
135     }
136     Aia_Instr *lbl_in = ___aia_block_peek_first_instr(twin_b);
137     Aia_Operand *lbl_op = aia_instr_get_dest_op(lbl_in);
138
139     String lbl_name = aia_tmp_num_append(aia,
140           aia_operand_label_get_name(lbl_op));
141
142     Aia_Operand *new_lbl_op = ___aia_operand_label_alloc(aia, lbl_name,
143           aia_operand_label_get_offset(lbl_op), AIA_OPERAND_LABEL);
144
145     aia_instr_replace_op(lbl_in, -1, new_lbl_op);
146
147     return twin_b;
148  }
149
150  static inline Uns ___aia_block_sucessor_count_tmp_jump(Aia_Block *b)
151  {
152     Double_List_Node *ln = double_list_peek_last(&b->instructions);
153     switch (AIA_INSTR_OF(ln)->type) {
154     AIA_CASE_COND_TMP_JUMP:
155        return 2;
156     case ___AIA_JMP:
157        return 1;
158     default:
159        return 0;
160     }
161  }
162
163  static inline Aia_Block *___aia_label_to_block_tmp_jump(Aia *aia,
164        Aia_Operand *lbl)
165  {
166     assert(lbl);
167     return aia_label_to_instruction(aia, lbl)->containing_block;
168  }
169
170  Aia_Instr *___aia_block_peek_first_instr(Aia_Block *b)
171  {
172     Double_List_Node *n = double_list_peek_first(&b->instructions);
173     if (!n)
174        return NULL;
175     return AIA_INSTR_OF(n);
176  }
177
178  Aia_Instr *___aia_block_peek_last_instr(Aia_Block *b)
179  {
180     Double_List_Node *n = double_list_peek_last(&b->instructions);
181     if (!n)
182        return NULL;
183     return AIA_INSTR_OF(n);
184  }
185
186  #define AIA_BLOCK_FOR_EACH_SUCESSOR_TMP_JUMP(block, sucessor, aia)   \
187     for (Double_List_Node *___n =                                     \
188              double_list_peek_last(&(block)->instructions);    \
189           ___n;                                                     \
190           ___n = NULL)                                              \
191        for (Uns ___s = 0,                                           \
192              ___c = ___aia_block_sucessor_count_tmp_jump(b);    \
193              ___s < ___c;                                           \
194              ___s++)                                                \
195           if ((sucessor = ___aia_label_to_block_tmp_jump(aia,    \
196                    aia_instr_get_src_op(AIA_INSTR_OF(___n), ___s))) || \
197                 !sucessor)
198
```

```
199 static void ___aia_block_set_predecessors_start(Aia_Block *b, Aia *aia)
200 {
201    if (b->visit_count)
202       return;
203
204    b->visit_count = 1;
205
206    Aia_Block *suc;
207    AIA_BLOCK_FOR_EACH_SUCESSOR_TMP_JUMP(b, suc, aia) {
208       ___aia_block_append_predecessor(suc, b);
209       ___aia_block_set_predecessors_start(suc, aia);
210    }
211 }
212
213 static void ___aia_block_set_predecessors_end(Aia_Block *b, Aia *aia)
214 {
215    if (!b->visit_count)
216       return;
217
218    b->visit_count = 0;
219
220    Aia_Block *suc;
221    AIA_BLOCK_FOR_EACH_SUCESSOR_TMP_JUMP(b, suc, aia)
222       ___aia_block_set_predecessors_end(suc, aia);
223 }
224
225 static inline void ___aia_block_replace_jump(Aia_Block *b, Aia *aia)
226 {
227    Aia_Block *block;
228    Aia_Operand *old_lbl;
229    Uns op_count = ___aia_block_sucessor_count_tmp_jump(b);
230
231    if (!op_count) // Exit block or .ret instruction
232       return;
233
234    Double_List_Node *n = double_list_peek_last(&b->instructions);
235    Aia_Instr *jin = AIA_INSTR_OF(n);
236    switch (jin->type) {
237    AIA_CASE_COND_TMP_JUMP:
238       old_lbl = aia_instr_get_src_op(jin, 1);
239       assert(old_lbl->op_type == AIA_OPERAND_LABEL &&
240             !old_lbl->iden.op_label->offset);
241
242       block = ___aia_label_to_block_tmp_jump(aia, old_lbl);
243       ___aia_operand_release(old_lbl);
244       aia_instr_set_src_op(jin, 1, aia_operand_block_alloc(aia, block));
245       /* Fall through. */
246    case ___AIA_JMP:
247       old_lbl = aia_instr_get_src_op(jin, 0);
248       assert(old_lbl->op_type == AIA_OPERAND_LABEL &&
249             !old_lbl->iden.op_label->offset);
250
251       block = ___aia_label_to_block_tmp_jump(aia, old_lbl);
252       ___aia_operand_release(old_lbl);
253       aia_instr_set_src_op(jin, 0, aia_operand_block_alloc(aia, block));
254       break;
255    default:
256       fatal_error(S("Unexpected branch instruction. Aborting...\n"));
257    }
258    jin->type = AIA_LABEL_JUMP_TO_BLOCK_JUMP(jin->type);
259 }
260
261 static void ___aia_block_replace_jumps(Double_List *blist, Aia *aia)
262 {
263    Double_List_Node *bnode;
264    DOUBLE_LIST_FOR_EACH(blist, bnode)
265       ___aia_block_replace_jump(AIA_BLOCK_OF_DBNODE(bnode), aia);
266 }
267
268 static void ___aia_append_nop(Aia_Block *b)
269 {
270    Aia_Instr *tmp = ___aia_block_peek_last_instr(b);
271    Aia_Instr *in = aia_instr_alloc_0op(AIA_NOP, b, -1,
272          aia_instr_get_location(tmp));
```

```
273     ___aia_block_append_instr(b, in);
274  }
275
276  static void ___aia_finish_blocks(Aia *aia)
277  {
278     Aia_Section *sec;
279     AIA_FOR_EACH_SECTION(aia, sec) {
280        Aia_Func *func;
281        ___aia_block_set_predecessors_start(sec->entry_block, aia);
282        ___aia_block_set_predecessors_end(sec->entry_block, aia);
283        ___aia_block_replace_jumps(&sec->sec_blist, aia);
284        ___aia_append_nop(sec->exit_block);
285
286        AIA_SECTION_FOR_EACH_FUNC(sec, func) {
287           ___aia_block_set_predecessors_start(func->entry_block, aia);
288           ___aia_block_set_predecessors_end(func->entry_block, aia);
289           ___aia_block_replace_jumps(&func->blist, aia);
290           ___aia_append_nop(func->exit_block);
291
292           Aia_Func_Trampoline *tramp;
293           AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp) {
294              ___aia_block_replace_jump(tramp->block, aia);
295              ___aia_append_nop(tramp->block);
296           }
297        }
298     }
299  }
300
301  #if 0
302  /* Returns suc if it's removed, else return NULL. */
303  Aia_Block *___aia_block_remove_sucessor(Aia_Block *b, Aia_Block *suc)
304  {
305     Aia_Operand *block_op;
306     Aia_Instr *last_instr = ___aia_block_peek_last_instr(b);
307     Aia_Block *ret = NULL;
308
309     switch (last_instr->type) {
310     AIA_CASE_COND_JUMP:
311        block_op = aia_instr_get_src_op(last_instr, 1);
312        if (block_op->iden.op_block == suc) {
313           ret = suc;
314           block_op->iden.op_block = NULL;
315           break;
316        }
317        /* Fall through. */
318
319     case AIA_JMP:
320        block_op = aia_instr_get_src_op(last_instr, 0);
321        if (block_op->iden.op_block == suc) {
322           ret = suc;
323           block_op->iden.op_block = NULL;
324        }
325        break;
326
327     default:
328        fatal_error(S("unable to find jump instruction in the end of a block. "
329                  "Aborting...\n"));
330     }
331     return ret;
332  }
333
334  /* Returns pred if it's removed, else return NULL. */
335  Aia_Block *___aia_block_remove_predecessor(Aia_Block *b, Aia_Block *pred)
336  {
337     if (vector_remove_ptr(&b->predecessors, pred))
338        return pred;
339     return NULL;
340  }
341
342  void ___aia_block_remove_from_predecessors(Aia_Block *b)
343  {
344     Aia_Block *pred;
345     AIA_BLOCK_FOR_EACH_PREDECESSOR(b, pred) {
346        Aia_Block *ret = ___aia_block_remove_sucessor(pred, b);
```

```
347         (void)ret;
348         assert(ret);
349      }
350   }
351
352   void ___aia_block_remove_from_sucessors(Aia_Block *b)
353   {
354      Aia_Block *suc;
355      AIA_BLOCK_FOR_EACH_SUCESSOR(b, suc) {
356         Aia_Block *ret = ___aia_block_remove_predecessor(suc, b);
357         (void)ret;
358         assert(ret);
359      }
360   }
361
362   void ___aia_block_for_each_sucessor_destroy(Aia_Block *entry)
363   {
364      void recursive_destroy(Aia_Block *b)
365      {
366         ___aia_block_remove_from_predecessors(b);
367
368         Aia_Block *suc;
369         AIA_BLOCK_FOR_EACH_SUCESSOR(b, suc)
370            recursive_destroy(suc);
371
372         ___aia_block_lone_destroy(b);
373      }
374
375      recursive_destroy(entry);
376   }
377   #endif
378
379   void aia_block_remove_from_predecessors(Aia_Block *b)
380   {
381      Aia_Block *suc;
382      AIA_BLOCK_FOR_EACH_SUCESSOR(b, suc)
383         vector_remove_ptr(&suc->predecessors, b);
384   }
385
386   void aia_block_forget_predecessor(Aia_Block *b, Aia_Block *pred)
387   {
388      bool res = vector_remove_ptr(&b->predecessors, pred);
389      (void)res;
390      assert(res);
391   }
392
393   void aia_block_blist_remove_destroy(Aia_Block *b)
394   {
395      double_list_remove(&b->blist_node);
396      ___aia_block_lone_destroy(b);
397   }
398
399   void ___aia_block_lone_db_destroy(Double_List_Node *n)
400   {
401      ___aia_block_lone_destroy(AIA_BLOCK_OF_DBNODE(n));
402   }
403
404   static void aia_insert_default_funcs(Aia *aia)
405   {
406      Aia_Func *func;
407      Uns hash;
408
409      func = ___aia_func_alloc(aia, AIA_FUNC_WRITELNI);
410      hash = string_hash_code(aia_func_get_name(func));
411      hash_map_insert(&aia->default_funcs, &func->hash_slot, hash);
412
413      func = ___aia_func_alloc(aia, AIA_FUNC_WRITELNB);
414      hash = string_hash_code(aia_func_get_name(func));
415      hash_map_insert(&aia->default_funcs, &func->hash_slot, hash);
416
417      func = ___aia_func_alloc(aia, AIA_FUNC_WRITELNC);
418      hash = string_hash_code(aia_func_get_name(func));
419      hash_map_insert(&aia->default_funcs, &func->hash_slot, hash);
420
```

```
421     func = ___aia_func_alloc(aia, AIA_FUNC_WRITELNS);
422     hash = string_hash_code(aia_func_get_name(func));
423     hash_map_insert(&aia->default_funcs, &func->hash_slot, hash);
424
425     func = ___aia_func_alloc(aia, AIA_FUNC_WRITELNR);
426     hash = string_hash_code(aia_func_get_name(func));
427     hash_map_insert(&aia->default_funcs, &func->hash_slot, hash);
428
429     func = ___aia_func_alloc(aia, AIA_FUNC_WRITELNA);
430     hash = string_hash_code(aia_func_get_name(func));
431     hash_map_insert(&aia->default_funcs, &func->hash_slot, hash);
432
433     func = ___aia_func_alloc(aia, AIA_FUNC_WRITELNN);
434     hash = string_hash_code(aia_func_get_name(func));
435     hash_map_insert(&aia->default_funcs, &func->hash_slot, hash);
436
437     func = ___aia_func_alloc(aia, AIA_FUNC_ALLOCATEAB);
438     hash = string_hash_code(aia_func_get_name(func));
439     hash_map_insert(&aia->default_funcs, &func->hash_slot, hash);
440
441     func = ___aia_func_alloc(aia, AIA_FUNC_ALLOCATEAL);
442     hash = string_hash_code(aia_func_get_name(func));
443     hash_map_insert(&aia->default_funcs, &func->hash_slot, hash);
444
445     func = ___aia_func_alloc(aia, AIA_FUNC_ALLOCATE);
446     hash = string_hash_code(aia_func_get_name(func));
447     hash_map_insert(&aia->default_funcs, &func->hash_slot, hash);
448
449     func = ___aia_func_alloc(aia, AIA_FUNC_DELETEA);
450     hash = string_hash_code(aia_func_get_name(func));
451     hash_map_insert(&aia->default_funcs, &func->hash_slot, hash);
452
453     func = ___aia_func_alloc(aia, AIA_FUNC_DELETE);
454     hash = string_hash_code(aia_func_get_name(func));
455     hash_map_insert(&aia->default_funcs, &func->hash_slot, hash);
456 }
457
458 void ___aia_finish(Aia *aia)
459 {
460     ___aia_set_exit_block(aia);
461     ___aia_finish_blocks(aia);
462     aia_insert_default_funcs(aia);
463 }
464
465 Aia_Operand *aia_operand_addr_ref_alloc(Aia *aia UNUSED,
466         Aia_Operand *label,
467         Aia_Operand *disp,
468         Aia_Operand *base,
469         Aia_Operand *index,
470         Aia_Operand *scale)
471 {
472     Aia_Operand *op = ALLOC_NEW(Aia_Operand);
473     op->iden.addr_ref = ALLOC_NEW(Aia_Operand_Addr_Ref);
474
475     DEBUGT(def,
476         assert(base);
477         if (label)
478             assert(label->op_type == AIA_OPERAND_LABEL);
479         if (disp)
480             assert(disp->op_type == AIA_OPERAND_CONST_INT);
481         if (scale) {
482             assert(scale->op_type == AIA_OPERAND_CONST_INT);
483             switch (scale->iden.int_const) {
484             case 1:
485             case 2:
486             case 4:
487                 break;
488             default:
489                 assert(false);
490             }
491         }
492     );
493
494     if (label)
```

```
495         ++label->ref_count;
496      if (disp)
497         ++disp->ref_count;
498      ++base->ref_count;
499      if (index)
500         ++index->ref_count;
501      if (scale)
502         ++scale->ref_count;
503
504      *op->iden.addr_ref = (Aia_Operand_Addr_Ref){
505         label, disp, base, index, scale
506      };
507
508      op->op_type = AIA_OPERAND_ADDR_REF;
509      op->ref_count = 0;
510      return op;
511   }
512
513   void ___aia_insert_label_instr(Aia *aia, Const_String lbl_name,
514         int32_t lbl_offset, uint8_t alignment, Aia_Linkage linkage,
515         Aia_Label_Type lbl_type, int32_t obj_byte_size,
516         File_Location *loc)
517   {
518      Aia_Instr *lbl_instr = ___aia_2op_instr(aia, ___AIA_LABEL,
519            AIA_LONG, AIA_LONG, loc);
520      Aia_Operand *lbl = aia_operand_label_alloc(aia, lbl_name, lbl_offset);
521
522      Aia_Label_Data d;
523      d.alignment = alignment;
524      d.linkage = linkage;
525      d.label_type = lbl_type;
526
527      Aia_Operand *icon = aia_operand_const_int_alloc(aia, d.data);
528      aia_instr_set_src_op(lbl_instr, 0, icon);
529
530      icon = aia_operand_const_int_alloc(aia, obj_byte_size);
531      aia_instr_set_src_op(lbl_instr, 1, icon);
532
533      aia_instr_set_dest_op(lbl_instr, lbl);
534
535      Aia_Label_Instr_Entry *e = ALLOC_NEW(Aia_Label_Instr_Entry);
536      e->label_instr = lbl_instr;
537      Uns hash = string_hash_code(lbl->iden.op_label->label_name);
538
539      assert(!hash_map_contains(&aia->label_instr_map, lbl, hash));
540      hash_map_insert(&aia->label_instr_map, &e->hash_slot, hash);
541   }
542
543   static CONST_STRING(aia_section_init_std, ".init");
544   static CONST_STRING(aia_section_init_lib, ".Vit_libinit, \"xa\"");
545
546   Const_String ___aia_section_names[AIA_SECTION_COUNT] = {
547      [AIA_SECTION_INIT]  = NULL,
548      [AIA_SECTION_FINI]  = S(".fini"),
549      [AIA_SECTION_TEXT]  = S(".text"),
550      [AIA_SECTION_DATA]  = S(".data"),
551      [AIA_SECTION_RODATA] = S(".rodata")
552   };
553
554   void ___aia_func_trampoline_destroy(Aia_Func_Trampoline *t)
555   {
556      string_destroy(t->trampoline_name);
557      double_list_for_each_destroy(&t->blist, ___aia_block_lone_db_destroy);
558      free_mem(t);
559   }
560
561   bool ___aia_func_comparator(String search_func, Hash_Map_Slot *maps)
562   {
563      Aia_Func *f = AIA_FUNC_OF(maps);
564      return !string_compare(search_func, f->func_name);
565   }
566
567   Aia *aia_alloc(Const_String src_fname)
568   {
```

```
569     if (cmdopts.library_init)
570        ___aia_section_names[AIA_SECTION_INIT] = aia_section_init_lib;
571     else
572        ___aia_section_names[AIA_SECTION_INIT] = aia_section_init_std;
573
574     Aia *aia = ALLOC_NEW(Aia);
575     aia->label_instr_map = HASH_MAP_INIT(
576           (Hash_Map_Comparator)aia_label_instr_comparator);
577     aia->default_funcs = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_23,
578           (Hash_Map_Comparator)___aia_func_comparator);
579
580     for (Uns i = 0; i < AIA_SECTION_COUNT; i++)
581        aia->sections[i] = NULL;
582
583     aia->curr_func = NULL;
584     aia->curr_block = NULL;
585     aia->curr_blist = NULL;
586
587     aia->curr_tmp_reg_num = 0;
588     aia->curr_tmp_label_num = 0;
589
590     aia->aia_instr_dump_callback = NULL;
591
592     aia->source_file_name = string_duplicate(src_fname);
593     aia->source_null_file_loc =
594           FILE_LOCATION_INIT(aia->source_file_name, 0, 0);
595
596     aia->record_self_ptr = aia_operand_local_ref_alloc(aia,
597           SELF_STR/*, AIA_LONG*/);
598     ___aia_operand_acquire(aia->record_self_ptr);
599
600     return aia;
601  }
602
603  Aia_Func *aia_func_lookup(Aia *aia, Const_String func_name)
604  {
605     Hash_Map_Slot *fslot;
606     Uns hash = string_hash_code(func_name);
607
608     fslot = hash_map_get(&aia->default_funcs, (String)func_name, hash);
609     if (fslot)
610        return AIA_FUNC_OF(fslot);
611
612     if (aia->sections[AIA_SECTION_TEXT]) {
613        fslot = hash_map_get(
614              &aia->sections[AIA_SECTION_TEXT]->functions,
615              (String)func_name,
616              hash);
617        if (fslot)
618           return AIA_FUNC_OF(fslot);
619     }
620
621     for (Uns i = 0; i < AIA_SECTION_TEXT; i++) {
622        if (aia->sections[i]) {
623           fslot = hash_map_get(
624                 &aia->sections[i]->functions,
625                 (String)func_name,
626                 hash);
627           if (fslot)
628              return AIA_FUNC_OF(fslot);
629        }
630     }
631     for (Uns i = AIA_SECTION_TEXT + 1;
632           i < AIA_SECTION_COUNT; i++) {
633        if (aia->sections[i]) {
634           fslot = hash_map_get(
635                 &aia->sections[i]->functions,
636                 (String)func_name,
637                 hash);
638           if (fslot)
639              return AIA_FUNC_OF(fslot);
640        }
641     }
642     return NULL;
```

```
643 }
644
645 static void dump_block(Aia_Block *b, Aia *aia)
646 {
647    FILE *stream = aia->meta_data;
648    file_print_message(stream, S("# AIA block start\n"));
649    Aia_Instr *in;
650    AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
651       aia_instr_dump(stream, in, aia);
652    file_print_message(stream, S("# AIA block end\n"));
653 }
654
655 #if 0
656 static void aia_dump_blocks(Aia *aia,
657       Aia_Block *entry_b, Aia_Block *exit_b)
658 {
659    if (entry_b != exit_b)
660       aia_block_for_each_depth(entry_b, exit_b, dump_block, aia);
661    else
662       dump_block(entry_b, aia);
663 }
664 #endif
665
666 static void aia_dump_blocks(Aia *aia, Double_List *blist)
667 {
668    Double_List_Node *dbnode;
669    DOUBLE_LIST_FOR_EACH(blist, dbnode) {
670       Aia_Block *b = AIA_BLOCK_OF_DBNODE(dbnode);
671       dump_block(b, aia);
672    }
673 }
674
675 static void aia_dump_trampoline(Aia *aia, Aia_Func_Trampoline *t)
676 {
677    FILE *stream = aia->meta_data;
678    file_print_message(stream, S("\n@trampoline(%S)\n"), t->trampoline_name);
679
680    Const_String str;
681    VECTOR_FOR_EACH_ENTRY(t->func_params, str)
682       file_print_message(stream, S("\t@param(%S)\n"), str);
683
684    aia_dump_blocks(aia, &t->blist);
685
686    file_print_message(stream, S(".size %1$S, . - %1$S\n"),
687          t->trampoline_name);
688    file_print_message(stream, S("# end %S\n\n"), t->trampoline_name);
689 }
690
691 static void aia_dump_func(Aia *aia, Aia_Func *f)
692 {
693    FILE *stream = aia->meta_data;
694    Aia_Func_Trampoline *t;
695    VECTOR_FOR_EACH_ENTRY(&f->trampolines, t)
696       aia_dump_trampoline(aia, t);
697
698    file_print_message(stream, S("\n@procedure(%S)\n"), f->func_name);
699
700    Const_String str;
701    VECTOR_FOR_EACH_ENTRY(&f->parameters, str)
702       file_print_message(stream, S("\t@param(%S)\n"), str);
703
704    ssize_t display;
705    VECTOR_FOR_EACH_ENTRY(&f->preserve_display_indices, display)
706       file_print_message(stream, S("\t@push_display(%zd)\n"), display);
707
708    VECTOR_FOR_EACH_ENTRY(&f->locals, str)
709       file_print_message(stream, S("\t@var(%S)\n"), str);
710
711    aia_dump_blocks(aia, &f->blist);
712
713    file_print_message(stream, S(".size %1$S, . - %1$S\n"), f->func_name);
714    file_print_message(stream, S("# end %S\n\n"), f->func_name);
715 }
716
```

```
717 Aia_Instr *aia_private_label_before(Aia *aia, Aia_Operand *lbl,
718       Aia_Instr *sucessor)
719 {
720    Aia_Instr *lbl_instr = aia_instr_alloc_2op(___AIA_LABEL,
721          aia_instr_get_block(sucessor), AIA_LONG, AIA_LONG,
722          aia_instr_get_location(sucessor));
723
724    Aia_Operand *icon = aia_operand_const_int_alloc(aia, 0);
725    aia_instr_set_src_op(lbl_instr, 0, icon);
726    icon = aia_operand_const_int_alloc(aia, AIA_LINKAGE_PRIVATE);
727    aia_instr_set_src_op(lbl_instr, 1, icon);
728    aia_instr_set_dest_op(lbl_instr, lbl);
729
730    Aia_Label_Instr_Entry *e = ALLOC_NEW(Aia_Label_Instr_Entry);
731    e->label_instr = lbl_instr;
732    Uns hash = string_hash_code(lbl->iden.op_label->label_name);
733
734    assert(!hash_map_contains(&aia->label_instr_map, lbl, hash));
735    hash_map_insert(&aia->label_instr_map, &e->hash_slot, hash);
736
737    aia_instr_insert_before(lbl_instr, sucessor);
738
739    return lbl_instr;
740 }
741
742 Aia_Instr *aia_type_mov_before(uint16_t mov_instr, Aia_Operand *src_op,
743       Aia_Operand *dest_op, Aia_Instr *sucessor,
744       uint8_t src_size, uint8_t dest_size)
745 {
746    DEBUGT(def,
747       switch (mov_instr) {
748       case AIA_MOV:
749       case AIA_MOVS:
750       case AIA_MOVZ:
751          break;
752       default:
753          assert(false);
754       }
755    );
756
757    Aia_Instr *mov_in = aia_instr_alloc_1op(mov_instr,
758          aia_instr_get_block(sucessor), dest_size, src_size,
759          aia_instr_get_location(sucessor));
760    aia_instr_set_src_op(mov_in, 0, src_op);
761    aia_instr_set_dest_op(mov_in, dest_op);
762
763    aia_instr_insert_before(mov_in, sucessor);
764
765    return mov_in;
766 }
767
768 Aia_Instr *aia_mov_before(Aia_Operand *src_op, Aia_Operand *dest_op,
769       Aia_Instr *sucessor, uint8_t op_sizes)
770 {
771    Aia_Instr *mov_in = aia_instr_alloc_1op(AIA_MOV,
772          aia_instr_get_block(sucessor), op_sizes, op_sizes,
773          aia_instr_get_location(sucessor));
774    aia_instr_set_src_op(mov_in, 0, src_op);
775    aia_instr_set_dest_op(mov_in, dest_op);
776
777    aia_instr_insert_before(mov_in, sucessor);
778
779    return mov_in;
780 }
781
782 Aia_Instr *aia_mov_after(Aia_Operand *src_op, Aia_Operand *dest_op,
783       Aia_Instr *predecessor, uint8_t op_sizes)
784 {
785    Aia_Instr *mov_in = aia_instr_alloc_1op(AIA_MOV,
786          aia_instr_get_block(predecessor), op_sizes, op_sizes,
787          aia_instr_get_location(predecessor));
788    aia_instr_set_src_op(mov_in, 0, src_op);
789    aia_instr_set_dest_op(mov_in, dest_op);
790
```

```
791     aia_instr_insert_after(mov_in, predecessor);
792
793     return mov_in;
794 }
795
796 void aia_dump(Aia *aia, FILE *stream)
797 {
798     if (!aia_is_valid(aia))
799         return;
800
801     aia->meta_data = stream;
802
803     Aia_Section *sec;
804     AIA_FOR_EACH_SECTION(aia, sec) {
805         file_print_message(stream, S(".section %S\n"), sec->section_name);
806
807         aia_dump_blocks(aia, &sec->sec_blist);
808
809         Aia_Func *func;
810         AIA_SECTION_FOR_EACH_FUNC(sec, func)
811             aia_dump_func(aia, func);
812         file_print_message(stream, S("\n"));
813     }
814 }
```

:

A.7.2 src/aia/aia.h

```
1  #ifndef AIA_H
2  #define AIA_H
3
4  #include <std_include.h>
5  #include <hash_map.h>
6  #include <vector.h>
7  #include <double_list.h>
8  #include <debug.h>
9  #include "aia_operand.h"
10 #include "aia_instr.h"
11
12 #undef DEBUG_TYPE
13 #define DEBUG_TYPE aia-gen
14
15 #define VMT_CSTR ".vmt"
16 #define VMT_STR S(VMT_CSTR)
17
18 #define SELF_STR S(".slf")
19 #define DISP_CSTR_PREFIX ".disp."
20
21 #define AIA_FUNC_WRITELNI S("_Vit_writelni")
22 #define AIA_FUNC_WRITELNS S("_Vit_writelns")
23 #define AIA_FUNC_WRITELNC S("_Vit_writelnc")
24 #define AIA_FUNC_WRITELNB S("_Vit_writelnb")
25 #define AIA_FUNC_WRITELNR S("_Vit_writelnr")
26 #define AIA_FUNC_WRITELNA S("_Vit_writelna")
27 #define AIA_FUNC_WRITELNN S("_Vit_writelnn")
28 #define AIA_FUNC_ALLOCATEAB S("_Vit_allocab")
29 #define AIA_FUNC_ALLOCATEAL S("_Vit_allocal")
30 #define AIA_FUNC_ALLOCATE S("_Vit_alloc")
31 #define AIA_FUNC_DELETEA S("_Vit_deletea")
32 #define AIA_FUNC_DELETE  S("_Vit_delete")
33
34 #define AIA_NUM_DEFAULT_FUNCS 8
35
36 typedef struct Aia_Section Aia_Section;
37
38 typedef struct Aia_Func Aia_Func;
39
40 typedef enum Aia_Linkage {
41     AIA_LINKAGE_PRIVATE,
42     AIA_LINKAGE_GLOBAL,
```

```
43     AIA_LINKAGE_WEAK
44  } Aia_Linkage;
45
46  typedef enum Aia_Label_Type {
47     AIA_LABEL_TYPE_NONE,
48     AIA_LABEL_TYPE_FUNC,
49     AIA_LABEL_TYPE_OBJ
50  } Aia_Label_Type;
51
52  typedef union Aia_Label_Data {
53     struct {
54        unsigned alignment   : 8;
55        Aia_Linkage linkage   : 8;
56        Aia_Label_Type label_type : 8;
57        unsigned             : 8;
58     };
59     uint32_t data;
60  } Aia_Label_Data;
61
62  typedef enum Aia_Section_Type {
63     AIA_SECTION_INIT,
64     AIA_SECTION_FINI,
65     AIA_SECTION_TEXT,
66     AIA_SECTION_DATA,
67     AIA_SECTION_RODATA,
68     AIA_SECTION_COUNT // Must be last (not really a section)
69  } Aia_Section_Type;
70
71  struct Aia_Block {
72     Vector predecessors;
73     Double_List instructions;
74     Aia_Section *section;
75     Aia_Func *function;
76     void *meta_data;
77     Uns visit_count;
78     Double_List_Node blist_node;
79  };
80
81  #define AIA_BLOCK_OF_DBNODE(node) \
82     DOUBLE_LIST_ENTRY(node, Aia_Block, blist_node)
83
84  typedef struct Aia_Func_Trampoline {
85     String trampoline_name;
86     Const_String func_name;
87     Vector *func_params;
88     Aia_Block *block;
89     void *meta_data;
90     Double_List blist;
91  } Aia_Func_Trampoline;
92
93  typedef struct Aia_Func {
94     String func_name;
95     File_Location location;
96     Vector preserve_display_indices;
97     Vector parameters;
98     Vector locals;
99     Vector trampolines;
100    Hash_Map_Slot hash_slot;
101    Aia_Block *entry_block;
102    Aia_Block *exit_block;
103    Aia_Func *parent_func;
104    void *meta_data;
105    void *func_access_struct;
106    void *func_kills_struct;
107    Double_List blist;
108    Int num_display_params;
109 } Aia_Func;
110
111 #define AIA_FUNC_OF(slot) HASH_MAP_ENTRY(slot, Aia_Func, hash_slot)
112
113 typedef struct Aia_Section {
114    Const_String section_name;
115    Aia_Block *entry_block;
116    Aia_Block *exit_block;
```

```
117     Aia *aia;
118     void *meta_data;
119     Hash_Map functions;
120     Double_List sec_blist;
121     Aia_Section_Type sec_type;
122  } Aia_Section;
123
124  typedef struct Aia {
125     String source_file_name;
126     File_Location source_null_file_loc;
127     Aia_Section *sections[AIA_SECTION_COUNT];
128     Aia_Func *curr_func;
129     Aia_Block *curr_block;
130     Double_List *curr_blist;
131     void *meta_data;
132     void (*aia_instr_dump_callback)(FILE *stream, Aia_Instr *in);
133     Aia_Operand *record_self_ptr;
134     Hash_Map label_instr_map;
135     Hash_Map default_funcs;
136     Aia_Section_Type curr_sec;
137     Uns curr_tmp_reg_num;
138     Uns curr_tmp_label_num;
139  } Aia;
140
141  #define AIA_FOR_EACH_SECTION(aia, sec)          \
142     for (Uns ___i = 0; ___i < AIA_SECTION_COUNT; ___i++)  \
143        if ((sec = (aia)->sections[___i]))
144
145  static inline Aia_Operand *aia_operand_display_ref_alloc(Aia *aia UNUSED,
146        Aia_Operand *display_reg, Const_String var_name,
147        Const_String func_name /*, uint8_t var_size */)
148  {
149     Aia_Operand *op = ALLOC_NEW(Aia_Operand);
150     op->iden.display_ref = ALLOC_NEW(Aia_Operand_Display_Ref);
151     *op->iden.display_ref = (Aia_Operand_Display_Ref){
152        display_reg,
153        string_duplicate(var_name),
154        string_duplicate(func_name) /*,
155        var_size */
156     };
157     ++display_reg->ref_count;
158     op->op_type = AIA_OPERAND_DISPLAY_REF;
159     op->ref_count = 0;
160     return op;
161  }
162
163  static inline Aia_Operand *___aia_operand_local_ref_alloc(Aia *aia UNUSED,
164        String var_name /* , uint8_t var_size */)
165  {
166     Aia_Operand *op = ALLOC_NEW(Aia_Operand);
167     op->iden.local_ref = ALLOC_NEW(Aia_Operand_Local_Ref);
168     *op->iden.local_ref = (Aia_Operand_Local_Ref){
169        var_name /*,
170        var_size */
171     };
172     op->op_type = AIA_OPERAND_LOCAL_REF;
173     op->ref_count = 0;
174     return op;
175  }
176
177  static inline Aia_Operand *aia_operand_local_ref_alloc(Aia *aia,
178        Const_String var_name /*, uint8_t var_size */)
179  {
180     return ___aia_operand_local_ref_alloc(aia, string_duplicate(var_name) /*,
181           var_size */);
182  }
183
184  static inline Aia_Operand *aia_operand_arg_alloc(Aia *aia UNUSED,
185        int32_t idx)
186  {
187     Aia_Operand *op = ALLOC_NEW(Aia_Operand);
188     op->iden.int_const = idx;
189     op->op_type = AIA_OPERAND_ARG;
190     op->ref_count = 0;
```

```
191     return op;
192 }
193
194 static inline Aia_Operand *aia_operand_const_int_alloc(Aia *aia UNUSED,
195       int32_t int_val)
196 {
197     Aia_Operand *op = ALLOC_NEW(Aia_Operand);
198     op->iden.int_const = int_val;
199     op->op_type = AIA_OPERAND_CONST_INT;
200     op->ref_count = 0;
201     return op;
202 }
203
204 static inline Aia_Operand *aia_operand_const_string_alloc(Aia *aia UNUSED,
205       Const_String op_name)
206 {
207     Aia_Operand *op = ALLOC_NEW(Aia_Operand);
208     op->iden.op_name = string_duplicate(op_name);
209     op->op_type = AIA_OPERAND_CONST_STRING;
210     op->ref_count = 0;
211     return op;
212 }
213
214 static inline Aia_Operand *aia_operand_block_alloc(Aia *aia UNUSED,
215       Aia_Block *block)
216 {
217     Aia_Operand *op = ALLOC_NEW(Aia_Operand);
218     op->iden.op_block = block;
219     op->op_type = AIA_OPERAND_BLOCK;
220     op->ref_count = 0;
221     return op;
222 }
223
224 static inline Aia_Operand *___aia_operand_label_alloc(Aia *aia UNUSED,
225       String name, Int offset, Aia_Operand_Type lbl_type)
226 {
227     assert(lbl_type == AIA_OPERAND_LABEL ||
228           lbl_type == AIA_OPERAND_LABEL_ADDR);
229
230     Aia_Operand *op = ALLOC_NEW(Aia_Operand);
231     op->iden.op_label = ALLOC_NEW(Aia_Operand_Label);
232     op->op_type = lbl_type;
233     op->iden.op_label->offset = offset;
234     op->iden.op_label->label_name = name;
235     op->ref_count = 0;
236     return op;
237 }
238
239 static inline Aia_Operand *aia_operand_label_alloc(Aia *aia,
240       Const_String name, Int offset)
241 {
242     return ___aia_operand_label_alloc(aia, string_duplicate(name),
243           offset, AIA_OPERAND_LABEL);
244 }
245
246 static inline Aia_Operand *aia_operand_label_addr_alloc(Aia *aia,
247       Const_String name, Int offset)
248 {
249     return ___aia_operand_label_alloc(aia, string_duplicate(name),
250           offset, AIA_OPERAND_LABEL_ADDR);
251 }
252
253 static inline Aia_Operand *___aia_operand_reg_alloc(Aia *aia UNUSED,
254       String reg)
255 {
256     Aia_Operand *op = ALLOC_NEW(Aia_Operand);
257     op->iden.op_name = reg;
258     op->op_type = AIA_OPERAND_REG;
259     op->ref_count = 0;
260     return op;
261 }
262
263 static inline Aia_Operand *aia_operand_reg_alloc(Aia *aia, Const_String reg)
264 {
```

```
265     return ___aia_operand_reg_alloc(aia, string_duplicate(reg));
266  }
267
268  static inline Aia_Operand *aia_operand_tmp_reg_alloc(Aia *aia)
269  {
270     return ___aia_operand_reg_alloc(aia, string_from_format(S("%U"),
271              aia->curr_tmp_reg_num++));
272  }
273
274  static inline String aia_tmp_num_append(Aia *aia, Const_String prefix)
275  {
276     return string_from_format(S("%S.%U"), prefix, aia->curr_tmp_label_num++);
277  }
278
279  static inline String aia_tmp_name_gen(Aia *aia, Const_String prefix)
280  {
281     return string_from_format(S(".%S.%U"), prefix, aia->curr_tmp_label_num++);
282  }
283
284  static inline Aia_Operand *aia_operand_tmp_label_alloc(Aia *aia,
285        Const_String prefix)
286  {
287     String lbl_name = aia_tmp_name_gen(aia, prefix);
288     return ___aia_operand_label_alloc(aia, lbl_name, 0, AIA_OPERAND_LABEL);
289  }
290
291  Aia_Operand *aia_operand_addr_ref_alloc(Aia *aia,
292        Aia_Operand *label,
293        Aia_Operand *disp,
294        Aia_Operand *base,
295        Aia_Operand *index,
296        Aia_Operand *scale);
297
298  static inline void ___aia_block_append_instr(Aia_Block *b, Aia_Instr *in);
299
300  static inline void ___aia_curr_block_append_instr(Aia *aia, Aia_Instr *in)
301  {
302     ___aia_block_append_instr(aia->curr_block, in);
303  }
304
305  static inline Const_String aia_get_file_name(Aia *aia);
306
307  static inline Aia_Instr *___aia_0op_instr(Aia *aia, uint32_t type,
308        uint8_t dest_op_size, File_Location *loc)
309  {
310     File_Location tmp = FILE_LOCATION_INIT(aia_get_file_name(aia),
311           loc->line, loc->column);
312     Aia_Instr *instr = aia_instr_alloc_vop(type, aia->curr_block,
313           dest_op_size, -1, 0, &tmp);
314     ___aia_curr_block_append_instr(aia, instr);
315     return instr;
316  }
317
318  static inline Aia_Instr *___aia_1op_instr(Aia *aia, uint32_t type,
319        uint8_t dest_op_size, uint8_t src_op_size, File_Location *loc)
320  {
321     File_Location tmp = FILE_LOCATION_INIT(aia_get_file_name(aia),
322           loc->line, loc->column);
323     Aia_Instr *instr = aia_instr_alloc_vop(type, aia->curr_block,
324           dest_op_size, src_op_size, 1, &tmp);
325     ___aia_curr_block_append_instr(aia, instr);
326     return instr;
327  }
328
329  static inline Aia_Instr *___aia_2op_instr(Aia *aia, uint32_t type,
330        uint8_t dest_op_size, uint8_t src_ops_size, File_Location *loc)
331  {
332     File_Location tmp = FILE_LOCATION_INIT(aia_get_file_name(aia),
333           loc->line, loc->column);
334     Aia_Instr *instr = aia_instr_alloc_vop(type, aia->curr_block,
335           dest_op_size, src_ops_size, 2, &tmp);
336     ___aia_curr_block_append_instr(aia, instr);
337     return instr;
338  }
```

```
339
340 static inline Aia_Instr *___aia_vop_instr(Aia *aia, uint32_t type,
341       uint8_t dest_op_size, uint8_t src_ops_size, Uns nops,
342       File_Location *loc)
343 {
344    File_Location tmp = FILE_LOCATION_INIT(aia_get_file_name(aia),
345          loc->line, loc->column);
346    Aia_Instr *instr = aia_instr_alloc_vop(type, aia->curr_block,
347          dest_op_size, src_ops_size, nops, &tmp);
348    ___aia_curr_block_append_instr(aia, instr);
349    return instr;
350 }
351
352 static inline void ___aia_block_append_instr(Aia_Block *b, Aia_Instr *in)
353 {
354    double_list_append(&b->instructions, &in->dbnode);
355 }
356
357 static inline void ___aia_block_append_predecessor(Aia_Block *b,
358       Aia_Block *pred)
359 {
360    vector_append(&b->predecessors, pred);
361 }
362
363 static inline Aia_Block *___aia_block_alloc(Aia_Section *sec,
364       Aia_Func *func)
365 {
366    assert(sec);
367    Aia_Block *b = ALLOC_NEW(Aia_Block);
368    b->instructions = DOUBLE_LIST_INIT(b->instructions);
369    b->predecessors = VECTOR_INIT_SIZE(2);
370    b->section = sec;
371    b->function = func;
372    b->visit_count = 0;
373    return b;
374 }
375
376 static inline Aia_Block *___aia_block(Aia *aia)
377 {
378    Aia_Block *b = ___aia_block_alloc(aia->sections[aia->curr_sec],
379          aia->curr_func);
380    aia->curr_block = b;
381    double_list_append(aia->curr_blist, &b->blist_node);
382    return b;
383 }
384
385 static inline Aia_Block *___aia_block_alloc_entry(Aia_Section *sec,
386       Aia_Func *f)
387 {
388    Aia_Block *entry = ___aia_block_alloc(sec, f);
389    return entry;
390 }
391
392 Aia_Block *aia_block_twin(Aia_Block *b, Aia *aia);
393
394 static inline Uns aia_block_predecessor_count(Aia_Block *b)
395 {
396    return vector_size(&b->predecessors);
397 }
398
399 static inline Uns aia_block_sucessor_count(Aia_Block *b)
400 {
401    Double_List_Node *ln = double_list_peek_last(&b->instructions);
402    switch (AIA_INSTR_OF(ln)->type) {
403    AIA_CASE_COND_JUMP:
404       return 2;
405    case AIA_JMP:
406       return 1;
407    default:
408       return 0;
409    }
410 }
411
412 Aia_Instr *___aia_block_peek_first_instr(Aia_Block *b);
```

```
413
414  Aia_Instr *___aia_block_peek_last_instr(Aia_Block *b);
415
416  #define AIA_BLOCK_FOR_EACH_SUCESSOR(block, sucessor)      \
417     for (Double_List_Node *___n =                          \
418              double_list_peek_last(&(block)->instructions);    \
419           ___n;                                             \
420           ___n = NULL)                                      \
421        for (Int ___c = aia_block_sucessor_count(b) - 1;     \
422              ___c >= 0;                                     \
423              ___c--)                                        \
424           if ((sucessor = aia_instr_get_src_op(AIA_INSTR_OF(___n),  \
425                       ___c)->iden.op_block))
426
427  #define AIA_BLOCK_FOR_EACH_PREDECESSOR(block, predecessor) \
428     VECTOR_FOR_EACH_ENTRY(&block->predecessors, predecessor)
429
430  #define AIA_BLOCK_FOR_EACH_INSTRUCTION(block, instr)  \
431     for (Double_List_Node *___n = NULL; ___n == NULL;)  \
432        DOUBLE_LIST_FOR_EACH(&block->instructions, ___n) \
433           if ((instr = AIA_INSTR_OF(___n)) || !instr)
434
435  #define AIA_BLOCK_FOR_EACH_INSTRUCTION_REVERSED(block, instr)  \
436     for (Double_List_Node *___n = NULL; ___n == NULL;)    \
437        DOUBLE_LIST_FOR_EACH_REVERSED(&block->instructions, ___n) \
438           if ((instr = AIA_INSTR_OF(___n)) || !instr)
439
440  void aia_block_remove_from_predecessors(Aia_Block *b);
441
442  void aia_block_blist_remove_destroy(Aia_Block *b);
443
444  static inline void ___aia_block_lone_destroy(Aia_Block *b)
445  {
446     double_list_for_each_destroy(&b->instructions, ___aia_instr_db_destroy);
447     vector_clear(&b->predecessors);
448     free_mem(b);
449  }
450
451  #if 0
452  static inline bool aia_block_is_empty(Aia_Block *b)
453  {
454     bool ret = false;
455     if (aia_block_predecessor_count(b) != 1 ||
456           aia_block_sucessor_count(b) != 1)
457        goto out;
458
459     Uns idx = 0;
460     Aia_Instr *in;
461     AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in) {
462        if (idx == 1) {
463           switch (aia_instr_get_type(in)) {
464           AIA_CASE_COND_JUMP:
465           case AIA_JMP:
466              ret = true;
467
468           default:
469              goto out;
470           }
471        } else if (idx > 1) {
472           ret = false;
473           goto out;
474        }
475        ++idx;
476     }
477  out:
478     return ret;
479  }
480  #endif
481
482  typedef void (*Aia_Block_Callback)(Aia_Block *block, void *arg);
483
484  static inline void ___aia_block_zero_visit_count(Double_List *blist)
485  {
486     Double_List_Node *bnode;
```

```
487     DOUBLE_LIST_FOR_EACH(blist, bnode)
488        AIA_BLOCK_OF_DBNODE(bnode)->visit_count = 0;
489  }
490
491  /* Don't call this function. Use aia_func_for_each_block_depth(),
492   * or aia_section_for_each_block_depth() instead. */
493  static inline void ___aia_block_for_each_depth(Aia_Block *entry_block,
494        Aia_Block_Callback callback, void *arg)
495  {
496     extern void ___aia_block_for_each_depth_visit(Aia_Block *b,
497           Aia_Block_Callback callback, void *arg);
498
499     ___aia_block_for_each_depth_visit(entry_block, callback, arg);
500  }
501
502  static inline void ___aia_block_for_each_depth2(Aia_Block *entry_block,
503        Aia_Block_Callback start_callback,
504        Aia_Block_Callback ret_callback,
505        void *arg)
506  {
507     extern void ___aia_block_for_each_depth2_visit(Aia_Block *b,
508           Aia_Block_Callback start_callback,
509           Aia_Block_Callback ret_callback,
510           void *arg);
511
512     ___aia_block_for_each_depth2_visit(entry_block, start_callback,
513           ret_callback, arg);
514  }
515
516  /* Don't call this function. Use aia_func_for_each_block_depth2(),
517   * or aia_section_for_each_block_depth2() instead. */
518  static inline void aia_func_for_each_block_depth2(Aia_Func *f,
519        Aia_Block_Callback start_cb, Aia_Block_Callback ret_cb, void *arg)
520  {
521     ___aia_block_zero_visit_count(&f->blist);
522     ___aia_block_for_each_depth2(f->entry_block, start_cb, ret_cb, arg);
523  }
524
525  static inline void aia_func_for_each_block_depth(Aia_Func *f,
526        Aia_Block_Callback callback, void *arg)
527  {
528     ___aia_block_zero_visit_count(&f->blist);
529     ___aia_block_for_each_depth(f->entry_block, callback, arg);
530  }
531
532  void ___aia_block_lone_db_destroy(Double_List_Node *n);
533
534  void aia_block_forget_predecessor(Aia_Block *b, Aia_Block *pred);
535
536  void ___aia_block_recursive_destroy(Aia_Block *root);
537
538  Aia_Func *___aia_func_alloc(Aia *aia, Const_String func_name);
539
540  static inline void ___aia_set_curr_func_parent(Aia *aia, Aia_Func *parent)
541  {
542     assert(aia->curr_func);
543     aia->curr_func->parent_func = parent;
544  }
545
546  static inline void aia_set_curr_func_location(Aia *aia, File_Location *loc)
547  {
548     assert(aia->curr_func);
549     aia->curr_func->location = FILE_LOCATION_INIT(aia_get_file_name(aia),
550           loc->line, loc->column);
551  }
552
553  static inline Aia_Func *aia_func_get_parent_func(Aia_Func *f)
554  {
555     return f->parent_func;
556  }
557
558  static inline File_Location *aia_func_get_last_location(Aia_Func *f)
559  {
560     Aia_Instr *last_in = ___aia_block_peek_last_instr(f->exit_block);
```

```
561     return aia_instr_get_location(last_in);
562 }
563
564 static inline bool aia_func_is_nested(Aia_Func *f)
565 {
566     return aia_func_get_parent_func(f);
567 }
568
569 static inline Const_String aia_func_get_name(Aia_Func *f)
570 {
571     return f->func_name;
572 }
573
574 static inline File_Location *aia_func_get_location(Aia_Func *f)
575 {
576     return &f->location;
577 }
578
579 #define AIA_FUNC_GET_SOURCE_NAME(aia_func) \
580     STRING_AFTER_LAST((aia_func)->func_name, '.')
581
582 static inline Aia_Block *aia_func_get_exit_block(Aia_Func *f)
583 {
584     return f->exit_block;
585 }
586
587 static inline Aia_Block *aia_func_get_entry_block(Aia_Func *f)
588 {
589     return f->entry_block;
590 }
591
592 Aia_Func_Trampoline *___aia_func_trampoline_alloc(Aia *aia,
593       Const_String tramp_name, Vector *params, Aia_Func *func);
594
595 void ___aia_func_trampoline_destroy(Aia_Func_Trampoline *t);
596
597 void ___aia_func_destroy(Aia_Func *f);
598
599 /* Get function with name func_name. Return NULL if func does not exist. */
600 Aia_Func *aia_func_lookup(Aia *aia, Const_String func_name);
601
602 bool ___aia_func_comparator(String search_func, Hash_Map_Slot *maps);
603
604 void ___aia_func_hash_destroy(Hash_Map_Slot *s);
605
606 static inline void ___aia_section_destroy(Aia_Section *s)
607 {
608     hash_map_for_each_destroy(&s->functions, ___aia_func_hash_destroy);
609     //___aia_block_for_each_sucessor_destroy(s->entry_block);
610     double_list_for_each_destroy(&s->sec_blist, ___aia_block_lone_db_destroy);
611     free_mem(s);
612 }
613
614 extern Const_String ___aia_section_names[AIA_SECTION_COUNT];
615
616 static inline Const_String ___aia_section_name(
617       Aia_Section_Type sec)
618 {
619     return ___aia_section_names[sec];
620 }
621
622 static inline void ___aia_section_init(Aia_Section *s,
623      Aia_Section_Type sec, Aia *aia)
624 {
625     s->section_name = ___aia_section_name(sec);
626     Aia_Block *entry = ___aia_block_alloc_entry(s, NULL);
627     s->entry_block = s->exit_block = entry;
628     s->functions = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_23,
629           (Hash_Map_Comparator)___aia_func_comparator);
630     s->sec_blist = DOUBLE_LIST_INIT(s->sec_blist);
631     s->sec_type = sec;
632     s->aia = aia;
633     double_list_append(&s->sec_blist, &s->entry_block->blist_node);
634 }
```

```
635
636 static inline Const_String aia_section_get_name(Aia_Section *s)
637 {
638    return s->section_name;
639 }
640
641 static inline Aia_Block *aia_section_get_entry_block(Aia_Section *s)
642 {
643    return s->entry_block;
644 }
645
646 static inline Aia_Block *aia_section_get_exit_block(Aia_Section *s)
647 {
648    return s->exit_block;
649 }
650
651 static inline void aia_section_for_each_block_depth(Aia_Section *s,
652       Aia_Block_Callback callback, void *arg)
653 {
654    ___aia_block_zero_visit_count(&s->sec_blist);
655    ___aia_block_for_each_depth(s->entry_block, callback, arg);
656 }
657
658 static inline void aia_section_for_each_block_depth2(Aia_Section *s,
659       Aia_Block_Callback start_cb, Aia_Block_Callback ret_cb, void *arg)
660 {
661    ___aia_block_zero_visit_count(&s->sec_blist);
662    ___aia_block_for_each_depth2(s->entry_block, start_cb, ret_cb, arg);
663 }
664
665 /* As long as sec < AIA_SECTION_COUNT this function
666  * returns a valid section. */
667 Aia_Section *___aia_get_section(Aia *aia,
668       Aia_Section_Type sec);
669
670 // Warning use goto to break this loop
671 #define AIA_SECTION_FOR_EACH_FUNC(sec, fun)           \
672    for (Hash_Map_Slot *___fs = INT_TO_PTR(1); ___fs; ___fs = NULL)  \
673       HASH_MAP_FOR_EACH(&(sec)->functions, ___fs)      \
674          if ((fun = AIA_FUNC_OF(___fs)) || !fun)
675
676 #define AIA_SECTION_FOR_EACH_BLOCK(sec, block)        \
677    for (Double_List_Node *___bnode = NULL; ___bnode == NULL;)   \
678       DOUBLE_LIST_FOR_EACH(&(sec)->sec_blist, ___bnode)    \
679          if ((block = AIA_BLOCK_OF_DBNODE(___bnode)) || !block)
680
681 #define AIA_SECTION_FOR_EACH_BLOCK_REVERSED(sec, block)     \
682    for (Double_List_Node *___bnode = NULL; ___bnode == NULL;)   \
683       DOUBLE_LIST_FOR_EACH_REVERSED(&(sec)->sec_blist, ___bnode)  \
684          if ((block = AIA_BLOCK_OF_DBNODE(___bnode)) || !block)
685
686 static inline void ___aia_set_exit_block(Aia *aia)
687 {
688    if (aia->curr_func)
689       aia->curr_func->exit_block = aia->curr_block;
690    else if (aia->curr_block)
691       aia->sections[aia->curr_sec]->exit_block = aia->curr_block;
692 }
693
694 static inline void ___aia_set_section(Aia *aia,
695       Aia_Section_Type sec, Aia_Section *s)
696 {
697    ___aia_set_exit_block(aia);
698    aia->sections[sec] = s;
699    aia->curr_sec = sec;
700    aia->curr_func = NULL;
701    aia->curr_block = aia->sections[sec]->exit_block;
702    aia->curr_blist = &aia->sections[sec]->sec_blist;
703 }
704
705 static inline Aia_Section *aia_get_section(Aia *aia, Aia_Section_Type t)
706 {
707    return aia->sections[t];
708 }
```

```
709
710 static inline void ___aia_switch_section(Aia *aia, Aia_Section_Type sec)
711 {
712    Aia_Section *s = ___aia_get_section(aia, sec);
713    if (s)
714       ___aia_set_section(aia, sec, s);
715    // else ___aia_get_section() called ___aia_set_section() for us.
716 }
717
718 static inline Aia_Section_Type ___aia_get_curr_section_type(Aia *aia)
719 {
720    return aia->curr_sec;
721 }
722
723 Aia_Func *___aia_get_func(Aia *aia, Const_String func_name);
724
725 static inline void ___aia_set_func(Aia *aia, Aia_Func *func)
726 {
727    aia->curr_func = func;
728    aia->curr_block = aia->curr_func->exit_block;
729    aia->curr_blist = &func->blist;
730 }
731
732 static inline void ___aia_switch_func(Aia *aia, Const_String func_name)
733 {
734    ___aia_set_exit_block(aia);
735    if (func_name) {
736       /* Currently it's only allowed to add functions to .text section. */
737       assert(!string_compare(
738                aia->sections[aia->curr_sec]->section_name,
739                ___aia_section_name(AIA_SECTION_TEXT)));
740
741       Aia_Func *func = ___aia_get_func(aia, func_name);
742       if (func)
743          ___aia_set_func(aia, func);
744    } else {
745       aia->curr_func = NULL;
746       aia->curr_block = aia->sections[aia->curr_sec]->exit_block;
747       aia->curr_blist = &aia->sections[aia->curr_sec]->sec_blist;
748    }
749 }
750
751 static inline Aia_Block *___aia_get_curr_block(Aia *aia)
752 {
753    return aia->curr_block;
754 }
755
756 static inline Aia_Func *___aia_get_curr_func(Aia *aia)
757 {
758    return aia->curr_func;
759 }
760
761 static inline void ___aia_set_func_trampiline_block(Aia *aia,
762       Aia_Func_Trampoline *t)
763 {
764    aia->curr_block = t->block;
765    aia->curr_blist = &t->blist;
766 }
767
768 static inline void ___aia_set_curr_func(Aia *aia, Aia_Func *f)
769 {
770    aia->curr_blist = &f->blist;
771    aia->curr_func = f;
772 }
773
774 /* idx == -1 means preserve own display. */
775 static inline void aia_func_append_preserve_display(Aia *aia, Int idx)
776 {
777    assert(aia->curr_func);
778    vector_append(&aia->curr_func->preserve_display_indices, INT_TO_PTR(idx));
779 }
780
781 /* idx == -1 means preserve own display. */
782 static inline void aia_func_prepend_preserve_display(Aia *aia, Int idx)
```

```
783 {
784    assert(aia->curr_func);
785    vector_insert(&aia->curr_func->preserve_display_indices, 0,
786          INT_TO_PTR(idx));
787 }
788
789 static inline void ___aia_func_append_param(Aia *aia, String param)
790 {
791    assert(aia->curr_func);
792    vector_append(&aia->curr_func->parameters, param);
793 }
794
795 static inline void ___aia_func_append_display_param(Aia *aia, String param)
796 {
797    ++aia->curr_func->num_display_params;
798    ___aia_func_append_param(aia, param);
799 }
800
801 static inline void aia_func_append_param(Aia *aia, Const_String param)
802 {
803    ___aia_func_append_param(aia, string_duplicate(param));
804 }
805
806 static inline Int aia_func_get_num_display_params(Aia_Func *f)
807 {
808    return f->num_display_params;
809 }
810
811 static inline void aia_func_append_local(Aia_Func *f, Const_String var_name)
812 {
813    vector_append(&f->locals, string_duplicate(var_name));
814 }
815
816 static inline void ___aia_func_append_local(Aia *aia, Const_String var_name)
817 {
818    assert(aia->curr_func);
819    aia_func_append_local(aia->curr_func, var_name);
820 }
821
822 static inline void aia_func_set_linkage(Aia *aia, Aia_Linkage linkage)
823 {
824    assert(aia->curr_func);
825    Aia_Block *b = aia->curr_func->entry_block;
826    Double_List_Node *n = double_list_peek_first(&b->instructions);
827    Aia_Instr *in = AIA_INSTR_OF(n);
828    assert(in->type == ___AIA_LABEL);
829    Aia_Operand *op = aia_instr_get_src_op(in, 0);
830    Aia_Label_Data lbld;
831    lbld.data = aia_operand_const_int_get_val(op);
832    lbld.linkage = linkage;
833    op->iden.int_const = lbld.data;
834 }
835
836 static inline Aia_Linkage aia_func_get_linkage(Aia_Func *f)
837 {
838    Aia_Block *b = f->entry_block;
839    Double_List_Node *n = double_list_peek_first(&b->instructions);
840    Aia_Instr *in = AIA_INSTR_OF(n);
841    assert(in->type == ___AIA_LABEL);
842    Aia_Operand *op = aia_instr_get_src_op(in, 1);
843    return op->iden.int_const;
844 }
845
846 /* Returns NULL if not currently inside function. */
847 static inline Const_String ___aia_get_curr_func_name(Aia *aia)
848 {
849    return aia->curr_func ? aia->curr_func->func_name : NULL;
850 }
851
852 #define AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp) \
853    VECTOR_FOR_EACH_ENTRY(&(func)->trampolines, tramp)
854
855 #define AIA_FUNC_FOR_EACH_BLOCK(func, block)       \
856    for (Double_List_Node *___bnode = NULL; ___bnode == NULL;)  \
```

```
857         DOUBLE_LIST_FOR_EACH(&(func)->blist, ___bnode)     \
858            if ((block = AIA_BLOCK_OF_DBNODE(___bnode)) || !block)
859
860   #define AIA_FUNC_FOR_EACH_BLOCK_REVERSED(func, block)     \
861      for (Double_List_Node *___bnode = NULL; ___bnode == NULL;)  \
862         DOUBLE_LIST_FOR_EACH_REVERSED(&(func)->blist, ___bnode)  \
863            if ((block = AIA_BLOCK_OF_DBNODE(___bnode)) || !block)
864
865   #define AIA_FUNC_TRAMPOLINE_FOR_EACH_BLOCK(tramp, block) \
866      if ((block = (tramp)->block) || !block)
867
868   #define AIA_FUNC_TRAMPOLINE_FOR_EACH_BLOCK_REVERSED(tramp, block) \
869      AIA_FUNC_TRAMPOLINE_FOR_EACH_BLOK(tramp, block)
870
871   static inline Aia_Instr *aia_label_to_instruction(Aia *aia, Aia_Operand *lbl)
872   {
873      assert(lbl);
874      Hash_Map_Slot *s = hash_map_get(&aia->label_instr_map, lbl,
875            string_hash_code(lbl->iden.op_label->label_name));
876      if (!s)
877         return NULL;
878      return AIA_LABEL_INSTR_ENTRY_OF(s)->label_instr;
879   }
880
881   void ___aia_insert_label_instr(Aia *aia, Const_String lbl_name,
882         int32_t lbl_offset, uint8_t alignment, Aia_Linkage linkage,
883         Aia_Label_Type lbl_type, int32_t obj_byte_size,
884         File_Location *loc);
885
886   static inline void ___aia_insert_jmp_label_instr(Aia *aia,
887         Const_String lbl_name)
888   {
889      ___aia_insert_label_instr(aia, lbl_name, 0, 0, AIA_LINKAGE_PRIVATE,
890            AIA_LABEL_TYPE_NONE, 0, &aia->source_null_file_loc);
891   }
892
893   static inline void ___aia_insert_string_instr(Aia *aia, Aia_Operand *str_op,
894         File_Location *loc)
895   {
896      File_Location tmp = FILE_LOCATION_INIT(aia_get_file_name(aia),
897            loc->line, loc->column);
898      Aia_Instr *str_instr = ___aia_lop_instr(aia, ___AIA_STRING,
899            0, AIA_LONG, &tmp);
900      aia_instr_set_src_op(str_instr, 0, str_op);
901   }
902
903   static inline void ___aia_insert_const_val_instr(Aia *aia, Aia_Operand *op,
904         uint8_t aia_size /* AIA_BYTE or AIA_LONG. */, File_Location *loc)
905   {
906      File_Location tmp = FILE_LOCATION_INIT(aia_get_file_name(aia),
907            loc->line, loc->column);
908      Aia_Instr *instr = ___aia_lop_instr(aia, ___AIA_INTEGER,
909            0, aia_size, &tmp);
910      aia_instr_set_src_op(instr, 0, op);
911   }
912
913   Aia_Instr *aia_private_label_before(Aia *aia, Aia_Operand *lbl,
914         Aia_Instr *sucessor);
915
916   Aia_Instr *aia_type_mov_before(uint16_t mov_instr, Aia_Operand *src_op,
917         Aia_Operand *dest_op, Aia_Instr *sucessor,
918         uint8_t src_size, uint8_t dest_size);
919
920   Aia_Instr *aia_mov_before(Aia_Operand *src_op, Aia_Operand *dest_op,
921         Aia_Instr *sucessor, uint8_t op_sizes);
922
923   Aia_Instr *aia_mov_after(Aia_Operand *src_op, Aia_Operand *dest_op,
924         Aia_Instr *predecessor, uint8_t op_sizes);
925
926   static inline Aia_Instr *aia_mov_to_tmp_reg_before(Aia *aia,
927         Aia_Operand *src_op, Aia_Instr *sucessor, uint8_t op_sizes)
928   {
929      Aia_Operand *tmp = aia_operand_tmp_reg_alloc(aia);
930      return aia_mov_before(src_op, tmp, sucessor, op_sizes);
```

```
931 }
932
933 Aia *aia_alloc(Const_String src_fname);
934
935 void ___aia_finish(Aia *aia);
936
937 static inline bool aia_is_valid(Aia *aia)
938 {
939    return aia;
940 }
941
942 static inline void aia_destroy(Aia *aia)
943 {
944    if (!aia_is_valid(aia))
945       return;
946
947    string_destroy(aia->source_file_name);
948
949    Aia_Section *sec;
950    AIA_FOR_EACH_SECTION(aia, sec)
951       ___aia_section_destroy(sec);
952    hash_map_for_each_destroy(&aia->label_instr_map, aia_label_entry_destroy);
953    hash_map_for_each_destroy(&aia->default_funcs, ___aia_func_hash_destroy);
954
955    ___aia_operand_release(aia->record_self_ptr);
956    free_mem(aia);
957 }
958
959 /* Remember to call aia_clear_instr_dump_callback() once AIA is dumped. */
960 static inline void aia_set_instr_dump_callback(Aia *aia,
961       void (*cb)(FILE *stream, Aia_Instr *in))
962 {
963    aia->aia_instr_dump_callback = cb;
964 }
965
966 static inline void aia_clear_instr_dump_callback(Aia *aia)
967 {
968    aia->aia_instr_dump_callback = NULL;
969 }
970
971 void aia_dump(Aia *aia, FILE *stream);
972
973 static inline Const_String aia_get_file_name(Aia *aia)
974 {
975    assert(aia_is_valid(aia));
976    return aia->source_file_name;
977 }
978
979 static inline File_Location *aia_get_null_location(Aia *aia)
980 {
981    assert(aia_is_valid(aia));
982    return &aia->source_null_file_loc;
983 }
984
985 #define AIA_FOR_EACH_FUNC(aia, func)            \
986    for (Aia_Section *sec = INT_TO_PTR(1); sec; sec = NULL)  \
987       AIA_FOR_EACH_SECTION(aia, sec)            \
988          AIA_SECTION_FOR_EACH_FUNC(sec, func)
989
990 #undef DEBUG_TYPE
991 #define DEBUG_TYPE def
992
993 #endif // AIA_H
```

:

A.7.3 src/aia/aia_functions_return.c

```
1 #include "aia.h"
2
3 #undef DEBUG_TYPE
```

```
4  #define DEBUG_TYPE func-ret
5
6  static bool block_control_returns(Aia_Block *b)
7  {
8     if (b->visit_count)
9        return true;
10    b->visit_count = 1;
11
12    Aia_Instr *in;
13    AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
14       if (aia_instr_get_type(in) == AIA_RET)
15          return true;
16
17    bool ret = false;
18    Aia_Block *suc;
19    AIA_BLOCK_FOR_EACH_SUCESSOR(b, suc) {
20       if (!block_control_returns(suc))
21          return false;
22       else
23          ret = true;
24    }
25
26    return ret;
27 }
28
29 static bool aia_func_returns(Aia_Func *f)
30 {
31    Aia_Block *b;
32    AIA_FUNC_FOR_EACH_BLOCK(f, b)
33       b->visit_count = 0;
34
35    if (block_control_returns(aia_func_get_entry_block(f)))
36       return true;
37
38    report_error_location(aia_func_get_last_location(f),
39          S("control flow reaches end of function " QFY("%S")
40             " without " QFY("return") "\n"),
41          AIA_FUNC_GET_SOURCE_NAME(f));
42    return false;
43 }
44
45 bool aia_functions_return(Aia *aia)
46 {
47    bool ret = true;
48
49    if (!aia_is_valid(aia))
50       goto out;
51
52    Aia_Func *func;
53    AIA_FOR_EACH_FUNC(aia, func)
54       ret &= aia_func_returns(func);
55
56 out:
57    return ret;
58 }
```

:

A.7.4 src/aia/aia_functions_return.h

```
1  #ifndef AIA_FUNCTIONS_RETURN_H
2  #define AIA_FUNCTIONS_RETURN_H
3
4  bool aia_functions_return(Aia *aia);
5
6  #endif // AIA_FUNCTIONS_RETURN_H
```

:

A.7.5 src/aia/aia_instr.c

```
1  #include "aia.h"
2
3  #undef DEBUG_TYPE
4  #define DEBUG_TYPE aia-instr
5
6  static void aia_instr_label_aia_remove(Aia_Instr *instr)
7  {
8     if (aia_instr_get_type(instr) != ___AIA_LABEL)
9        return;
10
11    Aia_Block *b = aia_instr_get_block(instr);
12    Aia_Section *sec = b->section;
13    Aia *aia = sec->aia;
14
15    Aia_Operand *op = aia_instr_get_dest_op(instr);
16    Hash_Map_Slot *s = hash_map_remove(&aia->label_instr_map, op,
17          string_hash_code(aia_operand_label_get_name(op)));
18    assert(s);
19    free_mem(AIA_LABEL_INSTR_ENTRY_OF(s));
20 }
21
22 void ___aia_instr_destroy(Aia_Instr *instr)
23 {
24    Aia_Operand *op;
25    AIA_INSTR_FOR_EACH_OPERAND(instr, op)
26       ___aia_operand_release(op);
27    free_mem(instr);
28 }
29
30 void aia_instr_destroy(Aia_Instr *instr)
31 {
32    aia_instr_label_aia_remove(instr);
33    ___aia_instr_destroy(instr);
34 }
35
36 void ___aia_instr_db_destroy(Double_List_Node *n)
37 {
38    aia_instr_destroy(AIA_INSTR_OF(n));
39 }
40
41 void aia_instr_label_dump(FILE *stream, Aia_Instr *instr)
42 {
43    STRING(str, "");
44
45    Aia_Operand *tmp = aia_instr_get_src_op(instr, 0);
46    Aia_Label_Data lbl_data;
47    lbl_data.data = aia_operand_const_int_get_val(tmp);
48
49    tmp = aia_instr_get_dest_op(instr);
50    Const_String lbl_name = aia_operand_label_get_name(tmp);
51
52    switch (lbl_data.linkage) {
53    case AIA_LINKAGE_PRIVATE:
54       break;
55    case AIA_LINKAGE_WEAK:
56       string_append_format(str, S(".weak %S\n"), lbl_name);
57       break;
58    case AIA_LINKAGE_GLOBAL:
59       string_append_format(str, S(".globl %S\n"), lbl_name);
60       break;
61    }
62
63    switch (lbl_data.label_type) {
64    case AIA_LABEL_TYPE_NONE:
65       break;
66    case AIA_LABEL_TYPE_FUNC:
67       string_append_format(str, S(".type %S, @function\n"), lbl_name);
68       break;
69    case AIA_LABEL_TYPE_OBJ:
70       string_append_format(str, S(".type %S, @object\n"), lbl_name);
71       break;
```

```
72       }
73
74       tmp = aia_instr_get_src_op(instr, 1);
75       int32_t size = aia_operand_const_int_get_val(tmp);
76       if (size)
77          string_append_format(str, S(".size %S, %" PRId32 "\n"),
78                lbl_name, size);
79
80       if (lbl_data.alignment)
81          string_append_format(str, S(".align %u\n"), lbl_data.alignment);
82
83       string_append_format(str, S("%S:"),
84             aia_instr_get_dest_op(instr)->iden.op_label->label_name);
85       file_print_message(stream, str);
86       string_clear(str);
87    }
88
89    void aia_instr_string_dump(FILE *stream, Aia_Instr *instr)
90    {
91       Const_String name = aia_instr_get_src_op(instr, 0)->iden.op_name;
92       file_print_message(stream, S("\t.byte "));
93       Uns len = string_length(name);
94       for (Uns i = 0; i < len; i++)
95          file_print_message(stream, S("%d,"), string_get(name, i));
96       file_print_message(stream, S("0"));
97    }
98
99    void aia_instr_integer_dump(FILE *stream, Aia_Instr *instr)
100   {
101      Aia_Operand *op = aia_instr_get_src_op(instr, 0);
102      if (instr->src_ops_size == AIA_LONG) {
103         file_print_message(stream, S("\t.long "));
104      } else if (aia_operand_get_type(op) == AIA_OPERAND_CONST_INT) {
105
106         assert((int8_t)aia_instr_get_src_op(instr, 0)->iden.int_const ==
107               aia_instr_get_src_op(instr, 0)->iden.int_const);
108
109         file_print_message(stream, S("\t.byte "));
110      }
111      aia_operand_dump(stream, op, false);
112   }
113
114   void aia_instr_call_dump(FILE *stream, Aia_Instr *instr,
115         Const_String name)
116   {
117      file_print_message(stream, S("\t%S"), name);
118      if (instr->src_op_count) {
119         file_print_message(stream, S(" "));
120         assert(instr->src_ops_size == AIA_LONG);
121         aia_operand_dump_size(stream, instr->src_ops_size);
122         Int i;
123         Aia_Operand *call_op = aia_instr_get_src_op(instr, 0);
124         if (call_op->op_type != AIA_OPERAND_LABEL)
125            file_print_message(stream, S("*"));
126         aia_operand_dump(stream, call_op, true);
127
128         if (instr->src_op_count > 1) {
129            file_print_message(stream, S(", "));
130            for (i = 1; i < (Int)instr->src_op_count - 1; i++) {
131               aia_operand_dump(stream, aia_instr_get_src_op(instr, i), true);
132               file_print_message(stream, S(", "));
133            }
134            aia_operand_dump(stream, aia_instr_get_src_op(instr, i), true);
135         }
136      }
137      if (instr->dest_op) {
138         file_print_message(stream, S(" -> "));
139         aia_operand_dump_size(stream, instr->dest_op_size);
140         aia_operand_dump(stream, instr->dest_op, true);
141      }
142   }
143
144   void aia_instr_nop_dump(FILE *stream, Aia_Instr *instr UNUSED,
145         Const_String name)
```

```
146 {
147    file_print_message(stream, S("\t%S"), name);
148 }
149
150 void aia_instr_vop_dump(FILE *stream, Aia_Instr *instr,
151       Const_String name)
152 {
153    file_print_message(stream, S("\t%S"), name);
154    if (instr->src_op_count) {
155       file_print_message(stream, S(" "));
156       aia_operand_dump_size(stream, instr->src_ops_size);
157       Int i;
158       if (instr->src_op_count > 0) {
159          for (i = 0; i < (Int)instr->src_op_count - 1; i++) {
160             aia_operand_dump(stream, aia_instr_get_src_op(instr, i), true);
161             file_print_message(stream, S(", "));
162          }
163          aia_operand_dump(stream, aia_instr_get_src_op(instr, i), true);
164       }
165    }
166    if (instr->dest_op) {
167       file_print_message(stream, S(" -> "));
168       aia_operand_dump_size(stream, instr->dest_op_size);
169       aia_operand_dump(stream, instr->dest_op, true);
170    }
171 }
172
173 void aia_instr_jump_dump(FILE *stream, Aia_Instr *instr,
174       Const_String name)
175 {
176    Aia_Operand *op;
177    file_print_message(stream, S("\t%S "), name);
178
179    assert(!instr->dest_op);
180    assert(instr->src_op_count > 0 && instr->src_op_count <= 2);
181    assert(instr->src_ops_size == AIA_LONG);
182
183    aia_operand_dump_size(stream, instr->src_ops_size);
184    op = aia_instr_get_src_op(instr, 0);
185    aia_operand_dump(stream, op, true);
186
187    if (instr->src_op_count == 2) {
188       file_print_message(stream, S(", "));
189       op = aia_instr_get_src_op(instr, 1);
190       aia_operand_dump(stream, op, true);
191    }
192 }
193
194 void aia_instr_dump(FILE *stream, Aia_Instr *instr, Aia *aia)
195 {
196    switch (instr->type) {
197    case AIA_MOV:
198       aia_instr_vop_dump(stream, instr, S(".mov"));
199       break;
200    case AIA_MOVS:
201       aia_instr_vop_dump(stream, instr, S(".movs"));
202       break;
203    case AIA_MOVZ:
204       aia_instr_vop_dump(stream, instr, S(".movz"));
205       break;
206    case AIA_ADD:
207       aia_instr_vop_dump(stream, instr, S(".add"));
208       break;
209    case AIA_SUB:
210       aia_instr_vop_dump(stream, instr, S(".sub"));
211       break;
212    case AIA_IMUL:
213       aia_instr_vop_dump(stream, instr, S(".imul"));
214       break;
215    case AIA_IDIV:
216       aia_instr_vop_dump(stream, instr, S(".idiv"));
217       break;
218    case AIA_CMP:
219       aia_instr_vop_dump(stream, instr, S(".cmp"));
```

```
220         break;
221      case AIA_SETE:
222         aia_instr_vop_dump(stream, instr, S(".sete"));
223         break;
224      case AIA_SETNE:
225         aia_instr_vop_dump(stream, instr, S(".setne"));
226         break;
227      case AIA_SETL:
228         aia_instr_vop_dump(stream, instr, S(".setl"));
229         break;
230      case AIA_SETG:
231         aia_instr_vop_dump(stream, instr, S(".setg"));
232         break;
233      case AIA_SETLE:
234         aia_instr_vop_dump(stream, instr, S(".setle"));
235         break;
236      case AIA_SETGE:
237         aia_instr_vop_dump(stream, instr, S(".setge"));
238         break;
239      case AIA_RET:
240         aia_instr_vop_dump(stream, instr, S(".ret"));
241         break;
242      case AIA_CALL:
243         aia_instr_call_dump(stream, instr, S(".call"));
244         break;
245      case AIA_NEG:
246         aia_instr_vop_dump(stream, instr, S(".neg"));
247         break;
248      case ___AIA_LABEL:
249         aia_instr_label_dump(stream, instr);
250         break;
251      case ___AIA_STRING:
252         aia_instr_string_dump(stream, instr);
253         break;
254      case ___AIA_INTEGER:
255         aia_instr_integer_dump(stream, instr);
256         break;
257      case AIA_JNE:
258         aia_instr_jump_dump(stream, instr, S(".jne"));
259         break;
260      case AIA_JE:
261         aia_instr_jump_dump(stream, instr, S(".je"));
262         break;
263      case AIA_JGE:
264         aia_instr_jump_dump(stream, instr, S(".jge"));
265         break;
266      case AIA_JG:
267         aia_instr_jump_dump(stream, instr, S(".jg"));
268         break;
269      case AIA_JLE:
270         aia_instr_jump_dump(stream, instr, S(".jle"));
271         break;
272      case AIA_JL:
273         aia_instr_jump_dump(stream, instr, S(".jl"));
274         break;
275      case AIA_JMP:
276         aia_instr_jump_dump(stream, instr, S(".jmp"));
277         break;
278      case AIA_CDQ:
279         aia_instr_vop_dump(stream, instr, S(".cdq"));
280         break;
281      case AIA_NOP:
282         aia_instr_nop_dump(stream, instr, S(".nop"));
283         break;
284
285      case ___AIA_JNE:
286         /* Fall */
287      case ___AIA_JE:
288         /* Fall */
289      case ___AIA_JMP:
290         fatal_error(S("Unable to dump unexpeceted jump instruction. "
291                       "Aborting...\n"));
292      default:
293         fatal_error(S("Unable to dump unexpeceted instruction. "
```

```
294                "Aborting...\n"));
295    }
296
297    if (aia->aia_instr_dump_callback)
298       aia->aia_instr_dump_callback(stream, instr);
299
300    file_print_message(stream, S("\n"));
301 }
302
303 void aia_label_entry_destroy(Hash_Map_Slot *s)
304 {
305    free_mem(AIA_LABEL_INSTR_ENTRY_OF(s));
306 }
307
308 bool aia_label_instr_comparator(Aia_Operand *search_lbl, Hash_Map_Slot *mslot)
309 {
310    Aia_Label_Instr_Entry *e = AIA_LABEL_INSTR_ENTRY_OF(mslot);
311    return !string_compare(search_lbl->iden.op_label->label_name,
312          aia_instr_get_dest_op(e->label_instr)->iden.op_label->label_name);
313 }
314
315 void aia_instr_append_sucessors(Aia_Instr *in, Vector *sucessors)
316 {
317    Aia_Instr *suc = aia_instr_get_sucessor(in);
318    if (suc) {
319       vector_append(sucessors, suc);
320    } else {
321       Aia_Block *b = aia_instr_get_block(in);
322       Aia_Block *suc_b;
323       AIA_BLOCK_FOR_EACH_SUCESSOR(b, suc_b) {
324          suc = ___aia_block_peek_first_instr(suc_b);
325          vector_append(sucessors, suc);
326       }
327    }
328 }
329
330 void aia_instr_cond_jump_to_jmp(Aia_Instr *cond_jump, Aia_Instr *jmp,
331       Aia_Operand *preserve_block)
332 {
333    Aia_Operand *op = aia_instr_get_src_op(cond_jump, 0);
334    Aia_Block *b = aia_operand_block_get_block(op);
335
336    if (!aia_operands_equal(op, preserve_block)) {
337       aia_block_forget_predecessor(b, aia_instr_get_block(cond_jump));
338    } else {
339       op = aia_instr_get_src_op(cond_jump, 1);
340       b = aia_operand_block_get_block(op);
341       assert(!aia_operands_equal(op, preserve_block));
342       aia_block_forget_predecessor(b, aia_instr_get_block(cond_jump));
343    }
344
345    ___aia_instr_replace(cond_jump, jmp);
346 }
347
348 Aia_Instr *aia_instr_twin(Aia_Instr *in, Aia_Block *contain_block)
349 {
350    uint16_t in_type = aia_instr_get_type(in);
351    Aia_Instr *twin = aia_instr_alloc_vop(in_type,
352          contain_block,
353          aia_instr_get_dest_op_size(in),
354          aia_instr_get_src_ops_size(in),
355          aia_instr_get_src_op_count(in),
356          aia_instr_get_location(in));
357
358    Int idx = 0;
359    Aia_Operand *op;
360    AIA_INSTR_FOR_EACH_SRC(in, op)
361       aia_instr_set_src_op(twin, idx++, op);
362
363    op = aia_instr_get_dest_op(in);
364    if (op)
365       aia_instr_set_dest_op(twin, op);
366
367    return twin;
```

```
368 }
369
370 void aia_instr_get_predecessors(Aia_Instr *in, Vector *preds)
371 {
372    Aia_Instr *p = aia_instr_get_predecessor(in);
373    if (p) {
374       vector_append(preds, p);
375       return;
376    }
377    Aia_Block *b = aia_instr_get_block(in);
378    Aia_Block *pred_b;
379    AIA_BLOCK_FOR_EACH_PREDECESSOR(b, pred_b) {
380       p = ___aia_block_peek_last_instr(pred_b);
381       vector_append(preds, p);
382    }
383 }
384
385 void aia_instr_get_sucessors(Aia_Instr *in, Vector *sucs)
386 {
387    Aia_Instr *s = aia_instr_get_sucessor(in);
388    if (s) {
389       vector_append(sucs, s);
390       return;
391    }
392    Aia_Block *b = aia_instr_get_block(in);
393    Aia_Block *suc_b;
394    AIA_BLOCK_FOR_EACH_PREDECESSOR(b, suc_b) {
395       s = ___aia_block_peek_last_instr(suc_b);
396       vector_append(sucs, s);
397    }
398 }
```

:

A.7.6 src/aia/aia_instr.h

```
1  #ifndef AIA_INSTR_H
2  #define AIA_INSTR_H
3
4  #include <std_include.h>
5  #include <double_list.h>
6  #include <vector.h>
7  #include <hash_map.h>
8  #include "aia_operand.h"
9
10 #define AIA_CASE_INCONCRETE \
11    case ___AIA_JNE:  \
12    case ___AIA_JL:   \
13    case ___AIA_JMP:  \
14    case ___AIA_JGE:  \
15    case ___AIA_STRING:  \
16    case ___AIA_INTEGER: \
17    case ___AIA_LABEL:  \
18    case AIA_NOP
19
20 #define AIA_CASE_SET \
21    case AIA_SETG:  \
22    case AIA_SETGE:  \
23    case AIA_SETL:  \
24    case AIA_SETLE:  \
25    case AIA_SETE:  \
26    case AIA_SETNE
27
28 #define AIA_CASE_COND_TMP_JUMP \
29    case ___AIA_JNE:     \
30    case ___AIA_JGE:     \
31    case ___AIA_JL:      \
32    case ___AIA_JE
33
34 #define AIA_CASE_COND_JUMP \
35    case AIA_JNE:     \
```

```
36      case AIA_JGE:      \
37      case AIA_JL:       \
38      case AIA_JE:       \
39      case AIA_JG:       \
40      case AIA_JLE
41
42  #define AIA_LABEL_JUMP_TO_BLOCK_JUMP(jmp_type) ({ \
43      Aia_Operand_Type ___r;                \
44      switch (jmp_type) {                   \
45      case ___AIA_JNE:                      \
46          ___r = AIA_JNE;                   \
47          break;                            \
48      case ___AIA_JE:                       \
49          ___r = AIA_JE;                    \
50          break;                            \
51      case ___AIA_JGE:                      \
52          ___r = AIA_JGE;                   \
53          break;                            \
54      case ___AIA_JMP:                      \
55          ___r = AIA_JMP;                   \
56          break;                            \
57      default:                              \
58          fatal_error(S("unexpected jump instruction. Aborting...\n")); \
59      }                                     \
60      ___r;                                 \
61  })
62
63  typedef struct Aia Aia;
64
65  /* AIA instuctions. */
66  enum {
67      // .mov @size(x) src -> @size(x) dest
68      AIA_MOV,
69      // .movs @size(4) src -> @size(1) dest
70      AIA_MOVS,
71      // .movz @size(4) src -> @size(1) dest
72      AIA_MOVZ,
73      // .add @size(4) src1, src2 -> @size(4) dest
74      AIA_ADD,
75      // .sub @size(4) src1, src2 -> @size(4) dest  # src1 - src2
76      AIA_SUB,
77      // .imul @size(4) src1, src2 -> @size(4) dest
78      AIA_IMUL,
79      // .idiv @size(4) src1, src2 -> @size(4) dest  # src1 / src2
80      AIA_IDIV,
81      // .cmp @size(x) src1, src2
82      AIA_CMP,
83      // .jne @size(4) ne_label -> @size(4) e_label
84      AIA_JNE,
85      // .je @size(4) e_label -> @size(4) ne_label
86      AIA_JE,
87      // .jge @size(4) ge_label -> @size(4) l_label
88      AIA_JGE,
89      // .jg @size(4) g_label -> @size(4) le_label
90      AIA_JG,
91      // .jle @size(4) le_label -> @size(4) g_label
92      AIA_JLE,
93      // .jl @size(4) l_label -> @size(4) ge_label
94      AIA_JL,
95      // .jmp -> @size(4) label
96      AIA_JMP,
97      // .sete -> @size(1) dest
98      AIA_SETE,
99      // .setne -> @size(1) dest
100     AIA_SETNE,
101     // .setl -> @size(1) dest
102     AIA_SETL,
103     // .setg -> @size(1) dest
104     AIA_SETG,
105     // .setle -> @size(1) dest
106     AIA_SETLE,
107     // .setge -> @size(1) dest
108     AIA_SETGE,
109     // .ret [@size(x) src]     # opt return value, no dest operand
```

```
110     AIA_RET,
111     // .call @size(4) mem/reg -> @size(x) result
112     AIA_CALL,
113     // .neg @size(4) src -> @size(4) dest
114     AIA_NEG,
115     // .cdq @size(4) src -> @size(4) dest # sign extend src into dest
116     AIA_CDQ,
117
118     // .nop
119     AIA_NOP,
120
121     // .tmp.jne @size(4) ne_label, e_label (gets replaced by AIA_JNE)
122     ___AIA_JNE,
123     // .tmp.je @size(4) e_label, ne_label (gets replaced by AIA_JE)
124     ___AIA_JE,
125     // .tmp.jge @size(4) ge_label, nge_label (gets replaced by AIA_JGE)
126     ___AIA_JGE,
127     // .tmp.jl @size(4) l_label, nl_label (gets replaced by AIA_JL)
128     ___AIA_JL,
129     // .tmp.jmp @size(4) label (gets replaced by AIA_JMP)
130     ___AIA_JMP,
131
132     // ___AIA_LABEL, dest is label operand,
133     // 1st src is an Aia_Label_Data union where
134     // the fields have the meaning:
135     // when alignment != 0:
136     //  [.align alignment]
137     // when linkage != PRIVATE:
138     //  [|.globl dest_label|.weak dest_label]
139     // when label_type != NONE
140     //  [|.type dest_lbl @function|.type dest_lbl @object]
141     // 2nd src operand is specifying an object size
142     // when size != 0:
143     //  [.size dest_lbl x]
144     //  dest_label:
145     ___AIA_LABEL, // Dest is a label (AIA_OPERAND_LABEL).
146     // .byte c1, c2, ..., cn
147     ___AIA_STRING, // Src is a static string (AIA_OPERAND_CONST_STRING).
148     // [.byte|.long] int_val
149     ___AIA_INTEGER // Src is a static int (AIA_OPERAND_CONST_INT).
150 };
151
152 typedef enum Aia_Cmp_Result {
153     AIA_CMP_NONE,
154     AIA_CMP_UNKNOWN,
155     AIA_CMP_LESS,
156     AIA_CMP_EQUAL,
157     AIA_CMP_GREAT
158 } Aia_Cmp_Result;
159
160 /* Source operand sizes. */
161 enum {
162     AIA_BYTE,
163     AIA_LONG
164 };
165
166 typedef struct Aia_Instr {
167     File_Location location;
168     Double_List_Node dbnode;
169     uint16_t type;
170     uint8_t dest_op_size;
171     uint8_t src_ops_size;
172     int32_t src_op_count;
173     void *meta_data;
174     int32_t flags;
175     Aia_Block *containing_block;
176     Aia_Operand *dest_op;
177     Aia_Operand *src_ops[0]; /* Optional source operands. */
178 } Aia_Instr;
179
180 #define AIA_INSTR_FLAG_NORMALIZED 1
181
182 #define AIA_INSTR_OF(node) DOUBLE_LIST_ENTRY(node, Aia_Instr, dbnode)
183
```

```
184 typedef struct Aia_Label_Instr_Entry {
185    Aia_Instr *label_instr;
186    Hash_Map_Slot hash_slot;
187 } Aia_Label_Instr_Entry;
188
189 #define AIA_LABEL_INSTR_ENTRY_OF(slot) \
190    HASH_MAP_ENTRY(slot, Aia_Label_Instr_Entry, hash_slot)
191
192 #define AIA_INSTR_FOR_EACH_SRC(instr, op)          \
193    for (int32_t ___i = 0; ___i < (instr)->src_op_count; ___i++) \
194       if ((op = (instr)->src_ops[___i]) || !op)
195
196 #define AIA_INSTR_FOR_EACH_OPERAND(instr, op)         \
197 for (Aia_Operand *___op = aia_instr_get_dest_op(instr),     \
198             *___i = INT_TO_PTR(-1);                   \
199       (PTR_TO_INT(___i) < (instr)->src_op_count);      \
200       ___i = (Aia_Operand *)((char *)___i + 1),       \
201            ___op = (PTR_TO_INT(___i) < (instr)->src_op_count) ? \
202            aia_instr_get_src_op(instr, PTR_TO_INT(___i)) : NULL) \
203         if ((op = ___op) || !op)
204
205 static inline File_Location *aia_instr_get_location(Aia_Instr *in)
206 {
207    return &in->location;
208 }
209
210 static inline Aia_Instr *___aia_instr_alloc(uint16_t type, Aia_Block *b,
211       uint8_t dest_op_size, uint8_t src_ops_size, int32_t nsrc_ops,
212       File_Location *loc)
213 {
214    Aia_Instr *ret = alloc_mem(sizeof(Aia_Instr) +
215          nsrc_ops * sizeof(Aia_Operand *));
216    ret->type = type;
217    ret->src_op_count = nsrc_ops;
218    ret->dest_op_size = dest_op_size;
219    ret->src_ops_size = src_ops_size;
220    ret->containing_block = b;
221    ret->dest_op = NULL;
222    ret->meta_data = NULL;
223    ret->flags = 0;
224    ret->location = FILE_LOCATION_INIT(file_location_get_file_name(loc),
225          loc->line, loc->column);
226    for (int32_t i = 0; i < nsrc_ops; i++)
227       ret->src_ops[i] = NULL;
228    return ret;
229 }
230
231 static inline bool aia_instr_is_normalized(Aia_Instr *in)
232 {
233    return in->flags & AIA_INSTR_FLAG_NORMALIZED;
234 }
235
236 static inline void aia_instr_set_normalized(Aia_Instr *in)
237 {
238    in->flags |= AIA_INSTR_FLAG_NORMALIZED;
239 }
240
241 static inline Aia_Instr *aia_instr_alloc_0op(uint16_t type,
242       Aia_Block *contain_block, uint8_t dest_op_size,
243       File_Location *loc)
244 {
245    return ___aia_instr_alloc(type, contain_block, dest_op_size, -1, 0, loc);
246 }
247
248 static inline Aia_Instr *aia_instr_alloc_1op(uint16_t type,
249       Aia_Block *contain_block, uint8_t dest_op_size, uint8_t src_ops_size,
250       File_Location *loc)
251 {
252    return ___aia_instr_alloc(type, contain_block, dest_op_size,
253          src_ops_size, 1, loc);
254 }
255
256 static inline Aia_Instr *aia_instr_alloc_2op(uint16_t type,
257       Aia_Block *contain_block, uint8_t dest_op_size, uint8_t src_ops_size,
```

```
258         File_Location *loc)
259 {
260    return ___aia_instr_alloc(type, contain_block, dest_op_size,
261          src_ops_size, 2, loc);
262 }
263
264 static inline Aia_Instr *aia_instr_alloc_vop(uint16_t type,
265       Aia_Block *contain_block, uint8_t dest_op_size,
266       uint8_t src_ops_size, Uns num_src_ops, File_Location *loc)
267 {
268    return ___aia_instr_alloc(type, contain_block, dest_op_size,
269          src_ops_size, num_src_ops, loc);
270 }
271
272 static inline uint16_t aia_instr_get_type(Aia_Instr *in)
273 {
274    return in->type;
275 }
276
277 static inline Aia_Block *aia_instr_get_block(Aia_Instr *in)
278 {
279    return in->containing_block;
280 }
281
282 static inline void aia_instr_set_src_op(Aia_Instr *instr, int32_t idx,
283       Aia_Operand *src_op)
284 {
285    assert(instr->src_op_count > idx);
286    ++src_op->ref_count;
287    instr->src_ops[idx] = src_op;
288 }
289
290 static inline Aia_Operand *aia_instr_get_src_op(Aia_Instr *instr, int32_t idx)
291 {
292    assert(instr->src_op_count > idx);
293    return instr->src_ops[idx];
294 }
295
296 static inline int32_t aia_instr_get_src_op_count(Aia_Instr *in)
297 {
298    return in->src_op_count;
299 }
300
301 static inline void aia_instr_set_dest_op(Aia_Instr *instr,
302       Aia_Operand *dest_op)
303 {
304    assert(dest_op);
305    assert(aia_operand_is_dest(dest_op));
306    if (!dest_op->ref_count)
307       assert(!dest_op->ref_count);
308    ++dest_op->ref_count;
309    instr->dest_op = dest_op;
310 }
311
312 // idx == -1 => set dest op
313 static inline void aia_instr_set_op(Aia_Instr *in, Int idx, Aia_Operand *op)
314 {
315    if (idx == -1)
316       aia_instr_set_dest_op(in, op);
317    else
318       aia_instr_set_src_op(in, idx, op);
319 }
320
321 static inline Aia_Operand *aia_instr_get_dest_op(Aia_Instr *instr)
322 {
323    return instr->dest_op;
324 }
325
326 // idx == -1 => set dest op
327 static inline Aia_Operand *aia_instr_get_op(Aia_Instr *in, Int idx)
328 {
329    if (idx == -1)
330       return aia_instr_get_dest_op(in);
331    return aia_instr_get_src_op(in, idx);
```

```
332 }
333
334 static inline uint8_t aia_instr_get_src_ops_size(Aia_Instr *in)
335 {
336    return in->src_ops_size;
337 }
338
339 static inline uint8_t aia_instr_get_dest_op_size(Aia_Instr *in)
340 {
341    return in->dest_op_size;
342 }
343
344 static inline bool aia_instr_is_set_instr(Aia_Instr *in)
345 {
346    switch (aia_instr_get_type(in)) {
347    AIA_CASE_SET:
348       return true;
349    default:
350       return false;
351    }
352 }
353
354 static inline bool aia_instr_is_cond_jump(Aia_Instr *in)
355 {
356    switch (aia_instr_get_type(in)) {
357    AIA_CASE_COND_JUMP:
358       return true;
359    default:
360       return false;
361    }
362 }
363
364 static inline bool aia_instr_is_movx(Aia_Instr *in)
365 {
366    switch (aia_instr_get_type(in)) {
367    case AIA_MOVZ:
368    case AIA_MOVS:
369    case AIA_MOV:
370       return true;
371    default:
372       return false;
373    }
374 }
375
376 static inline bool aia_instr_is_concrete(Aia_Instr *in)
377 {
378    switch (aia_instr_get_type(in)) {
379    AIA_CASE_INCONCRETE:
380       return false;
381    default:
382       return true;
383    }
384 }
385
386
387 static inline void aia_instr_replace_op(Aia_Instr *in, Int old_op_idx,
388       Aia_Operand *new_op)
389 {
390    Aia_Operand *old_op = aia_instr_get_op(in, old_op_idx);
391    aia_instr_set_op(in, old_op_idx, new_op);
392    ___aia_operand_release(old_op);
393 }
394
395 static inline void aia_instr_swap_ops(Aia_Instr *in, Int i1, Int i2)
396 {
397    assert(i1 != i2);
398
399    Aia_Operand *tmp;
400    if (i1 == -1) {
401       tmp = aia_instr_get_dest_op(in);
402       in->dest_op = aia_instr_get_src_op(in, i2);
403       in->src_ops[i2] = tmp;
404    } else if (i2 == -1) {
405       tmp = aia_instr_get_dest_op(in);
```

```
406         in->dest_op = aia_instr_get_src_op(in, i1);
407         in->src_ops[i1] = tmp;
408      } else {
409         tmp = aia_instr_get_src_op(in, i2);
410         in->src_ops[i2] = aia_instr_get_src_op(in, i1);
411         in->src_ops[i1] = tmp;
412      }
413   }
414
415   void aia_instr_destroy(Aia_Instr *instr);
416
417   void ___aia_instr_destroy(Aia_Instr *instr);
418
419   /* Returns NULL if in is the last instruction in the block. */
420   static inline Aia_Instr *aia_instr_get_sucessor(Aia_Instr *in)
421   {
422      extern Aia_Instr *___aia_block_peek_last_instr(Aia_Block *b);
423
424      if (in == ___aia_block_peek_last_instr(aia_instr_get_block(in)))
425         return NULL;
426
427      Aia_Instr *suc = AIA_INSTR_OF(in->dbnode.next);
428      return suc;
429   }
430
431   void aia_instr_append_sucessors(Aia_Instr *in, Vector *sucessors);
432
433   /* Returns NULL if in is the last instruction in the block. */
434   static inline Aia_Instr *aia_instr_get_predecessor(Aia_Instr *in)
435   {
436      extern Aia_Instr *___aia_block_peek_first_instr(Aia_Block *b);
437
438      if (in == ___aia_block_peek_first_instr(aia_instr_get_block(in)))
439         return NULL;
440
441      Aia_Instr *pred = AIA_INSTR_OF(in->dbnode.prev);
442      return pred;
443   }
444
445   static inline void ___aia_instr_remove(Aia_Instr *in)
446   {
447      double_list_remove(&in->dbnode);
448   }
449
450   static inline void aia_instr_remove(Aia_Instr *in)
451   {
452      DEBUGT(def,
453         switch (aia_instr_get_type(in)) {
454         AIA_CASE_COND_JUMP:
455         case AIA_JMP:
456            assert(false);
457         default:
458            break;
459         }
460      );
461      ___aia_instr_remove(in);
462   }
463
464   static inline void aia_instr_remove_destroy(Aia_Instr *in)
465   {
466      aia_instr_remove(in);
467      aia_instr_destroy(in);
468   }
469
470   static inline void aia_instr_insert_before(Aia_Instr *in, Aia_Instr *sucessor)
471   {
472      double_list_insert(&in->dbnode, sucessor->dbnode.prev, &sucessor->dbnode);
473   }
474
475   static inline void aia_instr_insert_after(Aia_Instr *in, Aia_Instr *pred)
476   {
477      double_list_insert(&in->dbnode, &pred->dbnode, pred->dbnode.next);
478   }
479
```

```
480 static inline void ___aia_instr_replace(Aia_Instr *old_in, Aia_Instr *new_in)
481 {
482    aia_instr_insert_before(new_in, old_in);
483    ___aia_instr_remove(old_in);
484 }
485
486 static inline void ___aia_instr_replace_destroy(Aia_Instr *old_in,
487       Aia_Instr *new_in)
488 {
489    aia_instr_insert_before(new_in, old_in);
490    ___aia_instr_remove(old_in);
491    aia_instr_destroy(old_in);
492 }
493
494 static inline void aia_instr_replace(Aia_Instr *old_in, Aia_Instr *new_in)
495 {
496    aia_instr_insert_before(new_in, old_in);
497    aia_instr_remove(old_in);
498 }
499
500 static inline void aia_instr_replace_destroy(Aia_Instr *old_in,
501       Aia_Instr *new_in)
502 {
503    aia_instr_replace(old_in, new_in);
504    aia_instr_destroy(old_in);
505 }
506
507 void aia_instr_get_predecessors(Aia_Instr *in, Vector *preds);
508
509 void aia_instr_get_sucessors(Aia_Instr *in, Vector *sucs);
510
511 void aia_instr_cond_jump_to_jmp(Aia_Instr *cond_jump, Aia_Instr *jmp,
512       Aia_Operand *preserve_block);
513
514 void aia_instr_dump(FILE *stream, Aia_Instr *instr, Aia *aia);
515
516 void ___aia_instr_db_destroy(Double_List_Node *dbnode);
517
518 void aia_instr_label_dump(FILE *stream, Aia_Instr *instr);
519
520 void aia_instr_string_dump(FILE *stream, Aia_Instr *instr);
521
522 void aia_instr_integer_dump(FILE *stream, Aia_Instr *instr);
523
524 void aia_instr_call_dump(FILE *stream, Aia_Instr *instr,
525       Const_String name);
526
527 void aia_instr_vop_dump(FILE *stream, Aia_Instr *instr,
528       Const_String name);
529
530 void aia_instr_jump_dump(FILE *stream, Aia_Instr *instr,
531       Const_String name);
532
533 bool aia_label_instr_comparator(Aia_Operand *search_lbl, Hash_Map_Slot *mslot);
534
535 void aia_label_entry_destroy(Hash_Map_Slot *s);
536
537 Aia_Instr *aia_instr_twin(Aia_Instr *in, Aia_Block *contain_block);
538
539 #endif // AIA_INSTR_H
```

:

A.7.7 src/aia/aia_normalize_addr.c

```
1 #include "aia_normalize_addr.h"
2 #include "aia.h"
3 #include <main.h>
4
5 static Aia_Operand *aia_mov_to_temp_reg(Aia *aia, Aia_Operand *src_op,
6       Aia_Instr *sucessor)
```

```
7  {
8     Aia_Instr *mov_in = aia_mov_to_tmp_reg_before(aia, src_op, sucessor,
9           AIA_LONG);
10    aia_normalize_if_addr(aia, mov_in);
11    return aia_instr_get_dest_op(mov_in);
12 }
13
14 static void do_normalize_addr(Aia *aia, Aia_Instr *in, Int op_idx)
15 {
16    Aia_Operand *op = aia_instr_get_op(in, op_idx);
17
18    Aia_Operand *scale_op = aia_operand_addr_ref_get_scale(op);
19    Aia_Operand *disp_op = aia_operand_addr_ref_get_disp(op);
20
21    bool delete_disp;
22    if (!disp_op)
23       delete_disp = true;
24    else
25       delete_disp = false;
26
27    Aia_Operand *index_reg = aia_operand_addr_ref_get_index(op);
28    if (index_reg) {
29       if (aia_operand_get_type(index_reg) == AIA_OPERAND_CONST_INT) {
30          int32_t disp;
31          if (!scale_op)
32             disp = aia_operand_const_int_get_val(index_reg);
33          else
34             disp = aia_operand_const_int_get_val(index_reg) *
35                aia_operand_const_int_get_val(scale_op);
36          if (!disp_op) {
37             disp_op = aia_operand_const_int_alloc(aia, disp);
38          } else {
39             Aia_Operand *tmp = aia_operand_const_int_alloc(aia,
40                   aia_operand_const_int_get_val(disp_op) + disp);
41             ___aia_operand_release(disp_op) ;
42             ___aia_operand_acquire(tmp);
43             op->iden.addr_ref->disp = tmp;
44          }
45          index_reg = scale_op = NULL;
46       } else if (aia_operand_get_type(index_reg) != AIA_OPERAND_REG) {
47          index_reg = aia_mov_to_temp_reg(aia, index_reg, in);
48       }
49    }
50
51    Aia_Operand *base_reg = aia_operand_addr_ref_get_base(op);
52    if (base_reg) {
53       if (aia_operand_get_type(base_reg) == AIA_OPERAND_CONST_INT) {
54          int32_t disp = base_reg->iden.int_const;
55          if (!disp_op) {
56             disp_op = aia_operand_const_int_alloc(aia, disp);
57          } else {
58             Aia_Operand *tmp = aia_operand_const_int_alloc(aia,
59                   aia_operand_const_int_get_val(disp_op) + disp);
60             ___aia_operand_release(disp_op) ;
61             ___aia_operand_acquire(tmp);
62             op->iden.addr_ref->disp = tmp;
63          }
64          base_reg = NULL;
65       } else if (aia_operand_get_type(base_reg) != AIA_OPERAND_REG) {
66          base_reg = aia_mov_to_temp_reg(aia, base_reg, in);
67       }
68    }
69
70    if (disp_op && !aia_operand_const_int_get_val(disp_op)) {
71       if (delete_disp)
72          ___aia_operand_destroy(disp_op);
73       disp_op = NULL;
74    }
75
76    Aia_Operand *label_op = aia_operand_addr_ref_get_label(op);
77    Aia_Operand *new_op = aia_operand_addr_ref_alloc(aia, label_op, disp_op,
78          base_reg, index_reg, scale_op);
79
80    aia_instr_replace_op(in, op_idx, new_op);
```

```
81  }
82
83  static void do_normalize_display(Aia *aia, Aia_Instr *in, Int op_idx)
84  {
85     Aia_Operand *op = aia_instr_get_op(in, op_idx);
86     if (aia_operand_get_type(op) != AIA_OPERAND_REG) {
87        Aia_Operand *reg = aia_mov_to_temp_reg(aia,
88              aia_operand_display_ref_get_display_reg(op),
89              in);
90        Aia_Operand *new_op = aia_operand_display_ref_alloc(aia,
91              reg,
92              aia_operand_display_ref_get_var_name(op),
93              aia_operand_display_ref_get_func_name(op)
94              /*, aia_operand_display_ref_get_var_size(op) */);
95        aia_instr_replace_op(in, op_idx, new_op);
96     }
97  }
98
99  void aia_normalize_if_addr(Aia *aia, Aia_Instr *in)
100 {
101    Int op_idx = -1;
102    Aia_Operand *op;
103    AIA_INSTR_FOR_EACH_OPERAND(in, op) {
104       if (op) {
105          if (aia_operand_get_type(op) == AIA_OPERAND_ADDR_REF)
106             do_normalize_addr(aia, in, op_idx);
107          else if (aia_operand_get_type(op) == AIA_OPERAND_DISPLAY_REF)
108             do_normalize_display(aia, in, op_idx);
109       }
110       ++op_idx;
111    }
112 }
113
114 static void aia_norm_addr_dump(Aia *aia)
115 {
116    String fname = string_from_format(S("%S.vitaly.norm-addr-ic"),
117          aia_get_file_name(aia));
118    FILE *dfname = file_open(fname, S("w"));
119    if (!dfname)
120       fatal_error(S("unable to create file %S for intermediate "
121             "code dump [%m]\n"), fname);
122    string_destroy(fname);
123    aia_dump(aia, dfname);
124    file_close(dfname);
125 }
126
127 void aia_normalize_block_callback(Aia_Block *b, void *arg)
128 {
129    Aia *aia = arg;
130    Aia_Instr *in;
131    AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
132       aia_normalize_if_addr(aia, in);
133 }
134
135 void aia_normalize_addr(Aia *aia)
136 {
137    if (!aia_is_valid(aia))
138       return;
139
140    Aia_Section *sec;
141    AIA_FOR_EACH_SECTION(aia, sec) {
142       aia_section_for_each_block_depth(sec,
143             aia_normalize_block_callback, aia);
144
145       Aia_Func *f;
146       AIA_SECTION_FOR_EACH_FUNC(sec, f) {
147          aia_func_for_each_block_depth(
148                f, aia_normalize_block_callback, aia);
149
150          Aia_Func_Trampoline *t;
151          AIA_FUNC_FOR_EACH_TRAMPOLINE(f, t)
152             aia_normalize_block_callback(t->block, aia);
153       }
154    }
```

```
155
156     if (cmdopts.dump_norm_addr_ic)
157        aia_norm_addr_dump(aia);
158  }
```

:

A.7.8 src/aia/aia_normalize_addr.h

```
1   #ifndef AIA_NORMALIZE_ADDR_H
2   #define AIA_NORMALIZE_ADDR_H
3
4   #include <vector.h>
5
6   typedef struct Aia Aia;
7
8   typedef struct Aia_Instr Aia_Instr;
9
10  void aia_normalize_addr(Aia *aia);
11
12  void aia_normalize_if_addr(Aia *aia, Aia_Instr *in);
13
14  static inline void aia_normalize_addr_instructions(Aia *aia, Vector *v)
15  {
16     Aia_Instr *in;
17     VECTOR_FOR_EACH_ENTRY(v, in)
18        aia_normalize_if_addr(aia, in);
19  }
20
21  #endif // AIA_NORMALIZE_ADDR_H
```

:

A.7.9 src/aia/aia_operand.c

```
1   #include "aia.h"
2   #include <hash_map.h>
3
4   bool aia_operands_equal(Aia_Operand *lhs, Aia_Operand *rhs);
5
6   static inline bool aia_operand_regs_equal(Aia_Operand *lhs, Aia_Operand *rhs)
7   {
8      return !string_compare(aia_operand_reg_get_name(lhs),
9            aia_operand_reg_get_name(rhs));
10  }
11
12  static inline bool aia_operand_labels_equal(Aia_Operand *lhs, Aia_Operand *rhs)
13  {
14     if (string_compare(aia_operand_label_get_name(lhs),
15              aia_operand_label_get_name(rhs)))
16        return false;
17     return aia_operand_label_get_offset(lhs) ==
18           aia_operand_label_get_offset(rhs);
19  }
20
21  static inline bool aia_operand_const_ints_equal(Aia_Operand *lhs,
22        Aia_Operand *rhs)
23  {
24     return aia_operand_const_int_get_val(lhs) ==
25           aia_operand_const_int_get_val(rhs);
26  }
27
28  static inline bool aia_operand_const_strings_equal(Aia_Operand *lhs,
29        Aia_Operand *rhs)
30  {
31     return !string_compare(aia_operand_const_string_get_val(lhs),
32           aia_operand_const_string_get_val(rhs));
```

```
33  }
34
35  static inline bool aia_operand_addr_ref_operands_equal(Aia_Operand *lhs,
36     Aia_Operand *rhs)
37  {
38     if (lhs && rhs)
39        return aia_operands_equal(lhs, rhs);
40     return lhs == rhs;
41  }
42
43  static inline bool aia_operand_addr_refs_equal(Aia_Operand *lhs,
44        Aia_Operand *rhs)
45  {
46     if (!aia_operand_addr_ref_operands_equal(
47              aia_operand_addr_ref_get_index(lhs),
48              aia_operand_addr_ref_get_index(rhs)))
49           return false;
50     if (!aia_operand_addr_ref_operands_equal(
51              aia_operand_addr_ref_get_base(lhs),
52              aia_operand_addr_ref_get_base(rhs)))
53           return false;
54     if (!aia_operand_addr_ref_operands_equal(
55              aia_operand_addr_ref_get_disp(lhs),
56              aia_operand_addr_ref_get_disp(rhs)))
57           return false;
58     if (!aia_operand_addr_ref_operands_equal(
59              aia_operand_addr_ref_get_scale(lhs),
60              aia_operand_addr_ref_get_scale(rhs)))
61           return false;
62     if (!aia_operand_addr_ref_operands_equal(
63              aia_operand_addr_ref_get_label(lhs),
64              aia_operand_addr_ref_get_label(rhs)))
65           return false;
66     return true;
67  }
68
69  static inline bool aia_operand_local_refs_equal(Aia_Operand *lhs,
70        Aia_Operand *rhs)
71  {
72     if (string_compare(aia_operand_local_ref_get_var_name(lhs),
73              aia_operand_local_ref_get_var_name(rhs)))
74        return false;
75     return true;
76  }
77
78  static inline bool aia_operand_args_equal(Aia_Operand *lhs,
79        Aia_Operand *rhs)
80  {
81     return aia_operand_arg_get_idx(lhs) ==
82           aia_operand_arg_get_idx(rhs);
83  }
84
85  static inline bool aia_operand_display_refs_equal(Aia_Operand *lhs,
86        Aia_Operand *rhs)
87  {
88  #if 0
89     if (aia_operand_display_ref_get_var_size(lhs) !=
90           aia_operand_display_ref_get_var_size(rhs))
91        return false;
92  #endif
93
94     if (string_compare(aia_operand_display_ref_get_var_name(lhs),
95              aia_operand_display_ref_get_var_name(rhs)))
96        return false;
97
98     if (string_compare(aia_operand_display_ref_get_func_name(lhs),
99              aia_operand_display_ref_get_func_name(rhs)))
100       return false;
101
102    return aia_operands_equal(aia_operand_display_ref_get_display_reg(lhs),
103          aia_operand_display_ref_get_display_reg(rhs));
104 }
105
106 static inline bool aia_operand_blocks_equal(Aia_Operand *lhs, Aia_Operand *rhs)
```

```
107 {
108    return aia_operand_block_get_block(lhs) ==
109          aia_operand_block_get_block(rhs);
110 }
111
112 bool aia_operands_equal(Aia_Operand *lhs, Aia_Operand *rhs)
113 {
114    Aia_Operand_Type t = aia_operand_get_type(lhs);
115    if (t != aia_operand_get_type(rhs))
116       return false;
117    switch (t) {
118    case AIA_OPERAND_REG:
119       return aia_operand_regs_equal(lhs, rhs);
120    case AIA_OPERAND_LABEL:
121       /* Fall through. */
122    case AIA_OPERAND_LABEL_ADDR:
123       return aia_operand_labels_equal(lhs, rhs);
124    case AIA_OPERAND_CONST_INT:
125       return aia_operand_const_ints_equal(lhs, rhs);
126    case AIA_OPERAND_CONST_STRING:
127       return aia_operand_const_strings_equal(lhs, rhs);
128    case AIA_OPERAND_ADDR_REF:
129       return aia_operand_addr_refs_equal(lhs, rhs);
130    case AIA_OPERAND_LOCAL_REF:
131       return aia_operand_local_refs_equal(lhs, rhs);
132    case AIA_OPERAND_ARG:
133       return aia_operand_args_equal(lhs, rhs);
134    case AIA_OPERAND_DISPLAY_REF:
135       return aia_operand_display_refs_equal(lhs, rhs);
136    case AIA_OPERAND_BLOCK:
137       return aia_operand_blocks_equal(lhs, rhs);
138    default:
139       fatal_error(S("unexpected operand type. Aborting...\n"));
140    }
141 }
142
143 void aia_operand_dump_size(FILE *stream, uint8_t type)
144 {
145    switch (type) {
146    case AIA_BYTE:
147       file_print_message(stream, S("@size(1) "));
148       break;
149    default: // just assume AIA_LONG
150       file_print_message(stream, S("@size(4) "));
151       break;
152    }
153 }
154
155 void aia_operand_dump(FILE *stream, Aia_Operand *op,
156       bool print_int_dollar)
157 {
158    if (!op)
159       return;
160
161    switch (op->op_type) {
162    case AIA_OPERAND_LABEL_ADDR:
163       if (op->iden.op_label->offset)
164          file_print_message(stream, S("$%S+%" PRId32),
165                op->iden.op_label->label_name,
166                op->iden.op_label->offset);
167       else
168          file_print_message(stream, S("$%S"),
169                op->iden.op_label->label_name);
170       break;
171
172    case AIA_OPERAND_REG:
173       file_print_message(stream, S("%%%S"), op->iden.op_name);
174       break;
175
176    case AIA_OPERAND_LABEL:
177       if (op->iden.op_label->offset)
178          file_print_message(stream, S("%S+%" PRId32),
179                op->iden.op_label->label_name,
180                op->iden.op_label->offset);
```

```
181         else
182            file_print_message(stream, S("%S"),
183                  op->iden.op_label->label_name);
184         break;
185
186      case AIA_OPERAND_CONST_INT:
187         if (print_int_dollar)
188            file_print_message(stream, S("$%" PRId32), op->iden.int_const);
189         else
190            file_print_message(stream, S("%" PRId32), op->iden.int_const);
191         break;
192
193      case AIA_OPERAND_ADDR_REF:
194         if (op->iden.addr_ref->label)
195            aia_operand_dump(stream, op->iden.addr_ref->label, false);
196         if (op->iden.addr_ref->disp && op->iden.addr_ref->label)
197            file_print_message(stream, S("+"));
198         if (op->iden.addr_ref->disp)
199            aia_operand_dump(stream, op->iden.addr_ref->disp, false);
200         file_print_message(stream, S("("));
201         if (op->iden.addr_ref->base)
202            aia_operand_dump(stream, op->iden.addr_ref->base, false);
203         if (op->iden.addr_ref->index || op->iden.addr_ref->scale)
204            file_print_message(stream, S(","));
205         if (op->iden.addr_ref->index) {
206            aia_operand_dump(stream, op->iden.addr_ref->index, false);
207            if (op->iden.addr_ref->scale)
208               file_print_message(stream, S(","));
209         }
210         if (op->iden.addr_ref->scale)
211            aia_operand_dump(stream, op->iden.addr_ref->scale, false);
212         file_print_message(stream, S(")"));
213         break;
214
215      case AIA_OPERAND_LOCAL_REF:
216         file_print_message(stream, S("@local(%S)"),
217               op->iden.local_ref->var_name);
218         break;
219
220      case AIA_OPERAND_ARG:
221         file_print_message(stream, S("@arg(%U)"),
222               aia_operand_arg_get_idx(op));
223         break;
224
225      case AIA_OPERAND_DISPLAY_REF:
226         file_print_message(stream, S("@display_ref("));
227         aia_operand_dump(stream,
228               aia_operand_display_ref_get_display_reg(op), false);
229         file_print_message(stream, S("::%S::%S)"),
230               op->iden.display_ref->func_name,
231               op->iden.display_ref->var_name);
232         break;
233
234      case AIA_OPERAND_BLOCK:;
235         Aia_Instr *lbl_instr =
236               ___aia_block_peek_first_instr(op->iden.op_block);
237         aia_operand_dump(stream, aia_instr_get_dest_op(lbl_instr), false);
238         break;
239
240      default:
241         fatal_error(S("Unexpected operand type for dump\n"));
242      }
243   }
244
245   void ___aia_operand_destroy(Aia_Operand *op)
246   {
247      Aia_Operand_Addr_Ref *addr_ref;
248      switch (op->op_type) {
249      case AIA_OPERAND_CONST_INT:
250         break;
251      case AIA_OPERAND_ADDR_REF:
252         addr_ref = op->iden.addr_ref;
253         ___aia_operand_release(addr_ref->index);
254         ___aia_operand_release(addr_ref->scale);
```

```
255         ___aia_operand_release(addr_ref->base);
256         ___aia_operand_release(addr_ref->disp);
257         ___aia_operand_release(addr_ref->label);
258         free_mem(addr_ref);
259         break;
260      case AIA_OPERAND_LOCAL_REF:
261         string_destroy(op->iden.local_ref->var_name);
262         free_mem(op->iden.local_ref);
263         break;
264      case AIA_OPERAND_ARG:
265         break;
266      case AIA_OPERAND_DISPLAY_REF:
267         string_destroy(op->iden.display_ref->func_name);
268         string_destroy(op->iden.display_ref->var_name);
269         ___aia_operand_release(op->iden.display_ref->display_reg);
270         free_mem(op->iden.display_ref);
271         break;
272      case AIA_OPERAND_LABEL:
273      case AIA_OPERAND_LABEL_ADDR:
274         string_destroy(op->iden.op_label->label_name);
275         free_mem(op->iden.op_label);
276         break;
277      case AIA_OPERAND_BLOCK:
278         break;
279      default:
280         string_destroy(op->iden.op_name);
281         break;
282      }
283      free_mem(op);
284   }
285
286   Uns aia_operand_block_hash_code(Aia_Operand *op)
287   {
288      return hash_map_aligned_ptr_hash(aia_operand_block_get_block(op));
289   }
290
291   Aia_Operand *aia_operand_display_ref_with_replaced_reg(Aia *aia,
292         Aia_Operand *disp_ref, Aia_Operand *new_reg)
293   {
294      assert(disp_ref->op_type == AIA_OPERAND_DISPLAY_REF);
295      return aia_operand_display_ref_alloc(aia, new_reg,
296            aia_operand_display_ref_get_var_name(disp_ref),
297            aia_operand_display_ref_get_func_name(disp_ref)
298            /* , aia_operand_display_ref_get_var_size(disp_ref) */);
299   }
300
301   Aia_Operand *aia_operand_addr_ref_with_replaced_index(Aia *aia,
302         Aia_Operand *addr_ref, Aia_Operand *new_op)
303   {
304      assert(aia_operand_get_type(addr_ref) == AIA_OPERAND_ADDR_REF);
305      return aia_operand_addr_ref_alloc(aia,
306            aia_operand_addr_ref_get_label(addr_ref),
307            aia_operand_addr_ref_get_disp(addr_ref),
308            aia_operand_addr_ref_get_base(addr_ref),
309            new_op,
310            aia_operand_addr_ref_get_scale(addr_ref));
311   }
312
313   Aia_Operand *aia_operand_addr_ref_with_replaced_base(Aia *aia,
314         Aia_Operand *addr_ref, Aia_Operand *new_op)
315   {
316      assert(aia_operand_get_type(addr_ref) == AIA_OPERAND_ADDR_REF);
317      return aia_operand_addr_ref_alloc(aia,
318            aia_operand_addr_ref_get_label(addr_ref),
319            aia_operand_addr_ref_get_disp(addr_ref),
320            new_op,
321            aia_operand_addr_ref_get_index(addr_ref),
322            aia_operand_addr_ref_get_scale(addr_ref));
323   }
```

:

A.7.10 src/aia/aia_operand.h

```
#ifndef AIA_OPERAND_H
#define AIA_OPERAND_H

#include <std_include.h>
#include <str.h>

/* Aia operand allocators are located in aia.h. */

typedef struct Aia_Operand Aia_Operand;

typedef struct Aia_Block Aia_Block;

typedef struct Aia Aia;

typedef struct Aia_Operand_Label {
   String label_name;
   Int offset;
} Aia_Operand_Label;

typedef struct Aia_Operand_Addr_Ref {
   Aia_Operand *label;
   Aia_Operand *disp;
   Aia_Operand *base;
   Aia_Operand *index;
   Aia_Operand *scale;
} Aia_Operand_Addr_Ref;

typedef struct Aia_Operand_Local_Ref {
   String var_name; // Unique variable name.
   // uint8_t var_size; // AIA_BYTE or AIA_LONG.
} Aia_Operand_Local_Ref;

typedef struct Aia_Operand_Display_Ref {
   Aia_Operand *display_reg; // Register with function display.
   String var_name;     // Unique variable name.
   String func_name;    // Unique function name.
   //uint8_t var_size;   // AIA_BYTE or AIA_LONG.
} Aia_Operand_Display_Ref;

typedef union Aia_Operand_Iden {
   String op_name;
   int32_t int_const;
   Aia_Operand_Addr_Ref *addr_ref;
   Aia_Operand_Local_Ref *local_ref;
   Aia_Operand_Display_Ref *display_ref;
   Aia_Operand_Label *op_label;
   Aia_Block *op_block;
} Aia_Operand_Iden;

typedef enum Aia_Operand_Type {
   AIA_OPERAND_REG,     // %reg
   AIA_OPERAND_LABEL,   // label[+displacement]
   AIA_OPERAND_LABEL_ADDR,  // $label[+displacement]
   AIA_OPERAND_CONST_INT,  // 42
   AIA_OPERAND_CONST_STRING, // "my-string"
   AIA_OPERAND_ADDR_REF,  // lbl+4(%1,%2,4)
   AIA_OPERAND_LOCAL_REF,  // local function variable or parameter
   AIA_OPERAND_ARG,     // argument to function call
   AIA_OPERAND_DISPLAY_REF, // reference to function display
   AIA_OPERAND_BLOCK    // Reference to an Aia_Block
} Aia_Operand_Type;

struct Aia_Operand {
   Aia_Operand_Iden iden;
   Aia_Operand_Type op_type;
   Uns ref_count;
};

static inline Aia_Operand_Type aia_operand_get_type(Aia_Operand *op)
{
   return op->op_type;
```

```
72  }
73
74  static inline bool aia_operand_is_dest(Aia_Operand *op)
75  {
76     switch (aia_operand_get_type(op)) {
77     case AIA_OPERAND_REG:
78     case AIA_OPERAND_LABEL:
79     case AIA_OPERAND_LOCAL_REF:
80     case AIA_OPERAND_ARG:
81     case AIA_OPERAND_DISPLAY_REF:
82     case AIA_OPERAND_ADDR_REF:
83        return true;
84     default:
85        return false;
86     }
87  }
88
89  static inline bool aia_operand_is_mem(Aia_Operand *op)
90  {
91     switch (aia_operand_get_type(op)) {
92     case AIA_OPERAND_LABEL:
93     case AIA_OPERAND_LOCAL_REF:
94     case AIA_OPERAND_ARG:
95     case AIA_OPERAND_DISPLAY_REF:
96     case AIA_OPERAND_ADDR_REF:
97        return true;
98     default:
99        return false;
100    }
101 }
102
103 static inline bool aia_operand_is_reg(Aia_Operand *op)
104 {
105    switch (aia_operand_get_type(op)) {
106    case AIA_OPERAND_REG:
107       return true;
108    default:
109       return false;
110    }
111 }
112
113 static inline bool aia_operand_is_integer(Aia_Operand *op)
114 {
115    switch (aia_operand_get_type(op)) {
116    case AIA_OPERAND_CONST_INT:
117    case AIA_OPERAND_LABEL_ADDR:
118       return true;
119    default:
120       return false;
121    }
122 }
123
124 bool aia_operands_equal(Aia_Operand *lhs, Aia_Operand *rhs);
125
126 void ___aia_operand_destroy(Aia_Operand *op);
127
128 static inline void ___aia_operand_release(Aia_Operand *op)
129 {
130    if (op && !--op->ref_count)
131       ___aia_operand_destroy(op);
132 }
133
134 static inline void ___aia_operand_acquire(Aia_Operand *op)
135 {
136    assert(op);
137    ++op->ref_count;
138 }
139
140 static inline Const_String aia_operand_local_ref_get_var_name(Aia_Operand *op)
141 {
142    assert(op->op_type == AIA_OPERAND_LOCAL_REF);
143    return op->iden.local_ref->var_name;
144 }
145
```

```
146 static inline int32_t aia_operand_arg_get_idx(Aia_Operand *op)
147 {
148    assert(op->op_type == AIA_OPERAND_ARG);
149    return op->iden.int_const;
150 }
151
152 #if 0
153 static inline uint8_t aia_operand_local_ref_get_var_size(Aia_Operand *op)
154 {
155    assert(op->op_type == AIA_OPERAND_LOCAL_REF);
156    return op->iden.local_ref->var_size;
157 }
158 #endif
159
160 static inline Const_String aia_operand_display_ref_get_func_name(Aia_Operand *op)
161 {
162    assert(op->op_type == AIA_OPERAND_DISPLAY_REF);
163    return op->iden.display_ref->func_name;
164 }
165
166 static inline Const_String aia_operand_display_ref_get_var_name(Aia_Operand *op)
167 {
168    assert(op->op_type == AIA_OPERAND_DISPLAY_REF);
169    return op->iden.display_ref->var_name;
170 }
171
172 static inline Aia_Operand *aia_operand_display_ref_get_display_reg(
173       Aia_Operand *op)
174 {
175    assert(op->op_type == AIA_OPERAND_DISPLAY_REF);
176    return op->iden.display_ref->display_reg;
177 }
178
179 Aia_Operand *aia_operand_display_ref_with_replaced_reg(Aia *aia,
180       Aia_Operand *disp_ref, Aia_Operand *new_reg);
181
182 #if 0
183 static inline uint8_t aia_operand_display_ref_get_var_size(Aia_Operand *op)
184 {
185    assert(op->op_type == AIA_OPERAND_DISPLAY_REF);
186    return op->iden.display_ref->var_size;
187 }
188 #endif
189
190 static inline Aia_Block *aia_operand_block_get_block(Aia_Operand *op)
191 {
192    assert(op->op_type == AIA_OPERAND_BLOCK);
193    return op->iden.op_block;
194 }
195
196 static inline Const_String aia_operand_const_string_get_val(Aia_Operand *op)
197 {
198    assert(op->op_type == AIA_OPERAND_CONST_STRING);
199    return op->iden.op_name;
200 }
201
202 static inline Const_String aia_operand_reg_get_name(Aia_Operand *op)
203 {
204    assert(op->op_type == AIA_OPERAND_REG);
205    return op->iden.op_name;
206 }
207
208 static inline int32_t aia_operand_const_int_get_val(Aia_Operand *op)
209 {
210    assert(op->op_type == AIA_OPERAND_CONST_INT);
211    return op->iden.int_const;
212 }
213
214 static inline Aia_Operand *aia_operand_addr_ref_get_label(Aia_Operand *op)
215 {
216    assert(aia_operand_get_type(op) == AIA_OPERAND_ADDR_REF);
217    return op->iden.addr_ref->label;
218 }
219
```

```
220 static inline Aia_Operand *aia_operand_addr_ref_get_disp(Aia_Operand *op)
221 {
222    assert(aia_operand_get_type(op) == AIA_OPERAND_ADDR_REF);
223    return op->iden.addr_ref->disp;
224 }
225
226 static inline Aia_Operand *aia_operand_addr_ref_get_base(Aia_Operand *op)
227 {
228    assert(aia_operand_get_type(op) == AIA_OPERAND_ADDR_REF);
229    return op->iden.addr_ref->base;
230 }
231
232 static inline Aia_Operand *aia_operand_addr_ref_get_index(Aia_Operand *op)
233 {
234    assert(aia_operand_get_type(op) == AIA_OPERAND_ADDR_REF);
235    return op->iden.addr_ref->index;
236 }
237
238 static inline Aia_Operand *aia_operand_addr_ref_get_scale(Aia_Operand *op)
239 {
240    assert(aia_operand_get_type(op) == AIA_OPERAND_ADDR_REF);
241    return op->iden.addr_ref->scale;
242 }
243
244 Aia_Operand *aia_operand_addr_ref_with_replaced_index(Aia *aia,
245       Aia_Operand *addr_ref, Aia_Operand *new_op);
246
247 Aia_Operand *aia_operand_addr_ref_with_replaced_base(Aia *aia,
248       Aia_Operand *addr_ref, Aia_Operand *new_op);
249
250 static inline Const_String aia_operand_label_get_name(Aia_Operand *lblop)
251 {
252    assert(lblop->op_type == AIA_OPERAND_LABEL || lblop->op_type ==
253          AIA_OPERAND_LABEL_ADDR);
254    return lblop->iden.op_label->label_name;
255 }
256
257 static inline Int aia_operand_label_get_offset(Aia_Operand *lblop)
258 {
259    assert(lblop->op_type == AIA_OPERAND_LABEL || lblop->op_type ==
260          AIA_OPERAND_LABEL_ADDR);
261    return lblop->iden.op_label->offset;
262 }
263
264 void aia_operand_dump_size(FILE *stream, uint8_t type);
265
266 void aia_operand_dump(FILE *stream, Aia_Operand *op,
267       bool print_int_dollar);
268
269 static inline Uns aia_operand_hash_code(Aia_Operand *op);
270
271 static inline Uns aia_operand_reg_hash_code(Aia_Operand *op)
272 {
273    return string_hash_code(aia_operand_reg_get_name(op));
274 }
275
276 static inline Uns aia_operand_label_hash_code(Aia_Operand *op)
277 {
278    return string_hash_code(aia_operand_label_get_name(op));
279 }
280
281 static inline Uns aia_operand_const_int_hash_code(Aia_Operand *op)
282 {
283    return (Uns)aia_operand_const_int_get_val(op);
284 }
285
286 static inline Uns aia_operand_const_string_hash_code(Aia_Operand *op)
287 {
288    return string_hash_code(aia_operand_const_string_get_val(op));
289 }
290
291 static inline Uns aia_operand_addr_ref_hash_code(Aia_Operand *op)
292 {
293    Uns hash = 0;
```

```
294
295     inline void add_hash_code(Aia_Operand *ref_op)
296     {
297        if (ref_op)
298           hash += aia_operand_hash_code(ref_op);
299     }
300
301     add_hash_code(aia_operand_addr_ref_get_base(op));
302     add_hash_code(aia_operand_addr_ref_get_index(op));
303     add_hash_code(aia_operand_addr_ref_get_disp(op));
304     add_hash_code(aia_operand_addr_ref_get_label(op));
305     add_hash_code(aia_operand_addr_ref_get_scale(op));
306
307     return hash;
308  }
309
310  static inline Uns aia_operand_local_ref_hash_code(Aia_Operand *op)
311  {
312     return string_hash_code(aia_operand_local_ref_get_var_name(op));
313  }
314
315  static inline Uns aia_operand_arg_hash_code(Aia_Operand *op)
316  {
317     return aia_operand_arg_get_idx(op);
318  }
319
320  static inline Uns aia_operand_display_ref_hash_code(Aia_Operand *op)
321  {
322     return string_hash_code(aia_operand_display_ref_get_var_name(op)) +
323        string_hash_code(aia_operand_display_ref_get_func_name(op));
324  }
325
326  Uns aia_operand_block_hash_code(Aia_Operand *op);
327
328  static inline Uns aia_operand_hash_code(Aia_Operand *op)
329  {
330     switch (op->op_type) {
331     case AIA_OPERAND_REG:
332        return aia_operand_reg_hash_code(op);
333     case AIA_OPERAND_LABEL:
334        return aia_operand_label_hash_code(op);
335     case AIA_OPERAND_LABEL_ADDR:
336        return aia_operand_label_hash_code(op);
337     case AIA_OPERAND_CONST_INT:
338        return aia_operand_const_int_hash_code(op);
339     case AIA_OPERAND_CONST_STRING:
340        return aia_operand_const_string_hash_code(op);
341     case AIA_OPERAND_ADDR_REF:
342        return aia_operand_addr_ref_hash_code(op);
343     case AIA_OPERAND_LOCAL_REF:
344        return aia_operand_local_ref_hash_code(op);
345     case AIA_OPERAND_ARG:
346        return aia_operand_arg_hash_code(op);
347     case AIA_OPERAND_DISPLAY_REF:
348        return aia_operand_display_ref_hash_code(op);
349     case AIA_OPERAND_BLOCK:
350        return aia_operand_block_hash_code(op);
351     }
352     fatal_error(S("taking hash code of unexpected operand type. "
353              "Aborting...\n"));
354  }
355
356  #endif // AIA_OPERAND_H
```

:

A.7.11 src/aia/aia_operand_map.c

```
1  #include "aia_operand_map.h"
2
3  void aia_operand_entry_hash_destroy(Hash_Map_Slot *slot)
```

```
{
   aia_operand_entry_destroy(AIA_OPERAND_MAP_ENTRY_OF(slot));
}

bool aia_operand_map_compare(Aia_Operand *lookup, Hash_Map_Slot *search_slot)
{
   Aia_Operand_Map_Entry *e = AIA_OPERAND_MAP_ENTRY_OF(search_slot);
   return aia_operands_equal(e->operand, lookup);
}
```

:

A.7.12 src/aia/aia_operand_map.h

```
#ifndef AIA_OPERAND_MAP_H
#define AIA_OPERAND_MAP_H

#include "aia.h"
#include <hash_map.h>

typedef Hash_Map Aia_Operand_Map;

typedef struct Aia_Operand_Map_Entry {
   Aia_Operand *operand;
   Aia_Operand *value;
   Hash_Map_Slot hash_slot;
} Aia_Operand_Map_Entry;

#define AIA_OPERAND_MAP_ENTRY_OF(slot) \
   HASH_MAP_ENTRY(slot, Aia_Operand_Map_Entry, hash_slot)

bool aia_operand_map_compare(Aia_Operand *lookup, Hash_Map_Slot *search_slot);

static inline void aia_operand_entry_destroy(Aia_Operand_Map_Entry *e)
{
   ___aia_operand_release(e->operand);
   ___aia_operand_release(e->value);
   free_mem(e);
}

/* Use as dtor argument to AIA_OPERAND_MAP_INIT* see aia_operand_map.c */
void aia_operand_entry_hash_destroy(Hash_Map_Slot *slot);

#define AIA_OPERAND_MAP_INIT() \
   HASH_MAP_INIT((Hash_Map_Comparator) aia_operand_map_compare)

#define AIA_OPERAND_MAP_FOR_EACH_ENTRY(opmap, ent)      \
   for (Hash_Map_Slot *___s = NULL; !___s; ___s = INT_TO_PTR(1))  \
      HASH_MAP_FOR_EACH(opmap, ___s)                    \
         if ((ent = AIA_OPERAND_MAP_ENTRY_OF(___s)) || !ent)

static inline Aia_Operand_Map *aia_operand_map_alloc()
{
   Aia_Operand_Map *ret = ALLOC_NEW(Aia_Operand_Map);
   *ret = AIA_OPERAND_MAP_INIT();
   return ret;
}

static inline void aia_operand_map_insert(Aia_Operand_Map *map,
      Aia_Operand *op, Aia_Operand *value)
{
   Aia_Operand_Map_Entry *e = ALLOC_NEW(Aia_Operand_Map_Entry);
   ___aia_operand_acquire(op);
   ___aia_operand_acquire(value);
   e->operand = op;
   e->value = value;
   hash_map_insert(map, &e->hash_slot, aia_operand_hash_code(op));
}

static inline bool aia_operand_map_contains(Aia_Operand_Map *map,
      Aia_Operand *op)
```

```
58  {
59     return hash_map_contains(map, op, aia_operand_hash_code(op));
60  }
61
62  static inline Aia_Operand *aia_operand_map_get_value(Aia_Operand_Map *map,
63        Aia_Operand *op)
64  {
65     Hash_Map_Slot *slot = hash_map_get(map, op,
66           aia_operand_hash_code(op));
67     if (!slot)
68        return NULL;
69     Aia_Operand_Map_Entry *e = AIA_OPERAND_MAP_ENTRY_OF(slot);
70     return e->value;
71  }
72
73  static inline void aia_operand_map_for_each_destroy(Aia_Operand_Map *map)
74  {
75     hash_map_for_each_destroy(map, aia_operand_entry_hash_destroy);
76  }
77
78  static inline bool aia_operand_map_is_empty(Aia_Operand_Map *map)
79  {
80     return !hash_map_size(map);
81  }
82
83  static inline Aia_Operand_Map_Entry *___aia_operand_map_remove(
84        Aia_Operand_Map *map, Aia_Operand *op)
85  {
86     Hash_Map_Slot *slot = hash_map_remove(map, op,
87           aia_operand_hash_code(op));
88     if (!slot)
89        return NULL;
90     return AIA_OPERAND_MAP_ENTRY_OF(slot);
91  }
92
93  static inline bool aia_operand_map_remove(Aia_Operand_Map *map,
94        Aia_Operand *op)
95  {
96     Aia_Operand_Map_Entry *e = ___aia_operand_map_remove(map, op);
97     if (e) {
98        aia_operand_entry_destroy(e);
99        return true;
100    }
101    return false;
102 }
103
104 static inline void aia_operand_map_destroy(Aia_Operand_Map *map)
105 {
106    if (map) {
107       aia_operand_map_for_each_destroy(map);
108       free_mem(map);
109    }
110 }
111
112 #endif // AIA_OPERAND_MAP_H
```

:

A.7.13 src/aia/aia_operand_set.c

```
1  #include "aia_operand_set.h"
2
3  void aia_operand_set_entry_hash_destroy(Hash_Map_Slot *slot)
4  {
5     aia_operand_set_entry_destroy(AIA_OPERAND_SET_ENTRY_OF(slot));
6  }
7
8  bool aia_operand_set_compare(Aia_Operand *lookup, Hash_Map_Slot *search_slot)
9  {
10    Aia_Operand_Set_Entry *e = AIA_OPERAND_SET_ENTRY_OF(search_slot);
11    return aia_operands_equal(e->operand, lookup);
```

```
12 }
```

:

A.7.14 src/aia/aia_operand_set.h

```
1  #ifndef AIA_OPERAND_SET_H
2  #define AIA_OPERAND_SET_H
3
4  #include "aia.h"
5  #include <hash_map.h>
6
7  typedef Hash_Map Aia_Operand_Set;
8
9  typedef struct Aia_Operand_Set_Entry {
10    Aia_Operand *operand;
11    Hash_Map_Slot hash_slot;
12 } Aia_Operand_Set_Entry;
13
14 #define AIA_OPERAND_SET_ENTRY_OF(slot) \
15    HASH_MAP_ENTRY(slot, Aia_Operand_Set_Entry, hash_slot)
16
17 bool aia_operand_set_compare(Aia_Operand *lookup, Hash_Map_Slot *search_slot);
18
19 static inline void aia_operand_set_entry_destroy(Aia_Operand_Set_Entry *e)
20 {
21    ___aia_operand_release(e->operand);
22    free_mem(e);
23 }
24
25 void aia_operand_set_entry_hash_destroy(Hash_Map_Slot *slot);
26
27 #define AIA_OPERAND_SET_INIT() \
28    HASH_MAP_INIT((Hash_Map_Comparator) aia_operand_set_compare)
29
30 #define AIA_OPERAND_SET_FOR_EACH_OPERAND(opmap, op)      \
31    for (Hash_Map_Slot *___s = NULL; !___s; ___s = INT_TO_PTR(1))  \
32       HASH_MAP_FOR_EACH(opmap, ___s)                    \
33          if ((op = AIA_OPERAND_SET_ENTRY_OF(___s)->operand) || !op)
34
35 static inline Aia_Operand_Set *aia_operand_set_alloc()
36 {
37    Aia_Operand_Set *ret = ALLOC_NEW(Aia_Operand_Set);
38    *ret = AIA_OPERAND_SET_INIT();
39    return ret;
40 }
41
42 static inline bool aia_operand_set_insert(Aia_Operand_Set *set,
43       Aia_Operand *op)
44 {
45    Uns hash = aia_operand_hash_code(op);
46    if (hash_map_contains(set, op, hash))
47       return false;
48
49    Aia_Operand_Set_Entry *e = ALLOC_NEW(Aia_Operand_Set_Entry);
50    ___aia_operand_acquire(op);
51    e->operand = op;
52    hash_map_insert(set, &e->hash_slot, hash);
53    return true;
54 }
55
56 static inline bool aia_operand_set_contains(Aia_Operand_Set *set,
57       Aia_Operand *op)
58 {
59    return hash_map_contains(set, op, aia_operand_hash_code(op));
60 }
61
62 static inline void aia_operand_set_for_each_destroy(Aia_Operand_Set *set)
63 {
64    hash_map_for_each_destroy(set, aia_operand_set_entry_hash_destroy);
65 }
```

```
66
67  static inline bool aia_operand_set_is_empty(Aia_Operand_Set *set)
68  {
69     return !hash_map_size(set);
70  }
71
72  static inline Aia_Operand_Set_Entry *___aia_operand_set_remove(
73        Aia_Operand_Set *set, Aia_Operand *op)
74  {
75     Hash_Map_Slot *slot = hash_map_remove(set, op,
76           aia_operand_hash_code(op));
77     if (!slot)
78        return NULL;
79     return AIA_OPERAND_SET_ENTRY_OF(slot);
80  }
81
82  static inline bool aia_operand_set_remove(Aia_Operand_Set *set,
83        Aia_Operand *op)
84  {
85     Aia_Operand_Set_Entry *e = ___aia_operand_set_remove(set, op);
86     if (e) {
87        aia_operand_set_entry_destroy(e);
88        return true;
89     }
90     return false;
91  }
92
93  static inline void aia_operand_set_destroy(Aia_Operand_Set *set)
94  {
95     if (set) {
96        aia_operand_set_for_each_destroy(set);
97        free_mem(set);
98     }
99  }
100
101
102 #endif // AIA_OPERAND_SET_H
```

:

A.7.15 src/aia/aia_warn_undefined.c

```
1  #include "aia_warn_undefined.h"
2  #include "aia_instr_live_sets.h"
3  #include <main.h>
4
5  static inline bool aia_warn_undefined_is_param(Aia_Operand *op,
6        Aia_Func *func)
7  {
8     Vector *params = &func->parameters;
9     Const_String name = aia_operand_local_ref_get_var_name(op);
10    if (vector_contains(params, (Vector_Comparator)string_compare, name))
11       return true;
12    return false;
13 }
14
15 static void aia_warn_undefined_do(Aia_Operand *op, Aia_Func *func)
16 {
17    Const_String loc_name = aia_operand_local_ref_get_var_name(op);
18    report_warning_location(aia_func_get_location(func),
19          S("varibale " QFY("%S") " declared in function "
20             QFY("%S") " might be uninitialized before use\n"),
21          STRING_AFTER_DOT(loc_name),
22          STRING_AFTER_DOT(aia_func_get_name(func)));
23 }
24
25 static void aia_warn_undefined_local(Aia_Func *func)
26 {
27    Aia_Instr *in = ___aia_block_peek_first_instr(func->entry_block);
28    Aia_Operand *op;
29
```

```
30     AIA_INSTR_LIVE_SET_FOR_EACH_OP(in, op) {
31        if (aia_operand_get_type(op) == AIA_OPERAND_LOCAL_REF &&
32              !aia_warn_undefined_is_param(op, func))
33           aia_warn_undefined_do(op, func);
34     }
35  }
36
37  void aia_warn_undefined(Aia *aia)
38  {
39     if (!cmdopts.warn_uninitialized)
40        return;
41
42     aia_instr_live_sets(aia, NULL, true);
43
44     if (cmdopts.dump_warn_uninit_liveness_ic)
45        aia_instr_live_sets_dump(aia, S("warn-uninit-liveness-ic"));
46
47     Aia_Func *func;
48     AIA_FOR_EACH_FUNC(aia, func)
49        aia_warn_undefined_local(func);
50
51     aia_instr_live_sets_destroy(aia);
52  }
```

:

A.7.16 src/aia/aia_warn_undefined.h

```
1  #ifndef AIA_WARN_UNDEFINED_H
2  #define AIA_WARN_UNDEFINED_H
3
4  #include "aia.h"
5
6  void aia_warn_undefined(Aia *aia);
7
8  #endif // AIA_WARN_UNDEFINED_H
```

A.8 Optimization

:

A.8.1 src/aia/aia_block_elim.c

```
1  #include "aia_block_elim.h"
2  #include <main.h>
3
4  #undef DEBUG_TYPE
5  #define DEBUG_TYPE block-elim
6
7  #define BLOCK_DEAD INT_TO_PTR(0)
8  #define BLOCK_LIVE INT_TO_PTR(1)
9
10 static void aia_live_block_callback(Aia_Block *b, void *arg UNUSED)
11 {
12    DEBUG(
13       Aia_Instr *lbl = ___aia_block_peek_first_instr(b);
14       Aia_Operand *lbl_op = aia_instr_get_dest_op(lbl);
15       DLOG("live block: ");
16       aia_operand_dump(stderr, lbl_op, false);
17       DLOG("\n");
18    );
19    b->meta_data = BLOCK_LIVE;
20 }
21
22 static void aia_section_dead_blocks(Aia_Section *sec, Aia *aia)
```

```
23  {
24     VECTOR(dead_blocks);
25
26     inline void add_unused_block(Aia_Block *b)
27     {
28        if (b->meta_data == BLOCK_DEAD) {
29           vector_append(&dead_blocks, b);
30           DEBUG(
31              Aia_Instr *lbl = ___aia_block_peek_first_instr(b);
32              Aia_Operand *lbl_op = aia_instr_get_dest_op(lbl);
33              DLOG("dead block: ");
34              aia_operand_dump(stderr, lbl_op, false);
35              DLOG("\n");
36           );
37        }
38     }
39
40     inline void remove_dead_blocks(Aia_Block *entry_b, Aia_Block *exit_b)
41     {
42        Aia_Block *b;
43        VECTOR_FOR_EACH_ENTRY(&dead_blocks, b) {
44           if (b != entry_b && b != exit_b) {
45              aia_block_remove_from_predecessors(b);
46              aia->meta_data = INT_TO_PTR(true);
47           }
48        }
49
50        VECTOR_FOR_EACH_ENTRY(&dead_blocks, b) {
51           if (b != entry_b && b != exit_b)
52              aia_block_blist_remove_destroy(b);
53        }
54        vector_clear(&dead_blocks);
55     }
56
57     Aia_Block *b;
58     AIA_SECTION_FOR_EACH_BLOCK(sec, b)
59        b->meta_data = BLOCK_DEAD;
60
61     aia_section_for_each_block_depth(sec, aia_live_block_callback, aia);
62
63     AIA_SECTION_FOR_EACH_BLOCK(sec, b)
64        add_unused_block(b);
65
66     remove_dead_blocks(sec->exit_block, sec->exit_block);
67
68     Aia_Func *func;
69     AIA_SECTION_FOR_EACH_FUNC(sec, func) {
70        AIA_FUNC_FOR_EACH_BLOCK(func, b) {
71           b->meta_data = BLOCK_DEAD;
72           DEBUG(
73              Aia_Instr *lbl = ___aia_block_peek_first_instr(b);
74              Aia_Operand *lbl_op = aia_instr_get_dest_op(lbl);
75              DLOG("existing block: ");
76              aia_operand_dump(stderr, lbl_op, false);
77              DLOG("\n");
78           );
79        }
80
81        aia_func_for_each_block_depth(func, aia_live_block_callback, aia);
82
83        AIA_FUNC_FOR_EACH_BLOCK(func, b) {
84           add_unused_block(b);
85           DEBUG(
86              Aia_Instr *lbl = ___aia_block_peek_first_instr(b);
87              Aia_Operand *lbl_op = aia_instr_get_dest_op(lbl);
88              DLOG("2 existing block: ");
89              aia_operand_dump(stderr, lbl_op, false);
90              DLOG("\n");
91           );
92        }
93        remove_dead_blocks(func->exit_block, func->exit_block);
94     }
95
96  }
```

```
97
98  static void aia_elim_dead_blocks(Aia *aia)
99  {
100    Aia_Section *sec;
101    AIA_FOR_EACH_SECTION(aia, sec)
102       aia_section_dead_blocks(sec, aia);
103 }
104
105 static UNUSED void aia_block_elim_dump(Aia *aia, Const_String post)
106 {
107    String fname = string_from_format(S("%S.vitaly.block-elim-ic-%S"),
108          aia_get_file_name(aia), post);
109    FILE *f = file_open(fname, S("w"));
110    if (!f)
111       fatal_error(S("cannot open file " QFY("%S")
112                 " for code elimination dump [%m]\n"),
113             fname);
114    string_destroy(fname);
115
116    aia_dump(aia, f);
117    file_close(f);
118 }
119
120 bool aia_block_elim(Aia *aia)
121 {
122    bool ret = false;
123
124    do {
125       aia->meta_data = NULL;
126       aia_elim_dead_blocks(aia);
127       if (aia->meta_data)
128          ret = true;
129    } while (aia->meta_data);
130
131    return ret;
132 }
```

:

A.8.2 src/aia/aia_block_elim.h

```
1  #ifndef AIA_BLOCK_ELIM_H
2  #define AIA_BLOCK_ELIM_H
3
4  #include "aia.h"
5
6  bool aia_block_elim(Aia *aia);
7
8  #endif // AIA_BLOCK_ELIM_H
```

:

A.8.3 src/aia/aia_const_prop.c

```
1  #include "aia_const_prop.h"
2  #include "aia_block_elim.h"
3  #include "aia_func_kills.h"
4  #include <main.h>
5
6  #undef DEBUG_TYPE
7  #define DEBUG_TYPE const-prop
8
9  static void const_opentry_insert(Aia_Const_Prop_Bmeta *bmeta,
10       Aia_Operand *op, Aia_Operand *value)
11 {
12    Aia_Operand_Map *map = &bmeta->const_ops;
13    aia_operand_map_insert(map, op, value);
```

```
14 }
15
16 static Aia_Operand *const_opentry_lookup_val(Aia_Const_Prop_Bmeta *bmeta,
17       Aia_Operand *op)
18 {
19    if (aia_operand_get_type(op) == AIA_OPERAND_CONST_INT)
20       return op;
21
22    Aia_Operand_Map *map = &bmeta->const_ops;
23
24    return aia_operand_map_get_value(map, op);
25 }
26
27 static void const_opentry_remove(Aia_Const_Prop_Bmeta *bmeta, Aia_Operand *op)
28 {
29    if (!op)
30       return;
31
32    Aia_Operand_Map *map = &bmeta->const_ops;
33    aia_operand_map_remove(map, op);
34 }
35
36 static void aia_const_prop_remove_instr(Aia_Instr *in,
37       Aia_Const_Prop_Bmeta *bmeta)
38 {
39    aia_instr_remove(in);
40    vector_append(&bmeta->removed_instrs, in);
41 }
42
43 static void aia_const_prop_mov(Aia_Instr *in,
44       Aia_Const_Prop_Bmeta *bmeta, Aia_Const_Prop_Ameta *ameta)
45 {
46    Aia_Operand *dest = aia_instr_get_dest_op(in);
47    Aia_Operand *src = aia_instr_get_src_op(in, 0);
48    Aia_Operand *val = const_opentry_lookup_val(bmeta, src);
49    if (val) {
50       DEBUG(
51          DLOGT(def, "value: ");
52          aia_operand_dump(stderr, val, false);
53          DLOGT(def, "\n");
54       );
55
56       Aia_Operand *dest_val = const_opentry_lookup_val(bmeta, dest);
57       const_opentry_remove(bmeta, dest);
58       if (dest_val && aia_operands_equal(dest_val, val)) {
59          switch (aia_operand_get_type(dest)) {
60          case AIA_OPERAND_ARG:
61             break;
62
63          default:
64             aia_const_prop_remove_instr(in, bmeta);
65             return;
66          }
67       }
68       assert(!aia_operand_map_contains(&bmeta->const_ops, dest));
69       DEBUG(
70          DLOGT(def, "new dest: ");
71          aia_operand_dump(stderr, dest, false);
72          DLOGT(def, "\n");
73       );
74       const_opentry_insert(bmeta, dest, val);
75
76       if (aia_operand_get_type(src) != AIA_OPERAND_CONST_INT) {
77          aia_type_mov_before(aia_instr_get_type(in), val, dest, in,
78                aia_instr_get_src_ops_size(in),
79                aia_instr_get_dest_op_size(in));
80          aia_const_prop_remove_instr(in, bmeta);
81          ameta->any_update = true;
82       }
83
84    } else {
85       const_opentry_remove(bmeta, dest);
86    }
87 }
```

```
88
89  static void aia_const_prop_2op_arith(Aia_Instr *in, Aia *aia,
90        Aia_Const_Prop_Bmeta *bmeta, Aia_Const_Prop_Ameta *ameta)
91  {
92     Aia_Operand *src = aia_instr_get_src_op(in, 0);
93     Aia_Operand *lhs = const_opentry_lookup_val(bmeta, src);
94
95     if (lhs) {
96        Aia_Operand *src_val = const_opentry_lookup_val(bmeta, src);
97        if (src_val && aia_operands_equal(lhs, src_val))
98           aia_instr_replace_op(in, 0, src_val);
99     }
100
101    src = aia_instr_get_src_op(in, 1);
102    Aia_Operand *rhs = const_opentry_lookup_val(bmeta, src);
103
104    if (rhs) {
105       Aia_Operand *src_val = const_opentry_lookup_val(bmeta, src);
106       if (src_val && aia_operands_equal(rhs, src_val))
107          aia_instr_replace_op(in, 1, src_val);
108    }
109
110    if (!rhs || !lhs)
111       return;
112
113    int32_t lhs_val = aia_operand_const_int_get_val(lhs);
114    int32_t rhs_val = aia_operand_const_int_get_val(rhs);
115    int32_t result;
116    switch (aia_instr_get_type(in)) {
117    case AIA_ADD:
118       result = lhs_val + rhs_val;
119       break;
120    case AIA_SUB:
121       result = lhs_val - rhs_val;
122       break;
123    case AIA_IMUL:
124       result = lhs_val * rhs_val;
125       break;
126    case AIA_IDIV:
127       if (rhs_val == 0) {
128          File_Location *loc = aia_instr_get_location(in);
129          if (cmdopts.warn_div_zero && !is_warning_reported_here(loc))
130             report_warning_location(loc, S("division by zero\n"));
131          return;
132       }
133       result = lhs_val / rhs_val;
134       break;
135
136    default:
137       assert(false);
138       return;
139    }
140
141    Aia_Operand *res_op = aia_operand_const_int_alloc(aia, result);
142    Aia_Operand *dest = aia_instr_get_dest_op(in);
143    aia_mov_before(res_op, dest, in, aia_instr_get_dest_op_size(in));
144
145    const_opentry_insert(bmeta, dest, res_op);
146    aia_const_prop_remove_instr(in, bmeta);
147    ameta->any_update = true;
148 }
149
150 static void aia_const_prop_cmp(Aia_Instr *in, Aia_Const_Prop_Bmeta *bmeta,
151       Aia_Const_Prop_Ameta *ameta)
152 {
153    Aia_Cmp_Result res = AIA_CMP_NONE;
154
155    Aia_Operand *lhs = const_opentry_lookup_val(bmeta,
156          aia_instr_get_src_op(in, 0));
157    if (!lhs)
158       goto out;
159    aia_instr_replace_op(in, 0, lhs);
160
161    Aia_Operand *rhs = const_opentry_lookup_val(bmeta,
```

```
162             aia_instr_get_src_op(in, 1));
163       if (!rhs)
164          goto out;
165       aia_instr_replace_op(in, 1, rhs);
166
167       int32_t lhs_val = aia_operand_const_int_get_val(lhs);
168       int32_t rhs_val = aia_operand_const_int_get_val(rhs);
169
170       if (lhs_val < rhs_val)
171          res = AIA_CMP_LESS;
172       else if (lhs_val > rhs_val)
173          res = AIA_CMP_GREAT;
174       else
175          res = AIA_CMP_EQUAL;
176
177       aia_instr_remove(in);
178       vector_append(&bmeta->removed_instrs, in);
179
180    out:
181       ameta->prev_cmp_result = res;
182    }
183
184    static void aia_const_prop_cond_jump(Aia_Instr *in,
185          Aia_Const_Prop_Bmeta *bmeta, Aia_Const_Prop_Ameta *ameta)
186    {
187       if (ameta->prev_cmp_result == AIA_CMP_NONE ||
188             ameta->prev_cmp_result == AIA_CMP_UNKNOWN)
189          return;
190
191       Aia_Block *b_in = aia_instr_get_block(in);
192
193       Aia_Instr *jmp_in = aia_instr_alloc_1op(AIA_JMP, b_in, -1, AIA_LONG,
194             aia_instr_get_location(in));
195
196       switch (aia_instr_get_type(in)) {
197       case AIA_JG:
198          if (ameta->prev_cmp_result == AIA_CMP_GREAT)
199             aia_instr_set_src_op(jmp_in, 0, aia_instr_get_src_op(in, 0));
200          else
201             aia_instr_set_src_op(jmp_in, 0, aia_instr_get_src_op(in, 1));
202          break;
203
204       case AIA_JLE:
205          if (ameta->prev_cmp_result == AIA_CMP_GREAT)
206             aia_instr_set_src_op(jmp_in, 0, aia_instr_get_src_op(in, 1));
207          else
208             aia_instr_set_src_op(jmp_in, 0, aia_instr_get_src_op(in, 0));
209          break;
210
211       case AIA_JL:
212          if (ameta->prev_cmp_result == AIA_CMP_LESS)
213             aia_instr_set_src_op(jmp_in, 0, aia_instr_get_src_op(in, 0));
214          else
215             aia_instr_set_src_op(jmp_in, 0, aia_instr_get_src_op(in, 1));
216          break;
217
218       case AIA_JGE:
219          if (ameta->prev_cmp_result == AIA_CMP_LESS)
220             aia_instr_set_src_op(jmp_in, 0, aia_instr_get_src_op(in, 1));
221          else
222             aia_instr_set_src_op(jmp_in, 0, aia_instr_get_src_op(in, 0));
223          break;
224
225       case AIA_JE:
226          if (ameta->prev_cmp_result == AIA_CMP_EQUAL)
227             aia_instr_set_src_op(jmp_in, 0, aia_instr_get_src_op(in, 0));
228          else
229             aia_instr_set_src_op(jmp_in, 0, aia_instr_get_src_op(in, 1));
230          break;
231
232       case AIA_JNE:
233          if (ameta->prev_cmp_result == AIA_CMP_EQUAL)
234             aia_instr_set_src_op(jmp_in, 0, aia_instr_get_src_op(in, 1));
235          else
```

```
236             aia_instr_set_src_op(jmp_in, 0, aia_instr_get_src_op(in, 0));
237          break;
238
239       default:
240          assert(false);
241       }
242
243       aia_instr_cond_jump_to_jmp(in, jmp_in, aia_instr_get_src_op(jmp_in, 0));
244       vector_append(&bmeta->removed_instrs, in);
245
246       ameta->any_update = true;
247    }
248
249    static void aia_const_prop_set(Aia_Instr *in, Aia *aia,
250          Aia_Const_Prop_Bmeta *bmeta, Aia_Const_Prop_Ameta *ameta)
251    {
252       if (ameta->prev_cmp_result == AIA_CMP_NONE ||
253             ameta->prev_cmp_result == AIA_CMP_UNKNOWN)
254          return;
255
256       int32_t result;
257
258       switch (aia_instr_get_type(in)) {
259       case AIA_SETL:
260          if (ameta->prev_cmp_result == AIA_CMP_LESS)
261             result = 1;
262          else
263             result = 0;
264          break;
265
266       case AIA_SETGE:
267          if (ameta->prev_cmp_result == AIA_CMP_LESS)
268             result = 0;
269          else
270             result = 1;
271          break;
272
273       case AIA_SETG:
274          if (ameta->prev_cmp_result == AIA_CMP_GREAT)
275             result = 1;
276          else
277             result = 0;
278          break;
279
280       case AIA_SETLE:
281          if (ameta->prev_cmp_result == AIA_CMP_GREAT)
282             result = 0;
283          else
284             result = 1;
285          break;
286
287       case AIA_SETE:
288          if (ameta->prev_cmp_result == AIA_CMP_EQUAL)
289             result = 1;
290          else
291             result = 0;
292          break;
293
294       case AIA_SETNE:
295          if (ameta->prev_cmp_result == AIA_CMP_EQUAL)
296             result = 0;
297          else
298             result = 1;
299          break;
300
301       default:
302          assert(false);
303       }
304
305       Aia_Operand *const_in = aia_operand_const_int_alloc(aia, result);
306       aia_mov_before(const_in, aia_instr_get_dest_op(in), in, AIA_BYTE);
307
308       aia_instr_remove(in);
309       vector_append(&bmeta->removed_instrs, in);
```

```
310
311      ameta->any_update = true;
312   }
313
314   static void aia_const_prop_ret(Aia_Instr *in, Aia_Const_Prop_Bmeta *bmeta)
315   {
316      if (!aia_instr_get_src_op_count(in))
317         return;
318
319      Aia_Operand *src = aia_instr_get_src_op(in, 0);
320      if (aia_operand_get_type(src) == AIA_OPERAND_CONST_INT)
321         return;
322
323      Aia_Operand *val = const_opentry_lookup_val(bmeta, src);
324      if (!val)
325         return;
326
327      aia_instr_replace_op(in, 0, val);
328      /* No need to set aia->meta_data->any_update */
329   }
330
331   static void aia_const_prop_neg(Aia_Instr *in, Aia *aia,
332         Aia_Const_Prop_Bmeta *bmeta, Aia_Const_Prop_Ameta *ameta)
333   {
334      Aia_Operand *val = const_opentry_lookup_val(bmeta,
335            aia_instr_get_src_op(in, 0));
336      if (!val)
337         return;
338
339      Aia_Operand *new_val = aia_operand_const_int_alloc(aia,
340            -aia_operand_const_int_get_val(val));
341      Aia_Operand *dest = aia_instr_get_dest_op(in);
342
343      aia_mov_before(new_val, dest, in, aia_instr_get_dest_op_size(in));
344
345      aia_instr_remove(in);
346      vector_append(&bmeta->removed_instrs, in);
347
348      ameta->any_update = true;
349   }
350
351   static void aia_const_prop_call(Aia_Instr *in, Aia *aia,
352         Aia_Const_Prop_Bmeta *bmeta)
353   {
354      Const_String fname;
355      Aia_Func *curr_func = ___aia_get_curr_func(aia);
356      Aia_Func *func = NULL;
357
358      VECTOR(delete_ops);
359
360      Aia_Operand *lbl_op = aia_instr_get_src_op(in, 0);
361      if (aia_operand_get_type(lbl_op) == AIA_OPERAND_LABEL) {
362         fname = aia_operand_label_get_name(lbl_op);
363         func = aia_func_lookup(aia, fname);
364      }
365
366      bool kills_global = false;
367
368      if (func) {
369         Func_Kill_Operand fkill_op = FUNC_KILL_OPERAND_INIT(
370               curr_func ? aia_func_get_name(curr_func) : NULL);
371
372         Const_String tmp_func_name = aia_func_get_name(func);
373         if (hash_map_contains(&aia->default_funcs, (String)tmp_func_name,
374                  string_hash_code(tmp_func_name)))
375            return;
376
377         Aia_Func_Kill_Meta *fmeta = func->func_kills_struct;
378         Hash_Map *fmap = &fmeta->func_kills;
379
380         Hash_Map_Slot *slot;
381         HASH_MAP_FOR_EACH(&bmeta->const_ops, slot) {
382            Aia_Operand_Map_Entry *e = AIA_OPERAND_MAP_ENTRY_OF(slot);
383            func_kill_operand_set_operand(&fkill_op, e->operand);
```

```
384            if (!cmdopts.opt_func_access) {
385               if (aia_func_is_nested(func))
386                  vector_append(&delete_ops, e->operand);
387            } else if (___func_kill_contains(fmap, &fkill_op)) {
388               vector_append(&delete_ops, e->operand);
389            }
390         }
391
392         if (cmdopts.opt_func_access)
393            kills_global = fmeta->kills_global;
394         else
395            kills_global = true;
396      } else {
397         // All global variables are killed. No local variables are killed.
398         kills_global = true;
399      }
400
401      if (kills_global) {
402         Hash_Map_Slot *slot;
403         HASH_MAP_FOR_EACH(&bmeta->const_ops, slot) {
404            Aia_Operand_Map_Entry *e = AIA_OPERAND_MAP_ENTRY_OF(slot);
405            if (aia_operand_get_type(e->operand) == AIA_OPERAND_LABEL)
406               vector_append(&delete_ops, e->operand);
407         }
408      }
409
410      Aia_Operand *op;
411      VECTOR_FOR_EACH_ENTRY(&delete_ops, op)
412         const_opentry_remove(bmeta, op);
413      vector_clear(&delete_ops);
414   }
415
416   void aia_const_prop_instr(Aia_Instr *in, Aia *aia,
417         Aia_Const_Prop_Bmeta *bmeta, Aia_Const_Prop_Ameta *ameta)
418   {
419      switch (aia_instr_get_type(in)) {
420      case AIA_MOV:
421         /* Fall through. */
422      case AIA_MOVZ:
423         /* Fall through. */
424      case AIA_MOVS:
425         aia_const_prop_mov(in, bmeta, ameta);
426         //ameta->prev_cmp_result = AIA_CMP_NONE;
427         break;
428
429      case AIA_ADD:
430         /* Fall through. */
431      case AIA_SUB:
432         /* Fall through. */
433      case AIA_IMUL:
434         /* Fall through. */
435      case AIA_IDIV:
436         const_opentry_remove(bmeta, aia_instr_get_dest_op(in));
437         aia_const_prop_2op_arith(in, aia, bmeta, ameta);
438         ameta->prev_cmp_result = AIA_CMP_NONE;
439         break;
440
441      case AIA_CMP:
442         aia_const_prop_cmp(in, bmeta, ameta);
443         break;
444
445      AIA_CASE_COND_JUMP:
446         aia_const_prop_cond_jump(in, bmeta, ameta);
447         //ameta->prev_cmp_result = AIA_CMP_NONE;
448         break;
449
450      case AIA_JMP:
451         break;
452
453      case AIA_SETE:
454         /* Fall through. */
455      case AIA_SETNE:
456         /* Fall through. */
457      case AIA_SETL:
```

```
458         /* Fall through. */
459      case AIA_SETG:
460         /* Fall through. */
461      case AIA_SETLE:
462         /* Fall through. */
463      case AIA_SETGE:
464         aia_const_prop_set(in, aia, bmeta, ameta);
465         //ameta->prev_cmp_result = AIA_CMP_NONE;
466         break;
467
468      case AIA_RET:
469         const_opentry_remove(bmeta, aia_instr_get_dest_op(in));
470         aia_const_prop_ret(in, bmeta);
471         ameta->prev_cmp_result = AIA_CMP_NONE;
472         break;
473      case AIA_CALL:
474         const_opentry_remove(bmeta, aia_instr_get_dest_op(in));
475         aia_const_prop_call(in, aia, bmeta);
476         ameta->prev_cmp_result = AIA_CMP_NONE;
477         break;
478      case AIA_NEG:
479         const_opentry_remove(bmeta, aia_instr_get_dest_op(in));
480         aia_const_prop_neg(in, aia, bmeta, ameta);
481         ameta->prev_cmp_result = AIA_CMP_NONE;
482         break;
483      case AIA_CDQ:
484         const_opentry_remove(bmeta, aia_instr_get_dest_op(in));
485         DLOGT(def, "cdq needs constant propagation implementation\n");
486         ameta->prev_cmp_result = AIA_CMP_NONE;
487         break;
488
489      case AIA_NOP:
490      case ___AIA_LABEL:
491      case ___AIA_STRING:
492      case ___AIA_INTEGER:
493         break;
494
495      default:
496         DLOGT(def, "unimplemented instruction for constant propagation\n");
497         break;
498      }
499   }
500
501   static void aia_block_meta_destroy(Aia_Block *b)
502   {
503      Aia_Const_Prop_Bmeta *bmeta = b->meta_data;
504      aia_operand_map_for_each_destroy(&bmeta->const_ops);
505      free_mem(bmeta);
506   }
507
508   static void aia_const_prop_get_pred_consts(Aia_Block *b)
509   {
510      Aia_Block *pred;
511
512      Uns num_preds = vector_size(&b->predecessors);
513      if (!num_preds)
514         return;
515
516      pred = vector_get(&b->predecessors, 0);
517      Aia_Const_Prop_Bmeta *pred_meta = pred->meta_data;
518
519      Hash_Map_Slot *slot;
520      HASH_MAP_FOR_EACH(&pred_meta->const_ops, slot) {
521         Aia_Operand_Map_Entry *e = AIA_OPERAND_MAP_ENTRY_OF(slot);
522
523         for (Uns i = 1; i < num_preds; i++) {
524            pred = vector_get(&b->predecessors, i);
525
526            Aia_Operand *tmp_val = const_opentry_lookup_val(pred->meta_data,
527                  e->operand);
528
529            if (!tmp_val)
530               goto skip_op;
531            if (!aia_operands_equal(tmp_val, e->value))
```

```
532             goto skip_op;
533         }
534
535         const_opentry_insert(b->meta_data, e->operand, e->value);
536     skip_op:;
537     }
538 }
539
540 static void ___aia_const_prop_block(Aia_Block *b, Aia *aia)
541 {
542     Aia_Const_Prop_Bmeta *bmeta = b->meta_data;
543
544     Aia_Instr *in;
545     AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
546         aia_const_prop_instr(in, aia, bmeta, aia->meta_data);
547
548     vector_for_each_destroy(&bmeta->removed_instrs,
549           (Vector_Destructor)aia_instr_destroy);
550 }
551
552 static void aia_const_prop_block(Aia_Block *b, Aia *aia)
553 {
554     Aia_Const_Prop_Bmeta *bmeta = b->meta_data;
555     aia_operand_map_for_each_destroy(&bmeta->const_ops);
556
557     aia_const_prop_get_pred_consts(b);
558     ___aia_const_prop_block(b, aia);
559 }
560
561 static void aia_const_prop_section_funcs(Aia_Section *sec, Aia *aia)
562 {
563     Aia_Func *func;
564     AIA_SECTION_FOR_EACH_FUNC(sec, func) {
565         ___aia_set_curr_func(aia, func);
566         Aia_Block *b;
567         AIA_FUNC_FOR_EACH_BLOCK(func, b)
568             aia_const_prop_block(b, aia);
569
570         Aia_Func_Trampoline *tramp;
571         AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
572             aia_const_prop_block(tramp->block, aia);
573     }
574 }
575
576 static void aia_const_prop_append_data_section(Aia_Section *dsec,
577       Aia_Const_Prop_Bmeta *bmeta)
578 {
579     if (!dsec)
580         return;
581
582     Aia_Block *b;
583     AIA_SECTION_FOR_EACH_BLOCK(dsec, b) {
584         Aia_Instr *prev = NULL;
585         Aia_Instr *curr;
586         AIA_BLOCK_FOR_EACH_INSTRUCTION(b, curr) {
587             if (aia_instr_get_type(curr) == ___AIA_INTEGER) {
588                 assert(aia_instr_get_type(prev) == ___AIA_LABEL);
589                 Aia_Operand *op = aia_instr_get_src_op(curr, 0);
590                 if (aia_operand_get_type(op) == AIA_OPERAND_CONST_INT) {
591                     Aia_Operand *lbl = aia_instr_get_dest_op(prev);
592                     const_opentry_insert(bmeta, lbl, op);
593                 }
594             }
595             prev = curr;
596         }
597     }
598 }
599
600 static void aia_const_prop_section(Aia_Section *sec, Aia *aia)
601 {
602     ___aia_set_curr_func(aia, NULL);
603
604     if (sec->sec_type == AIA_SECTION_INIT) {
605
```

```
606         Aia_Const_Prop_Bmeta *bmeta = sec->entry_block->meta_data;
607         aia_operand_map_for_each_destroy(&bmeta->const_ops);
608
609         aia_const_prop_append_data_section(
610               aia->sections[AIA_SECTION_DATA],
611               sec->entry_block->meta_data);
612
613         ___aia_const_prop_block(sec->entry_block, aia);
614
615         Double_List_Node *bnode;
616         DOUBLE_LIST_FOR_EACH_AFTER(&sec->sec_blist,
617               &sec->entry_block->blist_node, bnode)
618            aia_const_prop_block(AIA_BLOCK_OF_DBNODE(bnode), aia);
619      } else {
620         Double_List_Node *bnode;
621         DOUBLE_LIST_FOR_EACH(&sec->sec_blist, bnode)
622            aia_const_prop_block(AIA_BLOCK_OF_DBNODE(bnode), aia);
623      }
624
625      aia_const_prop_section_funcs(sec, aia);
626   }
627
628   static void aia_const_prop_dump(Aia *aia, Int it_count)
629   {
630      String fname = string_from_format(S("%S.vitaly.const-prop-ic-%D"),
631               aia_get_file_name(aia), it_count);
632
633      FILE *f = file_open(fname, S("w"));
634      if (!f)
635         fatal_error(S("cannot open file " QFY("%S")
636                  " for constant propagation dump [%m]\n"),
637               fname);
638      string_destroy(fname);
639
640      aia_dump(aia, f);
641      file_close(f);
642   }
643
644   static void aia_const_prop_init_blist(Double_List *blist)
645   {
646      Double_List_Node *bnode;
647      DOUBLE_LIST_FOR_EACH(blist, bnode) {
648         Aia_Block *b = AIA_BLOCK_OF_DBNODE(bnode);
649         b->meta_data = aia_const_prop_bmeta_alloc();
650      }
651   }
652
653   static void aia_const_prop_init(Aia *aia)
654   {
655      Aia_Section *sec;
656      AIA_FOR_EACH_SECTION(aia, sec)
657         aia_const_prop_init_blist(&sec->sec_blist);
658
659      Aia_Func *func;
660      AIA_FOR_EACH_FUNC(aia, func) {
661         aia_const_prop_init_blist(&func->blist);
662
663         Aia_Func_Trampoline *tramp;
664         AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
665            aia_const_prop_init_blist(&tramp->blist);
666      }
667   }
668
669   static void aia_const_prop_destroy_blist(Double_List *blist)
670   {
671      Double_List_Node *bnode;
672      DOUBLE_LIST_FOR_EACH(blist, bnode)
673         aia_block_meta_destroy(AIA_BLOCK_OF_DBNODE(bnode));
674   }
675
676   static void aia_const_prop_destroy(Aia *aia)
677   {
678      Aia_Section *sec;
679      AIA_FOR_EACH_SECTION(aia, sec)
```

```
680         aia_const_prop_destroy_blist(&sec->sec_blist);
681
682     Aia_Func *func;
683     AIA_FOR_EACH_FUNC(aia, func) {
684         aia_const_prop_destroy_blist(&func->blist);
685
686         Aia_Func_Trampoline *tramp;
687         AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
688             aia_const_prop_destroy_blist(&tramp->blist);
689     }
690 }
691
692 bool aia_const_prop(Aia *aia, Int it_count)
693 {
694     bool ret = false;
695
696     if (!cmdopts.opt_const_prop)
697         goto out;
698
699     aia_collect_func_kills(aia);
700
701     VECTOR(globals);
702
703     bool any_update = false;
704     for (;;) {
705         Aia_Const_Prop_Ameta ameta;
706         ameta.any_update = false;
707         ameta.prev_cmp_result = AIA_CMP_NONE;
708         aia->meta_data = &ameta;
709
710         aia_const_prop_init(aia);
711         for (;;) {
712             Aia_Section *sec;
713             AIA_FOR_EACH_SECTION(aia, sec)
714                 aia_const_prop_section(sec, aia);
715
716             if (ameta.any_update) {
717                 any_update = true;
718                 ameta.any_update = false;
719             } else {
720                 break;
721             }
722         }
723
724         if (any_update) {
725             aia_const_prop_destroy(aia);
726             aia_block_elim(aia);
727             ret = true;
728             any_update = false;
729         } else {
730             if (cmdopts.dump_const_prop_ic)
731                 aia_const_prop_dump(aia, it_count);
732             aia_const_prop_destroy(aia);
733             break;
734         }
735
736     }
737
738     vector_clear(&globals);
739     aia_destroy_func_kills(aia);
740
741 out:
742     return ret;
743 }
```

:

A.8.4 src/aia/aia_const_prop.h

```
1 #ifndef AIA_CONST_PROP_H
2 #define AIA_CONST_PROP_H
```

```
3
4   #include <std_include.h>
5   #include "aia.h"
6   #include "aia_operand_map.h"
7   #include "aia_operand_set.h"
8
9   typedef struct Aia_Const_Prop_Bmeta {
10     Aia_Operand_Map const_ops;
11     Vector removed_instrs;
12  } Aia_Const_Prop_Bmeta;
13
14  typedef struct Aia_Const_Prop_Ameta {
15     Aia_Cmp_Result prev_cmp_result;
16     bool any_update;
17  } Aia_Const_Prop_Ameta;
18
19  #define AIA_CONST_PROP_AMETA_INIT()    \
20  (Aia_Const_Prop_Ameta){           \
21     .any_update = false,           \
22     .prev_cmp_result = AIA_CMP_NONE    \
23  }
24
25  #define AIA_CONST_PROP_BMETA_INIT()    \
26  (Aia_Const_Prop_Bmeta){           \
27     .const_ops = AIA_OPERAND_MAP_INIT(), \
28     .removed_instrs = VECTOR_INIT()    \
29  }
30
31  static inline Aia_Const_Prop_Bmeta *aia_const_prop_bmeta_alloc()
32  {
33     Aia_Const_Prop_Bmeta *bmeta =
34        ALLOC_NEW(Aia_Const_Prop_Bmeta);
35     *bmeta = AIA_CONST_PROP_BMETA_INIT();
36     return bmeta;
37  }
38
39  /* Constant propagate instruction.
40   * Make sure to call ___aia_set_curr_func() first. */
41  void aia_const_prop_instr(Aia_Instr *in, Aia *aia,
42        Aia_Const_Prop_Bmeta *bmeta, Aia_Const_Prop_Ameta *ameta);
43
44  /* Constant propagation pass. */
45  bool aia_const_prop(Aia *aia, Int it_count);
46
47  #endif // AIA_CONST_PROP_H
```

:

A.8.5 src/aia/aia_def_to_use.c

```
1   #include "aia_def_to_use.h"
2   #include "aia_instr_live_sets.h"
3   #include "aia_operand_map.h"
4   #include "aia_func_kills.h"
5   #include "aia_func_access.h"
6   #include <main.h>
7
8   typedef struct Replacement_Entry {
9     Aia_Instr *new_suc;
10    Vector instrs;
11    Aia_Instr *in;
12    Hash_Map_Slot hash_slot;
13  } Replacement_Entry;
14
15  #define REPLACEMENT_ENTRY_OF(slot) \
16    HASH_MAP_ENTRY(slot, Replacement_Entry, hash_slot)
17
18  static void replacement_map_insert(Hash_Map *repl_map,
19        Aia_Instr *new_suc, Aia_Instr *in)
20  {
21    Replacement_Entry *e;
```

```
22     Uns hash = hash_map_aligned_ptr_hash(new_suc);
23     Hash_Map_Slot *slot = hash_map_get(repl_map, new_suc, hash);
24     if (slot) {
25        e = REPLACEMENT_ENTRY_OF(slot);
26        DEBUGT(def,
27           Aia_Instr *tmp;
28           VECTOR_FOR_EACH_ENTRY(&e->instrs, tmp)
29              assert(in != tmp);
30        );
31     } else {
32        e = ALLOC_NEW(Replacement_Entry);
33        e->instrs = VECTOR_INIT_SIZE(2);
34        e->new_suc = new_suc;
35        hash_map_insert(repl_map, &e->hash_slot, hash);
36     }
37     vector_append(&e->instrs, in);
38  }
39
40  static void replacement_entry_destroy(Hash_Map_Slot *slot)
41  {
42     Replacement_Entry *e = REPLACEMENT_ENTRY_OF(slot);
43     vector_clear(&e->instrs);
44     free_mem(e);
45  }
46
47  static bool replacement_entry_compare(Aia_Instr *in,
48        Hash_Map_Slot *slot)
49  {
50     Replacement_Entry *e = REPLACEMENT_ENTRY_OF(slot);
51     return e->new_suc == in;
52  }
53
54  static UNUSED Vector *replacement_map_get(Hash_Map *repl_map, Aia_Instr *in)
55  {
56     Uns hash = hash_map_aligned_ptr_hash(in);
57     Hash_Map_Slot *s = hash_map_get(repl_map, in, hash);
58     if (!s)
59        return NULL;
60     Replacement_Entry *e = REPLACEMENT_ENTRY_OF(s);
61     return &e->instrs;
62  }
63
64  static bool aia_def_to_use_operand_is_addressed(Aia_Operand *test_op,
65        Aia_Operand *use_op)
66  {
67     if (!test_op)
68        return false;
69
70     Aia_Operand *tmp;
71     switch (aia_operand_get_type(test_op)) {
72     case AIA_OPERAND_DISPLAY_REF:
73        tmp = aia_operand_display_ref_get_display_reg(test_op);
74        return aia_operands_equal(tmp, use_op);
75
76     case AIA_OPERAND_ADDR_REF:
77        tmp = aia_operand_addr_ref_get_base(test_op);
78        if (tmp && aia_operands_equal(tmp, use_op))
79           return true;
80        tmp = aia_operand_addr_ref_get_index(test_op);
81        if (tmp && aia_operands_equal(tmp, use_op))
82           return true;
83        break;
84
85     default:
86        break;
87     }
88
89     return false;
90  }
91
92  static bool aia_def_to_use_operand_uses(Aia_Operand *test_op,
93        Aia_Operand *use_op)
94  {
95     if (!test_op)
```

```
96          return false;
97       if (aia_operand_get_type(test_op) == AIA_OPERAND_REG)
98          return aia_operands_equal(test_op, use_op);
99       return aia_def_to_use_operand_is_addressed(test_op, use_op);
100   }
101
102   static Aia_Instr *aia_def_to_use_get_suc(Aia_Instr *in, Aia *aia)
103   {
104      assert(aia_instr_is_concrete(in));
105      Aia_Operand *dest = aia_instr_get_dest_op(in);
106      assert(dest);
107      assert(aia_operand_is_reg(dest));
108
109      Aia_Instr *ret = NULL;
110
111      Const_String caller = ___aia_get_curr_func_name(aia);
112
113      Aia_Operand *src;
114      Aia_Instr *suc = aia_instr_get_sucessor(in);
115      while (suc) {
116         Aia_Operand *tmp = aia_instr_get_dest_op(suc);
117         AIA_INSTR_FOR_EACH_SRC(in, src) {
118            if (tmp && aia_def_to_use_operand_uses(tmp, src))
119               goto out;
120         }
121         AIA_INSTR_FOR_EACH_OPERAND(suc, tmp) {
122            if (tmp && aia_def_to_use_operand_uses(tmp, dest))
123               goto out;
124         }
125
126         if (aia_instr_get_type(suc) == AIA_CALL) {
127            Const_String callee;
128            Aia_Operand *lbl_op = aia_instr_get_src_op(suc, 0);
129            if (aia_operand_get_type(lbl_op) == AIA_OPERAND_LABEL)
130               callee = aia_operand_label_get_name(lbl_op);
131            else
132               callee = NULL;
133            AIA_INSTR_FOR_EACH_SRC(in, src) {
134               if (func_kills_operand(callee, caller, src, aia))
135                  goto out;
136               if (aia_func_uses(callee, caller, src, aia))
137                  goto out;
138            }
139
140         }
141         suc = aia_instr_get_sucessor(suc);
142         ret = suc;
143      }
144
145   out:
146      return ret;
147   }
148
149   static Aia_Instr *aia_def_to_use_new_sucessor(Aia_Instr *in,
150         Aia_Operand_Map *map, Aia *aia)
151   {
152      switch (aia_instr_get_type(in)) {
153      AIA_CASE_INCONCRETE:
154         return NULL;
155      case AIA_CALL:
156         return NULL;
157      default:
158         break;
159      }
160
161      Aia_Operand *dest = aia_instr_get_dest_op(in);
162      if (!dest)
163         return NULL;
164
165      if (aia_operand_get_type(dest) != AIA_OPERAND_REG)
166         return NULL;
167
168      Aia_Instr *suc = aia_def_to_use_get_suc(in, aia);
169      if (!suc)
```

```
170         return NULL;
171
172      replacement_map_insert(map, suc, in);
173
174      return suc;
175   }
176
177   static void aia_def_to_use_block(Aia_Block *b, Aia *aia)
178   {
179      Hash_Map repl_map = HASH_MAP_INIT((Hash_Map_Comparator)
180            replacement_entry_compare);
181
182      Aia_Instr *in;
183      AIA_BLOCK_FOR_EACH_INSTRUCTION_REVERSED(b, in)
184         aia_def_to_use_new_sucessor(in, &repl_map, aia);
185
186      Hash_Map_Slot *slot;
187      HASH_MAP_FOR_EACH(&repl_map, slot) {
188         Replacement_Entry *e = REPLACEMENT_ENTRY_OF(slot);
189         VECTOR_FOR_EACH_ENTRY(&e->instrs, in) {
190            aia_instr_remove(in);
191            aia_instr_insert_before(in, e->new_suc);
192            if (!in->meta_data) {
193               aia->meta_data = INT_TO_PTR(true);
194               in->meta_data = INT_TO_PTR(true);
195            }
196         }
197      }
198
199      hash_map_for_each_destroy(&repl_map,
200            replacement_entry_destroy);
201   }
202
203   static inline void aia_def_to_use_dump(Aia *aia UNUSED, Int it_count)
204   {
205      String fname = string_from_format(S("def-to-use-ic-%D"),
206            it_count);
207      FILE *f = file_open(fname, S("w"));
208      if (!f)
209         fatal_error(S("cannot open file " QFY("%S")
210                  " for def to use dump [%m]\n"),
211               fname);
212      string_destroy(fname);
213
214      aia_dump(aia, f);
215      file_close(f);
216   }
217
218   static void aia_def_to_use_block_init(Aia_Block *b)
219   {
220      Aia_Instr *in;
221      AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
222         in->meta_data = INT_TO_PTR(false);
223   }
224
225   void aia_def_to_use(Aia *aia, Int it_count)
226   {
227      if (!cmdopts.opt_def_to_use)
228         return;
229
230      aia_collect_func_kills(aia);
231      aia_func_access(aia);
232
233      Aia_Block *b;
234      Aia_Section *sec;
235      AIA_FOR_EACH_SECTION(aia, sec) {
236         AIA_SECTION_FOR_EACH_BLOCK(sec, b)
237            aia_def_to_use_block_init(b);
238
239         Aia_Func *func;
240         AIA_SECTION_FOR_EACH_FUNC(sec, func) {
241            AIA_FUNC_FOR_EACH_BLOCK(func, b)
242               aia_def_to_use_block_init(b);
243
```

```
244            Aia_Func_Trampoline *tramp;
245            AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
246               aia_def_to_use_block_init(tramp->block);
247         }
248      }
249
250      do {
251         aia->meta_data = INT_TO_PTR(false);
252         AIA_FOR_EACH_SECTION(aia, sec) {
253            ___aia_set_curr_func(aia, NULL);
254            AIA_SECTION_FOR_EACH_BLOCK(sec, b)
255               aia_def_to_use_block(b, aia);
256
257            Aia_Func *func;
258            AIA_SECTION_FOR_EACH_FUNC(sec, func) {
259               ___aia_set_curr_func(aia, func);
260               AIA_FUNC_FOR_EACH_BLOCK(func, b)
261                  aia_def_to_use_block(b, aia);
262
263               Aia_Func_Trampoline *tramp;
264               AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
265                  aia_def_to_use_block(tramp->block, aia);
266            }
267         }
268      } while (aia->meta_data);
269
270      if (cmdopts.dump_def_to_use_ic)
271         aia_def_to_use_dump(aia, it_count);
272
273      aia_func_access_destroy(aia);
274      aia_destroy_func_kills(aia);
275   }
```

:

A.8.6 src/aia/aia_def_to_use.h

```
1  #ifndef AIA_DEF_TO_USE_H
2  #define AIA_DEF_TO_USE_H
3
4  #include "aia.h"
5
6  void aia_def_to_use(Aia *aia, Int it_count);
7
8  #endif // AIA_DEF_TO_USE_H
```

:

A.8.7 src/aia/aia_func_access.c

```
1  #include "aia_func_access.h"
2  #include "main.h"
3
4  #undef DEBUG_TYPE
5  #define DEBUG_TYPE func-access
6
7  typedef struct Func_Meta_Data {
8     Hash_Map func_uses;
9     bool uses_global;
10    bool any_update;
11 } Func_Meta_Data;
12
13 typedef struct Func_Use_Operand {
14    Const_String used_op_func; /* If NULL used_op is a global var. */
15    Aia_Operand *used_op;
16    Uns ___func_name_hash_code;
17    bool ___func_name_hash_code_set;
```

```
18 } Func_Use_Operand;
19
20 #define FUNC_USE_OPERAND_INIT(func_name) ((Func_Use_Operand){ \
21    .used_op_func = func_name,                    \
22    .used_op = NULL,                              \
23    .___func_name_hash_code = 0,                  \
24    .___func_name_hash_code_set = false           \
25 })
26
27 static inline void func_use_operand_set_op(Func_Use_Operand *fuse,
28       Aia_Operand *op)
29 {
30    fuse->used_op = op;
31 }
32
33 typedef struct Func_Use_Opentry {
34    Func_Use_Operand fuse;
35    Hash_Map_Slot hash_slot;
36 } Func_Use_Opentry;
37
38 #define FUNC_USE_OPENTRY_OF(slot) \
39    HASH_MAP_ENTRY(slot, Func_Use_Opentry, hash_slot)
40
41 static bool func_use_contains(Hash_Map *map, Func_Use_Operand *kill_op)
42 {
43    if (!cmdopts.opt_func_access)
44       return true;
45
46    if (!kill_op->___func_name_hash_code_set) {
47       if (kill_op->used_op_func)
48          kill_op->___func_name_hash_code = string_hash_code(
49                kill_op->used_op_func);
50       kill_op->___func_name_hash_code_set = true;
51    }
52    Uns hash = kill_op->___func_name_hash_code + aia_operand_hash_code(
53          kill_op->used_op);
54    return hash_map_contains(map, kill_op, hash);
55 }
56
57 static void func_use_opentry_destroy(Hash_Map_Slot *slot);
58
59 static bool func_use_insert_label(Aia *aia UNUSED, Hash_Map *map,
60       Aia_Operand *label)
61 {
62    ___aia_operand_acquire(label);
63
64    Func_Use_Opentry *e = ALLOC_NEW(Func_Use_Opentry);
65    e->fuse = FUNC_USE_OPERAND_INIT(NULL);
66    e->fuse.used_op_func = NULL;
67    e->fuse.used_op = label;
68    e->fuse.___func_name_hash_code_set = true;
69
70    if (func_use_contains(map, &e->fuse)) {
71       func_use_opentry_destroy(&e->hash_slot);
72       return false;
73    }
74
75    Uns hash = aia_operand_hash_code(label);
76    hash_map_insert(map, &e->hash_slot, hash);
77    return true;
78 }
79
80 static bool func_use_insert_display(Aia *aia, Hash_Map *map,
81       Aia_Operand *display_op)
82 {
83    Const_String func_name = aia_operand_display_ref_get_func_name(display_op);
84    Const_String op_name = aia_operand_display_ref_get_var_name(display_op);
85    // uint8_t var_size = aia_operand_display_ref_get_var_size(display_op);
86    Aia_Operand *kill = aia_operand_local_ref_alloc(aia, op_name
87          /*, var_size */);
88    ___aia_operand_acquire(kill);
89
90    Func_Use_Opentry *e = ALLOC_NEW(Func_Use_Opentry);
91    e->fuse = FUNC_USE_OPERAND_INIT(func_name);
```

```
92     e->fuse.used_op = kill;
93     e->fuse.___func_name_hash_code = string_hash_code(func_name);
94     e->fuse.___func_name_hash_code_set = true;
95
96     if (func_use_contains(map, &e->fuse)) {
97        func_use_opentry_destroy(&e->hash_slot);
98        return false;
99     }
100
101    Uns hash = e->fuse.___func_name_hash_code + aia_operand_hash_code(kill);
102    hash_map_insert(map, &e->hash_slot, hash);
103    return true;
104 }
105
106 static bool func_use_insert_use_operand(Hash_Map *map,
107       Func_Use_Operand *kill_op)
108 {
109    Const_String func_name = kill_op->used_op_func;
110    ___aia_operand_acquire(kill_op->used_op);
111
112    Func_Use_Opentry *e = ALLOC_NEW(Func_Use_Opentry);
113    e->fuse = FUNC_USE_OPERAND_INIT(func_name);
114    e->fuse.used_op = kill_op->used_op;
115    if (func_name)
116       e->fuse.___func_name_hash_code = string_hash_code(func_name);
117    e->fuse.___func_name_hash_code_set = true;
118
119    if (func_use_contains(map, &e->fuse)) {
120       func_use_opentry_destroy(&e->hash_slot);
121       return false;
122    }
123
124    Uns hash = e->fuse.___func_name_hash_code +
125          aia_operand_hash_code(e->fuse.used_op);
126    hash_map_insert(map, &e->hash_slot, hash);
127    return true;
128 }
129
130 static bool func_use_opentry_compare(Func_Use_Operand *search_op,
131       Hash_Map_Slot *slot)
132 {
133    Func_Use_Opentry *e = FUNC_USE_OPENTRY_OF(slot);
134    if (search_op->used_op_func && e->fuse.used_op_func) {
135       if (string_compare(search_op->used_op_func, e->fuse.used_op_func))
136          return false;
137    } else if (search_op->used_op_func || e->fuse.used_op_func) {
138       return false;
139    }
140    return aia_operands_equal(search_op->used_op, e->fuse.used_op);
141 }
142
143 static void func_use_opentry_destroy(Hash_Map_Slot *slot)
144 {
145    Func_Use_Opentry *e = FUNC_USE_OPENTRY_OF(slot);
146    ___aia_operand_release(e->fuse.used_op);
147    free_mem(e);
148 }
149
150 static void func_use_collect_uses(Aia_Operand *op,
151       Aia *aia, Func_Meta_Data *fmeta)
152 {
153    Hash_Map *func_use_map = &fmeta->func_uses;
154    if (!op)
155       return;
156
157    switch (aia_operand_get_type(op)) {
158    case AIA_OPERAND_LABEL:
159       if (func_use_insert_label(aia, func_use_map, op))
160          fmeta->any_update = INT_TO_PTR(true);
161       break;
162
163    case AIA_OPERAND_DISPLAY_REF:
164       if (func_use_insert_display(aia, func_use_map, op))
165          fmeta->any_update = INT_TO_PTR(true);
```

```
166         break;
167
168      default:
169         break;
170      }
171   }
172
173   static void func_use_collect_func_uses(Aia_Instr *in, Aia *aia)
174   {
175      if (aia_instr_get_type(in) != AIA_CALL)
176         return;
177
178      bool uses_global = false;
179
180      Aia_Func *curr_func = ___aia_get_curr_func(aia);
181
182      Func_Meta_Data *fmeta = curr_func->func_access_struct;
183
184      Aia_Operand *lbl_op = aia_instr_get_src_op(in, 0);
185      if (aia_operand_get_type(lbl_op) != AIA_OPERAND_LABEL) {
186         uses_global = true;
187         goto out;
188      }
189
190      Const_String callee_name = aia_operand_label_get_name(lbl_op);
191      Aia_Func *callee = aia_func_lookup(aia, callee_name);
192      if (!callee) {
193         uses_global = true;
194         goto out;
195      }
196
197      if (hash_map_contains(&aia->default_funcs, (String)callee_name,
198               string_hash_code(callee_name))) {
199         uses_global = false;
200         goto out;
201      }
202
203      Func_Meta_Data *callee_meta = callee->func_access_struct;
204
205      if (callee_meta->uses_global)
206         uses_global = true;
207
208      Hash_Map *curr_map = &fmeta->func_uses;
209
210      Hash_Map_Slot *slot;
211      HASH_MAP_FOR_EACH(&callee_meta->func_uses, slot) {
212         Func_Use_Opentry *e = FUNC_USE_OPENTRY_OF(slot);
213         if (!func_use_contains(curr_map, &e->fuse)) {
214            DLOG("any update 1\n");
215            fmeta->any_update = true;
216            func_use_insert_use_operand(curr_map, &e->fuse);
217         }
218      }
219
220   out:
221      if (uses_global && !fmeta->uses_global) {
222         DLOG("any update 2\n");
223         fmeta->any_update = true;
224         fmeta->uses_global = true;
225      }
226   }
227
228   static void func_use_collect_block_uses(Aia_Block *b, Aia *aia,
229         Func_Meta_Data *fmeta)
230   {
231      Aia_Instr *in;
232      AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in) {
233
234         switch (aia_instr_get_type(in)) {
235         case AIA_CALL:
236            func_use_collect_func_uses(in, aia);
237            break;
238
239         case ___AIA_LABEL:
```

```
240             break;
241          case ___AIA_STRING:
242             break;
243          case ___AIA_INTEGER:
244             break;
245
246          default:;
247             Aia_Operand *op;
248             AIA_INSTR_FOR_EACH_SRC(in, op)
249                func_use_collect_uses(op, aia, fmeta);
250             break;
251          }
252       }
253    }
254
255    static void aia_collect_func_uses(Aia *aia)
256    {
257       Func_Meta_Data *fmeta;
258       Aia_Func *func;
259       AIA_FOR_EACH_FUNC(aia, func) {
260          fmeta = ALLOC_NEW(Func_Meta_Data);
261          fmeta->func_uses = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_11,
262                (Hash_Map_Comparator)func_use_opentry_compare);
263          fmeta->uses_global = false;
264          fmeta->any_update = false;
265          func->func_access_struct = fmeta;
266       }
267
268       bool any_update;
269       do {
270          any_update = false;
271
272          AIA_FOR_EACH_FUNC(aia, func) {
273             ___aia_set_curr_func(aia, func);
274             fmeta = func->func_access_struct;
275
276             fmeta->any_update = false;
277
278             Double_List_Node *bnode;
279             DOUBLE_LIST_FOR_EACH(&func->blist, bnode) {
280                DLOG("collcect kill fror %S\n", func->func_name);
281                func_use_collect_block_uses(AIA_BLOCK_OF_DBNODE(bnode), aia,
282                      fmeta);
283             }
284
285             any_update |= fmeta->any_update;
286          }
287
288       } while (any_update);
289    }
290
291    static void aia_destroy_func_uses(Aia *aia)
292    {
293       if (!cmdopts.opt_func_access)
294          return;
295
296       Aia_Func *func;
297       AIA_FOR_EACH_FUNC(aia, func) {
298          Func_Meta_Data *fmeta = func->func_access_struct;
299          hash_map_for_each_destroy(&fmeta->func_uses,
300                func_use_opentry_destroy);
301          free_mem(fmeta);
302       }
303    }
304
305    void aia_func_access(Aia *aia)
306    {
307       if (!cmdopts.opt_func_access)
308          return;
309
310       aia_collect_func_uses(aia);
311    }
312
313    void aia_func_access_destroy(Aia *aia)
```

```
{
   aia_destroy_func_uses(aia);
}

bool aia_func_uses(Const_String callee_func_name,
      Const_String operands_func_name, Aia_Operand *operand, Aia *aia)
{
   Aia_Func *callee_func;
   if (callee_func_name) {
      if (hash_map_contains(&aia->default_funcs, (String)callee_func_name,
            string_hash_code(callee_func_name)))
         return false;

      callee_func = aia_func_lookup(aia, callee_func_name);
   } else {
      callee_func = NULL;
   }
   if (!callee_func ||
         (!cmdopts.opt_func_access && !aia_func_is_nested(callee_func))) {
      if (aia_operand_get_type(operand) == AIA_OPERAND_LABEL)
         return true;
      return false;
   }

   Func_Meta_Data *fmeta = callee_func->func_access_struct;
   if (aia_operand_get_type(operand) == AIA_OPERAND_LABEL &&
         (!cmdopts.opt_func_access || fmeta->uses_global))
      return true;

   Func_Use_Operand kill_op = FUNC_USE_OPERAND_INIT(operands_func_name);
   kill_op.used_op = operand;

   return func_use_contains(&fmeta->func_uses, &kill_op);
}
```

:

A.8.8 src/aia/aia_func_access.h

```
#ifndef AIA_FUNC_ACCESS_H
#define AIA_FUNC_ACCESS_H

#include "aia.h"

/* Note that aia_func_access() does not use func->meta_data any more.
 * It uses func->func_access_struct now, so leave that field untouched. */

/* Assemble information about which variables, functions use and save it
 * in func->func_access_struct. After aia_func_access() is called see
 * aia_func_uses() to test wherther a function uses a specific variable. */
void aia_func_access(Aia *aia);

void aia_func_access_destroy(Aia *aia);

/* Returns true if function 'callee_func_name' accesses the operand
 * 'operand' inside function 'operands_func_name'.
 * If 'operands_func_name' == NULL then it is assumed that 'operand'
 * is a global static varaible. And the function still returns true
 * when 'callee_func' accesses 'operand'.
 * If 'callee_func_name' == NULL then it is assumed callee_func_name
 * is a global unknown function. */
bool aia_func_uses(Const_String callee_func_name,
      Const_String operands_func_name, Aia_Operand *operand, Aia *aia);

#endif // AIA_FUNC_ACCESS_H
```

:

A.8.9 src/aia/aia_func_kills.c

```
#include "aia_func_kills.h"
#include <main.h>

#undef DEBUG_TYPE
#define DEBUG_TYPE func-kills

typedef struct Func_Kill_Opentry {
   Func_Kill_Operand fkill;
   Hash_Map_Slot hash_slot;
} Func_Kill_Opentry;

#define FUNC_KILL_OPENTRY_OF(slot) \
   HASH_MAP_ENTRY(slot, Func_Kill_Opentry, hash_slot)

bool ___func_kill_contains(Hash_Map *map, Func_Kill_Operand *kill_op)
{
   if (!cmdopts.opt_func_access)
      return true;

   if (!kill_op->___func_name_hash_code_set) {
      DLOG("func ptr: %p\n", kill_op->killed_op_func);
      if (kill_op->killed_op_func)
         kill_op->___func_hame_hash_code = string_hash_code(
               kill_op->killed_op_func);
      kill_op->___func_name_hash_code_set = true;
   }
   Uns hash = kill_op->___func_hame_hash_code + aia_operand_hash_code(
         kill_op->killed_op);
   return hash_map_contains(map, kill_op, hash);
}

static void func_kill_opentry_destroy(Hash_Map_Slot *slot);

static bool func_kill_insert_label(Aia *aia UNUSED, Hash_Map *map,
      Aia_Operand *label)
{
   ___aia_operand_acquire(label);

   Func_Kill_Opentry *e = ALLOC_NEW(Func_Kill_Opentry);
   e->fkill = FUNC_KILL_OPERAND_INIT(NULL);
   e->fkill.killed_op_func = NULL;
   e->fkill.killed_op = label;
   e->fkill.___func_name_hash_code_set = true;

   if (___func_kill_contains(map, &e->fkill)) {
      func_kill_opentry_destroy(&e->hash_slot);
      return false;
   }

   Uns hash = aia_operand_hash_code(label);
   hash_map_insert(map, &e->hash_slot, hash);
   return true;
}

static bool func_kill_insert_display(Aia *aia, Hash_Map *map,
      Aia_Operand *display_op)
{
   Const_String func_name = aia_operand_display_ref_get_func_name(display_op);
   Const_String op_name = aia_operand_display_ref_get_var_name(display_op);
   // uint8_t var_size = aia_operand_display_ref_get_var_size(display_op);
   Aia_Operand *kill = aia_operand_local_ref_alloc(aia, op_name
         /*, var_size */);
   ___aia_operand_acquire(kill);

   Func_Kill_Opentry *e = ALLOC_NEW(Func_Kill_Opentry);
   e->fkill = FUNC_KILL_OPERAND_INIT(func_name);
   e->fkill.killed_op = kill;
   e->fkill.___func_hame_hash_code = string_hash_code(func_name);
   e->fkill.___func_name_hash_code_set = true;

   if (___func_kill_contains(map, &e->fkill)) {
```

```
72          func_kill_opentry_destroy(&e->hash_slot);
73          return false;
74       }
75
76       Uns hash = e->fkill.___func_hame_hash_code + aia_operand_hash_code(kill);
77       hash_map_insert(map, &e->hash_slot, hash);
78       return true;
79    }
80
81    static void func_kill_insert_func_kill_operand(Hash_Map *map,
82          Func_Kill_Operand *kill_op)
83    {
84       Const_String func_name = kill_op->killed_op_func;
85       ___aia_operand_acquire(kill_op->killed_op);
86
87       Func_Kill_Opentry *e = ALLOC_NEW(Func_Kill_Opentry);
88       e->fkill = FUNC_KILL_OPERAND_INIT(func_name);
89       e->fkill.killed_op = kill_op->killed_op;
90       if (func_name)
91          e->fkill.___func_hame_hash_code = string_hash_code(func_name);
92       e->fkill.___func_name_hash_code_set = true;
93
94       Uns hash = e->fkill.___func_hame_hash_code +
95             aia_operand_hash_code(e->fkill.killed_op);
96       hash_map_insert(map, &e->hash_slot, hash);
97    }
98
99    static bool func_kill_opentry_compare(Func_Kill_Operand *search_op,
100         Hash_Map_Slot *slot)
101   {
102      Func_Kill_Opentry *e = FUNC_KILL_OPENTRY_OF(slot);
103      if (search_op->killed_op_func && e->fkill.killed_op_func) {
104         if (string_compare(search_op->killed_op_func, e->fkill.killed_op_func))
105            return false;
106      } else if (search_op->killed_op_func || e->fkill.killed_op_func) {
107         return false;
108      }
109      return aia_operands_equal(search_op->killed_op, e->fkill.killed_op);
110   }
111
112   static void func_kill_opentry_destroy(Hash_Map_Slot *slot)
113   {
114      Func_Kill_Opentry *e = FUNC_KILL_OPENTRY_OF(slot);
115      ___aia_operand_release(e->fkill.killed_op);
116      free_mem(e);
117   }
118
119   static void aia_collect_dest_op_kill(Aia_Operand *op,
120         Aia *aia, Aia_Func_Kill_Meta *fmeta)
121   {
122      if (!op)
123         return;
124
125      Hash_Map *func_kill_map = &fmeta->func_kills;
126
127      switch (aia_operand_get_type(op)) {
128      case AIA_OPERAND_LABEL:
129         if (func_kill_insert_label(aia, func_kill_map, op))
130            fmeta->any_update = INT_TO_PTR(true);
131         break;
132
133      case AIA_OPERAND_DISPLAY_REF:
134         if (func_kill_insert_display(aia, func_kill_map, op))
135            fmeta->any_update = INT_TO_PTR(true);
136         break;
137
138      default:
139         break;
140      }
141   }
142
143   static void aia_collect_func_call_op_kills(Aia_Instr *in, Aia *aia)
144   {
145      if (aia_instr_get_type(in) != AIA_CALL)
```

```
146         return;
147
148     bool kills_global = false;
149
150     Aia_Func *curr_func = ___aia_get_curr_func(aia);
151
152     Aia_Func_Kill_Meta *fmeta = curr_func->func_kills_struct;
153
154     Aia_Operand *lbl_op = aia_instr_get_src_op(in, 0);
155     if (aia_operand_get_type(lbl_op) != AIA_OPERAND_LABEL) {
156        kills_global = true;
157        goto out;
158     }
159
160     Const_String callee_name = aia_operand_label_get_name(lbl_op);
161     Aia_Func *callee = aia_func_lookup(aia, callee_name);
162     if (!callee) {
163        kills_global = true;
164        goto out;
165     }
166
167     if (hash_map_contains(&aia->default_funcs, (String)callee_name,
168              string_hash_code(callee_name))) {
169        kills_global = false;
170        goto out;
171     }
172
173     Aia_Func_Kill_Meta *callee_meta = callee->func_kills_struct;
174
175     if (callee_meta->kills_global)
176        kills_global = true;
177
178     Hash_Map *curr_map = &fmeta->func_kills;
179
180     Hash_Map_Slot *slot;
181     HASH_MAP_FOR_EACH(&callee_meta->func_kills, slot) {
182        Func_Kill_Opentry *e = FUNC_KILL_OPENTRY_OF(slot);
183        if (!___func_kill_contains(curr_map, &e->fkill)) {
184           DLOG("any update 1\n");
185           fmeta->any_update = true;
186           func_kill_insert_func_kill_operand(curr_map, &e->fkill);
187        }
188     }
189
190  out:
191     if (kills_global && !fmeta->kills_global) {
192        DLOG("any update 2\n");
193        fmeta->any_update = true;
194        fmeta->kills_global = true;
195     }
196  }
197
198  static void aia_collect_block_kills(Aia_Block *b, Aia *aia,
199        Aia_Func_Kill_Meta *fmeta)
200  {
201     Aia_Instr *in;
202     AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in) {
203        switch (aia_instr_get_type(in)) {
204        case AIA_CALL:
205           aia_collect_func_call_op_kills(in, aia);
206           break;
207
208        case ___AIA_LABEL:
209           break;
210        case ___AIA_STRING:
211           break;
212        case ___AIA_INTEGER:
213           break;
214
215        default:;
216           Aia_Operand *op = aia_instr_get_dest_op(in);
217           aia_collect_dest_op_kill(op, aia, fmeta);
218        }
219     }
```

```
220 }
221
222 void aia_collect_func_kills(Aia *aia)
223 {
224    if (!cmdopts.opt_func_access)
225       return;
226
227    Aia_Func_Kill_Meta *fmeta;
228    Aia_Func *func;
229    AIA_FOR_EACH_FUNC(aia, func) {
230       fmeta = ALLOC_NEW(Aia_Func_Kill_Meta);
231       fmeta->func_kills = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_11,
232             (Hash_Map_Comparator)func_kill_opentry_compare);
233       fmeta->kills_global = false;
234       fmeta->any_update = false;
235       func->func_kills_struct = fmeta;
236    }
237
238    bool any_update;
239    do {
240       any_update = false;
241
242       AIA_FOR_EACH_FUNC(aia, func) {
243          ___aia_set_curr_func(aia, func);
244          fmeta = func->func_kills_struct;
245
246          fmeta->any_update = false;
247
248          Double_List_Node *bnode;
249          DOUBLE_LIST_FOR_EACH(&func->blist, bnode)
250             aia_collect_block_kills(AIA_BLOCK_OF_DBNODE(bnode),
251                   aia, fmeta);
252
253          any_update |= fmeta->any_update;
254       }
255
256    } while (any_update);
257 }
258
259 void aia_destroy_func_kills(Aia *aia)
260 {
261    if (!cmdopts.opt_func_access)
262       return;
263
264    Aia_Func *func;
265    AIA_FOR_EACH_FUNC(aia, func) {
266       Aia_Func_Kill_Meta *fmeta = func->func_kills_struct;
267       hash_map_for_each_destroy(&fmeta->func_kills,
268             func_kill_opentry_destroy);
269       free_mem(fmeta);
270    }
271 }
272
273 bool func_kills_operand(Const_String callee_func_name,
274       Const_String operands_func_name, Aia_Operand *operand, Aia *aia)
275 {
276    Aia_Func *callee_func;
277    if (callee_func_name) {
278       if (hash_map_contains(&aia->default_funcs, (String)callee_func_name,
279                string_hash_code(callee_func_name)))
280          return false;
281
282       callee_func = aia_func_lookup(aia, callee_func_name);
283    } else {
284       callee_func = NULL;
285    }
286    if (!callee_func ||
287          (!cmdopts.opt_func_access && !aia_func_is_nested(callee_func))) {
288       if (aia_operand_get_type(operand) == AIA_OPERAND_LABEL)
289          return true;
290       return false;
291    }
292
293    Aia_Func_Kill_Meta *fmeta = callee_func->func_kills_struct;
```

```
294     if (aia_operand_get_type(operand) == AIA_OPERAND_LABEL &&
295           (!cmdopts.opt_func_access || fmeta->kills_global))
296        return true;
297
298     Func_Kill_Operand kill_op = FUNC_KILL_OPERAND_INIT(operands_func_name);
299     kill_op.killed_op = operand;
300
301     return ___func_kill_contains(&fmeta->func_kills, &kill_op);
302  }
```

:

A.8.10 src/aia/aia_func_kills.h

```
1   #ifndef AIA_FUNC_KILLS_H
2   #define AIA_FUNC_KILLS_H
3
4   #include "aia.h"
5
6   /* Note that aia_collect_func_kills() does not use func->meta_data any more.
7    * It uses func->func_kills_struct instead, so leave that field untouched. */
8
9   typedef struct Aia_Func_Kill_Meta {
10     Hash_Map func_kills;
11     bool kills_global;
12     bool any_update;
13  } Aia_Func_Kill_Meta;
14
15  typedef struct Func_Kill_Operand {
16     Const_String killed_op_func; /* If NULL killed_op is a global var. */
17     Aia_Operand *killed_op;
18     Uns ___func_hame_hash_code;
19     bool ___func_name_hash_code_set;
20  } Func_Kill_Operand;
21
22  #define FUNC_KILL_OPERAND_INIT(killed_func_name) ((Func_Kill_Operand){ \
23     .killed_op_func = killed_func_name,                \
24     .killed_op = NULL,                                 \
25     .___func_hame_hash_code = 0,                       \
26     .___func_name_hash_code_set = false                \
27  })
28
29  static inline void func_kill_operand_set_operand(Func_Kill_Operand *fkill,
30        Aia_Operand *op)
31  {
32     fkill->killed_op = op;
33  }
34
35  bool ___func_kill_contains(Hash_Map *map, Func_Kill_Operand *kill_op);
36
37  /* Returns true if 'callee_func' kills the operand 'operand' inside
38   * function 'operands_func_name'.
39   * If 'operands_func_name' == NULL then it is assumed that 'operand'
40   * is a global static varaible. And the function still returns true
41   * when 'callee_func' kills 'operand'.
42   * If 'callee_func_name' == NULL then it is assumed callee_func_name
43   * is a global unknown function. */
44  bool func_kills_operand(Const_String callee_func_name,
45        Const_String operands_func_name, Aia_Operand *operand, Aia *aia);
46
47  /* Assemble information about which variables functions kill and save it
48   * in func->func_kills_struct. After aia_collect_func_kills() is called see
49   * func_kill_contains() to test wherther a function
50   * kills a specific variable. */
51  void aia_collect_func_kills(Aia *aia);
52
53  void aia_destroy_func_kills(Aia *aia);
54
55  #endif // AIA_FUNC_KILLS_H
```

:

A.8.11 src/aia/aia_instr_elim.c

```
#include "aia_instr_elim.h"
#include "aia_instr_live_sets.h"
#include "aia_operand_set.h"
#include "main.h"

#undef DEBUG_TYPE
#define DEBUG_TYPE instr-elim

static bool aia_instr_elim_set_global(Aia *aia, Aia_Operand *label_operand,
      Aia_Operand *op, Aia_Operand_Set *fin_glob_set)
{
   Aia_Instr *lbl_in = aia_label_to_instruction(aia, label_operand);
   if (!lbl_in)
      return false;

   if (fin_glob_set) {
      DEBUG(
         DLOGT(def, " let ");
         aia_instr_dump(stderr, lbl_in, aia);
         DLOGT(def, "\n");
      );
      Aia_Operand *lbl_op = aia_instr_get_dest_op(lbl_in);
      if (!aia_operand_set_insert(fin_glob_set, lbl_op))
         return false;
   }

   if (aia_operand_get_type(op) != AIA_OPERAND_CONST_INT)
      return false;

   Aia_Instr *int_instr = aia_instr_get_sucessor(lbl_in);
   assert(int_instr);
   if (aia_instr_get_src_ops_size(int_instr) == AIA_BYTE) {
      int32_t orig = aia_operand_const_int_get_val(op);
      int8_t real = orig;
      File_Location *loc = aia_instr_get_location(lbl_in);
      if (real != orig) {
         if (cmdopts.warn_overflow && !is_warning_reported_here(loc))
            report_warning_location(loc,
                  S("constant implicitly truncated to " QFY("%" PRId8)
                     " to fit " QFY("char") " variable\n"), real);
         op = aia_operand_const_int_alloc(aia, real);
      }
   }
   aia_instr_replace_op(int_instr, 0, op);

   return true;
}

static void aia_instr_elim_block(Aia_Block *b, Aia *aia, Aia_Instr *init_in,
      Aia_Operand_Set *fin_glob_set)
{
   VECTOR(removed_ins);

   Aia_Instr *in;
   AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in) {
      Aia_Operand *dest = aia_instr_get_dest_op(in);

      switch (aia_instr_get_type(in)) {
      case AIA_RET:
         continue;
      case AIA_IDIV:
         continue;
      case AIA_CALL:
         continue;
      AIA_CASE_INCONCRETE:
         continue;
      default:
         break;
```

```
69          }
70
71          if (!dest)
72             continue;
73
74          switch (aia_operand_get_type(dest)) {
75          case AIA_OPERAND_ARG:
76             continue;
77
78          default:
79             break;
80          }
81
82          bool live_out = aia_instr_dest_live_out(in, in);
83          if (!live_out) {
84             if (aia_operand_get_type(dest) == AIA_OPERAND_LABEL) {
85
86                if (init_in && aia_instr_is_movx(in) &&
87                      !aia_instr_live_set_contains(init_in, dest)) {
88
89                   if (aia_instr_elim_set_global(aia, dest,
90                         aia_instr_get_src_op(in, 0), fin_glob_set))
91                      vector_append(&removed_ins, in);
92
93                }
94
95             } else if (!live_out) {
96                vector_append(&removed_ins, in);
97                switch (aia_instr_get_type(in)) {
98                AIA_CASE_SET:
99                   /* Fall through. */
100               AIA_CASE_COND_JUMP:;
101                  Aia_Instr *pred = aia_instr_get_predecessor(in);
102                  assert(aia_instr_get_type(pred) == AIA_CMP);
103                  vector_append(&removed_ins, pred);
104                  break;
105
106               default:
107                  break;
108               }
109            }
110         }
111   #if 0
112         if (init_in && aia_operand_get_type(dest) == AIA_OPERAND_LABEL)
113            aia_instr_elim_set_global(aia, dest,
114                  aia_instr_get_src_op(in, 0), fin_glob_set);
115   #endif
116         if (init_in && aia_operand_get_type(dest) == AIA_OPERAND_LABEL) {
117            if (fin_glob_set)
118               aia_operand_set_insert(fin_glob_set, dest);
119         }
120
121      }
122
123      VECTOR_FOR_EACH_ENTRY(&removed_ins, in) {
124         aia_instr_live_set_destroy(in);
125         aia_instr_remove_destroy(in);
126      }
127
128      if (vector_size(&removed_ins))
129         aia->meta_data = INT_TO_PTR(1);
130      vector_clear(&removed_ins);
131   }
132
133   static void aia_instr_elim_section(Aia_Section *sec, Aia *aia,
134         Aia_Operand_Set *fin_glob_set)
135   {
136      Aia_Instr *init_in;
137      if (sec->sec_type == AIA_SECTION_INIT)
138         init_in = ___aia_block_peek_first_instr(sec->entry_block);
139      else
140         init_in = NULL;
141
142      Aia_Block *b;
```

```
143     AIA_SECTION_FOR_EACH_BLOCK(sec, b)
144        aia_instr_elim_block(b, aia, init_in, fin_glob_set);
145
146     Aia_Func *func;
147     AIA_SECTION_FOR_EACH_FUNC(sec, func) {
148        AIA_FUNC_FOR_EACH_BLOCK_REVERSED(func, b)
149           aia_instr_elim_block(b, aia, NULL, fin_glob_set);
150
151  #if 0
152        Aia_Func_Trampoline *tramp;
153        AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
154           aia_instr_elim_block(tramp->block, aia, NULL, fin_glob_set);
155  #endif
156     }
157  }
158
159  static inline void aia_instr_elim_dump(Aia *aia, Int it_count)
160  {
161     String fname = string_from_format(S("instr-elim-ic-%D"),
162           it_count);
163     aia_instr_live_sets_dump(aia, fname);
164     string_destroy(fname);
165  }
166
167  static void aia_instr_elim_add_data_section(Aia_Section *dsec,
168        Aia_Instr_Forced_Liveness *f)
169  {
170     if (!dsec)
171        return;
172
173     Aia_Block *b;
174     AIA_SECTION_FOR_EACH_BLOCK(dsec, b) {
175        Aia_Instr *prev = NULL;
176        Aia_Instr *curr;
177        AIA_BLOCK_FOR_EACH_INSTRUCTION(b, curr) {
178           if (aia_instr_get_type(curr) == ___AIA_INTEGER) {
179              assert(aia_instr_get_type(prev) == ___AIA_LABEL);
180              Aia_Operand *op = aia_instr_get_src_op(curr, 0);
181              if (aia_operand_get_type(op) == AIA_OPERAND_CONST_INT) {
182                 op = aia_instr_get_dest_op(prev);
183                 aia_instr_forced_liveness_add(f, op);
184              }
185           }
186           prev = curr;
187        }
188     }
189  }
190
191  static inline Aia_Instr *aia_instr_elim_get_last_init_instr(Aia_Section *isec)
192  {
193     if (!isec)
194        return NULL;
195     return ___aia_block_peek_last_instr(isec->exit_block);
196  }
197
198  bool aia_instr_elim(Aia *aia, Int it_count, bool final_pass)
199  {
200     size_t ret = 0;
201
202     if (!cmdopts.opt_instr_elim)
203        goto out;
204
205     VECTOR_SIZE(force, 1);
206     Aia_Instr_Forced_Liveness f = AIA_INSTR_FORCED_LIVENESS_INIT();
207
208     Aia_Operand_Set *fin_glob_set;
209     if (!final_pass) {
210        fin_glob_set = NULL;
211        aia_instr_elim_add_data_section(aia->sections[AIA_SECTION_DATA], &f);
212        vector_append(&force, &f);
213     } else {
214        fin_glob_set = aia_operand_set_alloc();
215     }
216
```

```
217     for (;;) {
218        f.instr = aia_instr_elim_get_last_init_instr(
219              aia->sections[AIA_SECTION_INIT]);
220
221        aia_instr_live_sets(aia, &force, false);
222
223        aia->meta_data = NULL;
224
225        Aia_Section *sec;
226        AIA_FOR_EACH_SECTION(aia, sec)
227           aia_instr_elim_section(sec, aia, fin_glob_set);
228
229        if (!aia->meta_data || final_pass) {
230           if (cmdopts.dump_instr_elim_ic)
231              aia_instr_elim_dump(aia, it_count);
232           aia_instr_live_sets_destroy(aia);
233           break;
234        } else {
235           ret = true;
236        }
237
238        aia_instr_live_sets_destroy(aia);
239     }
240
241     vector_for_each_destroy(&force,
242           (Vector_Destructor)aia_instr_forced_liveness_clear);
243     if (final_pass)
244        aia_operand_set_destroy(fin_glob_set);
245
246  out:
247     return ret;
248  }
```

:

A.8.12 src/aia/aia_instr_elim.h

```
1  #ifndef AIA_INSTR_ELIM_H
2  #define AIA_INSTR_ELIM_H
3
4  #include "aia.h"
5
6  bool aia_instr_elim(Aia *aia, Int it_count, bool final_pass);
7
8  #endif // AIA_INSTR_ELIM_H
```

:

A.8.13 src/aia/aia_instr_live_sets.c

```
1  #include "aia_instr_live_sets.h"
2  #include "string_builder.h"
3  #include "aia_func_access.h"
4  #include "aia_func_kills.h"
5
6  typedef struct Aia_Meta {
7     Hash_Map *op_map;
8     bool funcs_always_kill;
9     bool any_update;
10 } Aia_Meta;
11
12 static bool aia_operand_hash_compare(Aia_Operand *search_op,
13       Hash_Map_Slot *slot)
14 {
15    Aia_Operand_Entry *e = AIA_OPERAND_ENTRY_OF(slot);
16    return aia_operands_equal(e->op, search_op);
17 }
```

```
18
19 static void aia_operand_hash_destroy(Hash_Map_Slot *slot)
20 {
21    free_mem(AIA_OPERAND_ENTRY_OF(slot));
22 }
23
24 static Live_Set_Entry *live_set_entry_alloc(Aia_Operand *op)
25 {
26    Live_Set_Entry *e = ALLOC_NEW(Live_Set_Entry);
27    e->live_operand = op;
28    ___aia_operand_acquire(op);
29    return e;
30 }
31
32 static void live_set_entry_destroy(Live_Set_Entry *e)
33 {
34    ___aia_operand_release(e->live_operand);
35    free_mem(e);
36 }
37
38 static inline bool live_set_remove(Live_Set *s, Aia_Operand *op)
39 {
40    Hash_Map_Slot *slot = hash_map_remove(s, op, aia_operand_hash_code(op));
41    if (slot) {
42       live_set_entry_destroy(LIVE_SET_ENTRY_OF(slot));
43       return true;
44    }
45    return false;
46 }
47
48 static inline bool live_set_contains(Live_Set *s, Aia_Operand *op)
49 {
50    return hash_map_contains(s, op, aia_operand_hash_code(op));
51 }
52
53 bool aia_instr_live_set_contains(Aia_Instr *in, Aia_Operand *op)
54 {
55    return live_set_contains(in->meta_data, op);
56 }
57
58 static inline void live_set_remove_entry(Live_Set *s, Live_Set_Entry *e)
59 {
60    Uns hash_code = hash_map_slot_get_hash_code(&e->hash_slot);
61    assert(hash_map_contains(s, e->live_operand, hash_code));
62    Hash_Map_Slot *slot = hash_map_remove(s, e->live_operand, hash_code);
63    live_set_entry_destroy(LIVE_SET_ENTRY_OF(slot));
64 }
65
66 static inline bool ___live_set_insert(Live_Set *s, Aia_Operand *op,
67       Uns hash_code)
68 {
69    if (hash_map_contains(s, op, hash_code))
70       return false;
71    Live_Set_Entry *e = live_set_entry_alloc(op);
72    hash_map_insert(s, &e->hash_slot, hash_code);
73    return true;
74 }
75
76 static inline bool live_set_insert(Live_Set *s, Aia_Operand *op)
77 {
78    return ___live_set_insert(s, op, aia_operand_hash_code(op));
79 }
80
81 static inline bool live_set_insert_entry(Live_Set *s, Live_Set_Entry *e)
82 {
83    return ___live_set_insert(s, e->live_operand,
84          hash_map_slot_get_hash_code(&e->hash_slot));
85 }
86
87 static bool live_set_entry_compare(Aia_Operand *search_op,
88       Hash_Map_Slot *live_slot)
89 {
90    Live_Set_Entry *e = LIVE_SET_ENTRY_OF(live_slot);
91    return aia_operands_equal(search_op, e->live_operand);
```

```
92  }
93
94  static inline Live_Set *live_set_alloc()
95  {
96     Live_Set *s = ALLOC_NEW(Live_Set);
97     *s = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_11,
98           (Hash_Map_Comparator)live_set_entry_compare);
99     return s;
100 }
101
102 static void live_set_entry_hash_destroy(Hash_Map_Slot *slot)
103 {
104    live_set_entry_destroy(LIVE_SET_ENTRY_OF(slot));
105 }
106
107 static inline void ___live_set_destroy(Live_Set *s)
108 {
109    if (s) {
110       hash_map_for_each_destroy(s, live_set_entry_hash_destroy);
111       free_mem(s);
112    }
113 }
114
115 void aia_instr_live_set_destroy(Aia_Instr *in)
116 {
117    ___live_set_destroy(in->meta_data);
118    in->meta_data = NULL;
119 }
120
121 static void aia_instr_add_operand_entry(Aia *aia, Aia_Operand *op)
122 {
123    if (!op)
124       return;
125
126    Aia_Meta *ameta = aia->meta_data;
127
128    switch (aia_operand_get_type(op)) {
129    case AIA_OPERAND_REG:
130       /* Fall through. */
131    case AIA_OPERAND_LABEL:
132       /* Fall through. */
133    case AIA_OPERAND_LOCAL_REF:
134       /* Fall through. */
135    case AIA_OPERAND_ARG:;
136       Uns hash = aia_operand_hash_code(op);
137       if (!hash_map_contains(ameta->op_map, op, hash)) {
138          Aia_Operand_Entry *e = ALLOC_NEW(Aia_Operand_Entry);
139          e->op = op;
140          hash_map_insert(ameta->op_map, &e->hash_slot, hash);
141       }
142       break;
143
144    case AIA_OPERAND_DISPLAY_REF:
145       aia_instr_add_operand_entry(aia,
146             aia_operand_display_ref_get_display_reg(op));
147       break;
148
149    case AIA_OPERAND_ADDR_REF:
150       aia_instr_add_operand_entry(aia, aia_operand_addr_ref_get_label(op));
151       aia_instr_add_operand_entry(aia, aia_operand_addr_ref_get_base(op));
152       aia_instr_add_operand_entry(aia, aia_operand_addr_ref_get_index(op));
153       break;
154
155    default:
156       break;
157    }
158 }
159
160 static void aia_instr_add_live_op(Aia_Instr *in, Aia_Operand *op, Aia *aia)
161 {
162    if (!op)
163       return;
164
165    switch (aia_operand_get_type(op)) {
```

```
166     case AIA_OPERAND_REG:
167        /* Fall through. */
168     case AIA_OPERAND_LABEL:
169        /* Fall through. */
170     case AIA_OPERAND_LOCAL_REF:
171        /* Fall through. */
172     case AIA_OPERAND_ARG:;
173        aia_instr_add_operand_entry(aia, op);
174        live_set_insert(in->meta_data, op);
175        break;
176
177     case AIA_OPERAND_DISPLAY_REF:
178        aia_instr_add_live_op(in,
179              aia_operand_display_ref_get_display_reg(op), aia);
180        break;
181
182     case AIA_OPERAND_ADDR_REF:
183        aia_instr_add_live_op(in, aia_operand_addr_ref_get_label(op), aia);
184        aia_instr_add_live_op(in, aia_operand_addr_ref_get_base(op), aia);
185        aia_instr_add_live_op(in, aia_operand_addr_ref_get_index(op), aia);
186        break;
187
188     default:
189        break;
190     }
191  }
192
193  static void aia_instr_live_init(Aia_Instr *in, Aia *aia)
194  {
195     in->meta_data = live_set_alloc();
196     Aia_Operand *op;
197     AIA_INSTR_FOR_EACH_SRC(in, op)
198        aia_instr_add_live_op(in, op, aia);
199
200     op = aia_instr_get_dest_op(in);
201     if (!op)
202        return;
203
204     aia_instr_add_operand_entry(aia, op);
205
206     switch (aia_operand_get_type(op)) {
207     case AIA_OPERAND_ADDR_REF:
208        /* Fall through. */
209     case AIA_OPERAND_DISPLAY_REF:
210        aia_instr_add_live_op(in, op, aia);
211        break;
212
213     default:
214        break;
215     }
216  }
217
218  static void aia_instr_live_func_access(Aia_Instr *in, Aia *aia)
219  {
220     if (aia_instr_get_type(in) != AIA_CALL)
221        return;
222
223     Aia_Meta *ameta = aia->meta_data;
224
225     Aia_Operand *lbl_op = aia_instr_get_src_op(in, 0);
226     if (aia_operand_get_type(lbl_op) != AIA_OPERAND_LABEL) {
227        // Add all global
228        Hash_Map *map = ameta->op_map;
229        Hash_Map_Slot *slot;
230        HASH_MAP_FOR_EACH(map, slot) {
231           Aia_Operand_Entry *e = AIA_OPERAND_ENTRY_OF(slot);
232           if (aia_operand_get_type(e->op) == AIA_OPERAND_LABEL)
233              aia_instr_add_live_op(in, e->op, aia);
234        }
235        return;
236     }
237
238     Const_String callee_name = aia_operand_label_get_name(lbl_op);
239
```

```
240 #if 0
241    if (hash_map_contains(&aia->default_funcs, (String)callee_name,
242              string_hash_code(callee_name)))
243       return;
244    Aia_Func *callee = aia_func_lookup(aia, callee_name);
245 #endif
246
247    Const_String curr_func_name = ___aia_get_curr_func_name(aia);
248
249    inline void add_operand(Aia_Operand *op)
250    {
251       if (ameta->funcs_always_kill && func_kills_operand(callee_name,
252                curr_func_name, op, aia))
253          return;
254
255       if (aia_func_uses(callee_name, curr_func_name, op, aia))
256          aia_instr_add_live_op(in, op, aia);
257    }
258
259    Hash_Map *map = ameta->op_map;
260    Hash_Map_Slot *slot;
261    HASH_MAP_FOR_EACH(map, slot) {
262       Aia_Operand_Entry *e = AIA_OPERAND_ENTRY_OF(slot);
263       add_operand(e->op);
264    }
265
266    if (!curr_func_name)
267       return;
268
269    Aia_Func *func = ___aia_get_curr_func(aia);
270
271    Vector *locals = &func->locals;
272    Const_String loc;
273    VECTOR_FOR_EACH_ENTRY(locals, loc) {
274       Aia_Operand *op = aia_operand_local_ref_alloc(aia, loc);
275       ___aia_operand_acquire(op);
276       add_operand(op);
277       ___aia_operand_release(op);
278    }
279 }
280
281 static inline void aia_instr_block_live_init(Aia_Block *b, Aia *aia)
282 {
283    Aia_Instr *in;
284    AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
285       aia_instr_live_init(in, aia);
286 }
287
288 static inline void aia_instr_block_func_access(Aia_Block *b, Aia *aia)
289 {
290    Aia_Instr *in;
291    AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
292       aia_instr_live_func_access(in, aia);
293 }
294
295 static void aia_instr_section_live_init(Aia_Section *sec, Aia *aia)
296 {
297    ___aia_set_curr_func(aia, NULL);
298
299    Aia_Meta *ameta = aia->meta_data;
300
301    Aia_Block *b;
302    AIA_SECTION_FOR_EACH_BLOCK_REVERSED(sec, b)
303       aia_instr_block_live_init(b, aia);
304    AIA_SECTION_FOR_EACH_BLOCK_REVERSED(sec, b)
305       aia_instr_block_func_access(b, aia);
306
307    hash_map_for_each_destroy(ameta->op_map, aia_operand_hash_destroy);
308
309    Aia_Func *func;
310    AIA_SECTION_FOR_EACH_FUNC(sec, func) {
311       ___aia_set_curr_func(aia, func);
312
313       AIA_FUNC_FOR_EACH_BLOCK_REVERSED(func, b)
```

```
314            aia_instr_block_live_init(b, aia);
315         AIA_FUNC_FOR_EACH_BLOCK_REVERSED(func, b)
316            aia_instr_block_func_access(b, aia);
317
318         hash_map_for_each_destroy(ameta->op_map, aia_operand_hash_destroy);
319
320         Aia_Func_Trampoline *tramp;
321         AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp) {
322            aia_instr_block_live_init(tramp->block, aia);
323            aia_instr_block_func_access(tramp->block, aia);
324            Aia_Instr *jmp_in = ___aia_block_peek_last_instr(tramp->block);
325            aia_instr_add_live_op(jmp_in, aia->record_self_ptr, aia);
326
327            hash_map_for_each_destroy(ameta->op_map, aia_operand_hash_destroy);
328         }
329      }
330   }
331
332   static inline void live_sets_init(Aia *aia, Vector *forced_live,
333         bool funcs_always_kill)
334   {
335      HASH_MAP(operand_map, (Hash_Map_Comparator)aia_operand_hash_compare);
336      aia->meta_data = &(Aia_Meta){ &operand_map, funcs_always_kill, false };
337
338      Aia_Section *sec;
339      AIA_FOR_EACH_SECTION(aia, sec)
340         aia_instr_section_live_init(sec, aia);
341
342      if (!forced_live)
343         return;
344
345      Aia_Instr_Forced_Liveness *f;
346      VECTOR_FOR_EACH_ENTRY(forced_live, f) {
347         Live_Set *set = f->instr->meta_data;
348
349         Aia_Operand *op;
350         VECTOR_FOR_EACH_ENTRY(&f->live_operands, op)
351            live_set_insert(set, op);
352      }
353   }
354
355   static inline bool aia_instr_call_defines_op(Aia_Instr *in,
356         Aia_Operand *op, Aia *aia)
357   {
358      if (aia_instr_get_type(in) != AIA_CALL)
359         return false;
360
361      Aia_Meta *ameta = aia->meta_data;
362      if (!ameta->funcs_always_kill)
363         return false;
364
365      Aia_Operand *lbl_op = aia_instr_get_src_op(in, 0);
366      if (aia_operand_get_type(lbl_op) != AIA_OPERAND_LABEL)
367         return false;
368
369      Const_String callee_name = aia_operand_label_get_name(lbl_op);
370      Const_String curr_func_name = ___aia_get_curr_func_name(aia);
371
372      return func_kills_operand(callee_name, curr_func_name, op, aia);
373   }
374
375   static bool aia_instr_defines_op(Aia_Instr *in, Aia_Operand *op, Aia *aia)
376   {
377      Aia_Operand *dest = aia_instr_get_dest_op(in);
378      if (!dest)
379         return false;
380
381      if (aia_instr_call_defines_op(in, op, aia))
382         return true;
383
384      switch (aia_operand_get_type(op)) {
385      case AIA_OPERAND_REG:
386         /* Fall through. */
387      case AIA_OPERAND_LABEL:
```

```
388         /* Fall through. */
389     case AIA_OPERAND_LOCAL_REF:
390         /* Fall through. */
391     case AIA_OPERAND_ARG:
392         /* Fall through. */
393         return aia_operands_equal(dest, op);
394
395     case AIA_OPERAND_DISPLAY_REF:
396         /* Fall through. */
397     case AIA_OPERAND_ADDR_REF:
398         return false;
399
400     default:
401         return false;
402     }
403 }
404
405 static void aia_instr_live_add(Aia_Instr *in, Live_Set *vars, Aia *aia)
406 {
407     Aia_Meta *ameta = aia->meta_data;
408     Live_Set_Entry *e;
409     LIVE_SET_FOR_EACH_ENTRY(vars, e) {
410         if (!aia_instr_defines_op(in, e->live_operand, aia)) {
411             if (live_set_insert_entry(in->meta_data, e))
412                 ameta->any_update = true;
413         }
414     }
415 }
416
417 static void aia_instr_live_set_build(Aia_Instr *in, Aia_Block *b, Aia *aia)
418 {
419     Aia_Instr *pred = aia_instr_get_predecessor(in);
420     if (!pred) {
421         Aia_Block *pred_block;
422         AIA_BLOCK_FOR_EACH_PREDECESSOR(b, pred_block) {
423             aia_instr_live_add(___aia_block_peek_last_instr(
424                     pred_block), in->meta_data, aia);
425         }
426     } else {
427         aia_instr_live_add(pred, in->meta_data, aia);
428     }
429 }
430
431
432 static void aia_instr_block_live_sets_build(Aia_Block *b, Aia *aia)
433 {
434     Aia_Instr *in;
435     AIA_BLOCK_FOR_EACH_INSTRUCTION_REVERSED(b, in)
436         aia_instr_live_set_build(in, b, aia);
437 }
438
439
440 static void aia_section_live_sets_build(Aia *aia, Aia_Section *sec)
441 {
442     ___aia_set_curr_func(aia, NULL);
443     Aia_Block *b;
444     AIA_SECTION_FOR_EACH_BLOCK_REVERSED(sec, b)
445         aia_instr_block_live_sets_build(b, aia);
446
447     Aia_Func *func;
448     AIA_SECTION_FOR_EACH_FUNC(sec, func) {
449         ___aia_set_curr_func(aia, func);
450         AIA_FUNC_FOR_EACH_BLOCK_REVERSED(func, b)
451             aia_instr_block_live_sets_build(b, aia);
452
453         Aia_Func_Trampoline *tramp;
454         AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
455             aia_instr_block_live_sets_build(tramp->block, aia);
456     }
457 }
458
459 static inline void live_sets_build(Aia *aia, bool funcs_always_kill)
460 {
461     Aia_Section *sec;
```

```
462     Aia_Meta ameta = { NULL, funcs_always_kill, false };
463     aia->meta_data = &ameta;
464     do {
465        ameta.any_update = false;
466        AIA_FOR_EACH_SECTION(aia, sec)
467           aia_section_live_sets_build(aia, sec);
468     } while (ameta.any_update);
469  }
470
471  static void aia_instr_live_destroy(Aia_Block *b)
472  {
473     Aia_Instr *in;
474     AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
475        aia_instr_live_set_destroy(in);
476  }
477
478  static void aia_instr_section_live_destroy(Aia_Section *sec)
479  {
480     Aia_Block *b;
481     AIA_SECTION_FOR_EACH_BLOCK_REVERSED(sec, b)
482           aia_instr_live_destroy(b);
483
484     Aia_Func *func;
485     AIA_SECTION_FOR_EACH_FUNC(sec, func) {
486        AIA_FUNC_FOR_EACH_BLOCK_REVERSED(func, b)
487              aia_instr_live_destroy(b);
488
489        Aia_Func_Trampoline *tramp;
490        AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
491           aia_instr_live_destroy(tramp->block);
492     }
493  }
494
495  void aia_instr_live_sets_destroy(Aia *aia)
496  {
497     Aia_Section *sec;
498     AIA_FOR_EACH_SECTION(aia, sec)
499        aia_instr_section_live_destroy(sec);
500  }
501
502  void aia_instr_live_sets(Aia *aia, Vector *forced_live,
503        bool funcs_always_kill)
504  {
505     if (funcs_always_kill)
506        aia_collect_func_kills(aia);
507
508     aia_func_access(aia);
509     live_sets_init(aia, forced_live, funcs_always_kill);
510     aia_func_access_destroy(aia);
511
512     live_sets_build(aia, funcs_always_kill);
513
514     if (funcs_always_kill)
515        aia_destroy_func_kills(aia);
516  }
517
518  static bool aia_instr_is_live_set_op(Aia_Operand *op)
519  {
520     if (!op)
521        return false;
522
523     switch (aia_operand_get_type(op)) {
524     case AIA_OPERAND_REG:
525        /* Fall through. */
526     case AIA_OPERAND_LABEL:
527        /* Fall through. */
528     case AIA_OPERAND_LOCAL_REF:
529        /* Fall through. */
530     case AIA_OPERAND_ARG:
531        /* Fall through. */
532        return true;
533
534     case AIA_OPERAND_DISPLAY_REF:
535        /* Fall through. */
```

```
536     case AIA_OPERAND_ADDR_REF:
537        /* Fall through. */
538     default:
539        return false;
540     }
541  }
542
543  static bool aia_instr_is_live_set_instr(Aia_Instr *in)
544  {
545     return aia_instr_is_concrete(in);
546  }
547
548  /* Returns true if destination operand of dest_instr is
549   * live going out of in. */
550  bool aia_instr_dest_live_out(Aia_Instr *in, Aia_Instr *dest_instr)
551  {
552     bool ret = true;
553
554     Aia_Operand *op = aia_instr_get_dest_op(dest_instr);
555
556     if (!op)
557        goto out;
558     if (!aia_instr_is_live_set_op(op))
559        goto out;
560     if (!aia_instr_is_live_set_instr(dest_instr))
561        goto out;
562
563     Aia_Instr *suc = aia_instr_get_sucessor(in);
564
565     if (!suc) {
566        Aia_Block *b = aia_instr_get_block(in);
567        Aia_Block *suc_block;
568        AIA_BLOCK_FOR_EACH_SUCESSOR(b, suc_block) {
569           suc = ___aia_block_peek_first_instr(suc_block);
570           if (live_set_contains(suc->meta_data, op)) {
571              ret = true;
572              goto out;
573           }
574        }
575        ret = false;
576     } else {
577        ret = live_set_contains(suc->meta_data, op);
578     }
579
580  out:
581     return ret;
582  }
583
584  static void aia_instr_live_set_dump(FILE *stream, Aia_Instr *in)
585  {
586     file_print_message(stream, S(" # live { "));
587     Live_Set_Entry *e;
588     Live_Set *s = in->meta_data;
589
590     Uns live_size = hash_map_size(s);
591     if (!live_size)
592        goto out;
593
594     LIVE_SET_FOR_EACH_ENTRY(s, e) {
595        aia_operand_dump(stream, e->live_operand, false);
596        if (--live_size)
597           file_print_message(stream, S(", "));
598     }
599
600  out:
601     file_print_message(stream, S(" }"));
602  }
603
604  void aia_instr_live_sets_dump(Aia *aia, Const_String postfix)
605  {
606     aia_set_instr_dump_callback(aia, aia_instr_live_set_dump);
607
608     String fname = string_from_format(S("%S.vitaly.%S"),
609           aia_get_file_name(aia), postfix);
```

```
610     FILE *f = file_open(fname, S("w"));
611     if (!f)
612        fatal_error(S("unable to open file %S for intermediate "
613                  "code dump [%m]\n"), fname);
614
615     string_destroy(fname);
616     aia_dump(aia, f);
617     file_close(f);
618
619     aia_clear_instr_dump_callback(aia);
620  }
```

:

A.8.14 src/aia/aia_instr_live_sets.h

```
1   #ifndef AIA_INSTR_LIVE_SETS_H
2   #define AIA_INSTR_LIVE_SETS_H
3
4   #include "aia.h"
5   #include <hash_map.h>
6
7   /* Uses instr->meta_data and aia->meta_data,
8    * so make sure they are free before calling aia_instr_live_sets().
9    * It is a requirement to let the instr->meta_data alone until
10  * aia_instr_live_sets_destroy() is called. */
11
12  typedef Hash_Map Live_Set;
13
14  typedef struct Live_Set_Entry {
15     Aia_Operand *live_operand;
16     Hash_Map_Slot hash_slot;
17  } Live_Set_Entry;
18
19  #define LIVE_SET_ENTRY_OF(slot) \
20     HASH_MAP_ENTRY(slot, Live_Set_Entry, hash_slot)
21
22  // Warning. Goto to break the loop.
23  #define LIVE_SET_FOR_EACH_ENTRY(live_set, ent)           \
24  for (Hash_Map_Slot *___s = INT_TO_PTR(1); ___s; ___s = NULL)    \
25     HASH_MAP_FOR_EACH((Live_Set *)live_set, ___s)         \
26        if ((ent = LIVE_SET_ENTRY_OF(___s)) || !ent)
27
28  #define AIA_INSTR_LIVE_SET_FOR_EACH_OP(instr, operand)    \
29     for (Live_Set_Entry *___e = NULL; !___e; ___e = INT_TO_PTR(1)) \
30        LIVE_SET_FOR_EACH_ENTRY((instr)->meta_data, ___e)   \
31           if ((operand = ___e->live_operand) || !operand)
32
33  typedef struct Aia_Operand_Entry {
34     Aia_Operand *op;
35     Hash_Map_Slot hash_slot;
36  } Aia_Operand_Entry;
37
38  #define AIA_OPERAND_ENTRY_OF(slot) \
39     HASH_MAP_ENTRY(slot, Aia_Operand_Entry, hash_slot)
40
41  /* Struct to force operands in live_operands live into instruction instr. */
42  typedef struct Aia_Instr_Forced_Liveness {
43     Aia_Instr *instr;
44     Vector live_operands;
45  } Aia_Instr_Forced_Liveness;
46
47  #define AIA_INSTR_FORCED_LIVENESS_INIT() ((Aia_Instr_Forced_Liveness){ \
48     .instr = NULL,                                        \
49     .live_operands = VECTOR_INIT()                        \
50  })
51
52  static inline void aia_instr_forced_liveness_add(Aia_Instr_Forced_Liveness *f,
53        Aia_Operand *op)
54  {
55     ___aia_operand_acquire(op);
```

```
56     vector_append(&f->live_operands, op);
57  }
58
59  static inline void aia_instr_forced_liveness_clear(
60        Aia_Instr_Forced_Liveness *f)
61  {
62     Aia_Operand *op;
63     VECTOR_FOR_EACH_ENTRY(&f->live_operands, op)
64        ___aia_operand_release(op);
65     vector_clear(&f->live_operands);
66  }
67
68  /* Saves Live sets in instr->meta_data.
69   * forced_liveness is a vector with Aia_Instr_Forced_Liveness structs
70   * to force liveness into instructions.
71   * forced_liveness == NULL is fine.
72   *
73   * If funcs_always_kill == true then the liveness analysis will
74   * assume that if a function kill some operand in some way
75   * the operand is never live in or out of the function. */
76  void aia_instr_live_sets(Aia *aia, Vector *forced_liveness,
77        bool funcs_always_kill);
78
79  /* Destroy the live sets in instr->meta_data. */
80  void aia_instr_live_sets_destroy(Aia *aia);
81
82  /* destroy live set in in->meta_data.
83   * Call this when an instruction is removed before
84   * calling aia_instr_live_sets_destroy(). */
85  void aia_instr_live_set_destroy(Aia_Instr *in);
86
87  /* Returns true if destination operand of dest_instr is
88   * live going out of in.
89   * Also returns true if dest == NULL. */
90  bool aia_instr_dest_live_out(Aia_Instr *in, Aia_Instr *dest_instr);
91
92  /* Dump IC with live sets and file name: "file.vit.vitaly.postfix". */
93  void aia_instr_live_sets_dump(Aia *aia, Const_String postfix);
94
95  /* Return true if instr has op in live set. */
96  bool aia_instr_live_set_contains(Aia_Instr *in, Aia_Operand *op);
97
98  #endif // AIA_INSTR_LIVE_SETS_H
```

:

A.8.15 src/aia/aia_optimize.c

```
1   #include "aia_optimize.h"
2   #include "aia_const_prop.h"
3   #include "aia_instr_elim.h"
4   #include "aia_block_elim.h"
5   #include "aia_unused_set.h"
6   #include "aia_def_to_use.h"
7   #include "aia_warn_undefined.h"
8   #include <main.h>
9
10  #undef DEBUG_TYPE
11  #define DEBUG_TYPE aia-optimize
12
13  void aia_optimize(Aia *aia)
14  {
15     if (!aia_is_valid(aia))
16        return;
17
18     aia_unused_set_eliminate(aia);
19
20     bool any_update;
21     Int it_count = 0;
22
23     inline void run()
```

```
24      {
25         do {
26            DLOG("optimize %S\n\tpass #%D\n",
27                  aia_get_file_name(aia), it_count + 1);
28            any_update = false;
29            any_update |= aia_const_prop(aia, it_count);
30            any_update |= aia_instr_elim(aia, it_count, false);
31            aia_def_to_use(aia, it_count);
32            ++it_count;
33         } while (any_update);
34      }
35
36      run();
37      aia_instr_elim(aia, it_count, true);
38      run();
39
40      aia_warn_undefined(aia);
41   }
```

:

A.8.16 src/aia/aia_optimize.h

```
1   #ifndef AIA_OPTIMIZE_H
2   #define AIA_OPTIMIZE_H
3
4   #include "aia.h"
5
6   void aia_optimize(Aia *aia);
7
8   #endif // AIA_OPTIMIZE_H
```

:

A.8.17 src/aia/aia_unused_set.c

```
1   #include "aia_unused_set.h"
2   #include "aia_instr_live_sets.h"
3   #include <main.h>
4
5   #ifdef SEQLEN
6   #undef SEQLEN
7   #endif
8
9   #ifdef SEQLAST
10  #undef SEQLAST
11  #endif
12
13  /* length of the instruction sequence: .cmp; .setxy; .cmp; .jxy; */
14  #define SEQLEN 4
15
16  #define SEQLAST (SEQLEN - 1)
17
18  static bool aia_unused_set_sequence(Aia_Instr *seq[SEQLEN],
19        Vector *removed_instr_dest)
20  {
21     if (aia_instr_get_type(seq[0]) != AIA_CMP)
22        return false;
23     if (!aia_instr_is_set_instr(seq[1]))
24        return false;
25     if (aia_instr_get_type(seq[2]) != AIA_CMP)
26        return false;
27     if (!aia_instr_is_cond_jump(seq[3]))
28        return false;
29
30     if (aia_instr_dest_live_out(seq[3], seq[1]))
31        return false;
```

```
32
33    inline bool operand_is_int0(Aia_Operand *op)
34    {
35       if (aia_operand_get_type(op) != AIA_OPERAND_CONST_INT)
36          return false;
37       return !aia_operand_const_int_get_val(op);
38    }
39
40    Aia_Operand *dest = aia_instr_get_dest_op(seq[1]);
41    if (!aia_operand_is_reg(dest))
42       return false;
43
44    Aia_Operand *op1 = aia_instr_get_src_op(seq[2], 0);
45    if (!aia_operands_equal(dest, op1))
46       return false;
47
48    Aia_Operand *op2 = aia_instr_get_src_op(seq[2], 1);
49    if (!operand_is_int0(op2))
50       return false;
51
52    uint16_t new_jump = AIA_JE; // assign something to make gcc shut up...
53
54    /* Assume the destination from the .set instruction is also destination
55     * in the 2nd .cmp instruction. */
56    switch (aia_instr_get_type(seq[1])) {
57    case AIA_SETE:
58       switch (aia_instr_get_type(seq[3])) {
59       case AIA_JNE:
60          new_jump = AIA_JE;
61          break;
62       case AIA_JE:
63          new_jump = AIA_JNE;
64          break;
65       case AIA_JG:
66          new_jump = AIA_JE;
67          break;
68       case AIA_JLE:
69          new_jump = AIA_JNE;
70          break;
71       case AIA_JL:
72          new_jump = AIA_JE;
73          break;
74       case AIA_JGE:
75          new_jump = AIA_JNE;
76          break;
77       default:
78          assert(false);
79       }
80       break;
81
82    case AIA_SETNE:
83       switch (aia_instr_get_type(seq[3])) {
84       case AIA_JNE:
85          new_jump = AIA_JNE;
86          break;
87       case AIA_JE:
88          new_jump = AIA_JE;
89          break;
90       case AIA_JG:
91          new_jump = AIA_JNE;
92          break;
93       case AIA_JLE:
94          new_jump = AIA_JE;
95          break;
96       case AIA_JL:
97          new_jump = AIA_JNE;
98          break;
99       case AIA_JGE:
100         new_jump = AIA_JE;
101         break;
102      default:
103         assert(false);
104      }
105      break;
```

```
106
107     case AIA_SETL:
108        switch (aia_instr_get_type(seq[3])) {
109        case AIA_JNE:
110           new_jump = AIA_JL;
111           break;
112        case AIA_JE:
113           new_jump = AIA_JGE;
114           break;
115        case AIA_JG:
116           new_jump = AIA_JL;
117           break;
118        case AIA_JLE:
119           new_jump = AIA_JGE;
120           break;
121        case AIA_JL:
122           new_jump = AIA_JL;
123           break;
124        case AIA_JGE:
125           new_jump = AIA_JGE;
126           break;
127        default:
128           assert(false);
129        }
130        break;
131
132     case AIA_SETGE:
133        switch (aia_instr_get_type(seq[3])) {
134        case AIA_JNE:
135           new_jump = AIA_JGE;
136           break;
137        case AIA_JE:
138           new_jump = AIA_JL;
139           break;
140        case AIA_JG:
141           new_jump = AIA_JGE;
142           break;
143        case AIA_JLE:
144           new_jump = AIA_JL;
145           break;
146        case AIA_JL:
147           new_jump = AIA_JGE;
148           break;
149        case AIA_JGE:
150           new_jump = AIA_JL;
151           break;
152        default:
153           assert(false);
154        }
155        break;
156
157     case AIA_SETG:
158        switch (aia_instr_get_type(seq[3])) {
159        case AIA_JNE:
160           new_jump = AIA_JG;
161           break;
162        case AIA_JE:
163           new_jump = AIA_JLE;
164           break;
165        case AIA_JG:
166           new_jump = AIA_JG;
167           break;
168        case AIA_JLE:
169           new_jump = AIA_JLE;
170           break;
171        case AIA_JL:
172           new_jump = AIA_JG;
173           break;
174        case AIA_JGE:
175           new_jump = AIA_JLE;
176           break;
177        default:
178           assert(false);
179        }
```

```
180         break;
181
182      case AIA_SETLE:
183         switch (aia_instr_get_type(seq[3])) {
184         case AIA_JNE:
185            new_jump = AIA_JLE;
186            break;
187         case AIA_JE:
188            new_jump = AIA_JG;
189            break;
190         case AIA_JG:
191            new_jump = AIA_JLE;
192            break;
193         case AIA_JLE:
194            new_jump = AIA_JG;
195            break;
196         case AIA_JL:
197            new_jump = AIA_JLE;
198            break;
199         case AIA_JGE:
200            new_jump = AIA_JG;
201            break;
202         default:
203            assert(false);
204         }
205         break;
206
207      default:
208         assert(false);
209      }
210
211      vector_append(removed_instr_dest, seq[1]);
212      vector_append(removed_instr_dest, seq[2]);
213      seq[3]->type = new_jump;
214
215      return true;
216   }
217
218   static void aia_unused_set_block(Aia_Block *b, Aia *aia)
219   {
220      VECTOR(removed_ins);
221
222      Aia_Instr *prev_ins[SEQLEN];
223      int i = 0;
224
225      Aia_Instr *in;
226      AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in) {
227         if (i < SEQLAST) {
228            prev_ins[i + 1] = in;
229         } else {
230            for (int j = 0; j < SEQLAST; j++) {
231               prev_ins[j] = prev_ins[j + 1];
232            }
233            prev_ins[SEQLAST] = in;
234            if (aia_unused_set_sequence(prev_ins, &removed_ins))
235               aia->meta_data = INT_TO_PTR(true);
236         }
237         ++i;
238      }
239
240      VECTOR_FOR_EACH_ENTRY(&removed_ins, in) {
241         aia_instr_live_set_destroy(in);
242         aia_instr_remove_destroy(in);
243      }
244      vector_clear(&removed_ins);
245   }
246
247   static void aia_unused_set_section(Aia_Section *sec, Aia *aia)
248   {
249      Aia_Block *b;
250      AIA_SECTION_FOR_EACH_BLOCK_REVERSED(sec, b)
251         aia_unused_set_block(b, aia);
252
253      Aia_Func *func;
```

```
254     AIA_SECTION_FOR_EACH_FUNC(sec, func) {
255        AIA_FUNC_FOR_EACH_BLOCK_REVERSED(func, b)
256           aia_unused_set_block(b, aia);
257
258        Aia_Func_Trampoline *tramp;
259        AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
260           aia_unused_set_block(tramp->block, aia);
261     }
262  }
263
264  bool aia_unused_set_eliminate(Aia *aia)
265  {
266     bool ret = false;
267     if (!cmdopts.opt_unused_set)
268        goto out;
269
270     aia_instr_live_sets(aia, NULL, false);
271
272     aia->meta_data = INT_TO_PTR(false);
273
274     Aia_Section *sec;
275     AIA_FOR_EACH_SECTION(aia, sec)
276        aia_unused_set_section(sec, aia);
277
278     ret = PTR_TO_INT(aia->meta_data);
279
280     aia_instr_live_sets_destroy(aia);
281
282  out:
283     return ret;
284  }
```

:

A.8.18 src/aia/aia_unused_set.h

```
1  #ifndef AIA_UNUSED_SET_H
2  #define AIA_UNUSED_SET_H
3
4  #include "aia.h"
5
6  bool aia_unused_set_eliminate(Aia *aia);
7
8  #endif // AIA_UNUSED_SET_H
```

:

A.8.19 src/x86_32/x86_32_regs.c

```
1  #include <aia/aia.h>
2  #include "x86_32_regs.h"
3  #include <hash_map.h>
4
5  CONST_STRING(reg_eax_str, "eax");
6  CONST_STRING(reg_al_str, "al");
7  CONST_STRING(reg_ah_str, "ah");
8
9  CONST_STRING(reg_ebx_str, "ebx");
10 CONST_STRING(reg_bl_str, "bl");
11 CONST_STRING(reg_bh_str, "bh");
12
13 CONST_STRING(reg_ecx_str, "ecx");
14 CONST_STRING(reg_cl_str, "cl");
15 CONST_STRING(reg_ch_str, "ch");
16
17 CONST_STRING(reg_edx_str, "edx");
18 CONST_STRING(reg_dl_str, "dl");
```

```
19  CONST_STRING(reg_dh_str, "dh");
20
21  CONST_STRING(reg_esi_str, "esi");
22  CONST_STRING(reg_edi_str, "edi");
23  CONST_STRING(reg_ebp_str, "ebp");
24  CONST_STRING(reg_esp_str, "esp");
25
26  Aia_Operand *reg_eax;
27  Aia_Operand *reg_al;
28  Aia_Operand *reg_ah;
29
30  Aia_Operand *reg_edx;
31  Aia_Operand *reg_dl;
32  Aia_Operand *reg_dh;
33
34  Aia_Operand *reg_ecx;
35  Aia_Operand *reg_cl;
36  Aia_Operand *reg_ch;
37
38  Aia_Operand *reg_ebx;
39  Aia_Operand *reg_bl;
40  Aia_Operand *reg_bh;
41
42  Aia_Operand *reg_esi;
43  Aia_Operand *reg_edi;
44  Aia_Operand *reg_ebp;
45  Aia_Operand *reg_esp;
46
47  X86_32_Reg_List *reg_list_eax;
48  X86_32_Reg_List *reg_list_al;
49  X86_32_Reg_List *reg_list_ah;
50
51  X86_32_Reg_List *reg_list_ebx;
52  X86_32_Reg_List *reg_list_bl;
53  X86_32_Reg_List *reg_list_bh;
54
55  X86_32_Reg_List *reg_list_ecx;
56  X86_32_Reg_List *reg_list_cl;
57  X86_32_Reg_List *reg_list_ch;
58
59  X86_32_Reg_List *reg_list_dl;
60  X86_32_Reg_List *reg_list_dh;
61  X86_32_Reg_List *reg_list_edx;
62
63  X86_32_Reg_List *reg_list_esi;
64  X86_32_Reg_List *reg_list_edi;
65  X86_32_Reg_List *reg_list_ebp;
66  X86_32_Reg_List *reg_list_esp;
67
68  typedef struct Reg_Idx_Entry {
69     Const_String reg_name;
70     Int reg_idx;
71     Hash_Map_Slot hash_slot;
72  } Reg_Idx_Entry;
73
74  #define REG_IDX_ENTRY_OF(slot) HASH_MAP_ENTRY(slot, Reg_Idx_Entry, hash_slot)
75
76  static bool idx_reg_hash_compare(ssize_t reg_idx, Hash_Map_Slot *slot)
77  {
78     Reg_Idx_Entry *e = REG_IDX_ENTRY_OF(slot);
79     return e->reg_idx == reg_idx;
80  }
81
82  static bool reg_idx_hash_compare(String reg_name, Hash_Map_Slot *slot)
83  {
84     Reg_Idx_Entry *e = REG_IDX_ENTRY_OF(slot);
85     return !string_compare(reg_name, e->reg_name);
86  }
87
88  static void reg_idx_hash_destroy(Hash_Map_Slot *s)
89  {
90     free_mem(REG_IDX_ENTRY_OF(s));
91  }
92
```

```
93  HASH_MAP_SIZE(reg_idx_to_lo8bit_name, HASH_MAP_SIZE_11,
94           (Hash_Map_Comparator)idx_reg_hash_compare);
95
96  HASH_MAP_SIZE(reg_idx_to_32bit_name, HASH_MAP_SIZE_11,
97           (Hash_Map_Comparator)idx_reg_hash_compare);
98
99  HASH_MAP_SIZE(reg_name_to_idx, HASH_MAP_SIZE_23,
100          (Hash_Map_Comparator)reg_idx_hash_compare);
101
102 Int x86_32_reg_name_get_idx(Const_String reg_name)
103 {
104    Uns hash = string_hash_code(reg_name);
105    Hash_Map_Slot *slot = hash_map_get(&reg_name_to_idx, (String)reg_name,
106          hash);
107    if (!slot)
108       return -1;
109    return REG_IDX_ENTRY_OF(slot)->reg_idx;
110 }
111
112 Const_String x86_32_reg_idx_get_lo8bit_name(Int idx)
113 {
114    Hash_Map_Slot *slot = hash_map_get(&reg_idx_to_lo8bit_name,
115          INT_TO_PTR(idx), idx);
116    if (!slot)
117       return NULL;
118    return REG_IDX_ENTRY_OF(slot)->reg_name;
119 }
120
121 Const_String x86_32_reg_idx_get_32bit_name(Int idx)
122 {
123    Hash_Map_Slot *slot = hash_map_get(&reg_idx_to_32bit_name,
124          INT_TO_PTR(idx), idx);
125    if (!slot)
126       return NULL;
127    return REG_IDX_ENTRY_OF(slot)->reg_name;
128 }
129
130 typedef struct Reg_Str_Entry {
131    Const_String reg;
132    Hash_Map_Slot hash_slot;
133 } Reg_Str_Entry;
134
135 #define REG_STR_ENTRY_OF(slot) HASH_MAP_ENTRY(slot, Reg_Str_Entry, hash_slot)
136
137 static bool reg_str_map_compare(String search_reg, Hash_Map_Slot *s)
138 {
139    Reg_Str_Entry *e = REG_STR_ENTRY_OF(s);
140    return !string_compare(e->reg, search_reg);
141 }
142
143 static HASH_MAP(reg_str_map, (Hash_Map_Comparator)reg_str_map_compare);
144
145 static void reg_str_map_hash_destroy(Hash_Map_Slot *s)
146 {
147    free_mem(REG_STR_ENTRY_OF(s));
148 }
149
150 #define X86_32_REG_LIST_OF(slot) \
151    HASH_MAP_ENTRY(slot, X86_32_Reg_List, hash_slot)
152
153 static bool reg_list_map_compare(String search_reg, Hash_Map_Slot *s)
154 {
155    X86_32_Reg_List *list = X86_32_REG_LIST_OF(s);
156    return !string_compare(aia_operand_reg_get_name(list->reg_list[0]),
157          search_reg);
158 }
159
160 static HASH_MAP(reg_list_map, (Hash_Map_Comparator)reg_list_map_compare);
161
162 static void reg_list_map_hash_destroy(Hash_Map_Slot *s)
163 {
164    free_mem(X86_32_REG_LIST_OF(s));
165 }
166
```

```
167 void x86_32_regs_init(Aia *aia)
168 {
169    Uns hash1, hash2, hash3;
170    Reg_Str_Entry *str_e;
171
172    reg_eax = aia_operand_reg_alloc(aia, reg_eax_str);
173    str_e = ALLOC_NEW(Reg_Str_Entry);
174    str_e->reg = reg_eax_str;
175    hash1 = string_hash_code(reg_eax_str);
176    hash_map_insert(&reg_str_map, &str_e->hash_slot, hash1);
177    ___aia_operand_acquire(reg_eax);
178
179    reg_al = aia_operand_reg_alloc(aia, reg_al_str);
180    str_e = ALLOC_NEW(Reg_Str_Entry);
181    str_e->reg = reg_al_str;
182    hash2 = string_hash_code(reg_al_str);
183    hash_map_insert(&reg_str_map, &str_e->hash_slot, hash2);
184    ___aia_operand_acquire(reg_al);
185
186    reg_ah = aia_operand_reg_alloc(aia, reg_ah_str);
187    str_e = ALLOC_NEW(Reg_Str_Entry);
188    str_e->reg = reg_ah_str;
189    hash3 = string_hash_code(reg_ah_str);
190    hash_map_insert(&reg_str_map, &str_e->hash_slot, hash3);
191    ___aia_operand_acquire(reg_ah);
192
193    reg_list_eax = alloc_mem(sizeof(X86_32_Reg_List) +
194          sizeof(Aia_Operand *) * 3);
195    reg_list_eax->num_regs = 3;
196    reg_list_eax->reg_list[0] = reg_eax;
197    reg_list_eax->reg_list[1] = reg_al;
198    reg_list_eax->reg_list[2] = reg_ah;
199    hash_map_insert(&reg_list_map, &reg_list_eax->hash_slot, hash1);
200
201    reg_list_al = alloc_mem(sizeof(X86_32_Reg_List) +
202          sizeof(Aia_Operand *) * 2);
203    reg_list_al->num_regs = 2;
204    reg_list_al->reg_list[0] = reg_al;
205    reg_list_al->reg_list[1] = reg_eax;
206    hash_map_insert(&reg_list_map, &reg_list_al->hash_slot, hash2);
207
208    reg_list_ah = alloc_mem(sizeof(X86_32_Reg_List) +
209          sizeof(Aia_Operand *) * 2);
210    reg_list_ah->num_regs = 2;
211    reg_list_ah->reg_list[0] = reg_ah;
212    reg_list_ah->reg_list[1] = reg_eax;
213    hash_map_insert(&reg_list_map, &reg_list_ah->hash_slot, hash3);
214
215    reg_edx = aia_operand_reg_alloc(aia, reg_edx_str);
216    str_e = ALLOC_NEW(Reg_Str_Entry);
217    str_e->reg = reg_edx_str;
218    hash1 = string_hash_code(reg_edx_str);
219    hash_map_insert(&reg_str_map, &str_e->hash_slot, hash1);
220    ___aia_operand_acquire(reg_edx);
221
222    reg_dl = aia_operand_reg_alloc(aia, reg_dl_str);
223    str_e = ALLOC_NEW(Reg_Str_Entry);
224    str_e->reg = reg_dl_str;
225    hash2 = string_hash_code(reg_dl_str);
226    hash_map_insert(&reg_str_map, &str_e->hash_slot, hash2);
227    ___aia_operand_acquire(reg_dl);
228
229    reg_dh = aia_operand_reg_alloc(aia, reg_dh_str);
230    str_e = ALLOC_NEW(Reg_Str_Entry);
231    str_e->reg = reg_dh_str;
232    hash3 = string_hash_code(reg_dh_str);
233    hash_map_insert(&reg_str_map, &str_e->hash_slot, hash3);
234    ___aia_operand_acquire(reg_dh);
235
236    reg_list_edx = alloc_mem(sizeof(X86_32_Reg_List) +
237          sizeof(Aia_Operand *) * 3);
238    reg_list_edx->num_regs = 3;
239    reg_list_edx->reg_list[0] = reg_edx;
240    reg_list_edx->reg_list[1] = reg_dl;
```

```
241     reg_list_edx->reg_list[2] = reg_dh;
242     hash_map_insert(&reg_list_map, &reg_list_edx->hash_slot, hash1);
243
244     reg_list_dl = alloc_mem(sizeof(X86_32_Reg_List) +
245           sizeof(Aia_Operand *) * 2);
246     reg_list_dl->num_regs = 2;
247     reg_list_dl->reg_list[0] = reg_dl;
248     reg_list_dl->reg_list[1] = reg_edx;
249     hash_map_insert(&reg_list_map, &reg_list_dl->hash_slot, hash2);
250
251     reg_list_dh = alloc_mem(sizeof(X86_32_Reg_List) +
252           sizeof(Aia_Operand *) * 2);
253     reg_list_dh->num_regs = 2;
254     reg_list_dh->reg_list[0] = reg_dh;
255     reg_list_dh->reg_list[1] = reg_edx;
256     hash_map_insert(&reg_list_map, &reg_list_dh->hash_slot, hash3);
257
258     reg_ecx = aia_operand_reg_alloc(aia, reg_ecx_str);
259     str_e = ALLOC_NEW(Reg_Str_Entry);
260     str_e->reg = reg_ecx_str;
261     hash1 = string_hash_code(reg_ecx_str);
262     hash_map_insert(&reg_str_map, &str_e->hash_slot, hash1);
263     ___aia_operand_acquire(reg_ecx);
264
265     reg_cl = aia_operand_reg_alloc(aia, reg_cl_str);
266     str_e = ALLOC_NEW(Reg_Str_Entry);
267     str_e->reg = reg_cl_str;
268     hash2 = string_hash_code(reg_cl_str);
269     hash_map_insert(&reg_str_map, &str_e->hash_slot, hash2);
270     ___aia_operand_acquire(reg_cl);
271
272     reg_ch = aia_operand_reg_alloc(aia, reg_ch_str);
273     str_e = ALLOC_NEW(Reg_Str_Entry);
274     str_e->reg = reg_ch_str;
275     hash3 = string_hash_code(reg_ch_str);
276     hash_map_insert(&reg_str_map, &str_e->hash_slot, hash3);
277     ___aia_operand_acquire(reg_ch);
278
279     reg_list_ecx = alloc_mem(sizeof(X86_32_Reg_List) +
280           sizeof(Aia_Operand *) * 3);
281     reg_list_ecx->num_regs = 3;
282     reg_list_ecx->reg_list[0] = reg_ecx;
283     reg_list_ecx->reg_list[1] = reg_cl;
284     reg_list_ecx->reg_list[2] = reg_ch;
285     hash_map_insert(&reg_list_map, &reg_list_ecx->hash_slot, hash1);
286
287     reg_list_cl = alloc_mem(sizeof(X86_32_Reg_List) +
288           sizeof(Aia_Operand *) * 2);
289     reg_list_cl->num_regs = 2;
290     reg_list_cl->reg_list[0] = reg_cl;
291     reg_list_cl->reg_list[1] = reg_ecx;
292     hash_map_insert(&reg_list_map, &reg_list_cl->hash_slot, hash2);
293
294     reg_list_ch = alloc_mem(sizeof(X86_32_Reg_List) +
295           sizeof(Aia_Operand *) * 2);
296     reg_list_ch->num_regs = 2;
297     reg_list_ch->reg_list[0] = reg_ch;
298     reg_list_ch->reg_list[1] = reg_ecx;
299     hash_map_insert(&reg_list_map, &reg_list_ch->hash_slot, hash3);
300
301     reg_ebx = aia_operand_reg_alloc(aia, reg_ebx_str);
302     str_e = ALLOC_NEW(Reg_Str_Entry);
303     str_e->reg = reg_ebx_str;
304     hash1 = string_hash_code(reg_ebx_str);
305     hash_map_insert(&reg_str_map, &str_e->hash_slot, hash1);
306     ___aia_operand_acquire(reg_ebx);
307
308     reg_bl = aia_operand_reg_alloc(aia, reg_bl_str);
309     str_e = ALLOC_NEW(Reg_Str_Entry);
310     str_e->reg = reg_bl_str;
311     hash2 = string_hash_code(reg_bl_str);
312     hash_map_insert(&reg_str_map, &str_e->hash_slot, hash2);
313     ___aia_operand_acquire(reg_bl);
314
```

```
315     reg_bh = aia_operand_reg_alloc(aia, reg_bh_str);
316     str_e = ALLOC_NEW(Reg_Str_Entry);
317     str_e->reg = reg_bh_str;
318     hash3 = string_hash_code(reg_bh_str);
319     hash_map_insert(&reg_str_map, &str_e->hash_slot, hash3);
320     ___aia_operand_acquire(reg_bh);
321
322     reg_list_ebx = alloc_mem(sizeof(X86_32_Reg_List) +
323           sizeof(Aia_Operand *) * 3);
324     reg_list_ebx->num_regs = 3;
325     reg_list_ebx->reg_list[0] = reg_ebx;
326     reg_list_ebx->reg_list[1] = reg_bl;
327     reg_list_ebx->reg_list[2] = reg_bh;
328     hash_map_insert(&reg_list_map, &reg_list_ebx->hash_slot, hash1);
329
330     reg_list_bl = alloc_mem(sizeof(X86_32_Reg_List) +
331           sizeof(Aia_Operand *) * 2);
332     reg_list_bl->num_regs = 2;
333     reg_list_bl->reg_list[0] = reg_bl;
334     reg_list_bl->reg_list[1] = reg_ebx;
335     hash_map_insert(&reg_list_map, &reg_list_bl->hash_slot, hash2);
336
337     reg_list_bh = alloc_mem(sizeof(X86_32_Reg_List) +
338           sizeof(Aia_Operand *) * 2);
339     reg_list_bh->num_regs = 2;
340     reg_list_bh->reg_list[0] = reg_bh;
341     reg_list_bh->reg_list[1] = reg_ebx;
342     hash_map_insert(&reg_list_map, &reg_list_bh->hash_slot, hash3);
343
344     reg_esi = aia_operand_reg_alloc(aia, reg_esi_str);
345     str_e = ALLOC_NEW(Reg_Str_Entry);
346     str_e->reg = reg_esi_str;
347     hash1 = string_hash_code(reg_esi_str);
348     hash_map_insert(&reg_str_map, &str_e->hash_slot, hash1);
349     ___aia_operand_acquire(reg_esi);
350
351     reg_list_esi = alloc_mem(sizeof(X86_32_Reg_List) + sizeof(Aia_Operand *));
352     reg_list_esi->num_regs = 1;
353     reg_list_esi->reg_list[0] = reg_esi;
354     hash_map_insert(&reg_list_map, &reg_list_esi->hash_slot, hash1);
355
356     reg_edi = aia_operand_reg_alloc(aia, reg_edi_str);
357     str_e = ALLOC_NEW(Reg_Str_Entry);
358     str_e->reg = reg_edi_str;
359     hash1 = string_hash_code(reg_edi_str);
360     hash_map_insert(&reg_str_map, &str_e->hash_slot, hash1);
361     ___aia_operand_acquire(reg_edi);
362
363     reg_list_edi = alloc_mem(sizeof(X86_32_Reg_List) + sizeof(Aia_Operand *));
364     reg_list_edi->num_regs = 1;
365     reg_list_edi->reg_list[0] = reg_edi;
366     hash_map_insert(&reg_list_map, &reg_list_edi->hash_slot, hash1);
367
368     reg_ebp = aia_operand_reg_alloc(aia, reg_ebp_str);
369     str_e = ALLOC_NEW(Reg_Str_Entry);
370     str_e->reg = reg_ebp_str;
371     hash1 = string_hash_code(reg_ebp_str);
372     hash_map_insert(&reg_str_map, &str_e->hash_slot, hash1);
373     ___aia_operand_acquire(reg_ebp);
374
375     reg_list_ebp = alloc_mem(sizeof(X86_32_Reg_List) + sizeof(Aia_Operand *));
376     reg_list_ebp->num_regs = 1;
377     reg_list_ebp->reg_list[0] = reg_ebp;
378     hash_map_insert(&reg_list_map, &reg_list_ebp->hash_slot, hash1);
379
380     reg_esp = aia_operand_reg_alloc(aia, reg_esp_str);
381     str_e = ALLOC_NEW(Reg_Str_Entry);
382     str_e->reg = reg_esp_str;
383     hash1 = string_hash_code(reg_esp_str);
384     hash_map_insert(&reg_str_map, &str_e->hash_slot, hash1);
385     ___aia_operand_acquire(reg_esp);
386
387     reg_list_esp = alloc_mem(sizeof(X86_32_Reg_List) + sizeof(Aia_Operand *));
388     reg_list_esp->num_regs = 1;
```

```
389     reg_list_esp->reg_list[0] = reg_esp;
390     hash_map_insert(&reg_list_map, &reg_list_esp->hash_slot, hash1);
391
392     /* Important. The given register indices are significant. */
393
394     Reg_Idx_Entry *regi_en;
395     Const_String reg_name;
396
397     reg_name = reg_eax_str;
398     regi_en = ALLOC_NEW(Reg_Idx_Entry);
399     regi_en->reg_name = reg_name;
400     regi_en->reg_idx = 0;
401     hash_map_insert(&reg_name_to_idx, &regi_en->hash_slot,
402           string_hash_code(reg_name));
403
404     reg_name = reg_al_str;
405     regi_en = ALLOC_NEW(Reg_Idx_Entry);
406     regi_en->reg_name = reg_name;
407     regi_en->reg_idx = 0;
408     hash_map_insert(&reg_name_to_idx, &regi_en->hash_slot,
409           string_hash_code(reg_name));
410
411     reg_name = reg_ah_str;
412     regi_en = ALLOC_NEW(Reg_Idx_Entry);
413     regi_en->reg_name = reg_name;
414     regi_en->reg_idx = 0;
415     hash_map_insert(&reg_name_to_idx, &regi_en->hash_slot,
416           string_hash_code(reg_name));
417
418     reg_name = reg_edx_str;
419     regi_en = ALLOC_NEW(Reg_Idx_Entry);
420     regi_en->reg_name = reg_name;
421     regi_en->reg_idx = 1;
422     hash_map_insert(&reg_name_to_idx, &regi_en->hash_slot,
423           string_hash_code(reg_name));
424
425     reg_name = reg_dl_str;
426     regi_en = ALLOC_NEW(Reg_Idx_Entry);
427     regi_en->reg_name = reg_name;
428     regi_en->reg_idx = 1;
429     hash_map_insert(&reg_name_to_idx, &regi_en->hash_slot,
430           string_hash_code(reg_name));
431
432     reg_name = reg_dh_str;
433     regi_en = ALLOC_NEW(Reg_Idx_Entry);
434     regi_en->reg_name = reg_name;
435     regi_en->reg_idx = 1;
436     hash_map_insert(&reg_name_to_idx, &regi_en->hash_slot,
437           string_hash_code(reg_name));
438
439     reg_name = reg_ecx_str;
440     regi_en = ALLOC_NEW(Reg_Idx_Entry);
441     regi_en->reg_name = reg_name;
442     regi_en->reg_idx = 2;
443     hash_map_insert(&reg_name_to_idx, &regi_en->hash_slot,
444           string_hash_code(reg_name));
445
446     reg_name = reg_cl_str;
447     regi_en = ALLOC_NEW(Reg_Idx_Entry);
448     regi_en->reg_name = reg_name;
449     regi_en->reg_idx = 2;
450     hash_map_insert(&reg_name_to_idx, &regi_en->hash_slot,
451           string_hash_code(reg_name));
452
453     reg_name = reg_ch_str;
454     regi_en = ALLOC_NEW(Reg_Idx_Entry);
455     regi_en->reg_name = reg_name;
456     regi_en->reg_idx = 2;
457     hash_map_insert(&reg_name_to_idx, &regi_en->hash_slot,
458           string_hash_code(reg_name));
459
460     reg_name = reg_ebx_str;
461     regi_en = ALLOC_NEW(Reg_Idx_Entry);
462     regi_en->reg_name = reg_name;
```

```
463     regi_en->reg_idx = 3;
464     hash_map_insert(&reg_name_to_idx, &regi_en->hash_slot,
465           string_hash_code(reg_name));
466
467     reg_name = reg_bl_str;
468     regi_en = ALLOC_NEW(Reg_Idx_Entry);
469     regi_en->reg_name = reg_name;
470     regi_en->reg_idx = 3;
471     hash_map_insert(&reg_name_to_idx, &regi_en->hash_slot,
472           string_hash_code(reg_name));
473
474     reg_name = reg_bh_str;
475     regi_en = ALLOC_NEW(Reg_Idx_Entry);
476     regi_en->reg_name = reg_name;
477     regi_en->reg_idx = 3;
478     hash_map_insert(&reg_name_to_idx, &regi_en->hash_slot,
479           string_hash_code(reg_name));
480
481     reg_name = reg_esi_str;
482     regi_en = ALLOC_NEW(Reg_Idx_Entry);
483     regi_en->reg_name = reg_name;
484     regi_en->reg_idx = 4;
485     hash_map_insert(&reg_name_to_idx, &regi_en->hash_slot,
486           string_hash_code(reg_name));
487
488     reg_name = reg_edi_str;
489     regi_en = ALLOC_NEW(Reg_Idx_Entry);
490     regi_en->reg_name = reg_name;
491     regi_en->reg_idx = 5;
492     hash_map_insert(&reg_name_to_idx, &regi_en->hash_slot,
493           string_hash_code(reg_name));
494
495     reg_name = reg_ebp_str;
496     regi_en = ALLOC_NEW(Reg_Idx_Entry);
497     regi_en->reg_name = reg_name;
498     regi_en->reg_idx = 6;
499     hash_map_insert(&reg_name_to_idx, &regi_en->hash_slot,
500           string_hash_code(reg_name));
501
502     regi_en = ALLOC_NEW(Reg_Idx_Entry);
503     regi_en->reg_name = reg_eax_str;
504     regi_en->reg_idx = 0;
505     hash_map_insert(&reg_idx_to_32bit_name, &regi_en->hash_slot,
506           (Uns)regi_en->reg_idx);
507
508     regi_en = ALLOC_NEW(Reg_Idx_Entry);
509     regi_en->reg_name = reg_edx_str;
510     regi_en->reg_idx = 1;
511     hash_map_insert(&reg_idx_to_32bit_name, &regi_en->hash_slot,
512           (Uns)regi_en->reg_idx);
513
514     regi_en = ALLOC_NEW(Reg_Idx_Entry);
515     regi_en->reg_name = reg_ecx_str;
516     regi_en->reg_idx = 2;
517     hash_map_insert(&reg_idx_to_32bit_name, &regi_en->hash_slot,
518           (Uns)regi_en->reg_idx);
519
520     regi_en = ALLOC_NEW(Reg_Idx_Entry);
521     regi_en->reg_name = reg_ebx_str;
522     regi_en->reg_idx = 3;
523     hash_map_insert(&reg_idx_to_32bit_name, &regi_en->hash_slot,
524           (Uns)regi_en->reg_idx);
525
526     regi_en = ALLOC_NEW(Reg_Idx_Entry);
527     regi_en->reg_name = reg_esi_str;
528     regi_en->reg_idx = 4;
529     hash_map_insert(&reg_idx_to_32bit_name, &regi_en->hash_slot,
530           (Uns)regi_en->reg_idx);
531
532     regi_en = ALLOC_NEW(Reg_Idx_Entry);
533     regi_en->reg_name = reg_edi_str;
534     regi_en->reg_idx = 5;
535     hash_map_insert(&reg_idx_to_32bit_name, &regi_en->hash_slot,
536           (Uns)regi_en->reg_idx);
```

```
537
538     regi_en = ALLOC_NEW(Reg_Idx_Entry);
539     regi_en->reg_name = reg_ebp_str;
540     regi_en->reg_idx = 6;
541     hash_map_insert(&reg_idx_to_32bit_name, &regi_en->hash_slot,
542           (Uns)regi_en->reg_idx);
543
544     regi_en = ALLOC_NEW(Reg_Idx_Entry);
545     regi_en->reg_name = reg_al_str;
546     regi_en->reg_idx = 0;
547     hash_map_insert(&reg_idx_to_lo8bit_name, &regi_en->hash_slot,
548           (Uns)regi_en->reg_idx);
549
550     regi_en = ALLOC_NEW(Reg_Idx_Entry);
551     regi_en->reg_name = reg_dl_str;
552     regi_en->reg_idx = 1;
553     hash_map_insert(&reg_idx_to_lo8bit_name, &regi_en->hash_slot,
554           (Uns)regi_en->reg_idx);
555
556     regi_en = ALLOC_NEW(Reg_Idx_Entry);
557     regi_en->reg_name = reg_cl_str;
558     regi_en->reg_idx = 2;
559     hash_map_insert(&reg_idx_to_lo8bit_name, &regi_en->hash_slot,
560           (Uns)regi_en->reg_idx);
561
562     regi_en = ALLOC_NEW(Reg_Idx_Entry);
563     regi_en->reg_name = reg_bl_str;
564     regi_en->reg_idx = 3;
565     hash_map_insert(&reg_idx_to_lo8bit_name, &regi_en->hash_slot,
566           (Uns)regi_en->reg_idx);
567 }
568
569 void x86_32_regs_release()
570 {
571     ___aia_operand_release(reg_eax);
572     ___aia_operand_release(reg_al);
573     ___aia_operand_release(reg_ah);
574
575     ___aia_operand_release(reg_edx);
576     ___aia_operand_release(reg_dl);
577     ___aia_operand_release(reg_dh);
578
579     ___aia_operand_release(reg_ecx);
580     ___aia_operand_release(reg_cl);
581     ___aia_operand_release(reg_ch);
582
583     ___aia_operand_release(reg_ebx);
584     ___aia_operand_release(reg_bl);
585     ___aia_operand_release(reg_bh);
586
587     ___aia_operand_release(reg_esi);
588     ___aia_operand_release(reg_edi);
589     ___aia_operand_release(reg_ebp);
590     ___aia_operand_release(reg_esp);
591
592     hash_map_for_each_destroy(&reg_str_map, reg_str_map_hash_destroy);
593     hash_map_for_each_destroy(&reg_list_map, reg_list_map_hash_destroy);
594
595     hash_map_for_each_destroy(&reg_name_to_idx, reg_idx_hash_destroy);
596     hash_map_for_each_destroy(&reg_idx_to_32bit_name, reg_idx_hash_destroy);
597     hash_map_for_each_destroy(&reg_idx_to_lo8bit_name, reg_idx_hash_destroy);
598 }
599
600 bool x86_32_is_concrete_reg_str(Const_String str)
601 {
602     return hash_map_contains(&reg_str_map, (String)str, string_hash_code(str));
603 }
604
605 bool x86_32_is_concrete_reg(Aia_Operand *op)
606 {
607     if (!aia_operand_get_type(op) == AIA_OPERAND_REG)
608         return false;
609
610     return x86_32_is_concrete_reg_str(aia_operand_reg_get_name(op));
```

```
611 }
612
613 Aia_Operand *x86_32_get_reg_operand(Const_String reg_str)
614 {
615    X86_32_Reg_List *list = x86_32_get_reg_list(reg_str);
616    if (!list)
617       return NULL;
618    return list->reg_list[0];
619 }
620
621 X86_32_Reg_List *x86_32_get_reg_list(Const_String reg)
622 {
623    Hash_Map_Slot *slot = hash_map_get(&reg_list_map, (String)reg,
624          string_hash_code(reg));
625    if (slot)
626       return X86_32_REG_LIST_OF(slot);
627
628    return NULL;
629 }
630
631 bool x86_32_is_callee_save_reg_str(Const_String str)
632 {
633    Int idx = x86_32_reg_name_get_idx(str);
634    if (idx <= 2)
635       return false;
636    return true;
637 }
```

:

A.8.20 src/x86_32/x86_32_regs.h

```
1  #ifndef X86_32_REGS_H
2  #define X86_32_REGS_H
3
4  #include <aia/aia.h>
5
6  #define X86_32_REG_COUNT  7
7  #define X86_32_REG_COUNT_8BIT (X86_32_REG_COUNT - 3)
8
9  typedef struct X86_32_Reg_List {
10    Uns num_regs;
11    Hash_Map_Slot hash_slot;
12    Aia_Operand *reg_list[0];
13 } X86_32_Reg_List;
14
15 extern Const_String reg_eax_str;
16 extern Const_String reg_al_str;
17 extern Const_String reg_ah_str;
18
19 extern Const_String reg_ebx_str;
20 extern Const_String reg_bl_str;
21 extern Const_String reg_bh_str;
22
23 extern Const_String reg_ecx_str;
24 extern Const_String reg_cl_str;
25 extern Const_String reg_ch_str;
26
27 extern Const_String reg_edx_str;
28 extern Const_String reg_dl_str;
29 extern Const_String reg_dh_str;
30
31 extern Const_String reg_esi_str;
32 extern Const_String reg_edi_str;
33 extern Const_String reg_ebp_str;
34 extern Const_String reg_esp_str;
35
36 extern Aia_Operand *reg_eax;
37 extern Aia_Operand *reg_al;
38 extern Aia_Operand *reg_ah;
39
```

```
40  extern Aia_Operand *reg_ebx;
41  extern Aia_Operand *reg_bl;
42  extern Aia_Operand *reg_bh;
43
44  extern Aia_Operand *reg_ecx;
45  extern Aia_Operand *reg_cl;
46  extern Aia_Operand *reg_ch;
47
48  extern Aia_Operand *reg_edx;
49  extern Aia_Operand *reg_dl;
50  extern Aia_Operand *reg_dh;
51
52  extern Aia_Operand *reg_esi;
53  extern Aia_Operand *reg_edi;
54  extern Aia_Operand *reg_ebp;
55  extern Aia_Operand *reg_esp;
56
57  extern X86_32_Reg_List *reg_list_eax;
58  extern X86_32_Reg_List *reg_list_al;
59  extern X86_32_Reg_List *reg_list_ah;
60
61  extern X86_32_Reg_List *reg_list_ebx;
62  extern X86_32_Reg_List *reg_list_bl;
63  extern X86_32_Reg_List *reg_list_bh;
64
65  extern X86_32_Reg_List *reg_list_ecx;
66  extern X86_32_Reg_List *reg_list_cl;
67  extern X86_32_Reg_List *reg_list_ch;
68
69  extern X86_32_Reg_List *reg_list_dl;
70  extern X86_32_Reg_List *reg_list_dh;
71  extern X86_32_Reg_List *reg_list_edx;
72
73  extern X86_32_Reg_List *reg_list_esi;
74  extern X86_32_Reg_List *reg_list_edi;
75  extern X86_32_Reg_List *reg_list_ebp;
76  extern X86_32_Reg_List *reg_list_esp;
77
78  void x86_32_regs_init(Aia *aia);
79
80  void x86_32_regs_release();
81
82  bool x86_32_is_callee_save_reg_str(Const_String str);
83
84  static inline bool x86_32_is_callee_save_reg(Aia_Operand *reg)
85  {
86     return x86_32_is_callee_save_reg_str(aia_operand_reg_get_name(reg));
87  }
88
89  Int x86_32_reg_name_get_idx(Const_String reg_name);
90
91  static inline Int x86_32_reg_get_idx(Aia_Operand *reg)
92  {
93     return x86_32_reg_name_get_idx(aia_operand_reg_get_name(reg));
94  }
95
96  Const_String x86_32_reg_idx_get_lo8bit_name(Int idx);
97
98  Const_String x86_32_reg_idx_get_32bit_name(Int idx);
99
100 bool x86_32_is_concrete_reg_str(Const_String str);
101
102 bool x86_32_is_concrete_reg(Aia_Operand *op);
103
104 Aia_Operand *x86_32_get_reg_operand(Const_String reg_str);
105
106 X86_32_Reg_List *x86_32_get_reg_list(Const_String reg);
107
108 #endif // X86_32_REGS_H
```

:

A.8.21 src/x86_32/x86_32_reg_alloc.h

```
#ifndef X86_32_REG_ALLOC_H
#define X86_32_REG_ALLOC_H

#include "x86_32_reg_alloc_color.h"

/* Does register allocation.
 * repl_map is mapping temporary registers to memory locations
 * which should be used as spill location. */
static inline void x86_32_reg_alloc(Aia *aia, Aia_Operand_Map *repl_map)
{
   x86_32_reg_alloc_color(aia, repl_map);
}

#endif // X86_32_REG_ALLOC_H
```

:

A.8.22 src/x86_32/x86_32_reg_alloc_color.c

```
#include "x86_32_regs.h"
#include "x86_32_normalize.h"
#include <hash_map.h>
#include <string_builder.h>
#include <aia/aia_operand_map.h>
#include <aia/aia_normalize_addr.h>
#include <main.h>

#undef DEBUG_TYPE
#define DEBUG_TYPE liveness-alloc

typedef struct Live_Node {
   Aia_Operand *init_operand;
   Const_String init_var_name;
   Const_String assigned_var_name;
   Vector interferences;
   Hash_Map interference_map;
   Double_List_Node dbnode;
   Hash_Map_Slot graph_slot;
   Hash_Map_Slot regraph_slot;
   Int reg_idx;
   uint8_t var_size;
} Live_Node;

typedef struct Live_Node_Inter_Entry {
   Live_Node *node;
   Hash_Map_Slot hash_slot;
} Live_Node_Inter_Entry;

#define LIVE_NODE_INTER_ENTRY_OF(slot) \
   HASH_MAP_ENTRY(slot, Live_Node_Inter_Entry, hash_slot)

static inline Live_Node_Inter_Entry *live_node_inter_entry_alloc(Live_Node *n)
{
   Live_Node_Inter_Entry *e = ALLOC_NEW(Live_Node_Inter_Entry);
   e->node = n;
   return e;
}

static void live_node_inter_hash_destroy(Hash_Map_Slot *s)
{
   free_mem(LIVE_NODE_INTER_ENTRY_OF(s));
}

static inline void live_node_insert_interference(Live_Node *n,
      Live_Node *inter)
{
   Live_Node_Inter_Entry *e = live_node_inter_entry_alloc(inter);
   hash_map_insert(&n->interference_map, &e->hash_slot,
```

```
50          hash_map_aligned_ptr_hash(inter));
51  }
52
53  static inline bool live_node_remove_interference(Live_Node *n,
54        Live_Node *inter)
55  {
56     Hash_Map_Slot *slot = hash_map_remove(&n->interference_map, inter,
57           hash_map_aligned_ptr_hash(inter));
58     if (!slot)
59        return false;
60
61     Live_Node_Inter_Entry *e = LIVE_NODE_INTER_ENTRY_OF(slot);
62     free_mem(e);
63     return true;
64  }
65
66  static inline bool live_node_has_interference(Live_Node *n, Live_Node *inter)
67  {
68     return hash_map_contains(&n->interference_map, inter,
69           hash_map_aligned_ptr_hash(inter));
70  }
71
72  static bool live_node_inter_entry_hash_compare(Live_Node *search_node,
73        Hash_Map_Slot *map_slot)
74  {
75     Live_Node_Inter_Entry *e = LIVE_NODE_INTER_ENTRY_OF(map_slot);
76     return search_node == e->node;
77  }
78
79  #define LIVE_NODE_FOR_EACH_INTERFERENCE(n, inter)         \
80     for (Hash_Map_Slot *___s = INT_TO_PTR(1); ___s; ___s = NULL)    \
81        HASH_MAP_FOR_EACH(&(n)->interference_map, ___s)       \
82           if ((inter = LIVE_NODE_INTER_ENTRY_OF(___s)->node) || !inter)
83
84  #define LIVE_NODE_OF_GRAPH_SLOT(slot) \
85     HASH_MAP_ENTRY(slot, Live_Node, graph_slot)
86
87  #define LIVE_NODE_OF_REGRAPH_SLOT(slot) \
88     HASH_MAP_ENTRY(slot, Live_Node, regraph_slot)
89
90  #define LIVE_NODE_OF_DBNODE(node) HASH_MAP_ENTRY(node, Live_Node, dbnode)
91
92  typedef struct Live_Graph {
93     Hash_Map live_node_map;
94     Hash_Map regraph_map;
95     Live_Node global_ebp;
96     Live_Node global_esi;
97     Live_Node global_edi;
98     Double_List assign_queue;
99     Double_List wait_queue;
100    Vector live_node_stack;
101    Vector spill_list;
102    bool free_regs[X86_32_REG_COUNT];
103 } Live_Graph;
104
105 static UNUSED void live_graph_print(Live_Graph *g)
106 {
107    DLOG("\nLIVE GRAPH:\n");
108    Hash_Map_Slot *slot01;
109    HASH_MAP_FOR_EACH(&g->live_node_map, slot01) {
110       Live_Node *ln = LIVE_NODE_OF_GRAPH_SLOT(slot01);
111       DLOG("%S => ", ln->init_var_name);
112       Live_Node *lni;
113       LIVE_NODE_FOR_EACH_INTERFERENCE(ln, lni)
114          DLOG("%S, ", lni->init_var_name);
115       DLOG("\n");
116    }
117    DLOG("\n\n");
118 }
119
120 static bool live_node_regraph_compare(Live_Node *search_node,
121       Hash_Map_Slot *slot)
122 {
123    return search_node == LIVE_NODE_OF_REGRAPH_SLOT(slot);
```

```
124 }
125
126 static bool live_node_graph_compare(String search_var,
127       Hash_Map_Slot *map_slot)
128 {
129    Live_Node *n = LIVE_NODE_OF_GRAPH_SLOT(map_slot);
130    return !string_compare(n->init_var_name, search_var);
131 }
132
133 static inline Live_Node *live_graph_lookup_var(Live_Graph *g,
134       Const_String var_name)
135 {
136    Uns hash = string_hash_code(var_name);
137    Hash_Map_Slot *nslot = hash_map_get(&g->live_node_map,
138          (String)var_name, hash);
139    if (nslot)
140       return LIVE_NODE_OF_GRAPH_SLOT(nslot);
141    return NULL;
142 }
143
144 static inline Live_Node *live_graph_lookup(Live_Graph *g,
145       Aia_Operand *op)
146 {
147    assert(aia_operand_is_reg(op));
148    return live_graph_lookup_var(g, aia_operand_reg_get_name(op));
149 }
150
151 static inline bool live_node_add_interference(Live_Node *lhs, Live_Node *rhs);
152
153 static void live_node_set_init_var_name(Live_Node *n,
154       Const_String var_name)
155 {
156    n->init_var_name = var_name;
157    n->assigned_var_name = var_name;
158    n->reg_idx = x86_32_reg_name_get_idx(var_name);
159 }
160
161 static void live_node_set_assigned_var_name(Live_Node *n,
162       Int idx)
163 {
164    Const_String var_name;
165    if (n->var_size == AIA_BYTE)
166       var_name = x86_32_reg_idx_get_lo8bit_name(idx);
167    else
168       var_name = x86_32_reg_idx_get_32bit_name(idx);
169
170    assert(var_name);
171
172    n->reg_idx = idx;
173    n->assigned_var_name = var_name;
174 }
175
176 #if 0
177 static void live_node_default_8bit_interferences(Live_Node *n, Live_Graph *g)
178 {
179    live_node_add_interference(n, &g->global_ebp);
180    live_node_add_interference(n, &g->global_esi);
181    live_node_add_interference(n, &g->global_edi);
182 }
183 #endif
184
185 static void live_node_init(Live_Graph *g UNUSED, Live_Node *n,
186       Aia_Operand *op, uint8_t var_size)
187 {
188    assert(aia_operand_is_reg(op));
189
190    ___aia_operand_acquire(op);
191
192    n->interferences = VECTOR_INIT();
193    n->interference_map = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_11,
194          (Hash_Map_Comparator)live_node_inter_entry_hash_compare);
195    n->var_size = var_size;
196    n->init_operand = op;
197    live_node_set_init_var_name(n, aia_operand_reg_get_name(op));
```

```
198
199 #if 0
200    if (var_size == AIA_BYTE)
201       live_node_default_8bit_interferences(n, g);
202 #endif
203 }
204
205 static inline Live_Node *___live_graph_get(Live_Graph *g, Aia_Operand *op,
206       uint8_t var_size)
207 {
208    Live_Node *n;
209
210    assert(aia_operand_is_reg(op));
211    Const_String var_name = aia_operand_reg_get_name(op);
212
213    Uns hash = string_hash_code(var_name);
214
215    Hash_Map_Slot *nslot = hash_map_get(&g->live_node_map,
216          (String)var_name, hash);
217    if (nslot)
218       return LIVE_NODE_OF_GRAPH_SLOT(nslot);
219
220    n = ALLOC_NEW(Live_Node);
221    live_node_init(g, n, op, var_size);
222
223    hash_map_insert(&g->live_node_map, &n->graph_slot, hash);
224
225    return n;
226 }
227
228 static inline void live_node_clear(Live_Node *n)
229 {
230    ___aia_operand_release(n->init_operand);
231    hash_map_for_each_destroy(&n->interference_map,
232          live_node_inter_hash_destroy);
233    vector_clear(&n->interferences);
234 }
235
236 static inline void live_node_destroy(Live_Node *n)
237 {
238    live_node_clear(n);
239    free_mem(n);
240 }
241
242 static void live_node_graph_hash_destroy(Hash_Map_Slot *s)
243 {
244    live_node_destroy(LIVE_NODE_OF_GRAPH_SLOT(s));
245 }
246
247 static inline bool live_node_link(Live_Node *lhs, Live_Node *rhs)
248 {
249    if (lhs == rhs)
250       return false;
251
252    if (live_node_has_interference(lhs, rhs))
253       return false;
254
255    DLOG("add link %S and %S\n", lhs->init_var_name,
256          rhs->init_var_name);
257
258    Int lhs_i = x86_32_reg_name_get_idx(lhs->init_var_name);
259    if (lhs_i != -1) {
260       Int rhs_i = x86_32_reg_name_get_idx(rhs->init_var_name);
261       if (rhs_i == lhs_i)
262          return false;
263    }
264
265    live_node_insert_interference(lhs, rhs);
266    live_node_insert_interference(rhs, lhs);
267
268    return true;
269 }
270
271 static inline bool live_node_add_interference(Live_Node *lhs, Live_Node *rhs)
```

```
{
   if (live_node_link(lhs, rhs)) {
      vector_append(&lhs->interferences, rhs);
      vector_append(&rhs->interferences, lhs);
      return true;
   }
   return false;
}

static Live_Graph *live_graph_alloc()
{
   Live_Graph *g = ALLOC_NEW(Live_Graph);
   g->live_node_map = HASH_MAP_INIT(
         (Hash_Map_Comparator)live_node_graph_compare);
   g->assign_queue = DOUBLE_LIST_INIT(g->assign_queue);
   g->wait_queue = DOUBLE_LIST_INIT(g->wait_queue);
   g->live_node_stack = VECTOR_INIT_SIZE(100);
   g->spill_list = VECTOR_INIT();
   g->regraph_map = HASH_MAP_INIT(
         (Hash_Map_Comparator)live_node_regraph_compare);

   for (Uns i = 0; i < X86_32_REG_COUNT; i++)
      g->free_regs[i] = true;

   live_node_init(g, &g->global_ebp, reg_ebp, AIA_LONG);
   live_node_init(g, &g->global_esi, reg_esi, AIA_LONG);
   live_node_init(g, &g->global_edi, reg_edi, AIA_LONG);

   return g;
}

static inline void live_graph_destroy(Live_Graph *g)
{
#if 0
   hash_map_for_each_destroy(&g->reg_name_to_idx, reg_idx_hash_destroy);
   hash_map_for_each_destroy(&g->reg_idx_to_lo8bit_name,
         reg_idx_hash_destroy);
   hash_map_for_each_destroy(&g->reg_idx_to_32bit_name, reg_idx_hash_destroy);
#endif
   hash_map_for_each_destroy(&g->live_node_map, live_node_graph_hash_destroy);
   hash_map_clear(&g->regraph_map);
   vector_clear(&g->live_node_stack);
   vector_clear(&g->spill_list);
   live_node_clear(&g->global_esi);
   live_node_clear(&g->global_edi);
   live_node_clear(&g->global_ebp);
   free_mem(g);
}

typedef Hash_Map Live_Set;

typedef struct Live_Set_Entry {
   Const_String var_name;
   Hash_Map_Slot hash_slot;
} Live_Set_Entry;

#define LIVE_SET_ENTRY_OF(slot) \
   HASH_MAP_ENTRY(slot, Live_Set_Entry, hash_slot)

// Warning. Goto to break the loop.
#define LIVE_SET_FOR_EACH_VAR(live_set, vname)           \
for (Hash_Map_Slot *___s = INT_TO_PTR(1); ___s; ___s = NULL)    \
   HASH_MAP_FOR_EACH(live_set, ___s)                     \
      if ((vname = LIVE_SET_ENTRY_OF(___s)->var_name) || !vname)

// Warning. Goto to break the loop.
#define LIVE_SET_FOR_EACH_ENTRY(live_set, ent)           \
for (Hash_Map_Slot *___s = INT_TO_PTR(1); ___s; ___s = NULL)    \
   HASH_MAP_FOR_EACH(live_set, ___s)                     \
      if ((ent = LIVE_SET_ENTRY_OF(___s)) || !ent)

static inline bool live_set_remove_var(Live_Set *s, Const_String var)
{
   Hash_Map_Slot *slot = hash_map_remove(s, (String)var,
```

```
346            string_hash_code(var));
347      if (slot) {
348         free_mem(LIVE_SET_ENTRY_OF(slot));
349         return true;
350      }
351      return false;
352   }
353
354   static inline bool live_set_remove_op(Live_Set *s, Aia_Operand *op)
355   {
356      if (!aia_operand_is_reg(op))
357         return false;
358      return live_set_remove_var(s, aia_operand_reg_get_name(op));
359   }
360
361   static inline bool live_set_contains(Live_Set *s, Const_String var)
362   {
363      return hash_map_contains(s, (String)var, string_hash_code(var));
364   }
365
366   static inline bool live_set_contains_op(Live_Set *s, Aia_Operand *op)
367   {
368      if (aia_operand_is_reg(op))
369         return live_set_contains(s, aia_operand_reg_get_name(op));
370      return false;
371   }
372
373   static inline bool is_operand_live_out(Aia_Instr *in, Aia_Operand *op)
374   {
375      if (!op)
376         return false;
377
378      Aia_Instr *suc;
379
380      switch (aia_operand_get_type(op)) {
381      case AIA_OPERAND_REG:
382         suc = aia_instr_get_sucessor(in);
383         if (suc) {
384            return live_set_contains(suc->meta_data,
385                  aia_operand_reg_get_name(op));
386         } else {
387            Aia_Block *b = aia_instr_get_block(in);
388            Aia_Block *suc_b;
389            AIA_BLOCK_FOR_EACH_SUCESSOR(b, suc_b) {
390               suc = ___aia_block_peek_first_instr(suc_b);
391               if (live_set_contains(suc->meta_data,
392                        aia_operand_reg_get_name(op)))
393                  return true;
394            }
395            return false;
396         }
397
398      case AIA_OPERAND_ADDR_REF:
399         return true;
400
401      case AIA_OPERAND_DISPLAY_REF:
402         return true;
403
404      default:
405         return true;
406      }
407   }
408
409
410   static inline void live_set_remove_entry(Live_Set *s, Live_Set_Entry *e)
411   {
412      Uns hash_code = hash_map_slot_get_hash_code(&e->hash_slot);
413      assert(hash_map_contains(s, (String)e->var_name, hash_code));
414      Hash_Map_Slot *slot = hash_map_remove(s, (String)e->var_name, hash_code);
415      free_mem(LIVE_SET_ENTRY_OF(slot));
416   }
417
418   static inline bool ___live_set_insert_var(Live_Set *s, Const_String var,
419         Uns hash_code)
```

```
420 {
421    if (hash_map_contains(s, (String)var, hash_code))
422       return false;
423    Live_Set_Entry *e = ALLOC_NEW(Live_Set_Entry);
424    e->var_name = var;
425    hash_map_insert(s, &e->hash_slot, hash_code);
426    return true;
427 }
428
429 static inline bool live_set_insert_var(Live_Set *s, Const_String var)
430 {
431    return ___live_set_insert_var(s, var, string_hash_code(var));
432 }
433
434 static inline bool live_set_insert_op(Live_Set *s, Aia_Operand *op)
435 {
436    if (!aia_operand_is_reg(op))
437       return false;
438    return live_set_insert_var(s, aia_operand_reg_get_name(op));
439 }
440
441 static inline bool live_set_insert_entry(Live_Set *s, Live_Set_Entry *e)
442 {
443    return ___live_set_insert_var(s, e->var_name,
444          hash_map_slot_get_hash_code(&e->hash_slot));
445 }
446
447 static bool live_set_entry_compare(String search_str, Hash_Map_Slot *live_slot)
448 {
449    Live_Set_Entry *e = LIVE_SET_ENTRY_OF(live_slot);
450    return !string_compare(search_str, e->var_name);
451 }
452
453 static inline Live_Set *live_set_alloc()
454 {
455    Live_Set *s = ALLOC_NEW(Live_Set);
456    *s = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_11,
457          (Hash_Map_Comparator)live_set_entry_compare);
458    return s;
459 }
460
461 static void live_set_entry_hash_destroy(Hash_Map_Slot *slot)
462 {
463    free_mem(LIVE_SET_ENTRY_OF(slot));
464 }
465
466 static inline void live_set_destroy(Live_Set *s)
467 {
468    if (s) {
469       hash_map_for_each_destroy(s, live_set_entry_hash_destroy);
470       free_mem(s);
471    }
472 }
473
474 static bool x86_32_instr_defines_op(Aia_Instr *in, Const_String op_name)
475 {
476    Aia_Operand *dest = aia_instr_get_dest_op(in);
477    if (!dest)
478       return false;
479
480    switch (aia_operand_get_type(dest)) {
481    case AIA_OPERAND_REG:
482       return !string_compare(op_name, aia_operand_reg_get_name(dest));
483
484    case AIA_OPERAND_LABEL:
485       return false;
486
487    case AIA_OPERAND_LOCAL_REF:
488       return false;
489
490    case AIA_OPERAND_ARG:
491       return false;
492
493    case AIA_OPERAND_DISPLAY_REF:
```

```
494         /* Fall through. */
495      case AIA_OPERAND_ADDR_REF:
496         return false;
497
498      default:
499         fatal_error(S("unexpected dest instruction operand type. "
500                  "Aborting...\n"));
501      }
502   }
503
504   static void x86_32_instr_add_live_vars(Aia_Instr *in, Live_Set *vars, Aia *aia)
505   {
506      Live_Set_Entry *e;
507      LIVE_SET_FOR_EACH_ENTRY(vars, e) {
508         if (!x86_32_instr_defines_op(in, e->var_name)) {
509            if (live_set_insert_entry(in->meta_data, e))
510               aia->meta_data = INT_TO_PTR(1);
511         }
512      }
513   }
514
515   static void x86_32_instr_reg_alloc(Aia_Instr *in, Aia_Block *b, Aia *aia)
516   {
517      Aia_Instr *pred = aia_instr_get_predecessor(in);
518      if (!pred) {
519         Aia_Block *pred_block;
520         AIA_BLOCK_FOR_EACH_PREDECESSOR(b, pred_block)
521            x86_32_instr_add_live_vars(___aia_block_peek_last_instr(
522                     pred_block), in->meta_data, aia);
523      } else {
524         x86_32_instr_add_live_vars(pred, in->meta_data, aia);
525      }
526   }
527
528   static void x86_32_block_reg_alloc(Aia_Block *b, Aia *aia)
529   {
530      Aia_Instr *in;
531      AIA_BLOCK_FOR_EACH_INSTRUCTION_REVERSED(b, in)
532         x86_32_instr_reg_alloc(in, b, aia);
533   }
534
535   static void x86_32_section_reg_alloc(Aia *aia, Aia_Section *sec)
536   {
537      Aia_Block *b;
538      AIA_SECTION_FOR_EACH_BLOCK_REVERSED(sec, b)
539         x86_32_block_reg_alloc(b, aia);
540
541      Aia_Func *func;
542      AIA_SECTION_FOR_EACH_FUNC(sec, func) {
543         AIA_FUNC_FOR_EACH_BLOCK_REVERSED(func, b)
544            x86_32_block_reg_alloc(b, aia);
545
546         Aia_Func_Trampoline *tramp;
547         AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
548            x86_32_block_reg_alloc(tramp->block, aia);
549      }
550   }
551
552   static void x86_32_instr_add_live_op(Aia_Instr *in, Aia_Operand *op)
553   {
554      switch (aia_operand_get_type(op)) {
555      case AIA_OPERAND_REG:
556         live_set_insert_var(in->meta_data, aia_operand_reg_get_name(op));
557         break;
558
559      case AIA_OPERAND_LABEL:
560         break;
561
562      case AIA_OPERAND_LOCAL_REF:
563         break;
564
565      case AIA_OPERAND_ARG:
566         break;
567
```

```
568     case AIA_OPERAND_DISPLAY_REF:
569        assert(aia_operand_is_reg(
570                  aia_operand_display_ref_get_display_reg(op)));
571        x86_32_instr_add_live_op(in,
572              aia_operand_display_ref_get_display_reg(op));
573        break;
574
575     case AIA_OPERAND_ADDR_REF:
576        if (aia_operand_addr_ref_get_base(op)) {
577           assert(aia_operand_is_reg(aia_operand_addr_ref_get_base(op)));
578           x86_32_instr_add_live_op(in,
579                 aia_operand_addr_ref_get_base(op));
580        }
581        if (aia_operand_addr_ref_get_index(op)) {
582           assert(aia_operand_is_reg(aia_operand_addr_ref_get_index(op)));
583           x86_32_instr_add_live_op(in,
584                 aia_operand_addr_ref_get_index(op));
585        }
586        break;
587
588     default:
589        fatal_error(S("unexpected instruction operand type. Aborting...\n"));
590     }
591
592  }
593
594  static inline void add_default_interferences(Aia_Instr *in)
595  {
596     switch (aia_instr_get_type(in)) {
597  #if 0
598     case AIA_CALL:
599        live_set_insert_var(in->meta_data, reg_ecx_str);
600        /* Fall through. */
601  #endif
602     case AIA_IDIV:
603        live_set_insert_var(in->meta_data, reg_eax_str);
604        live_set_insert_var(in->meta_data, reg_edx_str);
605
606     default:
607        break;
608     }
609  }
610
611  static void x86_32_instr_live_init(Aia_Instr *in)
612  {
613     in->meta_data = live_set_alloc();
614     Aia_Operand *op;
615     AIA_INSTR_FOR_EACH_SRC(in, op) {
616        if (aia_operand_is_dest(op))
617           x86_32_instr_add_live_op(in, op);
618     }
619
620     op = aia_instr_get_dest_op(in);
621     if (!op)
622        return;
623
624     switch (aia_operand_get_type(op)) {
625     case AIA_OPERAND_ADDR_REF:
626        /* Fall through. */
627     case AIA_OPERAND_DISPLAY_REF:
628        x86_32_instr_add_live_op(in, op);
629        break;
630
631     default:
632        break;
633     }
634
635     add_default_interferences(in);
636  }
637
638  static void x86_32_block_live_init(Aia_Block *b, void *data UNUSED)
639  {
640     Aia_Instr *in;
641     AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
```

```
642         x86_32_instr_live_init(in);
643     }
644
645     static void x86_32_section_live_init(Aia_Section *sec)
646     {
647        Aia_Block *b;
648        AIA_SECTION_FOR_EACH_BLOCK_REVERSED(sec, b)
649           x86_32_block_live_init(b, NULL);
650
651        Aia_Func *func;
652        AIA_SECTION_FOR_EACH_FUNC(sec, func) {
653           AIA_FUNC_FOR_EACH_BLOCK_REVERSED(func, b)
654              x86_32_block_live_init(b, NULL);
655
656           Aia_Func_Trampoline *tramp;
657           AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
658              x86_32_block_live_init(tramp->block, NULL);
659        }
660     }
661
662     static void x86_32_block_live_destroy(Aia_Block *b, void *data UNUSED)
663     {
664        Aia_Instr *in;
665        AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
666           live_set_destroy(in->meta_data);
667     }
668
669     static void x86_32_section_live_destroy(Aia_Section *sec)
670     {
671        Aia_Block *b;
672        AIA_SECTION_FOR_EACH_BLOCK_REVERSED(sec, b)
673              x86_32_block_live_destroy(b , NULL);
674
675        Aia_Func *func;
676        AIA_SECTION_FOR_EACH_FUNC(sec, func) {
677           AIA_FUNC_FOR_EACH_BLOCK_REVERSED(func, b)
678                 x86_32_block_live_destroy(b , NULL);
679
680           Aia_Func_Trampoline *tramp;
681           AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
682              x86_32_block_live_destroy(tramp->block, NULL);
683        }
684     }
685
686     static inline void live_sets_init(Aia *aia)
687     {
688        Aia_Section *sec;
689        AIA_FOR_EACH_SECTION(aia, sec)
690           x86_32_section_live_init(sec);
691     }
692
693     static inline void live_sets_destroy(Aia *aia)
694     {
695        Aia_Section *sec;
696        AIA_FOR_EACH_SECTION(aia, sec)
697           x86_32_section_live_destroy(sec);
698     }
699
700     static inline void live_sets_build(Aia *aia)
701     {
702        Aia_Section *sec;
703        do {
704           aia->meta_data = NULL;
705           AIA_FOR_EACH_SECTION(aia, sec)
706              x86_32_section_reg_alloc(aia, sec);
707        } while (aia->meta_data);
708     }
709
710     static void x86_32_nop_mov_remove_block(Aia_Block *b, void *arg UNUSED)
711     {
712        VECTOR(removed_ins);
713
714        Aia_Instr *in;
715        AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in) {
```

```
716         if (aia_instr_get_type(in) == AIA_MOV) {
717            Aia_Operand *src = aia_instr_get_src_op(in, 0);
718            Aia_Operand *dest = aia_instr_get_dest_op(in);
719            if (aia_operands_equal(src, dest))
720               vector_append(&removed_ins, in);
721         }
722      }
723
724      vector_for_each_destroy(&removed_ins,
725            (Vector_Destructor)aia_instr_remove_destroy);
726   }
727
728   static inline void x86_32_nop_mov_remove(Aia *aia)
729   {
730      Aia_Section *sec;
731      AIA_FOR_EACH_SECTION(aia, sec) {
732         aia_section_for_each_block_depth(sec,
733               (Aia_Block_Callback)x86_32_nop_mov_remove_block, NULL);
734
735         Aia_Func *func;
736         AIA_SECTION_FOR_EACH_FUNC(sec, func) {
737            aia_func_for_each_block_depth(func,
738                  (Aia_Block_Callback)x86_32_nop_mov_remove_block, NULL);
739
740            Aia_Func_Trampoline *tramp;
741            AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
742               x86_32_nop_mov_remove_block(tramp->block, NULL);
743         }
744      }
745   }
746
747   static Aia_Operand *x86_32_get_assigned_reg_operand(Aia_Operand *op,
748         Live_Graph *g, uint8_t reg_size)
749   {
750      Const_String op_name = aia_operand_reg_get_name(op);
751      Uns hash = string_hash_code(op_name);
752      DLOG("instr assign %S to reg\n", op_name);
753
754      Hash_Map_Slot *s = hash_map_get(&g->live_node_map, (String)op_name, hash);
755      if (!s)
756         return NULL;
757
758      Live_Node *n = LIVE_NODE_OF_GRAPH_SLOT(s);
759
760      assert(x86_32_is_concrete_reg_str(n->assigned_var_name));
761      Aia_Operand *reg = x86_32_get_reg_operand(n->assigned_var_name);
762      assert(reg);
763
764      DLOG("found assigned reg: %S\n", aia_operand_reg_get_name(reg));
765
766      Int reg_idx = x86_32_reg_get_idx(reg);
767      assert(reg_idx > -1);
768      if (reg_size == AIA_LONG) {
769         Const_String name = x86_32_reg_idx_get_32bit_name(reg_idx);
770         reg = x86_32_get_reg_operand(name);
771      } else {
772         Const_String name = x86_32_reg_idx_get_lo8bit_name(reg_idx);
773         reg = x86_32_get_reg_operand(name);
774      }
775
776      return reg;
777   }
778
779   static inline bool x86_32_instr_assign_reg(Aia_Instr *in,
780         Aia_Operand *op, Int idx, Live_Graph *g)
781   {
782      Aia_Operand *reg;
783      uint8_t reg_size;
784      if (idx == -1)
785         reg_size = aia_instr_get_dest_op_size(in);
786      else
787         reg_size = aia_instr_get_src_ops_size(in);
788
789      Aia_Block *b = aia_instr_get_block(in);
```

```
790     Aia *aia = b->section->aia;
791
792     switch (aia_operand_get_type(op)) {
793     case AIA_OPERAND_REG:
794        reg = x86_32_get_assigned_reg_operand(op, g, reg_size);
795        if (!reg)
796           return false;
797        aia_instr_replace_op(in, idx, reg);
798        break;
799
800     case AIA_OPERAND_DISPLAY_REF:
801        reg = aia_operand_display_ref_get_display_reg(op);
802        reg = x86_32_get_assigned_reg_operand(reg, g, AIA_LONG);
803        assert(reg);
804        op = aia_operand_display_ref_with_replaced_reg(aia, op, reg);
805        aia_instr_replace_op(in, idx, op);
806        break;
807
808     case AIA_OPERAND_ADDR_REF:
809        reg = aia_operand_addr_ref_get_base(op);
810        if (reg) {
811           reg = x86_32_get_assigned_reg_operand(reg, g, AIA_LONG);
812           assert(reg);
813           op = aia_operand_addr_ref_with_replaced_base(aia, op, reg);
814           aia_instr_replace_op(in, idx, op);
815        }
816        reg = aia_operand_addr_ref_get_index(op);
817        if (reg) {
818           reg = x86_32_get_assigned_reg_operand(reg, g, AIA_LONG);
819           assert(reg);
820           op = aia_operand_addr_ref_with_replaced_index(aia, op, reg);
821           aia_instr_replace_op(in, idx, op);
822        }
823        break;
824
825     default:
826        break;
827     }
828
829     return true;
830  }
831
832  static void x86_32_instr_assign_regs(Aia_Instr *in, Live_Graph *g)
833  {
834     Int idx = -1;
835     Aia_Operand *op;
836
837     AIA_INSTR_FOR_EACH_OPERAND(in, op) {
838        if (op && !x86_32_instr_assign_reg(in, op, idx, g)) {
839           Aia_Block *b = aia_instr_get_block(in);
840           if (!b->meta_data)
841              b->meta_data = vector_alloc();
842           if (aia_instr_get_type(in) == AIA_CALL) {
843              assert(idx == -1);
844              ___aia_operand_release(op);
845              in->dest_op = NULL;
846           } else {
847              vector_append(b->meta_data, in);
848              break;
849           }
850        }
851        ++idx;
852     }
853  }
854
855  static void x86_32_block_assign_regs(Aia_Block *b, Live_Graph *g)
856  {
857     b->meta_data = NULL;
858     Aia_Instr *in;
859     AIA_BLOCK_FOR_EACH_INSTRUCTION_REVERSED(b, in)
860        x86_32_instr_assign_regs(in, g);
861
862     if (b->meta_data) {
863        Aia_Instr *in;
```

```
864         Vector *invec = b->meta_data;
865         VECTOR_FOR_EACH_ENTRY(invec, in) {
866            live_set_destroy(in->meta_data);
867            assert(aia_instr_get_type(in) != AIA_IDIV);
868            assert(aia_instr_get_type(in) != AIA_CALL);
869            aia_instr_remove_destroy(in);
870         }
871         vector_destroy(invec, NULL);
872      }
873   }
874
875   static void x86_32_section_assign_regs(Aia *aia, Aia_Section *sec)
876   {
877      Aia_Block *b;
878      AIA_SECTION_FOR_EACH_BLOCK_REVERSED(sec, b)
879         x86_32_block_assign_regs(b, aia->meta_data);
880
881      Aia_Func *func;
882      AIA_SECTION_FOR_EACH_FUNC(sec, func) {
883         AIA_FUNC_FOR_EACH_BLOCK_REVERSED(func, b)
884            x86_32_block_assign_regs(b, aia->meta_data);
885
886         Aia_Func_Trampoline *tramp;
887         AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
888            x86_32_block_assign_regs(tramp->block, aia->meta_data);
889      }
890   }
891
892   static inline void x86_32_assign_regs(Aia *aia, Live_Graph *g)
893   {
894      Aia_Section *sec;
895      aia->meta_data = g;
896      AIA_FOR_EACH_SECTION(aia, sec)
897         x86_32_section_assign_regs(aia, sec);
898   }
899
900   typedef struct X86_32_Spill_Meta_Data {
901      Live_Graph *graph;
902      Aia_Section *curr_sec;
903      Vector tmp_var_names;
904      Vector inserted_tmp_var_labels;
905      Vector norm_instrs;
906      Aia_Operand_Map *repl_map;
907   } X86_32_Spill_Meta_Data;
908
909   static inline bool x86_32_reg_alloc_replace_reg(Aia_Instr *in, Int idx,
910         Aia_Operand *from, Aia_Operand *repl)
911   {
912      Aia_Operand *op = aia_instr_get_op(in, idx);
913      if (!aia_operands_equal(op, from))
914         return false;
915
916      assert(op);
917      DEBUG(
918         DLOGT(def, "replace: ");
919         aia_operand_dump(stderr, op, false);
920         DLOGT(def, " with: ");
921         aia_operand_dump(stderr, repl, false);
922         DLOGT(def, "\n");
923      );
924
925      aia_instr_replace_op(in, idx, repl);
926      return true;
927   }
928
929   static bool x86_32_reg_alloc_replace_addr_ref(Aia_Instr *in, Int idx,
930         Aia_Operand *from, Aia_Operand *repl)
931   {
932      Aia_Operand *op = aia_instr_get_op(in, idx);
933      assert(op);
934
935      bool ret = false;
936
937      Aia_Block *b = aia_instr_get_block(in);
```

```
938     Aia *aia = b->section->aia;
939
940     Aia_Operand *base = aia_operand_addr_ref_get_base(op);
941     if (base && aia_operands_equal(base, from)) {
942        op = aia_operand_addr_ref_with_replaced_base(aia, op, repl);
943        aia_instr_replace_op(in, idx, op);
944        ret = true;
945     }
946
947     Aia_Operand *index = aia_operand_addr_ref_get_index(op);
948     if (index && aia_operands_equal(index, from)) {
949        op = aia_operand_addr_ref_with_replaced_index(aia, op, repl);
950        aia_instr_replace_op(in, idx, op);
951        ret = true;
952     }
953
954     DEBUG(
955        DLOGT(def, "new addr ref: ");
956        aia_operand_dump(stderr, op, false);
957        DLOGT(def, "\n");
958     );
959
960     return ret;
961  }
962
963  static bool x86_32_reg_alloc_replace_display_ref(Aia_Instr *in, Int idx,
964        Aia_Operand *from, Aia_Operand *repl)
965  {
966     Aia_Operand *op = aia_instr_get_op(in, idx);
967     assert(op);
968
969     Aia_Block *b = aia_instr_get_block(in);
970     Aia *aia = b->section->aia;
971
972     Aia_Operand *reg = aia_operand_display_ref_get_display_reg(op);
973     assert(reg);
974
975     if (!aia_operands_equal(from, reg))
976        return false;
977
978     op = aia_operand_display_ref_with_replaced_reg(aia, op, repl);
979     aia_instr_replace_op(in, idx, op);
980
981     DEBUG(
982        DLOGT(def, "new display ref: ");
983        aia_operand_dump(stderr, op, false);
984        DLOGT(def, "\n");
985     );
986
987     return true;
988  }
989
990  static inline void x86_32_instr_spill(Aia_Instr *in, Aia_Operand *op,
991        Int in_idx, Int md_idx, Aia *aia)
992  {
993     X86_32_Spill_Meta_Data *md = aia->meta_data;
994
995     Live_Node *live_node = vector_get(&md->graph->spill_list, md_idx);
996     Const_String spill_var = live_node->init_var_name;
997     Const_String new_var_name = vector_get(&md->tmp_var_names, md_idx);
998
999     Aia_Operand *repl1 = NULL;
1000    Aia_Operand *repl2 = NULL;
1001    Const_String op_name;
1002    switch (aia_operand_get_type(op)) {
1003    case AIA_OPERAND_REG:
1004       repl1 = op;
1005       op_name = aia_operand_reg_get_name(op);
1006       if (string_compare(op_name, spill_var))
1007          return;
1008       assert(!x86_32_is_concrete_reg_str(op_name));
1009       break;
1010
1011    case AIA_OPERAND_ADDR_REF:;
```

```
1012        repl2 = aia_operand_addr_ref_get_index(op);
1013        Const_String tn;
1014        if (repl2)
1015           tn = aia_operand_reg_get_name(repl2);
1016        else
1017           tn = S(" ");
1018
1019        repl1 = aia_operand_addr_ref_get_base(op);
1020        if (repl1)
1021           op_name = aia_operand_reg_get_name(repl1);
1022        else
1023           op_name = S("");
1024
1025        bool repl2_res = string_compare(tn, spill_var);
1026        bool repl1_res = string_compare(op_name, spill_var);
1027        if (repl1_res && repl2_res)
1028           return;
1029
1030        if (repl1_res)
1031           repl1 = NULL;
1032        if (repl2_res)
1033           repl2 = NULL;
1034
1035        assert(!x86_32_is_concrete_reg_str(tn));
1036        assert(!x86_32_is_concrete_reg_str(op_name));
1037        break;
1038
1039     case AIA_OPERAND_DISPLAY_REF:
1040        repl1 = aia_operand_display_ref_get_display_reg(op);
1041        assert(repl1);
1042        op_name = aia_operand_reg_get_name(repl1);
1043        if (string_compare(op_name, spill_var))
1044           return;
1045        assert(!x86_32_is_concrete_reg_str(op_name));
1046        break;
1047
1048     default:
1049        return;
1050     }
1051
1052     Aia_Operand *new_op;
1053     uint8_t size;
1054
1055     if (in_idx < 0)
1056        size = aia_instr_get_dest_op_size(in);
1057     else
1058        size = aia_instr_get_src_ops_size(in);
1059
1060     Aia_Operand_Map *repl_map = md->repl_map;
1061     if (repl1)
1062        new_op = aia_operand_map_get_value(repl_map, repl1);
1063     else
1064        new_op = aia_operand_map_get_value(repl_map, repl2);
1065
1066     if (!new_op) {
1067        if (___aia_get_curr_func(aia)) {
1068           DLOG("spill local\n");
1069           new_op = aia_operand_local_ref_alloc(aia, new_var_name
1070                 /* , size */);
1071           if (!vector_get(&md->inserted_tmp_var_labels, md_idx)) {
1072              vector_set(&md->inserted_tmp_var_labels, md_idx,
1073                    INT_TO_PTR(1));
1074              ___aia_func_append_local(aia, new_var_name);
1075           }
1076        } else {
1077           if (!vector_get(&md->inserted_tmp_var_labels, md_idx)) {
1078              vector_set(&md->inserted_tmp_var_labels, md_idx,
1079                    INT_TO_PTR(1));
1080              DLOG("insert label: %S\n", new_var_name);
1081              ___aia_switch_section(aia, AIA_SECTION_DATA);
1082              ___aia_insert_label_instr(aia,
1083                    new_var_name,
1084                    0,
1085                    size == AIA_LONG ? 4 : 0,
```

```
1086                    AIA_LINKAGE_PRIVATE,
1087                    AIA_LABEL_TYPE_OBJ,
1088                    size == AIA_LONG ? 4 : 1,
1089                    aia_get_null_location(aia));
1090             Aia_Operand *val = aia_operand_const_int_alloc(aia, 0);
1091             ___aia_insert_const_val_instr(aia, val, size,
1092                    aia_get_null_location(aia));
1093          }
1094
1095          new_op = aia_operand_label_alloc(aia, new_var_name, 0);
1096       }
1097    }
1098
1099    switch (aia_operand_get_type(op)) {
1100    case AIA_OPERAND_REG:
1101       x86_32_reg_alloc_replace_reg(in, in_idx, repl1, new_op);
1102       break;
1103
1104    case AIA_OPERAND_ADDR_REF:
1105       if (repl1)
1106          x86_32_reg_alloc_replace_addr_ref(in, in_idx, repl1, new_op);
1107       if (repl2)
1108          x86_32_reg_alloc_replace_addr_ref(in, in_idx, repl2, new_op);
1109       break;
1110
1111    case AIA_OPERAND_DISPLAY_REF:
1112       x86_32_reg_alloc_replace_display_ref(in, in_idx, repl1, new_op);
1113       break;
1114
1115    default:
1116       assert(false);
1117    }
1118    vector_append(&md->norm_instrs, in);
1119 }
1120
1121 static void x86_32_instr_spill_regs(Aia_Instr *in, Aia *aia)
1122 {
1123    Int idx = -1;
1124    Aia_Operand *op;
1125
1126    X86_32_Spill_Meta_Data *md = aia->meta_data;
1127
1128    AIA_INSTR_FOR_EACH_OPERAND(in, op) {
1129       if (op) {
1130          ___aia_operand_acquire(op);
1131          for (Uns i = 0; i < vector_size(&md->graph->spill_list); i++)
1132             x86_32_instr_spill(in, op, idx, i, aia);
1133          ___aia_operand_release(op);
1134       }
1135       ++idx;
1136    }
1137 }
1138
1139 static void x86_32_block_spill_regs(Aia_Block *b, Aia *aia)
1140 {
1141    X86_32_Spill_Meta_Data *md = aia->meta_data;
1142    Aia_Instr *in;
1143    AIA_BLOCK_FOR_EACH_INSTRUCTION_REVERSED(b, in) {
1144       x86_32_instr_spill_regs(in, aia);
1145       //aia_normalize_addr_instructions(aia, &md->norm_instrs);
1146       //x86_32_normalize_instructions(aia, &md->norm_instrs);
1147       vector_clear(&md->norm_instrs);
1148    }
1149 }
1150
1151 static void x86_32_section_spill_regs(Aia *aia, Aia_Section *sec)
1152 {
1153    X86_32_Spill_Meta_Data *md = aia->meta_data;
1154    md->curr_sec = sec;
1155    ___aia_set_curr_func(aia, NULL);
1156
1157    Aia_Block *b;
1158    AIA_SECTION_FOR_EACH_BLOCK_REVERSED(sec, b)
1159       x86_32_block_spill_regs(b, aia);
```

```
1160
1161     Aia_Func *func;
1162     AIA_SECTION_FOR_EACH_FUNC(sec, func) {
1163        ___aia_set_curr_func(aia, func);
1164        AIA_FUNC_FOR_EACH_BLOCK_REVERSED(func, b)
1165           x86_32_block_spill_regs(b, aia);
1166     }
1167  }
1168
1169  static inline void x86_32_spill_regs(Aia *aia, Live_Graph *g,
1170        Aia_Operand_Map *repl_map)
1171  {
1172     aia->meta_data = ALLOC_NEW(X86_32_Spill_Meta_Data);
1173     X86_32_Spill_Meta_Data *md = aia->meta_data;
1174     md->graph = g;
1175     md->tmp_var_names = VECTOR_INIT();
1176     md->inserted_tmp_var_labels = VECTOR_INIT();
1177     md->norm_instrs = VECTOR_INIT();
1178     md->repl_map = repl_map;
1179
1180     Live_Node *n;
1181     VECTOR_FOR_EACH_ENTRY(&g->spill_list, n) {
1182        vector_append(&md->tmp_var_names, aia_tmp_name_gen(aia,
1183                  n->init_var_name));
1184        vector_append(&md->inserted_tmp_var_labels, NULL);
1185     }
1186
1187     Aia_Section *sec;
1188     AIA_FOR_EACH_SECTION(aia, sec)
1189        x86_32_section_spill_regs(aia, sec);
1190
1191     //aia_normalize_addr_instructions(aia, &md->norm_instrs);
1192     //x86_32_normalize_instructions(aia, &md->norm_instrs);
1193
1194     assert(vector_is_empty(&md->norm_instrs));
1195     vector_clear(&md->inserted_tmp_var_labels);
1196     vector_for_each_destroy(&md->tmp_var_names,
1197           (Vector_Destructor)string_destroy);
1198     free_mem(aia->meta_data);
1199
1200     ___aia_set_curr_func(aia, NULL);
1201  }
1202
1203  static void ___x86_32_instr_force_interferences(Aia_Instr *in, Live_Graph *g,
1204        Live_Node *interfear_node)
1205  {
1206     Live_Set *live_set;
1207     Live_Node *oth;
1208     Const_String var;
1209
1210     live_set = in->meta_data;
1211     LIVE_SET_FOR_EACH_VAR(live_set, var) {
1212        oth = live_graph_lookup_var(g, var);
1213        assert(oth);
1214        DLOG("interference: %S and %S\n",
1215              interfear_node->init_var_name, oth->init_var_name);
1216        live_node_add_interference(interfear_node, oth);
1217     }
1218  }
1219
1220  static void x86_32_instr_add_interferences(Aia_Instr *in, Live_Graph *g,
1221        Live_Node *interfear_node)
1222  {
1223     if (!live_set_contains(in->meta_data, interfear_node->init_var_name))
1224        return;
1225
1226     ___x86_32_instr_force_interferences(in, g, interfear_node);
1227  }
1228
1229  static void live_graph_build_queues(Live_Graph *g)
1230  {
1231     Hash_Map_Slot *slot;
1232     HASH_MAP_FOR_EACH(&g->live_node_map, slot) {
1233        Live_Node *n = LIVE_NODE_OF_GRAPH_SLOT(slot);
```

```
1234        if (x86_32_is_concrete_reg_str(n->init_var_name))
1235           continue;
1236        if (n->var_size == AIA_LONG) {
1237           if (hash_map_size(&n->interference_map) < X86_32_REG_COUNT)
1238              double_list_append(&g->assign_queue, &n->dbnode);
1239           else
1240              double_list_append(&g->wait_queue, &n->dbnode);
1241        } else {
1242           if (hash_map_size(&n->interference_map) < X86_32_REG_COUNT_8BIT)
1243              double_list_append(&g->assign_queue, &n->dbnode);
1244           else
1245              double_list_append(&g->wait_queue, &n->dbnode);
1246        }
1247     }
1248  }
1249
1250  static void live_graph_push_node(Live_Graph *g, Live_Node *n)
1251  {
1252     Live_Node *inode;
1253
1254     assert(!x86_32_is_concrete_reg_str(n->init_var_name));
1255
1256     DLOG("iterate: %S\n", n->init_var_name);
1257
1258     LIVE_NODE_FOR_EACH_INTERFERENCE(n, inode) {
1259
1260        if (x86_32_is_concrete_reg_str(inode->init_var_name))
1261           continue;
1262
1263        DLOG("test %S interfears with %S\n", inode->init_var_name,
1264              n->init_var_name);
1265
1266        assert(live_node_has_interference(inode, n));
1267        DLOG("remove interference from %S to %S\n", inode->init_var_name,
1268              n->init_var_name);
1269        live_node_remove_interference(inode, n);
1270
1271        if (inode->var_size == AIA_LONG) {
1272           if (hash_map_size(&inode->interference_map) ==
1273                 X86_32_REG_COUNT - 1) {
1274              double_list_remove(&inode->dbnode);
1275              double_list_append(&g->assign_queue, &inode->dbnode);
1276           }
1277        } else {
1278           assert(inode->var_size == AIA_BYTE);
1279           if (hash_map_size(&inode->interference_map) ==
1280                 X86_32_REG_COUNT_8BIT - 1) {
1281              double_list_remove(&inode->dbnode);
1282              double_list_append(&g->assign_queue, &inode->dbnode);
1283           }
1284        }
1285     }
1286
1287     VECTOR_FOR_EACH_ENTRY(&n->interferences, inode) {
1288        if (x86_32_is_concrete_reg_str(inode->init_var_name))
1289           continue;
1290        live_node_remove_interference(n, inode);
1291     }
1292
1293     vector_append(&g->live_node_stack, n);
1294  }
1295
1296  static bool live_graph_build_stack(Live_Graph *g)
1297  {
1298     ALWAYS_INLINE Live_Node *get_spill()
1299     {
1300        Live_Node *spill;
1301        Double_List_Node *node;
1302        Double_List *list = &g->wait_queue;
1303
1304        node = double_list_peek_first(list);
1305        spill = LIVE_NODE_OF_DBNODE(node);
1306        Uns spill_size = hash_map_size(&spill->interference_map);
1307
```

```
1308        DOUBLE_LIST_FOR_EACH_AFTER(list, node, node) {
1309           Live_Node *curr = LIVE_NODE_OF_DBNODE(node);
1310           Uns curr_size = hash_map_size(&curr->interference_map);
1311           if (curr_size > spill_size) {
1312              spill = curr;
1313              spill_size = curr_size;
1314           }
1315        }
1316
1317        return spill;
1318     }
1319
1320     Double_List_Node *dbnode;
1321     Live_Node *n;
1322     bool ret = true;
1323
1324     for (;;) {
1325        while (!double_list_is_empty(&g->assign_queue)) {
1326           dbnode = double_list_pop_first(&g->assign_queue);
1327           live_graph_push_node(g, LIVE_NODE_OF_DBNODE(dbnode));
1328        }
1329
1330        if (double_list_is_empty(&g->wait_queue))
1331           break;
1332
1333        ret = false;
1334
1335        n = get_spill();
1336        double_list_remove(&n->dbnode);
1337        live_graph_push_node(g, n);
1338        vector_append(&g->spill_list, n);
1339     }
1340
1341     return ret;
1342  }
1343
1344  static void live_node_assign_reg(Live_Node *n, Live_Graph *g)
1345  {
1346     assert(n->reg_idx < 0);
1347
1348     Live_Node *inter;
1349     VECTOR_FOR_EACH_ENTRY(&n->interferences, inter) {
1350        if (hash_map_contains(&g->regraph_map, inter,
1351              hash_map_aligned_ptr_hash(inter))) {
1352           bool link_ret = live_node_link(n, inter);
1353           (void)link_ret;
1354           assert(link_ret);
1355        }
1356     }
1357
1358     LIVE_NODE_FOR_EACH_INTERFERENCE(n, inter) {
1359        assert(inter->reg_idx >= 0);
1360        DLOG("found interference: %S\n",
1361             x86_32_reg_idx_get_32bit_name(inter->reg_idx));
1362        g->free_regs[inter->reg_idx] = false;
1363     }
1364
1365     hash_map_insert(&g->regraph_map, &n->regraph_slot,
1366           hash_map_aligned_ptr_hash(n));
1367
1368     for (Uns i = 0; i < X86_32_REG_COUNT; i++) {
1369        if (g->free_regs[i]) {
1370           live_node_set_assigned_var_name(n, i);
1371           break;
1372        }
1373     }
1374
1375     for (Uns i = 0; i < X86_32_REG_COUNT; i++)
1376        g->free_regs[i] = true;
1377
1378     assert(n->reg_idx >= 0);
1379  }
1380
1381  static void live_graph_assign_regs(Live_Graph *g)
```

```
1382 {
1383    Vector *vec = &g->live_node_stack;
1384
1385    while (!vector_is_empty(vec)) {
1386       Live_Node *next = vector_pop_last(vec);
1387       live_node_assign_reg(next, g);
1388    }
1389
1390    hash_map_clear(&g->regraph_map);
1391 }
1392
1393 static void ___x86_32_instr_add_interferences(Aia_Instr *in,
1394       Aia_Instr *suc, Live_Graph *g)
1395 {
1396    Live_Node *n;
1397    switch (aia_instr_get_type(in)) {
1398    case AIA_IDIV:
1399       n = live_graph_lookup(g, reg_eax);
1400       assert(n);
1401       x86_32_instr_add_interferences(suc, g, n);
1402       n = live_graph_lookup(g, reg_edx);
1403       assert(n);
1404       x86_32_instr_add_interferences(suc, g, n);
1405       return;
1406
1407    default:
1408       break;
1409    }
1410
1411    Aia_Operand *dest = aia_instr_get_dest_op(in);
1412    if (!dest)
1413       return;
1414
1415    switch (aia_operand_get_type(dest)) {
1416    case AIA_OPERAND_REG:
1417       n = live_graph_lookup(g, dest);
1418       assert(n);
1419       x86_32_instr_add_interferences(suc, g, n);
1420       break;
1421
1422    case AIA_OPERAND_DISPLAY_REF:
1423       n = live_graph_lookup(g,
1424             aia_operand_display_ref_get_display_reg(dest));
1425       assert(n);
1426       x86_32_instr_add_interferences(suc, g, n);
1427       break;
1428
1429    case AIA_OPERAND_ADDR_REF:;
1430       Aia_Operand *tmp = aia_operand_addr_ref_get_base(dest);
1431       if (tmp) {
1432          n = live_graph_lookup(g, tmp);
1433          assert(n);
1434          x86_32_instr_add_interferences(suc, g, n);
1435       }
1436       tmp = aia_operand_addr_ref_get_index(dest);
1437       if (tmp) {
1438          n = live_graph_lookup(g, tmp);
1439          assert(n);
1440          x86_32_instr_add_interferences(suc, g, n);
1441       }
1442       break;
1443
1444    case AIA_OPERAND_LABEL:
1445       /* Fall through. */
1446    case AIA_OPERAND_LOCAL_REF:
1447       /* Fall through. */
1448    case AIA_OPERAND_ARG:
1449       /* Fall through. */
1450       break;
1451
1452    default:
1453       fatal_error(S("unexpected instruction dest-operand type. "
1454                "Aborting...\n"));
1455    }
```

```
1456 }
1457
1458 static void x86_32_instr_live_graph_build(Aia_Instr *in, Live_Graph *g)
1459 {
1460    Aia_Block *b = aia_instr_get_block(in);
1461    Aia_Instr *suc = aia_instr_get_sucessor(in);
1462    if (!suc) {
1463       Aia_Block *suc_block;
1464       AIA_BLOCK_FOR_EACH_SUCESSOR(b, suc_block) {
1465          ___x86_32_instr_add_interferences(in,
1466                ___aia_block_peek_first_instr(suc_block), g);
1467       }
1468    } else {
1469       ___x86_32_instr_add_interferences(in, suc, g);
1470    }
1471
1472 #if 0
1473    void add_default_8bit_interferences(Aia_Operand *src)
1474    {
1475       DEBUG(
1476          if (aia_operand_is_reg(src))
1477             DLOG("try add default interference to: %S\n",
1478                   aia_operand_reg_get_name(src));
1479       );
1480
1481       if (aia_operand_is_reg(src) &&
1482             aia_instr_get_src_ops_size(in) == AIA_BYTE) {
1483          DLOG("DO add default interference to: %S\n",
1484                aia_operand_reg_get_name(src));
1485          Live_Node *live_node = live_graph_lookup(g, src);
1486          assert(live_node);
1487          live_node_default_8bit_interferences(live_node, g);
1488       }
1489    }
1490
1491    Aia_Operand *src;
1492    AIA_INSTR_FOR_EACH_SRC(in, src)
1493       add_default_8bit_interferences(src);
1494 #endif
1495 }
1496
1497 static void x86_32_block_live_graph_build(Aia_Block *b, Live_Graph *g)
1498 {
1499    Aia_Instr *in;
1500    AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
1501       x86_32_instr_live_graph_build(in, g);
1502 }
1503
1504 static void x86_32_section_live_graph_build(Aia_Section *sec, Live_Graph *g)
1505 {
1506    Aia_Block *b;
1507    AIA_SECTION_FOR_EACH_BLOCK_REVERSED(sec, b)
1508       x86_32_block_live_graph_build(b, g);
1509
1510    Aia_Func *func;
1511    AIA_SECTION_FOR_EACH_FUNC(sec, func) {
1512       AIA_FUNC_FOR_EACH_BLOCK_REVERSED(func, b)
1513          x86_32_block_live_graph_build(b, g);
1514
1515       Aia_Func_Trampoline *tramp;
1516       AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
1517          x86_32_block_live_graph_build(tramp->block, g);
1518    }
1519 }
1520
1521 static inline void live_graph_build(Aia *aia, Live_Graph *g)
1522 {
1523    Aia_Section *sec;
1524    AIA_FOR_EACH_SECTION(aia, sec)
1525       x86_32_section_live_graph_build(sec, g);
1526 }
1527
1528 static void live_graph_insert(Live_Graph *g, Aia_Operand *op, uint8_t var_size)
1529 {
```

```
1530     if (!op)
1531        return;
1532
1533     switch (aia_operand_get_type(op)) {
1534     case AIA_OPERAND_REG:
1535        break;
1536     case AIA_OPERAND_DISPLAY_REF:
1537        live_graph_insert(g,
1538              aia_operand_display_ref_get_display_reg(op), var_size);
1539        return;
1540     case AIA_OPERAND_ADDR_REF:
1541        live_graph_insert(g, aia_operand_addr_ref_get_base(op), var_size);
1542        live_graph_insert(g, aia_operand_addr_ref_get_index(op), var_size);
1543        return;
1544
1545     default:
1546        return;
1547     }
1548
1549     Live_Node *n = ___live_graph_get(g, op, var_size);
1550     if (var_size != AIA_LONG) {
1551        assert(var_size == AIA_BYTE);
1552        n->var_size = var_size;
1553     }
1554  }
1555
1556  static void live_graph_block_init(Aia_Block *b, Live_Graph *g, Aia *aia UNUSED)
1557  {
1558     Aia_Operand *op;
1559
1560     Aia_Instr *in;
1561     AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in) {
1562        AIA_INSTR_FOR_EACH_SRC(in, op)
1563           live_graph_insert(g, op, aia_instr_get_src_ops_size(in));
1564
1565        op = aia_instr_get_dest_op(in);
1566        live_graph_insert(g, op, aia_instr_get_dest_op_size(in));
1567     }
1568  }
1569
1570  static void live_graph_insert_x86_32_regs(Live_Graph *g)
1571  {
1572     live_graph_insert(g, reg_eax, AIA_LONG);
1573     live_graph_insert(g, reg_edx, AIA_LONG);
1574     live_graph_insert(g, reg_ecx, AIA_LONG);
1575     live_graph_insert(g, reg_ebx, AIA_LONG);
1576     live_graph_insert(g, reg_esi, AIA_LONG);
1577     live_graph_insert(g, reg_edi, AIA_LONG);
1578     live_graph_insert(g, reg_ebp, AIA_LONG);
1579     live_graph_insert(g, reg_esp, AIA_LONG);
1580     live_graph_insert(g, reg_al, AIA_BYTE);
1581     live_graph_insert(g, reg_dl, AIA_BYTE);
1582     live_graph_insert(g, reg_cl, AIA_BYTE);
1583     live_graph_insert(g, reg_bl, AIA_BYTE);
1584     live_graph_insert(g, reg_ah, AIA_BYTE);
1585     live_graph_insert(g, reg_dh, AIA_BYTE);
1586     live_graph_insert(g, reg_ch, AIA_BYTE);
1587     live_graph_insert(g, reg_bh, AIA_BYTE);
1588  }
1589
1590  static void live_graph_init(Aia *aia, Live_Graph *g)
1591  {
1592     live_graph_insert_x86_32_regs(g);
1593
1594     Aia_Section *sec;
1595     AIA_FOR_EACH_SECTION(aia, sec) {
1596        Aia_Block *b;
1597        AIA_SECTION_FOR_EACH_BLOCK_REVERSED(sec, b)
1598              live_graph_block_init(b, g, aia);
1599
1600        Aia_Func *func;
1601        AIA_SECTION_FOR_EACH_FUNC(sec, func) {
1602           AIA_FUNC_FOR_EACH_BLOCK_REVERSED(func, b)
1603              live_graph_block_init(b, g, aia);
```

```
1604
1605            Aia_Func_Trampoline *tramp;
1606            AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
1607               live_graph_block_init(tramp->block, g, aia);
1608         }
1609      }
1610   }
1611
1612   static void live_graph_instr_call_add_interference(Aia_Instr *in,
1613         Live_Graph *g)
1614   {
1615      if (aia_instr_get_type(in) != AIA_CALL)
1616         return;
1617
1618      DLOG("add call interferences\n");
1619
1620      Live_Set *vars = in->meta_data;
1621      Live_Set_Entry *e;
1622      LIVE_SET_FOR_EACH_ENTRY(vars, e) {
1623         ___x86_32_instr_force_interferences(in, g,
1624               live_graph_lookup(g, reg_cl));
1625         ___x86_32_instr_force_interferences(in, g,
1626               live_graph_lookup(g, reg_al));
1627         ___x86_32_instr_force_interferences(in, g,
1628               live_graph_lookup(g, reg_dl));
1629      }
1630   }
1631
1632   static void live_graph_block_default_interferences(Aia_Block *b,
1633         Live_Graph *g)
1634   {
1635      Aia_Instr *in;
1636      AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
1637         live_graph_instr_call_add_interference(in, g);
1638   }
1639
1640   static inline void live_graph_default_interferences(Aia *aia, Live_Graph *g)
1641   {
1642      Aia_Block *b;
1643      Aia_Section *sec;
1644      AIA_FOR_EACH_SECTION(aia, sec) {
1645         AIA_SECTION_FOR_EACH_BLOCK_REVERSED(sec, b)
1646            live_graph_block_default_interferences(b, g);
1647
1648         Aia_Func *func;
1649         AIA_SECTION_FOR_EACH_FUNC(sec, func) {
1650            AIA_FUNC_FOR_EACH_BLOCK_REVERSED(func, b)
1651               live_graph_block_default_interferences(b, g);
1652
1653            Aia_Func_Trampoline *tramp;
1654            AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
1655               live_graph_block_default_interferences(tramp->block, g);
1656         }
1657      }
1658   }
1659
1660   static void x86_32_reg_alloc_do_replace(Aia_Instr *in,
1661         Aia_Operand *from, Aia_Operand *to)
1662   {
1663      if (!aia_operand_is_reg(from) || !aia_operand_is_reg(to))
1664         return;
1665      if (x86_32_is_concrete_reg(from))
1666         return;
1667      if (aia_operands_equal(from, to))
1668         return;
1669
1670      ___aia_operand_acquire(from);
1671
1672      DEBUG(
1673         DLOGT(def, "try to replace ");
1674         aia_operand_dump(stderr, from, false);
1675         DLOGT(def, " with ");
1676         aia_operand_dump(stderr, to, false);
1677         DLOGT(def, "\n");
```

```
1678     );
1679
1680     Aia_Instr *suc = aia_instr_get_sucessor(in);
1681     for (; suc; suc = aia_instr_get_sucessor(suc)) {
1682        if (!live_set_contains_op(suc->meta_data, from))
1683           break;
1684
1685        if (!aia_instr_is_concrete(suc))
1686           continue;
1687        if (aia_instr_get_type(suc) == AIA_CALL) {
1688           if (x86_32_is_concrete_reg(to) &&
1689                 !x86_32_is_callee_save_reg(to))
1690              goto out;
1691        }
1692        Aia_Operand *dest = aia_instr_get_dest_op(suc);
1693        if (dest) {
1694
1695           if (aia_operands_equal(dest, from) &&
1696                 live_set_contains_op(suc->meta_data, to))
1697              goto out;
1698
1699           if (aia_operands_equal(dest, to)) {
1700              switch (aia_instr_get_type(suc)) {
1701              case AIA_MOV:;
1702                 Aia_Operand *src = aia_instr_get_src_op(suc, 0);
1703                 if (aia_operands_equal(from, src) ||
1704                       aia_operands_equal(to, src))
1705                    continue;
1706
1707                 break;
1708
1709              default:
1710                 break;
1711              }
1712              goto out;
1713           }
1714        }
1715     }
1716
1717     if (!suc)
1718        goto out;
1719
1720     suc = in;
1721     do {
1722        Int idx = -1;
1723        Aia_Operand *op;
1724        bool did_replace = false;
1725        AIA_INSTR_FOR_EACH_OPERAND(suc, op) {
1726           if (op) {
1727              switch (aia_operand_get_type(op)) {
1728              case AIA_OPERAND_REG:
1729                 did_replace |= x86_32_reg_alloc_replace_reg(suc, idx,
1730                       from, to);
1731                 break;
1732              case AIA_OPERAND_ADDR_REF:
1733                 did_replace |= x86_32_reg_alloc_replace_addr_ref(suc,
1734                       idx, from, to);
1735                 break;
1736              case AIA_OPERAND_DISPLAY_REF:
1737                 did_replace |= x86_32_reg_alloc_replace_display_ref(suc,
1738                       idx, from, to);
1739                 break;
1740
1741              default:
1742                 break;
1743              }
1744           }
1745           ++idx;
1746        }
1747
1748        if (live_set_remove_op(suc->meta_data, from))
1749           live_set_insert_op(suc->meta_data, to);
1750
1751        suc = aia_instr_get_sucessor(suc);
```

```
1752     } while (live_set_contains_op(suc->meta_data, from));
1753
1754  out:
1755     ___aia_operand_release(from);
1756  }
1757
1758  static void x86_32_reg_alloc_replace_regs_block(Aia_Block *b)
1759  {
1760     Aia_Instr *in;
1761     Aia_Operand *src;
1762     Aia_Operand *dest;
1763     AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in) {
1764        switch (aia_instr_get_type(in)) {
1765        case AIA_MOV:
1766           src = aia_instr_get_src_op(in, 0);
1767           dest = aia_instr_get_dest_op(in);
1768           x86_32_reg_alloc_do_replace(in, dest, src);
1769           break;
1770
1771        default:
1772           break;
1773        }
1774     }
1775  }
1776
1777  static void x86_32_reg_alloc_replace_regs(Aia *aia)
1778  {
1779     Aia_Block *b;
1780     Aia_Section *sec;
1781     AIA_FOR_EACH_SECTION(aia, sec) {
1782        AIA_SECTION_FOR_EACH_BLOCK_REVERSED(sec, b)
1783           x86_32_reg_alloc_replace_regs_block(b);
1784
1785        Aia_Func *func;
1786        AIA_SECTION_FOR_EACH_FUNC(sec, func) {
1787           AIA_FUNC_FOR_EACH_BLOCK_REVERSED(func, b)
1788              x86_32_reg_alloc_replace_regs_block(b);
1789
1790           Aia_Func_Trampoline *tramp;
1791           AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
1792              x86_32_reg_alloc_replace_regs_block(tramp->block);
1793        }
1794     }
1795  }
1796
1797  static void x86_32_instr_live_set_dump(FILE *stream, Aia_Instr *in)
1798  {
1799     String_Builder sb = STRING_BUILDER_INIT();
1800     string_builder_assign(&sb, S(" # live { "));
1801     Const_String v;
1802     Live_Set *s = in->meta_data;
1803     LIVE_SET_FOR_EACH_VAR(s, v) {
1804        string_builder_append(&sb, v);
1805        string_builder_append_char(&sb, ' ');
1806     }
1807     string_builder_append_char(&sb, '}');
1808     file_print_message(stream, string_builder_const_str(&sb));
1809     string_builder_clear(&sb);
1810  }
1811
1812  static void x86_32_reg_liveness_dump(Aia *aia, Const_String postfix)
1813  {
1814     aia_set_instr_dump_callback(aia, x86_32_instr_live_set_dump);
1815
1816     String fname = string_from_format(S("%S.vitaly.%S"),
1817           aia_get_file_name(aia), postfix);
1818     FILE *f = file_open(fname, S("w"));
1819     if (!f)
1820        fatal_error(S("unable to open file %S for intermediate "
1821                  "code dump [%m]\n"), fname);
1822     string_destroy(fname);
1823     aia_dump(aia, f);
1824     file_close(f);
1825
```

```
1826     aia_clear_instr_dump_callback(aia);
1827  }
1828
1829  static void x86_32_reg_alloc_dump(Aia *aia)
1830  {
1831     String fname = string_from_format(S("%S.vitaly.reg-alloc-x86-32-ic"),
1832           aia_get_file_name(aia));
1833     FILE *f = file_open(fname, S("w"));
1834     if (!f)
1835        fatal_error(S("unable to open file %S for intermediate code dump\n"),
1836              fname);
1837     string_destroy(fname);
1838     aia_dump(aia, f);
1839     file_close(f);
1840  }
1841
1842  void x86_32_reg_alloc_color(Aia *aia, Aia_Operand_Map *repl_map)
1843  {
1844     bool init_liveness_dumped = false;
1845
1846     DEBUG(
1847        Aia_Operand_Map_Entry *e;
1848        AIA_OPERAND_MAP_FOR_EACH_ENTRY(repl_map, e) {
1849           aia_operand_dump(stderr, e->operand, false);
1850           DLOGT(def, " -> ");
1851           aia_operand_dump(stderr, e->value, false);
1852           DLOGT(def, "\n");
1853        }
1854     );
1855
1856     DLOG("reg alloc file: %S\n", aia_get_file_name(aia));
1857     if (cmdopts.opt_unused_mov) {
1858        live_sets_init(aia);
1859        live_sets_build(aia);
1860
1861        if (cmdopts.dump_init_liveness_x86_32_ic) {
1862           x86_32_reg_liveness_dump(aia, S("init-liveness-x86-32-ic"));
1863           init_liveness_dumped = true;
1864        }
1865
1866        x86_32_reg_alloc_replace_regs(aia);
1867
1868        if (cmdopts.dump_unused_mov_ic)
1869           x86_32_reg_liveness_dump(aia, S("unused-mov-ic"));
1870
1871        live_sets_destroy(aia);
1872
1873     }
1874
1875     x86_32_nop_mov_remove(aia);
1876
1877     for (;;) {
1878        live_sets_init(aia);
1879        live_sets_build(aia);
1880
1881        if (cmdopts.dump_init_liveness_x86_32_ic && !init_liveness_dumped) {
1882           x86_32_reg_liveness_dump(aia, S("init-liveness-x86-32-ic"));
1883           init_liveness_dumped = true;
1884        }
1885
1886        Live_Graph *g = live_graph_alloc();
1887        live_graph_init(aia, g);
1888        live_graph_build(aia, g);
1889        live_graph_default_interferences(aia, g);
1890
1891        live_graph_build_queues(g);
1892
1893        if (live_graph_build_stack(g)) {
1894           if (cmdopts.dump_liveness_x86_32_ic)
1895              x86_32_reg_liveness_dump(aia, S("liveness-x86-32-ic"));
1896
1897           live_graph_assign_regs(g);
1898           x86_32_assign_regs(aia, g);
1899
```

```
1900            if (cmdopts.dump_reg_alloc_x86_32_ic)
1901               x86_32_reg_alloc_dump(aia);
1902
1903            live_graph_destroy(g);
1904            live_sets_destroy(aia);
1905            break;
1906
1907         }
1908         x86_32_spill_regs(aia, g, repl_map);
1909
1910         live_graph_destroy(g);
1911         live_sets_destroy(aia);
1912
1913         x86_32_nop_mov_remove(aia);
1914
1915         X86_32_Spill_Meta_Data *md = aia->meta_data;
1916         x86_32_normalize(aia);
1917         aia->meta_data = md;
1918
1919         aia_normalize_addr(aia);
1920      }
1921
1922      x86_32_nop_mov_remove(aia);
1923   }
```

:

A.8.23 src/x86_32/x86_32_reg_alloc_color.h

```
1  #ifndef X86_32_REG_ALLOC_COLOR_H
2  #define X86_32_REG_ALLOC_COLOR_H
3
4  #include <aia/aia_operand_map.h>
5
6  void x86_32_reg_alloc_color(Aia *aia, Aia_Operand_Map *repl_map);
7
8  #endif // X86_32_REG_ALLOC_COLOR_H
```

:

A.8.24 src/x86_32/x86_32_reg_vars.c

```
1  #include "x86_32_reg_vars.h"
2  #include <aia/aia_func_access.h>
3  #include <aia/aia_func_kills.h>
4  #include <aia/aia_operand_set.h>
5  #include <aia/aia_operand_map.h>
6  #include <main.h>
7
8  typedef struct Instr_Meta {
9     Aia_Operand_Set use_set;
10    Aia_Operand_Set def_set;
11    bool is_inserted;
12 } Instr_Meta;
13
14 typedef struct Aia_Meta {
15    Aia_Operand_Map subst_map;
16    Aia_Operand_Map *repl_map;
17 } Aia_Meta;
18
19 static inline bool x86_32_reg_vars_operand_significant(Aia_Operand *op)
20 {
21    switch (aia_operand_get_type(op)) {
22    case AIA_OPERAND_LABEL:
23       /* Fall through. */
24    case AIA_OPERAND_LOCAL_REF:
25       return true;
```

```
26      default:
27         return false;
28      }
29   }
30
31   static void x86_32_reg_vars_init_instr(Aia_Instr *in, bool is_inserted)
32   {
33      Instr_Meta *imeta = ALLOC_NEW(Instr_Meta);
34      imeta->use_set = AIA_OPERAND_SET_INIT();
35      imeta->def_set = AIA_OPERAND_SET_INIT();
36      imeta->is_inserted = is_inserted;
37      in->meta_data = imeta;
38   }
39
40   static void x86_32_reg_vars_init_block(Aia_Block *b)
41   {
42      Aia_Instr *in;
43      AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
44         x86_32_reg_vars_init_instr(in, false);
45   }
46
47   static void x86_32_reg_vars_ins_glob_uses_defs(Aia_Block *b,
48         Aia_Operand_Set *glob_use_set,
49         Aia_Operand_Set *all_defs,
50         Aia_Operand_Set *all_uses,
51         Aia *aia UNUSED)
52   {
53      Aia_Instr *in;
54      AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in) {
55
56         switch (aia_instr_get_type(in)) {
57         AIA_CASE_INCONCRETE:
58            continue;
59         case AIA_CALL:
60            continue;
61         default:
62            break;
63         }
64
65         Aia_Operand *op = aia_instr_get_dest_op(in);
66         if (op) {
67            if (aia_operand_get_type(op) == AIA_OPERAND_LABEL)
68               aia_operand_set_insert(glob_use_set, op);
69            if (x86_32_reg_vars_operand_significant(op))
70               aia_operand_set_insert(all_defs, op);
71         }
72
73         AIA_INSTR_FOR_EACH_SRC(in, op) {
74            if (x86_32_reg_vars_operand_significant(op))
75               aia_operand_set_insert(all_uses, op);
76         }
77      }
78   }
79
80   static void x86_32_reg_vars_insert_call_ops(Aia_Block *b,
81         Aia_Operand_Set *all_defs, Aia *aia)
82   {
83      Aia_Instr *in;
84      AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in) {
85         if (aia_instr_get_type(in) != AIA_CALL)
86            continue;
87
88         Instr_Meta *imeta = in->meta_data;
89         Aia_Operand_Set *use_set = &imeta->use_set;
90         Aia_Operand_Set *def_set = &imeta->def_set;
91
92         Aia_Operand *call_lbl = aia_instr_get_src_op(in, 0);
93         Const_String callee_name;
94         if (aia_operand_get_type(call_lbl) == AIA_OPERAND_LABEL)
95            callee_name = aia_operand_label_get_name(call_lbl);
96         else
97            callee_name = NULL;
98         Const_String curr_func = ___aia_get_curr_func_name(aia);
99
```

```
100         Aia_Operand *op;
101         AIA_OPERAND_SET_FOR_EACH_OPERAND(all_defs, op) {
102            if (aia_func_uses(callee_name, curr_func, op, aia))
103               aia_operand_set_insert(use_set, op);
104            if (func_kills_operand(callee_name, curr_func, op, aia)) {
105               aia_operand_set_insert(def_set, op);
106               aia_operand_set_insert(use_set, op);
107            }
108         }
109      }
110   }
111
112   static void x86_32_reg_vars_ins_entry_defs(Aia_Operand_Set *def_set,
113         Aia_Operand_Set *all_uses)
114   {
115      Aia_Operand *op;
116      AIA_OPERAND_SET_FOR_EACH_OPERAND(all_uses, op)
117         aia_operand_set_insert(def_set, op);
118   }
119
120   static void x86_32_reg_vars_init(Aia *aia)
121   {
122      inline Instr_Meta *get_last_instr_meta(Aia_Block *b)
123      {
124         Aia_Instr *in = ___aia_block_peek_last_instr(b);
125         return in->meta_data;
126      }
127
128      inline Instr_Meta *get_first_instr_meta(Aia_Block *b)
129      {
130         Aia_Instr *in = ___aia_block_peek_first_instr(b);
131         return in->meta_data;
132      }
133
134      Aia_Block *b;
135      Instr_Meta *imeta;
136      Aia_Operand_Set all_defs = AIA_OPERAND_SET_INIT();
137      Aia_Operand_Set all_uses = AIA_OPERAND_SET_INIT();
138
139      Aia_Section *sec;
140      AIA_FOR_EACH_SECTION(aia, sec) {
141         ___aia_set_curr_func(aia, NULL);
142         AIA_SECTION_FOR_EACH_BLOCK(sec, b)
143            x86_32_reg_vars_init_block(b);
144
145         imeta = get_last_instr_meta(sec->exit_block);
146         AIA_SECTION_FOR_EACH_BLOCK(sec, b)
147            x86_32_reg_vars_ins_glob_uses_defs(b, &imeta->use_set,
148                  &all_defs, &all_uses, aia);
149
150         imeta = get_first_instr_meta(sec->entry_block);
151         x86_32_reg_vars_ins_entry_defs(&imeta->def_set, &all_uses);
152         aia_operand_set_for_each_destroy(&all_uses);
153
154         AIA_SECTION_FOR_EACH_BLOCK(sec, b)
155            x86_32_reg_vars_insert_call_ops(b, &all_defs, aia);
156
157         aia_operand_set_for_each_destroy(&all_defs);
158
159         Aia_Func *func;
160         AIA_SECTION_FOR_EACH_FUNC(sec, func) {
161            ___aia_set_curr_func(aia, func);
162            AIA_FUNC_FOR_EACH_BLOCK(func, b)
163               x86_32_reg_vars_init_block(b);
164
165            imeta = get_last_instr_meta(func->exit_block);
166            AIA_FUNC_FOR_EACH_BLOCK(func, b)
167               x86_32_reg_vars_ins_glob_uses_defs(b, &imeta->use_set,
168                     &all_defs, &all_uses, aia);
169
170            imeta = get_first_instr_meta(func->entry_block);
171            x86_32_reg_vars_ins_entry_defs(&imeta->def_set,
172                  &all_uses);
173            aia_operand_set_for_each_destroy(&all_uses);
```

```
174
175           AIA_FUNC_FOR_EACH_BLOCK(func, b)
176              x86_32_reg_vars_insert_call_ops(b, &all_defs, aia);
177
178           aia_operand_set_for_each_destroy(&all_defs);
179
180  #if 0
181           Aia_Func_Trampoline *tramp;
182           AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp) {
183              x86_32_reg_vars_init_block(tramp->block);
184              imeta = get_last_instr_meta(tramp->block);
185
186              x86_32_reg_vars_ins_glob_uses_defs(tramp->block,
187                    &imeta->use_set, &all_defs, &all_uses, aia);
188
189              imeta = get_first_instr_meta(tramp->block);
190              x86_32_reg_vars_ins_entry_defs(&imeta->def_set,
191                    &all_uses);
192              aia_operand_set_for_each_destroy(&all_uses);
193
194              x86_32_reg_vars_insert_call_ops(b, &all_defs, aia);
195
196              aia_operand_set_for_each_destroy(&all_defs);
197           }
198  #endif
199        }
200     }
201  }
202
203  static inline void x86_32_reg_vars_instr_destroy(Aia_Instr *in)
204  {
205     Instr_Meta *imeta = in->meta_data;
206     if (imeta) {
207        aia_operand_set_for_each_destroy(&imeta->use_set);
208        aia_operand_set_for_each_destroy(&imeta->def_set);
209        free_mem(imeta);
210     }
211  }
212
213  static void x86_32_reg_vars_destroy(Aia *aia)
214  {
215     Aia_Instr *in;
216     Aia_Block *b;
217
218     Aia_Section *sec;
219     AIA_FOR_EACH_SECTION(aia, sec) {
220        AIA_SECTION_FOR_EACH_BLOCK(sec, b) {
221           AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
222              x86_32_reg_vars_instr_destroy(in);
223        }
224
225        Aia_Func *func;
226        AIA_SECTION_FOR_EACH_FUNC(sec, func) {
227           AIA_FUNC_FOR_EACH_BLOCK(func, b) {
228              AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
229                 x86_32_reg_vars_instr_destroy(in);
230           }
231
232  #if 0
233           Aia_Func_Trampoline *tramp;
234           AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp) {
235              b = tramp->block;
236              AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
237                 x86_32_reg_vars_instr_destroy(in);
238           }
239  #endif
240        }
241     }
242  }
243
244  static void x86_32_reg_vars_insert_uses_instr(Aia_Instr *pred,
245        Aia_Instr *in, Aia *aia)
246  {
247     Instr_Meta *imeta = in->meta_data;
```

```
248     Aia_Operand_Set *set = &imeta->use_set;
249     Instr_Meta *pred_imeta = pred->meta_data;
250     Aia_Operand_Set *pred_set = &pred_imeta->use_set;
251
252     Aia_Operand *dest = aia_instr_get_dest_op(pred);
253     Aia_Operand *op;
254     AIA_OPERAND_SET_FOR_EACH_OPERAND(set, op) {
255        if (!dest || !aia_operands_equal(dest, op)) {
256           /* Don't change aia->meta_data when it's != NULL,
257            * It might be pointing to Aia_Meta. */
258           if (aia_operand_set_insert(pred_set, op) && !aia->meta_data)
259              aia->meta_data = INT_TO_PTR(true);
260        }
261     }
262
263     if (!aia_instr_is_concrete(in))
264        return;
265
266     Aia_Operand_Set *def_set = &imeta->def_set;
267     AIA_INSTR_FOR_EACH_SRC(in, op) {
268        if (aia_operand_set_contains(def_set, op))
269           /* Don't change aia->meta_data when it's != NULL,
270            * It might be pointing to Aia_Meta. */
271           if (aia_operand_set_insert(set, op) && !aia->meta_data)
272              aia->meta_data = INT_TO_PTR(true);
273     }
274  }
275
276  static void x86_32_reg_vars_insert_defs_mov(Aia_Instr *suc,
277        Aia_Instr *in, Aia *aia)
278  {
279     Instr_Meta *imeta = in->meta_data;
280     Aia_Operand_Set *set = &imeta->def_set;
281     Instr_Meta *suc_imeta = suc->meta_data;
282     Aia_Operand_Set *suc_set = &suc_imeta->def_set;
283
284     Aia_Operand *d = aia_instr_get_dest_op(suc);
285     Aia_Operand *s = aia_instr_get_src_op(suc, 0);
286
287     Aia_Operand *op;
288     AIA_OPERAND_SET_FOR_EACH_OPERAND(set, op) {
289        bool src_same = aia_operands_equal(s, op);
290        if (!d || (!aia_operands_equal(d, op) && !src_same)) {
291           /* Don't change aia->meta_data when it's != NULL,
292            * It might be pointing to Aia_Meta. */
293           if (aia_operand_set_insert(suc_set, op) && !aia->meta_data)
294              aia->meta_data = INT_TO_PTR(true);
295        } else if (src_same) {
296           aia_operand_set_insert(&imeta->use_set, op);
297        }
298     }
299  }
300
301  static void x86_32_reg_vars_insert_defs_instr(Aia_Instr *suc,
302        Aia_Instr *in, Aia *aia)
303  {
304     switch (aia_instr_get_type(suc)) {
305     case AIA_MOV:
306     case AIA_MOVS:
307        x86_32_reg_vars_insert_defs_mov(suc, in, aia);
308        return;
309
310     default:
311        break;
312     }
313
314     Instr_Meta *imeta = in->meta_data;
315     Aia_Operand_Set *set = &imeta->def_set;
316     Instr_Meta *suc_imeta = suc->meta_data;
317     Aia_Operand_Set *suc_set = &suc_imeta->def_set;
318
319     Aia_Operand *dest = aia_instr_get_dest_op(suc);
320     Aia_Operand *op;
321     AIA_OPERAND_SET_FOR_EACH_OPERAND(set, op) {
```

```
322         if (!dest || !aia_operands_equal(dest, op)) {
323            if (aia_operand_set_insert(suc_set, op) && !aia->meta_data)
324               aia->meta_data = INT_TO_PTR(true);
325         }
326      }
327   }
328
329   static void x86_32_reg_vars_build_uses_instr(Aia_Instr *in, Aia *aia)
330   {
331      Aia_Instr *pred = aia_instr_get_predecessor(in);
332      if (!pred) {
333         Aia_Block *b = aia_instr_get_block(in);
334         Aia_Block *pred_block;
335         AIA_BLOCK_FOR_EACH_PREDECESSOR(b, pred_block) {
336            x86_32_reg_vars_insert_uses_instr(
337                  ___aia_block_peek_last_instr(pred_block), in, aia);
338         }
339      } else {
340         x86_32_reg_vars_insert_uses_instr(pred, in, aia);
341      }
342   }
343
344   static void x86_32_reg_vars_build_defs_instr(Aia_Instr *in, Aia *aia)
345   {
346      Aia_Instr *suc = aia_instr_get_sucessor(in);
347      if (!suc) {
348         Aia_Block *b = aia_instr_get_block(in);
349         Aia_Block *suc_block;
350         AIA_BLOCK_FOR_EACH_SUCESSOR(b, suc_block) {
351            x86_32_reg_vars_insert_defs_instr(
352                  ___aia_block_peek_first_instr(suc_block), in, aia);
353         }
354      } else {
355         x86_32_reg_vars_insert_defs_instr(suc, in, aia);
356      }
357   }
358
359   static inline void x86_32_reg_vars_build_uses_block(Aia_Block *b, Aia *aia)
360   {
361      Aia_Instr *in;
362      AIA_BLOCK_FOR_EACH_INSTRUCTION_REVERSED(b, in)
363         x86_32_reg_vars_build_uses_instr(in, aia);
364   }
365
366   static inline void x86_32_reg_vars_build_defs_block(Aia_Block *b, Aia *aia)
367   {
368      Aia_Instr *in;
369      AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
370         x86_32_reg_vars_build_defs_instr(in, aia);
371   }
372
373   static void x86_32_reg_vars_build_uses(Aia *aia)
374   {
375      do {
376         aia->meta_data = INT_TO_PTR(false);
377
378         Aia_Block *b;
379         Aia_Section *sec;
380         AIA_FOR_EACH_SECTION(aia, sec) {
381            ___aia_set_curr_func(aia, NULL);
382            AIA_SECTION_FOR_EACH_BLOCK_REVERSED(sec, b)
383               x86_32_reg_vars_build_uses_block(b, aia);
384
385            Aia_Func *func;
386            AIA_SECTION_FOR_EACH_FUNC(sec, func) {
387               ___aia_set_curr_func(aia, func);
388               AIA_FUNC_FOR_EACH_BLOCK_REVERSED(func, b)
389                  x86_32_reg_vars_build_uses_block(b, aia);
390
391   #if 0
392               Aia_Func_Trampoline *tramp;
393               AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
394                  x86_32_reg_vars_build_uses_block(tramp->block, aia);
395   #endif
```

```
396            }
397         }
398      } while (aia->meta_data);
399   }
400
401   static void x86_32_reg_vars_build_defs(Aia *aia)
402   {
403      do {
404         aia->meta_data = INT_TO_PTR(false);
405
406         Aia_Block *b;
407         Aia_Section *sec;
408         AIA_FOR_EACH_SECTION(aia, sec) {
409            ___aia_set_curr_func(aia, NULL);
410            AIA_SECTION_FOR_EACH_BLOCK(sec, b)
411               x86_32_reg_vars_build_defs_block(b, aia);
412
413            Aia_Func *func;
414            AIA_SECTION_FOR_EACH_FUNC(sec, func) {
415               ___aia_set_curr_func(aia, func);
416               AIA_FUNC_FOR_EACH_BLOCK(func, b)
417                  x86_32_reg_vars_build_defs_block(b, aia);
418
419   #if 0
420               Aia_Func_Trampoline *tramp;
421               AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
422                  x86_32_reg_vars_build_defs_block(tramp->block, aia);
423   #endif
424            }
425         }
426      } while (aia->meta_data);
427   }
428
429   static bool x86_32_reg_vars_use_starts(Aia_Instr *in, Aia_Operand *op)
430   {
431      Instr_Meta *imeta = in->meta_data;
432
433      Aia_Instr *suc = aia_instr_get_sucessor(in);
434      if (!suc)
435         return false;
436
437      Instr_Meta *smeta = suc->meta_data;
438      if (!aia_operand_set_contains(&imeta->use_set, op) &&
439            aia_operand_set_contains(&smeta->use_set, op))
440         return true;
441
442      return false;
443   }
444
445   static bool x86_32_reg_vars_def_ends(Aia_Instr *in, Aia_Operand *op)
446   {
447      Instr_Meta *imeta = in->meta_data;
448      if (imeta->is_inserted)
449         return false;
450
451      Aia_Instr *pred = aia_instr_get_predecessor(in);
452      if (!pred)
453         return false;
454
455      Instr_Meta *pmeta = pred->meta_data;
456      if (!aia_operand_set_contains(&imeta->def_set, op) &&
457            aia_operand_set_contains(&pmeta->def_set, op))
458         return true;
459
460      return false;
461   }
462
463   static inline Aia_Operand *x86_32_reg_vars_get_repl(Aia *aia, Aia_Operand *op)
464   {
465      Aia_Meta *ameta = aia->meta_data;
466      Aia_Operand *val = aia_operand_map_get_value(&ameta->subst_map, op);
467      if (!val) {
468         val = aia_operand_tmp_reg_alloc(aia);
469         aia_operand_map_insert(&ameta->subst_map, op, val);
```

```
470     }
471     return val;
472  }
473
474  static Aia_Operand *x86_32_reg_vars_replace_op(Aia_Instr *in, Int idx,
475        Aia_Operand *op, Aia *aia)
476  {
477     if (!x86_32_reg_vars_operand_significant(op))
478        return NULL;
479
480     Aia_Operand *val = x86_32_reg_vars_get_repl(aia, op);
481
482     aia_instr_replace_op(in, idx, val);
483     return val;
484  }
485
486  static void x86_32_reg_vars_insert_sucessors_use_set(Aia_Instr *in, Aia *aia)
487  {
488     Aia_Instr *suc = aia_instr_get_sucessor(in);
489     assert(suc);
490     x86_32_reg_vars_insert_uses_instr(in, suc, aia);
491  }
492
493  static void x86_32_reg_vars_insert_predecessors_def_set(Aia_Instr *in,
494        Aia *aia)
495  {
496     Aia_Instr *pred = aia_instr_get_predecessor(in);
497     assert(pred);
498     x86_32_reg_vars_insert_defs_instr(in, pred, aia);
499  }
500
501  static void x86_32_reg_vars_replace_instr(Aia_Instr *in, Aia *aia)
502  {
503     if (!aia_instr_is_concrete(in))
504        return;
505
506     Instr_Meta *imeta = in->meta_data;
507     if (imeta->is_inserted)
508        return;
509
510     Aia_Operand *op;
511     Aia_Operand *val;
512     Aia_Operand_Set *def_set = &imeta->def_set;
513
514     switch (aia_instr_get_type(in)) {
515     case AIA_MOV:
516     case AIA_MOVS:
517        op = aia_instr_get_src_op(in, 0);
518        if (x86_32_reg_vars_def_ends(in, op)) {
519           val = x86_32_reg_vars_get_repl(aia, op);
520           Aia_Instr *new_mov = aia_mov_before(op, val, in,
521                 aia_instr_get_dest_op_size(in));
522           x86_32_reg_vars_init_instr(new_mov, true);
523           x86_32_reg_vars_insert_sucessors_use_set(new_mov, aia);
524           x86_32_reg_vars_insert_predecessors_def_set(new_mov, aia);
525        }
526        break;
527
528     default:
529        break;
530     }
531
532     if (aia_instr_get_type(in) != AIA_CALL) {
533        Int idx = 0;
534        AIA_INSTR_FOR_EACH_SRC(in, op) {
535           if (!aia_operand_set_contains(def_set, op) &&
536                 !x86_32_reg_vars_def_ends(in, op))
537              x86_32_reg_vars_replace_op(in, idx, op, aia);
538           ++idx;
539        }
540     }
541
542     op = aia_instr_get_dest_op(in);
543     if (!op)
```

```
544         return;
545
546      ___aia_operand_acquire(op);
547      val = x86_32_reg_vars_replace_op(in, -1, op, aia);
548      if (val && x86_32_reg_vars_use_starts(in, op)) {
549         Aia_Instr *new_mov = aia_mov_after(val, op, in,
550               aia_instr_get_dest_op_size(in));
551         x86_32_reg_vars_init_instr(new_mov, true);
552         x86_32_reg_vars_insert_sucessors_use_set(new_mov, aia);
553         x86_32_reg_vars_insert_predecessors_def_set(new_mov, aia);
554      }
555      ___aia_operand_release(op);
556   }
557
558   static inline void x86_32_reg_vars_replace_block(Aia_Block *b, Aia *aia)
559   {
560      Aia_Instr *in;
561      AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in)
562         x86_32_reg_vars_replace_instr(in, aia);
563   }
564
565   static inline void x86_32_reg_vars_init_maps(Aia *aia)
566   {
567      Aia_Meta *ameta = aia->meta_data;
568      ameta->subst_map = AIA_OPERAND_MAP_INIT();
569   }
570
571   static inline void x86_32_reg_vars_finalize_subst_map(Aia *aia)
572   {
573      Aia_Meta *ameta = aia->meta_data;
574      Aia_Operand_Map *smap = &ameta->subst_map;
575      Aia_Operand_Map *rmap = ameta->repl_map;
576
577      Aia_Operand_Map_Entry *e;
578      AIA_OPERAND_MAP_FOR_EACH_ENTRY(smap, e)
579         aia_operand_map_insert(rmap, e->value, e->operand);
580
581      aia_operand_map_for_each_destroy(smap);
582   }
583
584   static inline void x86_32_reg_vars_init_ameta(Aia *aia,
585         Aia_Operand_Map *repl_map)
586   {
587      Aia_Meta *ameta = ALLOC_NEW(Aia_Meta);
588      aia->meta_data = ameta;
589      ameta->repl_map = repl_map;
590   }
591
592   static inline void x86_32_reg_vars_finalize_ameta(Aia *aia)
593   {
594      Aia_Meta *ameta = aia->meta_data;
595      free_mem(ameta);
596   }
597
598   static void x86_32_reg_vars_replace(Aia *aia, Aia_Operand_Map *repl_map)
599   {
600      x86_32_reg_vars_init_ameta(aia, repl_map);
601
602      Aia_Block *b;
603      Aia_Section *sec;
604      AIA_FOR_EACH_SECTION(aia, sec) {
605         x86_32_reg_vars_init_maps(aia);
606         AIA_SECTION_FOR_EACH_BLOCK(sec, b)
607            x86_32_reg_vars_replace_block(b, aia);
608         x86_32_reg_vars_finalize_subst_map(aia);
609
610         Aia_Func *func;
611         AIA_SECTION_FOR_EACH_FUNC(sec, func) {
612            x86_32_reg_vars_init_maps(aia);
613            AIA_FUNC_FOR_EACH_BLOCK(func, b)
614               x86_32_reg_vars_replace_block(b, aia);
615            x86_32_reg_vars_finalize_subst_map(aia);
616
617   #if 0
```

```
618            x86_32_reg_vars_init_maps(aia);
619            Aia_Func_Trampoline *tramp;
620            AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
621               x86_32_reg_vars_replace_block(tramp->block, aia);
622            x86_32_reg_vars_finalize_subst_map(aia);
623     #endif
624          }
625       }
626
627       x86_32_reg_vars_finalize_ameta(aia);
628    }
629
630    static void x86_32_reg_vars_dump_sets(FILE *stream, Aia_Instr *in)
631    {
632       Instr_Meta *imeta = in->meta_data;
633       file_print_message(stream, S("\t# uses { "));
634       Aia_Operand_Set *use_set = &imeta->use_set;
635
636       Uns size = hash_map_size(use_set);
637       if (!size)
638          goto def_set;
639
640       Aia_Operand *op;
641       AIA_OPERAND_SET_FOR_EACH_OPERAND(use_set, op) {
642          aia_operand_dump(stream, op, false);
643          if (--size)
644             file_print_message(stream, S(", "));
645       }
646
647    def_set:
648       file_print_message(stream, S(" } defs { "));
649       Aia_Operand_Set *def_set = &imeta->def_set;
650
651       size = hash_map_size(def_set);
652       if (!size)
653          goto out;
654
655       AIA_OPERAND_SET_FOR_EACH_OPERAND(def_set, op) {
656          aia_operand_dump(stream, op, false);
657          if (--size)
658             file_print_message(stream, S(", "));
659       }
660
661    out:
662       file_print_message(stream, S(" }"));
663
664       if (imeta->is_inserted)
665          file_print_message(stream, S(" inserted"));
666
667    }
668
669    void x86_32_reg_vars_dump(Aia *aia, Const_String postfix)
670    {
671       aia_set_instr_dump_callback(aia, x86_32_reg_vars_dump_sets);
672
673       String fname = string_from_format(S("%S.vitaly.%S"),
674             aia_get_file_name(aia), postfix);
675       FILE *f = file_open(fname, S("w"));
676       if (!f)
677          fatal_error(S("unable to open file %S for intermediate "
678                   "code dump [%m]\n"), fname);
679
680       string_destroy(fname);
681       aia_dump(aia, f);
682       file_close(f);
683
684       aia_clear_instr_dump_callback(aia);
685    }
686
687    Aia_Operand_Map *x86_32_reg_vars(Aia *aia)
688    {
689       Aia_Operand_Map *repl_map = aia_operand_map_alloc();
690       if (!cmdopts.opt_reg_vars)
691          goto out;
```

```
692
693     aia_func_access(aia);
694     aia_collect_func_kills(aia);
695
696     x86_32_reg_vars_init(aia);
697
698     aia_func_access_destroy(aia);
699     aia_destroy_func_kills(aia);
700
701     x86_32_reg_vars_build_defs(aia);
702     x86_32_reg_vars_build_uses(aia);
703
704     if (cmdopts.dump_reg_vars_liveness_ic)
705        x86_32_reg_vars_dump(aia, S("reg-vars-liveness-ic"));
706
707     x86_32_reg_vars_replace(aia, repl_map);
708
709     if (cmdopts.dump_reg_vars_ic)
710        x86_32_reg_vars_dump(aia, S("reg-vars-ic"));
711
712     x86_32_reg_vars_destroy(aia);
713
714 out:
715     return repl_map;
716 }
```

:

A.8.25 src/x86_32/x86_32_reg_vars.h

```
1  #ifndef X86_32_REG_VARS_H
2  #define X86_32_REG_VARS_H
3
4  #include <aia/aia.h>
5  #include <aia/aia_operand_map.h>
6
7  /* Modifies AIA such that variables are kept in
8   * registers as longer.
9   *
10  * Returns mapping from register to memory location register
11  * allocator can use for choosing spill locations. */
12 Aia_Operand_Map *x86_32_reg_vars(Aia *aia);
13
14 #endif // X86_32_REG_VARS_H
```

A.9 Code Generation

:

A.9.1 src/vit/end.s

```
1  .section .init
2     popl  %ebp
3     popl  %edi
4     popl  %esi
5     popl  %ebx
6
7  .section .fini
8     popl  %ebp
9     popl  %edi
10    popl  %esi
11    popl  %ebx
12
13 .section .Vit_libinit, "xa"
14    ret
```

:

A.9.2 src/vit/ini.s

```
.section .init
   pushl %ebx
   pushl %esi
   pushl %edi
   pushl %ebp
   call  _Vit_libinit

.section .fini
   pushl %ebx
   pushl %esi
   pushl %edi
   pushl %ebp

.section .Vit_libinit, "xa"
.type _Vit_libinit, @function
.align 4
_Vit_libinit:
```

:

A.9.3 src/vit/lib.c

```
#include <stdio.h>
#include <stdlib.h>
#include <inttypes.h>
#include <errno.h>

void _Vit_writelnn()
{
   puts("null");
}

void _Vit_writelni(int32_t i)
{
   printf("%" PRId32 "\n", i);
}

void _Vit_writelnr(void *rec)
{
   if (!rec)
      _Vit_writelnn();
   else
      printf("%p\n", rec);
}

void _Vit_writelna(void *ary)
{
   _Vit_writelnr(ary);
}

void _Vit_writelnc(char c)
{
   printf("%c\n", c);
}

void _Vit_writelns(const char *s)
{
   if (s)
      puts(s);
   else
      _Vit_writelnn();
}

void _Vit_writelnb(int8_t b)
```

```
43 {
44    if (b)
45       puts("true");
46    else
47       puts("false");
48 }
49
50 void *_Vit_allocab(int32_t size)
51 {
52    if (size < 0) {
53       errno = EINVAL;
54       return NULL;
55    }
56    int32_t *ret = malloc(size + sizeof(int32_t));
57    if (ret)
58       *ret = size;
59    return ret + 1;
60 }
61
62 void *_Vit_allocal(int32_t size)
63 {
64    if (size < 0) {
65       errno = EINVAL;
66       return NULL;
67    }
68    if (size > (INT32_MAX >> 2) - (int32_t)sizeof(int32_t)) {
69       errno = ERANGE;
70       return NULL;
71    }
72    int32_t *ret = malloc((size << 2) + sizeof(int32_t));
73    if (ret)
74       *ret = size;
75    return ret + 1;
76 }
77
78 void *_Vit_alloc(int32_t size)
79 {
80    if (size < 0) {
81       errno = EINVAL;
82       return NULL;
83    }
84    if (!size)
85       size = 1;
86    return malloc(size);
87 }
88
89 void _Vit_deletea(int32_t *ary)
90 {
91    if (ary)
92       free(ary - 1);
93 }
94
95 void _Vit_delete(void *p)
96 {
97    free(p);
98 }
```

:

A.9.4 src/vit/lib.s

```
1  .section .rodata
2  writelni_fmt:
3     .string "%d\n"
4  writelnc_fmt:
5     .string "%c\n"
6  writelnb_true:
7     .string "true"
8  writelnb_false:
9     .string "false"
10 writelnr_fmt:
```

```
11      .string "%p\n"
12  writelnn_str:
13      .string "null"
14
15  .align 4
16  .type _Vit_writelnn, @function
17  .globl _Vit_writelnn
18  _Vit_writelnn:
19  .cfi_startproc
20      pushl $writelnn_str
21      call  puts
22      addl  $4, %esp
23      ret
24  .cfi_endproc
25  .size _Vit_writelnn, . - _Vit_writelnn
26
27  .align 4
28  .type _Vit_writelni, @function
29  .globl _Vit_writelni
30  _Vit_writelni:
31  .cfi_startproc
32      pushl 4(%esp)
33      pushl $writelni_fmt
34      call  printf
35      addl  $8, %esp
36      ret
37  .cfi_endproc
38  .size _Vit_writelni, . - _Vit_writelni
39
40  .align 4
41  .type null_check, @function
42  null_check:
43  .cfi_startproc
44      cmpl  $0, 8(%esp)
45      jne   1f
46      pushl $writelnn_str
47      call  puts
48      addl  $8, %esp
49  1:
50      ret
51  .cfi_endproc
52  .size null_check, . - null_check
53
54  .align 4
55  .type _Vit_writelnr, @function
56  .globl _Vit_writelnr
57  _Vit_writelnr:
58  .cfi_startproc
59      call  null_check
60      pushl 4(%esp)
61      pushl $writelnr_fmt
62      call  printf
63      addl  $8, %esp
64      ret
65  .cfi_endproc
66  .size _Vit_writelnr, . - _Vit_writelnr
67
68  .align 4
69  .type _Vit_writelna, @function
70  .globl _Vit_writelna
71  _Vit_writelna:
72  .cfi_startproc
73      jmp   _Vit_writelnr
74  .cfi_endproc
75  .size _Vit_writelna, . - _Vit_writelna
76
77  .align 4
78  .type _Vit_writelnc, @function
79  .globl _Vit_writelnc
80  _Vit_writelnc:
81  .cfi_startproc
82      pushl 4(%esp)
83      pushl $writelnc_fmt
84      call  printf
```

```
85     addl  $8, %esp
86     ret
87  .cfi_endproc
88  .size _Vit_writelnc, . - _Vit_writelnc
89
90  .align 4
91  .type _Vit_writelns, @function
92  .globl _Vit_writelns
93  _Vit_writelns:
94  .cfi_startproc
95     call  null_check
96     pushl 4(%esp)
97     call  puts
98     addl  $4, %esp
99     ret
100 .cfi_endproc
101 .size _Vit_writelns, . - _Vit_writelns
102
103 .align 4
104 .type _Vit_writelnb, @function
105 .globl _Vit_writelnb
106 _Vit_writelnb:
107 .cfi_startproc
108    cmpb  $0, 4(%esp)
109    jne   1f
110    pushl $writelnb_false
111    jmp   2f
112 1:
113    pushl $writelnb_true
114 2:
115    call  puts
116    addl  $4, %esp
117    ret
118 .cfi_endproc
119 .size _Vit_writelnb, . - _Vit_writelnb
120
121 .align 4
122 .type _Vit_allocab, @function
123 .globl _Vit_allocab
124 _Vit_allocab:
125 .cfi_startproc
126    cmpl  $0, 4(%esp)
127    jle   2f
128    addl  $4, 4(%esp)
129    pushl 4(%esp)
130    call  malloc
131    testl %eax, %eax # Return if nothing was allocated (error probably).
132    jnz   1f
133    popl  %ecx     # expose return address.
134    ret
135 1:
136    addl  $4, %esp
137    movl  4(%esp), %edx
138    subl  $4, %edx
139    movl  %edx, (%eax)
140    addl  $4, %eax
141    ret
142 2:
143    xorl  %eax, %eax
144    ret
145 .cfi_endproc
146 .size _Vit_allocab, . - _Vit_allocab
147
148 .align 4
149 .type _Vit_allocal, @function
150 .globl _Vit_allocal
151 _Vit_allocal:
152 .cfi_startproc
153    cmpl  $0, 4(%esp)
154    jl    2f
155    shll  $2, 4(%esp)
156    addl  $4, 4(%esp)
157    pushl 4(%esp)
158    call  malloc
```

```
159     testl %eax, %eax # Return if nothing was allocated (error probably).
160     jnz   1f
161     popl  %ecx      # expose return address.
162     ret
163 1:
164     addl  $4, %esp
165     movl  4(%esp), %edx
166     shrl  $2, %edx
167     sub   $1, %edx
168     movl  %edx, (%eax)
169     addl  $4, %eax
170     ret
171 2:
172     xorl  %eax, %eax
173     ret
174 .cfi_endproc
175 .size _Vit_allocal, . - _Vit_allocal
176
177 .align 4
178 .type _Vit_alloc, @function
179 .globl _Vit_alloc
180 _Vit_alloc:
181 .cfi_startproc
182     cmpl  $0, 4(%esp)
183     jle   1f
184     jmp   malloc
185 1:
186     xorl  %eax, %eax
187     ret
188 .cfi_endproc
189 .size _Vit_alloc, . - _Vit_alloc
190
191 .align 4
192 .type _Vit_deletea, @function
193 .globl _Vit_deletea
194 _Vit_deletea:
195 .cfi_startproc
196     cmpl  $0, 4(%esp)
197     je    1f
198     subl  $4, 4(%esp)
199     jmp   free
200 1:
201     ret
202 .cfi_endproc
203 .size _Vit_deletea, . - _Vit_deletea
204
205 .align 4
206 .type _Vit_delete, @function
207 .globl _Vit_delete
208 _Vit_delete:
209 .cfi_startproc
210     jmp   free
211 .cfi_endproc
212 .size _Vit_delete, . - _Vit_delete
```

:

A.9.5 src/vit/retmain.s

```
1 .section .text
2 .align 4
3 .type main, @function
4 .globl main
5 main:
6     xorl  %eax, %eax
7     ret
8 .size main, . - main
```

:

A.9.6 src/vit/vitmain.s

```
.section .text
.align 4
.type main, @function
.globl main
main:
.cfi_startproc
   /* Hack alert!
    * Apparently glibc uses a pointer to the command line arguments the
    * kernel pushed on the stack just before calling _start().
    * Thus argc is also located at *((int *)(argv - 1)) implying
    * argv is a vitaly array of string. Just pass that to _Vit_main()! */
   movl  8(%esp), %eax
   movl  %eax, 4(%esp)
   jmp   _Vit_main
.cfi_endproc
.size main, . - main

/*
.section .text
.align 4
.type main, @function
.globl main
main:
.cfi_startproc
   pushl %ebp
   movl  %esp, %ebp

   movl  8(%ebp), %ecx  # argc
   leal  -4(, %ecx, 4), %edx
   addl  12(%ebp), %edx  # argv, 4*(argc-1)

   pushl (%edx)
   cmpl  %edx, 12(%ebp)
   je    enter_vit
1:
   subl  $4, %edx
   pushl (%edx)
   cmpl  %edx, 12(%ebp)
   jne   1b

enter_vit:
   pushl 8(%ebp)
   leal  4(%esp), %eax
   pushl %eax
   call  _Vit_main
   leave
   ret
.cfi_endproc
.size main, . - main
*/
```

:

A.9.7 src/x86_32/x86_32.c

```
#include "x86_32.h"
#include "x86_32_regs.h"
#include "x86_32_normalize.h"
#include "x86_32_reg_alloc.h"
#include "x86_32_func_normalize.h"
#include "x86_32_reg_vars.h"
#include "x86_32_emit.h"
#include <main.h>

String x86_32_gen(Aia *aia)
{
   String asm_fname = NULL;

```

```
14     if (!aia_is_valid(aia))
15        goto out;
16
17     x86_32_regs_init(aia);
18
19     x86_32_normalize(aia);
20
21     Aia_Operand_Map *repl_map = x86_32_reg_vars(aia);
22
23     x86_32_reg_alloc(aia, repl_map);
24     aia_operand_map_destroy(repl_map);
25
26     x86_32_func_normalize(aia);
27
28     asm_fname = x86_32_emit(aia);
29
30     x86_32_regs_release();
31
32  out:
33     return asm_fname;
34  }
```

:

A.9.8 src/x86_32/x86_32.h

```
1  #ifndef X86_32_H
2  #define X86_32_H
3
4  #include <aia/aia.h>
5
6  /* Returns name of generated asm file.
7   * NULL if the AIA is invalid. */
8  String x86_32_gen(Aia *aia);
9
10 #endif // X86_32_H
```

:

A.9.9 src/x86_32/x86_32_emit.c

```
1  #include "x86_32_emit.h"
2  #include "x86_32_regs.h"
3  #include <main.h>
4
5  #undef DEBUG_TYPE
6  #define DEBUG_TYPE x86-32-emit
7
8  #define VITMAIN_CSTR "_Vit_main"
9  #define VITMAIN_STR  S(VITMAIN_CSTR)
10 #define MAIN_CSTR  "main"
11 #define MAIN_STR  S(MAIN_CSTR)
12
13 typedef struct Aia_Meta_Data {
14    Uns cfi_offset;
15    bool inside_func;
16 } Aia_Meta_Data;
17
18 static Uns x86_32_emit_prev_line;
19
20 static void ___x86_32_emit_line_number(FILE *asm_file, Aia_Instr *in)
21 {
22    File_Location *loc = aia_instr_get_location(in);
23    if ((cmdopts.dump_asm || cmdopts.assemble_only) && loc->line &&
24          loc->line != x86_32_emit_prev_line) {
25       x86_32_emit_prev_line = loc->line;
26       file_print_message(asm_file, S("# line %U\n"), loc->line);
```

```
27       }
28    }
29
30    static void x86_32_emit_line_number(FILE *asm_file, Aia_Instr *in)
31    {
32       switch (aia_instr_get_type(in)) {
33       AIA_CASE_COND_JUMP:
34       case AIA_JMP:
35          break;
36       default:
37          ___x86_32_emit_line_number(asm_file, in);
38       }
39    }
40
41    static void x86_32_operand_dump(FILE *asm_file, Aia_Operand *op,
42          bool print_int_dollar)
43    {
44       switch (op->op_type) {
45       case AIA_OPERAND_LABEL_ADDR:
46          if (op->iden.op_label->offset)
47             file_print_message(asm_file, S("$%S+%" PRId32),
48                   op->iden.op_label->label_name,
49                   op->iden.op_label->offset);
50          else
51             file_print_message(asm_file, S("$%S"),
52                   op->iden.op_label->label_name);
53          break;
54
55       case AIA_OPERAND_REG:
56          assert(x86_32_is_concrete_reg(op));
57          file_print_message(asm_file, S("%%%S"), op->iden.op_name);
58          break;
59
60       case AIA_OPERAND_LABEL:
61          if (op->iden.op_label->offset)
62             file_print_message(asm_file, S("%S+%" PRId32),
63                   op->iden.op_label->label_name,
64                   op->iden.op_label->offset);
65          else
66             file_print_message(asm_file, S("%S"),
67                   op->iden.op_label->label_name);
68          break;
69
70       case AIA_OPERAND_CONST_INT:
71          if (print_int_dollar)
72             file_print_message(asm_file, S("$%" PRId32), op->iden.int_const);
73          else
74             file_print_message(asm_file, S("%" PRId32), op->iden.int_const);
75          break;
76
77       case AIA_OPERAND_ADDR_REF:
78          if (op->iden.addr_ref->label)
79             aia_operand_dump(asm_file, op->iden.addr_ref->label, false);
80          if (op->iden.addr_ref->disp && op->iden.addr_ref->label)
81             file_print_message(asm_file, S("+"));
82          if (op->iden.addr_ref->disp)
83             aia_operand_dump(asm_file, op->iden.addr_ref->disp, false);
84          file_print_message(asm_file, S("("));
85          if (op->iden.addr_ref->base)
86             aia_operand_dump(asm_file, op->iden.addr_ref->base, false);
87          if (op->iden.addr_ref->index || op->iden.addr_ref->scale)
88             file_print_message(asm_file, S(","));
89          if (op->iden.addr_ref->index) {
90             aia_operand_dump(asm_file, op->iden.addr_ref->index, false);
91             if (op->iden.addr_ref->scale)
92                file_print_message(asm_file, S(","));
93          }
94          if (op->iden.addr_ref->scale)
95             aia_operand_dump(asm_file, op->iden.addr_ref->scale, false);
96          file_print_message(asm_file, S(")"));
97          break;
98
99       case AIA_OPERAND_LOCAL_REF:
100         fatal_error(S("unexpected local ref AIA operand. Aborting...\n"));
```

```
101
102     case AIA_OPERAND_ARG:
103        fatal_error(S("unexpected arg ref AIA operand. Aborting...\n"));
104
105     case AIA_OPERAND_DISPLAY_REF:
106        fatal_error(S("unexpected display ref AIA operand. Aborting...\n"));
107
108     case AIA_OPERAND_BLOCK:;
109        Aia_Instr *lbl_instr =
110              ___aia_block_peek_first_instr(op->iden.op_block);
111        aia_operand_dump(asm_file, aia_instr_get_dest_op(lbl_instr), false);
112        break;
113
114     default:
115        fatal_error(S("Unexpected operand type for x86-32 emit\n"));
116     }
117  }
118
119  static CONST_STRING(x86_32_instr_postfix_b, "b");
120
121  static CONST_STRING(x86_32_instr_postfix_l, "l");
122
123  typedef struct Pending_Jmp {
124     Aia_Instr *instr;
125     Const_String instr_name;
126     bool emit_second_jmp;
127  } Pending_Jmp;
128
129  Pending_Jmp pending_jmp;
130
131  static Const_String x86_32_get_instr_postfix(Aia_Instr *in, bool dest)
132  {
133     switch (dest ? aia_instr_get_dest_op_size(in) :
134           aia_instr_get_src_ops_size(in)) {
135     case AIA_BYTE:
136        return x86_32_instr_postfix_b;
137     case AIA_LONG:
138        return x86_32_instr_postfix_l;
139     default:
140        fatal_error(S("unexpected mov instruction. Aborting...\n"));
141     }
142  }
143
144  static inline Const_String x86_32_get_instr_postfix_dest(Aia_Instr *in)
145  {
146     return x86_32_get_instr_postfix(in, true);
147  }
148
149  static void x86_32_pending_jmp_emit(FILE *asm_file)
150  {
151     if (!pending_jmp.instr)
152        return;
153
154     ___x86_32_emit_line_number(asm_file, pending_jmp.instr);
155
156     file_print_message(asm_file, S("\t%S\t"), pending_jmp.instr_name);
157     x86_32_operand_dump(asm_file,
158           aia_instr_get_src_op(pending_jmp.instr, 0), true);
159
160     if (pending_jmp.emit_second_jmp) {
161        file_print_message(asm_file, S("\n\tjmp\t"));
162        x86_32_operand_dump(asm_file,
163              aia_instr_get_src_op(pending_jmp.instr, 1), true);
164     }
165
166     file_print_message(asm_file, S("\n"));
167     pending_jmp.instr = NULL;
168  }
169
170  static void x86_32_jmp_emit(FILE *asm_file UNUSED, Aia_Instr *instr,
171        Const_String instr_name)
172  {
173     assert(instr->src_ops_size == AIA_LONG);
174     pending_jmp.instr = instr;
```

```
175     pending_jmp.instr_name = instr_name;
176  }
177
178  static void x86_32_mov_emit(FILE *asm_file, Aia_Instr *instr,
179        Const_String in_name)
180  {
181     assert(aia_instr_get_type(instr) == AIA_MOV);
182     assert(aia_instr_get_dest_op_size(instr) ==
183           aia_instr_get_src_ops_size(instr));
184
185     Const_String instr_postfix = x86_32_get_instr_postfix_dest(instr);
186
187     file_print_message(asm_file, S("\t%S%S\t"), in_name, instr_postfix);
188     x86_32_operand_dump(asm_file, aia_instr_get_src_op(instr, 0), true);
189     file_print_message(asm_file, S(", "));
190     x86_32_operand_dump(asm_file, aia_instr_get_dest_op(instr), true);
191  }
192
193  static void x86_32_movbl_emit(FILE *asm_file, Aia_Instr *instr,
194        Const_String in_name)
195  {
196     assert(aia_instr_get_dest_op_size(instr) == AIA_LONG &&
197           aia_instr_get_src_ops_size(instr) == AIA_BYTE);
198
199     file_print_message(asm_file, S("\t%Sbl\t"), in_name);
200     x86_32_operand_dump(asm_file, aia_instr_get_src_op(instr, 0), true);
201     file_print_message(asm_file, S(", "));
202     x86_32_operand_dump(asm_file, aia_instr_get_dest_op(instr), true);
203  }
204
205  static void x86_32_2op_arith_emit(FILE *asm_file, Aia_Instr *instr,
206        Const_String in_name, Aia_Meta_Data *ameta)
207  {
208     assert(aia_instr_get_dest_op_size(instr) ==
209           aia_instr_get_src_ops_size(instr));
210
211     Aia_Operand *dest = aia_instr_get_dest_op(instr);
212     Aia_Operand *src = aia_instr_get_src_op(instr, 1);
213     DEBUGT(def,
214        Aia_Operand *tmp_src = aia_instr_get_src_op(instr, 0);
215        assert(aia_operands_equal(dest, tmp_src));
216     );
217
218     Const_String instr_postfix = x86_32_get_instr_postfix_dest(instr);
219
220     file_print_message(asm_file, S("\t%S%S\t"), in_name, instr_postfix);
221     x86_32_operand_dump(asm_file, src, true);
222     file_print_message(asm_file, S(", "));
223     x86_32_operand_dump(asm_file, dest, true);
224
225     if (ameta->inside_func && aia_operands_equal(dest, reg_esp)) {
226        assert(aia_operand_get_type(src) == AIA_OPERAND_CONST_INT);
227        switch (aia_instr_get_type(instr)) {
228        case AIA_ADD:
229           ameta->cfi_offset -= aia_operand_const_int_get_val(src);
230           break;
231        case AIA_SUB:
232           ameta->cfi_offset += aia_operand_const_int_get_val(src);
233           break;
234
235        default:
236           break;
237        }
238        file_print_message(asm_file, S("\n.cfi_def_cfa_offset %U"),
239              ameta->cfi_offset);
240     }
241  }
242
243  static void x86_32_cmp_emit(FILE *asm_file, Aia_Instr *instr,
244        Const_String in_name)
245  {
246     Const_String instr_postfix = x86_32_get_instr_postfix(instr, false);
247
248     file_print_message(asm_file, S("\t%S%S\t"), in_name, instr_postfix);
```

```
249     x86_32_operand_dump(asm_file, aia_instr_get_src_op(instr, 1), true);
250     file_print_message(asm_file, S(", "));
251     x86_32_operand_dump(asm_file, aia_instr_get_src_op(instr, 0), true);
252  }
253
254  static void x86_32_set_emit(FILE *asm_file, Aia_Instr *instr,
255        Const_String in_name)
256  {
257     file_print_message(asm_file, S("\t%S\t"), in_name);
258     x86_32_operand_dump(asm_file, aia_instr_get_dest_op(instr), true);
259  }
260
261  static void x86_32_ret_emit(FILE *asm_file, Aia_Instr *instr UNUSED,
262        Const_String in_name)
263  {
264     file_print_message(asm_file, S("\t%S"), in_name);
265  }
266
267  static void x86_32_call_emit(FILE *asm_file, Aia_Instr *instr,
268        Const_String in_name)
269  {
270     file_print_message(asm_file, S("\t%S\t"), in_name);
271     Aia_Operand *call_op = aia_instr_get_src_op(instr, 0);
272     if (aia_operand_get_type(call_op) != AIA_OPERAND_LABEL)
273        file_print_message(asm_file, S("*"));
274     x86_32_operand_dump(asm_file, call_op, true);
275  }
276
277  static void x86_32_neg_emit(FILE *asm_file, Aia_Instr *instr,
278        Const_String in_name)
279  {
280     assert(aia_instr_get_dest_op_size(instr) ==
281           aia_instr_get_src_ops_size(instr));
282     assert(aia_operands_equal(aia_instr_get_dest_op(instr),
283              aia_instr_get_src_op(instr, 0)));
284     Const_String post = x86_32_get_instr_postfix_dest(instr);
285     file_print_message(asm_file, S("\t%S%S\t"), in_name, post);
286     x86_32_operand_dump(asm_file, aia_instr_get_dest_op(instr), true);
287  }
288
289  static void x86_32_cdq_dump(FILE *asm_file, Aia_Instr *instr UNUSED)
290  {
291     assert(aia_operands_equal(aia_instr_get_dest_op(instr), reg_edx));
292     assert(aia_operands_equal(aia_instr_get_src_op(instr, 0), reg_eax));
293     file_print_message(asm_file, S("\tcdq"));
294  }
295
296  static void x86_32_imul_emit(FILE *asm_file, Aia_Instr *instr,
297        Const_String name)
298  {
299     file_print_message(asm_file, S("\t%Sl\t"), name);
300     Aia_Operand *op = aia_instr_get_src_op(instr, 1);
301     if (aia_operand_is_integer(op)) {
302        x86_32_operand_dump(asm_file, op, true);
303        file_print_message(asm_file, S(", "));
304
305        op = aia_instr_get_src_op(instr, 0);
306        x86_32_operand_dump(asm_file, op, true);
307        file_print_message(asm_file, S(", "));
308     } else {
309        op = aia_instr_get_src_op(instr, 1);
310        x86_32_operand_dump(asm_file, op, true);
311        file_print_message(asm_file, S(", "));
312     }
313
314     op = aia_instr_get_dest_op(instr);
315     x86_32_operand_dump(asm_file, op, true);
316  }
317
318  static void x86_32_idiv_emit(FILE *asm_file, Aia_Instr *instr,
319        Const_String name)
320  {
321     file_print_message(asm_file, S("\t%Sl\t"), name);
322     Aia_Operand *op = aia_instr_get_src_op(instr, 1);
```

```
323     x86_32_operand_dump(asm_file, op, true);
324  }
325
326  static bool x86_32_label_block_stick(Aia_Operand *label_op, Int jmp_op_idx)
327  {
328     Aia_Operand *jmp_op = aia_instr_get_src_op(pending_jmp.instr, jmp_op_idx);
329     if (aia_operand_get_type(jmp_op) == AIA_OPERAND_BLOCK) {
330        Aia_Block *jmp_block = aia_operand_block_get_block(jmp_op);
331        Aia_Instr *lbl_in = ___aia_block_peek_first_instr(jmp_block);
332        jmp_op = aia_instr_get_dest_op(lbl_in);
333        assert(jmp_block);
334     }
335     if (aia_operands_equal(label_op, jmp_op))
336        return true;
337     return false;
338  }
339
340  static CONST_STRING(jmp_str, "jmp");
341
342  static CONST_STRING(je_str, "je");
343  static CONST_STRING(jne_str, "jne");
344
345  static CONST_STRING(jge_str, "jge");
346  static CONST_STRING(jl_str, "jl");
347
348  static CONST_STRING(jg_str, "jg");
349  static CONST_STRING(jle_str, "jle");
350
351  static Const_String x86_32_negated_jmp_name(Aia_Instr *jmp_in)
352  {
353     switch (aia_instr_get_type(jmp_in)) {
354     case AIA_JG:
355        return jle_str;
356     case AIA_JLE:
357        return jg_str;
358     case AIA_JNE:
359        return je_str;
360     case AIA_JE:
361        return jne_str;
362     case AIA_JGE:
363        return jl_str;
364     case AIA_JL:
365        return jge_str;
366     default:
367        fatal_error(S("unexpected instruction, expecetd cond jmp. "
368                  "Aborting...\n"));
369     }
370  }
371
372  static void x86_32_instr_pending_jump(FILE *asm_file, Aia_Instr *instr)
373  {
374     if (pending_jmp.instr && aia_instr_get_type(instr) == ___AIA_LABEL) {
375        Aia_Operand *lbl = aia_instr_get_dest_op(instr);
376
377        switch (aia_instr_get_type(pending_jmp.instr)) {
378        AIA_CASE_COND_JUMP:
379           if (x86_32_label_block_stick(lbl, 1)) {
380              pending_jmp.emit_second_jmp = false;
381              break;
382           } else {
383              pending_jmp.emit_second_jmp = true;
384           }
385           if (x86_32_label_block_stick(lbl, 0)) {
386              pending_jmp.instr_name = x86_32_negated_jmp_name(
387                    pending_jmp.instr);
388              pending_jmp.emit_second_jmp = false;
389              aia_instr_swap_ops(pending_jmp.instr, 0, 1);
390           }
391           break;
392
393        case AIA_JMP:
394           pending_jmp.emit_second_jmp = false;
395           if (x86_32_label_block_stick(lbl, 0)) {
396              pending_jmp.instr = NULL;
```

```
397                return;
398             }
399             break;
400
401          default:
402             fatal_error(S("unexpected instriction, expected jmp. "
403                      "Aborting...\n"));
404          }
405
406       }
407
408       x86_32_pending_jmp_emit(asm_file);
409    }
410
411    static void x86_32_emit_integer(FILE *asm_file, Aia_Instr *instr, Aia *aia)
412    {
413       Aia_Operand *op = aia_instr_get_src_op(instr, 0);
414       if (aia_instr_get_src_ops_size(instr) == AIA_BYTE &&
415             aia_operand_get_type(op) == AIA_OPERAND_CONST_INT) {
416          int32_t orig = aia_operand_const_int_get_val(op);
417          int8_t val = orig;
418          if (val != orig) {
419             if (cmdopts.warn_overflow)
420                report_warning_location(aia_instr_get_location(instr),
421                      S("constant implicitly truncated to " QFY("%" PRId8)
422                         " to fit " QFY("char") " variable\n"), val);
423             Aia_Operand *new_op = aia_operand_const_int_alloc(aia, val);
424             aia_instr_replace_op(instr, 0, new_op);
425          }
426       }
427       aia_instr_integer_dump(asm_file, instr);
428    }
429
430    static void x86_32_emit_main_label(FILE *asm_file, Aia_Instr *instr, Aia *aia)
431    {
432       Aia_Operand *main_op = aia_operand_label_alloc(aia, VITMAIN_STR, 0);
433       Aia_Instr *main_in = aia_instr_alloc_2op(___AIA_LABEL,
434             aia_instr_get_block(instr),
435             aia_instr_get_dest_op_size(instr),
436             aia_instr_get_src_ops_size(instr),
437             aia_instr_get_location(instr));
438
439       aia_instr_set_dest_op(main_in, main_op);
440       aia_instr_set_src_op(main_in, 0, aia_instr_get_src_op(instr, 0));
441       aia_instr_set_src_op(main_in, 1, aia_instr_get_src_op(instr, 1));
442
443       aia_instr_label_dump(asm_file, main_in);
444
445       ___aia_instr_destroy(main_in);
446    }
447
448    static void x86_32_emit_label(FILE *asm_file, Aia_Instr *instr, Aia *aia)
449    {
450       Aia_Operand *data = aia_instr_get_src_op(instr, 0);
451       Aia_Label_Data lbl_data;
452       lbl_data.data = aia_operand_const_int_get_val(data);
453
454       if (lbl_data.linkage == AIA_LINKAGE_GLOBAL) {
455          Aia_Operand *lbl_op = aia_instr_get_dest_op(instr);
456          Const_String lbl_name = aia_operand_label_get_name(lbl_op);
457          if (!string_compare(lbl_name, MAIN_STR)) {
458             x86_32_emit_main_label(asm_file, instr, aia);
459             return;
460          }
461       }
462
463       aia_instr_label_dump(asm_file, instr);
464    }
465
466    static void x86_32_instr_emit(FILE *asm_file, Aia *aia, Aia_Instr *instr)
467    {
468       if (aia_instr_get_type(instr) == AIA_NOP)
469          return;
470
```

```
471     x86_32_instr_pending_jump(asm_file, instr);
472     x86_32_emit_line_number(asm_file, instr);
473
474     Aia_Meta_Data *ameta = aia->meta_data;
475
476     switch (aia_instr_get_type(instr)) {
477     case AIA_MOV:
478        x86_32_mov_emit(asm_file, instr, S("mov"));
479        break;
480     case AIA_MOVS:
481        x86_32_movbl_emit(asm_file, instr, S("movs"));
482        break;
483     case AIA_MOVZ:
484        x86_32_movbl_emit(asm_file, instr, S("movz"));
485        break;
486     case AIA_ADD:
487        x86_32_2op_arith_emit(asm_file, instr, S("add"), ameta);
488        break;
489     case AIA_SUB:
490        x86_32_2op_arith_emit(asm_file, instr, S("sub"), ameta);
491        break;
492     case AIA_IMUL:
493        x86_32_imul_emit(asm_file, instr, S("imul"));
494        break;
495     case AIA_IDIV:
496        x86_32_idiv_emit(asm_file, instr, S("idiv"));
497        break;
498     case AIA_CMP:
499        x86_32_cmp_emit(asm_file, instr, S("cmp"));
500        break;
501     case AIA_SETE:
502        x86_32_set_emit(asm_file, instr, S("sete"));
503        break;
504     case AIA_SETNE:
505        x86_32_set_emit(asm_file, instr, S("setne"));
506        break;
507     case AIA_SETL:
508        x86_32_set_emit(asm_file, instr, S("setl"));
509        break;
510     case AIA_SETG:
511        x86_32_set_emit(asm_file, instr, S("setg"));
512        break;
513     case AIA_SETLE:
514        x86_32_set_emit(asm_file, instr, S("setle"));
515        break;
516     case AIA_SETGE:
517        x86_32_set_emit(asm_file, instr, S("setge"));
518        break;
519     case AIA_RET:
520        x86_32_ret_emit(asm_file, instr, S("ret"));
521        break;
522     case AIA_CALL:
523        x86_32_call_emit(asm_file, instr, S("call"));
524        break;
525     case AIA_NEG:
526        x86_32_neg_emit(asm_file, instr, S("neg"));
527        break;
528     case ___AIA_LABEL:
529        x86_32_emit_label(asm_file, instr, aia);
530        break;
531     case ___AIA_STRING:
532        aia_instr_string_dump(asm_file, instr);
533        break;
534     case ___AIA_INTEGER:
535        x86_32_emit_integer(asm_file, instr, aia);
536        break;
537     case AIA_JLE:
538        x86_32_jmp_emit(asm_file, instr, jle_str);
539        /* Don't print "\n". */
540        return;
541     case AIA_JG:
542        x86_32_jmp_emit(asm_file, instr, jg_str);
543        /* Don't print "\n". */
544        return;
```

```
545     case AIA_JNE:
546        x86_32_jmp_emit(asm_file, instr, jne_str);
547        /* Don't print "\n". */
548        return;
549     case AIA_JE:
550        x86_32_jmp_emit(asm_file, instr, je_str);
551        /* Don't print "\n". */
552        return;
553     case AIA_JGE:
554        x86_32_jmp_emit(asm_file, instr, jge_str);
555        /* Don't print "\n". */
556        return;
557     case AIA_JL:
558        x86_32_jmp_emit(asm_file, instr, jl_str);
559        /* Don't print "\n". */
560        return;
561     case AIA_JMP:
562        x86_32_jmp_emit(asm_file, instr, jmp_str);
563        /* Don't print "\n". */
564        return;
565     case AIA_CDQ:
566        x86_32_cdq_dump(asm_file, instr);
567        break;
568
569     case ___AIA_JNE:
570        /* Fall */
571     case ___AIA_JE:
572        /* Fall */
573     case ___AIA_JMP:
574        fatal_error(S("Unable to dump unexpeceted jump instruction. "
575                  "Aborting...\n"));
576
577     default:
578        fatal_error(S("Unable to dump unexpeceted instruction. "
579                  "Aborting...\n"));
580     }
581
582     if (!ameta->cfi_offset && ameta->inside_func) {
583        ameta->cfi_offset = 4;
584        file_print_message(asm_file, S("\n.cfi_startproc\n"));
585     } else {
586        file_print_message(asm_file, S("\n"));
587     }
588  }
589
590  static void x86_32_emit_block(FILE *asm_file, Aia_Block *b, Aia *aia)
591  {
592     if (!b->meta_data)
593        return;
594
595     Aia_Instr *instr;
596     AIA_BLOCK_FOR_EACH_INSTRUCTION(b, instr)
597        x86_32_instr_emit(asm_file, aia, instr);
598  }
599
600  static void x86_32_emit_blocks(FILE *asm_file, Aia *aia, Double_List *blist)
601  {
602     Double_List_Node *dbnode;
603     DOUBLE_LIST_FOR_EACH(blist, dbnode)
604        x86_32_emit_block(asm_file, AIA_BLOCK_OF_DBNODE(dbnode), aia);
605  }
606
607  static void x86_32_func_emit(FILE *asm_file, Aia *aia, Aia_Func *func)
608  {
609     Aia_Meta_Data *ameta = aia->meta_data;
610
611
612     Aia_Func_Trampoline *tramp;
613     AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp) {
614        x86_32_emit_prev_line = 0;
615        ameta->cfi_offset = 0;
616        ameta->inside_func = true;
617
618        x86_32_emit_blocks(asm_file, aia, &tramp->blist);
```

```
619         //x86_32_pending_jmp_emit(asm_file);
620         file_print_message(asm_file, S(".cfi_endproc\n"));
621         file_print_message(asm_file, S(".size %1$S, . - %1$S\n"),
622               tramp->trampoline_name);
623      }
624
625      x86_32_emit_prev_line = 0;
626      ameta->cfi_offset = 0;
627      ameta->inside_func = true;
628
629      x86_32_emit_blocks(asm_file, aia, &func->blist);
630      x86_32_pending_jmp_emit(asm_file);
631      file_print_message(asm_file, S(".cfi_endproc\n"));
632
633      Const_String fname;
634      if (string_compare(func->func_name, MAIN_STR))
635         fname = func->func_name;
636      else
637         fname = VITMAIN_STR;
638      file_print_message(asm_file, S(".size %1$S, . - %1$S\n"), fname);
639   }
640
641   static void x86_32_section_emit(FILE *asm_file, Aia *aia, Aia_Section *sec)
642   {
643      x86_32_emit_prev_line = 0;
644
645      Aia_Meta_Data *ameta = aia->meta_data;
646      ameta->cfi_offset = 0;
647      ameta->inside_func = false;
648
649      file_print_message(asm_file, S(".section %S\n"),
650            aia_section_get_name(sec));
651
652      x86_32_emit_blocks(asm_file, aia, &sec->sec_blist);
653
654      bool any_func = false;
655      Aia_Func *func;
656      AIA_SECTION_FOR_EACH_FUNC(sec, func) {
657         x86_32_func_emit(asm_file, aia, func);
658         any_func = true;
659      }
660      x86_32_pending_jmp_emit(asm_file);
661      if (!any_func)
662         file_print_message(asm_file, S("\n"));
663   }
664
665   static String x86_32_get_file_name(Aia *aia)
666   {
667      if (cmdopts.dump_asm)
668         return string_from_format(S("%S.vitaly" ASM1_SUFFIX_CSTR),
669               aia_get_file_name(aia));
670      return string_to_tmp_file(ASM1_SUFFIX_STR);
671   }
672
673   static FILE *x86_32_get_file(Const_String fname)
674   {
675      FILE *f = file_open(fname, S("w"));
676      if (!f)
677         fatal_error(S("unable to create file %S for assembly code [%m]\n"),
678               fname);
679      return f;
680   }
681
682   static void x86_32_emit_sections(Const_String asm_fname, Aia *aia)
683   {
684      FILE *asm_file = x86_32_get_file(asm_fname);
685      Aia_Section *sec;
686
687      Aia_Meta_Data ameta = { 0, false };
688      aia->meta_data = &ameta;
689
690      AIA_FOR_EACH_SECTION(aia, sec)
691         x86_32_section_emit(asm_file, aia, sec);
692      file_close(asm_file);
```

```
693 }
694
695 static void x86_32_reset_blist(Double_List *blist)
696 {
697    Double_List_Node *bnode;
698    DOUBLE_LIST_FOR_EACH(blist, bnode)
699       AIA_BLOCK_OF_DBNODE(bnode)->meta_data = NULL;
700 }
701
702 static void x86_32_emit_reset(Aia *aia)
703 {
704    Aia_Section *sec;
705    AIA_FOR_EACH_SECTION(aia, sec) {
706       x86_32_reset_blist(&sec->sec_blist);
707       Aia_Func *f;
708       AIA_SECTION_FOR_EACH_FUNC(sec, f) {
709          x86_32_reset_blist(&f->blist);
710          Aia_Func_Trampoline *t;
711          AIA_FUNC_FOR_EACH_TRAMPOLINE(f, t)
712             x86_32_reset_blist(&f->blist);
713       }
714    }
715 }
716
717 static void x86_32_emit_mark_live_block(Aia_Block *b, void *arg UNUSED)
718 {
719    b->meta_data = INT_TO_PTR(1);
720 }
721
722 static void x86_32_emit_mark_live(Aia *aia)
723 {
724    Aia_Section *sec;
725    AIA_FOR_EACH_SECTION(aia, sec) {
726       aia_section_for_each_block_depth(sec,
727             x86_32_emit_mark_live_block, NULL);
728       Aia_Func *f;
729       AIA_SECTION_FOR_EACH_FUNC(sec, f) {
730          aia_func_for_each_block_depth(f,
731                x86_32_emit_mark_live_block, NULL);
732          Aia_Func_Trampoline *t;
733          AIA_FUNC_FOR_EACH_TRAMPOLINE(f, t)
734             x86_32_emit_mark_live_block(t->block, NULL);
735       }
736    }
737 }
738
739 String x86_32_emit(Aia *aia)
740 {
741    String fname = NULL;
742    if (!aia_is_valid(aia))
743       goto out;
744
745    x86_32_emit_reset(aia);
746    x86_32_emit_mark_live(aia);
747
748    fname = x86_32_get_file_name(aia);
749    x86_32_emit_sections(fname, aia);
750
751    if (cmdopts.assemble_only) {
752       if (cmdopts.output_name) {
753          x86_32_emit_sections(cmdopts.output_name, aia);
754       } else {
755          String tmp = string_cpy_replace_from(aia_get_file_name(aia), '.',
756                ASM1_SUFFIX_STR);
757          x86_32_emit_sections(tmp, aia);
758          string_destroy(tmp);
759       }
760    }
761
762 out:
763    return fname;
764 }
```

:

A.9.10 src/x86_32/x86_32_emit.h

```
#ifndef X86_32_EMIT_H
#define X86_32_EMIT_H

#include <aia/aia.h>

String x86_32_emit(Aia *aia);

#endif // X86_32_EMIT_H
```

:

A.9.11 src/x86_32/x86_32_func_normalize.c

```
#include "x86_32_regs.h"
#include "main.h"

#undef DEBUG_TYPE
#define DEBUG_TYPE func-norm

typedef struct Aia_Func_Meta {
   Aia_Instr *prologue_in;
   Aia_Instr *epilogue_in;
   Aia_Operand *ret_label;
   Hash_Map func_local_offsets;
   Int max_arg_count;
   Int esp_delta_bytes;
#ifndef NDEBUG
   Int prev_arg_idx;
#endif
   bool preserve_reg[X86_32_REG_COUNT];
   bool uses_display;
} Aia_Func_Meta;

typedef struct Func_Local_Off {
   Const_String name;
   Int byte_offset;
   Hash_Map_Slot hash_slot;
} Func_Local_Off;

#define FUNC_LOCAL_OFF_OF(slot) HASH_MAP_ENTRY(slot, Func_Local_Off, hash_slot)

typedef struct Aia_Block_Meta {
   Aia_Func *curr_func;
   Aia *aia;
   Aia_Func *called_func;
   Vector func_ret_instrs;
   Hash_Map *curr_func_locals;
   Int esp_byte_increment;
} Aia_Block_Meta;

static bool func_local_hash_compare(String search_str, Hash_Map_Slot *s)
{
   Func_Local_Off *off = FUNC_LOCAL_OFF_OF(s);
   return !string_compare(off->name, search_str);
}

static void func_local_hash_destroy(Hash_Map_Slot *s)
{
   free_mem(FUNC_LOCAL_OFF_OF(s));
}

static inline void func_local_insert(Hash_Map *local_offsets,
      Const_String local_name, Int byte_off)
{
```

```
52     Func_Local_Off *loc = ALLOC_NEW(Func_Local_Off);
53     loc->name = local_name;
54     loc->byte_offset = byte_off;
55     Uns hash = string_hash_code(local_name);
56     assert(!hash_map_contains(local_offsets,
57           (String)local_name, hash));
58     hash_map_insert(local_offsets, &loc->hash_slot, hash);
59  }
60
61  static Int func_local_get_offset(Hash_Map *local_offsets, Const_String local)
62  {
63     Hash_Map_Slot *s = hash_map_get(local_offsets, (String)local,
64           string_hash_code(local));
65     assert(s);
66     return FUNC_LOCAL_OFF_OF(s)->byte_offset;
67  }
68
69  static Aia_Operand *x86_32_alloc_ref(Aia *aia, Aia_Operand *base, int32_t disp)
70  {
71     Aia_Operand *disp_op;
72     if (disp)
73        disp_op = aia_operand_const_int_alloc(aia, disp);
74     else
75        disp_op = NULL;
76     Aia_Operand *ret = aia_operand_addr_ref_alloc(aia,
77           NULL, disp_op, base, NULL, NULL);
78     return ret;
79  }
80
81  static void x86_32_setup_call_esp_increment(Aia_Instr *call_in,
82        Aia_Block_Meta *bmeta)
83  {
84     Aia_Operand *lbl = aia_instr_get_src_op(call_in, 0);
85     if (aia_operand_get_type(lbl) != AIA_OPERAND_LABEL)
86        goto out_no_inc;
87
88     Const_String name = aia_operand_label_get_name(lbl);
89     bmeta->called_func = aia_func_lookup(bmeta->aia, name);
90     //assert(bmeta->called_func);
91     if (!bmeta->called_func) // then it's an imported function.
92        goto out_no_inc;
93
94     if (bmeta->curr_func && aia_func_is_nested(bmeta->called_func) &&
95           ((Aia_Func_Meta *)bmeta->called_func->meta_data)->uses_display) {
96        Aia_Func_Meta *fmeta = bmeta->curr_func->meta_data;
97
98        bmeta->esp_byte_increment = 4 * (fmeta->max_arg_count -
99              vector_size(&bmeta->called_func->parameters) +
100             aia_func_get_num_display_params(bmeta->called_func));
101    } else {
102       goto out_no_inc;
103    }
104
105    assert(bmeta->esp_byte_increment >= 0);
106    return;
107
108 out_no_inc:
109    bmeta->esp_byte_increment = 0;
110 }
111
112 static void x86_32_setup_called_func(Aia_Instr *in, Aia_Block_Meta *bmeta)
113 {
114    while (aia_instr_get_type(in) != AIA_CALL) {
115       Aia_Instr *tmp = aia_instr_get_sucessor(in);
116       if (!tmp) {
117          Aia_Block *b = aia_instr_get_block(in);
118          Aia_Block *suc = NULL;
119          AIA_BLOCK_FOR_EACH_SUCESSOR(b, suc)
120             break;
121
122          assert(suc);
123          in = ___aia_block_peek_first_instr(suc);
124          assert(in);
125       } else {
```

```
126            in = tmp;
127         }
128      }
129      x86_32_setup_call_esp_increment(in, bmeta);
130   }
131
132   static void x86_32_instr_op_finalize(Aia_Instr *in, Int op_idx,
133         Aia_Block_Meta *bmeta)
134   {
135      Aia_Func_Meta *fmeta;
136      Aia_Operand *op = aia_instr_get_op(in, op_idx);
137      Aia_Operand *ref;
138      Const_String oth_func_name;
139      Int offset;
140      switch (aia_operand_get_type(op)) {
141      case AIA_OPERAND_LOCAL_REF:
142         offset = func_local_get_offset(bmeta->curr_func_locals,
143               aia_operand_local_ref_get_var_name(op));
144         ref = x86_32_alloc_ref(bmeta->aia, reg_esp, offset);
145         break;
146
147      case AIA_OPERAND_DISPLAY_REF:
148         oth_func_name = aia_operand_display_ref_get_func_name(op);
149         Aia_Func *oth = aia_func_lookup(bmeta->aia, oth_func_name);
150         assert(oth);
151         fmeta = oth->meta_data;
152         offset = func_local_get_offset(&fmeta->func_local_offsets,
153               aia_operand_display_ref_get_var_name(op));
154         ref = x86_32_alloc_ref(bmeta->aia,
155               aia_operand_display_ref_get_display_reg(op), offset);
156         break;
157
158      case AIA_OPERAND_ARG:
159
160         if (!bmeta->called_func)
161            x86_32_setup_called_func(in, bmeta);
162
163         offset = 4 * aia_operand_arg_get_idx(op) + bmeta->esp_byte_increment;
164         ref = x86_32_alloc_ref(bmeta->aia, reg_esp, offset);
165         break;
166
167      default:
168         return;
169      }
170      aia_instr_replace_op(in, op_idx, ref);
171   }
172
173   static void x86_32_call_instr_finalize(Aia_Instr *in, Aia_Block_Meta *bmeta)
174   {
175      Aia_Operand *add_const;
176      Aia_Instr *add_in;
177
178      if (!bmeta->called_func)
179         x86_32_setup_call_esp_increment(in, bmeta);
180
181      if (bmeta->esp_byte_increment) {
182         add_const = aia_operand_const_int_alloc(bmeta->aia,
183               bmeta->esp_byte_increment);
184         add_in = aia_instr_alloc_2op(AIA_ADD,
185               aia_instr_get_block(in), AIA_LONG, AIA_LONG,
186               aia_instr_get_location(in));
187         aia_instr_set_dest_op(add_in, reg_esp);
188         aia_instr_set_src_op(add_in, 0, reg_esp);
189         aia_instr_set_src_op(add_in, 1, add_const);
190
191         aia_instr_insert_before(add_in, in);
192
193         add_const = aia_operand_const_int_alloc(bmeta->aia,
194               -bmeta->esp_byte_increment);
195         add_in = aia_instr_alloc_2op(AIA_ADD,
196               aia_instr_get_block(in), AIA_LONG, AIA_LONG,
197               aia_instr_get_location(in));
198         aia_instr_set_dest_op(add_in, reg_esp);
199         aia_instr_set_src_op(add_in, 0, reg_esp);
```

```
200         aia_instr_set_src_op(add_in, 1, add_const);
201
202         aia_instr_insert_after(add_in, in);
203      }
204
205      bmeta->called_func = NULL;
206   }
207
208   static void x86_32_block_finalize(Aia_Block *b, Aia_Block_Meta *bmeta)
209   {
210      Aia_Instr *in;
211      AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in) {
212         Aia_Operand *op;
213         Int op_idx = -1;
214         AIA_INSTR_FOR_EACH_OPERAND(in, op) {
215            if (op)
216               x86_32_instr_op_finalize(in, op_idx, bmeta);
217            ++op_idx;
218         }
219         switch (aia_instr_get_type(in)) {
220         case AIA_CALL:
221            x86_32_call_instr_finalize(in, bmeta);
222            break;
223
224         case AIA_RET:
225            vector_append(&bmeta->func_ret_instrs, in);
226            break;
227
228         default:
229            break;
230         }
231      }
232   }
233
234   static void ___x86_32_section_normalize(Aia *aia, Aia_Section *sec)
235   {
236      Aia_Block_Meta bmeta;
237      bmeta.called_func = NULL;
238      bmeta.curr_func = NULL;
239      bmeta.curr_func_locals = NULL;
240      bmeta.esp_byte_increment = 0;
241      bmeta.aia = aia;
242      aia_section_for_each_block_depth(sec,
243            (Aia_Block_Callback)x86_32_block_finalize, &bmeta);
244   }
245
246   static void set_preserve_regs_from_op(Aia_Operand *op,
247         bool preserve_reg[X86_32_REG_COUNT]);
248
249   static void ___x86_32_trampoline_normalize(Aia *aia,
250         Aia_Func_Trampoline *tramp)
251   {
252      HASH_MAP_SIZE(tramp_locals, HASH_MAP_SIZE_11,
253            (Hash_Map_Comparator)func_local_hash_compare);
254
255      bool preserve_reg[X86_32_REG_COUNT];
256      for (int i = 0; i < X86_32_REG_COUNT; i++)
257         preserve_reg[i] = false;
258
259      Aia_Instr *in;
260      AIA_BLOCK_FOR_EACH_INSTRUCTION(tramp->block, in) {
261         Aia_Operand *op;
262         AIA_INSTR_FOR_EACH_OPERAND(in, op) {
263            if (op)
264               set_preserve_regs_from_op(op, preserve_reg);
265         }
266      }
267
268      int32_t esp_dec = 0;
269      for (int i = 0; i < X86_32_REG_COUNT; i++) {
270         if (preserve_reg[i])
271            esp_dec += 4;
272      }
273
```

```
274     int32_t off = 4 + esp_dec;
275     Const_String loc;
276     VECTOR_FOR_EACH_ENTRY(tramp->func_params, loc) {
277        func_local_insert(&tramp_locals, loc, off);
278        off += 4;
279     }
280
281     Aia_Block_Meta bmeta;
282     bmeta.called_func = NULL;
283     bmeta.curr_func = NULL;
284     bmeta.curr_func_locals = &tramp_locals;
285     bmeta.esp_byte_increment = 0;
286     bmeta.aia = aia;
287     x86_32_block_finalize(tramp->block, &bmeta);
288
289     if (esp_dec) {
290        Aia_Instr *first_in = ___aia_block_peek_first_instr(tramp->block);
291        Aia_Instr *last_in = ___aia_block_peek_last_instr(tramp->block);
292
293        Aia_Instr *tmp = aia_instr_alloc_2op(AIA_ADD, tramp->block,
294              AIA_LONG, AIA_LONG, aia_instr_get_location(first_in));
295        Aia_Operand *op = aia_operand_const_int_alloc(aia, -esp_dec);
296        aia_instr_set_dest_op(tmp, reg_esp);
297        aia_instr_set_src_op(tmp, 0, reg_esp);
298        aia_instr_set_src_op(tmp, 1, op);
299        aia_instr_insert_after(tmp, first_in);
300
301        off = 0;
302        for (Int i = 0; i < X86_32_REG_COUNT; i++) {
303           if (preserve_reg[i]) {
304              Const_String reg_str = x86_32_reg_idx_get_32bit_name(i);
305              Aia_Operand *reg = x86_32_get_reg_operand(reg_str);
306              Aia_Operand *disp;
307              if (off) {
308                 disp = aia_operand_const_int_alloc(aia, off);
309              } else {
310                 disp = NULL;
311              }
312              Aia_Operand *esp_addr = aia_operand_addr_ref_alloc(aia,
313                    NULL, disp, reg_esp, NULL, NULL);
314              aia_mov_after(reg, esp_addr, tmp, AIA_LONG);
315
316              off += 4;
317           }
318        }
319
320        tmp = aia_instr_alloc_2op(AIA_ADD, tramp->block, AIA_LONG, AIA_LONG,
321              aia_instr_get_location(last_in));
322        op = aia_operand_const_int_alloc(aia, esp_dec);
323        aia_instr_set_dest_op(tmp, reg_esp);
324        aia_instr_set_src_op(tmp, 0, reg_esp);
325        aia_instr_set_src_op(tmp, 1, op);
326        aia_instr_insert_before(tmp, last_in);
327
328        off = 0;
329        for (Int i = 0; i < X86_32_REG_COUNT; i++) {
330           if (preserve_reg[i]) {
331              Const_String reg_str = x86_32_reg_idx_get_32bit_name(i);
332              Aia_Operand *reg = x86_32_get_reg_operand(reg_str);
333              Aia_Operand *disp;
334              if (off) {
335                 disp = aia_operand_const_int_alloc(aia, off);
336              } else {
337                 disp = NULL;
338              }
339              Aia_Operand *esp_addr = aia_operand_addr_ref_alloc(aia,
340                    NULL, disp, reg_esp, NULL, NULL);
341              aia_mov_before(esp_addr, reg, tmp, AIA_LONG);
342
343              off += 4;
344           }
345        }
346     }
347
```

```
348
349     hash_map_for_each_destroy(&tramp_locals,
350           func_local_hash_destroy);
351  }
352
353  static void ___x86_32_func_normalize(Aia *aia, Aia_Func *func)
354  {
355     Aia_Func_Meta *fmeta = func->meta_data;
356
357     Aia_Block_Meta bmeta;
358     bmeta.called_func = NULL;
359     bmeta.curr_func = func;
360     bmeta.curr_func_locals = &fmeta->func_local_offsets;
361     bmeta.esp_byte_increment = 0;
362     bmeta.func_ret_instrs = VECTOR_INIT_SIZE(4);
363     bmeta.aia = aia;
364     aia_func_for_each_block_depth(func,
365           (Aia_Block_Callback)x86_32_block_finalize, &bmeta);
366
367     Aia_Instr *last_ret = ___aia_block_peek_last_instr(func->exit_block);
368     assert(aia_instr_get_type(last_ret) == AIA_RET);
369
370
371     Aia_Instr *jmp_in;
372     Aia_Instr *ret_in;
373     VECTOR_FOR_EACH_ENTRY(&bmeta.func_ret_instrs, ret_in) {
374        if (ret_in != last_ret) {
375           jmp_in = aia_instr_alloc_1op(AIA_JMP,
376                 aia_instr_get_block(ret_in), -1, AIA_LONG,
377                 aia_instr_get_location(ret_in));
378           aia_instr_set_src_op(jmp_in, 0, fmeta->ret_label);
379           aia_instr_replace_destroy(ret_in, jmp_in);
380        }
381     }
382
383     vector_clear(&bmeta.func_ret_instrs);
384  }
385
386  static UNUSED void ___x86_32_tramp_reg_verify(Aia *aia UNUSED,
387        Aia_Func_Trampoline *tramp UNUSED)
388  {
389     return;
390  #if 0
391     Aia_Instr *in;
392     AIA_BLOCK_FOR_EACH_INSTRUCTION(tramp->block, in) {
393        Aia_Operand *op;
394        AIA_INSTR_FOR_EACH_OPERAND(in, op) {
395           if (!op)
396              continue;
397
398           switch (aia_operand_get_type(op)) {
399           case AIA_OPERAND_REG:
400              assert(!x86_32_is_callee_save_reg(op));
401              break;
402
403           case AIA_OPERAND_DISPLAY_REF:
404              assert(!x86_32_is_callee_save_reg(
405                    aia_operand_display_ref_get_display_reg(op)));
406              break;
407
408           case AIA_OPERAND_ADDR_REF:
409              if (aia_operand_addr_ref_get_base(op))
410                 assert(!x86_32_is_callee_save_reg(
411                       aia_operand_addr_ref_get_base(op)));
412              if (aia_operand_addr_ref_get_index(op))
413                 assert(!x86_32_is_callee_save_reg(
414                       aia_operand_addr_ref_get_index(op)));
415              break;
416
417           default:
418              break;
419           }
420        }
421     }
```

```
422 #endif
423 }
424
425 static void set_preserve_regs_from_op(Aia_Operand *op,
426       bool preserve_reg[X86_32_REG_COUNT])
427 {
428    Aia_Operand *tmp;
429
430    switch (aia_operand_get_type(op)) {
431    case AIA_OPERAND_REG:
432       if (x86_32_is_callee_save_reg(op))
433          preserve_reg[x86_32_reg_get_idx(op)] = true;
434       break;
435
436    case AIA_OPERAND_DISPLAY_REF:
437       tmp = aia_operand_display_ref_get_display_reg(op);
438       if (x86_32_is_callee_save_reg(tmp))
439          preserve_reg[x86_32_reg_get_idx(tmp)] = true;
440       break;
441
442    case AIA_OPERAND_ADDR_REF:
443       if (aia_operand_addr_ref_get_base(op)) {
444          tmp = aia_operand_addr_ref_get_base(op);
445          if (x86_32_is_callee_save_reg(tmp))
446             preserve_reg[x86_32_reg_get_idx(tmp)] = true;
447       }
448       if (aia_operand_addr_ref_get_index(op)) {
449          tmp = aia_operand_addr_ref_get_index(op);
450          if (x86_32_is_callee_save_reg(tmp))
451             preserve_reg[x86_32_reg_get_idx(tmp)] = true;
452       }
453       break;
454
455    default:
456       break;
457    }
458 }
459
460 static void x86_32_func_block_init(Aia_Block *b, Aia_Func *func)
461 {
462    Aia_Instr *in;
463    Aia_Func_Meta *fmeta = func->meta_data;
464    AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in) {
465       Aia_Operand *op;
466
467       DEBUGT(def,
468          if (aia_instr_get_type(in) == AIA_CALL)
469             fmeta->prev_arg_idx = -1;
470       );
471
472       AIA_INSTR_FOR_EACH_OPERAND(in, op) {
473          if (!op)
474             continue;
475
476          set_preserve_regs_from_op(op, fmeta->preserve_reg);
477
478          if (aia_operand_get_type(op) == AIA_OPERAND_DISPLAY_REF)
479             fmeta->uses_display = true;
480
481          if (aia_operand_get_type(op) == AIA_OPERAND_ARG) {
482             if (aia_operand_arg_get_idx(op) >= fmeta->max_arg_count)
483                fmeta->max_arg_count = aia_operand_arg_get_idx(op) + 1;
484
485             DEBUGT(def,
486                assert(fmeta->prev_arg_idx < aia_operand_arg_get_idx(op));
487                fmeta->prev_arg_idx = aia_operand_arg_get_idx(op);
488             );
489          }
490       }
491
492    }
493    if (!fmeta->uses_display && vector_size(&func->preserve_display_indices)) {
494       if (vector_size(&func->preserve_display_indices) > 1 ||
495             vector_get(&func->preserve_display_indices, 0) !=
```

```
496             INT_TO_PTR(-1))
497          fmeta->uses_display = true;
498    }
499 }
500
501 static inline void x86_32_func_add_reg_locals(Aia_Func *func)
502 {
503    Aia_Func_Meta *fmeta = func->meta_data;
504    for (Int i = 0; i < X86_32_REG_COUNT; i++) {
505       if (fmeta->preserve_reg[i]) {
506          Const_String reg = x86_32_reg_idx_get_32bit_name(i);
507          aia_func_append_local(func, reg);
508       }
509    }
510 }
511
512 static void x86_32_func_insert_ret(Aia_Func *func, Aia *aia)
513 {
514    Aia_Func_Meta *fmeta = func->meta_data;
515    if (aia_instr_get_type(fmeta->epilogue_in) != AIA_RET) {
516       Aia_Instr *ret = aia_instr_alloc_0op(AIA_RET,
517             aia_instr_get_block(fmeta->epilogue_in), -1,
518             aia_func_get_last_location(func));
519       aia_instr_insert_after(ret, fmeta->epilogue_in);
520       fmeta->epilogue_in = ret;
521    }
522    String tmp_ret = aia_tmp_name_gen(aia, S("RET"));
523    fmeta->ret_label = ___aia_operand_label_alloc(aia, tmp_ret,
524          0, AIA_OPERAND_LABEL);
525    aia_private_label_before(aia, fmeta->ret_label, fmeta->epilogue_in);
526 }
527
528 static void x86_32_func_esp_setup(Aia_Func *func, Aia *aia)
529 {
530    Aia_Func_Meta *fmeta = func->meta_data;
531    if (!fmeta->esp_delta_bytes)
532       return;
533
534    Aia_Operand *val = aia_operand_const_int_alloc(aia,
535          -fmeta->esp_delta_bytes);
536    Aia_Instr *add_in = aia_instr_alloc_2op(AIA_ADD,
537          aia_instr_get_block(fmeta->prologue_in),
538          AIA_LONG, AIA_LONG,
539          aia_func_get_location(func));
540
541    aia_instr_set_dest_op(add_in, reg_esp);
542    aia_instr_set_src_op(add_in, 0, reg_esp);
543    aia_instr_set_src_op(add_in, 1, val);
544    aia_instr_insert_after(add_in, fmeta->prologue_in);
545    fmeta->prologue_in = add_in;
546
547    val = aia_operand_const_int_alloc(aia,
548          fmeta->esp_delta_bytes);
549    add_in = aia_instr_alloc_2op(AIA_ADD,
550          aia_instr_get_block(fmeta->epilogue_in),
551          AIA_LONG, AIA_LONG,
552          aia_func_get_location(func));
553
554    aia_instr_set_dest_op(add_in, reg_esp);
555    aia_instr_set_src_op(add_in, 0, reg_esp);
556    aia_instr_set_src_op(add_in, 1, val);
557    aia_instr_insert_before(add_in, fmeta->epilogue_in);
558    fmeta->epilogue_in = add_in;
559 }
560
561 static void x86_32_func_regs_setup(Aia_Func *func, Aia *aia)
562 {
563    Aia_Func_Meta *fmeta = func->meta_data;
564    for (Int i = 0; i < X86_32_REG_COUNT; i++) {
565       if (fmeta->preserve_reg[i]) {
566          Const_String reg_str = x86_32_reg_idx_get_32bit_name(i);
567          Aia_Operand *local =
568                aia_operand_local_ref_alloc(aia, reg_str /*, AIA_LONG */);
569          Aia_Operand *reg = x86_32_get_reg_operand(reg_str);
```

```
570            fmeta->prologue_in = aia_mov_after(reg, local, fmeta->prologue_in,
571                  AIA_LONG);
572            fmeta->epilogue_in = aia_mov_before(local, reg,
573                  fmeta->epilogue_in, AIA_LONG);
574         }
575      }
576   }
577
578   static void x86_32_func_display_setup(Aia_Func *func, Aia *aia)
579   {
580      Aia_Func_Meta *fmeta = func->meta_data;
581
582      Int param_esp_off = fmeta->esp_delta_bytes +
583         vector_size(&func->parameters) * 4;
584
585      Int arg_esp_off = 4 * (fmeta->max_arg_count +
586            vector_size(&func->preserve_display_indices)) - 4;
587
588      ssize_t idx UNUSED;
589      VECTOR_FOR_EACH_ENTRY(&func->preserve_display_indices, idx) {
590         Aia_Operand *ref;
591         Aia_Operand *src;
592
593         if (idx != -1) {
594            ref = x86_32_alloc_ref(aia, reg_esp, param_esp_off);
595            fmeta->prologue_in = aia_mov_after(ref, reg_eax,
596                  fmeta->prologue_in, AIA_LONG);
597            src = reg_eax;
598            param_esp_off -= 4;
599         } else {
600            src = reg_esp;
601         }
602
603         ref = x86_32_alloc_ref(aia, reg_esp, arg_esp_off);
604         fmeta->prologue_in = aia_mov_after(src, ref,
605               fmeta->prologue_in, AIA_LONG);
606
607         arg_esp_off -= 4;
608      }
609   }
610
611   static void x86_32_func_insert_logue(Aia_Func *func, Aia *aia)
612   {
613      Aia_Func_Meta *fmeta = func->meta_data;
614      x86_32_func_add_reg_locals(func);
615      DLOG("logue for func: %S\n", func->func_name);
616      DLOG("\tnum locals: %D\n", vector_size(&func->locals));
617      DLOG("\tnum preserves: %D\n", vector_size(&func->preserve_display_indices));
618      DLOG("\tmax arg count: %D\n", fmeta->max_arg_count);
619      fmeta->esp_delta_bytes = 4 * (vector_size(&func->locals) +
620         vector_size(&func->preserve_display_indices) + fmeta->max_arg_count);
621
622      fmeta->prologue_in = ___aia_block_peek_first_instr(func->entry_block);
623      fmeta->epilogue_in = ___aia_block_peek_last_instr(func->exit_block);
624      assert(fmeta->prologue_in);
625      assert(fmeta->epilogue_in);
626      assert(aia_instr_get_type(fmeta->prologue_in) == ___AIA_LABEL);
627
628      x86_32_func_insert_ret(func, aia);
629      x86_32_func_esp_setup(func, aia);
630      x86_32_func_regs_setup(func, aia);
631      x86_32_func_display_setup(func, aia);
632
633      Int off = fmeta->esp_delta_bytes - 4;
634      Const_String loc;
635      VECTOR_FOR_EACH_ENTRY(&func->locals, loc) {
636         DLOG("\toffset %D: %S\n", off, loc);
637         func_local_insert(&fmeta->func_local_offsets, loc, off);
638         off -= 4;
639      }
640
641      off = fmeta->esp_delta_bytes + 4;
642      VECTOR_FOR_EACH_ENTRY(&func->parameters, loc) {
643         DLOG("\toffset %D: %S\n", off, loc);
```

```
644         func_local_insert(&fmeta->func_local_offsets, loc, off);
645         off += 4;
646      }
647   }
648
649   static void x86_32_section_set_max_arg_count(Aia_Block *b, Aia_Section *sec)
650   {
651      Aia_Instr *in;
652      Int max = PTR_TO_INT(sec->meta_data);
653      AIA_BLOCK_FOR_EACH_INSTRUCTION(b, in) {
654         Aia_Operand *op;
655         AIA_INSTR_FOR_EACH_OPERAND(in, op) {
656            if (op && aia_operand_get_type(op) == AIA_OPERAND_ARG) {
657               if (aia_operand_arg_get_idx(op) >= max)
658                  max = aia_operand_arg_get_idx(op) + 1;
659            }
660         }
661      }
662      sec->meta_data = INT_TO_PTR(max);
663   }
664
665   static void x86_32_section_esp_setup(Aia_Section *sec, Aia *aia)
666   {
667      Int count = PTR_TO_INT(sec->meta_data) * 4;
668      if (!count)
669         return;
670
671      Aia_Instr *first_in = ___aia_block_peek_first_instr(sec->entry_block);
672      assert(first_in);
673      assert(aia_instr_get_type(first_in) == ___AIA_LABEL);
674      Aia_Instr *last_in = ___aia_block_peek_last_instr(sec->exit_block);
675      assert(last_in);
676
677      Aia_Operand *val = aia_operand_const_int_alloc(aia, -count);
678      Aia_Instr *add_in = aia_instr_alloc_2op(AIA_ADD,
679            aia_instr_get_block(first_in),
680            AIA_LONG, AIA_LONG,
681            aia_instr_get_location(first_in));
682      aia_instr_set_dest_op(add_in, reg_esp);
683      aia_instr_set_src_op(add_in, 0, reg_esp);
684      aia_instr_set_src_op(add_in, 1, val);
685      aia_instr_insert_after(add_in, first_in);
686
687      val = aia_operand_const_int_alloc(aia, count);
688      add_in = aia_instr_alloc_2op(AIA_ADD,
689            aia_instr_get_block(last_in),
690            AIA_LONG, AIA_LONG,
691            aia_instr_get_location(last_in));
692      aia_instr_set_dest_op(add_in, reg_esp);
693      aia_instr_set_src_op(add_in, 0, reg_esp);
694      aia_instr_set_src_op(add_in, 1, val);
695      aia_instr_insert_after(add_in, last_in);
696   }
697
698   static void aia_section_insert_logue(Aia_Section *sec, Aia *aia)
699   {
700      x86_32_section_esp_setup(sec, aia);
701   }
702
703   static void x86_32_dump_final_ic(Aia *aia)
704   {
705      String fname = string_from_format(S("%S.vitaly.final-x86-32-ic"),
706            aia_get_file_name(aia));
707      FILE *f = file_open(fname, S("w"));
708      if (!f)
709         fatal_error(S("unable to open file %S for intermediate code dump\n"),
710               fname);
711      string_destroy(fname);
712      aia_dump(aia, f);
713      file_close(f);
714   }
715
716   void x86_32_func_normalize(Aia *aia)
717   {
```

```
718     Aia_Section *sec;
719     Aia_Func *func;
720     Aia_Func_Trampoline *tramp;
721     Aia_Func_Meta *fmeta;
722
723     AIA_FOR_EACH_SECTION(aia, sec) {
724        sec->meta_data = NULL;
725        aia_section_for_each_block_depth(sec, (Aia_Block_Callback)
726              x86_32_section_set_max_arg_count, sec);
727        aia_section_insert_logue(sec, aia);
728
729        AIA_SECTION_FOR_EACH_FUNC(sec, func) {
730           func->meta_data = fmeta = alloc_zeros(sizeof(Aia_Func_Meta));
731           fmeta->uses_display = false;
732           fmeta->func_local_offsets = HASH_MAP_INIT_SIZE(HASH_MAP_SIZE_11,
733                 (Hash_Map_Comparator)func_local_hash_compare);
734
735           DEBUGT(def, fmeta->prev_arg_idx = -1);
736           aia_func_for_each_block_depth(func, (Aia_Block_Callback)
737                 x86_32_func_block_init, func);
738
739           x86_32_func_insert_logue(func, aia);
740        }
741     }
742
743     AIA_FOR_EACH_SECTION(aia, sec) {
744        ___x86_32_section_normalize(aia, sec);
745
746        AIA_SECTION_FOR_EACH_FUNC(sec, func) {
747           ___x86_32_func_normalize(aia, func);
748
749           AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp) {
750              DEBUGT(def, ___x86_32_tramp_reg_verify(aia, tramp));
751              ___x86_32_trampoline_normalize(aia, tramp);
752           }
753        }
754     }
755
756     AIA_FOR_EACH_FUNC(aia, func) {
757        fmeta = func->meta_data;
758        hash_map_for_each_destroy(&fmeta->func_local_offsets,
759              func_local_hash_destroy);
760        free_mem(func->meta_data);
761     }
762
763     if (cmdopts.dump_final_x86_32_ic)
764        x86_32_dump_final_ic(aia);
765  }
```

:

A.9.12 src/x86_32/x86_32_func_normalize.h

```
1  #ifndef X86_32_FUNC_NORMALIZE_H
2  #define X86_32_FUNC_NORMALIZE_H
3
4  void x86_32_func_normalize(Aia *aia);
5
6  #endif // X86_32_FUNC_NORMALIZE_H
```

:

A.9.13 src/x86_32/x86_32_normalize.c

```
1  #include "x86_32_normalize.h"
2  #include "x86_32.h"
3  #include "x86_32_regs.h"
```

```
4  #include <main.h>
5
6  static inline void x86_32_verify_src_operand(Aia_Operand *src_op UNUSED)
7  {
8     DEBUGT(def,
9        switch (aia_operand_get_type(src_op)) {
10       case AIA_OPERAND_CONST_STRING:
11       case AIA_OPERAND_BLOCK:
12          assert(false);
13       default:
14          break;
15       }
16    );
17 }
18
19 static inline void x86_32_verify_src_dest_operands(Aia_Operand *dest UNUSED,
20       Uns src_op_count UNUSED, ...)
21 {
22    DEBUGT(def,
23       if (dest)
24          assert(aia_operand_is_dest(dest));
25       VA_SETUP(vl, src_op_count);
26       while (src_op_count--)
27          x86_32_verify_src_operand(va_arg(vl, Aia_Operand *));
28       VA_END(vl);
29    );
30 }
31
32 static inline Aia_Instr *x86_32_mov(Aia_Operand *src, Aia_Operand *dest,
33       uint8_t op_sizes, Aia_Block *block, File_Location *loc)
34 {
35    Aia_Instr *mov_in = aia_instr_alloc_1op(AIA_MOV,
36          block, op_sizes, op_sizes, loc);
37    aia_instr_set_dest_op(mov_in, dest);
38    aia_instr_set_src_op(mov_in, 0, src);
39    return mov_in;
40 }
41
42 static void x86_32_mov_normalize(Aia *aia, Aia_Instr *instr)
43 {
44    Aia_Operand *dest = aia_instr_get_dest_op(instr);
45    Aia_Operand *src = aia_instr_get_src_op(instr, 0);
46    Aia_Operand *tmp_dest = NULL;
47
48    x86_32_verify_src_dest_operands(dest, 1, src);
49
50    switch (aia_instr_get_type(instr)) {
51    case AIA_MOVS:
52       /* Fall. */
53    case AIA_MOVZ:
54       if (aia_operand_is_integer(src)) {
55          Aia_Instr *new_mov = x86_32_mov(src, dest,
56                aia_instr_get_dest_op_size(instr),
57                aia_instr_get_block(instr),
58                aia_instr_get_location(instr));
59          aia_instr_replace(instr, new_mov);
60          vector_append(aia->meta_data, instr);
61          instr = new_mov;
62       }
63       if (aia_operand_get_type(src) != AIA_OPERAND_REG) {
64          Aia_Instr *new_mov = aia_mov_to_tmp_reg_before(aia, src, instr,
65             aia_instr_get_src_ops_size(instr));
66          aia_instr_replace_op(instr, 0, aia_instr_get_dest_op(new_mov));
67       }
68       if (aia_operand_get_type(dest) != AIA_OPERAND_REG) {
69          tmp_dest = aia_operand_tmp_reg_alloc(aia);
70          aia_instr_replace_op(instr, -1, tmp_dest);
71       }
72       break;
73
74    case AIA_MOV:
75       if (aia_operand_is_mem(src) && aia_operand_is_mem(dest)) {
76          Aia_Instr *new_mov = aia_mov_to_tmp_reg_before(aia, src, instr,
77                aia_instr_get_src_ops_size(instr));
```

```
78             aia_instr_replace_op(instr, 0, aia_instr_get_dest_op(new_mov));
79          }
80          break;
81
82       default:
83
84          fatal_error(S("unexpected mov instruction. Aborting...\n"));
85          break;
86       }
87       if (aia_instr_get_src_ops_size(instr) == AIA_BYTE &&
88             aia_operand_get_type(src) == AIA_OPERAND_CONST_INT) {
89          int32_t orig = aia_operand_const_int_get_val(src);
90          int8_t val = orig;
91          if (val != orig) {
92             Aia_Operand *nconst = aia_operand_const_int_alloc(aia, 0);
93             aia_instr_replace_op(instr, 0, nconst);
94             if (cmdopts.warn_overflow)
95                report_warning_location(aia_instr_get_location(instr),
96                      S("constant implicitly truncated to " QFY("%" PRId8)
97                         " to fit " QFY("char") " variable\n"), val);
98          }
99       }
100      if (tmp_dest)
101         aia_mov_after(tmp_dest, dest, instr, AIA_LONG);
102   }
103
104   static inline Aia_Operand *x86_32_arith_instr_get_const_int(Aia *aia,
105         Aia_Operand *src_dest, Aia_Operand *src_src, Aia_Instr *instr)
106   {
107      int32_t in_result;
108      int32_t lhs = aia_operand_const_int_get_val(src_dest);
109      int32_t rhs = aia_operand_const_int_get_val(src_src);
110      switch (aia_instr_get_type(instr)) {
111      case AIA_SUB:
112         in_result = lhs - rhs;
113         break;
114      case AIA_ADD:
115         in_result = lhs + rhs;
116         break;
117      case AIA_IMUL:
118         in_result = lhs * rhs;
119         break;
120      case AIA_IDIV:
121         in_result = lhs / rhs;
122         break;
123      default:
124         assert(false);
125      }
126      return aia_operand_const_int_alloc(aia, in_result);
127   }
128
129   static inline Aia_Operand *x86_32_arith_instr_get_label_addr(Aia *aia,
130         Aia_Operand *src_label, Aia_Operand *src_int, Aia_Instr *instr)
131   {
132      int32_t val = aia_operand_const_int_get_val(src_int);
133      switch (aia_instr_get_type(instr)) {
134      case AIA_SUB:
135         val = -val;
136         break;
137      case AIA_ADD:
138         break;
139      default:
140         assert(false);
141      }
142      return aia_operand_label_addr_alloc(aia,
143            aia_operand_label_get_name(src_label),
144            aia_operand_label_get_offset(src_label) + val);
145   }
146
147   static inline Aia_Operand *x86_32_arith_instr_get_src_integer(Aia *aia,
148         Aia_Operand *src_dest, Aia_Operand *src_src, Aia_Instr *instr)
149   {
150      Aia_Operand_Type dest_type = aia_operand_get_type(src_dest);
151      Aia_Operand_Type src_type = aia_operand_get_type(src_src);
```

```
152     if (dest_type == src_type) {
153        assert(dest_type != AIA_OPERAND_LABEL_ADDR);
154        return x86_32_arith_instr_get_const_int(aia, src_dest, src_src, instr);
155     } else {
156        if (dest_type == AIA_OPERAND_LABEL_ADDR)
157           return x86_32_arith_instr_get_label_addr(aia, src_dest,
158                 src_src, instr);
159        return x86_32_arith_instr_get_label_addr(aia, src_src,
160              src_dest, instr);
161     }
162  }
163
164  static inline void x86_32_arith_instr_to_mov(Aia *aia, Aia_Instr *instr)
165  {
166     Aia_Operand *dest = aia_instr_get_dest_op(instr);
167     Aia_Operand *src_dest = aia_instr_get_src_op(instr, 0);
168     Aia_Operand *src_src = aia_instr_get_src_op(instr, 1);
169
170     Aia_Operand *src_int = x86_32_arith_instr_get_src_integer(aia, src_dest,
171           src_src, instr);
172
173     Aia_Instr *mov_in = x86_32_mov(src_int, dest,
174           aia_instr_get_dest_op_size(instr),
175           aia_instr_get_block(instr),
176           aia_instr_get_location(instr));
177
178     aia_instr_replace(instr, mov_in);
179     vector_append(aia->meta_data, instr);
180  }
181
182  static void x86_32_add_sub_normalize(Aia *aia, Aia_Instr *instr)
183  {
184     Aia_Operand *dest = aia_instr_get_dest_op(instr);
185     Aia_Operand *src_dest = aia_instr_get_src_op(instr, 0);
186     Aia_Operand *src_src = aia_instr_get_src_op(instr, 1);
187
188     x86_32_verify_src_dest_operands(dest, 2, src_dest, src_src);
189     assert(aia_instr_get_dest_op_size(instr) ==
190           aia_instr_get_src_ops_size(instr));
191
192     if (aia_operand_is_integer(src_dest) && aia_operand_is_integer(src_src)) {
193        x86_32_arith_instr_to_mov(aia, instr);
194        return;
195     } else if (!aia_operands_equal(src_dest, dest)) {
196        Aia_Instr *mov_in = x86_32_mov(src_dest, dest,
197              aia_instr_get_dest_op_size(instr),
198              aia_instr_get_block(instr),
199              aia_instr_get_location(instr));
200        aia_instr_insert_before(mov_in, instr);
201        x86_32_mov_normalize(aia, mov_in);
202        aia_instr_replace_op(instr, 0, dest);
203     }
204     if (aia_operand_is_mem(src_src) && aia_operand_is_mem(dest)) {
205        Aia_Instr *new_mov = aia_mov_to_tmp_reg_before(aia, src_src, instr,
206              aia_instr_get_dest_op_size(instr));
207        aia_instr_replace_op(instr, 1, aia_instr_get_dest_op(new_mov));
208     }
209  }
210
211  static void x86_32_imul_normalize(Aia *aia, Aia_Instr *instr)
212  {
213     Aia_Operand *dest = aia_instr_get_dest_op(instr);
214     Aia_Operand *src_dest = aia_instr_get_src_op(instr, 0);
215     Aia_Operand *src_src = aia_instr_get_src_op(instr, 1);
216
217     x86_32_verify_src_dest_operands(dest, 2, src_dest, src_src);
218
219     if (aia_operand_is_integer(src_dest) && aia_operand_is_integer(src_src)) {
220        x86_32_arith_instr_to_mov(aia, instr);
221        return;
222     }
223
224     if (!aia_operand_is_reg(dest)) {
225        Aia_Operand *tmp = aia_operand_tmp_reg_alloc(aia);
```

```
226         Aia_Instr *mov_in = x86_32_mov(tmp, dest, AIA_LONG,
227               aia_instr_get_block(instr),
228               aia_instr_get_location(instr));
229         dest = tmp;
230         aia_instr_replace_op(instr, -1, dest);
231         aia_instr_insert_after(mov_in, instr);
232      }
233
234      if (aia_operand_is_integer(src_dest)) {
235         aia_instr_swap_ops(instr, 0, 1);
236         return;
237      } else if (aia_operand_is_integer(src_src)) {
238         return;
239      }
240
241      Aia_Instr *mov_in = x86_32_mov(src_dest, dest, AIA_LONG,
242            aia_instr_get_block(instr),
243            aia_instr_get_location(instr));
244      aia_instr_insert_before(mov_in, instr);
245      aia_instr_replace_op(instr, 0, dest);
246   }
247
248   static void x86_32_idiv_normalize(Aia *aia, Aia_Instr *instr)
249   {
250      if (aia_instr_is_normalized(instr))
251         return;
252
253      Aia_Operand *dest = aia_instr_get_dest_op(instr);
254      Aia_Operand *src_dest = aia_instr_get_src_op(instr, 0);
255      Aia_Operand *src_src = aia_instr_get_src_op(instr, 1);
256
257      x86_32_verify_src_dest_operands(dest, 2, src_dest, src_src);
258
259      if (aia_operand_is_integer(src_dest) && aia_operand_is_integer(src_src)) {
260         if (aia_operand_get_type(src_src) != AIA_OPERAND_CONST_INT ||
261               aia_operand_const_int_get_val(src_src) != 0) {
262            x86_32_arith_instr_to_mov(aia, instr);
263            return;
264         }
265      }
266
267      Aia_Block *block = aia_instr_get_block(instr);
268
269      Aia_Instr *mov_in = x86_32_mov(src_dest, reg_eax, AIA_LONG, block,
270            aia_instr_get_location(instr));
271      aia_instr_insert_before(mov_in, instr);
272
273      Aia_Instr *cdq = aia_instr_alloc_1op(AIA_CDQ, block,
274            AIA_LONG, AIA_LONG, aia_instr_get_location(instr));
275      aia_instr_set_src_op(cdq, 0, reg_eax);
276      aia_instr_set_dest_op(cdq, reg_edx);
277      aia_instr_insert_before(cdq, instr);
278
279      if (aia_operand_is_integer(src_src)) {
280         Aia_Operand *tmp_reg = aia_operand_tmp_reg_alloc(aia);
281         mov_in = x86_32_mov(src_src, tmp_reg, AIA_LONG, block,
282               aia_instr_get_location(instr));
283         aia_instr_insert_before(mov_in, instr);
284         src_src = tmp_reg;
285      }
286
287      mov_in = x86_32_mov(reg_eax, dest, AIA_LONG, block,
288            aia_instr_get_location(instr));
289      aia_instr_insert_after(mov_in, instr);
290
291      aia_instr_replace_op(instr, -1, reg_eax);
292      aia_instr_replace_op(instr, 0, reg_eax);
293      aia_instr_replace_op(instr, 1, src_src);
294   }
295
296   static inline bool x86_32_cmp_is_commutative(Aia_Instr *instr)
297   {
298      Aia_Instr *suc = aia_instr_get_sucessor(instr);
299      assert(suc);
```

```
300      switch (aia_instr_get_type(suc)) {
301      case AIA_JE:
302         /* Fall through. */
303      case AIA_JNE:
304         /* Fall through. */
305      case AIA_SETE:
306         /* Fall through. */
307      case AIA_SETNE:
308         return true;
309
310      default:
311         return false;
312      }
313   }
314
315   static void x86_32_cmp_normalize(Aia *aia, Aia_Instr *instr)
316   {
317      Aia_Operand *src_dest = aia_instr_get_src_op(instr, 0);
318      Aia_Operand *src_src = aia_instr_get_src_op(instr, 1);
319
320      x86_32_verify_src_dest_operands(NULL, 2, src_dest, src_src);
321
322      if ((aia_operand_is_mem(src_dest) && aia_operand_is_mem(src_src)) ||
323            (aia_operand_is_integer(src_dest) &&
324            (!x86_32_cmp_is_commutative(instr) ||
325            aia_operand_is_integer(src_src)))) {
326         Aia_Instr *mov_in = aia_mov_to_tmp_reg_before(aia, src_dest, instr,
327               aia_instr_get_src_ops_size(instr));
328         aia_instr_replace_op(instr, 0, aia_instr_get_dest_op(mov_in));
329      } else if (aia_operand_is_integer(src_dest)) {
330         aia_instr_swap_ops(instr, 0, 1);
331      }
332   }
333
334   static void x86_32_ret_normalize(Aia *aia UNUSED, Aia_Instr *instr)
335   {
336      if (!aia_instr_get_src_op_count(instr) || aia_instr_is_normalized(instr))
337         return;
338
339      Aia_Operand *ret = aia_instr_get_src_op(instr, 0);
340
341      x86_32_verify_src_dest_operands(NULL, 1, ret);
342
343      Aia_Block *block = aia_instr_get_block(instr);
344
345      Aia_Instr *mov_in;
346      Aia_Operand *a_reg;
347      if (aia_instr_get_src_ops_size(instr) == AIA_LONG) {
348         mov_in = x86_32_mov(ret, reg_eax, AIA_LONG, block,
349               aia_instr_get_location(instr));
350         a_reg = reg_eax;
351      } else {
352         assert(aia_instr_get_src_ops_size(instr) == AIA_BYTE);
353         mov_in = x86_32_mov(ret, reg_al, AIA_BYTE, block,
354               aia_instr_get_location(instr));
355         a_reg = reg_al;
356      }
357      aia_instr_insert_before(mov_in, instr);
358      aia_instr_replace_op(instr, 0, a_reg);
359   }
360
361   static void x86_32_call_normalize(Aia *aia UNUSED, Aia_Instr *instr)
362   {
363      if (aia_instr_is_normalized(instr))
364         return;
365
366      Aia_Operand *ret = aia_instr_get_dest_op(instr);
367      Aia_Operand *src = aia_instr_get_src_op(instr, 0);
368
369      x86_32_verify_src_dest_operands(ret, 1, src);
370
371      if (ret) {
372         Aia_Block *block = aia_instr_get_block(instr);
373
```

```
374         Aia_Instr *mov_in;
375         Aia_Operand *a_reg;
376         if (aia_instr_get_dest_op_size(instr) == AIA_LONG) {
377            mov_in = x86_32_mov(reg_eax, ret, AIA_LONG, block,
378                  aia_instr_get_location(instr));
379            a_reg = reg_eax;
380         } else {
381            mov_in = x86_32_mov(reg_al, ret, AIA_BYTE, block,
382                  aia_instr_get_location(instr));
383            a_reg = reg_al;
384         }
385         aia_instr_insert_after(mov_in, instr);
386         aia_instr_replace_op(instr, -1, a_reg);
387      }
388   }
389
390   static void x86_32_neg_normalize(Aia *aia, Aia_Instr *instr)
391   {
392      Aia_Operand *src = aia_instr_get_src_op(instr, 0);
393      Aia_Operand *dest = aia_instr_get_dest_op(instr);
394
395      x86_32_verify_src_dest_operands(dest, 1, src);
396      if (aia_operand_is_integer(src)) {
397         assert(aia_operand_get_type(src) == AIA_OPERAND_CONST_INT);
398         Aia_Operand *cint = aia_operand_const_int_alloc(aia,
399               -aia_operand_const_int_get_val(src));
400         Aia_Instr *mov_in = x86_32_mov(cint, dest, AIA_LONG,
401               aia_instr_get_block(instr), aia_instr_get_location(instr));
402         aia_instr_replace(instr, mov_in);
403         vector_append(aia->meta_data, instr);
404         return;
405      }
406      if (!aia_operands_equal(src, dest)) {
407         Aia_Instr *mov_in = x86_32_mov(src, dest, AIA_LONG,
408               aia_instr_get_block(instr),
409               aia_instr_get_location(instr));
410         aia_instr_insert_before(mov_in, instr);
411         aia_instr_replace_op(instr, 0, dest);
412      }
413   }
414
415   static void x86_32_instr_normalize(Aia *aia, Aia_Instr *instr)
416   {
417      switch (aia_instr_get_type(instr)) {
418      case AIA_MOV:
419         assert(aia_instr_get_dest_op_size(instr) ==
420               aia_instr_get_src_ops_size(instr));
421         x86_32_mov_normalize(aia, instr);
422         break;
423
424      case AIA_MOVZ:
425         /* Fall through. */
426      case AIA_MOVS:
427         assert(aia_instr_get_dest_op_size(instr) == AIA_LONG &&
428               aia_instr_get_src_ops_size(instr) == AIA_BYTE);
429         x86_32_mov_normalize(aia, instr);
430         break;
431
432      case AIA_ADD:
433         /* Fall through. */
434      case AIA_SUB:
435         assert(aia_instr_get_dest_op_size(instr) == AIA_LONG &&
436               aia_instr_get_src_ops_size(instr) == AIA_LONG);
437         x86_32_add_sub_normalize(aia, instr);
438         break;
439
440      case AIA_IMUL:
441         assert(aia_instr_get_dest_op_size(instr) == AIA_LONG &&
442               aia_instr_get_src_ops_size(instr) == AIA_LONG);
443         x86_32_imul_normalize(aia, instr);
444         break;
445
446      case AIA_IDIV:
447         assert(aia_instr_get_dest_op_size(instr) == AIA_LONG &&
```

```
448             aia_instr_get_src_ops_size(instr) == AIA_LONG);
449       x86_32_idiv_normalize(aia, instr);
450       break;
451
452    case AIA_CMP:
453       x86_32_cmp_normalize(aia, instr);
454       break;
455
456    AIA_CASE_COND_JUMP:
457    case AIA_JMP:
458       break;
459    case AIA_NOP:
460       break;
461
462    case AIA_SETE:
463       /* Fall through. */
464    case AIA_SETNE:
465       /* Fall through. */
466    case AIA_SETL:
467       /* Fall through. */
468    case AIA_SETG:
469       /* Fall through. */
470    case AIA_SETLE:
471       /* Fall through. */
472    case AIA_SETGE:
473       x86_32_verify_src_dest_operands(aia_instr_get_dest_op(instr), 0);
474       break;
475
476    case AIA_RET:
477       x86_32_ret_normalize(aia, instr);
478       break;
479    case AIA_CALL:
480       assert(aia_instr_get_src_ops_size(instr) == AIA_LONG);
481       x86_32_call_normalize(aia, instr);
482       break;
483    case AIA_NEG:
484       assert(aia_instr_get_dest_op_size(instr) == AIA_LONG &&
485             aia_instr_get_src_ops_size(instr) == AIA_LONG);
486       x86_32_neg_normalize(aia, instr);
487       break;
488    case AIA_CDQ:
489       break;
490
491    /* Special AIA implementation specific instructions. */
492    case ___AIA_LABEL:
493       break;
494    case ___AIA_STRING:
495       break;
496    case ___AIA_INTEGER:
497       break;
498
499    default:
500       fatal_error(S("unimplemented x86-32 instruction normalization\n"));
501    }
502
503    aia_instr_set_normalized(instr);
504 }
505
506 static void x86_32_block_callback(Aia_Block *b, Aia *aia)
507 {
508    Aia_Instr *instr;
509    AIA_BLOCK_FOR_EACH_INSTRUCTION(b, instr)
510       x86_32_instr_normalize(aia, instr);
511    vector_for_each_destroy(aia->meta_data,
512          (Vector_Destructor)aia_instr_destroy);
513 }
514
515 static void x86_32_section_normalize(Aia *aia, Aia_Section *sec)
516 {
517    Double_List_Node *bnode;
518    DOUBLE_LIST_FOR_EACH(&sec->sec_blist, bnode)
519       x86_32_block_callback(AIA_BLOCK_OF_DBNODE(bnode), aia);
520
521    Aia_Func *func;
```

```
522     AIA_SECTION_FOR_EACH_FUNC(sec, func) {
523        DOUBLE_LIST_FOR_EACH(&func->blist, bnode)
524           x86_32_block_callback(AIA_BLOCK_OF_DBNODE(bnode), aia);
525
526        Aia_Func_Trampoline *tramp;
527        AIA_FUNC_FOR_EACH_TRAMPOLINE(func, tramp)
528           x86_32_block_callback(tramp->block, aia);
529     }
530  }
531
532  static void x86_32_normalize_dump(Aia *aia)
533  {
534     String fname = string_from_format(S("%S.vitaly.norm-x86-32-ic"),
535           aia_get_file_name(aia));
536     FILE *f = file_open(fname, S("w"));
537     if (!f)
538        fatal_error(S("unable to open file %S for intermediate code dump\n"),
539              fname);
540     aia_dump(aia, f);
541     file_close(f);
542     string_destroy(fname);
543  }
544
545  void x86_32_normalize_instructions(Aia *aia, Vector *instructions)
546  {
547     void *saved_data = aia->meta_data;
548     aia->meta_data = vector_alloc();
549     Aia_Instr *in;
550     VECTOR_FOR_EACH_ENTRY(instructions, in)
551        x86_32_instr_normalize(aia, in);
552     vector_destroy(aia->meta_data, (Vector_Destructor)aia_instr_destroy);
553     aia->meta_data = saved_data;
554  }
555
556  void x86_32_normalize(Aia *aia)
557  {
558     if (!aia_is_valid(aia))
559        return;
560
561     aia->meta_data = vector_alloc();
562     Aia_Section *sec;
563     AIA_FOR_EACH_SECTION(aia, sec)
564        x86_32_section_normalize(aia, sec);
565     vector_destroy(aia->meta_data, (Vector_Destructor)aia_instr_destroy);
566     if (cmdopts.dump_norm_x86_32_ic)
567        x86_32_normalize_dump(aia);
568  }
```

:

A.9.14 src/x86_32/x86_32_normalize.h

```
1  #ifndef X86_32_NORMALIZE_H
2  #define X86_32_NORMALIZE_H
3
4  #include <aia/aia.h>
5
6  typedef struct Vector Vector;
7
8  //void x86_32_normalize_instructions(Aia *aia, Vector *instructions);
9
10 /* Scrambles aia->meta_data. */
11 void x86_32_normalize(Aia *aia);
12
13 #endif // X86_32_NORMALIZE_H
```

A.10 Compiler Library

:

A.10.1 src/alloc.c

```
#include <std_include.h>
#include <stdlib.h>

void *alloc_zeros(Uns size)
{
   void *ptr;
   if (!(ptr = calloc(1, size)) && size > 0)
      fatal_error(S("unable to allocate memory\n"));
   return ptr;
}

void *alloc_mem(Uns size)
{
   void *ptr;
   if (!(ptr = malloc(size)) && size > 0)
      fatal_error(S("unable to allocate memory\n"));
   return ptr;
}

void *realloc_mem(void *old_ptr, Uns size)
{
   void *ptr;
   if (!(ptr = realloc(old_ptr, size)) && size > 0)
      fatal_error(S("unable to allocate memory\n"));
   return ptr;
}

void free_mem(void *ptr)
{
   free(ptr);
}
```

:

A.10.2 src/alloc.h

```
#ifndef ALLOC_HANDLER_H
#define ALLOC_HANDLER_H

void *alloc_mem(Uns size) __attribute__((malloc));

void *realloc_mem(void *old_ptr, Uns size);

void *alloc_zeros(Uns size) __attribute__((malloc));

void free_mem(void *ptr);

#define ALLOC_NEW(obj_name) alloc_mem(sizeof(obj_name))

#endif // ALLOC_HANDLER_H
```

:

A.10.3 src/bit_vector.h

```
#ifndef BIT_VECTOR_H
#define BIT_VECTOR_H

#include <vector.h>
```

```
5
6   typedef Vector Bit_Vector;
7
8   static inline Bit_Vector *bit_vector_alloc()
9   {
10     return vector_alloc();
11  }
12
13  static inline Uns ___bit_vector_get_vector_idx(Bit_Vector *v, Uns idx)
14  {
15     Uns v_idx = idx / PTR_BITS;
16     while (v_idx >= vector_size(v))
17        vector_append(v, INT_TO_PTR(0));
18     return v_idx;
19  }
20
21  static inline void bit_vector_set(Bit_Vector *v, Uns idx)
22  {
23     Uns v_idx = ___bit_vector_get_vector_idx(v, idx);
24     v->array[v_idx] |= 1 << (idx - v_idx * PTR_BITS);
25  }
26
27  static inline void bit_vector_clear(Bit_Vector *v, Uns idx)
28  {
29     Uns v_idx = ___bit_vector_get_vector_idx(v, idx);
30     v->array[v_idx] &= ~(1 << (idx - v_idx * PTR_BITS));
31  }
32
33  static inline bool bit_vector_test(Bit_Vector *v, Uns idx)
34  {
35     Uns v_idx = ___bit_vector_get_vector_idx(v, idx);
36     return v->array[v_idx] & (1 << (idx - v_idx * PTR_BITS));
37  }
38
39  static inline void bit_vector_complement(Bit_Vector *v, Uns idx)
40  {
41     if (bit_vector_test(v, idx))
42        bit_vector_clear(v, idx);
43     else
44        bit_vector_set(v, idx);
45  }
46
47  #endif // BIT_VECTOR_H
```

:

A.10.4 src/debug.c

```
1   #ifndef NDEBUG
2   #include <debug.h>
3
4   #include <hash_map.h>
5   #include <stdlib.h>
6   #include <string.h>
7   #include <vector.h>
8
9   typedef struct Debug_Type {
10     Hash_Map_Slot slot;
11     String type;
12  } Debug_Type;
13
14  #define DEBUG_TYPE_OF(s) HASH_MAP_ENTRY(s, Debug_Type, slot)
15
16  static bool debug_comparator(void *sobj, Hash_Map_Slot *mslot)
17  {
18     Const_String s = (Const_String)sobj;
19     Debug_Type *t = DEBUG_TYPE_OF(mslot);
20     return string_compare(s, t->type) == 0;
21  }
22
23  HASH_MAP_SIZE(debug_hmap, HASH_MAP_SIZE_11, debug_comparator);
```

```
24
25 void ___debug_enable_type(Const_String type)
26 {
27    Uns hash = string_hash_code(type);
28    if (!hash_map_contains(&debug_hmap, (void *)type, hash)) {
29       Debug_Type *t = ALLOC_NEW(Debug_Type);
30       t->type = string_duplicate(type);
31       hash_map_insert(&debug_hmap, &t->slot, hash);
32    }
33 }
34
35 void ___debug_disable_type(Const_String type)
36 {
37    if (string_compare(type, DEBUG_DEFAULT_STR) == 0)
38       return;
39    Hash_Map_Slot *slot = hash_map_remove(&debug_hmap, (void *)type,
40          string_hash_code(type));
41    if (slot) {
42       string_destroy(DEBUG_TYPE_OF(slot)->type);
43       free_mem(DEBUG_TYPE_OF(slot));
44    }
45 }
46
47 bool ___debug_type_is_enabled(Const_String type)
48 {
49    Vector *v = string_split(type, DEBUG_DELIMITER_STR);
50    String s;
51    bool valid = false;
52    VECTOR_FOR_EACH_ENTRY(v, s) {
53       if (hash_map_contains(&debug_hmap, s, string_hash_code(s))) {
54          valid = true;
55          break;
56       }
57    }
58    vector_destroy(v, (Vector_Destructor)string_destroy);
59    return valid;
60 }
61
62 void ___debug_log_enabled_types()
63 {
64    Hash_Map_Slot *s;
65    HASH_MAP_FOR_EACH(&debug_hmap, s)
66       DLOGT(DEBUG_DEFAULT, "DEBUG TYPE ENABLED: %S\n",
67             DEBUG_TYPE_OF(s)->type);
68 }
69
70 static void debug_insert_values() CONSTRUCTOR;
71 static void debug_insert_values()
72 {
73    Vector *v;
74    String s;
75    char *debug_types = getenv(DEBUG_ENVIRON_CSTR);
76    if (debug_types) {
77       v = string_split(S(debug_types), DEBUG_DELIMITER_STR);
78       VECTOR_FOR_EACH_ENTRY(v, s)
79          ___debug_enable_type(s);
80       vector_destroy(v, (Vector_Destructor)string_destroy);
81    }
82    ___debug_enable_type(DEBUG_DEFAULT_STR);
83 }
84
85 static void debug_destructor(Hash_Map_Slot *slot)
86 {
87    Debug_Type *t = DEBUG_TYPE_OF(slot);
88    string_destroy(t->type);
89    free_mem(t);
90 }
91
92 static void debug_shutdown() DESTRUCTOR;
93 static void debug_shutdown()
94 {
95    hash_map_for_each_destroy(&debug_hmap, debug_destructor);
96 }
97
```

```
98 #endif // NDEBUG
```

:

A.10.5 src/debug.h

```
1  #ifndef DEBUG_H
2  #define DEBUG_H
3
4  #include <io.h>
5
6  #define DEBUG_DEFAULT def
7
8  #ifndef DEBUG_TYPE
9  #define DEBUG_TYPE DEBUG_DEFAULT
10 #endif
11
12 #define DEBUG_DEFAULT_STR STRINGIFY(DEBUG_DEFAULT)
13 #define DEBUG_DELIMITER_STR S(":")
14 #define DEBUG_ENVIRON_CSTR "DEBUG"
15
16 #ifndef NDEBUG
17
18 void ___debug_enable_type(Const_String type);
19
20 void ___debug_disable_type(Const_String type);
21
22 bool ___debug_type_is_enabled(Const_String type);
23
24 void ___debug_log_enabled_types();
25
26 #define DEBUGT(type, statements)                    \
27    do {                                             \
28       if (___debug_type_is_enabled(STRINGIFY(type))) {   \
29          statements;                                \
30       }                                             \
31    } while (0)
32
33 #define DEBUG(statements) DEBUGT(DEBUG_TYPE, statements)
34
35 #define DLOGT(type, fmt, ...) \
36    DEBUGT(type, file_print_message(stderr, S(fmt), ## __VA_ARGS__);)
37
38 #define DLOG(fmt, ...) \
39    DEBUG(file_print_message(stderr, S(fmt), ## __VA_ARGS__);)
40
41 /* Print enabled debugging types to stderr. */
42 #define DEBUG_PRINT_TYPES() ___debug_log_enabled_types()
43
44 #if 0
45 #define DEBUG_ENABLE(type) ___debug_enable_type(STRINGIFY(type))
46 #define DEBUG_DISABLE(type) ___debug_disable_type(STRINGIFY(type))
47 #endif
48
49 #else
50
51 #define DEBUGT(type, statements) do {} while (0)
52 #define DEBUG(statements)   do {} while (0)
53 #define DLOGT(type, fmt, ...)  do {} while (0)
54 #define DLOG(fmt, ...)     do {} while (0)
55 #define DEBUG_PRINT_TYPES()   do {} while (0)
56 #if 0
57 #define DEBUG_ENABLE(type)   do {} while (0)
58 #define DEBUG_DISABLE(type)   do {} while (0)
59 #endif
60
61 #endif // NDEBUG
62
63 #endif // DEBUG_H
```

:

A.10.6 src/dot_printer.c

```
1  #include <dot_printer.h>
2  #include <alloc.h>
3
4  Dot_Printer *dot_printer_init(Const_String file_name_prefix,
5       Const_String file_name_suffix, Const_String rank_dir)
6  {
7     String file_name = string_from_format(S("%S.%S.dot"),
8           file_name_prefix, file_name_suffix);
9
10    Dot_Printer *dot_printer = ALLOC_NEW(Dot_Printer);
11    dot_printer->output_file = file_open(file_name, S("w"));
12    dot_printer->id_stack = SINGLE_LIST_INIT();
13    dot_printer->file_name_prefix = file_name_prefix;
14    dot_printer->file_name_suffix = file_name_suffix;
15
16    if (!dot_printer->output_file)
17       fatal_error(S("unable to open file '%S' for graph dump\n"),
18             file_name);
19    string_destroy(file_name);
20    file_print_message(dot_printer->output_file,
21          S("strict digraph {\n\trankdir=%S;\n"), rank_dir);
22
23    dot_printer_push_id(dot_printer, (void *) 0);
24    return dot_printer;
25 }
26
27 void stack_destructor(Single_List_Node *node)
28 {
29    free_mem(CONTAINER_OF(node, Dot_Printer_Id_Stack_Node, list_node));
30 }
31
32 void dot_printer_destroy(Dot_Printer *dot_printer)
33 {
34    single_list_for_each_destroy(&dot_printer->id_stack, stack_destructor);
35    free_mem(dot_printer);
36 }
37
38 void dot_printer_fin_com_des(Dot_Printer *p, Const_String type)
39 {
40    dot_printer_finalize(p);
41    dot_printer_compile(p, type);
42    dot_printer_destroy(p);
43 }
44
45 void dot_printer_push_id(Dot_Printer *dot_printer, void *id)
46 {
47    Dot_Printer_Id_Stack_Node *node = ALLOC_NEW(Dot_Printer_Id_Stack_Node);
48    node->id = id;
49    void *from = dot_printer_peek_current_id(dot_printer);
50    if (id && from)
51       dot_printer_insert_relation(dot_printer, from, id);
52    single_list_prepend(&dot_printer->id_stack, &node->list_node);
53 }
54
55 void *dot_printer_pop_current_id(Dot_Printer *dot_printer)
56 {
57    void * ret = NULL;
58    Single_List_Node *node = single_list_pop_first(&dot_printer->id_stack);
59    if (node) {
60       Dot_Printer_Id_Stack_Node *stack_node =
61          SINGLE_LIST_ENTRY(node, Dot_Printer_Id_Stack_Node, list_node);
62       ret = stack_node->id;
63       free_mem(stack_node);
64    }
65    return ret;
66 }
67
68 void *dot_printer_peek_current_id(Dot_Printer *dot_printer)
```

```
69  {
70     void * ret = NULL;
71     Single_List_Node *node = single_list_peek_first(&dot_printer->id_stack);
72     if (node) {
73        Dot_Printer_Id_Stack_Node *stack_node =
74           SINGLE_LIST_ENTRY(node, Dot_Printer_Id_Stack_Node, list_node);
75        ret = stack_node->id;
76     }
77     return ret;
78  }
79
80  void dot_printer_begin_table(Dot_Printer *p, void *id, int c)
81  {
82     p->current_table_size = c;
83     file_print_message(p->output_file,
84           S("\t%lu[label="
85              "<<table BORDER=\"0\" CELLBORDER=\"1\" CELLSPACING=\"0\">\n"),
86           (long unsigned) id);
87  }
88
89  void dot_printer_insert_row(Dot_Printer *p, int c, ...)
90  {
91     Const_String cell;
92     String tmp_str;
93
94     if (c-p->current_table_size > 0)
95        c = p->current_table_size;
96
97     String_Builder sb = STRING_BUILDER_INIT();
98
99     string_builder_append(&sb, S("\t\t<tr>"));
100
101    VA_SETUP(vl, c);
102    for ( ; (cell = va_arg(vl, Const_String)) && c--; ) {
103       tmp_str = string_from_format(S("<td>%S</td>"), cell);
104       string_builder_append(&sb, tmp_str);
105       string_destroy(tmp_str);
106    }
107    VA_END(vl);
108
109    string_builder_append(&sb, S("</tr>\n"));
110
111    file_print_message(p->output_file, string_builder_const_str(&sb));
112
113    string_builder_clear(&sb);
114 }
115
116 void dot_printer_insert_merge_row(Dot_Printer *p, Const_String header)
117 {
118    file_print_message(p->output_file,
119          S("\t\t<tr><td BGCOLOR=\"gray\" COLSPAN=\"%U\">%S</td></tr>\n"),
120          p->current_table_size, header);
121 }
122
123
124 void dot_printer_end_table(Dot_Printer *p)
125 {
126    file_print_message(p->output_file, S("\t</table>> shape=plaintext]\n"));
127 }
128
129 void dot_printer_compile(Dot_Printer *p, Const_String type)
130 {
131    String cmd = string_from_format(
132          S("dot -T%S %2$S.%3$S.dot -o %2$S.%3$S.pdf"),
133             type, p->file_name_prefix, p->file_name_suffix);
134
135    //TODO handle error
136    int ret = system(string_to_cstr(cmd));
137    if(ret == -1){
138       report_error(p->file_name_prefix, S("Call to system() failed!\n"));
139    } else if (WEXITSTATUS(ret)){
140       report_error(p->file_name_prefix, S("Call to dot returned: %d\n"),
141             WEXITSTATUS(ret));
142    }
```

```
143
144     string_destroy(cmd);
145 }
```

:

A.10.7 src/dot_printer.h

```
1   #ifndef DOT_PRINTER_H
2   #define DOT_PRINTER_H
3
4   #include <single_list.h>
5   #include <std_include.h>
6   #include <alloc.h>
7   #include <string_builder.h>
8   #include <sys/wait.h>
9
10  typedef struct Dot_Printer_Id_Stack_Node {
11     Single_List_Node list_node;
12     void *id;
13  } Dot_Printer_Id_Stack_Node;
14
15  typedef struct Dot_Printer {
16     Single_List id_stack;
17     FILE *output_file;
18     Const_String file_name_prefix;
19     Const_String file_name_suffix;
20     Uns current_table_size;
21  } Dot_Printer;
22
23  /* Allocates and initializes a new dot_printer.
24   *
25   * file_name_prefix specifies the prefix of the filename, to which the output
26   * will be written. The new file created will have the name
27   * file_name_prefix.graph.dot
28   *
29   * rank_dir specifies the direction of the graph created. This should be
30   * either "LR", "RL", "TB" or "BT". For directions left-rigth, right-left,
31   * top-bottom and bottom-top. */
32  Dot_Printer *dot_printer_init(Const_String file_name_prefix,
33        Const_String file_name_suffix,
34        Const_String rank_dir);
35
36  /* Destroys and deallocate a Dot_Printer previously created with
37   * dot_printer_init.
38   *
39   * This function also finishes up the .graph.dot file, so that it is ready for
40   * compilation. */
41  void dot_printer_compile_destroy(Dot_Printer *dot_printer);
42
43  /* Used to enter a new scope, with the scopes parent beeing id. */
44  void dot_printer_push_id(Dot_Printer *dot_printer, void * id);
45
46  /* Used to leave current scope. */
47  void *dot_printer_pop_current_id(Dot_Printer *dot_printer);
48
49  /* Used to identify the currents scope's parent. */
50  void *dot_printer_peek_current_id(Dot_Printer *dot_printer);
51
52  /* Inserts a new node which is identified by id.
53   *
54   * label specifies how the node is reprensented on the final graph. */
55  inline static void dot_printer_insert_node(Dot_Printer *dot_printer,
56        void *id, Const_String label)
57  {
58     file_print_message(dot_printer->output_file,
59           S("\t%lu[label=\"%S\" shape=box];\n"), (long unsigned)id, label);
60  }
61
62  /* Inserts a new node into the graph as a child to the current scope, also
63   * enters a new scope. So that nodes that are inserted, before
```

```
64  * dot_printer_pop_current_id() is called, are added as children
65  * of this node. */
66 inline static void dot_printer_push_insert(Dot_Printer *p, void *id,
67       Const_String str)
68 {
69    dot_printer_push_id(p, id);
70    dot_printer_insert_node(p, id, str);
71 }
72
73 /* Insert a relation from node with id1 to another node identified by id2.
74  *
75  * If id1 and id2 does not exist as nodes in the graph, arbitrary nodes will
76  * be inserted so that the relation holds. (Functionality of dot). */
77 inline static void dot_printer_insert_relation(Dot_Printer *dot_printer,
78       void *id1, void *id2)
79 {
80    if(id1 && id2)
81       file_print_message(dot_printer->output_file,
82             S("\t%lu -> %lu;\n"),
83             (long unsigned) id1,
84             (long unsigned) id2);
85 }
86
87 /* Finalizes and closes the output file. */
88 inline static void dot_printer_finalize(Dot_Printer *p)
89 {
90    file_print_message(p->output_file, S("}"));
91    file_close(p->output_file);
92 }
93
94 /* Compiles the .dot file associated with the Dot_Printer using Graphviz Dot.
95  *
96  * type specifies the filetype which to compile to. Normally "pdf", see man
97  * pages for dot for more valid types. */
98 void dot_printer_compile(Dot_Printer *p, Const_String type);
99
100 /* Used to finalize, then compile and finally destroy the Dot_Printer pointed
101  * to by p. */
102 void dot_printer_fin_com_des(Dot_Printer *p, Const_String type);
103
104 /*************************** HANDLE TABLE NODES ***************************/
105
106 /* Begin a new table node, with id=id and c columns.
107  * Note that this also creates a new scope, until dot_printer_pop_current_id()
108  * is called.
109  *
110  * Must be followed by dot_printer_end_table(), only dot_printer_insert_row()
111  * or dot_printer_insert_merge_row() are allowed in between. */
112 void dot_printer_begin_table(Dot_Printer *p, void *id, int c);
113
114 inline static void dot_printer_push_begin_table(Dot_Printer *p,
115       void *id, int c)
116 {
117    dot_printer_push_id(p, id);
118    dot_printer_begin_table(p, id, c);
119 }
120
121 /* Inserts a row in the current table, containing c columns.
122  *
123  * Note if c is larger than the current table size, only the table size first
124  * columns are inserted. */
125 void dot_printer_insert_row(Dot_Printer *p, int c, ...);
126
127 /* Inserts a row in the current table, where all cells are merged together.
128  * Usefull for adding section headers in the table. */
129 void dot_printer_insert_merge_row(Dot_Printer *p, Const_String header);
130
131 /* Finishes up the current table. After this, other nodes can be inserted.
132  *
133  * If this function isn't called at somepoint after dot_printer_begin_table(),
134  * the ouput file might be corrupted. */
135 void dot_printer_end_table(Dot_Printer *p);
136
137 #endif
```

:

A.10.8 src/double_list.c

```
1  // #include <double_list.h>
```

:

A.10.9 src/double_list.h

```
1  #ifndef DOUBLE_LIST_H
2  #define DOUBLE_LIST_H
3
4  #include <std_define.h>
5
6  typedef struct Double_List_Node Double_List_Node;
7
8  struct Double_List_Node {
9     Double_List_Node *prev;
10    Double_List_Node *next;
11 };
12
13 typedef Double_List_Node Double_List;
14
15 #define DOUBLE_LIST_STATIC_INIT(list) {  \
16    .prev = (Double_List_Node *)&(list), \
17    .next = (Double_List_Node *)&(list)  \
18 }
19
20 #define DOUBLE_LIST_INIT(list) \
21    ((Double_List)DOUBLE_LIST_STATIC_INIT(list))
22
23 #define DOUBLE_LIST(list) Double_List list = DOUBLE_LIST_STATIC_INIT(list)
24
25 #define DOUBLE_LIST_ENTRY(node_ptr, container_type, node_member_name) \
26    CONTAINER_OF(node_ptr, container_type, node_member_name)
27
28 static inline Double_List *double_list_alloc()
29 {
30    Double_List *list = ALLOC_NEW(Double_List);
31    *list = DOUBLE_LIST_INIT(*list);
32    return list;
33 }
34
35 static inline void double_list_insert(Double_List_Node *node,
36       Double_List_Node *prev, Double_List_Node *next)
37 {
38    next->prev = node;
39    node->next = next;
40    node->prev = prev;
41    prev->next = node;
42 }
43
44 static inline void double_list_append(Double_List *list,
45       Double_List_Node *node)
46 {
47    double_list_insert(node, list->prev, (void *)list);
48 }
49
50 static inline void double_list_prepend(Double_List *list,
51       Double_List_Node *node)
52 {
53    double_list_insert(node, (void *)list, list->next);
54 }
55
56 static inline bool double_list_is_empty(const Double_List *list)
57 {
58    return list->next == (void *)list;
```

```
59  }
60
61  static inline Double_List_Node *double_list_peek_last(Double_List *list)
62  {
63     if (!double_list_is_empty(list))
64        return list->prev;
65     return NULL;
66  }
67
68  static inline Double_List_Node *double_list_peek_first(Double_List *list)
69  {
70     if (!double_list_is_empty(list))
71        return list->next;
72     return NULL;
73  }
74
75  static inline void double_list_remove(Double_List_Node *node)
76  {
77     node->prev->next = node->next;
78     node->next->prev = node->prev;
79  }
80
81  static inline Double_List_Node *double_list_pop_last(Double_List *list)
82  {
83     Double_List_Node *node;
84     if (!double_list_is_empty(list)) {
85        node = list->prev;
86        double_list_remove(node);
87        return node;
88     }
89     return NULL;
90  }
91
92  static inline Double_List_Node *double_list_pop_first(Double_List *list)
93  {
94     Double_List_Node *node;
95     if (!double_list_is_empty(list)) {
96        node = list->next;
97        double_list_remove(node);
98        return node;
99     }
100    return NULL;
101 }
102
103 typedef void (*Double_List_Destructor)(Double_List_Node *node);
104
105 static inline void double_list_for_each_destroy(Double_List *list,
106       Double_List_Destructor destructor)
107 {
108    for (Double_List_Node *n = double_list_pop_first(list); n;
109          n = double_list_pop_last(list))
110       destructor(n);
111 }
112
113 /* Don't free elements from the list while iterating this loop.
114  * At least you need to break the loop right after. */
115 #define DOUBLE_LIST_FOR_EACH(list_ptr, node_ptr) \
116    for (node_ptr = (list_ptr)->next;    \
117          node_ptr != (void *)(list_ptr);   \
118          node_ptr = (node_ptr)->next)
119
120 /* Don't free elements from the list while iterating this loop.
121  * At least you need to break the loop right after. */
122 #define DOUBLE_LIST_FOR_EACH_REVERSED(list_ptr, node_ptr) \
123    for (node_ptr = (list_ptr)->prev;         \
124          node_ptr != (void *)(list_ptr);     \
125          node_ptr = (node_ptr)->prev)
126
127 /* Don't free elements from the list while iterating this loop.
128  * At least you need to break the loop right after. */
129 #define DOUBLE_LIST_FOR_EACH_AFTER(list_ptr, init_node, node_ptr) \
130    for (node_ptr = (init_node)->next;              \
131          node_ptr != (void *)(list_ptr);           \
132          node_ptr = (node_ptr)->next)
```

```
133
134 /* Don't free elements from the list while iterating this loop.
135  * At least you need to break the loop right after. */
136 #define DOUBLE_LIST_FOR_EACH_FROM(list_ptr, init_node, node_ptr) \
137    for (node_ptr = init_node;                                    \
138         node_ptr != (void *)(list_ptr);                          \
139         node_ptr = (node_ptr)->next)
140
141 #endif // DOUBLE_LIST_H
```

:

A.10.10 src/file_location.c

```
1 #include <str.h>
2
3 CONST_STRING(file_location_stdin_file_name, "stdin");
```

:

A.10.11 src/file_location.h

```
1  #ifndef FILE_LOCATION_H
2  #define FILE_LOCATION_H
3
4  #include <str.h>
5
6  typedef struct File_Location {
7     Const_String ___file_name;
8     Uns line;
9     Uns column;
10 } File_Location;
11
12 #define FILE_LOCATION_STATIC_INIT(fname, lineno, colno) { \
13    .___file_name = fname,                                  \
14    .line = lineno,                                         \
15    .column = colno                                         \
16 }
17
18 #define FILE_LOCATION_INIT(fname, lineno, colno) \
19    ((File_Location)FILE_LOCATION_STATIC_INIT(fname, lineno, colno))
20
21 static inline void file_location_set_file_name(File_Location *f,
22       Const_String file)
23 {
24    f->___file_name = file;
25 }
26
27 static inline Const_String file_location_get_file_name(const File_Location *f)
28 {
29    extern Const_String file_location_stdin_file_name;
30    (void)file_location_stdin_file_name;
31
32    Const_String ret;
33 #ifdef STDIN_INPUT_ENABLED
34    if (string_ends_with(f->___file_name, STDIN_FILE_SUFFIX_STR))
35       ret = file_location_stdin_file_name;
36    else
37       ret = f->___file_name;
38 #else
39    ret = f->___file_name;
40 #endif
41    return ret;
42 }
43
44 /* Compare two file locations based on line number and column number.
45  * Returns -1 if lhs < rhs,
```

```
 * returns 1 if lhs > rhs,
 * else returns 0. */
static inline Int file_location_cmp_lncol(File_Location *lhs,
      File_Location *rhs)
{
   if (lhs->line < rhs->line)
      return -1;
   if (rhs->line < lhs->line)
      return 1;
   if (lhs->column < rhs->column)
      return -1;
   if (rhs->column < lhs->column)
      return 1;
   return 0;
}

/* Compare two file locations based based on file name, line number
 * and column number.
 * Returns -1 if lhs < rhs,
 * returns 1 if lhs > rhs,
 * else returns 0. */
static inline Int file_location_cmp(File_Location *lhs, File_Location *rhs)
{
   Int res = string_compare(file_location_get_file_name(lhs),
         file_location_get_file_name(rhs));
   if (res)
      return res;
   return file_location_cmp_lncol(lhs, rhs);
}

#endif // FILE_LOCATION_H
```

:

A.10.12 src/hash_map.c

```
#include <hash_map.h>
#include <std_include.h>

const Uns HASH_MAP_PRIME_LIST[HASH_MAP_PRIME_LIST_SIZE] = {
   2,
   5,
   11,
   23,
   47,
   97,
   197,
   397,
   797,
   1597,
   3203,
   6421,
   12853,
   25717,
   51437,
   102877,
   205759,
   411527,
   823117,
   1646237,
   3292489,
   6584983,
   13169977,
   26339969,
   52679969,
   105359939,
   210719881,
   421439783,
   842879579
};

```

```
36  static inline Uns hash_map_get_hash_idx(Hash_Map *map, Uns hash_code)
37  {
38     return hash_code % map->num_slots;
39  }
40
41  static inline void hash_map_slot_set_hash_code(Hash_Map_Slot *slot,
42        Uns hash_code)
43  {
44     slot->hash_code = hash_code;
45  }
46
47  static inline void hash_map_hash(Hash_Map *map, Hash_Map_Slot *slot)
48  {
49     Uns idx = hash_map_get_hash_idx(map, slot->hash_code);
50     single_list_prepend(&map->slots[idx], &slot->neighbor);
51  }
52
53  static void hash_map_rehash(Hash_Map *map, Uns new_size_idx)
54  {
55     Single_List *prev_slots;
56     Single_List *current;
57     Single_List_Node *node;
58     Uns prev_num_slots;
59
60     prev_slots = map->slots;
61     prev_num_slots = map->num_slots;
62     map->num_slots = HASH_MAP_PRIME_LIST[new_size_idx];
63     map->slots = alloc_zeros(sizeof(Single_List) * map->num_slots);
64     map->size_idx = new_size_idx;
65
66     if (prev_slots) {
67        for (Uns idx = 0; idx < prev_num_slots; idx++) {
68           current = &prev_slots[idx];
69           while ((node = single_list_pop_first(current)))
70              hash_map_hash(map, HASH_MAP_SLOT_OF(node));
71        }
72        free_mem(prev_slots);
73     } else {
74        map->num_elements = 0;
75     }
76  }
77
78  void hash_map_insert(Hash_Map *map, Hash_Map_Slot *slot, Uns hash_code)
79  {
80     if ((float)map->num_elements / map->num_slots >=
81           HASH_MAP_MAX_LOAD_FACTOR &&
82           map->size_idx < HASH_MAP_PRIME_LIST_SIZE) {
83        hash_map_rehash(map, map->size_idx + 1);
84     }
85     hash_map_slot_set_hash_code(slot, hash_code);
86     hash_map_hash(map, slot);
87     ++map->num_elements;
88  }
89
90  bool hash_map_contains(Hash_Map *map, void *search_obj,
91        Uns search_hash_code)
92  {
93     if (!map->slots)
94        return false;
95
96     Single_List_Node *n;
97     Uns idx = hash_map_get_hash_idx(map, search_hash_code);
98     Single_List *bucket = &map->slots[idx];
99     SINGLE_LIST_FOR_EACH(bucket, n)
100       if (map->comparator(search_obj, HASH_MAP_SLOT_OF(n)))
101          return true;
102
103    return false;
104 }
105
106 Hash_Map_Slot *hash_map_get(Hash_Map *map, void *search_obj,
107       Uns search_hash_code)
108 {
109    if (!map->slots)
```

```
110         return NULL;
111
112      Uns idx = hash_map_get_hash_idx(map, search_hash_code);
113      Hash_Map_Slot *slot;
114      Single_List *bucket = &map->slots[idx];
115      Single_List_Node *n;
116
117      SINGLE_LIST_FOR_EACH(bucket, n) {
118         slot = HASH_MAP_SLOT_OF(n);
119         if (map->comparator(search_obj, slot))
120            return slot;
121      }
122
123      return NULL;
124   }
125
126   Hash_Map_Slot *hash_map_remove(Hash_Map *map, void *search_obj,
127         Uns search_hash_code)
128   {
129      if (!map->slots)
130         return NULL;
131
132      Uns idx = hash_map_get_hash_idx(map, search_hash_code);
133      Hash_Map_Slot *slot;
134      Single_List *bucket = &map->slots[idx];
135      Single_List_Node *n, *prev = NULL;
136
137      SINGLE_LIST_FOR_EACH(bucket, n) {
138         slot = HASH_MAP_SLOT_OF(n);
139         if (map->comparator(search_obj, slot)) {
140            single_list_remove(bucket, n, prev);
141            --map->num_elements;
142
143            if ((float)map->num_elements / map->num_slots <
144                  HASH_MAP_MIN_LOAD_FACTOR &&
145                  map->size_idx > map->initial_size) {
146               hash_map_rehash(map, map->size_idx - 1);
147            }
148
149            return slot;
150         }
151         prev = n;
152      }
153
154      return NULL;
155   }
156
157   void hash_map_for_each_destroy(Hash_Map *map, Hash_Map_Destructor destructor)
158   {
159      void single_destructor(Single_List_Node *node)
160      {
161         destructor(HASH_MAP_SLOT_OF(node));
162      }
163
164      if (!map->slots)
165         return;
166
167      Single_List *bucket;
168      Uns num_slots = map->num_slots;
169      for (Uns i = 0; i < num_slots; i++) {
170         bucket = &map->slots[i];
171         single_list_for_each_destroy(bucket, single_destructor);
172      }
173
174      hash_map_clear(map);
175   }
```

:

A.10.13 src/hash_map.h

```
1  #ifndef HASH_MAP_H
2  #define HASH_MAP_H
3
4  #include <std_define.h>
5  #include <single_list.h>
6  #include <alloc.h>
7
8  /* XXX Don't use debug macros to debug hash map implementation since the
9   * debug implementation uses hash map. */
10
11 typedef enum Hash_Map_Size {
12    HASH_MAP_SIZE_2,
13    HASH_MAP_SIZE_5,
14    HASH_MAP_SIZE_11,
15    HASH_MAP_SIZE_23,
16    HASH_MAP_SIZE_47,
17    HASH_MAP_SIZE_97,
18    HASH_MAP_SIZE_197,
19    HASH_MAP_SIZE_397,
20    HASH_MAP_SIZE_797,
21    HASH_MAP_SIZE_1_597,
22    HASH_MAP_SIZE_3_203,
23    HASH_MAP_SIZE_6_421,
24    HASH_MAP_SIZE_12_853,
25    HASH_MAP_SIZE_25_717,
26    HASH_MAP_SIZE_51_437,
27    HASH_MAP_SIZE_102_877,
28    HASH_MAP_SIZE_205_759,
29    HASH_MAP_SIZE_411_527,
30    HASH_MAP_SIZE_823_117,
31    HASH_MAP_SIZE_1_646_237,
32    HASH_MAP_SIZE_3_292_489,
33    HASH_MAP_SIZE_6_584_983,
34    HASH_MAP_SIZE_13_169_977,
35    HASH_MAP_SIZE_26_339_969,
36    HASH_MAP_SIZE_52_679_969,
37    HASH_MAP_SIZE_105_359_939,
38    HASH_MAP_SIZE_210_719_881,
39    HASH_MAP_SIZE_421_439_783,
40    HASH_MAP_SIZE_842_879_579
41 } Hash_Map_Size;
42
43 #define HASH_MAP_PRIME_LIST_SIZE (HASH_MAP_SIZE_842_879_579 + 1)
44
45 #define HASH_MAP_MAX_LOAD_FACTOR 0.75f
46
47 #define HASH_MAP_MIN_LOAD_FACTOR (HASH_MAP_MAX_LOAD_FACTOR / 4.0f)
48
49 extern const Uns HASH_MAP_PRIME_LIST[HASH_MAP_PRIME_LIST_SIZE];
50
51 typedef struct Hash_Map_Slot {
52    Single_List_Node neighbor;
53    Uns hash_code;
54 } Hash_Map_Slot;
55
56 static inline Uns hash_map_slot_get_hash_code(Hash_Map_Slot *s)
57 {
58    return s->hash_code;
59 }
60
61 #define HASH_MAP_SLOT_OF(list_node) \
62    SINGLE_LIST_ENTRY(list_node, Hash_Map_Slot, neighbor)
63
64 /* Compare search_obj with tree_node in some specified way.
65  * Return true if search_obj == tree_node.
66  * Otherwise return false. */
67 typedef bool (*Hash_Map_Comparator)(void *search_obj,
68       Hash_Map_Slot *map_slot);
69
70 typedef struct Hash_Map {
71    Single_List *slots;
72    Hash_Map_Comparator comparator;
73    Int size_idx;
```

```
74     Int initial_size;
75     Uns num_slots;
76     Uns num_elements;
77  } Hash_Map;
78
79  #define HASH_MAP_DEFAULT_SIZE HASH_MAP_SIZE_197
80
81  #define INITIAL_NUM_SLOTS 1
82  #define INITIAL_NUM_ELEMENTS INITIAL_NUM_SLOTS
83
84  #define HASH_MAP_GET_INIT_SIZE_IDX(idx) (idx - 1)
85
86  #define HASH_MAP_STATIC_INIT_SIZE(size_index, comp_fun) { \
87     .slots = NULL,                              \
88     .comparator = comp_fun,                     \
89     .size_idx = HASH_MAP_GET_INIT_SIZE_IDX(size_index),  \
90     .initial_size = size_index,                 \
91     .num_slots = INITIAL_NUM_SLOTS,             \
92     .num_elements = INITIAL_NUM_ELEMENTS        \
93  }
94
95  #define HASH_MAP_STATIC_INIT(comp_fun) \
96     HASH_MAP_STATIC_INIT_SIZE(HASH_MAP_DEFAULT_SIZE, comp_fun)
97
98  #define HASH_MAP_INIT(comp_fun) \
99     ((Hash_Map)HASH_MAP_STATIC_INIT(comp_fun))
100
101 #define HASH_MAP_INIT_SIZE(size_index, comp_fun) \
102    ((Hash_Map)HASH_MAP_STATIC_INIT_SIZE(size_index, comp_fun))
103
104 #define HASH_MAP(hmname, comp_fun) \
105    Hash_Map hmname = HASH_MAP_STATIC_INIT(comp_fun)
106
107 #define HASH_MAP_SIZE(hmname, size_index, comp_fun) \
108    Hash_Map hmname = HASH_MAP_STATIC_INIT_SIZE(size_index, comp_fun)
109
110 #define HASH_MAP_ENTRY(slot, type_name, field_name) \
111    CONTAINER_OF(slot, type_name, field_name)
112
113 /* Insert a slot into the hash map.
114  * This is a multi map, so you can insert multiple slots
115  * with the same value. */
116 void hash_map_insert(Hash_Map *map, Hash_Map_Slot *slot, Uns hash_code);
117
118 bool hash_map_contains(Hash_Map *map, void *search_obj,
119       Uns search_hash_code);
120
121 /* Uses Hash_Map_Comparator to compare search_obj with slots.
122  * If Hash_Map_Comparator return 0 for some slot then remove the
123  * slot and return the slot else no slot is removed and returns NULL. */
124 Hash_Map_Slot *hash_map_remove(Hash_Map *map, void *search_obj,
125       Uns search_hash_code);
126
127 /* Uses Hash_Map_Comparator to compare search_obj with slots.
128  * If Hash_Map_Comparator return 0 for some slot then
129  * return the slot else returns NULL. */
130 Hash_Map_Slot *hash_map_get(Hash_Map *map, void *search_obj,
131       Uns search_hash_code);
132
133 typedef void (*Hash_Map_Destructor)(Hash_Map_Slot *slot);
134
135 /* Free memory allocated by the hash map.
136  * See hash_map_for_each_destroy(). */
137 static inline void hash_map_clear(Hash_Map *map)
138 {
139    free_mem(map->slots);
140    map->slots = NULL;
141    map->num_slots = INITIAL_NUM_SLOTS;
142    map->num_elements = INITIAL_NUM_ELEMENTS;
143    map->size_idx = HASH_MAP_GET_INIT_SIZE_IDX(map->initial_size);
144 }
145
146 /* Free memory allocated by the hash map and
147  * call destructor with each slot in the map to free the slot containers. */
```

```
148 void hash_map_for_each_destroy(Hash_Map *map, Hash_Map_Destructor destructor);
149
150 static inline Uns hash_map_size(Hash_Map *map)
151 {
152    return map->slots ? map->num_elements : 0;
153 }
154
155 // XXX - Use goto to break this loop.
156 #define HASH_MAP_FOR_EACH(map, slot)                        \
157    if ((map)->slots)                                        \
158       for (Single_List_Node *___n, *___i = 0;               \
159             PTR_TO_UINT(___i) < (map)->num_slots;           \
160             ___i = INT_TO_PTR(PTR_TO_UINT(___i) + 1))       \
161          SINGLE_LIST_FOR_EACH(&(map)->slots[PTR_TO_UINT(___i)], ___n) \
162             if ((slot = HASH_MAP_SLOT_OF(___n)) || !slot)
163
164 /* Get hash code of pointer which is sizeof(void *) aligned. */
165 static inline Uns hash_map_aligned_ptr_hash(void *p)
166 {
167 #if PTR_SIZE == 8
168 # define ___HASH_SHIFT 3
169 #elif PTR_SIZE == 4
170 # define ___HASH_SHIFT 2
171 #else
172 # define ___HASH_SHIFT 1
173 #endif
174    return (Uns)(PTR_TO_INT(p) >> ___HASH_SHIFT);
175 #undef ___HASH_SHIFT
176 }
177
178 #endif // HASH_MAP_H
```

:

A.10.14 src/help_msg.c

```
1  #include <str.h>
2
3  CONST_STRING(help_msg,
4  #ifdef STDIN_INPUT_ENABLED
5  "Usage: %S [OPTION]... [FILE]...\n"
6  #else
7  "Usage: %S [OPTION]... FILE...\n"
8  #endif
9  "  OPTION\n"
10 "    --help (-h)\n"
11 "      display this message\n"
12 "    --help=optimize\n"
13 "      display information about optimization options\n"
14 "    --help=warning\n"
15 "      display information about warning options\n"
16 "    --help=dump\n"
17 "      display information about options for dumping internal\n"
18 "      data structures\n"
19 "\n"
20 "    --output=OUTFILE (-o OUTFILE)\n"
21 "      write output to OUTFILE\n"
22 "    --main (-m)\n"
23 "      insert code that calls function main when linking program\n"
24 "    --ign-main\n"
25 "      ignore the --main (-m) option\n"
26 "    --lib-init\n"
27 "      put code in the global scope into an initialization section\n"
28 "      executed before the normal initialization section\n"
29 "    --ign-lib-init\n"
30 "      ignore the --lib-init option\n"
31 "    --thread\n"
32 "      include support for libvitaly threads\n"
33 "    --ign-thread\n"
34 "      ignore the --thread option\n"
35 "    --no-libvit (-x)\n"
```

```
36  "    do not link with libvitaly (standard library becomes inaccessible)\n"
37  "   --ign-no-libvit\n"
38  "    ignore the --no-libvit (-x) option\n"
39  "   --lib-path=PATH (-L PATH)\n"
40  "    add PATH to the list of paths with library files\n"
41  "   --lib=LIB (-l LIB)\n"
42  "    link against library LIB accessible though one of the library\n"
43  "    search paths\n"
44  "   --import-path=PATH (-i PATH)\n"
45  "    add PATH to the list of paths searched when looking for import files\n"
46  "   --max-msg=n\n"
47  "    do not produce more than n error and warning messages\n"
48  "   --stubborn\n"
49  "    keep compiling new input source files, even when errors are detected\n"
50  "   --ign-stubborn\n"
51  "    ignore the --stubborn option\n"
52  "   --compile-only (-c)\n"
53  "    assemble, compile and keep object files, but do not link\n"
54  "   --ign-compile-only\n"
55  "    ignore the --compile-only (-c) option\n"
56  "   --asm-only (-s)\n"
57  "    produce assembly output, do not compile or link\n"
58  "   --ign-asm-only\n"
59  "    ignore the --asm-only (-s) option\n"
60  "   --keep-obj (-k)\n"
61  "    keep generated object files\n"
62  "   --ign-keep-obj\n"
63  "    ignore the --keep-obj (-k) option\n"
64  "   --verbose (-v)\n"
65  "    print verbose output to standard output\n"
66  "   --ign-verbose\n"
67  "    ignore the --verbose (-v) option\n"
68  "   --recursive (-r)\n"
69  "    recursive compilation, automatically compile imported files\n"
70  "   --ign-recirsive\n"
71  "    ignore the --recursive (-r) option\n"
72  "   --gen-viti (-I)\n"
73  "    generate a .viti file used as import file instead of the\n"
74  "    corresponding .vit file\n"
75  "   --ign-gen-viti\n"
76  "    ignore the --gen-viti (-I) option\n"
77  );
78
79  CONST_STRING(dump_help_msg,
80  "Options for dumping internal data structures\n"
81  "  --dump=OPTION[,OPTION]...\n"
82  "   OPTION\n"
83  "    parse-tree\n"
84  "     dump XML parse tree\n"
85  "    parse-tree-graph\n"
86  "     dump PDF parse tree\n"
87  "    symbol-table\n"
88  "     dump ACSII symbol table\n"
89  "    symbol-table-graph\n"
90  "     dump PDF symbol table\n"
91  "    init-ic\n"
92  "     dump initial intermediate code representation\n"
93  "    norm-addr-ic\n"
94  "     dump intermediate code representation right after initial\n"
95  "     normalization of addressing instructions\n"
96  "    const-prop-ic\n"
97  "     dump intermediate code after each constant propagation pass\n"
98  "    instr-elim-ic\n"
99  "     dump intermediate code after dead instruction elimination passes\n"
100 "    def-to-use-ic\n"
101 "     dump intermediate code after def-to-use optimization pass\n"
102 "    norm-x86-32-ic\n"
103 "     dump intermediate code after instructions have been converted to\n"
104 "     x86-32 compatible instructions\n"
105 "    unused-mov-ic\n"
106 "     dump intermediate code after elimination of unused mov instructions\n"
107 "    reg-alloc-x86-32-ic\n"
108 "     dump intermediate code right after register allocation\n"
109 "    reg-vars-liveness-ic\n"
```

```
110 "      dump liveness analysis before deciding which variables should\n"
111 "      stay in registers\n"
112 "    reg-vars-ic\n"
113 "      dump liveness analysis after register variables have been chosen\n"
114 "    init-liveness-x86-32-ic\n"
115 "      dump liveness analysis before register allocation\n"
116 "    liveness-x86-32-ic\n"
117 "      dump liveness analysis right before assigning pseudo registers to\n"
118 "      x86-32 registers\n"
119 "    reg-alloc-x86-32-ic\n"
120 "      dump intermediate code right after register allocation\n"
121 "    warn-uninit-liveness-ic\n"
122 "      dump liveness analysis before locating variables which might be\n"
123 "      uninitialized before use\n"
124 "    final-x86-32-ic\n"
125 "      dump final intermediate code representation before emitting\n"
126 "      machine code\n"
127 "    c-header\n"
128 "      dump C header file with vitaly record declarations as C structs\n"
129 "    asm\n"
130 "      dump assembly source file before assembling\n"
131 );
132
133 CONST_STRING(warn_help_msg,
134 "Options for enabling and disabling warnings\n"
135 " --warning=OPTION[,OPTION]... (-w OPTION[,OPTION]...)\n"
136 "   OPTION\n"
137 "    all\n"
138 "      enable all warning options\n"
139 "    ign-all\n"
140 "      disable all warning options\n"
141 "\n"
142 "    is-error\n"
143 "      treat warnings as errors\n"
144 "    ign-is-error\n"
145 "      ignore the is-error warning option\n"
146 "\n"
147 "    no-finalize\n"
148 "      show warning when extended records doesn't have a finalize function\n"
149 "    ign-no-finalize\n"
150 "      ignore the no-finalize warning option\n"
151 "    implicit-cast [enabled by default]\n"
152 "      give warning about implicit type casts\n"
153 "    ign-implicit-cast\n"
154 "      ignore the implicit-cast warning option\n"
155 "    ref-compare [enabled by default]\n"
156 "      give warning when comparing reference types\n"
157 "    ign-ref-compare\n"
158 "      ignore the ref-compare warning option\n"
159 "    overflow [enabled by default]\n"
160 "      give warning when overflow is detected\n"
161 "    ign-overflow\n"
162 "      ignore the overflow warning option\n"
163 "    div-zero [enabled by default]\n"
164 "      give warning when division by zero is detected\n"
165 "    ign-div-zero\n"
166 "      ignore the div-zero warning option\n"
167 "    uninitialized [enabled by default]\n"
168 "      give warning when variables might be uninitialized before use\n"
169 "    ign-unitialized\n"
170 "      ignore the unitialized warning option\n"
171 );
172
173 CONST_STRING(opt_help_msg,
174 "Options for enabling and disabling optimizations\n"
175 " --optimize=OPTION[,OPTION]... (-O OPTION[,OPTION]...)\n"
176 "   OPTION\n"
177 "    all [enabled by default]\n"
178 "      enable all optimizations\n"
179 "    ign-all\n"
180 "      disable all optimization options\n"
181 "\n"
182 "    const-prop [enabled by default]\n"
183 "      do constant propagation optimization\n"
```

```
"    ign-const-prop\n"
"      ignore the const-prop optimization option\n"
"    instr-elim [enabled by default]\n"
"      do instruction elimination optimization (dead code elimination)\n"
"    ign-instr-elim\n"
"      ignore the instr-elim optimization option\n"
"    unused-mov [enabled by default]\n"
"      try to minimize the number register to register mov instructions\n"
"    ign-unused-mov\n"
"      ignore the unused-mov optimization option\n"
"    unused-set [enabled by default]\n"
"      try to eliminate useless set instructions\n"
"    ign-unused-set\n"
"      ignore the unused-set optimization option\n"
"    reg-vars [enabled by default]\n"
"      try to keep variables in registers when possible\n"
"    ign-reg-vars\n"
"      ignore the reg-vars optimization option\n"
"    def-to-use [enabled by default]\n"
"      move definitions of variables closer to where they are used\n"
"    ign-def-to-use\n"
"      ignore the def-to-use optimization option\n"
"    func-access [enabled by default]\n"
"      detect information about which variables functions are using\n"
"    ign-func-access\n"
"      ignore the func-access optimization option\n"
);
```

:

A.10.15 src/help_msg.h

```
#ifndef HELP_MSG_H
#define HELP_MSG_H

#include <str.h>

extern Const_String help_msg;
extern Const_String dump_help_msg;
extern Const_String warn_help_msg;
extern Const_String opt_help_msg;

#endif // HELP_MSG_H
```

:

A.10.16 src/io.c

```
#include <printf.h>
#include <main.h>
#include <unistd.h>
#include <sys/stat.h>

static int string_printf_function(FILE *stream,
      const struct printf_info *info, const void *const *args)
{
   const Const_String s = *((const Const_String *)(args[0]));
   return fprintf(stream, "%*s",
         info->left ? -info->width : info->width,
         string_to_cstr(s));
}

static int string_printf_arginfo(const struct printf_info *info UNUSED,
      size_t n, int *argtypes, int *size UNUSED)
{
   if (n > 0)
      argtypes[0] = PA_POINTER;
```

```
20    return 1;
21 }
22
23 static int uns_printf_function(FILE *stream,
24       const struct printf_info *info, const void *const *args)
25 {
26    const Uns u = *((const Uns *)(args[0]));
27    return fprintf(stream, "%*" PRIu32,
28          info->left ? -info->width : info->width,
29          u);
30 }
31
32 static int uns_printf_arginfo(const struct printf_info *info UNUSED,
33       size_t n, int *argtypes, int *size UNUSED)
34 {
35    if (n > 0)
36       argtypes[0] = PA_INT;
37    return 1;
38 }
39
40 static int int_printf_function(FILE *stream,
41       const struct printf_info *info, const void *const *args)
42 {
43    const Int i = *((const Int *)(args[0]));
44    return fprintf(stream, "%*" PRId32,
45          info->left ? -info->width : info->width,
46          i);
47 }
48
49 static int int_printf_arginfo(const struct printf_info *info UNUSED,
50       size_t n, int *argtypes, int *size UNUSED)
51 {
52    if (n > 0)
53       argtypes[0] = PA_INT;
54    return 1;
55 }
56
57 static int file_location_printf_function(FILE *stream,
58       const struct printf_info *info, const void *const *args)
59 {
60    const File_Location *loc = *((const File_Location **)(args[0]));
61    const char *file_name = string_to_cstr(file_location_get_file_name(loc));
62    if (loc->line == 0 || loc->column == 0)
63       return fprintf(stream, "%*s",
64             info->left ? -info->width : info->width,
65             file_name);
66    else
67       return fprintf(stream, "%*s:%" PRIu32 ":%" PRIu32,
68             info->left ? -info->width : info->width,
69             file_name,
70             loc->line,
71             loc->column);
72 }
73
74 static int file_location_printf_arginfo(const struct printf_info *info UNUSED,
75       size_t n, int *argtypes, int *size UNUSED)
76 {
77    if (n > 0)
78       argtypes[0] = PA_POINTER;
79    return 1;
80 }
81
82 void io_handler_constructor() CONSTRUCTOR;
83 void io_handler_constructor()
84 {
85    register_printf_specifier(STRING_PRINTF_SPECIFIER, string_printf_function,
86          string_printf_arginfo);
87    register_printf_specifier(UNS_PRINTF_SPECIFIER, uns_printf_function,
88          uns_printf_arginfo);
89    register_printf_specifier(INT_PRINTF_SPECIFIER, int_printf_function,
90          int_printf_arginfo);
91    register_printf_specifier(FILE_LOCATION_PRINTF_SPECIFIER,
92          file_location_printf_function, file_location_printf_arginfo);
93 }
```

```
94
95
96  static const char FATAL_ERROR_PREFIX[] = "(fatal error) ";
97
98  /* Do not call any function that might call fatal_error() from fatal_error().
99   * The function will try to tell the user that something went wrong before
100  * quickly aborting. */
101 void fatal_error(Const_String format, ...)
102 {
103    VA_SETUP(vl, format);
104    if (fprintf(stderr, "%s: %s",
105             string_to_cstr(cmdopts.vitaly_program_name),
106             FATAL_ERROR_PREFIX) < 0 ||
107          vfprintf(stderr, string_to_cstr(format), vl) < 0) {
108       printf("\n");
109       printf("%s: %s",
110             string_to_cstr(cmdopts.vitaly_program_name),
111             FATAL_ERROR_PREFIX);
112       vprintf(string_to_cstr(format), vl);
113    }
114    VA_END(vl);
115    exit_failure();
116 }
117
118 void print_vamessage(Const_String format, va_list vl)
119 {
120    if (vprintf(string_to_cstr(format), vl) < 0)
121       fatal_error(S("was unable to print to stdout\n"));
122 }
123
124 void print_message(Const_String format, ...)
125 {
126    VA_SETUP(vl, format);
127    print_vamessage(format, vl);
128    VA_END(vl);
129 }
130
131 void file_print_vamessage(FILE *stream, Const_String format, va_list vl)
132 {
133    if (vfprintf(stream, string_to_cstr(format), vl) < 0)
134       fatal_error(S("was unable to print to file stream\n"));
135 }
136
137 void file_print_message(FILE *stream, Const_String format, ...)
138 {
139    VA_SETUP(vl, format);
140    file_print_vamessage(stream, format, vl);
141    VA_END(vl);
142 }
143
144 void print_error(Const_String format, ...)
145 {
146    VA_SETUP(vl, format);
147    String new_fmt = string_from_format(S("%S: %S"),
148          cmdopts.vitaly_program_name, format);
149    file_print_vamessage(stderr, new_fmt, vl);
150    string_destroy(new_fmt);
151    VA_END(vl);
152 }
153
154 time_t file_get_mtime(Const_String fname)
155 {
156    struct stat buf;
157    if (stat(string_to_cstr(fname), &buf)) {
158       return (time_t) -1;
159    }
160    return buf.st_mtime;
161 }
162
163 bool file_access(Const_String fname, int mode)
164 {
165    return !access(string_to_cstr(fname), mode);
166 }
167
```

```
168 bool file_access_read(Const_String fname)
169 {
170    return file_access(fname, R_OK);
171 }
172
173 bool file_unlink(Const_String f)
174 {
175    return unlink(string_to_cstr(f)) != -1;
176 }
```

:

A.10.17 src/io.h

```
1  #ifndef IO_HANDLER_H
2  #define IO_HANDLER_H
3
4  #include <str.h>
5  #include <std_define.h>
6  #include <stdio.h>
7  #include <report.h>
8
9  #define STRING_PRINTF_SPECIFIER   'S'
10 #define UNS_PRINTF_SPECIFIER   'U'
11 #define INT_PRINTF_SPECIFIER   'D'
12 #define FILE_LOCATION_PRINTF_SPECIFIER 'F'
13
14 NORETURN void fatal_error(Const_String format, ...);
15
16 void print_vamessage(Const_String, va_list vl);
17
18 void print_message(Const_String format, ...);
19
20 void file_print_vamessage(FILE *stream, Const_String format, va_list vl);
21
22 void file_print_message(FILE *stream, Const_String format, ...);
23
24 void print_error(Const_String format, ...);
25
26 /* See fopen ($ man fopen). */
27 static inline FILE *file_open(Const_String fname, Const_String mode)
28 {
29    return fopen(string_to_cstr(fname), string_to_cstr(mode));
30 }
31
32 /* See fclose ($ man fclose). */
33 static inline Int file_close(FILE *file)
34 {
35    return fclose(file);
36 }
37
38 /* See man page for unlink(), returns true on success. */
39 bool file_unlink(Const_String f);
40
41 /* Unlink a temp file. Report warning on failure. */
42 static inline void file_unlink_temp(Const_String file)
43 {
44    if (!file_unlink(file))
45       report_warning(file, S("unable to remove temporary file "
46                QFY("%S") " [%m]"), file);
47 }
48
49 /* check errno see stat ($ man stat). */
50 time_t file_get_mtime(Const_String fname);
51
52 /* check errno see access ($ man access). */
53 bool file_access(Const_String fname, int mode);
54
55 /* see file_access */
56 bool file_access_read(Const_String fname);
57
```

```
58 static inline Int sys_cmd(Const_String cmd)
59 {
60    extern void inc_error_count();
61    int sys_ret = system(string_to_cstr(cmd));
62    if (sys_ret == -1)
63       fatal_error(S("unable to execute command:\n\t%S\n"), cmd);
64    if (sys_ret)
65       inc_error_count();
66    return sys_ret;
67 }
68
69 #endif // IO_HANDLER_H
```

:

A.10.18 src/pointer_hash.c

```
1  #include <pointer_hash.h>
2
3  bool pointer_hash_map_compare(void *search_obj, Hash_Map_Slot *map_slot)
4  {
5     Pointer_Slot *ms = POINTER_SLOT_OF(map_slot);
6     return search_obj == ms->key;
7  }
8
9  void pointer_hash_map_destructor(Hash_Map_Slot *slot)
10 {
11    free_mem(POINTER_SLOT_OF(slot));
12 }
```

:

A.10.19 src/pointer_hash.h

```
1  #ifndef POINTER_HASH_H
2  #define POINTER_HASH_H
3
4  #include <hash_map.h>
5
6  typedef struct Pointer_Slot {
7     Hash_Map_Slot slot;
8     void *key;
9     void *val;
10 } Pointer_Slot;
11
12 #define POINTER_SLOT_OF(s) CONTAINER_OF(s, Pointer_Slot, slot)
13
14 bool pointer_hash_map_compare(void *search_obj, Hash_Map_Slot *map_slot);
15
16 void pointer_hash_map_destructor(Hash_Map_Slot *slot);
17
18 #endif
```

:

A.10.20 src/rb_tree.c

```
1  #include <rb_tree.h>
2
3  /*
4   * Right rotate:
5   *     p         p      p       p
6   *    / \       / \    / \     / \
7   *   n         t         n       t
```

```
 *   / \   =>  / \  or    / \ =>  / \
 *  t        l  n      t       l  n
 * / \          /      / \        /
 * l r         r      l  r       r
 */
static ALWAYS_INLINE void rb_tree_right_rotate(Rb_Tree *tree, Rb_Tree_Node *node)
{
   Rb_Tree_Node *tmp = node->left, *parent = node->parent;
   node->left = tmp->right;
   tmp->right->parent = node;
   tmp->parent = parent;
   if (parent == RB_TREE_NULL(tree))
      tree->root = tmp;
   else if (node == parent->right)
      parent->right = tmp;
   else
      parent->left = tmp;
   tmp->right = node;
   node->parent = tmp;
}

// Left rotate (reverse of right rotate).
static ALWAYS_INLINE void rb_tree_left_rotate(Rb_Tree *tree, Rb_Tree_Node *node)
{
   Rb_Tree_Node *tmp = node->right, *parent = node->parent;
   node->right = tmp->left;
   tmp->left->parent = node;
   tmp->parent = parent;
   if (parent == RB_TREE_NULL(tree))
      tree->root = tmp;
   else if (node == parent->left)
      parent->left = tmp;
   else
      parent->right = tmp;
   tmp->left = node;
   node->parent = tmp;
}

void rb_tree_insert(Rb_Tree *tree, Rb_Tree_Node *node)
{
   Rb_Tree_Node *tmp, *gparent, *parent = tree->root;
   assert(tree->size < UINT32_MAX);
   ++tree->size;

   if (parent == RB_TREE_NULL(tree)) {
      tree->root = node;
      node->color = RB_TREE_BLACK;
      node->left = node->right = node->parent = RB_TREE_NULL(tree);
      return;
   }

   for (;;) {
      if (tree->comparator(node, parent)) {
         if (parent->left != RB_TREE_NULL(tree)) {
            parent = parent->left;
         } else {
            parent->left = node;
            break;
         }
      } else {
         if (parent->right != RB_TREE_NULL(tree)) {
            parent = parent->right;
         } else {
            parent->right = node;
            break;
         }
      }
   }

   node->color = RB_TREE_RED;
   node->left = node->right = RB_TREE_NULL(tree);
   node->parent = parent;
   if (parent->color == RB_TREE_BLACK)
      return;
```

```
82
83      for (;;) {
84         gparent = parent->parent;
85
86         if (parent == gparent->left) {
87            if (gparent->right->color == RB_TREE_RED) {
88               // Case 1.
89               gparent->right->color = RB_TREE_BLACK;
90               parent->color = RB_TREE_BLACK;
91               gparent->color = RB_TREE_RED;
92               // Fall through to end of loop.
93            } else {
94               if (node == parent->right) {
95                  tmp = parent->right;
96
97                  // Case 2 (left rotate):
98                  parent->right = tmp->left;
99                  tmp->left->parent = parent;
100                 gparent->left = tmp;
101                 tmp->parent = gparent;
102                 tmp->left = parent;
103                 parent->parent = tmp;
104
105                 node->color = RB_TREE_BLACK;
106              } else {
107                 parent->color = RB_TREE_BLACK;
108              }
109              // Case 3.
110              gparent->color = RB_TREE_RED;
111              rb_tree_right_rotate(tree, gparent);
112              break;
113           }
114        } else { // Then: parent == gparent->right
115           if (gparent->left->color == RB_TREE_RED) {
116              // Case 1.
117              gparent->left->color = RB_TREE_BLACK;
118              parent->color = RB_TREE_BLACK;
119              gparent->color = RB_TREE_RED;
120              // Fall through to end of loop.
121           } else {
122              if (node == parent->left) {
123                 tmp = parent->left;
124
125                 // Case 2 (right rotate).
126                 parent->left = tmp->right;
127                 tmp->right->parent = parent;
128                 gparent->right = tmp;
129                 tmp->parent = gparent;
130                 tmp->right = parent;
131                 parent->parent = tmp;
132
133                 node->color = RB_TREE_BLACK;
134              } else {
135                 parent->color = RB_TREE_BLACK;
136              }
137              // Case 3.
138              gparent->color = RB_TREE_RED;
139              rb_tree_left_rotate(tree, gparent);
140              break;
141           }
142        }
143
144        if (gparent->parent->color == RB_TREE_RED) {
145           parent = gparent->parent;
146           node = gparent;
147        } else {
148           tree->root->color = RB_TREE_BLACK;
149           break;
150        }
151
152     }
153  }
154
155  void rb_tree_for_each(Rb_Tree *tree, RB_Tree_Callback callback)
```

```
156 {
157    inline void rb_tree_inorder_call(Rb_Tree_Node *node)
158    {
159       if (node->left != RB_TREE_NULL(tree))
160          rb_tree_inorder_call(node->left);
161       callback(node);
162       if (node->right != RB_TREE_NULL(tree))
163          rb_tree_inorder_call(node->right);
164    }
165
166    if (tree->root != RB_TREE_NULL(tree))
167       rb_tree_inorder_call(tree->root);
168 }
169
170 void rb_tree_for_each_reversed(Rb_Tree *tree, RB_Tree_Callback callback)
171 {
172    inline void rb_tree_inorder_call(Rb_Tree_Node *node)
173    {
174       if (node->right != RB_TREE_NULL(tree))
175          rb_tree_inorder_call(node->right);
176       callback(node);
177       if (node->left != RB_TREE_NULL(tree))
178          rb_tree_inorder_call(node->left);
179    }
180
181    if (tree->root != RB_TREE_NULL(tree))
182       rb_tree_inorder_call(tree->root);
183 }
184
185 void rb_tree_for_each_destroy(Rb_Tree *tree, Rb_Tree_Destructor destructor)
186 {
187    inline void rb_tree_delete_nodes(Rb_Tree_Node *node)
188    {
189       if (node->left != RB_TREE_NULL(tree))
190          rb_tree_delete_nodes(node->left);
191       if (node->right != RB_TREE_NULL(tree))
192          rb_tree_delete_nodes(node->right);
193       destructor(node);
194    }
195
196    if (tree->root != RB_TREE_NULL(tree)) {
197       rb_tree_delete_nodes(tree->root);
198       tree->size = 0;
199       tree->root = RB_TREE_NULL(tree);
200       tree->color = RB_TREE_BLACK;
201    }
202 }
203
204 static ALWAYS_INLINE void rb_tree_transplant(Rb_Tree *tree, Rb_Tree_Node *node,
205       Rb_Tree_Node *child)
206 {
207    if (node->parent == RB_TREE_NULL(tree))
208       tree->root = child;
209    else if (node == node->parent->left)
210       node->parent->left = child;
211    else
212       node->parent->right = child;
213    child->parent = node->parent;
214 }
215
216 void rb_tree_remove(Rb_Tree *tree, Rb_Tree_Node *node)
217 {
218    Rb_Tree_Node *transp, *sibling, *parent, *tmp;
219    Rb_Tree_Color del_color;
220    --tree->size;
221
222    if (node->left == RB_TREE_NULL(tree)) {
223       del_color = node->color;
224       transp = node->right;
225       rb_tree_transplant(tree, node, transp);
226    } else if (node->right == RB_TREE_NULL(tree)) {
227       del_color = node->color;
228       transp = node->left;
229       rb_tree_transplant(tree, node, transp);
```

```
230     } else {
231        tmp = node->right;
232        while (tmp->left != RB_TREE_NULL(tree))
233           tmp = tmp->left;
234        del_color = tmp->color;
235        transp = tmp->right;
236        if (tmp->parent == node) {
237           transp->parent = tmp;
238        } else {
239           tmp->parent->left = transp;
240           transp->parent = tmp->parent;
241           tmp->right = node->right;
242           tmp->right->parent = tmp;
243        }
244        rb_tree_transplant(tree, node, tmp);
245        tmp->left = node->left;
246        tmp->left->parent = tmp;
247        tmp->color = node->color;
248     }
249
250     if (del_color == RB_TREE_RED)
251        return;
252     if (transp->color == RB_TREE_RED || transp == tree->root) {
253        transp->color = RB_TREE_BLACK;
254        return;
255     }
256
257     for ( ; ; ) {
258        /*
259         * Loop invariant:
260         * 1. transp != tree->root.
261         * 2. transp->color == RB_TREE_BLACK.
262         * 3. The simple paths from tree->root through transp to leaf
263         *    contains one less black node than the other simple paths
264         *    from root to leaf.
265         */
266        parent = transp->parent;
267        if (transp != parent->right) {
268           // Then: transp == parent->left.
269           sibling = parent->right;
270           if (sibling->color == RB_TREE_RED) {
271              // Case 1.
272              sibling->color = RB_TREE_BLACK;
273              parent->color = RB_TREE_RED;
274              rb_tree_left_rotate(tree, parent);
275              sibling = parent->right;
276           }
277           if (sibling->right->color == RB_TREE_BLACK) {
278              tmp = sibling->left;
279              if (tmp->color == RB_TREE_BLACK) {
280                 // Case 2.
281                 sibling->color = RB_TREE_RED;
282                 if (parent->color == RB_TREE_RED) {
283                    parent->color = RB_TREE_BLACK;
284                 } else if (parent != tree->root) {
285                       transp = parent;
286                       continue;
287                 }
288                 break;
289              }
290              tmp->color = RB_TREE_BLACK;
291              sibling->color = RB_TREE_RED;
292
293              // Case 3 (right rotate):
294              sibling->left = tmp->right;
295              tmp->right->parent = sibling;
296              if (parent == RB_TREE_NULL(tree))
297                 tree->root = tmp;
298              else
299                 parent->right = tmp;
300              tmp->parent = parent;
301              tmp->right = sibling;
302              sibling->parent = tmp;
303
```

```
304             sibling = tmp;
305          }
306          // Case 4.
307          sibling->color = parent->color;
308          parent->color = RB_TREE_BLACK;
309          sibling->right->color = RB_TREE_BLACK;
310          rb_tree_left_rotate(tree, parent);
311          break;
312       } else {
313          // Then: transp == parent->right.
314          sibling = parent->left;
315          if (sibling->color == RB_TREE_RED) {
316             // Case 1.
317             sibling->color = RB_TREE_BLACK;
318             parent->color = RB_TREE_RED;
319             rb_tree_right_rotate(tree, parent);
320             sibling = parent->left;
321          }
322          if (sibling->left->color == RB_TREE_BLACK) {
323             tmp = sibling->right;
324             if (tmp->color == RB_TREE_BLACK) {
325                // Case 2.
326                sibling->color = RB_TREE_RED;
327                if (parent->color == RB_TREE_RED) {
328                   parent->color = RB_TREE_BLACK;
329                } else if (parent != tree->root) {
330                      transp = parent;
331                      continue;
332                }
333                break;
334             }
335             tmp->color = RB_TREE_BLACK;
336             sibling->color = RB_TREE_RED;
337
338             // Case 3 (left rotate):
339             sibling->right = tmp->left;
340             tmp->left->parent = sibling;
341             if (parent == RB_TREE_NULL(tree))
342                tree->root = tmp;
343             else
344                parent->left = tmp;
345             tmp->parent = parent;
346             tmp->left = sibling;
347             sibling->parent = tmp;
348
349             sibling = tmp;
350          }
351          // Case 4.
352          sibling->color = parent->color;
353          parent->color = RB_TREE_BLACK;
354          sibling->left->color = RB_TREE_BLACK;
355          rb_tree_right_rotate(tree, parent);
356          break;
357       }
358    }
359 }
```

:

A.10.21 src/rb_tree.h

```
1  #ifndef RB_TREE_H
2  #define RB_TREE_H
3
4  #include <std_define.h>
5  #include <alloc.h>
6
7  typedef struct Rb_Tree_Node Rb_Tree_Node;
8
9  /* Should return true when: search_node <= tree_node,
10  * and return false when: search_node > tree_node
```

```
11  * Where search_node is the data we are inserting for and tree_node
12  * is a node from the tree. */
13 typedef bool (*Rb_Tree_Node_Comparator)(Rb_Tree_Node *search_node,
14       Rb_Tree_Node *tree_node);
15
16 #define RB_TREE_INTERFACE \
17    Rb_Tree_Color color; \
18    Rb_Tree_Node *parent
19
20 typedef enum Rb_Tree_Color {
21    RB_TREE_RED,
22    RB_TREE_BLACK
23 } Rb_Tree_Color;
24
25 struct Rb_Tree_Node {
26    RB_TREE_INTERFACE;
27    Rb_Tree_Node *left;
28    Rb_Tree_Node *right;
29 };
30
31 typedef struct Rb_Tree {
32    RB_TREE_INTERFACE;
33    Rb_Tree_Node *root;
34    Rb_Tree_Node_Comparator comparator;
35    Uns size;
36 } Rb_Tree;
37
38 #define RB_TREE_NULL(tree_ptr) ((Rb_Tree_Node *)(tree_ptr))
39
40 #define RB_TREE_STATIC_INIT(tree_name, comp_fun) { \
41    .root = RB_TREE_NULL(&(tree_name)),    \
42    .parent = RB_TREE_NULL(&(tree_name)),   \
43    .comparator = comp_fun,             \
44    .color = RB_TREE_BLACK,             \
45    .size = 0                           \
46 }
47
48 #define RB_TREE_INIT(tree_name, comp_fun) \
49    ((Rb_Tree)RB_TREE_STATIC_INIT(tree_name, comp_fun))
50
51 #define RB_TREE(tree, comp_fun) \
52    Rb_Tree tree = RB_TREE_STATIC_INIT(tree, comp_fun)
53
54 #define RB_TREE_ENTRY(node_ptr, container_type, node_member_name) \
55    CONTAINER_OF(node_ptr, container_type, node_member_name)
56
57 void rb_tree_insert(Rb_Tree *tree, Rb_Tree_Node *node);
58
59 static inline bool rb_tree_is_empty(const Rb_Tree *tree)
60 {
61    return tree->root == RB_TREE_NULL(tree);
62 }
63
64 static inline Uns rb_tree_size(Rb_Tree *tree)
65 {
66    return tree->size;
67 }
68
69 /* Compare arg with tree_node in some specified way.
70  * Return -1 if arg < tree_node.
71  * Return 1 if arg > tree_node.
72  * Return 0 if arg == tree_node */
73 typedef Int (*Rb_Tree_Search_Comparator)(void *arg, Rb_Tree_Node *tree_node);
74
75 /* Search the tree using comparator until comparator returns 0.
76  * Return the node which cause comparator to return 0.
77  * If comparator never returns 0 then rb_tree_search returns NULL. */
78 static inline Rb_Tree_Node *rb_tree_search(Rb_Tree *tree,
79       Rb_Tree_Search_Comparator comparator, void *comparator_arg)
80 {
81    for (Rb_Tree_Node *n = tree->root; n != RB_TREE_NULL(tree);) {
82       Int res = comparator(comparator_arg, n);
83       if (res < 0)
84          n = n->left;
```

```
85          else if (res > 0)
86             n = n->right;
87          else
88             return n;
89       }
90       return NULL;
91    }
92
93    /* Return true if data is in the tree. */
94    static inline bool rb_tree_contains(Rb_Tree *tree,
95          Rb_Tree_Search_Comparator comparator, void *comparator_arg)
96    {
97       return rb_tree_search(tree, comparator, comparator_arg);
98    }
99
100   typedef void (*Rb_Tree_Destructor)(Rb_Tree_Node *node);
101
102   /* Remove node from the tree. */
103   void rb_tree_remove(Rb_Tree *tree, Rb_Tree_Node *node);
104
105   /* Search for a node where comparator returns 0.
106    * If such a node is found remove the node from the tree and return the node.
107    * Otherwise return NULL. */
108   static inline Rb_Tree_Node *rb_tree_search_remove(Rb_Tree *tree,
109         Rb_Tree_Search_Comparator comparator, void *comparator_arg)
110   {
111      Rb_Tree_Node *n = rb_tree_search(tree, comparator, comparator_arg);
112      if (n)
113         rb_tree_remove(tree, n);
114      return n;
115   }
116
117   typedef void (*RB_Tree_Callback)(Rb_Tree_Node *node);
118
119   /* Inorder tree walk, call callback for each node in the tree. */
120   void rb_tree_for_each(Rb_Tree *tree, RB_Tree_Callback callback);
121
122   /* Reversed inorder tree walk, call callback for each node in the tree. */
123   void rb_tree_for_each_reversed(Rb_Tree *tree, RB_Tree_Callback callback);
124
125   void rb_tree_for_each_destroy(Rb_Tree *tree, Rb_Tree_Destructor destructor);
126
127   static inline Rb_Tree *rb_tree_alloc(Rb_Tree_Node_Comparator comparator)
128   {
129      Rb_Tree *t = ALLOC_NEW(Rb_Tree);
130      *t = RB_TREE_INIT(*t, comparator);
131      return t;
132   }
133
134   static inline void rb_tree_destroy(Rb_Tree *tree,
135         Rb_Tree_Destructor destructor)
136   {
137      if (destructor)
138         rb_tree_for_each_destroy(tree, destructor);
139      free_mem(tree);
140   }
141
142   #endif // RB_TREE_H
```

:

A.10.22 src/report.c

```
1  #include <main.h>
2  #include <std_include.h>
3  #include <rb_tree.h>
4
5  typedef enum Report_Type {
6     REPORT_TYPE_WARNING,
7     REPORT_TYPE_ERROR
8  } Report_Type;
```

```
9
10 typedef struct Report {
11    Rb_Tree_Node rb_node;
12    String message;
13    File_Location location;
14    Report_Type type;
15 } Report;
16
17 static int32_t error_count;
18 static int32_t warning_count;
19 static int32_t reset_error_count;
20 static int32_t reset_warning_count;
21
22 #define REPORT_OF(node) RB_TREE_ENTRY(node, Report, rb_node)
23
24 static bool report_comparator(Rb_Tree_Node *search_node,
25       Rb_Tree_Node *tree_node)
26 {
27    Report *se = REPORT_OF(search_node);
28    Report *te = REPORT_OF(tree_node);
29    Int res = file_location_cmp(&se->location, &te->location);
30    if (!res)
31       return se->type <= te->type;
32    return res == -1;
33 }
34
35 static inline Int search_comparator(void *location, Rb_Tree_Node *tree_node,
36       Report_Type search_type)
37 {
38    Report *rep = REPORT_OF(tree_node);
39    File_Location *loc = location;
40    Int res = file_location_cmp(loc, &rep->location);
41    if (!res) {
42       if (rep->type == search_type)
43          return 0;
44       if (rep->type < search_type)
45          return -1;
46       return 1;
47    }
48    return res;
49 }
50
51 static Int error_search_comparator(void *location, Rb_Tree_Node *tree_node)
52 {
53    return search_comparator(location, tree_node, REPORT_TYPE_ERROR);
54 }
55
56 static Int warning_search_comparator(void *location, Rb_Tree_Node *tree_node)
57 {
58    return search_comparator(location, tree_node, REPORT_TYPE_WARNING);
59 }
60
61 static RB_TREE(report_tree, report_comparator);
62
63 void report_reset()
64 {
65    reset_error_count = error_count;
66    reset_warning_count = warning_count;
67 }
68
69 bool report_exhausted()
70 {
71    return get_error_count() + get_warning_count() >= cmdopts.max_msg;
72 }
73
74 void inc_error_count()
75 {
76    ++error_count;
77 }
78
79 static inline void inc_warning_count()
80 {
81    ++warning_count;
82 }
```

```
83
84  int32_t get_error_count()
85  {
86     return error_count;
87  }
88
89  int32_t get_warning_count()
90  {
91     return warning_count;
92  }
93
94  bool was_error_reported()
95  {
96     return reset_error_count != get_error_count();
97  }
98
99  bool was_warning_reported()
100 {
101    return reset_warning_count != get_warning_count();
102 }
103
104 bool is_error_reported_here(File_Location *loc)
105 {
106    return rb_tree_contains(&report_tree, error_search_comparator, loc);
107 }
108
109 bool is_warning_reported_here(File_Location *loc)
110 {
111    if (cmdopts.warn_is_error)
112       return is_error_reported_here(loc);
113    return rb_tree_contains(&report_tree, warning_search_comparator, loc);
114 }
115
116 void report_vaerror(Const_String file_name, Const_String format, va_list vl)
117 {
118    File_Location loc = FILE_LOCATION_INIT(file_name, 0, 0);
119    report_vaerror_location(&loc, format, vl);
120 }
121
122 void report_error(Const_String file_name, Const_String format, ...)
123 {
124    VA_SETUP(vl, format);
125    report_vaerror(file_name, format, vl);
126    VA_END(vl);
127 }
128
129 void report_vaerror_location(File_Location *loc,
130       Const_String format, va_list vl)
131 {
132    if (report_exhausted())
133       return;
134
135    String new_format;
136
137    Report *rep = ALLOC_NEW(Report);
138    rep->location = *loc;
139    rep->type = REPORT_TYPE_ERROR;
140
141    new_format = string_from_format(S("%F: " ERROR_PREFIX "%S"), loc, format);
142    rep->message = string_from_vaformat(new_format, vl);
143    string_destroy(new_format);
144
145    rb_tree_insert(&report_tree, &rep->rb_node);
146
147    inc_error_count();
148 }
149
150 void report_error_location(File_Location *loc, Const_String format, ...)
151 {
152    VA_SETUP(vl, format);
153    report_vaerror_location(loc, format, vl);
154    VA_END(vl);
155 }
156
```

```
157 void report_vawarning(Const_String file_name, Const_String format, va_list vl)
158 {
159    File_Location loc = FILE_LOCATION_INIT(file_name, 0, 0);
160    report_vawarning_location(&loc, format, vl);
161 }
162
163 void report_warning(Const_String file_name, Const_String format, ...)
164 {
165    VA_SETUP(vl, format);
166    report_vawarning(file_name, format, vl);
167    VA_END(vl);
168 }
169
170 void report_vawarning_location(File_Location *loc,
171       Const_String format, va_list vl)
172 {
173    if (cmdopts.warn_is_error) {
174       report_vaerror_location(loc, format, vl);
175       return;
176    }
177
178    if (report_exhausted())
179       return;
180
181    String new_format;
182
183    Report *rep = ALLOC_NEW(Report);
184    rep->location = *loc;
185    rep->type = REPORT_TYPE_WARNING;
186
187    new_format = string_from_format(S("%F: " WARNING_PREFIX "%S"),
188          loc, format);
189    rep->message = string_from_vaformat(new_format, vl);
190    string_destroy(new_format);
191
192    rb_tree_insert(&report_tree, &rep->rb_node);
193
194    inc_warning_count();
195 }
196
197 void report_warning_location(File_Location *loc, Const_String format, ...)
198 {
199    VA_SETUP(vl, format);
200    report_vawarning_location(loc, format, vl);
201    VA_END(vl);
202 }
203
204 static void report_destructor(Rb_Tree_Node *rb_node)
205 {
206    Report *rep = REPORT_OF(rb_node);
207    string_destroy(rep->message);
208    free_mem(rep);
209 }
210
211 void clear_reports()
212 {
213    rb_tree_for_each_destroy(&report_tree, report_destructor);
214 }
215
216 static void show_report_callback(Rb_Tree_Node *rb_node)
217 {
218    Report *rep = REPORT_OF(rb_node);
219    file_print_message(stderr, rep->message);
220 }
221
222 void show_reports()
223 {
224    rb_tree_for_each(&report_tree, show_report_callback);
225 }
226
227 void report_print()
228 {
229    STRING(msg, "");
230    int32_t e = get_error_count();
```

```
231     int32_t w = get_warning_count();
232     if (w && e)
233        string_append_format(msg, S("%U error%s, %U warning%s\n"),
234              e, e > 1 ? "s" : "", w, w > 1 ? "s" : "");
235     else if (get_error_count())
236        string_append_format(msg, S("%U error%s\n"), e, e > 1 ? "s" : "");
237     else if (get_warning_count())
238        string_append_format(msg, S("%U warning%s\n"), w, w > 1 ? "s" : "");
239     else
240        goto out;
241
242     print_error(msg);
243
244  out:
245     string_clear(msg);
246  }
```

:

A.10.23 src/report.h

```
1   #ifndef ERROR_HANDLER_H
2   #define ERROR_HANDLER_H
3
4   #include <file_location.h>
5
6   #define ERROR_PREFIX "(error) "
7
8   #define WARNING_PREFIX "(warning) "
9
10  void report_error_location(File_Location *loc,
11        Const_String format, ...);
12
13  void report_warning_location(File_Location *loc, Const_String format, ...);
14
15  void report_vaerror_location(File_Location *loc,
16        Const_String format, va_list vl);
17
18  void report_vawarning_location(File_Location *loc,
19        Const_String format, va_list vl);
20
21  void report_vaerror(Const_String file_name, Const_String format, va_list vl);
22
23  void report_vawarning(Const_String file_name, Const_String format, va_list vl);
24
25  void report_error(Const_String file_name, Const_String format, ...);
26
27  void report_warning(Const_String file_name, Const_String format, ...);
28
29  /* Returns true if there has been reported an error since the
30   * report_reset() function was called last.
31   * If report_reset() has never been called was_error_reported()
32   * returns true if an error has been reporetd. */
33  bool was_error_reported();
34
35  bool was_warning_reported();
36
37  bool is_error_reported_here(File_Location *loc);
38
39  bool is_warning_reported_here(File_Location *loc);
40
41  int32_t get_error_count();
42
43  int32_t get_warning_count();
44
45  void clear_reports();
46
47  void show_reports();
48
49  void report_reset();
50
```

```
51 void report_print();
52
53 bool report_exhausted();
54
55 static inline void show_reports_clear()
56 {
57    show_reports();
58    clear_reports();
59 }
60
61 void force_error_reported();
62
63 #endif // ERROR_HANDLER_H
```

:

A.10.24 src/single_list.c

```
1  #include <main.h>
2  #include <single_list.h>
3
4  void single_list_prepend(Single_List *list, Single_List_Node *node)
5  {
6     if (single_list_is_empty(list)) {
7        list->head = node;
8        node->next = NULL;
9     } else {
10       node->next = list->head;
11       list->head = node;
12    }
13 }
14
15 Single_List_Node *single_list_pop_first(Single_List *list)
16 {
17    if (!single_list_is_empty(list)) {
18       Single_List_Node *h = single_list_peek_first(list);
19       list->head = h->next;
20       return h;
21    }
22    return NULL;
23 }
```

:

A.10.25 src/single_list.h

```
1  #ifndef SINGLE_LIST_H
2  #define SINGLE_LIST_H
3
4  #include <stdint.h>
5  #include <stdbool.h>
6
7  typedef struct Single_List_Node {
8     struct Single_List_Node *next;
9  } Single_List_Node;
10
11 /* You may assume that sizeof(Single_List) == sizeof(size_t) and
12  * that head == NULL when the list is empty. Might be usefull to know. */
13 typedef struct Single_List {
14    Single_List_Node *head;
15 } Single_List;
16
17 #define SINGLE_LIST_STATIC_INIT() { .head = NULL }
18
19 #define SINGLE_LIST_INIT() ((Single_List)SINGLE_LIST_STATIC_INIT())
20
21 #define SINGLE_LIST(list) Single_List list = SINGLE_LIST_STATIC_INIT()
```

```
22
23 #define SINGLE_LIST_ENTRY(node_ptr, container_type, node_member_name) \
24    CONTAINER_OF(node_ptr, container_type, node_member_name)
25
26 static inline bool single_list_is_empty(const Single_List *list)
27 {
28    return !list->head;
29 }
30
31 static inline Single_List_Node *single_list_peek_first(Single_List *list)
32 {
33    return list->head;
34 }
35
36 Single_List_Node *single_list_pop_first(Single_List *list);
37
38 typedef void (*Single_List_Destructor)(Single_List_Node *node);
39
40 static inline void single_list_for_each_destroy(Single_List *list,
41       Single_List_Destructor destructor)
42 {
43    for (Single_List_Node *n = single_list_pop_first(list); n;
44          n = single_list_pop_first(list))
45       destructor(n);
46 }
47
48 /* Remove node from the single list. Node prev is the single list node
49  * before node in the list. If prev == NULL then node is assumed to be
50  * the first element in the list. */
51 static inline void single_list_remove(Single_List *list,
52       Single_List_Node *node, Single_List_Node *prev)
53 {
54    if (prev)
55       prev->next = node->next;
56    else
57       single_list_pop_first(list);
58 }
59
60 void single_list_prepend(Single_List *list, Single_List_Node *node);
61
62 /* Don't free elements from the list while iterating this loop.
63  * At least you need to break the loop right after. */
64 #define SINGLE_LIST_FOR_EACH(list_ptr, node_ptr) \
65    for (node_ptr = (list_ptr)->head; node_ptr; node_ptr = (node_ptr)->next)
66
67 #endif // SINGLE_LIST_H
```

A.10.26 src/std_define.h

```
1  #ifndef STD_DEFINE_H
2  #define STD_DEFINE_H
3
4  #include <stdlib.h>
5  #include <stdbool.h>
6  #include <stdint.h>
7  #include <stddef.h>
8  #include <assert.h>
9  #include <stdarg.h>
10 #include <inttypes.h>
11
12 #define CONTAINER_OF(ptr, type, member) ({     \
13    const __typeof__(((type *)0)->member) *___mptr = (ptr); \
14    (type *)((char *)___mptr - offsetof(type, member));  \
15 })
16
17 #define ___CSTRINGIFY(arg) # arg
18 #define CSTRINGIFY(arg) ___CSTRINGIFY(arg)
19
20 #define QFY(str) "'" str "'"
21
```

```
22  #define UNLIKELY(x) __builtin_expect((long)!!(x), true)
23  #define LIKELY(x) __builtin_expect((long)!!(x), false)
24
25  #define ALWAYS_INLINE __attribute__((always_inline)) inline
26  #define REGPARM(n) __attribute__((regparm(n)))
27  #define UNUSED  __attribute__((unused))
28  #define CONSTRUCTOR __attribute__((constructor))
29  #define DESTRUCTOR __attribute__((destructor))
30  #define NORETURN __attribute__((noreturn))
31  #define ALIGNED(size) __attribute__((aligned(size)))
32
33  #define PTR_TO_INT(ptr) ((ptrdiff_t)(ptr))
34  #define PTR_TO_UINT(ptr) ((size_t)(ptr))
35  #define INT_TO_PTR(i) ((void *)(size_t)(i))
36
37  #define VA_SETUP(vl, last) va_list vl; va_start(vl, last)
38  #define VA_END(vl)  va_end(vl)
39
40  typedef uint32_t Uns;
41  typedef int32_t Int;
42
43  #define UNSIGNED_MAX UINT32_MAX
44  #define INTEGER_MAX INT32_MAX
45
46  #define PTR_SIZE __SIZEOF_POINTER__
47  #define PTR_BITS (PTR_SIZE * 8)
48
49  #define SOURCE_SUFFIX_CSTR  ".vit"
50  #define INTERFACE_SUFFIX_CSTR ".viti"
51  #define OBJ_SUFFIX_CSTR   ".o"
52  #define STATIC_LIB_SUFFIX_CSTR ".a"
53  #define ASM1_SUFFIX_CSTR  ".s"
54  #define ASM2_SUFFIX_CSTR  ".asm"
55  #define SOURCE_SUFFIX_STR  S(SOURCE_SUFFIX_CSTR)
56  #define INTERFACE_SUFFIX_STR S(INTERFACE_SUFFIX_CSTR)
57  #define OBJ_SUFFIX_STR   S(OBJ_SUFFIX_CSTR)
58  #define STATIC_LIB_SUFFIX_STR S(STATIC_LIB_SUFFIX_CSTR)
59  #define ASM1_SUFFIX_STR   S(ASM1_SUFFIX_CSTR)
60  #define ASM2_SUFFIX_STR   S(ASM2_SUFFIX_CSTR)
61
62  #define MAIN_FUNC_CSTR   "main"
63  #define MAIN_FUNC_STR   S(MAIN_FUNC_CSTR)
64
65  #define STDIN_FILE_SUFFIX_CSTR ".vitaly.vit"
66  #define STDIN_FILE_SUFFIX_STR S(STDIN_FILE_SUFFIX_CSTR)
67
68  #endif // STD_DEFINE_H
```

:

A.10.27 src/std_include.h

```
1   #ifndef STD_INCLUDE_H
2   #define STD_INCLUDE_H
3
4   #include <report.h>
5   #include <io.h>
6   #include <alloc.h>
7   #include <str.h>
8   #include <file_location.h>
9
10  __attribute__((noreturn)) static inline void exit_failure()
11  {
12     exit(EXIT_FAILURE);
13  }
14
15  #endif // STD_INCLUDE_H
```

:

A.10.28 src/str.c

```
#include <io.h>
#include <vector.h>
#include <errno.h>
#include <libgen.h>
#include <ctype.h>

String string_from_vaformat(Const_String format, va_list vl)
{
   String dest = ALLOC_STRING();
   if (vasprintf(&dest->str, string_to_cstr(format), vl) == -1)
      fatal_error(S("Unable to allocate memory for new string\n"));
   dest->dynamic = true;
   return dest;
}

void string_append_vaformat(String s, Const_String format, va_list vl)
{
   char *tmp;
   if (vasprintf(&tmp, string_to_cstr(format), vl) == -1)
      fatal_error(S("Unable to allocate memory for new string\n"));
   string_append(s, S(tmp));
   free_mem(tmp);
}

void string_assign(String s, Const_String other)
{
   if (string_to_cstr(s) != string_to_cstr(other)) {
      string_clear(s);
      string_append(s, other);
   } else {
      String oth = string_duplicate(other);
      string_clear(s);
      string_append(s, oth);
      string_destroy(oth);
   }
}

void string_assign_vaformat(String s, Const_String format, va_list vl)
{
   if (string_to_cstr(s) != string_to_cstr(format)) {
      string_clear(s);
      string_append_vaformat(s, format, vl);
   } else {
      String fmt = string_duplicate(format);
      string_clear(s);
      string_append_vaformat(s, fmt, vl);
      string_destroy(fmt);
   }
}

int32_t string_base10_to_int32(Const_String s)
{
   const char *cstr = string_to_cstr(s);
   char *endptr;
   long val = strtol(cstr, &endptr, 10);
   if (UNLIKELY(endptr == cstr)) {
      errno = EINVAL;
      return 0;
   }
   if (UNLIKELY(*endptr != '\0')) {
      errno = EINVAL;
      return 0;
   }
   if (UNLIKELY(val > INT32_MAX)) {
      errno = ERANGE;
      return INT32_MAX;
   }
   if (UNLIKELY(val < INT32_MIN)) {
      errno = ERANGE;
      return INT32_MIN;
   }
```

```
72     return val;
73  }
74
75  String string_substring(Const_String s, Uns from, Uns to)
76  {
77     String ret = ALLOC_STRING();
78     Uns len = to - from;
79     Uns size = len + 1;
80     const char *cstr = string_to_cstr(s);
81     char *new_cstr = alloc_mem(size);
82
83     strncpy(new_cstr, cstr + from, size);
84     new_cstr[len] = '\0';
85
86     ret->str = new_cstr;
87     ret->dynamic = true;
88     return ret;
89  }
90
91  Vector *string_split(Const_String s, Const_String delimiter)
92  {
93     const char *start, *end;
94     const char *cstr = string_to_cstr(s), *delim = string_to_cstr(delimiter);
95     Uns delim_len = string_length(delimiter);
96     Uns cstr_len = string_length(s);
97     const char *const cstr_end = cstr + cstr_len;
98
99     Vector *v = vector_alloc();
100
101    start = cstr;
102    while (start + delim_len <= cstr_end) {
103       if (strncmp(start, delim, delim_len)) {
104          end = strstr(start + delim_len, delim);
105          if (!end)
106             break;
107          vector_append(v,
108                string_substring(s, start - cstr, end - cstr));
109          start = end + delim_len;
110       } else {
111          start += delim_len;
112       }
113    }
114    if (start != cstr_end)
115       vector_append(v, string_substring(s, start - cstr, cstr_len));
116    return v;
117 }
118
119 Uns string_count(Const_String s, Const_String delimiter)
120 {
121    Uns ret = 0;
122    const char *start, *end;
123    const char *cstr = string_to_cstr(s), *delim = string_to_cstr(delimiter);
124    Uns delim_len = string_length(delimiter);
125    Uns cstr_len = string_length(s);
126    const char *const cstr_end = cstr + cstr_len;
127
128    start = cstr;
129    while (start + delim_len <= cstr_end) {
130       if (strncmp(start, delim, delim_len)) {
131          end = strstr(start + delim_len, delim);
132          if (!end)
133             break;
134          ret ++;
135       start = end + delim_len;
136       } else {
137          start += delim_len;
138       }
139    }
140    return ret;
141 }
142
143 void string_remove_first_last(String s)
144 {
145    Uns i;
```

```
146     if (!s->dynamic)
147        string_assign(s, s);
148
149     char *cstr = s->str;
150     if (*cstr) {
151        i = 1;
152        if (cstr[1]) {
153           for (; cstr[i + 1]; i++)
154              cstr[i - 1] = cstr[i];
155        }
156        cstr[i - 1] = '\0';
157     }
158  }
159
160  void string_remove_all(String s, char c)
161  {
162     Uns i, j;
163     if (!s->dynamic)
164        string_assign(s, s);
165
166     char *cstr = s->str;
167     for (i = 0, j = 0; cstr[j]; j++) {
168        if (cstr[j] != c)
169           cstr[i++] = cstr[j];
170     }
171     cstr[i] = cstr[j];
172  }
173
174  String string_basename(Const_String s)
175  {
176     String tmp = string_duplicate(s);
177     String ret = string_alloc(S(basename(tmp->str)));
178     string_destroy(tmp);
179     return ret;
180  }
181
182  String string_dirname(Const_String s)
183  {
184     String tmp = string_duplicate(s);
185     String ret = string_alloc(S(dirname(tmp->str)));
186     string_destroy(tmp);
187     return ret;
188  }
189
190  bool string_ends_with(Const_String s, Const_String ending)
191  {
192     Uns end_len = string_length(ending);
193     Uns s_len = string_length(s);
194     if (s_len < end_len)
195        return false;
196     return !strcmp(string_to_cstr(ending), &s->const_str[s_len - end_len]);
197  }
198
199  String string_to_module_name(Const_String s)
200  {
201     String ret = NULL;
202     Int idx = string_last_index_char(s, '.');
203     if (idx == -1)
204        goto out;
205     if (!strcmp(&s->const_str[idx], SOURCE_SUFFIX_CSTR) ||
206           !strcmp(&s->const_str[idx], INTERFACE_SUFFIX_CSTR)) {
207        ret = string_duplicate(s);
208        string_set(ret, idx, '\0');
209     }
210  out:
211     return ret;
212  }
213
214  String string_to_unique_file(Const_String suffix)
215  {
216     static const char tmp_suffix[] = "XXXXXX";
217     char *tmp = alloc_mem(sizeof(tmp_suffix));
218     memcpy(tmp, tmp_suffix, sizeof(tmp_suffix));
219
```

```
220     tmp = mktemp(tmp);
221     if (!*tmp)
222        fatal_error(S("unable to generate unique file name [%m]\n"));
223
224     String ret = string_alloc(S(tmp));
225     free_mem(tmp);
226
227     string_append(ret, suffix);
228     return ret;
229  }
230
231  String string_to_tmp_file(Const_String suffix)
232  {
233     String ret = string_alloc(S("/tmp/"));
234     String tmp = string_to_unique_file(suffix);
235     string_append(ret, tmp);
236     string_destroy(tmp);
237     return ret;
238  }
239
240  void string_replace_from(String s, char c, Const_String new_end)
241  {
242     Int idx = string_last_index_char(s, c);
243     if (idx != -1)
244        s->str[idx] = '\0';
245     string_append(s, new_end);
246  }
247
248  void string_toupper(String s)
249  {
250     if (!s->dynamic)
251        string_assign(s, s);
252     char *str = s->str;
253     for (Uns i = 0; str[i]; i++)
254        str[i] = toupper(str[i]);
255  }
```

:

A.10.29 src/str.h

```
1   #ifndef STR_H
2   #define STR_H
3
4   /* Implementation of a semi dynamic string structure.
5    *
6    * XXX Note: The DEBUG* DLOG* macros use the dynamic string implementation.So
7    * don't use the debugging macros to debug dynamic string implementation code.
8    *
9    * How to create strings:
10   * STRING(s1, "Hello");  // Allocate string statically or on the stack.
11   * String s2 = string_duplicate(S("Hello")); // Allocate string dynamically
12   * String s3 = STRING_INIT(s3, "Hello");  // Same as with s1
13   * CONST_STRING(s4, "Hello"); // Same as with s1, but this string is const.
14   *
15   * Note that it is your job to determine whether to call
16   * string_destroy() to free the memory used by strings.
17   * In general if you initialize a string with STRING() or STRING_INIT()
18   * you should NOT call string_destroy() (it will cause a seg fault).
19   *
20   * If you initialize a Const_String with CONST_STRING(), CONST_STRING_INIT()
21   * or even S() you must NOT call string_clear() to free memory used
22   * by the string. After initializing a string with STRING() or STRING_INIT()
23   * you should call string_clear() to free the memory used by the string.
24   *
25   * If you for some reason pass a dynamically allocated C string to STRING(),
26   * STRING_INIT(), CONST_STRING(), CONST_STRING_INIT() or S() you must NOT
27   * deallocate the C string before the String (or Const_String) is not needed
28   * anymore. Also note that it is jour job to deallocate the C string at some
29   * point. As a general rule don't pass a dynamically allocated C string to
30   * any of the String (or Const_String) initialization macros like STRING()
```

```
31  * unless you know what you are doing, use string_duplicate() instead.
32  *
33  * If you allocate a String with string_duplicate (for example) you must
34  * call string_destroy() to deallocate the string when not needed anymore.
35  *
36  * If you want to pass a Const_String to a function you can use the S() macro.
37  * For example:
38  *  print_message(S("%D\n"), 1);
39  * Will output:
40  *  1
41  *
42  * Also note that if you would like to print a String (or Const_String)
43  * You can use the %S printf specifier. For example:
44  *  CONST_STRING(s, "Hello ");
45  *  report_error(S("file-name"), S("%S %S\n"), s, S("world"));
46  * Will output:
47  *  Hello world
48  *
49  * A bigger example:
50  *  STRING(s1, "Hello");
51  *  String s2 = string_duplicate(S("world"));
52  *  String s3 = string_from_format(S("%S %S %D"), s1, s2, 2);
53  *  string_append(s1, S(" world 1"));
54  *
55  *  print_message("%S\n%S\n", s1, s2);
56  *
57  *  // Free memory used by the strings:
58  *  string_clear(s1);  // This one was allocated on the stack.
59  *  string_destroy(s2); // This one was dynamically allocated.
60  *  string_destroy(s3);
61  *
62  * Output:
63  *  Hello world 1
64  *  Hello world 2 */
65
66  #include <std_define.h>
67  #include <alloc.h>
68  #include <string.h>
69
70  /* Don't mind this String_Struct. (Implementation details). */
71  typedef struct String_Struct {
72     union {
73        struct {
74           union {
75              char *str;
76              const char *const_str;
77           };
78           bool dynamic;
79        };
80        const char *const_string_value;
81     };
82  } *String;
83
84  typedef const struct String_Struct *Const_String;
85
86  /* Allocate memory for a new string. */
87  #define ALLOC_STRING() ALLOC_NEW(struct String_Struct)
88
89  /* Used by the implementation. You probably should not use this macro. */
90  #define ALLOC_CSTR(length) alloc_mem((length) + 1)
91
92  /* Macros to initialize strings and const strings. */
93  #define STRING_STATIC_INIT(value) \
94  (&(struct String_Struct){{{ { .const_str = (value) }, .dynamic = false }}})
95
96  #define CONST_STRING_STATIC_INIT(value) \
97  (&(const struct String_Struct){ { .const_string_value = (value) } })
98
99  #define STRING_INIT(value) STRING_STATIC_INIT(value)
100
101 #define CONST_STRING_INIT(value) CONST_STRING_STATIC_INIT(value)
102
103 #define STRING(sname, value) String sname = STRING_STATIC_INIT(value)
104
```

```
105 #define CONST_STRING(sname, value) \
106    Const_String sname = CONST_STRING_STATIC_INIT(value)
107
108 #define STRING_EMPTY(sname) STRING(sname, "")
109
110 #define CONST_STRING_EMPTY(sname) CONST_STRING(sname, "")
111
112 /* Convenience macro to create a Const_String. */
113 #define S(value) CONST_STRING_INIT(value)
114
115 #define STRINGIFY(arg) S(CSTRINGIFY(arg))
116
117 /* Get C string representation.
118  * Respect that the returned C string is const, and don't
119  * deallocate the C string at any point. */
120 static inline const char *string_to_cstr(Const_String s)
121 {
122    return s->const_str;
123 }
124
125 static inline bool string_is_empty(Const_String s)
126 {
127    return !*string_to_cstr(s);
128 }
129
130 /* Allocate a new string and assign it with a format which is
131  * a vprintf like format String with a corresponding va_list.
132  * See string_from_format() for usage example.
133  * Also take a look at the documentation for vprintf ($ man vprintf). */
134 String string_from_vaformat(Const_String format, va_list vl);
135
136 /* Allocate a new string and assign it with a printf format with
137  * a variable number of arguments.
138  * Usage:
139  *  String s = string_from_format(S("%S%s%c"), S("A"), "B", 'C');
140  *  ...
141  *  string_destroy(s);
142  * Output:
143  *  ABC */
144 static inline String string_from_format(Const_String format, ...)
145 {
146    VA_SETUP(vl, format);
147    String s = string_from_vaformat(format, vl);
148    VA_END(vl);
149    return s;
150 }
151
152 /* XXX - Don't use this function directly.
153  * Take a look at string_clear() instead. */
154 static inline void ___string_free_cstr(String s)
155 {
156    if (s->dynamic)
157       free_mem(s->str);
158 }
159
160 /* Free memory used by the String s.
161  * Don't pass Const_String to this function.
162  * After call to this function s == "".
163  * So you can still use s after a calling this function.
164  * See string_destroy() if you want to deallocate the string completely. */
165 static inline void string_clear(String s)
166 {
167    ___string_free_cstr(s);
168    s->dynamic = false;
169    s->const_str = "";
170 }
171
172 /* Deallocate a string along with it's contents.
173  * XXX - Important not to try to deallocate statically allocated strings
174  * which have been initialized with one of the string initialization
175  * macros like STRING() or STRING_INIT(). */
176 static inline void string_destroy(String s)
177 {
178    if (s) {
```

```
179         ___string_free_cstr(s);
180         free_mem(s);
181      }
182   }
183
184   static inline size_t string_length(Const_String s)
185   {
186      return strlen(string_to_cstr(s));
187   }
188
189   /* Append other to s. */
190   static inline void string_append(String s, Const_String other)
191   {
192      char *tmp = ALLOC_CSTR(string_length(s) + string_length(other));
193      strcpy(tmp, string_to_cstr(s));
194      strcat(tmp, string_to_cstr(other));
195      ___string_free_cstr(s);
196      s->str = tmp;
197      s->dynamic = true;
198   }
199
200   /* Like string_from_vaformat(), but append s with the formatted string. */
201   void string_append_vaformat(String s, Const_String format, va_list vl);
202
203   /* Like string_from_format(), but append s with the formatted string. */
204   static inline void string_append_format(String s, Const_String format, ...)
205   {
206      VA_SETUP(vl, format);
207      string_append_vaformat(s, format, vl);
208      VA_END(vl);
209   }
210
211   /* Like string_from_format, but append the format to String s. */
212   void string_append_format(String s, Const_String format, ...);
213
214   /* Duplicate String (other) and return a new String == other.
215    * You can freely deallocate other whenever you want after calling this
216    * function.
217    * Remember to free the returned String with string_destroy() when
218    * it's not needed anymore. */
219   static inline String string_duplicate(Const_String other)
220   {
221      String s = ALLOC_STRING();
222      s->str = ALLOC_CSTR(string_length(other));
223      strcpy(s->str, string_to_cstr(other));
224      s->dynamic = true;
225      return s;
226   }
227
228   /* Same as string_duplicate(). See string_duplicate() and string_destroy(). */
229   static inline String string_alloc(Const_String contents)
230   {
231      return string_duplicate(contents);
232   }
233
234   /* String compare s1 with s2.
235    * Returns -1 if s1 < s2,
236    * returns 0 if s1 == s2,
237    * returns 1 if s1 > s2. */
238   static inline Int string_compare(Const_String s1, Const_String s2)
239   {
240      return strcmp(string_to_cstr(s1), string_to_cstr(s2));
241   }
242
243   /* Case insensitive version of string_compare() */
244   static inline Int string_compare_nocase(Const_String s1, Const_String s2)
245   {
246      return strcasecmp(string_to_cstr(s1), string_to_cstr(s2));
247   }
248
249   /* Clear the String s and afterwards let s == other.
250    * You can freely deallocate other whenever you want after calling
251    * this function. */
252   void string_assign(String s, Const_String other);
```

```
253
254 /* Like string_from_vaformat(), but assign s with the formatted string. */
255 void string_assign_vaformat(String s, Const_String format, va_list vl);
256
257 /* Like string_from_format(), but assign s with the formatted string. */
258 static inline void string_assign_format(String s, Const_String format, ...)
259 {
260    VA_SETUP(vl, format);
261    string_assign_vaformat(s, format, vl);
262    VA_END(vl);
263 }
264
265 /* Convert s into a base 10 integer.
266  * You might have to check errno after calling this function.
267  * If s is not an integer the function returns 0 with errno == EINVAL.
268  * If the integer in s is too big i.e. the int32_t overflows the
269  * function returns INT32_MAX with errno == ERANGE.
270  * If the integer in s is too small i.e. the int32_t underflows the
271  * function returns INT32_MIN with errno == ERANGE.
272  * Otherwise the function returns s converted to an Int. */
273 int32_t string_base10_to_int32(Const_String s);
274
275 /* Get the hash code of a string. (Idea stolen from java String class). */
276 static inline Uns string_hash_code(Const_String s)
277 {
278    Uns hash = 0;
279    for (const char *val = string_to_cstr(s); *val; val++)
280       hash = (hash << 5) - hash + *val;
281    return hash;
282 }
283
284 /* Warning, no bounds checking.
285  * Slow operation if the string is not already dynamic.
286  * (When s->dynamic == false). */
287 static inline void string_set(String s, Uns idx, char val)
288 {
289    if (!s->dynamic)
290       string_assign(s, s);
291    s->str[idx] = val;
292 }
293
294 /* Set last char of s to val. */
295 static inline void string_set_last_char(String s, char val)
296 {
297    string_set(s, string_length(s) - 1, val);
298 }
299
300 /* Warning, no bounds checking. */
301 static inline char string_get(Const_String s, Uns idx)
302 {
303    return string_to_cstr(s)[idx];
304 }
305
306 /* Get last char of s. */
307 static inline char string_get_last(Const_String s)
308 {
309    Uns len = string_length(s);
310    if (len)
311       return string_get(s, len - 1);
312    return '\0';
313 }
314
315 /* Returns -1 if char c is not in the string.
316  * Else returns index of first occurrence of c in s. */
317 static inline Int string_first_index_char(Const_String s, char c)
318 {
319    const char *cstr = string_to_cstr(s);
320    const char *tmp = strchr(cstr, c);
321    if (!tmp)
322       return -1;
323    return tmp - cstr;
324 }
325
326 /* Returns -1 if char c is not in the string.
```

```
327  * Else returns index of last occurrence of c in s. */
328 static inline Int string_last_index_char(Const_String s, char c)
329 {
330    const char *cstr = string_to_cstr(s);
331    const char *tmp = strrchr(cstr, c);
332    if (!tmp)
333       return -1;
334    return tmp - cstr;
335 }
336
337 /* Replace first occurrence of search_char with replace_char. */
338 static inline void string_search_replace_char(String s, char search_char,
339       char replace_char)
340 {
341    const char *cstr = string_to_cstr(s);
342    const char *tmp = strchr(cstr, search_char);
343    if (tmp)
344       string_set(s, tmp - cstr, replace_char);
345 }
346
347 /* Get substring of s with first char at index 'from' and last char
348  * at index 'to' - 1.
349  * Warning, no bounds checking:
350  * So make sure 'from' <= length of string and to <= length of string. */
351 String string_substring(Const_String s, Uns from, Uns to);
352
353 typedef struct Vector Vector;
354
355 /* Remember to destroy the vector with
356  * vector_destroy(vector, (Vector_Destructor)string_destroy). */
357 Vector *string_split(Const_String s, Const_String delimiter);
358
359 /* Count the number of occurences of delimiter */
360 Uns string_count(Const_String s, Const_String delimiter);
361
362 /* Remove first and last character from s. */
363 void string_remove_first_last(String s);
364
365 /* Remove all occurrences of c from s. */
366 void string_remove_all(String s, char c);
367
368 /* Shift String s left with 'amount' characters. */
369 static inline void string_shift_left(String s, Uns amount)
370 {
371    Uns len = string_length(s);
372    if (len < amount)
373       string_clear(s);
374    else
375       for (Uns i = 0; i < len - amount + 1; i++)
376          string_set(s, i, string_get(s, i + amount));
377 }
378
379 static inline void string_replace_all(String s, char old_c, char new_c)
380 {
381    if (!s->dynamic)
382       string_assign(s, s);
383    char *c = s->str;
384    while (*c != '\0') {
385       if (*c == old_c)
386          *c = new_c;
387       ++c;
388    }
389 }
390
391 static inline String string_cpy_replace_all(Const_String s, char old_c,
392       char new_c)
393 {
394    String ret = string_duplicate(s);
395    string_replace_all(ret, old_c, new_c);
396    return ret;
397 }
398
399 bool string_ends_with(Const_String s, Const_String ending);
400
```

```
401 String string_basename(Const_String s);
402
403 String string_dirname(Const_String s);
404
405 String string_to_module_name(Const_String s);
406
407 static inline String string_dir_concat(Const_String dir, Const_String lhs)
408 {
409    return string_from_format(S("%S/%S"), dir, lhs);
410 }
411
412 static inline const char *___string_after_last(Const_String s, char c)
413 {
414    const char *result;
415    Int idx = string_last_index_char(s, c);
416    if (idx == -1)
417       result = string_to_cstr(s);
418    else
419       result = &string_to_cstr(s)[idx + 1];
420    return result;
421 }
422
423 static inline const char *___string_after_first(Const_String s, char c)
424 {
425    const char *result;
426    Int idx = string_first_index_char(s, c);
427    if (idx == -1)
428       result = string_to_cstr(s);
429    else
430       result = &string_to_cstr(s)[idx + 1];
431    return result;
432 }
433
434 #define STRING_AFTER_LAST(str, ch) S(___string_after_last(str, ch))
435
436 #define STRING_AFTER_DOT(str) S(___string_after_last(str, '.'))
437
438 #define STRING_AFTER_FIRST(str, ch) S(___string_after_first(str, ch))
439
440 static inline String string_between_alloc(Const_String s, char c)
441 {
442    String ret = string_duplicate(STRING_AFTER_FIRST(s, c));
443    Int last_idx = string_last_index_char(ret, c);
444    if (last_idx != -1)
445       ret->str[last_idx] = '\0';
446    return ret;
447 }
448
449 /* Get a unique file name name ending with 'suffix'. */
450 String string_to_unique_file(Const_String suffix);
451
452 /* Get a unique file name name starting with "/tmp/" and
453  * ending with 'suffix'. */
454 String string_to_tmp_file(Const_String suffix);
455
456 /* Replace characters from last c with new_end.
457  * If c is not in the string new_end is just appended to the end of s.
458  * Example:
459  *  if s == "file.vit" then
460  *  string_replace_after(s, '.', S(".o")) results in
461  *  s == "file.o" */
462 void string_replace_from(String s, char c, Const_String new_end);
463
464 static inline String string_cpy_replace_from(Const_String s, char c,
465       Const_String new_end)
466 {
467    String ret = string_duplicate(s);
468    string_replace_from(ret, c, new_end);
469    return ret;
470 }
471
472 void string_toupper(String s);
473
474 #endif // STR_H
```

:

A.10.30 src/string_builder.c

```
#include <string_builder.h>

void string_builder_append(String_Builder *b, Const_String s)
{
   Uns slen, new_len;

   if (!b->str_buf) {
      ___string_builder_assign(b, s);
      return;
   }

   slen = string_length(s);
   new_len = b->str_len + slen;

   if (b->buf_size <= new_len) {
      char *nbuf;
      b->buf_size = (new_len << STRING_BUILDER_SHIFT) + 1;
      nbuf = alloc_mem(b->buf_size);
      memcpy(nbuf, b->str_buf, b->str_len + 1);
      free_mem(b->str_buf);
      b->str_buf = nbuf;
   }

   memcpy(b->str_buf + b->str_len, string_to_cstr(s), slen + 1);
   b->str_len = new_len;
}
```

:

A.10.31 src/string_builder.h

```
#ifndef STRING_BUILDER_H
#define STRING_BUILDER_H

#include <str.h>

typedef struct String_Builder {
   union {
      struct {
         char *str_buf;
         Uns buf_size;
         Uns str_len;
      };
      struct String_Struct string_struct;
   };
} String_Builder;

#define STRING_BUILDER_STATIC_INIT() {{{ \
   .str_buf = NULL,              \
   .buf_size = 0,                \
   .str_len = 0                  \
}}}

#define STRING_BUILDER_INIT() ((String_Builder)STRING_BUILDER_STATIC_INIT())

#define STRING_BUILDER(name) String_Builder name = STRING_BUILDER_STATIC_INIT()

#define STRING_BUILDER_SHIFT 2

static inline void string_builder_clear(String_Builder *b)
{
   free_mem(b->str_buf);
   b->buf_size = 0;
   b->str_len = 0;
```

```
34    b->str_buf = NULL;
35 }
36
37 static inline void ___string_builder_assign(String_Builder *b, Const_String s)
38 {
39    b->str_len = string_length(s);
40    b->buf_size = (b->str_len << STRING_BUILDER_SHIFT) + 1;
41    b->str_buf = alloc_mem(b->buf_size);
42    memcpy(b->str_buf, string_to_cstr(s), b->str_len + 1);
43 }
44
45 static inline void string_builder_assign(String_Builder *b, Const_String s)
46 {
47    free_mem(b->str_buf);
48    ___string_builder_assign(b, s);
49 }
50
51 void string_builder_append(String_Builder *b, Const_String s);
52
53 static inline void string_builder_append_char(String_Builder *b, Int c)
54 {
55    c &= (Int)0xff;
56    string_builder_append(b, S((const char *)&c));
57 }
58
59 static inline void string_builder_append_int16(String_Builder *b, Int chars)
60 {
61    chars &= (Int)0xffff;
62    string_builder_append(b, S((const char *)&chars));
63 }
64
65 static inline void string_builder_set_last_char(String_Builder *b, char c)
66 {
67    b->str_buf[b->str_len - 1] = c;
68 }
69
70 /* Warning. Might return NULL if the string builder
71  * has not been assigned a value. */
72 static inline const char *string_builder_to_cstr(String_Builder *b)
73 {
74    return b->str_buf;
75 }
76
77 /* Warning. Might return NULL if the string builder
78  * has not been assigned a value. */
79 static inline Const_String string_builder_const_str(String_Builder *b)
80 {
81    if (b->str_buf)
82       return &b->string_struct;
83    else
84       return NULL;
85 }
86
87 #endif // STRING_BUILDER_H
```

:

A.10.32 src/test/test_hash_map.c

```
1  #include <parser.h>
2  #include <std_define.h>
3  #include <std_include.h>
4  #include <stdio.h>
5
6  #include <time.h>
7  #include <hash_map.h>
8  #include <stdlib.h>
9
10 typedef struct Integer_Slot {
11    Hash_Map_Slot slot;
12    Uns val;
```

```
13  } Integer_Slot;
14
15  #define INTEGER_SLOT_OF(s) CONTAINER_OF(s, Integer_Slot, slot)
16
17  bool hash_search_compare(void *search_obj, Hash_Map_Slot *map_slot)
18  {
19     Uns i = PTR_TO_INT(search_obj);
20     Integer_Slot *ms = INTEGER_SLOT_OF(map_slot);
21     return i == ms->val;
22  }
23
24  void hash_map_destructor(Hash_Map_Slot *slot)
25  {
26     free_mem(INTEGER_SLOT_OF(slot));
27  }
28
29  void test_hash_map()
30  {
31     srand(time(NULL));
32
33  #define UNEXPECTED_VALUE1 8
34  #define UNEXPECTED_VALUE2 8
35  #define NUM_REMOVED 5
36
37     Uns insert_values[] = { UNEXPECTED_VALUE2, UNEXPECTED_VALUE1, 12, UNEXPECTED_VALUE1, 15, 6, 0, UNEXPECTED_VALU
38     Uns remove_values[] = { UNEXPECTED_VALUE1, UNEXPECTED_VALUE2, 2000, UNEXPECTED_VALUE1, 0, UNEXPECTED_VALUE1, 1
39
40  #define INSERT_SIZE (sizeof(insert_values) / sizeof(Uns))
41  #define REMOVE_SIZE (sizeof(remove_values) / sizeof(Uns))
42
43     HASH_MAP(map, hash_search_compare);
44
45     for (Uns i = 0; i < INSERT_SIZE; i++) {
46        Integer_Slot *s = ALLOC_NEW(Integer_Slot);
47        s->val = insert_values[i];
48        hash_map_insert(&map, &s->slot, s->val);
49     }
50
51     if (hash_map_size(&map) != INSERT_SIZE) {
52        print_message(S("1. Unexpected map size %U\n"), hash_map_size(&map));
53        exit_failure();
54     }
55
56     for (Uns i = 0; i < INSERT_SIZE; i++) {
57        if (!hash_map_contains(&map, INT_TO_PTR(insert_values[i]),
58              insert_values[i])) {
59           print_message(S("1. Could not find expected value: %U\n"),
60              insert_values[i]);
61           exit_failure();
62        }
63     }
64
65     for (Uns i = 0; i < REMOVE_SIZE; i++)
66        free_mem(hash_map_remove(&map, INT_TO_PTR(remove_values[i]),
67              remove_values[i]));
68
69     for (Uns i = 0; i < INSERT_SIZE; i++) {
70        bool expected = true;
71        if (insert_values[i] == UNEXPECTED_VALUE1 ||
72              insert_values[i] == UNEXPECTED_VALUE2) {
73           expected = false;
74        }
75        if (expected != hash_map_contains(&map, INT_TO_PTR(insert_values[i]),
76              insert_values[i])) {
77           print_message(S("Unexpected. Hash map contains %U? %s\n"),
78              insert_values[i], expected ? "true" : "false");
79           exit_failure();
80        }
81     }
82
83     if (hash_map_size(&map) != INSERT_SIZE - NUM_REMOVED) {
84        print_message(S("2. Unexpected map size %U\n"), hash_map_size(&map));
85        exit_failure();
86     }
```

```
87
88  #define NUM_INSERTIONS2 (100000 * 10)
89     Uns *insertions2 = alloc_mem(sizeof(Uns) * NUM_INSERTIONS2);
90     for (int i = 0; i < NUM_INSERTIONS2; i++) {
91        Integer_Slot *s = ALLOC_NEW(Integer_Slot);
92        s->val = rand() % (NUM_INSERTIONS2 >> 1);
93        insertions2[i] = s->val;
94        hash_map_insert(&map, &s->slot, s->val);
95        if (map.num_slots > hash_map_size(&map) * (1 / HASH_MAP_MAX_LOAD_FACTOR) * 3.05 &&
96              map.num_slots > HASH_MAP_PRIME_LIST[HASH_MAP_DEFAULT_SIZE]) {
97           print_message(S("1. Unexpected number of slots size %U\n"), map.num_slots);
98           exit_failure();
99        }
100    }
101
102    if (hash_map_size(&map) != NUM_INSERTIONS2 + INSERT_SIZE - NUM_REMOVED) {
103       print_message(S("3. Unexpected map size %U\n"), hash_map_size(&map));
104       exit_failure();
105    }
106
107    for (Uns i = 0; i < NUM_INSERTIONS2; i++) {
108       if (!hash_map_contains(&map, INT_TO_PTR(insertions2[i]),
109                insertions2[i])) {
110          print_message(S("2. Could not find expected value: %U\n"),
111                insertions2[i]);
112          exit_failure();
113       }
114    }
115
116    for (int i = 0; i < NUM_INSERTIONS2 - NUM_INSERTIONS2 / 10; i++) {
117       free_mem(hash_map_remove(&map, INT_TO_PTR(insertions2[i]),
118             insertions2[i]));
119       if (map.num_slots > hash_map_size(&map) * 6) {
120          print_message(S("2. Unexpected number of slots size %U\n"), map.num_slots);
121          exit_failure();
122       }
123    }
124
125    if (hash_map_size(&map) !=
126          NUM_INSERTIONS2 / 10 + INSERT_SIZE - NUM_REMOVED) {
127       print_message(S("4. Unexpected map size %U\n"), hash_map_size(&map));
128       exit_failure();
129    }
130
131    for (Uns i = NUM_INSERTIONS2 - NUM_INSERTIONS2 / 10; i < NUM_INSERTIONS2; i++) {
132       if (!hash_map_contains(&map, INT_TO_PTR(insertions2[i]),
133                insertions2[i])) {
134          print_message(S("3. Could not find expected value: %U\n"),
135                insertions2[i]);
136          exit_failure();
137       }
138    }
139
140    for (int i = NUM_INSERTIONS2 - NUM_INSERTIONS2 / 10; i < NUM_INSERTIONS2; i++)
141       free_mem(hash_map_remove(&map, INT_TO_PTR(insertions2[i]),
142             insertions2[i]));
143
144    for (Uns i = 0; i < INSERT_SIZE; i++)
145       free_mem(hash_map_remove(&map, INT_TO_PTR(insert_values[i]),
146             insert_values[i]));
147
148    if (hash_map_size(&map) != 0) {
149       print_message(S("5. Unexpected map size %U\n"), hash_map_size(&map));
150       exit_failure();
151    }
152
153    free_mem(insertions2);
154
155 #define NUM_INSERTIONS3 10000
156    for (int i = 0; i < NUM_INSERTIONS3; i++) {
157       Integer_Slot *s = ALLOC_NEW(Integer_Slot);
158       s->val = rand() % 5;
159       hash_map_insert(&map, &s->slot, s->val);
160    }
```

```
161
162     if (hash_map_size(&map) != NUM_INSERTIONS3) {
163        print_message(S("6. Unexpected map size %U\n"), hash_map_size(&map));
164        exit_failure();
165     }
166
167     hash_map_for_each_destroy(&map, hash_map_destructor);
168
169     if (hash_map_size(&map) != 0) {
170        print_message(S("7. Unexpected map size %U\n"), hash_map_size(&map));
171        exit_failure();
172     }
173
174     print_message(S("Hash map test success.\n"));
175  }
```

:

A.10.33 src/test/test_include.h

```
1  #ifndef TEST_INCLUDE_H
2  #define TEST_INCLUDE_H
3
4  void test_hash_map();
5  void test_rb_tree();
6  void test_lists();
7  void test_import_handler();
8
9  #endif // TEST_INCLUDE_H
```

:

A.10.34 src/test/test_lists.c

```
1  #include <std_define.h>
2  #include <std_include.h>
3  #include <timer.h>
4  #include <rb_tree.h>
5  #include <vector.h>
6  #include <double_list.h>
7  #include <single_list.h>
8
9  struct number {
10    Single_List_Node n;
11    int i;
12 };
13
14 struct db_number {
15    Double_List_Node n;
16    int i;
17 };
18
19 struct rb_number {
20    Rb_Tree_Node n;
21    int i;
22 };
23
24 void single_destructor(Single_List_Node *node)
25 {
26    free_mem(CONTAINER_OF(node, struct number, n));
27 }
28
29 void double_destructor(Double_List_Node *node)
30 {
31    free_mem(CONTAINER_OF(node, struct db_number, n));
32 }
33
```

```
34  void tree_destructor(Rb_Tree_Node *node)
35  {
36     free_mem(CONTAINER_OF(node, struct rb_number, n));
37  }
38
39  bool rb_compare(Rb_Tree_Node *ins_node, Rb_Tree_Node *tree_node)
40  {
41     return RB_TREE_ENTRY(ins_node, struct rb_number, n)->i <=
42           RB_TREE_ENTRY(tree_node, struct rb_number, n)->i;
43  }
44
45  #define COUNT 1000000
46
47  void test_lists()
48  {
49     SINGLE_LIST(list);
50     DOUBLE_LIST(d);
51     VECTOR(v);
52     RB_TREE(tree, rb_compare);
53
54     Timer t = TIMER_INIT;
55
56     for (int i = 0; i < COUNT; i++) {
57        struct db_number *num = ALLOC_NEW(struct db_number);
58        num->i = i;
59        double_list_prepend(&d, &num->n);
60     }
61     double_list_for_each_destroy(&d, double_destructor);
62
63     timer_restart(&t);
64     for (int i = 0; i < COUNT; i++) {
65        struct number *num = ALLOC_NEW(struct number);
66        num->i = i;
67        single_list_prepend(&list, &num->n);
68     }
69     timer_stop(&t);
70     print_message(S("Insert %D into single list time: %.2fms\n"),
71           COUNT, timer_get_time(&t));
72     single_list_for_each_destroy(&list, single_destructor);
73
74     timer_restart(&t);
75     for (int i = 0; i < COUNT; i++) {
76        struct db_number *num = ALLOC_NEW(struct db_number);
77        num->i = i;
78        double_list_prepend(&d, &num->n);
79     }
80     timer_stop(&t);
81     print_message(S("Insert %D into double list time: %.2fms\n"),
82           COUNT, timer_get_time(&t));
83     double_list_for_each_destroy(&d, double_destructor);
84
85     timer_restart(&t);
86     for (int i = 0; i < COUNT; i++)
87        vector_append(&v, INT_TO_PTR(i));
88     timer_stop(&t);
89     print_message(S("Insert %D into vector time: %.2fms\n"),
90           COUNT, timer_get_time(&t));
91     vector_clear(&v);
92
93     timer_restart(&t);
94     for (int i = 0; i < COUNT; i++) {
95        struct rb_number *num = ALLOC_NEW(struct rb_number);
96        num->i = i;
97        rb_tree_insert(&tree, &num->n);
98     }
99     timer_stop(&t);
100    print_message(S("Insert %D into rb tree time: %.2fms\n"),
101          COUNT, timer_get_time(&t));
102    rb_tree_for_each_destroy(&tree, tree_destructor);
103 }
```

:

A.10.35 src/test/test_rb_tree.c

```
#include <parser.h>
#include <std_define.h>
#include <std_include.h>
#include <stdio.h>
#include <double_list.h>

#include <time.h>
#include <stdlib.h>
#include <rb_tree.h>

static Uns black_count;

struct RB_Data {
   Rb_Tree_Node n;
   int i;
};

Rb_Tree_Color test_tree(Rb_Tree *tree, Rb_Tree_Node *node, Uns bc)
{
   if (node->color == RB_TREE_BLACK)
      ++bc;

   if (node == RB_TREE_NULL(tree)) {
      if (!black_count)
         black_count = bc;
      else if (bc != black_count)
         print_message(S("WRONG BLACK COUNT! Black count = %U\n"), bc);
      return node->color;
   }

   if (test_tree(tree, node->left, bc) == RB_TREE_RED &&
         node->color == RB_TREE_RED)
      print_message(S("TWO RED NODES IN A ROW!\n"));
   if (test_tree(tree, node->right, bc) == RB_TREE_RED &&
         node->color == RB_TREE_RED)
      print_message(S("TWO RED NODES IN A ROW!\n"));

   return node->color;
}

void test_tree_balance(Rb_Tree *tree)
{
   black_count = 0;
   if (tree->root->color == RB_TREE_RED)
      print_message(S("RED ROOT MAN!\n"));
   test_tree(tree, tree->root, 0);
}

static Uns print_tree_indent;

void print_node_inorder(Rb_Tree *tree, Rb_Tree_Node *n)
{
   struct RB_Data *data = RB_TREE_ENTRY(n, struct RB_Data, n);
   for (Uns i = 0; i < print_tree_indent; i++)
      print_message(S(" "));
   print_message(S("<node color=\"%S\" value=\"%D\">\n"),
         n->color == RB_TREE_BLACK ? S("black") : S("red"),
         data->i);
   print_tree_indent += 4;
   for (Uns i = 0; i < print_tree_indent - 4; i++)
      print_message(S(" "));
   print_message(S("LEFT:\n"));
   if (n->left != RB_TREE_NULL(tree))
      print_node_inorder(tree, n->left);
   for (Uns i = 0; i < print_tree_indent - 4; i++)
      print_message(S(" "));
   print_message(S("RIGHT:\n"));
   if (n->right != RB_TREE_NULL(tree))
      print_node_inorder(tree, n->right);
   print_tree_indent -= 4;
#if 0
```

```
72       for (Uns i = 0; i < print_tree_indent; i++)
73          print_message(S(" "));
74       print_message(S("</node color=\"%S\" value=\"%ld\">\n"),
75             n->color == RB_TREE_BLACK ? S("black") : S("red"),
76             PTR_TO_INT(n->data));
77    #endif
78    }
79
80    void print_tree(Rb_Tree *tree)
81    {
82       print_tree_indent = 0;
83       if (tree->root != RB_TREE_NULL(tree))
84          print_node_inorder(tree, tree->root);
85    }
86
87    static int prev_value;
88
89    void callback(Rb_Tree_Node *node)
90    {
91       struct RB_Data *data = RB_TREE_ENTRY(node, struct RB_Data, n);
92       if (prev_value > data->i)
93          print_message(S("TREE CORRUPTED!\n"));
94       prev_value = data->i;
95    }
96
97    bool compare(Rb_Tree_Node *search_node, Rb_Tree_Node *tree_node)
98    {
99       struct RB_Data *lhs = RB_TREE_ENTRY(search_node, struct RB_Data, n);
100      struct RB_Data *rhs = RB_TREE_ENTRY(tree_node, struct RB_Data, n);
101      return lhs->i <= rhs->i;
102   }
103
104   Int search_compare(void *arg, Rb_Tree_Node *tree_node)
105   {
106      struct RB_Data *d = RB_TREE_ENTRY(tree_node, struct RB_Data, n);
107      if (PTR_TO_INT(arg) < d->i)
108         return -1;
109      if (PTR_TO_INT(arg) > d->i)
110         return 1;
111      return 0;
112   }
113
114   void destructor(Rb_Tree_Node *node)
115   {
116      free_mem(RB_TREE_ENTRY(node, struct RB_Data, n));
117   }
118
119   void test_rb_tree()
120   {
121      srand(time(NULL));
122
123      RB_TREE(t, compare);
124
125   #define OUTER_ITERS 100
126   #define LOOP_ITERS 10000
127   #define VALUES_SIZE (LOOP_ITERS - 1)
128
129      int *values = alloc_mem(sizeof(int) * VALUES_SIZE);
130
131      for (Uns u = 0; u < OUTER_ITERS; u++) {
132         for (Uns i = 0; i < LOOP_ITERS; i++) {
133            struct RB_Data *d = ALLOC_NEW(struct RB_Data);
134            d->i = rand();
135            rb_tree_insert(&t, &d->n);
136            if (i < VALUES_SIZE)
137               values[i] = d->i;
138         }
139
140         prev_value = 0;
141         rb_tree_for_each(&t, callback);
142         test_tree_balance(&t);
143
144         for (Uns i = 0; i < VALUES_SIZE; i++) {
145            Rb_Tree_Node *removed_node = rb_tree_search_remove(&t,
```

```
                search_compare, INT_TO_PTR(values[i]));
            free_mem(removed_node);
        }

        prev_value = 0;
        rb_tree_for_each(&t, callback);
        test_tree_balance(&t);
    }

    free_mem(values);
    // print_tree(&t);
    print_message(S("Tree size: %U\n"), rb_tree_size(&t));

    rb_tree_for_each_destroy(&t, destructor);
}
```

:

A.10.36 src/timer.c

```
#include <timer.h>
#include <sys/time.h>
#include <stddef.h>

void timer_start(Timer *t)
{
    struct timeval tv;
    if (!t->start_time) {
        /* Should never fail here. */
        gettimeofday(&tv, NULL);
        t->start_time = tv.tv_sec * 1000.0 + tv.tv_usec / 1000.0;
    }
    t->started = 1;
}

void timer_restart(Timer *t)
{
    t->start_time = 0.0;
    timer_start(t);
}

void timer_stop(Timer *t)
{
    struct timeval tv;
    if (t->started) {
        /* Should never fail here. */
        gettimeofday(&tv, NULL);
        t->stop_time = tv.tv_sec * 1000.0 + tv.tv_usec / 1000.0;
    }
}

double timer_get_time(Timer *t)
{
    return t->stop_time - t->start_time;
}
```

:

A.10.37 src/timer.h

```
#ifndef TIMER_H
#define TIMER_H

typedef struct Timer {
    double start_time;
    double stop_time;
    int started;
```

```
8  } Timer;
9
10 #define TIMER_STATIC_INIT {0.0, 0.0, 0}
11 #define TIMER_INIT ((Timer)TIMER_STATIC_INIT)
12
13 void timer_start(Timer *t);
14
15 void timer_restart(Timer *t);
16
17 void timer_stop(Timer *t);
18
19 double timer_get_time(Timer *t);
20
21 #endif // TIMER_H
```

:

A.10.38 src/vector.c

```
1  #include <vector.h>
2
3  void *vector_pop_last(Vector *v)
4  {
5     Uns next_idx;
6     void *data;
7     next_idx = v->next_idx;
8
9     assert(next_idx > 0);
10
11    data = v->array[--next_idx];
12    if (next_idx <= v->curr_size >> 2 && next_idx >= v->min_size) {
13       v->next_size = v->curr_size;
14       v->curr_size >>= 1;
15       v->array = realloc_mem(v->array, v->curr_size * sizeof(void *));
16    }
17    v->next_idx = next_idx;
18    return data;
19 }
20
21 void vector_sort(Vector *v, Vector_Comparator comparator)
22 {
23    int vector_comparator_bounce(const void *lhs, const void *rhs)
24    {
25       return comparator(*(const void **)lhs, *(const void **)rhs);
26    }
27    qsort(v->array, vector_size(v), sizeof(void *), vector_comparator_bounce);
28 }
```

:

A.10.39 src/vector.h

```
1  #ifndef VECTOR_H
2  #define VECTOR_H
3
4  #include <std_define.h>
5  #include <alloc.h>
6
7  /* XXX Don't use debug macros to debug vector implementation since the
8   * debug implementation uses Vector. */
9
10 typedef struct Vector {
11    void **array;
12    Uns min_size;
13    Uns next_size;
14    Uns curr_size;
15    Uns next_idx;
```

```
16 } Vector;
17
18 #define VECTOR_DEFAULT_SIZE 8
19
20 /* Note that init_size must be > 0 */
21 #define VECTOR_STATIC_INIT_SIZE(init_size) { \
22    .array = NULL,                    \
23    .min_size = init_size,            \
24    .next_size = init_size,           \
25    .curr_size = 0,                   \
26    .next_idx = 0                     \
27 }
28
29 #define VECTOR_INIT_SIZE(init_size) \
30    ((Vector)VECTOR_STATIC_INIT_SIZE(init_size))
31
32 #define VECTOR_STATIC_INIT() VECTOR_STATIC_INIT_SIZE(VECTOR_DEFAULT_SIZE)
33
34 #define VECTOR_INIT() ((Vector)VECTOR_STATIC_INIT())
35
36 #define VECTOR(vec) Vector vec = VECTOR_STATIC_INIT()
37
38 /* Note that init_size must be > 0 */
39 #define VECTOR_SIZE(vec, size) Vector vec = VECTOR_STATIC_INIT_SIZE(size)
40
41 /* Allocate and initialize vector with initial size: 'size'. */
42 static inline Vector *vector_alloc_size(Uns size)
43 {
44    Vector *ret = ALLOC_NEW(Vector);
45    *ret = VECTOR_INIT_SIZE(size);
46    return ret;
47 }
48
49 /* Allocate and initialize vector with initial default size. */
50 static inline Vector *vector_alloc()
51 {
52    return vector_alloc_size(VECTOR_DEFAULT_SIZE);
53 }
54
55 /* Warning. The function does not check whether the Uns integer containing
56  * the size of the vector overflows. So make sure the size of the vector
57  * is <= UNSIGNED_MAX before calling this function. */
58 static inline void vector_append(Vector *v, void *data)
59 {
60    assert(v->next_idx <= UNSIGNED_MAX);
61    if (v->next_idx >= v->curr_size) {
62       v->array = realloc_mem(v->array, v->next_size * sizeof(void *));
63       v->curr_size = v->next_size;
64       v->next_size <<= 1;
65    }
66    v->array[v->next_idx++] = data;
67 }
68
69 /* Warning, no bounds checking. Make sure size of vector > 0. */
70 void *vector_pop_last(Vector *v);
71
72 static inline Uns vector_size(Vector *v)
73 {
74    return v->next_idx;
75 }
76
77 static inline void *vector_peek_last(Vector *v)
78 {
79    assert(vector_size(v) > 0);
80    return v->array[vector_size(v) - 1];
81 }
82
83 typedef void (*Vector_Destructor)(void *data);
84
85 /* Should return -1 when search_obj < vec_obj,
86  * and return 0 when search_obj == vec_obj,
87  * and return 1 when search_obj > vec_obj. */
88 typedef int (*Vector_Comparator)(const void *search_obj, const void *vec_obj);
89
```

```
90  static inline void vector_set(Vector *v, Uns idx, void *data)
91  {
92     assert(idx <= v->next_idx);
93     if (idx < v->next_idx)
94        v->array[idx] = data;
95     else
96        vector_append(v, data);
97  }
98
99  /* Warning, no bounds checking. Make sure size of vector > 0. */
100 static inline void vector_set_last(Vector *v, void *data)
101 {
102    assert(vector_size(v) > 0);
103    v->array[vector_size(v) - 1] = data;
104 }
105
106 /* Warning, no bounds checking. Make sure idx < size of vector. */
107 static inline void *vector_get(Vector *v, Uns idx)
108 {
109    assert(idx < v->next_idx);
110    return v->array[idx];
111 }
112
113 /* Swap two vector elements.
114  * Warning, no bounds checking. Make sure idx1 < size of vector
115  * and idx2 < size of vector. */
116 static inline void vector_swap(Vector *v, Uns idx1, Uns idx2)
117 {
118    void *tmp = vector_get(v, idx1);
119    vector_set(v, idx1, vector_get(v, idx2));
120    vector_set(v, idx2, tmp);
121 }
122
123 /* idx must be <= vector size. */
124 static inline void vector_insert(Vector *v, Uns idx, void *data)
125 {
126    Uns size = vector_size(v);
127    assert(idx <= size);
128    if (idx < size) {
129       vector_append(v, vector_get(v, size - 1));
130       for (Uns i = idx; i < size - 1; i++)
131          vector_set(v, i + 1, vector_get(v, i));
132       vector_set(v, idx, data);
133    } else {
134       vector_append(v, data);
135    }
136 }
137
138 /* idx must be < vector size. */
139 static inline void *vector_remove(Vector *v, Uns idx)
140 {
141    Uns size = vector_size(v);
142    assert(idx < size);
143    void *ret = vector_get(v, idx);
144    for (Uns i = idx; i < size - 1; i++)
145       vector_set(v, i, vector_get(v, i + 1));
146    vector_pop_last(v);
147    return ret;
148 }
149
150 /* remove ptr from v.
151  * Returns true if ptr was in the vector.
152  * Otherwise returns false. */
153 static inline bool vector_remove_ptr(Vector *v, void *ptr)
154 {
155    Uns size = vector_size(v);
156    for (Uns i = 0; i < size; i++) {
157       if (vector_get(v, i) == ptr) {
158          vector_remove(v, i);
159          return true;
160       }
161    }
162    return false;
163 }
```

```
164
165  /* Warning, no bounds checking. Make sure idx < size of vector. */
166  static inline void *vector_peek_first(Vector *v)
167  {
168     return vector_get(v, 0);
169  }
170
171  static inline bool vector_is_empty(const Vector *v)
172  {
173     return !v->next_idx;
174  }
175
176  #define VECTOR_FOR_EACH_ENTRY(vec_ptr, data_ptr)      \
177  for (Uns ___i = 0; ___i < (vec_ptr)->next_idx &&      \
178        ((data_ptr = (__typeof__(data_ptr))(vec_ptr)->array[___i]) || \
179        !data_ptr); ___i++)
180
181  #define VECTOR_FOR_EACH_ENTRY_REVERSED(vec_ptr, data_ptr)     \
182  if ((vec_ptr)->next_idx)                                      \
183     for (Uns ___i = (vec_ptr)->next_idx; ___i > 0 &&      \
184           ((data_ptr = (__typeof__(data_ptr))(vec_ptr)->array[--___i]) || \
185           !data_ptr); )
186
187  static inline void vector_clear(Vector *v)
188  {
189     v->next_size = v->min_size;
190     v->curr_size = 0;
191     v->next_idx = 0;
192     free_mem(v->array);
193     v->array = NULL;
194  }
195
196  static inline void vector_for_each_destroy(Vector *v,
197        Vector_Destructor destructor)
198  {
199     void *data;
200     VECTOR_FOR_EACH_ENTRY(v, data)
201        destructor(data);
202     vector_clear(v);
203  }
204
205  static inline void vector_destroy(Vector *v, Vector_Destructor destructor)
206  {
207     if (!v)
208        return;
209
210     if (destructor)
211        vector_for_each_destroy(v, destructor);
212     vector_clear(v);
213     free_mem(v);
214  }
215
216  static inline bool vector_contains_ptr(Vector *v, const void *p)
217  {
218     void *oth;
219     VECTOR_FOR_EACH_ENTRY(v, oth) {
220        if (oth == p)
221           return true;
222     }
223     return false;
224  }
225
226  static inline bool vector_contains(Vector *v, Vector_Comparator comparator,
227        const void *comparator_arg)
228  {
229     void *data;
230     VECTOR_FOR_EACH_ENTRY(v, data) {
231        if (!comparator(comparator_arg, data))
232           return true;
233     }
234     return false;
235  }
236
237  void vector_sort(Vector *v, Vector_Comparator comparator);
```

```
238
239 #endif // VECTOR_H
```

A.11 Makefile System

:

A.11.1 src/aia/Makefile

```
1
2 ROOT_DIR := $(shell for i in `seq 0 9`;  \
3   do if [ -n "`ls | grep Makefile.inc`" ]; \
4   then pwd; break; else cd ..; fi; done)
5
6 CSOURCE := $(shell ls *.c)
7
8 include $(ROOT_DIR)/Makefile.inc
```

:

A.11.2 src/ast/Makefile

```
1
2 ROOT_DIR := $(shell for i in `seq 0 9`;  \
3   do if [ -n "`ls | grep Makefile.inc`" ]; \
4   then pwd; break; else cd ..; fi; done)
5
6 CSOURCE := $(shell ls *.c)
7
8 include $(ROOT_DIR)/Makefile.inc
```

:

A.11.3 src/Makefile

```
1
2 ROOT_DIR := $(shell for i in `seq 0 9`;  \
3   do if [ -n "`ls | grep Makefile.inc`" ]; \
4   then pwd; break; else cd ..; fi; done)
5
6 BIN_NAME := vitaly
7 AST_DIR := ast
8 AIA_DIR := aia
9 X86_32_DIR := x86_32
10 PARSER_DIR := parser
11 PARSER_GEN_DIR := $(PARSER_DIR)/gen
12 TEST_DIR := test
13 VIT_DIR := vit
14
15 EXTRA_BUILD_TARGETS := $(BIN_NAME) vitalysrc
16 EXTRA_CLEAN_TARGETS := $(BIN_NAME)_clean vitalysrc_clean
17 NEEDED_PROGRAMS := $(FLEX) $(BISON)
18 DEPDIRS := $(PARSER_DIR) $(PARSER_GEN_DIR) $(AIA_DIR) $(AST_DIR) \
19   $(X86_32_DIR) $(TEST_DIR)
20
21 SCAN_C := $(PARSER_GEN_DIR)/scanner.yy.c
22 PARSE_C := $(PARSER_GEN_DIR)/parser.tab.c
23
24 CSOURCE := $(shell ls *.c) $(SCAN_C) $(PARSE_C)
25
26 include $(ROOT_DIR)/Makefile.inc
27
```

```
28 LD = $(CC)
29 LIBS := -lfl
30 LFLAGS := -m$(ARCH)
31
32 BINARY_DIR := $(shell cd $(OUT_DIR)/.. 2> /dev/null; pwd)
33 BINARY := $(BINARY_DIR)/$(BIN_NAME)
34
35 $(BIN_NAME): $(BINARY)
36
37 $(BINARY): $(COBJ) $(OUT_DIR)/$(AST_DIR)/*.o $(OUT_DIR)/$(AIA_DIR)/*.o \
38   $(OUT_DIR)/$(TEST_DIR)/*.o $(OUT_DIR)/$(X86_32_DIR)/*.o
39 ifeq ($(VERBOSE), y)
40    $(LD) $(LFLAGS) -o $@ $^ $(LIBS)
41 else
42    @echo LD $@
43    @$(LD) $(LFLAGS) -o $@ $^ $(LIBS)
44 endif
45
46 $(BIN_NAME)_clean:
47 ifeq ($(VERBOSE), y)
48    $(RM) $(BINARY)
49 else
50    @echo clean $(BINARY_DIR)
51    @$(RM) $(BINARY)
52 endif
53
54 vitalysrc:
55    @$(MAKE) -C $(VIT_DIR)
56
57 vitalysrc_clean:
58    @$(MAKE) -C $(VIT_DIR) clean
```

:

A.11.4 src/parser/gen/Makefile

```
1
2 ROOT_DIR := $(shell for i in `seq 0 9`;  \
3   do if [ -n "`ls | grep Makefile.inc`" ]; \
4   then pwd; break; else cd ..; fi; done)
5
6 include $(ROOT_DIR)/Makefile.inc
```

:

A.11.5 src/parser/Makefile

```
1
2 ROOT_DIR := $(shell for i in `seq 0 9`;  \
3   do if [ -n "`ls | grep Makefile.inc`" ]; \
4   then pwd; break; else cd ..; fi; done)
5
6 LEX = flex
7 YACC = bison
8
9 EXTRA_BUILD_TARGETS := parser_source
10 EXTRA_CLEAN_TARGETS := scan_parse_clean
11 NEEDED_PROGRAMS := $(LEX) $(YACC)
12 DEPDIRS := gen
13
14 include $(ROOT_DIR)/Makefile.inc
15
16 GEN_DIR := $(WORKING_DIR)/gen
17 SCAN_C := $(GEN_DIR)/scanner.yy.c
18 PARSE_C := $(GEN_DIR)/parser.tab.c
19 PARSE_H := $(GEN_DIR)/parser.tab.h
20 PARSE_OUT := $(GEN_DIR)/parser.output
```

```
21
22 parser_source: $(PARSE_C) $(SCAN_C)
23
24 $(SCAN_C): scanner.l
25 ifeq ($(VERBOSE), y)
26    $(LEX) -o $(SCAN_C) scanner.l
27 else
28    @echo LEX $(SCAN_C)
29    @$(LEX) -o $(SCAN_C) scanner.l
30 endif
31
32 $(PARSE_C): parser.y
33 ifeq ($(VERBOSE), y)
34    $(YACC) -vd -o $(PARSE_C) --defines=$(PARSE_H) \
35      --report-file=$(PARSE_OUT) parser.y
36 else
37    @echo YACC $(PARSE_C)
38    @$(YACC) -vd -o $(PARSE_C) --defines=$(PARSE_H) \
39      --report-file=$(PARSE_OUT) parser.y
40 endif
41
42 scan_parse_clean:
43 ifeq ($(VERBOSE), y)
44    $(RM) $(SCAN_C)
45    $(RM) $(PARSE_C)
46    $(RM) $(PARSE_H)
47    $(RM) $(PARSE_OUT)
48 else
49    @echo clean $(GEN_DIR)
50    @$(RM) $(SCAN_C)
51    @$(RM) $(PARSE_C)
52    @$(RM) $(PARSE_H)
53    @$(RM) $(PARSE_OUT)
54 endif
```

:

A.11.6 src/test/Makefile

```
1
2 ROOT_DIR := $(shell for i in `seq 0 9`;  \
3   do if [ -n "`ls | grep Makefile.inc`" ]; \
4   then pwd; break; else cd ..; fi; done)
5
6 CSOURCE := $(shell ls *.c)
7
8 include $(ROOT_DIR)/Makefile.inc
```

:

A.11.7 src/vit/Makefile

```
1
2 ROOT_DIR := $(shell for i in `seq 0 9`;  \
3   do if [ -n "`ls | grep Makefile.inc`" ]; \
4   then pwd; break; else cd ..; fi; done)
5
6 LIBVIT_DIR := std
7 LIBVIT_THREAD_DIR := _vit_thread
8
9 EXTRA_BUILD_TARGETS := startfiles libvitaly
10 EXTRA_CLEAN_TARGETS := startfiles_clean libvitaly_clean
11
12 include $(ROOT_DIR)/Makefile.inc
13
14 CSOURCE := lib.c
15 COBJ  := $(CSOURCE:%.c=$(OUT_DIR)/%.o)
```

```
16
17 override CFLAGS := -O4 -Wall -Wextra -c -m32 -std=c99 -g
18
19 SSOURCE := ini.s vitmain.s retmain.s end.s # lib.s
20 SOBJ  := $(SSOURCE:%.s=$(OUT_DIR)/%.o)
21
22 startfiles: $(SOBJ) $(COBJ)
23
24 $(SOBJ): $(OUT_DIR)/%.o: %.s
25 ifeq ($(VERBOSE), y)
26    $(AS) $(SFLAGS) -o $@ $(@:$(OUT_DIR)/%.o=%.s)
27 else
28    @echo AS $(@:$(OUT_DIR)/%.o=$(shell pwd)/%.s)
29    @$(AS) $(SFLAGS) -o $@ $(@:$(OUT_DIR)/%.o=%.s)
30 endif
31
32 $(COBJ): $(OUT_DIR)/%.o: %.c
33 ifeq ($(VERBOSE), y)
34    $(CC) $(CFLAGS) -o $@ $(@:$(OUT_DIR)/%.o=%.c)
35 else
36    @echo CC $(@:$(OUT_DIR)/%.o=$(shell pwd)/%.c)
37    @$(CC) $(CFLAGS) -o $@ $(@:$(OUT_DIR)/%.o=%.c)
38 endif
39
40 startfiles_clean:
41 ifeq ($(VERBOSE), y)
42    $(RM) $(SOBJ)
43 else
44    @echo clean $(OUT_DIR)
45    @$(RM) $(SOBJ)
46 endif
47
48 libvitaly:
49    @$(MAKE) -C $(LIBVIT_DIR)
50    @$(MAKE) -C $(LIBVIT_THREAD_DIR)
51
52 libvitaly_clean:
53    @$(MAKE) -C $(LIBVIT_DIR) clean
54    @$(MAKE) -C $(LIBVIT_THREAD_DIR) clean
```

:

A.11.8 src/vit/std/c/Makefile

```
1
2 ROOT_DIR := $(shell for i in `seq 0 9`;  \
3  do if [ -n "`ls | grep Makefile.inc`" ]; \
4  then pwd; break; else cd ..; fi; done)
5
6 include $(ROOT_DIR)/Makefile.inc
```

:

A.11.9 src/vit/std/Makefile

```
1
2 ROOT_DIR := $(shell for i in `seq 0 9`;  \
3  do if [ -n "`ls | grep Makefile.inc`" ]; \
4  then pwd; break; else cd ..; fi; done)
5
6 EXTRA_BUILD_TARGETS := libvitaly
7 EXTRA_CLEAN_TARGETS := libvitaly_clean
8 DEPDIRS := c
9
10 include $(ROOT_DIR)/Makefile.inc
11
12 override CSOURCE := cerrno.c c/cstdio.c
```

```
override COBJ  := $(CSOURCE:%.c=$(OUT_DIR)/%.o)
override CFLAGS  := -Wall -g -c -m32

VITSOURCE := string.vit c/string.vit object.vit indexable.vit \
   array.vit comparator.vit sort.vit vector.vit errno.vit math.vit \
   stdio.vit c/stdio.vit c/ctype.vit stdlib.vit
VITOBJ   := $(VITSOURCE:%.vit=$(OUT_DIR)/%.o)
VITI     := $(VITSOURCE:%.vit=$(OUT_DIR)/%.viti)
VITFLAGS := -c -I --lib-init
VITALY   := $(ROOT_DIR)/bin/vitaly
LIBVIT   := $(OUT_DIR)/../libvitaly.a

libvitaly: $(LIBVIT) viti_mv

$(LIBVIT): $(COBJ) $(VITOBJ)
ifeq ($(VERBOSE), y)
   $(AR) ruv $@ $^
   ranlib $@
else
   @echo AR $@
   @$(AR) ruv $@ $^ > /dev/null
   @ranlib $@
endif

.PHONY: $(VITOBJ)
$(VITOBJ):
ifeq ($(VERBOSE), y)
   $(VITALY) $(VITFLAGS) -o $@ $(@:$(OUT_DIR)/%.o=%.vit)
else
   @echo VITALY $(@:$(OUT_DIR)/%.o=$(shell pwd)/%.vit)
   @$(VITALY) $(VITFLAGS) -o $@ $(@:$(OUT_DIR)/%.o=%.vit)
endif

.PHONY: $(COBJ)
$(COBJ):
ifeq ($(VERBOSE), y)
   $(CC) $(CFLAGS) -o $@ $(@:$(OUT_DIR)/%.o=%.c)
else
   @echo CC $(@:$(OUT_DIR)/%.o=$(shell pwd)/%.c)
   @$(CC) $(CFLAGS) -o $@ $(@:$(OUT_DIR)/%.o=%.c)
endif

viti_mv:
ifeq ($(VERBOSE), y)
   mv *.viti $(OUT_DIR)
   mv c/*.viti $(OUT_DIR)/c
else
   @mv *.viti $(OUT_DIR)
   @mv c/*.viti $(OUT_DIR)/c
endif

libvitaly_clean:
ifeq ($(VERBOSE), y)
   $(RM) $(VITI)
   $(RM) $(VITOBJ)
   $(RM) $(LIBVIT)
else
   @echo clean $(OUT_DIR)
   @$(RM) $(VITI)
   @$(RM) $(VITOBJ)
   @$(RM) $(LIBVIT)
endif
```

:

A.11.10 src/vit/_vit_thread/Makefile

```

ROOT_DIR := $(shell for i in `seq 0 9`;  \
  do if [ -n "`ls | grep Makefile.inc`" ]; \
  then pwd; break; else cd ..; fi; done)
```

```
5
6  DEPDIRS = std
7
8  include $(ROOT_DIR)/Makefile.inc
```

:

A.11.11 src/vit/_vit_thread/std/Makefile

```
1
2  ROOT_DIR := $(shell for i in `seq 0 9`;  \
3    do if [ -n "`ls | grep Makefile.inc`" ]; \
4    then pwd; break; else cd ..; fi; done)
5
6  EXTRA_BUILD_TARGETS := libvitaly_thread
7  EXTRA_CLEAN_TARGETS := libvitaly_thread_clean
8
9  include $(ROOT_DIR)/Makefile.inc
10
11 override CSOURCE := cthread.c clock.c
12 override COBJ  := $(CSOURCE:%.c=$(OUT_DIR)/%.o)
13 override CFLAGS  := -Wall -g -c -m32 -pthread -D_GNU_SOURCE
14
15 VITSOURCE   := thread.vit lock.vit
16 VITOBJ      := $(VITSOURCE:%.vit=$(OUT_DIR)/%.o)
17 VITI        := $(VITSOURCE:%.vit=$(OUT_DIR)/%.viti)
18 VITFLAGS    := -c -I --lib-init --thread
19 VITALY      := $(ROOT_DIR)/bin/vitaly
20 LIBVIT_THREAD := $(OUT_DIR)/../../libvitaly-thread.a
21
22 $(OUT_DIR)/thread.o: VITFLAGS += --dump=c-header
23 $(OUT_DIR)/lock.o:  VITFLAGS += --dump=c-header
24
25 libvitaly_thread: $(LIBVIT_THREAD) viti_mv
26
27 $(LIBVIT_THREAD): $(COBJ) $(VITOBJ)
28 ifeq ($(VERBOSE), y)
29    $(AR) ruv $@ $^
30    ranlib $@
31 else
32    @echo AR $@
33    @$(AR) ruv $@ $^ > /dev/null
34    @ranlib $@
35 endif
36
37 .PHONY: $(VITOBJ)
38 $(VITOBJ):
39 ifeq ($(VERBOSE), y)
40    $(VITALY) $(VITFLAGS) -o $@ $(@:$(OUT_DIR)/%.o=%.vit)
41 else
42    @echo VITALY $(@:$(OUT_DIR)/%.o=$(shell pwd)/%.vit)
43    @$(VITALY) $(VITFLAGS) -o $@ $(@:$(OUT_DIR)/%.o=%.vit)
44 endif
45
46 .PHONY: $(COBJ)
47 $(COBJ): $(VITOBJ)
48 ifeq ($(VERBOSE), y)
49    $(CC) $(CFLAGS) -o $@ $(@:$(OUT_DIR)/%.o=%.c)
50 else
51    @echo CC $(@:$(OUT_DIR)/%.o=$(shell pwd)/%.c)
52    @$(CC) $(CFLAGS) -o $@ $(@:$(OUT_DIR)/%.o=%.c)
53 endif
54
55 viti_mv:
56 ifeq ($(VERBOSE), y)
57    mv *.viti $(OUT_DIR)
58 else
59    @mv *.viti $(OUT_DIR)
60 endif
61
62 libvitaly_thread_clean:
```

```
ifeq ($(VERBOSE), y)
   $(RM) $(VITI)
   $(RM) $(VITOBJ)
   $(RM) $(LIBVIT)
   $(RM) *.vitaly.*
else
   @echo clean $(OUT_DIR)
   @echo clean $(shell pwd)
   @$(RM) $(VITI)
   @$(RM) $(VITOBJ)
   @$(RM) $(LIBVIT)
   @$(RM) *.vitaly.*
endif
```

:

A.11.12 src/x86_32/Makefile

```

ROOT_DIR := $(shell for i in `seq 0 9`;  \
  do if [ -n "`ls | grep Makefile.inc`" ]; \
  then pwd; break; else cd ..; fi; done)

CSOURCE := $(shell ls *.c)

include $(ROOT_DIR)/Makefile.inc
```

A.12 Vitaly Standard Library

:

A.12.1 src/vit/std/array.vit

```
package std;

import std.indexable;
import std.object;
import std.errno;

type Array = record of Indexable {
   _ary:array of Object;

   func record (size:int):void
      if (size < 0) then {
         errno.set(einval());
         _ary = null;
         return;
      }
      allocate _ary of length size;
   end record

   func get(i:int):Object
      if (!record[]._verifyIdx(i)) then
         return null;
      return _ary[i];
   end get

   func set(i:int, obj:Object):bool
      if (!record[]._verifyIdx(i)) then
         return false;
      _ary[i] = obj;
      return true;
   end set

   func _verifyIdx(i:int):bool
```

```
33          if (_ary == null) then {
34             errno.set(efault());
35             return false;
36          }
37
38          if (i < 0 || i >= size()) then {
39             errno.set(einval());
40             return false;
41          }
42
43          return true;
44       end _verifyIdx
45
46       func size():int
47          if (_ary == null) then {
48             errno.set(efault());
49             return 0 - 1;
50          }
51          return |_ary|;
52       end size
53
54       func destroy():void
55          i:int = 0;
56          while (i < size()) do {
57             delete get(i);
58             i = i + 1;
59          }
60          delete record;
61       end destroy
62
63       func finalize():void
64          delete _ary;
65       end finalize
66    };
```

:

A.12.2 src/vit/std/cerrno.c

```
1  #include <errno.h>
2
3  int _Vit_get_errno()
4  {
5     return errno;
6  }
7
8  void _Vit_set_errno(int no)
9  {
10    errno = no;
11 }
```

:

A.12.3 src/vit/std/c/cstdio.c

```
1  #include <stdio.h>
2  #include <stdbool.h>
3
4  int _Vit_gets(void *dest, int size)
5  {
6     size_t n = fread(dest, 1, (size_t)size, stdin);
7     return n;
8  }
9
10 bool _Vit_feof()
11 {
12    return feof(stdin);
```

```
}

bool _Vit_ferror()
{
   return ferror(stdin);
}
```

:

A.12.4 src/vit/std/c/ctype.vit

```
package std.c;

extern(C) func isspace(i:int):int;

extern(C) func isblank(i:int):int;
```

:

A.12.5 src/vit/std/c/stdio.vit

```
package std.c;

extern(C) func printf(fmt:string):int;
extern(C) func puts(s:string):int;
extern(C) func getchar():int;
```

:

A.12.6 src/vit/std/c/string.vit

```
package std.c;

import std.object;

extern(C) func strcmp(lhs:string, rhs:string):int;
extern(C) func strlen(s:string):int;

extern(C) func strnlen(s:string, maxLen:int):int;

extern(C) func memcpy(dest:array of char, src:string, size:int):void;
extern(C) func memcpy(dest:array of char, src:array of char, size:int):void;

func memcpy(dest:array of Object, src:array of Object, size:int):void
   extern(C) func memcpy(dest:array of Object, src:array of Object, size:int):void
       ;
   memcpy(dest, src, size * 4);
end memcpy
```

:

A.12.7 src/vit/std/comparator.vit

```
package std;

import object;

type Comparator = record of {
   func compare(obj:Object, obj2:Object):int
      return 0;
   end compare
```

```
};
```

:

A.12.8 src/vit/std/errno.vit

```
package std;

import std.string;
import std.object;

extern(C) func strerror(no:int):string;

func eperm():int
   return 1;
end eperm
func enoent():int
   return 2;
end enoent
func esrch():int
   return 3;
end esrch
func eintr():int
   return 4;
end eintr
func eio():int
   return 5;
end eio
func enxio():int
   return 6;
end enxio
func e2big():int
   return 7;
end e2big
func enoexec():int
   return 8;
end enoexec
func ebadf():int
   return 9;
end ebadf
func echild():int
   return 10;
end echild
func eagain():int
   return 11;
end eagain
func enomem():int
   return 12;
end enomem
func eacces():int
   return 13;
end eacces
func efault():int
   return 14;
end efault
func enotblk():int
   return 15;
end enotblk
func ebusy():int
   return 16;
end ebusy
func eexist():int
   return 17;
end eexist
func exdev():int
   return 18;
end exdev
func enodev():int
   return 19;
end enodev
func enotdir():int
```

```
66      return 20;
67   end enotdir
68   func eisdir():int
69      return 21;
70   end eisdir
71   func einval():int
72      return 22;
73   end einval
74   func enfile():int
75      return 23;
76   end enfile
77   func emfile():int
78      return 24;
79   end emfile
80   func enotty():int
81      return 25;
82   end enotty
83   func etxtbsy():int
84      return 26;
85   end etxtbsy
86   func efbig():int
87      return 27;
88   end efbig
89   func enospc():int
90      return 28;
91   end enospc
92   func espipe():int
93      return 29;
94   end espipe
95   func erofs():int
96      return 30;
97   end erofs
98   func emlink():int
99      return 31;
100  end emlink
101  func epipe():int
102     return 32;
103  end epipe
104  func edom():int
105     return 33;
106  end edom
107  func erange():int
108     return 34;
109  end erange
110
111  func errno():int
112     extern(C) func _Vit_get_errno():int;
113     return _Vit_get_errno();
114  end errno
115
116  func errno(no:int):void
117     extern(C) func _Vit_set_errno(no:int):void;
118     _Vit_set_errno(no);
119  end errno
120
121  type Errno = record of Object {
122
123     func set(no:int):int
124        old:int = get();
125        errno(no);
126        return old;
127     end set
128
129     func clear():int
130        return set(0);
131     end clear
132
133     func get():int
134        return errno();
135     end get
136
137     func appendTo(dest:String):void
138        dest.append(strerror(get()));
139     end appendTo
```

```
140
141     func assignTo(dest:String):void
142        dest.assign(strerror(get()));
143     end assignTo
144
145     func finalize():void
146     end finalize
147  };
148
149  errno:Errno;
150  allocate errno;
151  finalize delete errno;
```

:

A.12.9 src/vit/std/indexable.vit

```
1   package std;
2
3   import object;
4   import string;
5   import stdio;
6
7   type Indexable = record of Object{
8      _str:String;
9
10     func get(i:int):Object
11        return null;
12     end get
13
14     func set(i:int, o:Object):bool
15        return false;
16     end set
17
18     func size():int
19        return 0;
20     end size
21
22     func finalize():void
23     end finalize
24  };
```

:

A.12.10 src/vit/std/math.vit

```
1   package std;
2
3   func mod(nom:int, denom:int):int
4      return nom - (nom / denom) * denom;
5   end mod
```

:

A.12.11 src/vit/std/object.vit

```
1   package std;
2
3   import string;
4   import stdio;
5
6   type Object = record of {
7      func finalize():void
8      end finalize
```

```
};
```

:

A.12.12 src/vit/std/sort.vit

```
package std;

import object;
import indexable;
import comparator;

func sort(ary:Indexable, c:Comparator):void
   func exchange(i:int, j:int):void
      if (i == j) then
         return;
      tmp:Object = ary.get(i);
      ary.set(i, ary.get(j));
      ary.set(j, tmp);
   end exchange

   func partition(f:int, l:int):int
      i:int = f-1;
      j:int = f;
      while (j <= l - 1) do {
         if (c.compare(ary.get(j), ary.get(l)) < 0) then {
            i = i+1;
            exchange(i,j);
         }
         j = j+1;
      }
      exchange(i + 1,l);
      return i + 1;
   end partition

   func quicksort(f:int, l:int):void
      if (f < l) then {
         q:int = partition(f, l);
         quicksort(f, q - 1);
         quicksort(q + 1, l);
      }
   end quicksort

   quicksort(0, ary.size() - 1);
end sort
```

:

A.12.13 src/vit/std/stdio.vit

```
package std;

import errno;
import std.c.stdio;
import object;
import string;
import std.c.ctype;

type StdOstream = record of {

   func put(str:String):StdOstream
      if (str != null) then {
         put(str.str());
      } else {
         printf("null");
      }
      return record;
```

```
18      end put
19
20      func put(e:Errno):StdOstream
21         s:String;
22         allocate s;
23         e.assignTo(s);
24         put(s);
25         delete s;
26         return record;
27      end put
28
29      func put(i:int):StdOstream
30         s:String;
31         allocate s of record(i);
32         put(s);
33         delete s;
34         return record;
35      end put
36
37      func put(c:char):StdOstream
38         s:String;
39         allocate s of record(c);
40         put(s);
41         delete s;
42         return record;
43      end put
44
45      func put(b:bool):StdOstream
46         s:String;
47         allocate s of record(b);
48         put(s);
49         delete s;
50         return record;
51      end put
52
53      func put(s:string):StdOstream
54         printf(s);
55         return record;
56      end put
57
58      func put(a:array of char):StdOstream
59         s:String;
60         allocate s of record(a);
61         put(s);
62         delete s;
63         return record;
64      end put
65
66      func putln(obj:String):StdOstream
67         put(obj);
68         return ln();
69      end putln
70
71      func putln(e:Errno):StdOstream
72         put(e);
73         return ln();
74      end putln
75
76      func putln(i:int):StdOstream
77         put(i);
78         return ln();
79      end putln
80
81      func putln(c:char):StdOstream
82         put(c);
83         return ln();
84      end putln
85
86      func putln(b:bool):StdOstream
87         put(b);
88         return ln();
89      end putln
90
91      func putln(s:string):StdOstream
```

```
92          puts(s);
93          return record;
94       end putln
95
96       func putln(a:array of char):StdOstream
97          put(a);
98          return ln();
99       end putln
100
101      func ln():StdOstream
102         printf("\n");
103         return record;
104      end ln
105   };
106
107   stdo:StdOstream;
108   allocate stdo;
109   finalize delete stdo;
110
111   extern(C) func _Vit_gets(dest:array of char, size:int):int;
112   extern(C) func _Vit_feof():bool;
113   extern(C) func _Vit_ferror():bool;
114
115   type StdIstream = record of {
116      _next:char;
117
118      func _skipSpace():void
119         _next = getchar();
120         while (isspace(_next) != 0) do
121            _next = getchar();
122      end _skipSpace
123
124      func get(dest:String):StdIstream
125         _skipSpace();
126         while (isspace(_next) == 0 && _next != 0 - 1) do {
127            dest.append(_next);
128            _next = getchar();
129         }
130         dest.append(cast(char) 0);
131         return record;
132      end get
133
134      func getln(dest:String):StdIstream
135         _next = getchar();
136         while (_next != 10 && _next != 0 - 1) do {
137            dest.append(_next);
138            _next = getchar();
139         }
140         return record;
141      end getln
142   };
143
144   stdi:StdIstream;
145   allocate stdi;
146   finalize delete stdi;
```

:

A.12.14 src/vit/std/stdlib.vit

```
1  package std;
2
3  extern(C) func exit(status:int):void;
```

:

A.12.15 src/vit/std/string.vit

```
package std;

import c.string;
import object;
import math;

func intToString(i:int):String
   ret:String;
   allocate ret;
   orig:int = i;
   if (i == 0) then {
      ret.append("0");
      return ret;
   }

   if (i < 0) then
      i = 0 - i;

   while (i > 0) do {
      m:int = mod(i, 10);
      ret.append(cast(char) (m + 48));
      i = i / 10;
   }

   if (orig < 0) then
      ret.append("-");

   i = 0;
   j:int = ret.len() - 1;
   while i < j do {
      tmp:char = ret._str[j];
      ret._str[j] = ret._str[i];
      ret._str[i] = tmp;
      i = i + 1;
      j = j - 1;
   }

   return ret;
end intToString

func charToString(c:char):String
   a:array of char;
   allocate a of length 1;
   a[0] = c;

   ret:String;
   allocate ret of record(a);

   delete a;
   return ret;
end charToString

type String = record of Object {
   _str:array of char;
   _len:int;

   func record():void
      record[]._init("", 0);
   end record

   func record(s:string):void
      record[]._init(s, strlen(s));
   end record

   func record(oth:String):void
      if oth == null then
         record[]._init("null", 4);
      else
         record[]._init(oth.str(), oth.len());
   end record

   func record(a:array of char):void
      len:int = strnlen(cast(string) a, |a|);
```

```
74          record[]._init(cast(string) a, len);
75      end record
76
77      func record(b:bool):void
78          if (b) then
79              record[]._init("true", 4);
80          else
81              record[]._init("false", 5);
82      end record
83
84      func record(c:char):void
85          tmp:String = charToString(c);
86          record[]._init(tmp.str(), tmp.len());
87          delete tmp;
88      end record
89
90      func record(i:int):void
91          s:String = intToString(i);
92          record[]._init(s.str(), s.len());
93          delete s;
94      end record
95
96      func _init(s:string, len:int):void
97          if len < 0 then
98              len = 0;
99
100         _len = len;
101         allocate _str of length len + 1;
102         memcpy(_str, s, len);
103         _str[len] = 0;
104     end _init
105
106     func append(s:string, len:int):String
107         if len <= 0 then
108             return record;
109
110         offset:int = _len;
111         newLen:int = offset + len;
112
113         if newLen >= |_str| then
114             _expand(newLen);
115
116         i:int = 0;
117         while offset < newLen do {
118             _str[offset] = s[i];
119             i = i + 1;
120             offset = offset + 1;
121         }
122         _str[offset] = 0;
123         _len = newLen;
124
125         return record;
126     end append
127
128     func append(i:int):String
129         s:String = intToString(i);
130         append(s);
131         delete s;
132         return record;
133     end append
134
135     func append(c:char):String
136         s:String = charToString(c);
137         append(s);
138         delete s;
139         return record;
140     end append
141
142     func append(b:bool):String
143         if (b) then
144             return append("true", 4);
145         else
146             return append("false", 5);
147     end append
```

```
148
149     func append(s:string):String
150        return append(s, strlen(s));
151     end append
152
153     func append(oth:String):String
154        return append(oth.str(), oth.len());
155     end append
156
157     func append(a:array of char):String
158        len:int = strnlen(cast(string) a, |a|);
159        return append(cast(string) a, len);
160     end append
161
162     func assign(s:string, len:int):String
163        if len < 0 then
164           len = 0;
165
166        size:int;
167        if len < |_str| then
168           size = |_str|;
169        else
170           size = len + 1;
171
172        nstr:array of char;
173        allocate nstr of length size;
174
175        memcpy(nstr, s, len);
176        nstr[len] = 0;
177
178        delete _str;
179        _str = nstr;
180        _len = len;
181        return record;
182     end assign
183
184     func assign(s:string):String
185        return assign(s, strlen(s));
186     end assign
187
188     func assign(a:array of char):String
189        len:int = strnlen(cast(string) a, |a|);
190        return assign(cast(string) a, len);
191     end assign
192
193     func assign(oth:String):String
194        return assign(oth.str(), oth.len());
195     end assign
196
197     func assign(i:int):String
198        s:String = intToString(i);
199        assign(s);
200        delete s;
201        return record;
202     end assign
203
204     func assign(c:char):String
205        s:String = charToString(c);
206        assign(s);
207        delete s;
208        return record;
209     end assign
210
211     func assign(b:bool):String
212        if (b) then
213           return assign("true", 4);
214        else
215           return assign("false", 5);
216     end assign
217
218     func _expand(newLen:int):void
219        if newLen <= _len then
220           return;
221
```

```
222         tmp:array of char;
223         allocate tmp of length 2*newLen + 1;
224
225         i:int = 0;
226         while i < |_str| do {
227            tmp[i] = _str[i];
228            i = i + 1;
229         }
230
231         delete _str;
232         _str = tmp;
233      end _expand
234
235      func getLast():char
236         return _str[len() - 1];
237      end getLast
238
239      func len():int
240         return _len;
241      end len
242
243      func str():string
244         return cast(string) _str;
245      end str
246
247      func copy():String
248         ret:String;
249         allocate ret of record(record);
250         return ret;
251      end copy
252
253      func compare(oth:String):int
254         return strcmp(cast(string) _str, oth.str());
255      end compare
256
257      func finalize():void
258         delete _str;
259      end finalize
260   };
```

:

A.12.16 src/vit/std/vector.vit

```
1   package std;
2
3   import indexable;
4   import object;
5   import c.string;
6   import array;
7
8   type Vector = record of Array {
9      curIdx:int;
10
11     func record():void
12        record[](15);
13     end record
14
15     func record(size:int):void
16        record[Array](size);
17        curIdx = 0;
18     end record
19
20     func size():int
21        return curIdx;
22     end size
23
24     func append(obj:Object):bool
25        size:int = record[Array].size();
26        if (curIdx >= size) then
27           if (!_expand()) then
```

```
28              return false;
29          set(_incIdx(), obj);
30          return true;
31      end append
32
33      func _incIdx():int
34          curIdx = curIdx + 1;
35          return curIdx - 1;
36      end _incIdx
37
38      func _expand():bool
39          tmp:array of Object;
40          allocate tmp of length size() * 2;
41          if (tmp == null) then
42              return false;
43
44          size:int = record[Array].size();
45          if (size < 0) then
46              return false;
47
48          memcpy(tmp, _ary, size);
49
50          delete _ary;
51          _ary = tmp;
52          return true;
53      end _expand
54  };
```

:

A.12.17 src/vit/_vit_thread/std/clock.c

```
1   #include "lock.vit.vitaly.h"
2   #include <pthread.h>
3   #include <stdlib.h>
4
5   bool _Vit_lock_init(struct RT_std_lock_Lock *r)
6   {
7       r->_pthreadMutex = malloc(sizeof(pthread_mutex_t));
8       if (!r->_pthreadMutex)
9           return false;
10      return !pthread_mutex_init(r->_pthreadMutex, NULL);
11  }
12
13  bool _Vit_lock_do(struct RT_std_lock_Lock *r)
14  {
15      if (pthread_mutex_lock(r->_pthreadMutex) == -1)
16          return false;
17      return true;
18  }
19
20  bool _Vit_lock_trydo(struct RT_std_lock_Lock *r)
21  {
22      if (pthread_mutex_trylock(r->_pthreadMutex) == -1)
23          return false;
24      return true;
25  }
26
27  bool _Vit_lock_undo(struct RT_std_lock_Lock *r)
28  {
29      if (pthread_mutex_unlock(r->_pthreadMutex) == -1)
30          return false;
31      return true;
32  }
33
34  bool _Vit_lock_finalize(struct RT_std_lock_Lock *r)
35  {
36      bool ret = !pthread_mutex_destroy(r->_pthreadMutex);
37      free(r->_pthreadMutex);
38      return ret;
39  }
```

:

A.12.18 src/vit/_vit_thread/std/cthread.c

```
#include "thread.vit.vitaly.h"
#include <pthread.h>
#include <stdlib.h>
#include <errno.h>
#include <stdbool.h>
#include <stdio.h>
#include <string.h>

bool _Vit_thread_init(struct RT_std_thread_Thread *t)
{
   t->_pthread = malloc(sizeof(pthread_t));
   if (!t->_pthread)
      return false;
   return true;
}

void _Vit_thread_finalize(struct RT_std_thread_Thread *t)
{
   if (!t->_isStarted)
      goto out;

   if (pthread_tryjoin_np(*((pthread_t *)t->_pthread), NULL) == -1) {
      fprintf(stderr, "delete of live thread, aborting\n");
      abort();
   }

out:
   free(t->_pthread);
}

static void *_Vit_thread_run(void *vit_thread)
{
   struct RT_std_thread_Thread *t = vit_thread;
   struct RT_std_thread_Thread_vmt *vmt = t->_vmt;
   vmt->FRT_std_thread_Thread_run(vit_thread);
   return NULL;
}

bool _Vit_thread_start(struct RT_std_thread_Thread *t)
{
   int err = pthread_create(t->_pthread, NULL, _Vit_thread_run, t);
   if (err) {
      errno = err;
      return false;
   }
   return true;
}

bool _Vit_thread_join(struct RT_std_thread_Thread *t)
{
   int err = pthread_join(*((pthread_t *)t->_pthread), NULL);
   if (err) {
      errno = err;
      return false;
   }
   return true;
}
```

:

A.12.19 src/vit/_vit_thread/std/lock.vit

```
package std;

type Lock = record of {
   _pthreadMutex:record of {};
   _error:bool;

   func record():void
      extern(C) func _Vit_lock_init(r:Lock):bool;
      _error = !_Vit_lock_init(record);
   end record

   func lock():bool
      extern(C) func _Vit_lock_do(r:Lock):bool;
      return _Vit_lock_do(record);
   end lock

   func trylock():bool
      extern(C) func _Vit_lock_trydo(r:Lock):bool;
      return _Vit_lock_trydo(record);
   end trylock

   func unlock():bool
      extern(C) func _Vit_lock_undo(r:Lock):bool;
      return _Vit_lock_undo(record);
   end unlock

   func error():bool
      return _error;
   end error

   func finalize():void
      extern(C) func _Vit_lock_finalize(r:Lock):bool;
      _Vit_lock_finalize(record);
   end finalize
};
```

:

A.12.20 src/vit/_vit_thread/std/thread.vit

```

package std;

import std.errno;

type Thread = record of {
   _pthread:record of {};
   _isStarted:bool;
   _error:bool;

   func record():void
      extern(C) func _Vit_thread_init(t:Thread):bool;
      _isStarted = false;
      _error = !_Vit_thread_init(record);
   end record

   func run():void
   end run

   func error():bool
      return _error;
   end error

   func start():bool
      extern(C) func _Vit_thread_start(t:Thread):bool;
      if error() || started() then {
         errno.set(eperm());
         return false;
      }
      if _Vit_thread_start(record) then {
```

```
31          _isStarted = true;
32          return true;
33       }
34       if errno.get() != eagain() then
35          _error = true;
36       return false;
37    end start
38
39    func join():bool
40       extern(C) func _Vit_thread_join(t:Thread):bool;
41
42       if error() || !started() then {
43          errno.set(eperm());
44          return false;
45       }
46       return _Vit_thread_join(record);
47    end join
48
49    func started():bool
50       return _isStarted;
51    end started
52
53    func finalize():void
54       extern(C) func _Vit_thread_finalize(t:Thread):void;
55       _Vit_thread_finalize(record);
56    end finalize
57 };
```