GCC Internals and Porting

HelloGcc Workshop
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Outline

- Getting Started
- Overview
  - Compilation, Source Tree, Internal Framework
- Front End
  - Language Hooks, C Parser, Tree & GENERIC
- Middle End
  - GIMPLE, Call Graph, Passes
- Back End & Port
  - RTL, MD, Target Macros

Getting Started

http://gcc.gnu.org/wiki/GettingStarted

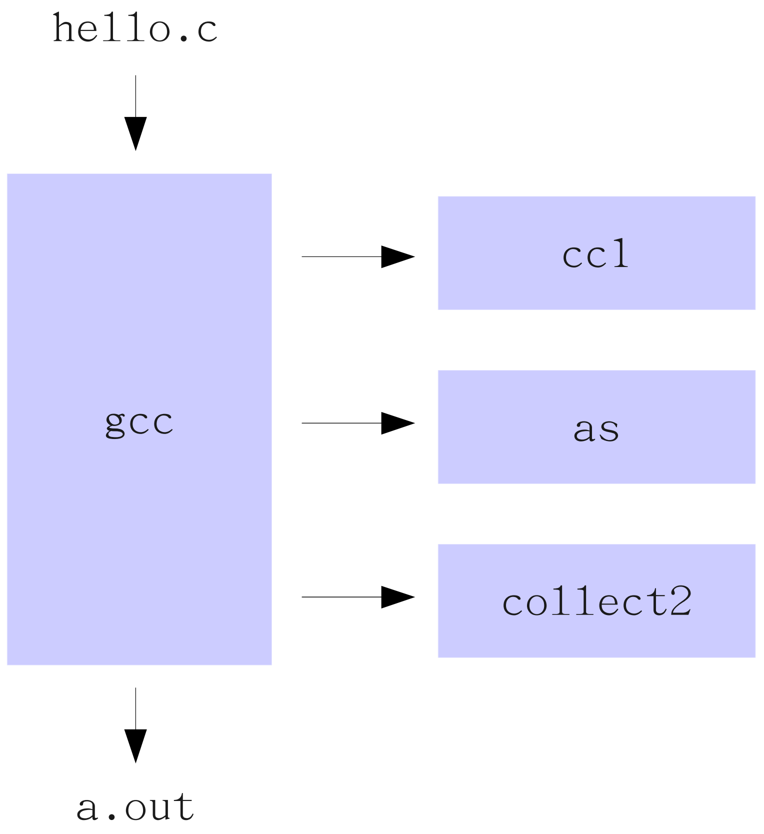
- Tutorials, HOWTOs
  - GCC Internals Podcast - English listening :)
  - GCC Internals Tutorial - Very detailed !
  - Workshop on GCC Internals - Spim port
- Internal Documentation
  - GCC Internals
- Dealing With the Source Code
  - Debugging, Testing, Writing pass/front-end/back-end
- Structure of GCC
  - Front end, Tree/RTL Optimizers, Passes

Overview

- Compilation
- Source Tree
- Internal Framework

Compilation

- gcc driver
  - Process spec strings: gcc.c
  - $ gcc -dumpspecs
- cc1
  - Entry point: toplev_main, toplev.c
  - Same to cc1plus, jc1, f771, etc.
- collect2
  - Real linker: ld
  - Handle initialization functions: main → __main → constructors



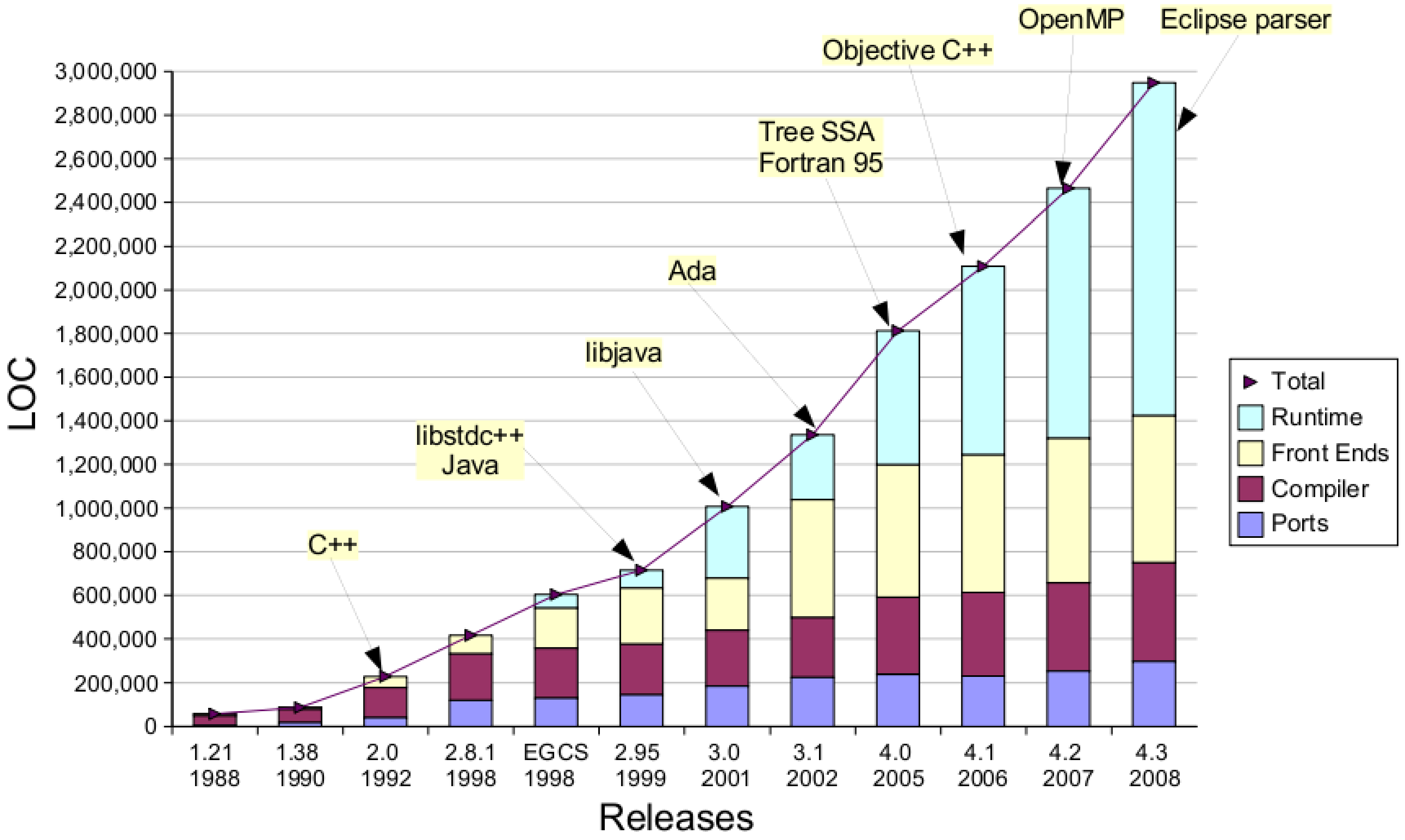
$ gcc -v hello.c

Source Tree

```
gcc-4.4.0
    boehm-gc
    config
    contrib
    fixincludes
    gcc
        ada
        config
            alpha
            arc
            arm
            mips
                *.md
                *.h
                *.c
                *.opt
                t-*
                x-*
                ...
            ...
        cp
        doc
        fortran
        ginclude
        java
        objc
        objcp
        po
        testsuite
        *.c/*.h ...
    INSTALL
    libgcc
    libada
    libgfortran
    libjava
    ...
```

- libraries
- front-ends
- middle-end
- back-end
- ports

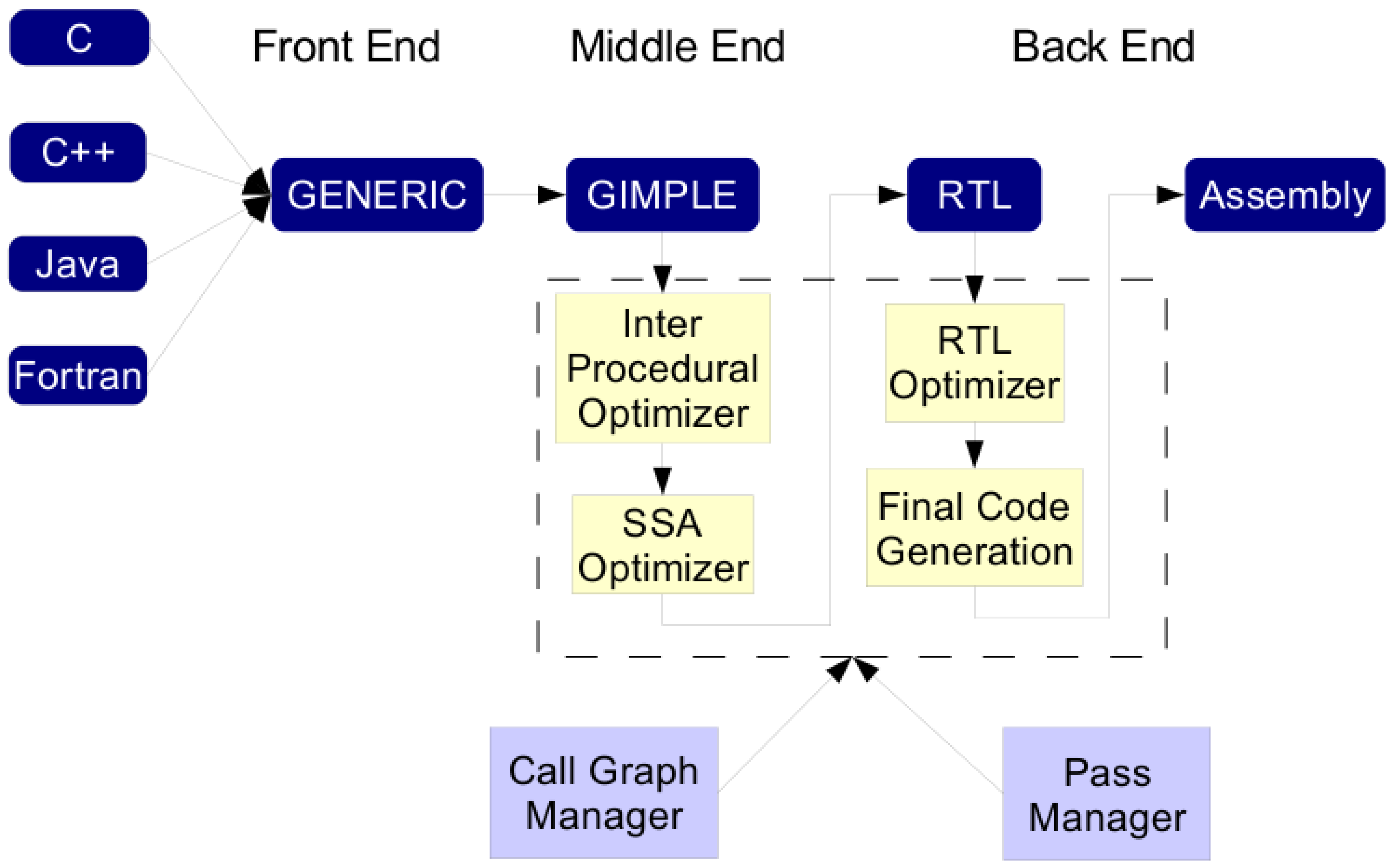
GCC Growth



[1]generated using David A. Wheeler's 'SLOCCount'.

From Diego Novillo's Slides

Internal Framework



From Diego Novillo's Slides

Front End

- Language Hooks
- C Parser
- Tree & GENERIC

Language Hooks

- Define the structure

```
struct lang_hooks
{
  ...
} /* langhooks.h */
```

- Define default functions

```
bool
hook_bool_void_false (void)
{
  return false;
} /* langhooks.c */
```

- Define the default initializer

```
#define LANG_HOOKS_NAME  "GNU unknown"
#define LANG_HOOKS_INIT \
 hook_bool_void_false
#define LANG_HOOKS_INITIALIZER { \
  …
} /* langhooks-def.h */
```

- Define specific functions

```
bool
c_objc_common_init (void)
{
  ...
} /* c-opts.c */

/* also in c-common.c, c-decl.c */
```

- Declare the variable & Initialize

```
#include "c-objc-common.h"

#undef LANG_HOOKS_NAME
#define LANG_HOOKS_NAME "GNU C"
#undef LANG_HOOKS_INIT
#define LANG_HOOKS_INIT c_objc_common_init
const struct lang_hooks = \
  LANG_HOOKS_INITIALIZER;
/* c-lang.c */
```

C Parser

- toplev_main → c_parser_file

```
toplev_main                                toplev.c
  do_compile                               toplev.c
    compile_file                           toplev.c
      lang_hooks.parse_file
      (c_common_parse_file)                c-opts.c
        c_parser_file                      c-parser.c
```

- Hand-written Recursive-descent Parser

```
translation-unit:
  external-declarations

external-declarations:
  external-declaration
  external-declarations external-declaration

external-declaration:
  function-definition
  declaration
```

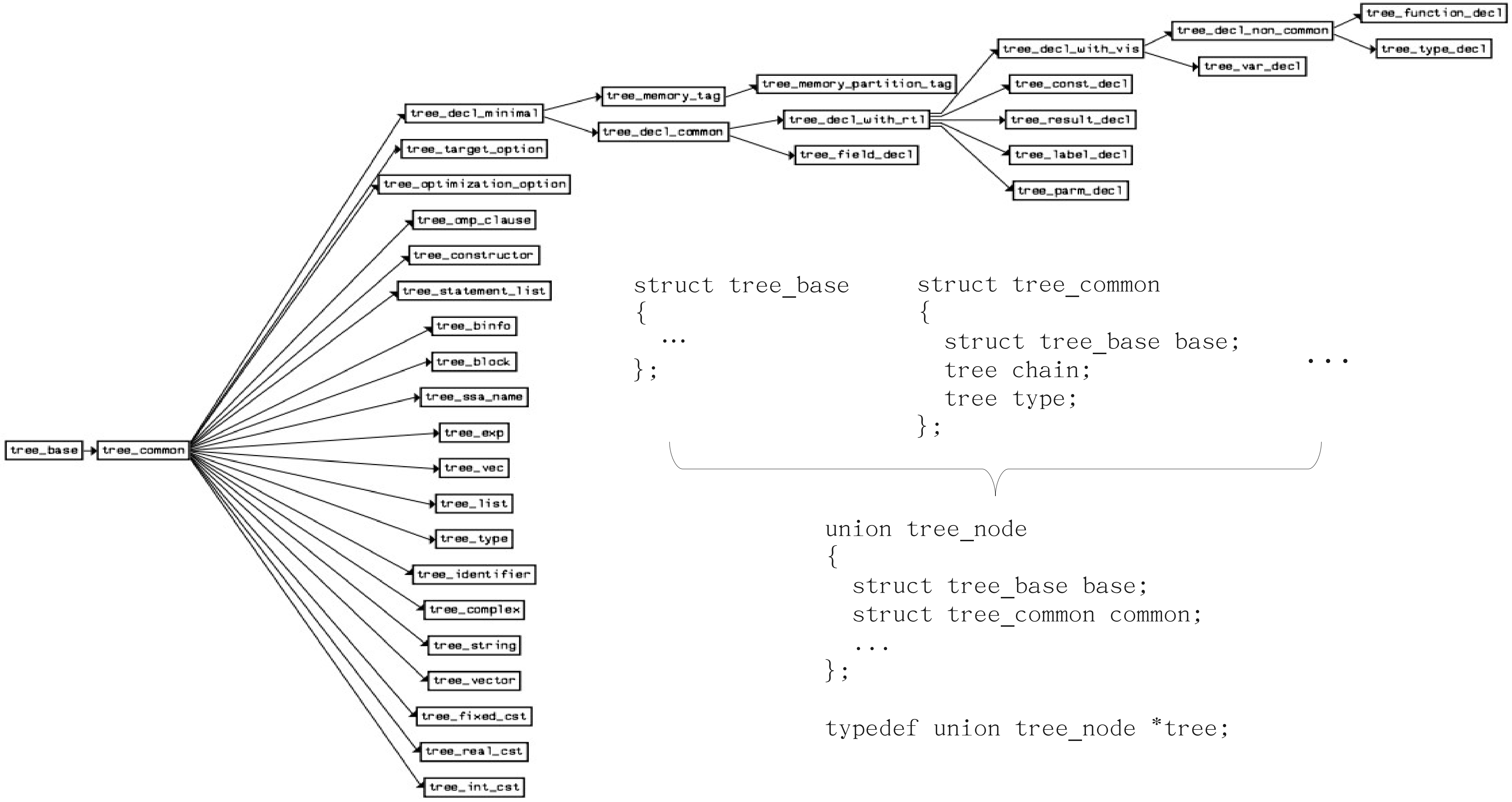
$$\begin{tikzcd}
\text{c\_parser\_translation\_unit} \arrow[d] \\
\text{c\_parser\_external\_declaration} \arrow[d] \\
\text{c\_parser\_declaration\_or\_fndef}
\end{tikzcd}$$

Tree & GENERIC

- Tree
  - Language-dependent IR
  - tree.def, c-common.def, java-tree.def ...
- GENERIC
  - Language-independent IR
  - tree.def
- Genericize
  - Tree → GENERIC (currently dose nothing)

```
c_parser_declaration_or_fndef        c-parser.c
  finish_function                    c-decl.c
    c_genericize                     c-gimplify.c
```

Tree Node



```
struct tree_base
{
  …
};
```

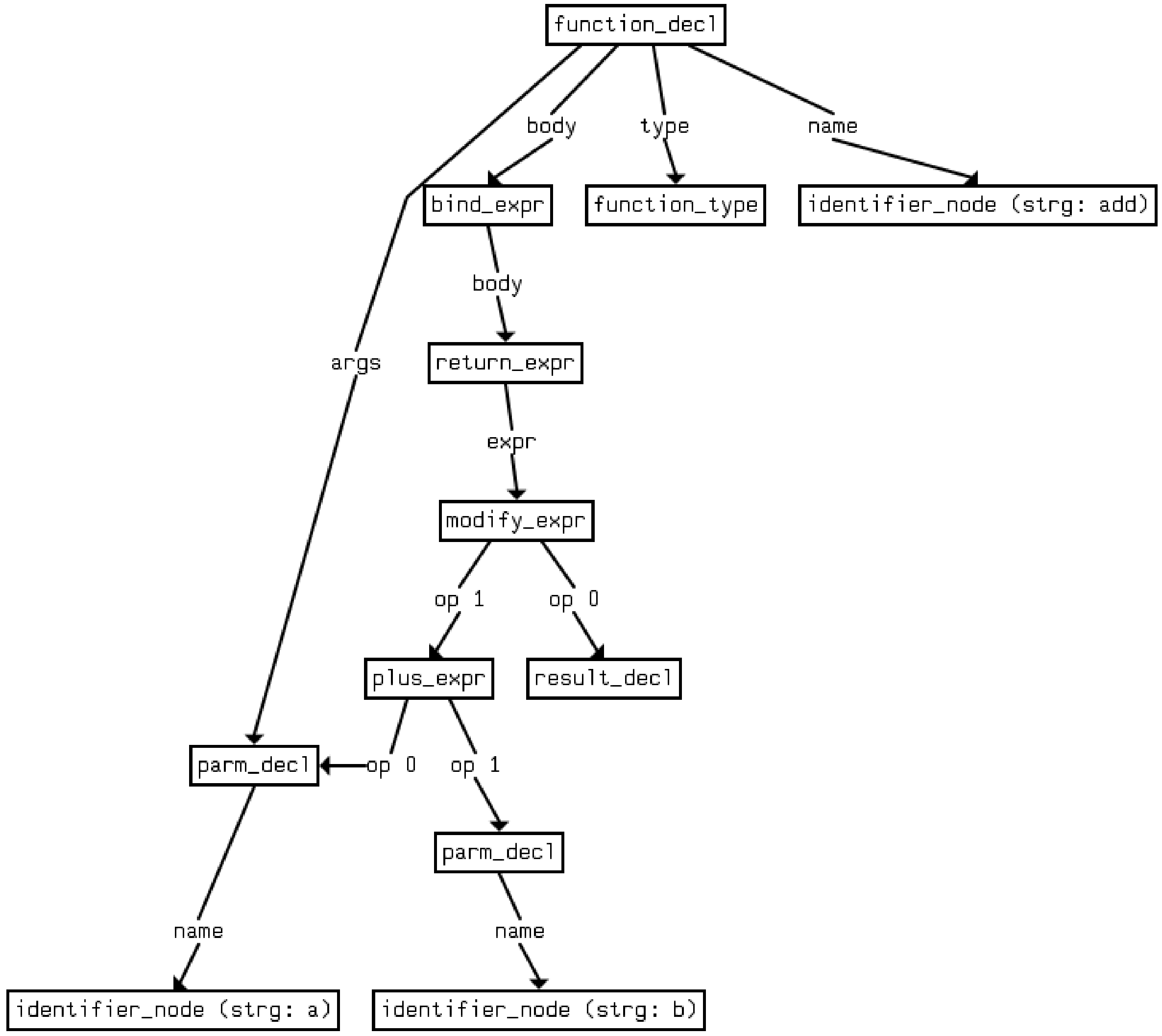
```
struct tree_common
{
  struct tree_base base;
  tree chain;
  tree type;
};
```

...

```
union tree_node
{
  struct tree_base base;
  struct tree_common common;
  ...
};

typedef union tree_node *tree;
```

Example: Tree



```
$ cat test.c
int
add (int a, int b)
{
  return a + b;
}
```

```
(gdb) b c_generic
(gdb) r
(gdb) p debug_function (fndecl, 4)
```

Middle End

- GIMPLE
- Call Graph (also for back-end)
- Passes (also for back-end)

Proceed to Middle End

```
compile_file                                              toplev.c
  lang_hooks.parse_file                                   toplev.c
  lang_hooks.final_write_globals                          toplev.c
    c_write_global_declarations                           c-decl.c
      cgraph_finalize_compilation_unit                    c-decl.c
        cgraph_analyze_functions                          cgraphunit.c
        cgraph_optimize                                   cgraphunit.c
```

```
/* We're done parsing; proceed to optimize and emit assembly.
   FIXME: shouldn't be the front end's responsibility to call this.  */
cgraph_finalize_compilation_unit ();
```

GIMPLE

- Derived from GENERIC
  - Tuple representation, no more than 3 operands
  - typedef union gimple_statement_d *gimple;
- Gimplifier
  - GENERIC → GIMPLE (currently tree → GIMPLE)

```
cgraph_analyze_function                 cgraphunit.c
  gimplify_function_tree                gimplify.c
    …
      gimplify_expr                     gimplify.c
        lang_hooks.gimplify_expr
        (c_gimplify_expr)               c-gimplify.c
```

Example: GIMPLE

```
test (int a, int b, int c)
{
  if (foo (a + b, c) != 0)
    {
      c = b++ / a;
    }
  return c;
}
```

GENERIC

```
test (int a, int b, int c)
{
  int D.1239;
  int D.1240;
  int D.1243;

  D.1239 = a + b;
  D.1240 = foo (D.1239, c);
  if (D.1240 != 0) goto <D.1241>; else goto <D.1242>;
  <D.1241>:
  c = b / a;
  b = b + 1;
  <D.1242>:
  D.1243 = c;
  return D.1243;
}
```

GIMPLE

Call Graph

- Call graph is a directed multigraph
  - Nodes are functions
  - Edges are call sites

```
struct cgraph_node
{
  tree decl;
  struct cgraph_edge *callees;
  struct cgraph_edge *callers;
  struct cgraph_node *next;
  struct cgraph_node *previous;
  …
};
```

- Build cgraph
  - cgraph_create_node
  - cgraph_finalize_function
  - cgraph_finalize_compilation_unit

A Pass

```
struct gimple_opt_pass pass_remove_useless_stmts =
{
 {
  GIMPLE_PASS,
  "useless",                /* name */
  NULL,                     /* gate */
  remove_useless_stmts,     /* execute */
  NULL,                     /* sub */
  NULL,                     /* next */
  0,                        /* static_pass_number */
  0,                        /* tv_id */
  PROP_gimple_any,          /* properties_required */
  0,                        /* properties_provided */
  0,                        /* properties_destroyed */
  0,                        /* todo_flags_start */
  TODO_dump_func            /* todo_flags_finish */
 }
};
```

Pass List

- Lowering passes
- Inter-procedural passes
  - Early inline passes
  - Early local passes
  - IPA passes
- Intra-procedural passes
  - GIMPLE passes
  - RTL passes

```
void
init_optimization_passes (void)
{
  ...
  p = &all_lowering_passes;
  NEXT_PASS (pass_remove_useless_stmts);
  NEXT_PASS (pass_mudflap_1);
  NEXT_PASS (pass_lower_omp);
  NEXT_PASS (pass_lower_cf);
  NEXT_PASS (pass_refactor_eh);
  NEXT_PASS (pass_lower_eh);
  NEXT_PASS (pass_build_cfg);
  NEXT_PASS (pass_lower_complex_O0);
  NEXT_PASS (pass_lower_vector);
  NEXT_PASS (pass_warn_function_return);
  NEXT_PASS (pass_build_cgraph_edges);
  NEXT_PASS (pass_inline_parameters);
  *p = NULL;
  …
}        /* passes.c */
```

Execute Passes

- Lowering passes

```
cgraph_finalize_compilation_unit ()
  for each node N in the cgraph
    cgraph_analyze_function (N)
      cgraph_lower_function (N) -> all_lowering_passes
```

- Inter-procedural & Intra-procedural passes

```
cgraph_optimize ()
  ipa_passes ()          -> all_ipa_passes
  cgraph_expand_all_functions ()
    for each node N in the cgraph
      cgraph_expand_function (N)
        tree_rest_of_compilation (DECL (N))  -> all_passes
```

Back End & Port

- RTL
- Machine Description
- Target Macros

RTL

- Low-level IR

Variable	→	Register
Reference	→	Memory
Type	→	Machine Mode

- Insns
  - RTL representation for a function, double-linked chain

```
/* An instruction that cannot jump.  */
DEF_RTL_EXPR(INSN, "insn", "iuuBieie", RTX_INSN)
```

- GIMPLE → Tree → RTL
  - pass_expand

Machine Description

- Describe Instructions, etc.
  - Define Instruction Patterns
  - Define Predicates
  - Define Constraints
  - Define Attributes
  - Define Delay Slot
  - Define Processor Pipeline
  - Define Peephole
  - Define Iterators
- MD → c

$$\begin{tikzcd}
\text{*.md} \arrow[r] & \text{gen*} \arrow[r] \arrow[dd] & \text{insn-*.c} \arrow[d] \\
 & & \text{build\_gcc-4.4.0/gcc/} \\
 & \text{build\_gcc-4.4.0/gcc/build/} &
\end{tikzcd}$$

Example: MD

```
(define_expand "add<mode>3"
  [(set (match_operand:GPR 0 "register_operand")
    (plus:GPR (match_operand:GPR 1 "register_operand")
          (match_operand:GPR 2 "arith_operand")))]
  "")

(define_insn "*add<mode>3"
  [(set (match_operand:GPR 0 "register_operand" "=d,d")
    (plus:GPR (match_operand:GPR 1 "register_operand" "d,d")
          (match_operand:GPR 2 "arith_operand" "d,Q")))]
  "!TARGET_MIPS16"
  "@
   <d>addu\t%0,%1,%2
   <d>addiu\t%0,%1,%2"
  [(set_attr "type" "arith")
   (set_attr "mode" "<MODE>")])
```

Predicate
Constraint
Name
RTL Template
Condition
Machine Mode Iterator
Output Template
Attribute

Example: MD

Gimple Statement

```
D.1237 = a + b;
```

RTL insn generated according to addsi3 pattern

```
(insn 9 8 10 3 add.c:4 (set (reg:SI 193 [ D.1237 ])
        (plus:SI (reg:SI 195)
            (reg:SI 196))) -1 (nil))
```

RTL insn recoginzed according to *addsi3 pattern

```
(insn 9 8 10 2 add.c:4 (set (reg:SI 193 [ D.1237 ])
        (plus:SI (reg:SI 195)
            (reg:SI 196))) 10 {*addsi3} (nil))
```

Target Macros

- Target Hooks
  - target.h, target-def.h, targhooks.c, targethooks.h, machine.h, machine.c
- Macros
  - Storage Layout
  - Type Layout
  - Registers
  - Stack & Calling
  - Addressing Modes
  - Costs
  - Scheduling
  - Sections
  - Assembler Format
  - Debugging Info

  ...

How to Port

- It depends
  - What does your target need to describe?
  - From scratch or base on the existing?
  - Contribute or not?
- Suggestions
  - Be familiar with gcc internals
  - Refer to an example
  - From simple to complex

Example: Picochip

- Story about contribution

> 03 Mar 2003, Dan Towner:
>
> For the last 18 months, I have been developing a port of...

> 10 Mar 2008 David Edelsohn:
>
> I am pleased to announce that the GCC Steering Committee has...

- gcc-4.4.0/gcc/config/picochip/

```
constraints.md dfa_space.md dfa_speed.md picochip.md predicates.md

picochip.c picochip.h picochip.opt picochip-protos.h t-picochip

libgccExtras/
```

- Build cross gcc

```
--target=picochip-unknown-none
```

Thanks!