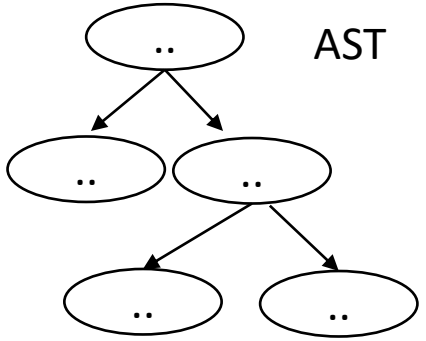
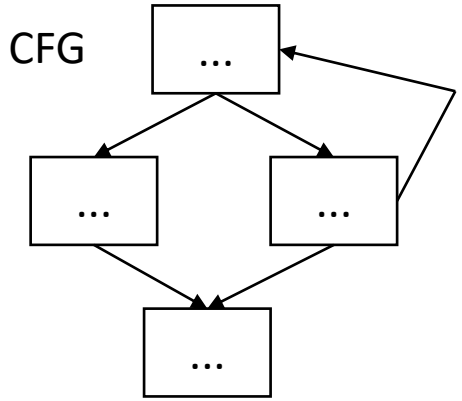
CSE110A: Compilers



Topics:

- *Module 3: Intermediate representations*
  - *Linear IRs*



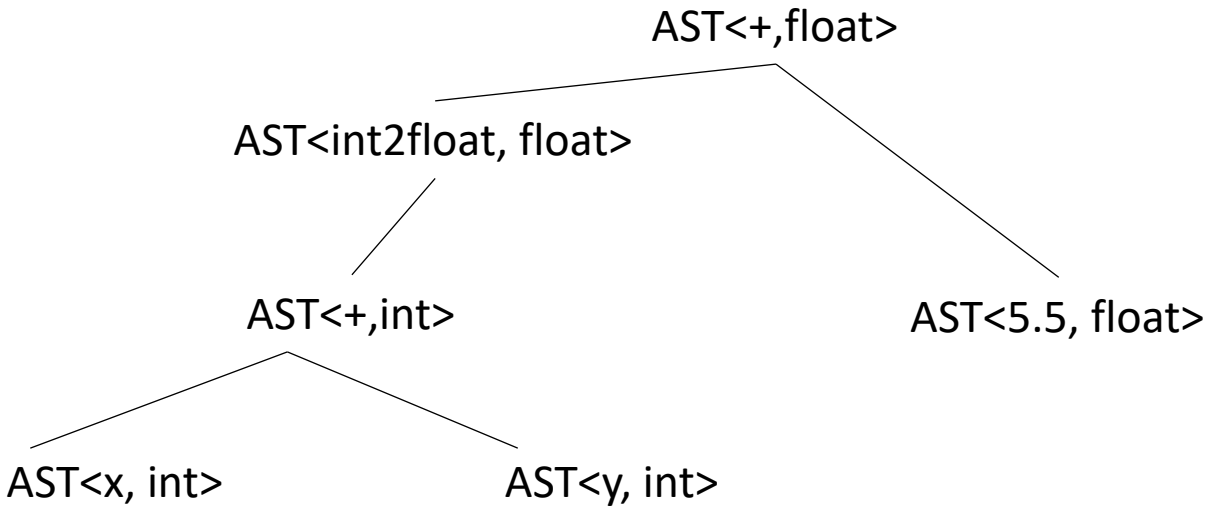
3 address code

```
store i32 0, ptr %2
%3 = load i32, ptr %1
%4 = add nsw i32 %3, 1,
store i32 %4, ptr %1
%5 = load i32, ptr %2
```

Converting AST into Class-IR

```
int x;
int y;
float w;
w = x + y + 5.5
```

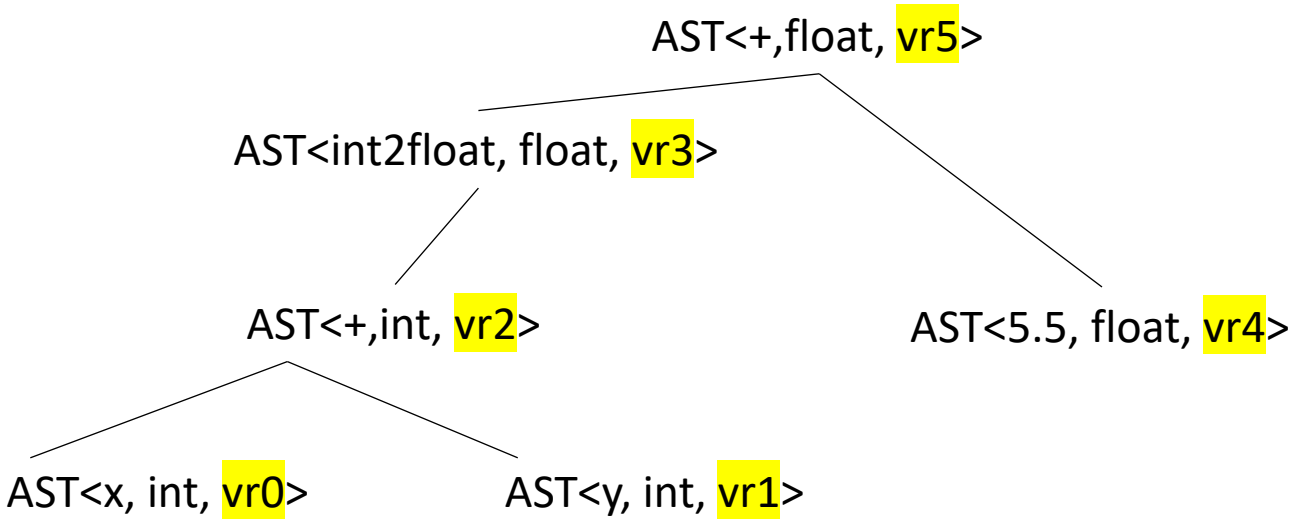
After type inference



Converting AST into Class-IR

```
int x;
int y;
float w;
w = x + y + 5.5
```

After type inference



We will start by adding a new member to each AST node:

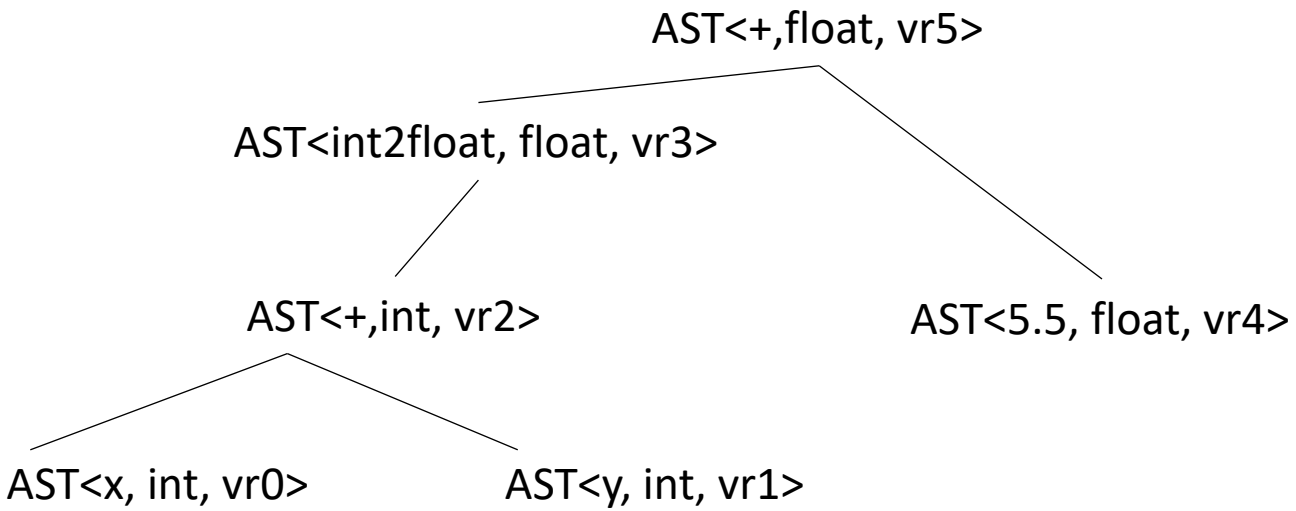
A virtual register

Each node needs a distinct virtual register

Converting AST into Class-IR

```
int x;
int y;
float w;
w = x + y + 5.5
```

After type inference

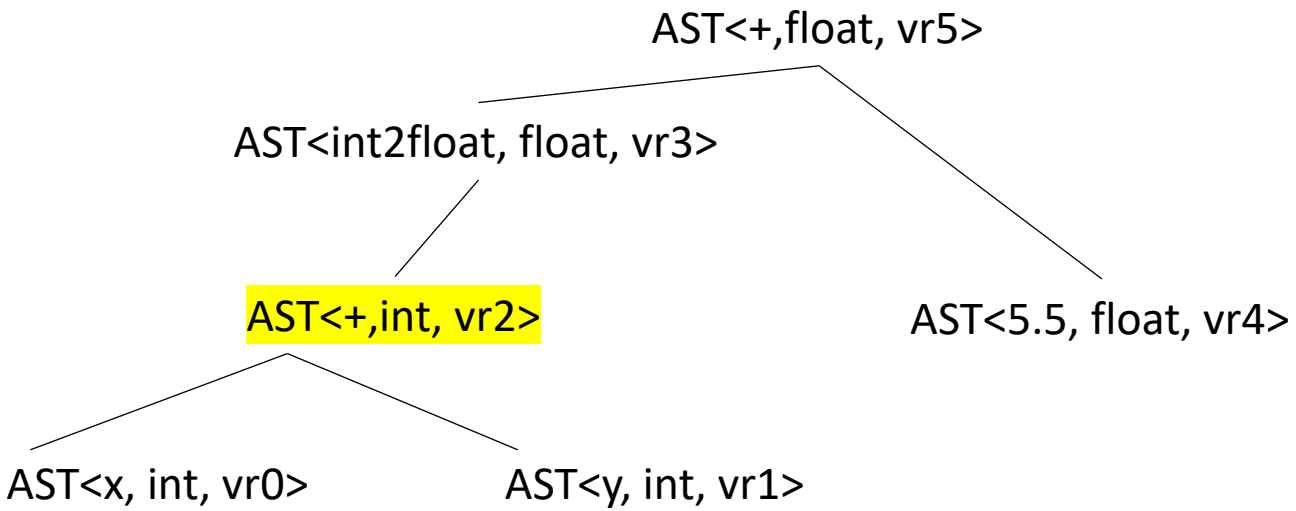


Next each AST node needs to know how to print a 3 address instruction

Converting AST into Class-IR

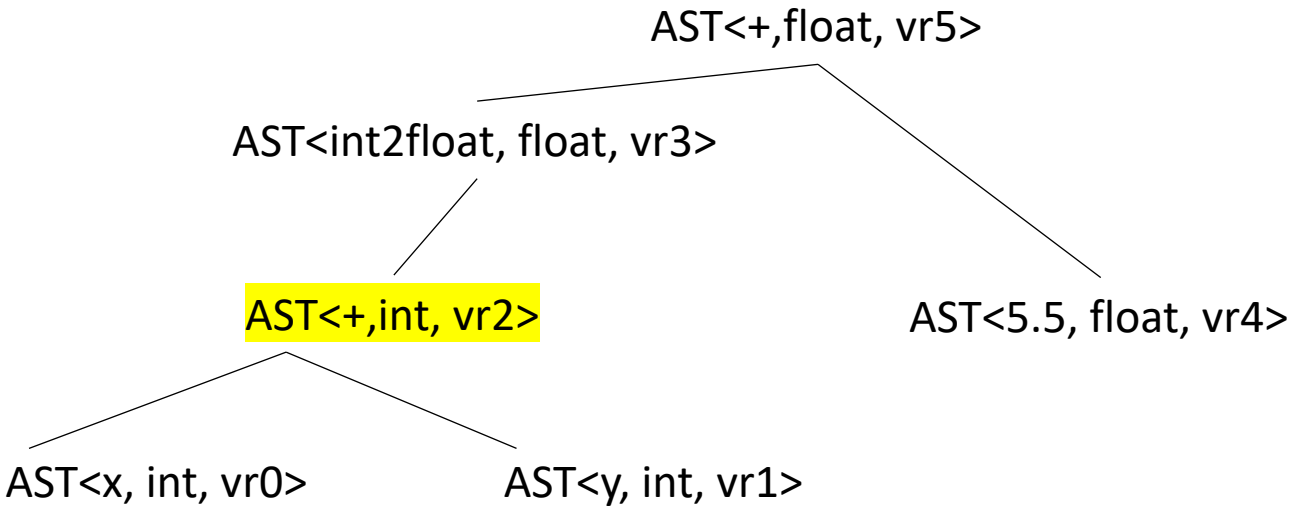
```
int x;
int y;
float w;
w = x + y + 5.5
```

After type inference



Next each AST node needs to know how to print a 3 address instruction

Let's look at add

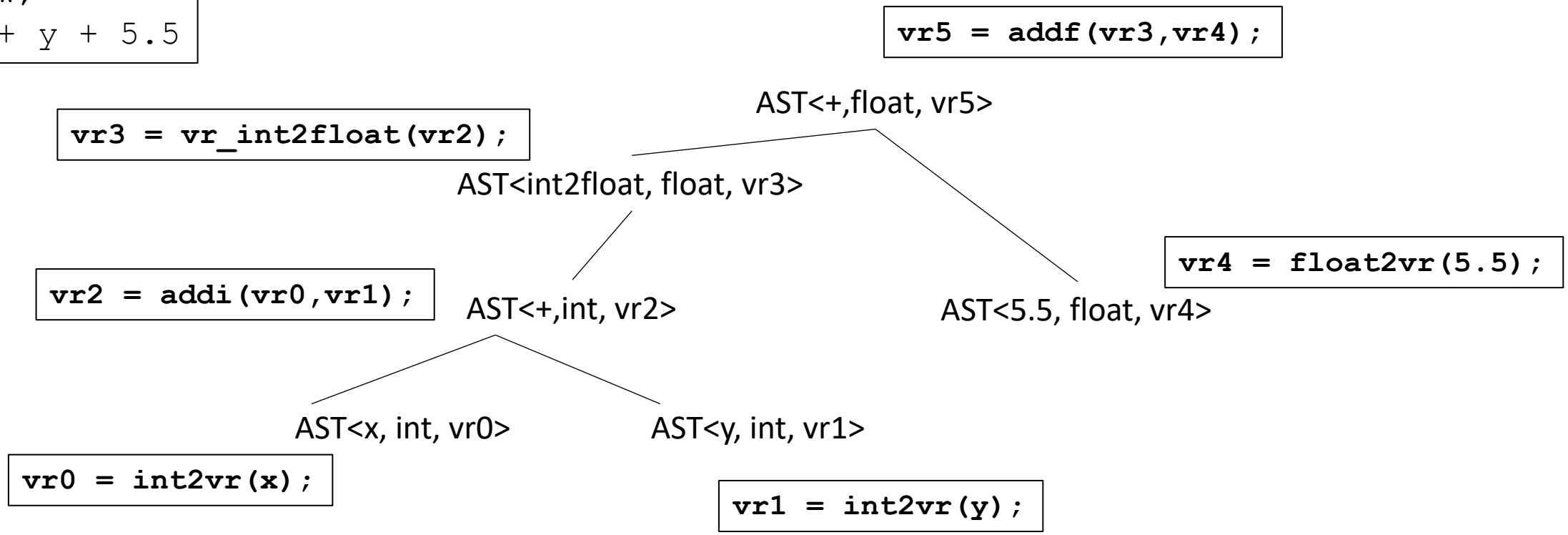



```
def get_op(self):
    if self.node_type is Types.INT:
        return "addi"
    else:
        return "addf"
```

```
return "%s = %s(%s,%s);" %
        (self.vr, self.get_op(), self.l_child.vr, self.r_child.vr)
```

```
vr2 = addi(vr0,vr1);
```

```
int x;
int y;
float w;
w = x + y + 5.5
```



```
 if_else_statement := IF LPAR expr RPAR statement ELSE statement

{
   ...
   # get resources
   end_label  = mk_new_label()
   else_label = mk_new_label()
   vrX        = mk_new_vr()

   # make instructions
   ins0 = "%s = int2vr(0)" % vrX
   ins1 = "beq(%s, %s, %s);" %
          (expr_ast.vr, vrX, else_label)
   ins2 = "branch(%s)" % end_label

   # concatenate all programs
   return program0 + [ins0, ins1] + program1
          + [ins2, label_code(else_label)]
          + program2 + [label_code(end_label)]
}
```

```
if (program0) {
  program1
}
else {
  program2
}
```

We need to convert this to 3 address code

```
  program0;
  vrX = int2vr(0)
  beq(expr_ast.vr, vrX, else_label);
  program1
  branch(end_label);
else_label:
  program2
end_label:
```

```
statement := declaration_statement
           |  assignment_statement
           |  if_else_statement
           |  block_statement
           |  for_loop_statement
```

We did these two

You do these two for your homework

Draw out for loops just like how we did with the if statements!

Compiler pragmatics

- New terminology I learned recently:
  - Implementation details

- We need to talk about different ID types (IO, VRs)
- We need to talk about scopes

Class-IR

Inputs/outputs (IO): 32-bit typed inputs

e.g.: `int x, int y, float z`

Program Variables (Variables): 32-bit untyped virtual register

given as `vrX` where `X` is an integer:

e.g. `vr0, vr1, vr2, vr3` …

we will assume input/output names are disjoint from virtual register names

Two different ID nodes

Gets compiled into an untyped virtual register

```
class ASTVarIDNode(ASTLeafNode):
    def __init__(self, value, value_type):
        super().__init__(value)
        self.node_type = value_type
```

Gets compiled into a typed IO variable

```
class ASTIOIDNode(ASTLeafNode):
    def __init__(self, value, value_type):
        super().__init__(value)
        self.node_type = value_type
```

Two different ID nodes

What we are compiling

```
void test4(float &x) {
  int i;
  for (i = 0; i < 100; i = i + 1) {
    x = i;
  }
}
```

Class-IR

What we are compiling

```
void test4(float &x) {
  int i;
  for (i = 0; i < 100; i = i + 1) {
    x = i;
  }
}
```

IO variables

program variables

```
int main() {
  int a = 0;
  test1(a);
  cout << a << endl;
  return 0;
}
```

What does this print?

What we are compiling

IO variables

```
void test4(float &x) {
  int i;
  for (i = 0; i < 100; i = i + 1) {
    x = i;
  }
}
```

program variables

Every time you access an IO variable, you need to convert it to a vr first using float2vr or int2vr

```
class ASTIOIDNode(ASTLeafNode):
...
    def three_addr_code(self):
        if self.node_type == Types.INT:
            return "%s = int2vr(%s);" % (self.vr, self.value)
        if self.node_type == Types.FLOAT:
            return "%s = float2vr(%s);" % (self.vr, self.value)
```

What we are compiling

IO variables

```
void test4(float &x) {
  int i;
  for (i = 0; i < 100; i = i + 1) {
    x = i;
  }
}
```

program variables

Every time you access a program variable, it does not need to be converted.

Because its value is a virtual register, you can even just use its value as its virtual register

```
class ASTVarIDNode(ASTLeafNode):
...

    def three_addr_code(self):
        return "%s = %s;" % (self.vr, self.value)
```

building an expression AST, we parse a unit at the base

```
unit := ID
      |  ...
```

How do we know whether to make an IO node or a Var node?

```
{
   id_name = self.to_match[1]
   data_type = # get type from symbol table
   eat("ID")
   return ASTIDNode(id_name, data_type)
}
```

Previously we had just one ID node

building an expression AST, we parse a unit at the base

```
unit := ID
      |  ...
```

How do we know whether to make an IO node or a Var node?

```
{
   id_name = self.to_match[1]
   data_type = # get type from symbol table
   eat("ID")
   return ASTIDNode(id_name, data_type)
}
```

building an expression AST, we parse a unit at the base

```
unit := ID
      |  ...
```

How do we know whether to make an IO node or a Var node?

```
{
   id_name = self.to_match[1]
   id_data = # get id_data from the symbol table
   eat("ID")
   return ASTIDNode(id_name, ...)
}
```

id_data should contain:
***id_type**: IO or Var*
***data_type**: int or float*

building an expression AST, we parse a unit at the base

```
unit := ID
      |  ...
```

How do we know whether to make an IO node or a Var node?

```
{
    id_name = self.to_match[1]
    id_data = # get id_data from the symbol table
    eat("ID")
    if (id_data.id_type == IO)
        return ASTIOIDNode(id_name, id_data.data_type)
    else
        return ASTVarIDNode(id_name, id_data.data_type)
}
```

id_data should contain:
***id_type**: IO or Var*
***data_type**: int or float*

Getting back to our statements:

```
statement := declaration_statement
           |  assignment_statement
           |  if_else_statement
           |  block_statement
           |  for_loop_statement
```

When we declare a variable, we need to mark it as a program variable in the symbol table

Getting back to our statements:

```
statement := declaration_statement
           |  assignment_statement
           |  if_else_statement
           |  block_statement
           |  for_loop_statement
```

We need to use symbol table data for something else. What?

Getting back to our statements:

```
statement := declaration_statement
           |  assignment_statement
           |  if_else_statement
           |  block_statement
           |  for_loop_statement
```

We need to use symbol table data for something else. What?

Scopes! Class IR has no {}s, so we need to manage scopes

Scopes

```
int x;
int y;
x = 5;
{
  int x;
  x = 6;
  y = x;
}
```

What does y hold?

Scopes

```
int x;
int y;
x = 5;
{
  int x;
  x = 6;
  y = x;
}
```

How can we get rid of the {}'s?

What does y hold?

Scopes

Let’s walk through it with a symbol table

```
int x;
int y;
x = 5;
{
  int x;
  x = 6;
  y = x;
}
```

Scopes

Let’s walk through it with a symbol table

```
int x;
int y;
x = 5;
{
  int x;
  x = 6;
  y = x;
}
```

HT0

symbol table hash table stack

Scopes

rename

Let’s walk through it with a symbol table

```
int x_0;
int y;
x = 5;
{
  int x;
  x = 6;
  y = x;
}
```

make a new unique name for x

HT0

```
x: (INT, VAR, “x_0”)
```

symbol table hash table stack

Scopes

Let’s walk through it with a symbol table

```
int x_0;
int y;
x = 5;
{
  int x;
  x = 6;
  y = x;
}
```

HT0

```
x: (INT, VAR, “x_0”)
```

symbol table hash table stack

Scopes

rename

Let's walk through it with a symbol table

```
int x_0;
int y_0;
x = 5;
{
  int x;
  x = 6;
  y = x;
}
```

make a new unique name for y

HT0

```
x: (INT, VAR, "x_0")
y: (INT, VAR, "y_0")
```

symbol table hash table stack

Scopes

search

Let’s walk through it with a symbol table

```
int x_0;
int y_0;
x = 5;
{
  int x;
  x = 6;
  y = x;
}
```

HT0

```
x: (INT, VAR, “x_0”)
y: (INT, VAR, “y_0”)
```

symbol table hash table stack

Scopes

replace
with
new name

Let's walk through it with a symbol table

```
int x_0;
int y_0;
x_0 = 5;
{
  int x;
  x = 6;
  y = x;
}
```

HT0

```
x: (INT, VAR, "x_0")
y: (INT, VAR, "y_0")
```

symbol table hash table stack

Scopes

Let's walk through it with a symbol table

```
int x_0;
int y_0;
x_0 = 5;
{
  int x;
  x = 6;
  y = x;
}
```

new scope. Add x with a new name

HT1

```
x: (INT, VAR, "x_1")
```

HT0

```
x: (INT, VAR, "x_0")
y: (INT, VAR, "y_0")
```

symbol table hash table stack

Scopes

Let’s walk through it with a symbol table

```
int x_0;
int y_0;
x_0 = 5;
{
  int x_1;
  x = 6;
  y = x;
}
```

new scope. Add x with a new name

HT1

```
x: (INT, VAR, “x_1”)
```

HT0

```
x: (INT, VAR, “x_0”)
y: (INT, VAR, “y_0”)
```

symbol table hash table stack

Scopes

Let’s walk through it with a symbol table

```
int x_0;
int y_0;
x_0 = 5;
{
  int x_1;
  x = 6;
  y = x;
}
```

lookup

new scope. Add x with a new name

HT1

```
x: (INT, VAR, “x_1”)
```

HT0

```
x: (INT, VAR, “x_0”)
y: (INT, VAR, “y_0”)
```

symbol table hash table stack

Scopes

Let’s walk through it with a symbol table

```
int x_0;
int y_0;
x_0 = 5;
{
  int x_1;
  x_1 = 6;
  y = x;
}
```

lookup

new scope. Add x with a new name

HT1

```
x: (INT, VAR, “x_1”)
```

HT0

```
x: (INT, VAR, “x_0”)
y: (INT, VAR, “y_0”)
```

symbol table hash table stack

Scopes

Let’s walk through it with a symbol table

```
int x_0;
int y_0;
x_0 = 5;
{
  int x_1;
  x_1 = 6;
  y = x;
}
```

lookup

new scope. Add x with a new name

HT1

```
x: (INT, VAR, “x_1”)
```

HT0

```
x: (INT, VAR, “x_0”)
y: (INT, VAR, “y_0”)
```

symbol table hash table stack

Scopes

Let’s walk through it with a symbol table

```
int x_0;
int y_0;
x_0 = 5;
{
  int x_1;
  x_1 = 6;
  y_0 = x_1;
}
```

lookup

new scope. Add x with a new name

HT1

```
x: (INT, VAR, “x_1”)
```

HT0

```
x: (INT, VAR, “x_0”)
y: (INT, VAR, “y_0”)
```

symbol table hash table stack

Scopes

Let's walk through it with a symbol table

```
int x_0;
int y_0;
x_0 = 5;
{
  int x_1;
  x_1 = 6;
  y_0 = x_1;
}
```

new scope. Add x with a new name

No more need for {}

HT1

```
x: (INT, VAR, "x_1")
```

HT0

```
x: (INT, VAR, "x_0")
y: (INT, VAR, "y_0")
```

symbol table hash table stack

Scopes

Let’s walk through it with a symbol table

```
int x_0;
int y_0;
x_0 = 5;
int x_1;
x_1 = 6;
y_0 = x_1;
```

new scope. Add x with a new name

HT1

```
x: (INT, VAR, “x_1”)
```

No more need for {}

HT0

```
x: (INT, VAR, “x_0”)
y: (INT, VAR, “y_0”)
```

symbol table hash table stack

Scopes

What happens with multiple scopes?

```
int x;
int y;
x = 5;
{
  int x;
  x = 6;
}
{
  int x;
  x = 1;
  y = x;
}
```

Scopes

What happens with multiple scopes?

```
int x;
int y;
x = 5;
{
  int x;
  x = 6;
}
{
  int x;
  x = 1;
  y = x;
}
```

What if x is uninitialized?

Class-IR

Remind ourselves what we are compiling

```
void test4(float &x) {
  int i;
  for (i = 0; i < 100; i = i + 1) {
    x = x + i;
  }
}
```

We only need new names for program variables, not for IO variables

building an expression AST, we parse a unit at the base

```
unit := ID
      |  ...
```

How do we know whether to make an IO node or a Var node?

```
{
    id_name = self.to_match[1]
    id_data = # get id_data from the symbol table
    eat("ID")
    if (id_data.id_type == IO)
        return ASTIOIDNode(id_name, id_data.data_type)
    else
        return ASTVarIDNode(id_data.new_name, id_data.data_type)
}
```

id_data should contain:
***id_type**: IO or Var*
***data_type**: int or float*
***new_name**: new unique name*

NEXT:

- Finish up talking about intermediate representaitons