6.110 Computer Language Engineering

Re-lecture 2

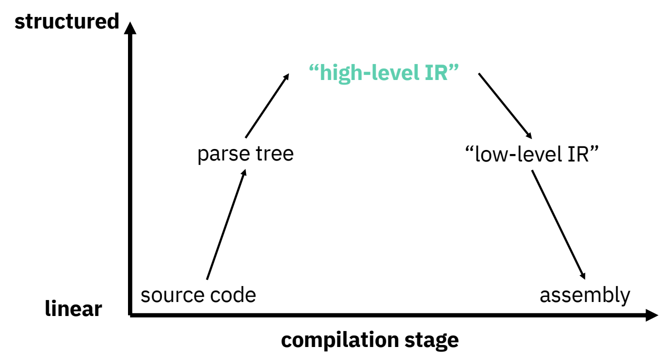
February 21, 2024

High-level IR ←
Semantic Analysis

Parse Tree
Directed Acyclic Graphs
Abstract Syntax Tree
High-level IR

Intermediate Representations

Basic Blocks
Single Static Assignment
Low-level IR
Control-flow Graph



High-level IR

- Goal: **semantic checking** and **program analysis**

High-level IR

- Goal: **understand what the code is doing**

```
x = 4 + f(true);
```

- What is `4`? What is `true`?
- What is `x`?
- What is `f`?

Symbol tables

- Stores relevant information about each identifier

identifier → *descriptor*

x	local variable id 1, type int
f	method id 3, type bool → int

Scope

```
import printf;                              global scope
int x = 0;

void main() {                               method scope
    int x = 1, y = 2;
    if (x > 0)
    {                                       block scope
        int x = 3;
        printf("%d %d", x + y);
    }
}
```

Symbol tables

```
printf   → imported method                        global symbol table
x        → global variable, type = int
main     → method, params = [], return type = void      child of
    x    → local variable, type = int             symbol table
    y    → local variable, type = int
                                                  child of
        x    → local variable, type = int         symbol table
```

Scope

```
import printf;                              global scope
int x = 0;

void main() {                               method scope
    int x = 1, y = 2;
    if (x > 0)
    {                                       block scope
        int x = 3;
        printf("%d %d", x + y);
    }
}
```

Summary

- One symbol table per scope
  - Each symbol table links to symbol table of parent scope
- First search for identifier in current scope
  - If not found, go to parent symbol table
  - If not found in any table, *semantic error!*

What goes in descriptors?

- Type (or signature for methods)
- Some identifying info (e.g. name, id, stack offset)
- Information about the "children" of the node
  - *Method descriptors*: method code, symbol table for method scope
  - *Class descriptors*: symbol table for class scope

Idea: **use descriptors to go down the tree**

What goes in symbol tables?

- Everything at that given scope
  - *Global scope:* functions, imported functions, global variables
  - *Method scope:* parameters, local variables
  - *Block scope:* local variables
  - *Class scope:* class fields, class methods
- Link to symbol table of parent scope

Idea: **use symbol tables to go up the tree**

Other designs are also possible!

Building high-level IR

- Recursively traverse parse tree to build corresponding IR nodes
  - Structure of high-level IR will be similar to language grammar
- Build up symbol tables as you go
  - Create a symbol table for each IR node corresponding to a scope

More practical tips in Recitation and Project 2 page (coming out soon!)

For the quiz, you should know how to:

- Explain what descriptors are and describe what information they contain
- Construct symbol tables for simple programs, including programs with simple classes
- Identify the scope of each identifier

High-level IR

Semantic Analysis ←

Semantic Analysis

- We want to make sure that our program *makes sense*.
- Here are some things that don't make sense, and how to detect them.

Name issues

```
void main() {
    int x, x; // x is defined twice
              in the same scope
}
```

Detection: check for duplicates in each symbol table

Name issues

```
void main() {
    y = 0; // y does not exist
}
```

Detection: look up each identifier, and check that it is in scope

Type errors: operations

```
4 + true  // + : (int, int) → int
4 && 5    // && : (bool, bool) → bool
false < 1 // < : (int, int) → bool
```

Detection: recursively determine the type of each operand

Type errors: assignments

```
int x = false; // x is int, not bool
int y[5];
y += 4; // y is int array, not int
```

Detection: check that LHS and RHS of each assignment has the same type

Type errors: constants

```
const int x; // uninitialized const
const int y = 1;
y = 2; // assignment to a const
```

Detection: (kinda ad-hoc)

- check that each const declaration is initialized
- check that LHS of assignments is not const

Type errors: methods

```
int f(int x) {} // should return int
void main() {
    f(0, 1); // wrong # arguments
    f(true); // wrong argument type
    return 1; // should not return
}
```

Detection: check method signature

Type compatibility

```
class A {
    int x;
}
class B extends A {
    int y;
}
```

We say

- B is compatible with A
- B is a subtype of A
- B can substitute for A

(The reverse is not true!)

Type compatibility

```
class A {
    int x;
}
class B extends A {
    int y;
}
B f(A a);
```

```
A a;
B b;
a.y = 1;   // invalid
b.x = 0;   // valid
a = b;     // valid
b = a;     // invalid
a = f(b);  // valid
```

For more type theory, take 6.5110 [6.820] or 6.5120 [6.822]

For the quiz, you should know how to:

- Determine what semantic checks need to be done for each given statement
- Perform semantic checks on a given program
- Determine compatibility of subclasses/superclasses

Encore: more object-oriented stuff

(See lecture slides, lectures cover this for historical reasons)