CS 536 Announcements for Wednesday, March 13, 2024

Programming Assignment 3 – due Friday, March 15

Midterm 2 – Thursday, March 21

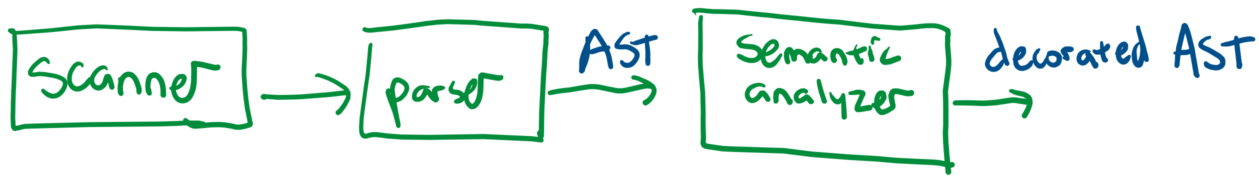
Last Time
- building a predictive parser
- predictive parsing and syntax-directed translation

Today
- static semantic analysis
- name analysis

Next Time
- continue name analysis
- exam review

known at compile time

Static Semantic Analysis



Two phases

- **name analysis** (aka **name resolution**)
  - for each scope
    - process declarations
      – add entries to symbol table
      – report multply-declared names (error)

    - process statements
      – update IdNodes to point to appropriate symbol table entry
      – find uses of undeclared variables (error)

- **type checking**
  - process statements
    – use symbol table to find types of each expression & sub-expression
    – find type errors (error)

Why do we need this phase?

Code generation

- different operations use different instructions
    - consistent variable access
    - integer addition vs floating-point addition
    - operator overloading

Optimization

- symbol table entry serves to identify which variable is used
    - can help in removing dead code (with some further analysis)
    - note: pointers can make these tasks hard

Error checking

Semantic error analysis

For non-trivial programming languages, we run into fundamental undecidability problems:

- does the program halt?
- does the program crash?

Even with simplifying assumptions (sometimes infeasible in practice) as well

- combinations of thread interleavings
- inter-procedural data analysis

In general – can't guarantee the absence of errors

Goal of static semantic analysis: catch some obvious errors

- undeclared identifiers
- multiply-declared identifiers
- ill-typed terms

Name analysis

Associating IDs with their uses

Need to bind names before we can do type analysis

Questions to consider:

- What definitions do we need about identifiers? → symbol table
- How do we bind definitions and uses together? → scope

Symbol Table

= (structured) dictionary that binds a name to information we need

Each entry in the symbol table stores a set of attributes:

- kind – tuple, variable, function, class
- type – integer, integer x string → logical, tuple
- nesting level
- runtime location – where in memory is it stored

Symbol table operations

When do we do these operations?

- insert entry
- lookup name
- add new sub-table
- remove/forget a sub-table

Implementation considerations

- efficiency of access is important
- size unknown ahead of time – need expansion to be graceful & efficient
- don't need to delete entries

⟹ use hash tables

Scoping

scope = block of code in which a name is visible/valid = lifetime of a name

No scope (flat name scope)

assembly, FORTRAN name is visible throughout program

Static/most-nested scope - starting with ALGOL 60

- block structure
  - nested visibility
  - easy to tell which def of a name applies
  - new decls apply to local scope

- name scopes ~ limit region of definition

Kinds of scoping

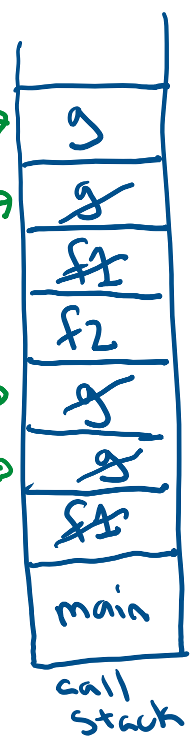
static - can tell at compile time the correspondence between use & declaration

dynamic - correspondence is determined at run time

Dynamic scoping example

What does this print, assuming dynamic scoping?

```
void main() {
    int x = 10;
    f1();
    g();
    f2();
}
void f1() {
    String x = "hello";
    g();
}
void f2() {
    double x = 2.5;
    f1();
    g();
}
void g() {
    print(x);
}
```



Output

hello
10
hello
2.5

Scoping issues to consider

Can the same name be used in multiple scopes?

variable shadowing

Do we allow names to be reused in nesting relations?

```
void verse(int a) {
    int a;
    if (a) {
        int a;
        if (a)
            int a;
    }
  }
}
```

What about when the kinds are different?

```
void chorus(int a) {
     int chorus;
}
```

overloading

Same name; different type

```
int bridge(int a) { … }
bool bridge(int a) { … }
bool bridge(bool a) { … }
int bridge(bool a, bool b) { … }
```

How do we match up uses to declarations?

Determine which uses correspond to which declarations

```
int 1 k = 10, 2 x = 20;
void 3 foo(int 4 k) {
    int 5 a = x 2 ;
    int 6 x = k 4 ;
    int 7 b = x 6 ;
    while (...) {
        int 8 x;
        if (x 8 == k 4 ) {
            int 9 k, 10 y;
            k 9 = y 10 = x 8 ;
        }
        if (x 8 == k 4) {
            int 11 x = y ;   ← error
        }
    }
}
```

Scoping issues to consider (cont.)

Where does declaration have to appear relatative to use?

forward references

How do we implement it?

```
void music(){
    lyrics();
}
void lyrics() {
    music();
}
```

Requires 2 passes

- 1 pass to fill sym tab
- 1 pass to use sym tab

Scope example

What uses and declarations are OK in this Java code?

```
class animal {

    // methods

    void attack(int animal) {
```

ok

not allowed - can't reuse var names inside nesting scopes

```
        for (int animal = 0; animal < 10; animal++) {
            int attack;
```

ok

```
        }
    }
```

overloaded methods cannot only differ in return type

```
    int attack(int x) {
        for (int attack = 0; attack < 10; attack++) {
```

ok

```
            int animal;
        }
    }

    void animal() { }
```

ok

```
    //fields
    double attack;
    int attack;
```

can't have multiple fields with same name

```
    int animal;
```

ok

```
}
```

← p4

Name analysis for base

base is designed for ease of symbol table use

- statically scoped
- global scope plus nested scopes
- all declarations are made at the top of a scope
- declarations can always be removed from table at end of scope

base scoping rules

- use most deeply nested scope to determine binding
- variable shadowing allowed
- formal parameters of function are in same scope as function body

Walk the AST

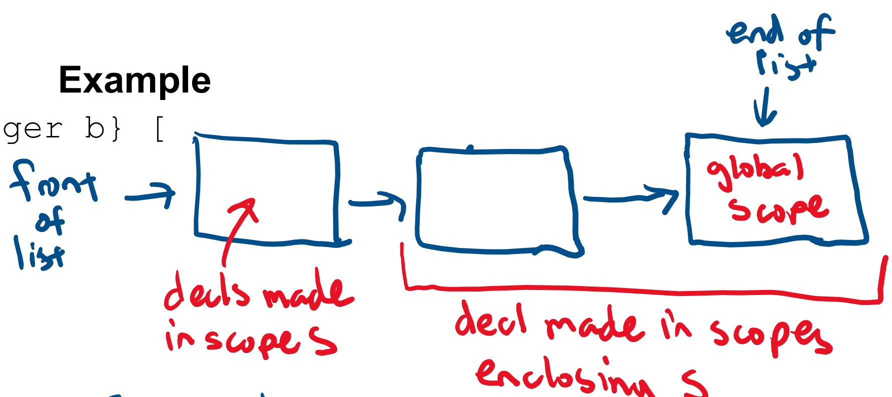
- put new entries into the symbol table when a declaration is encountered
- augment AST nodes where names appear (both declarations & uses) with a link to the relevant object in the symbol table

Symbol-table implementation

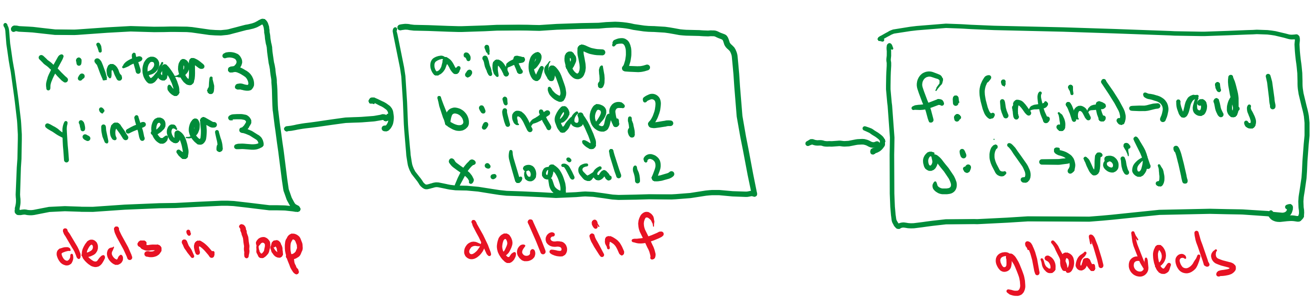
- use a list of hashmaps

Example

```
void f{integer a, integer b} [
    logical x.
    while … [
        integer x, y.
        …
    ]
]
void g{} [
    f().
]
```



Each hashtable corresponds to one scope (ie, contains all decls for that scope)



Symbol kinds

Symbol kinds (= types of identifiers)

- variable have a name, a type
- function declaration has a name, return type, list of parameter types
- `tuple` declaration has a name, list of fields (types w/ names), size

Implementation of Sym class

Many options, here's one suggestion

- `Sym` class for variable definitions
- `FnSym` subclass for function declarations
- `TupleDefSym` subclass for `tuple` type definitions
- `TupleSym` subclass for when you want an instance of a `tuple`

Symbol tables and `tuples`

- Compiler needs to
  - for each field: determine type, size, and offset with the `tuple`
  - determine overall size of `tuple`
  - verify declarations and uses of something of a `tuple` type are valid
- Idea: each `tuple` type definition contains its own symbol table for its field declarations
  - associated with the main symbol table entry for that `tuple`'s name

ie, global