CSE401: Semantic Analysis (A)

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Where are we?

- Lectures:
  - Overview, lexical, syntactic analysis
  - Next: semantic analysis
- Project:
  - Modify lexer, define EBNF for extended PL/0
  - Next: implement syntactic analysis

Semantic analysis

- Perform final checking of legality of input program
  - Properties not checked by lexical and syntactic checking
    - Ex: type checking, ensuring break statement is in a loop, etc.
- "Understand" program well enough to do the back-end activity of synthesis
  - Ex: relate declarations to references of particular variable

Symbol tables

- Key data structure
  - Produced (and used) during semantic analysis
  - Used during code generation
- Stores information about names used in the program
  - Declarations add entries to the symbol table
  - Uses of names lookup appropriate symbol table entry

What information about names?

- Kind of declaration
  - `var`, `const`, `proc`, etc.
- Type
- Value, if it's a `const`
- Place allocated in memory, if `var`
  - Not computed initially, but later on
- Call-by-value or call-by-ref, if formal parameter

Example: a PL/0 `DeclList`

```
var x : int;
var q : array[20] of bool;
procedure foo(a : int); begin … end foo;
const z : int = 10;
```

PL/0 symbol table entries

```
class SymTabEntry {
public:
  char* name();
  Type* type();

  virtual bool isConstant(;
  virtual bool isVariable();
  virtual bool isFormal(;
  virtual bool isProcedure();

  virtual int value(); //constants only
  virtual int offset(SymTabScope* s);
}
```

More in a lecture or two

`SymTab` subclasses

```
class VarSTE    : public SymTabEntry { … };
class FormalSTE : public VarSTE { … };
class ConstSTE  : public SymTabEntry { … };
class ProcSTE   : public SymTabEntry { … };
```


Nested scopes

```
procedure foo(x:int, w:int);
  var z:bool;
  const y:bool = true;
  procedure bar(x:array[5] of bool);
    var y:int;
  begin
    …
    x[y] := z;
  end bar;
begin
  …
  while z do
    var z:int, y:int;
    y := z * x;
    …
  end;
  output := x + y;
end foo;
```


How to handle nested scopes?

- What happens when the same name is declared in different scopes?
- This is first a question of language design: what is the defined semantics?
- Two standard choices
  - Lexical (static) scoping: use the block structure of the program
  - Do you remember choice #2 from 341?

Lexical/static scoping

- The syntactic (block) structure of the program defines how names are resolved
- Given a name in a block
  - Start looking in that block for a declaration of that name; if found, that's the declaration
  - Otherwise, look in the next outermost enclosing block; until a block is found with a declaration for that name
  - If it's not found, then it's an error

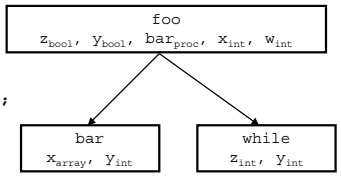
Dynamic scoping

Lexical scoping and symbol tables

- Each scope has its own symbol table
- Logically, for a block-structured program, there is a tree of symbol tables

Tree of symbol tables

```
procedure foo(x:int, w:int);
  var z:bool;
  const y:bool = true;
  procedure bar(x:array[5] of bool);
    var y:int;
  begin
    …
    x[y] := z;
  end bar;
begin
  …
  while z do
    var z:int, y:int;
    y := z * x;
    …
  end;
  output := x + y;
end foo;
```



Tree ⇒ Stack

- In PL/0 and in many compilers, we don't want to manage the full tree of symbol tables at all times
- Observation: we process the program scope by scope
  - When we are resolving names in a particular scope, we've already processed all enclosing scopes
  - Furthermore, we don't need *any* other scopes in the program
- So, instead, we can at any point use a stack to represent the pertinent symbol tables
  - The stack, at a given time, represents the static nesting structure of the program w.r.t. the scope being processed

Nested scope operations

- When we encounter a new scope during semantic analysis
  - Create a new, empty scope
  - Push it on top of symbol table stack
- When encounter a declaration
  - Add entry to the scope on top of the stack
  - Check for duplicates in the scope only (why?)
- When encounter a use
  - Search scopes for declaration, beginning with top of stack
- When exiting a scope
  - Pop top scope off stack

PL/0 symbol table interface

```
class SymTabScope {
public:
  SymTabScope(SymTabScope* enclosingScope);

  void enter(SymTabEntry* newSymbol);
  SymtabEntry* lookup(char* name);
  SymtabEntry* lookup(char* name,
                      SymTabScope*& retScope);
  …
}
```


Next lecture

- We'll start looking at the implementation issues in symbol tables
  - For instance, how to efficiently manage references to outer scopes
- With a particular focus on how PL/0 does it