Scope & Symbol Table

- Most modern programming languages have some notion of scope.
- Scope defines the “lifetime” of a program symbol.
- If a symbol is no longer accessible then we say that it is “out of scope.”
- The simplest scope is the “block scope.”
- With scope we need a notion of variable declaration which allows us to assert in which scope the variable is visible or accessible.

Read Chap 7

Cuppa2

- We extend our Cuppa1 language with variable declarations of the form

```
declare x = 10;
```

- Declares the variable x in the current scope and initializes it to the value 10
- If the current scope is the global (outermost) scope then we call x a "global" variable.

Cuppa2 Grammar

Listing 7.1: Grammar for the Cuppa2 language.

```
stmt_list : (stmt)*

stmt : declare ID (= exp)? ;?
     | ID = exp ;?
     | get ID ;?
     | put exp ;?
     | while \( exp \) stmt
     | if \( exp \) stmt (else stmt)?
     | \{ stmt_list \}

exp : exp_low
exp_low : exp_med ((== | =<) exp_med)*
exp_med : exp_high ((+ | -) exp_high)*
exp_high : primary ((\* | /) primary)*

primary : INTEGER
        | ID
        | \( exp \)
        | - primary
        | not primary

ID : <any valid variable name>
INTEGER : <any valid integer number>
```

```
stmt : declare ID (= exp)? ;?
```

Notice that the initializer for the declaration is optional.

Cuppa2 Frontend

cuppa2_fe.py

```
def stmt(stream):
    token = stream.pointer()
    if token.type in ['DECLARE']:
        stream.match('DECLARE')
        id_tk = stream.match('ID')
        if stream.pointer().type in ['ASSIGN']:
            stream.match('ASSIGN')
            e = exp(stream)
        else:
            # if no initializer assume default value
            e = ('INTEGER', 0)
        if stream.pointer().type in ['SEMI']:
            stream.match('SEMI')
        return ('DECLARE', ('ID', id_tk.value), e)
    elif token.type in ['ID']:   ...
```

The relevant piece of code in the frontend.

Cuppa2

- We can now write properly scoped programs
- Consider:

```
declare x = 1;
{
  declare x = 2;
  put x;
}
{
  declare x = 3;
  put x;
}
put x;
```

Variable Shadowing

- An issue with scoped declarations is that inner declarations can "overshadow" outer declarations
- Consider:

```
declare x = 2;
{
    declare x = 3;
    {
        declare y = x + 2;
        put y;
    }
}
```

What is the output of the program once it is run?

Variable update

- A variable update can be outside of our current scope.
- Consider

```
declare x = 2;
{
    declare y = 3;
    x = y + x;
    put x;
}
put x;
```

Symbol Tables

- To deal with programs like that we need something more sophisticated for variable lookup than a dictionary.

☞ *a dictionary stack*

- This stack needs to be able to support the following functionality
  - Declare a variable (insertion)
  - Lookup a variable
  - Update a variable value

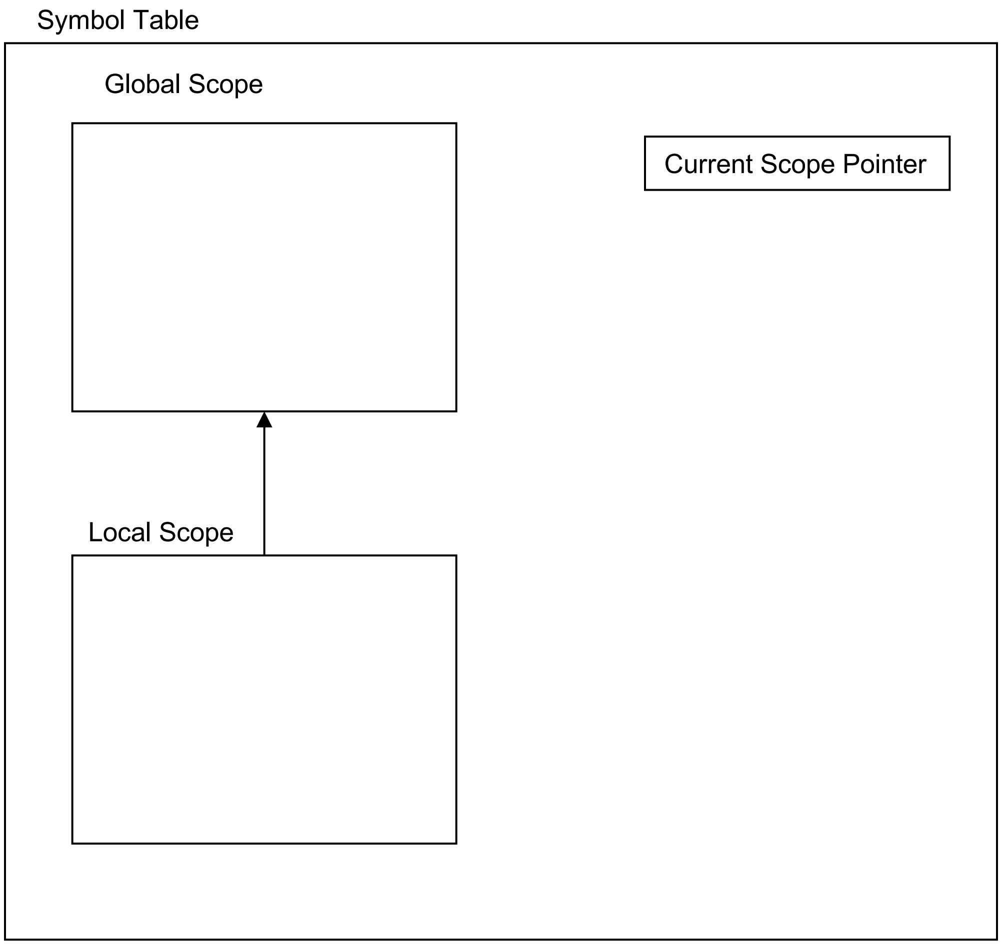
Semantic Rules for Variable Declarations

- Here are the rules which we informally used in the previous examples:
  - The ‘declare’ statement inserts a variable declaration into the current scope
    - a variable lookup returns a variable value from the current scope or the surrounding scopes
  - Every variable needs to be declared before use
  - No variable can be declared more than once in the current scope.

Symbol Tables

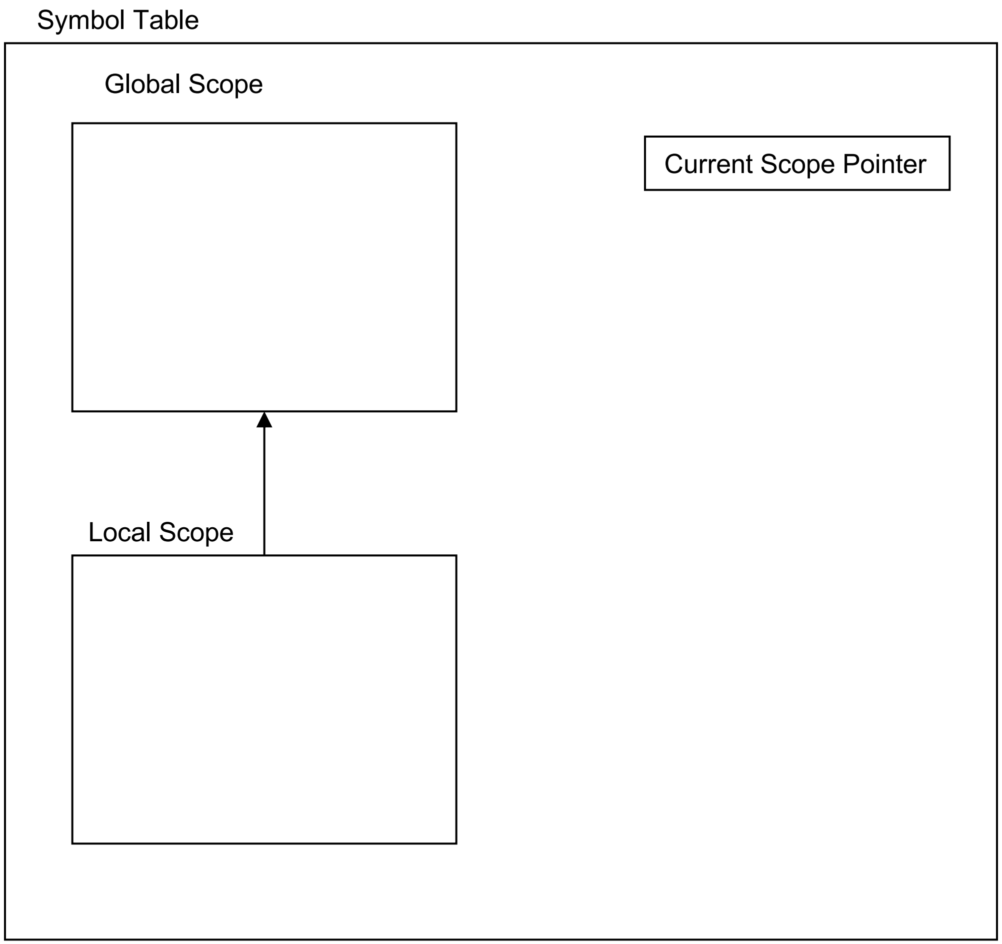
- Design:
  - we have a class SymTab that:
    - Holds a stack of scopes
      - scoped_symtab
    - Defines the interface to the symbol table
      - push_scope, pop_scope, declare_sym, *etc*
  - By default, SymTab is initialized with a single scope on the stack – *the global scope.*

Symbol Tables



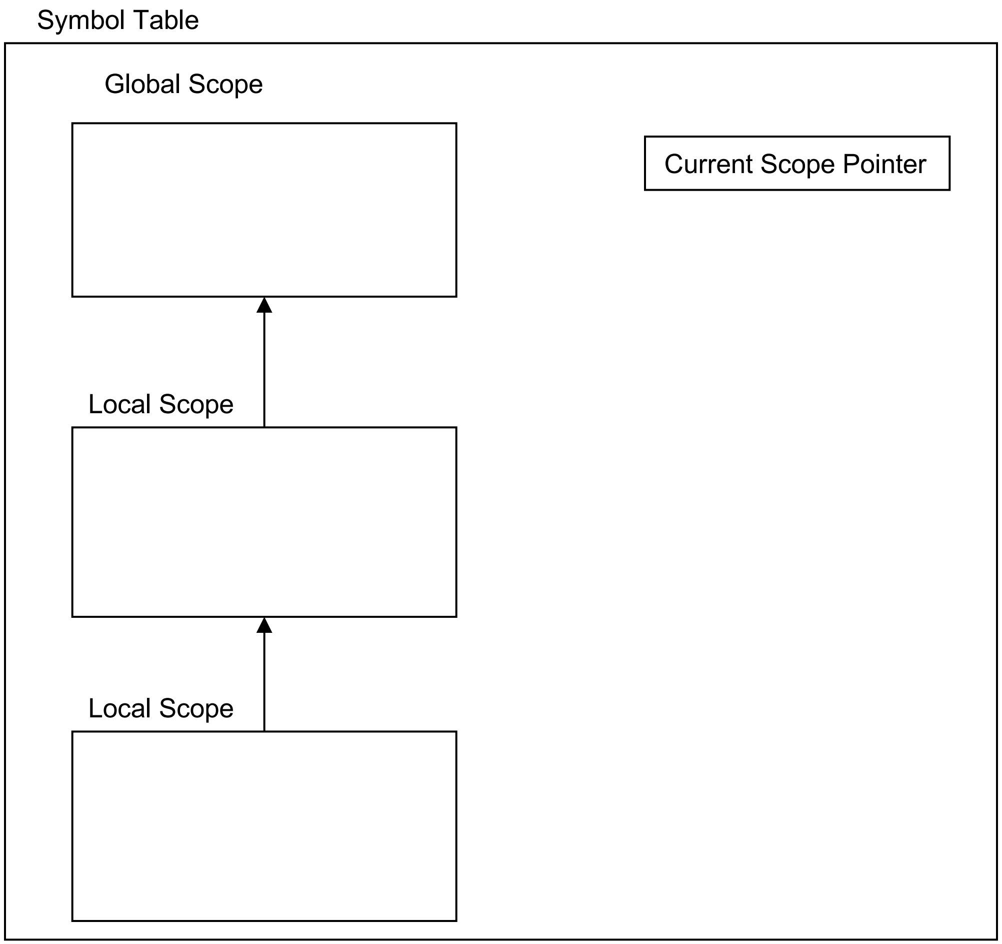

```
declare x = 2;
{
    declare y = 3;
    x = y + x;
    put x;
}
put x;
```

Symbol Tables




```
declare x;
get x;
If (0 <= x)
{
      declare i = x;
      put i;
}
else
{
       declare j = -1 * x;
       put j;
}
put x;
```

Symbol Tables




```
declare x = 2;
{
    declare x = 3;
    {
        declare y = x + 2;
        put y;
    }
}
```

Symbol

cuppa2_symtab.py

```
CURR_SCOPE = 0

class SymTab:

    #-------
    def __init__(self):
        # global scope dictionary must always be present
        self.scoped_symtab = [{}]

    #-------
    def push_scope(self):
        # push a new dictionary onto the stack - stack grows to the left
        self.scoped_symtab.insert(CURR_SCOPE,{})

    #-------
    def pop_scope(self):
        # pop the left most dictionary off the stack
        if len(self.scoped_symtab) == 1:
            raise ValueError("cannot pop the global scope")
        else:
            self.scoped_symtab.pop(CURR_SCOPE)

    #-------
    def declare_sym(self, sym, init):
        # declare the symbol in the current scope: dict @ position 0
        ...

    #-------
    def lookup_sym(self, sym):
        # find the first occurence of sym in the symtab stack
        # and return the associated value
        ...

    #-------
    def update_sym(self, sym, val):
        # find the first occurence of sym in the symtab stack
        # and update the associated value
        ...
```

Symbol Tables

```
def declare_sym(self, sym, init):
       # declare the symbol in the current scope: dict @ position 0

       # first we need to check whether the symbol was already declared
       # at this scope
       if sym in self.scoped_symtab[CURR_SCOPE]:
           raise ValueError("symbol {} already declared".format(sym))

       # enter the symbol in the current scope
       scope_dict = self.scoped_symtab[CURR_SCOPE]
       scope_dict[sym] = init
```

```
def lookup_sym(self, sym):
    # find the first occurence of sym in the symtab stack
    # and return the associated value


    n_scopes = len(self.scoped_symtab)


    for scope in range(n_scopes):
        if sym in self.scoped_symtab[scope]:
            val = self.scoped_symtab[scope].get(sym)
            return val


    # not found
    raise ValueError("{} was not declared".format(sym))
```

Symbol Tables

```
def update_sym(self, sym, val):
    # find the first occurence of sym in the symtab stack
    # and update the associated value

    n_scopes = len(self.scoped_symtab)

    for scope in range(n_scopes):
        if sym in self.scoped_symtab[scope]:
            scope_dict = self.scoped_symtab[scope]
            scope_dict[sym] = val
            return

    # not found
    raise ValueError("{} was not declared".format(sym))
```

Interpret Walker

Note: Same as Cuppa1 interpreter except for the addition of the declaration statement and additional functionality in block statements and variable expressions.

cuppa2_interp_walk.py

```
def walk(node):
    # node format: (TYPE, [child1[, child2[, ...]]])
    type = node[0]
    if type in dispatch:
        node_function = dispatch[type]
        return node_function(node)
    else:
        raise ValueError("walk: unknown tree node type: " + type)

# a dictionary to associate tree nodes with node functions
dispatch = {
    'STMTLIST' : stmtlist,
    'DECLARE'  : declare_stmt,
    'ASSIGN'   : assign_stmt,
    'GET'      : get_stmt,
    'PUT'      : put_stmt,
    'WHILE'    : while_stmt,
    'IF'       : if_stmt,
    'NIL'      : nil,
    'BLOCK'    : block_stmt,
    'INTEGER'  : integer_exp,
    'ID'       : id_exp,
    'PAREN'    : paren_exp,
    'PLUS'     : plus_exp,
    'MINUS'    : minus_exp,
    'MUL'      : mul_exp,
    'DIV'      : div_exp,
    'EQ'       : eq_exp,
    'LE'       : le_exp,
    'UMINUS'   : uminus_exp,
    'NOT'      : not_exp
}
```

Interpret Walker

```
def declare_stmt(node):

    (DECLARE, (ID, name), exp) = node

    value = walk(exp)
    symbol_table.declare_sym(name, value)

    return None
```

```
def block_stmt(node):

    (BLOCK, stmt_list) = node

    symbol_table.push_scope()
    walk(stmt_list)
    symbol_table.pop_scope()

    return None
```

```
def assign_stmt(node):

    (ASSIGN, (ID, name), exp) = node

    value = walk(exp)
    symbol_table.update_sym(name, value)

    return None
```

```
def get_stmt(node):

    (GET, (ID, name)) = node

    s = input("Value for " + name + '? ')

    try:
        value = int(s)
    except ValueError:
        raise ValueError("expected an integer value for " + name)

    symbol_table.update_sym(name, value)

    return None
```

That's it – everything else is the same as the Cuppa1 interpreter!

Syntactic vs Semantic Errors

- Grammars allow us to construct parsers that recognize the syntactic structure of languages.
- Any program that does not conform to the structure prescribed by the grammar is rejected by the parser.
- We call those errors "syntactic errors."

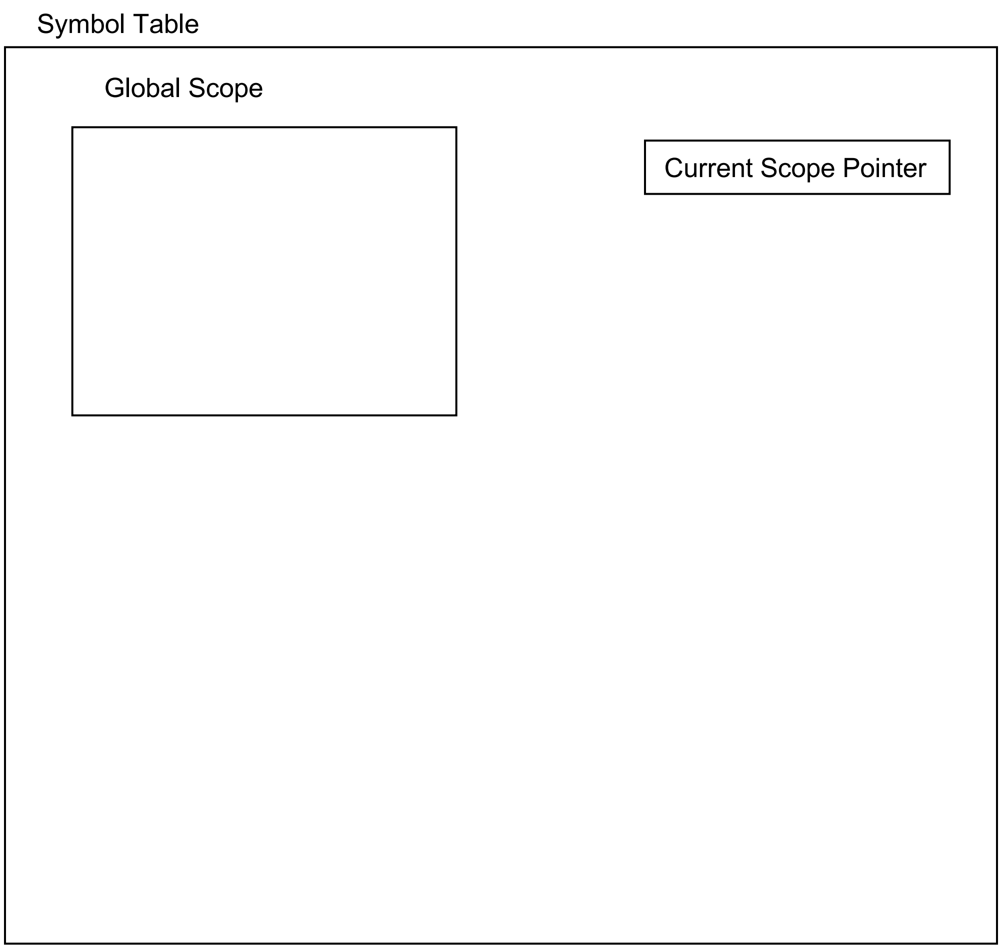
Syntactic vs Semantic Errors

- Semantic errors are errors in the behavior of the program and cannot be detected by the parser.
- Programs with semantic errors are usually syntactically correct
- A certain class of these semantic errors can be caught by the interpreter/compiler. Consider:

```
declare x = 10;
put x + 1;
declare x = 20;
put x + 2;
```

- Here we are redeclaring the variable ‘x’ which is not legal in many programming languages.
- Many other semantic errors cannot be detected by the interpreter/compiler and show up as “bugs” in the program.

Symbol Tables




```
declare x = 10;
put x + 1;
declare x = 20;
put x + 2;
```

Symbol Tables