The Symbol Table

Lecture 13

Section 7.6

Robb T. Koether

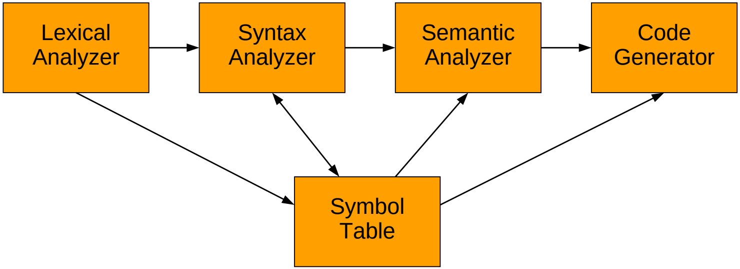
Hampden-Sydney College

Wed, Feb 25, 2009

Outline

The Symbol Table

- When identifiers are found, they will be entered into a symbol table, which will hold all relevant information about identifiers.
- This information will be used later by the semantic analyzer and the code generator.



Symbol Table Entries

- We will store the following information about identifiers.
  - The name (as a string).
  - The data type.
  - The block level.
  - The scope (global, local, or parameter).
  - The offset from the base pointer (for local variables and parameters only).

Symbol Table Entries

- This information is stored in an object called an `IdEntry`.
- This information may not all be known at once.
- We may begin by knowing only the name and data type, and then later learn the block level, scope, and the offset.

Symbol Table Functions

Symbol Table Functions

- `IdEntry install(String s, int blkLev)`
  Install a new symbol in the symbol table.
- `IdEntry idLookup(String s, int blkLev)`
  Return a reference to a symbol that is in the table.

- The two most basic symbol table functions are the ones that insert a new symbol and lookup an old symbol.

Inserting a Symbol

- The `install()` function will insert a new symbol into the symbol table.
- Each symbol has a block level.
  - Block level 1 contains keywords.
  - Block level 2 contains global variables.
  - Block level 3 contains parameters and local variables.
- `install()` will create an `IdEntry` object and store it in the table.

Inserting a Symbol

Contexts

```
int count;
int func(int sum, float count);
int count(int number);
int main()
{
    int count;
        ⋮
}
```

- When the symbol is first encountered by the lexer, we do not yet know the scope or type.
- That is determined later by the parser.
- For example, we could first encounter the symbol `count` in any of several contexts.

Looking up a Symbol

- Whenever a symbol is encountered, we must look it up in the symbol table.
  - If it is the first encounter, then `idLookup()` will return `null`.
  - If it is not the first encounter, then `idLookup()` will return a reference to the `IdEntry` for that identifier found in the table.
- Once we have the `IdEntry` object entered in the symbol table, we may add information to it.

Looking up a Symbol

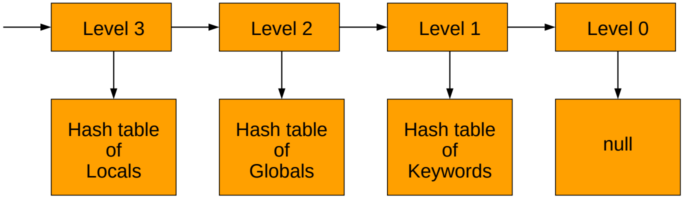
- Since a variable should be declared when it first appears,
    - If the parser is parsing a declaration, then it expects `idLookup()` to return `null`.
    - If the parser is not parsing a declaration, then it expects `idLookup()` to return non-null.
- In each case, anything else is an error.

Block Levels

- Keywords, global variables, and local variables are stored at different block levels.
- C and C++ recognize further levels (blocks) within functions, delimited by braces `{ }`.
- However, in C, variables local to a block must be declared at the beginning of the block.
- Every time we enter a block, the block level increases by 1 and every time we leave a block, it decreases by 1.

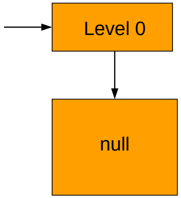
Structure of the Symbol Table

- We will implement the symbol table as a linked list of hash tables, one hash table for each block level.



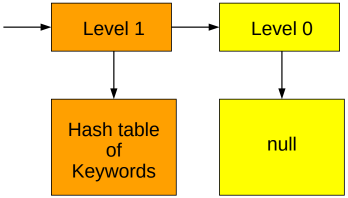
Structure of the Symbol Table

- Initially, we create a null hash table at level 0.



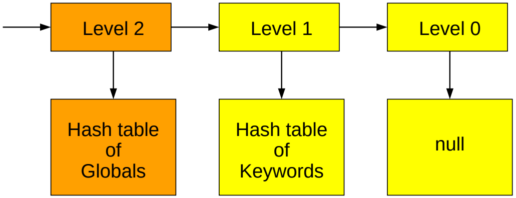
Structure of the Symbol Table

- Then we increase the block level and install the keywords in the symbol table at level 1.



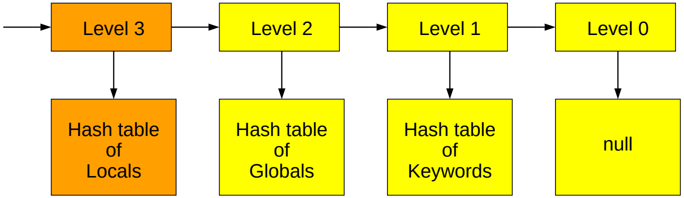
Structure of the Symbol Table

- Then we increase the block level and install the globals at level 2.



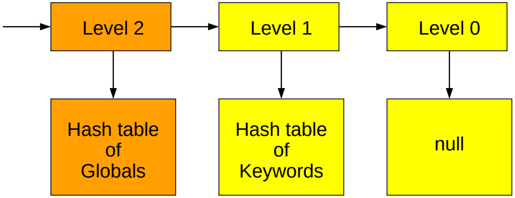
Structure of the Symbol Table

- When we enter a function, we create a level 3 hash table and store parameters and local variables there.



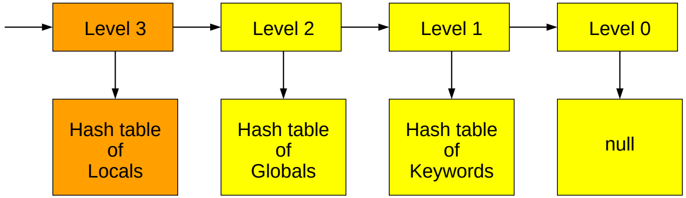
Structure of the Symbol Table

- When we leave the function, the hash table of local variables is deleted from the list.



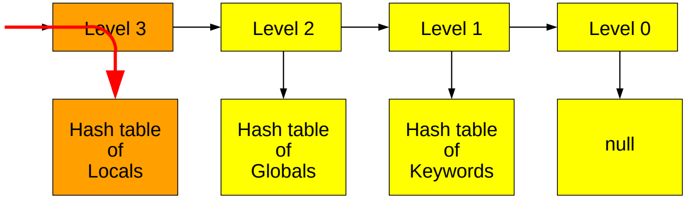
Structure of the Symbol Table

- If we enter another function, a new level 3 hash table is created.



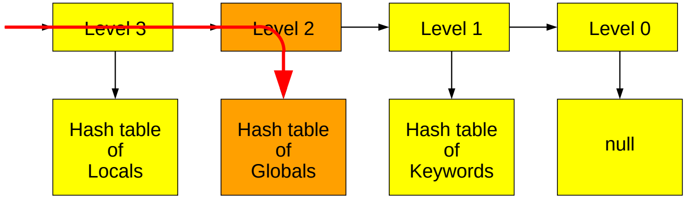
Structure of the Symbol Table

- When we look up an identifier, we begin the search at the head of the list.



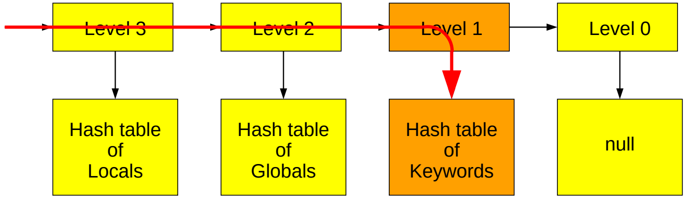
Structure of the Symbol Table

- If it is not found there, then the search continues at the lower levels.



Structure of the Symbol Table

- Keywords are found in the level 1 hash table.



Looking up a Symbol

- If an identifier is declared both globally and locally, which one will be found when it is looked up?
- If an identifier is declared only globally and we are in a function, how will it be found?
- How do we prevent the use of a keyword as a variable name?

Distinguishing Between Keywords and Identifiers

- The keywords are installed at level 1 before the lexer begins.
- When the lexer finds an “identifier,” it looks it up in the symbol table.
- If it finds it at level 1, it returns the appropriate keyword token.
- Otherwise, it returns an identifier token.

Distinguishing Between Keywords and Identifiers

- The benefit of this is that it greatly simplifies the lexer.
- For example, imagine writing a regular expression that accepts `i` and `iff`, but not `if`.
- The regular expression for true identifiers would be immensely complicated.
- However, in `JLex`, we could list the regular expressions of the keywords first, then the regular expression for identifiers.

Hash Tables

Definition (Hash Table)

A hash table is a list in which each member is accessed through a key.

- The key is used to determine where to store the value in the table.
- The function that produces a location from the key is called the hash function.
- For example, if it were a hash table of strings, the hash function might compute the sum of the ASCII values of the first 5 characters of the string, modulo the size of the table.

Hash Tables

- The numerical value of the hashed key gives the location of the member.
- Thus, there is no need to search for the member; the hashed key tells where it is located.
- For example, if the string were "**`return`**", then the key would be

```
(114 + 101 + 116 + 117 + 114) % 100 = 62.
```

- Thus, "**`return`**" would be located in position 62 of the hash table.

Clashes and Buckets

Definition (Clash)

A clash occurs when two entries have the same key.

- Clearly, there is the possibility of a clash.
- In that case, the hash table creates a list, called a bucket, of those values in the table with that same location.
- When that location comes up, the list is searched.
- However, it is generally a very short list, especially if the table size has been chosen well.

Hash Table Efficiency

- The two parameters that determine how efficiently the hash table performs are
  - The capacity - The number of buckets.
  - The load factor - How full the hash table is.

Hash Table Efficiency

- For a given hash table capacity,
  - If there are too many buckets, then many buckets will not be used, leading to space inefficiency.
  - If there are too few buckets, then there will be many clashes, causing the searches to degenerate into predominately sequential searches, leading to time inefficiency.

Hash Tables in Java

- Java has a `Hashtable` class.
- Look it up on the web to see what its member functions are.
- The Java `Hashtable` class will use its own hash function to hash the keys.
- It will manage its capacity and load factor automatically.
- The two most important `Hashtable` functions for us are `put()` and `get()`.

Hash Tables in Java

The put() Function

```
Object put(Object key, Object value);
```

- When we make the function call `put(key, value)`, the hashtable will
  - Hash `key` to compute the location.
  - Insert `value` into the appropriate bucket.
  - Handle any clashes.

Hash Tables in Java

The `get()` Function

```
Object get(Object key);
```

- When we make the function call `get(key)`, the hashtable will
  - Hash `key` to compute the location.
  - Return the `value` that matches the key.

String Tables

- Compilers generally create a table of strings.
- These strings are the “names” of the identifiers, keywords, and other strings used in the program.
- Thus, if the same string is used for several different identifiers, the string will be stored only once in the string table.
- Each symbol table entry will include a pointer to the string in the string table.
- For simplicity, we will not use a string table.

Assignment

Homework

- Read Section 7.6, pages 429 - 440.