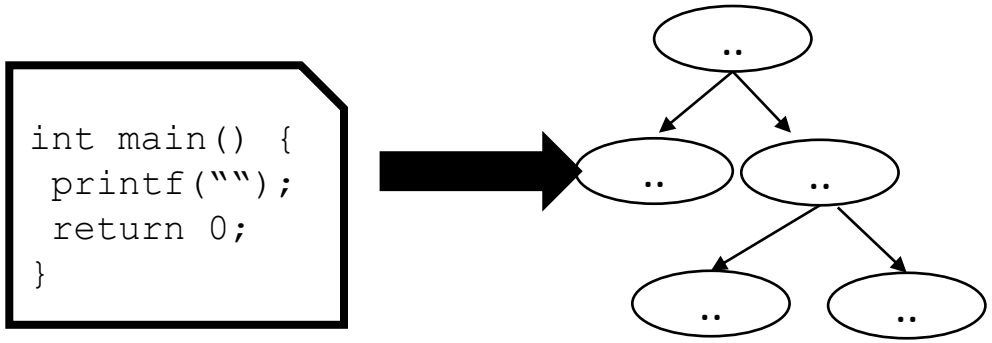
CSE110A: Compilers

Topics:

- *Scope*



Homework questions?

Scope

- What is scope?
- Can it be determined at compile time? Can it be determined at runtime?
- C vs. Python
- Anyone have any interesting scoping rules they know of?

One consideration: Scope

- Lexical scope example

```
int x = 0;
int y = 0;
{
  int y = 0;
  x+=1;
  y+=1;
}
x+=1;
y+=1;
```

What are the final values in x and y?

How to track scope?

- Symbol table object

- Two methods:
  - **`lookup(id)`** **`:`** `lookup an id in the symbol table. Returns None if the id is not in the symbol table.`
  - **`insert(id,info)`** **`:`** `insert a new id (or overwrite an existing id) into the symbol table along with a set of information about the id.`

What information might we store about an id?

a very simple programming language

ID = [a-z]+

INCREMENT = “\+\+”

TYPE = “int”

LBRAC = “{“

RBRAC = “}”

SEMI = “;”

```
int x;
x++;
int y;
y++;
```

statements are either a declaration or an increment

a very simple programming language

ID = [a-z]+

INCREMENT = “\+\+”

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```
int x;
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  x++;
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statements are either a declaration or an increment

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ID = [a-z]+

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TYPE = “int”

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```
int x;
{
   int y;
   x++;
   y++;
}
y++;
```

error!

statements are either a declaration or an increment

How to track scope?

- `SymbolTable ST;`

Say we are matched the statement:
`int x;`

declare_statement ::= TYPE ID SEMI

`{ }`

`lookup(id)` : lookup an id in the symbol table. Returns None if the id is not in the symbol table.

`insert(id,info)` : insert a new id (or overwrite an existing id) into the symbol table along with a set of information about the id.

How to track scope?

- `SymbolTable ST;`

Say we are matched the statement:
`int x;`

declare_statement ::= TYPE ID SEMI

```
{
  self.eat(TYPE)
  variable_name = self.to_match[1] # lexeme value
  self.eat(ID)
  ST.insert(variable_name,None)
  self.eat(SEMI)
}
```

How to track scope?

- `SymbolTable ST;`

Say we are matched string:
`x++;`

inc_statement ::= ID INCREMENT SEMI

`{}`

`lookup(id)` : lookup an id in the symbol table. Returns None if the id is not in the symbol table.

`insert(id,info)` : insert a new id (or overwrite an existing id) into the symbol table along with a set of information about the id.

How to track scope?

- `SymbolTable ST;`

Say we are matched string:
`x++;`

inc_statement ::= ID INCREMENT SEMI

```
{
  variable_name = self.to_match[1] # lexeme value
  if ST.lookup(variable_name) is None:
      raise SymbolTableException(variable_name)
  self.eat(ID)
  self.eat(INCREMENT)
  self.eat(SEMI)
}
```

How to track scope?

- `SymbolTable ST;`

statement : LBRAC statement_list RBRAC

```
int x;
{
   int y;
   x++;
   y++;
}
y++;
```

How to track scope?

- `SymbolTable ST;`

statement : LBRAC statement_list RBRAC

start a new scope S

remove the scope S

```
int x;
{
   int y;
   x++;
   y++;
}
y++;
```

How to track scope?

- Symbol table
- four methods:
  - **`lookup(id)`** : `lookup an id in the symbol table. Returns None if the id is not in the symbol table.`
  - **`insert(id,info)`** : `insert a new id into the symbol table along with a set of information about the id.`
  - **`push_scope()`** : `push a new scope to the symbol table`
  - **`pop_scope()`** : `pop a scope from the symbol table`

How to track scope?

- `SymbolTable ST;`

statement : LBRAC statement_list RBRAC

You will be adding the functions to push and pop scopes in your homework

How to implement a symbol table?

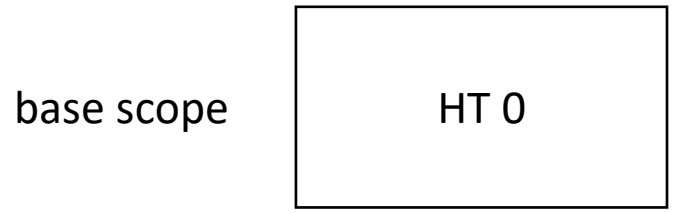
- Thoughts? What data structures are good at mapping strings?

- Symbol table
- four methods:
  - **`lookup(id)`** : `lookup an id in the symbol table. Returns None if the id is not in the symbol table.`
  - **`insert(id,info)`** : `insert a new id into the symbol table along with a set of information about the id.`
  - **`push_scope()`** : `push a new scope to the symbol table`
  - **`pop_scope()`** : `pop a scope from the symbol table`

How to implement a symbol table?

- Many ways to implement:

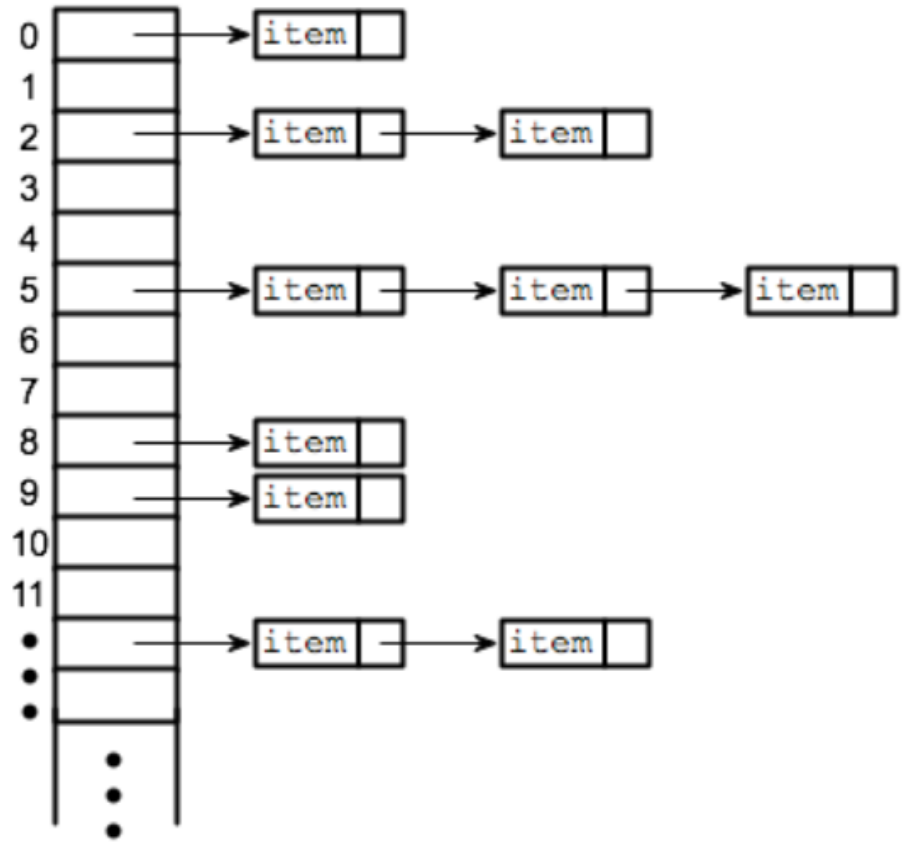
- A good way is a stack of hash tables:

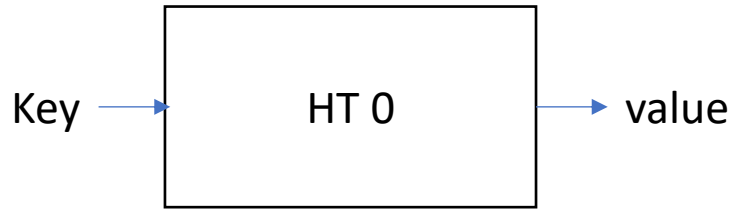


Stack of hash tables

What is a Hash Table?

- A HASH Table starts with a hashing function that maps a string (key) to an index.
- The Index goes into a table of buckets. The more indexes (bucket lists) the less likelihood of a collision.
- Bucket lists entries store each key, value pair.
- Dicts in Python are implemented using hash tables.





Src: https://www.hackerearth.com/practice/data-structures/hash-tables/basics-of-hash-tables/tutorial/

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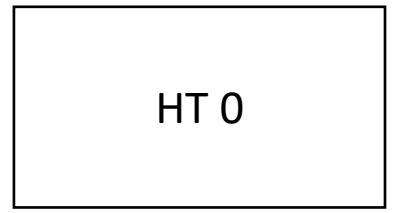

`push_scope()`

Stack of hash tables

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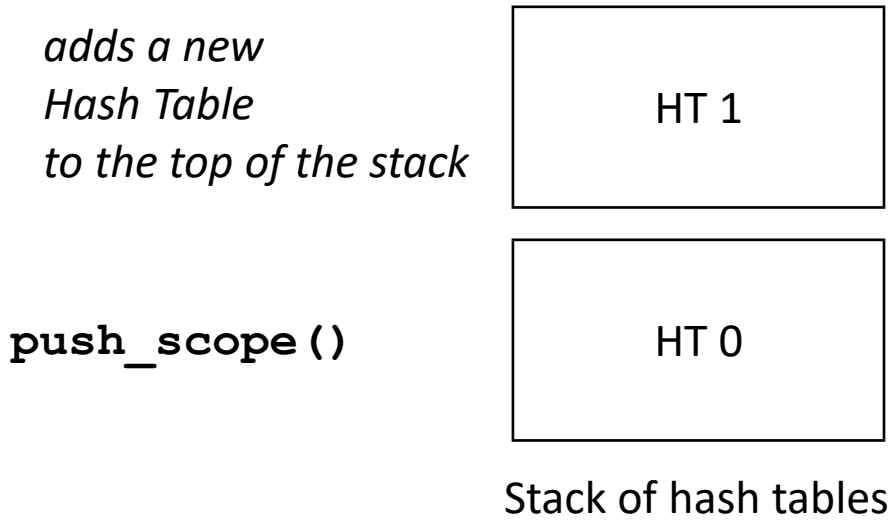

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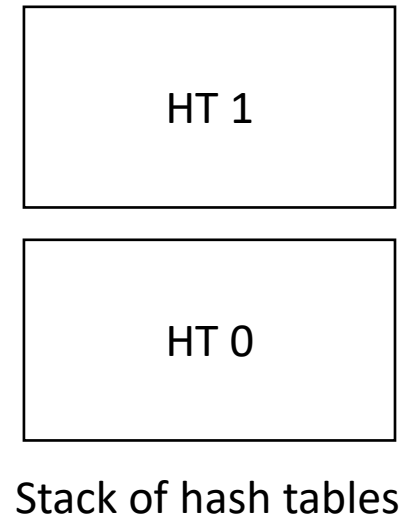

Stack of hash tables

How to implement a symbol table?

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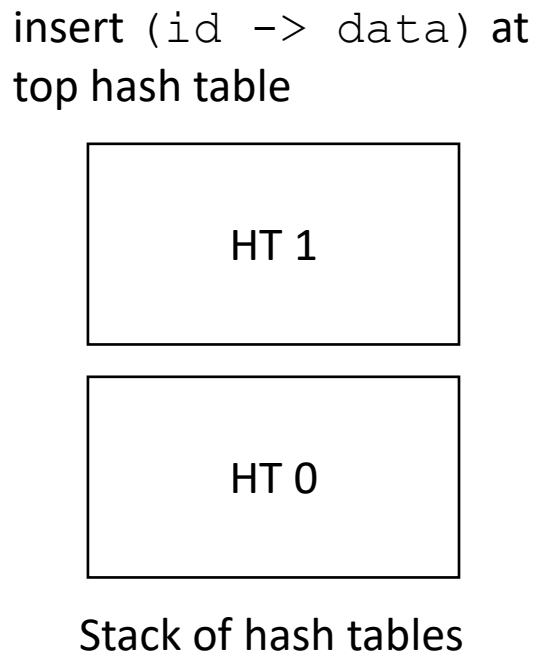
`insert(id,data)`



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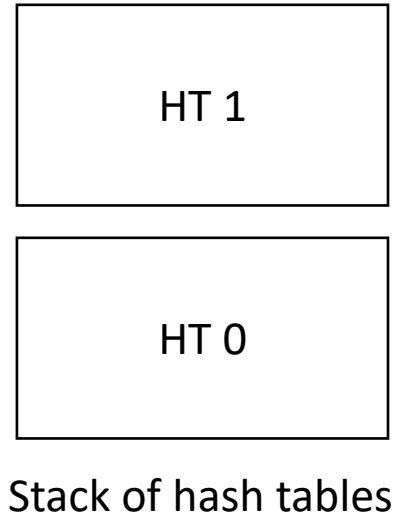

`lookup(id)`

Stack of hash tables

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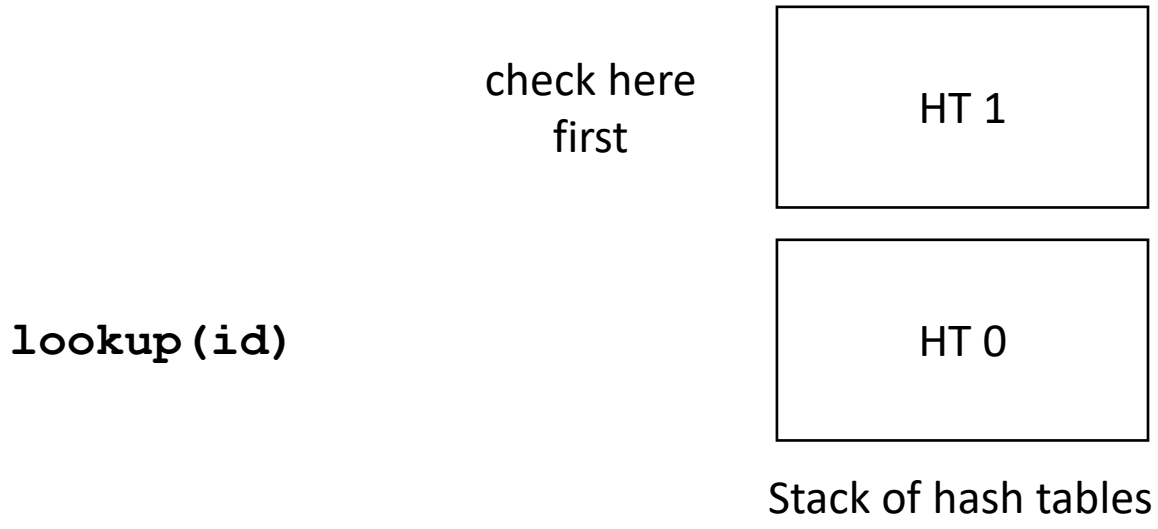

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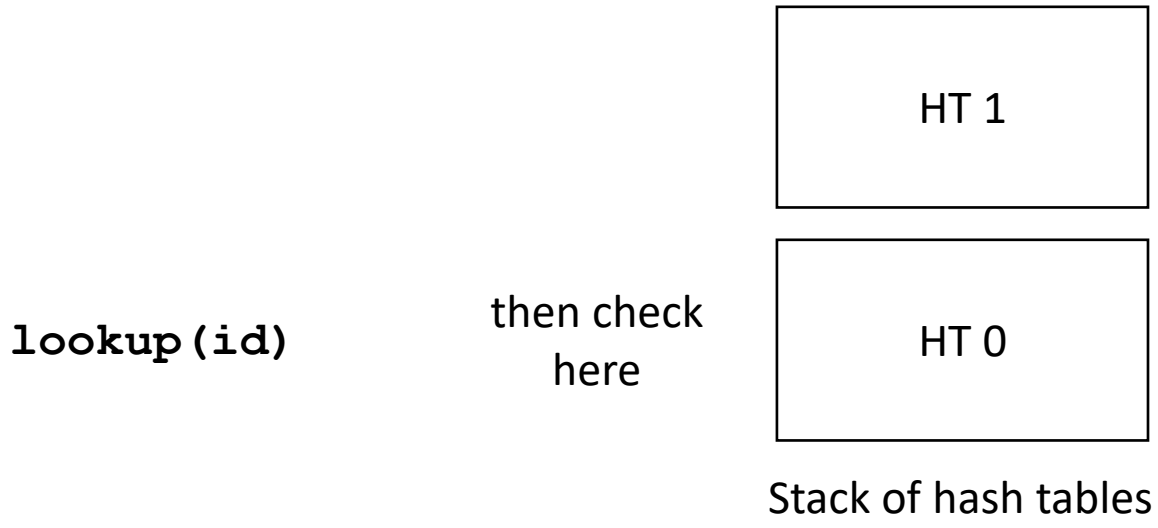

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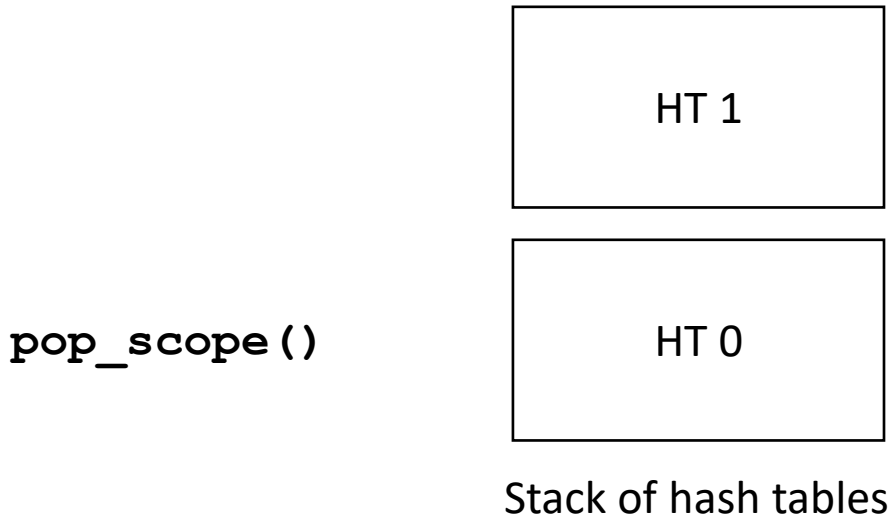

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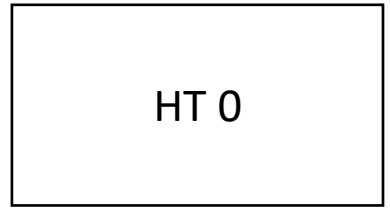
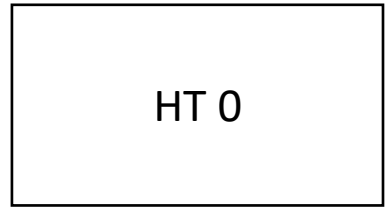


Stack of hash tables

How to implement a symbol table?

- Example

```
int x = 0;
int y = 0;
{
  int y = 0;
  x++;
  y++;
}
x++;
y++;
```



Stack of hash tables

WHAT ELSE?

- GLOBAL VARIABLES
- NAMED SPACES
- DYNAMIC SCOPES

What about Dynamic Scope?

- Example from Perl

```
use strict;
use warnings;
our $x = "global";  # Global variable
sub a {
    print "In a: x = $x\n";
    b();
}
sub b {
    print "In b: x = $x\n";
}
sub main {
    local $x = "local in main";  # Temporarily
override $x for dynamic scope
    print "In main: x = $x\n";
    a();
}
main();
print "After main: x = $x\n";
```

Some languages support dynamic scope, e.g. Perl and Lisp.

In the example x is a global variable (our $x) and a dynamic variable in main (local x) when main calls a() it masks out the global variable x and passes down the local variable to be used in function a and b. X in those functions is derived from the call chain on the stack.

Try it, play with it.

Stack of hash tables
Is dynamically chained
Based on the call stack

Next Topic:

- We will discuss parser generators