

Class 15: Implementing Scope in Function Calls

SI 413 - Programming Languages and Implementation

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Implementing Dynamic Scope

For dynamic scope, we need a stack of bindings for every name.

These are stored in a *Central Reference Table*.

This primarily consists of a mapping from a *name* to a *stack of values*.

The Central Reference Table may also contain a stack of sets, each containing identifiers that are in the current scope.

This tells us which values to pop when we come to an end-of-scope.

Example: Central Reference Tables with Lambdas

```
{  
  new x := 0;  
  new i := -1;  
  new g := lambda z { ret := i; };  
  new f := lambda p {  
    new i := x;  
    if (i > 0) { ret := p(0); }  
    else {  
      x := x + 1;  
      i := 3;  
      ret := f(g);  
    }  
  };  
  write f(lambda y {ret := 0});  
}
```

What gets printed by this (dynamically-scoped) SPL program?

Example: Central Reference Tables with Lambdas

The i in

```
new  $g$  := lambda  $z$  { write  $i$ ; };
```

from the previous program could be:

- The i in scope when the function is actually called.
- The i in scope when g is passed as p to f
- The i in scope when g is defined

Example: Central Reference Tables with Lambdas

The i in

```
new  $g := \text{lambda } z \{ \text{write } i; \};$ 
```

from the previous program could be:

- The i in scope when the function is actually called.
(*dynamic scope, shallow binding*)
- The i in scope when g is passed as p to f
(*dynamic scope, deep binding*)
- The i in scope when g is defined
(*lexical scope*)

Reminder: The class of functions

Recall that functions in a programming language can be:

- **Third class:** Never treated like variables
- **Second class:** Passed as parameters to other functions
- **First class:** Also returned from a function and assigned to a variable.

With *lexical scoping*, rules for binding get more complicated when functions have more flexibility.

Implementing Lexical Scope

What's tough about lexical scope?

Implementing Lexical Scope

What's tough about lexical scope? *Non-local references*.

Many older languages (C/C++, Fortran) avoid this by treating functions as third-class and prohibiting *nested functions*.

Then every name has local scope (to a function or block), or global scope.

The result is *compile-time name resolution* — fast code!

Lexical Scope with Nested Functions

What if we allow just things like this:

```
void f(int x) {  
    void g(int y) {  
        print(x+y);  
    }  
    if (x < 5) g(10);  
    else f(x-1);  
}  
  
int main() { f(6); }
```

Lexical Scope with Nested Functions

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```

We can use *static links* to find bindings in the most recent enclosing function call.

Lexical Scope with 2nd-Class Functions

What if functions have full 2nd-class privileges?

```
(define (f a g)
  (define (h b) (display (+ a b))))
(if (< a 5)
  (f (g a) h)
  (g a)))

(f 4 add1)
```

Lexical Scope with 2nd-Class Functions

What if functions have full 2nd-class privileges?

```
(define (f a g)
  (define (h b) (display (+ a b))))
(if (< a 5)
  (f (g a) h)
  (g a)))

(f 4 add1)
```

Bindings may be further down than most recent call.
We need *dynamic links* into the stack!

Lexical Scope with 1st-Class Functions

What happens here?

```
{  
  new f := lambda x {  
    new g := lambda y { ret := x * y; };  
    ret := g;  
  };  
  
  new h := f(2);  
  write h(3);  
}
```

Lexical Scope with 1st-Class Functions

What happens here?

```
{  
  new f := lambda x {  
    new g := lambda y { ret := x * y; };  
    ret := g;  
  };  
  
  new h := f(2);  
  write h(3);  
}
```

There are some *very* non-local references here!
Where should we store local variables?

Class outcomes

You should know:

- What is meant by shallow/deep binding (roughly)
- Why some language restrict functions to 3rd-class or 2nd-class
- What static links are, and when they can and can't be used
- What non-local references are, and what kind of headaches they create

You should be able to:

- Draw the state of the Central Reference Table at any point in running a dynamically-scoped program
- Trace the run of a lexically-scoped program.