Scope and Parameter Passing

Outline

Review of naming

Most languages provide a way to **name** and **reuse** stuff

Naming concepts

declaration	introduce a new name
binding	associate a name with a thing
reference	use the name to stand for the bound thing

C/Java variables

```
int x; int y;
x = slow(42);
y = x + x + x;
```

In Haskell:

Local variables

```
let x = slow 42
in x + x + x
```

Type names

```
type Radius = Float
data Shape = Circle Radius
```

Function parameters

```
area r = pi * r * r
```

Scope

Every name has a scope

The parts of the program where that name can be referenced

Block: shared scope of a group of declared names

Shadowing: when a declaration in an inner block temporarily hides a name in an outer block

C blocks

```
{ int x;
  int y;
  x = 2;
  if (x == 3) {
    int x = 4;
    int z = 5;
    y = x;
  }
  print(x);
}
```

Python locals

```
def demo():
  x = 6
  if x == 7:
    x = 8
    y = x
  print x
  print y
```

Haskell let

```
let x = 9
    y = x
 in let x = 5
        z = y
    in (x,y)
```

Implementing nested scopes

Recall CS 271 approach:

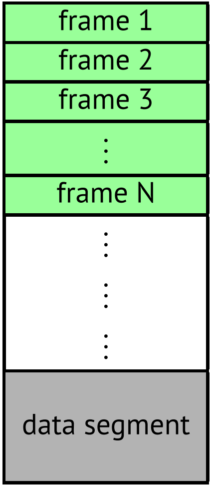
- local variables are stored in a **stack frame**
- **enter** a block: **push** a frame
- **exit** a block: **pop** a frame

```
type Frame = [(Var,Val)]
type Stack = [Frame]
```

Compare with **environments**:

```
type Env = [(Var,Val)]
```

Just a flat stack!



Outline

- Overview
  - Naming and scope
  - Function/procedure calls
- Static vs. dynamic scope
- Parameter passing schemes

Function/procedure declarations

Function definitions declare names in two scopes

1. the **function name**: in the file/module
2. the **argument names** (parameters): in the function body

Example: Haskell

```
triple :: Int -> Int
triple y = double y + y

double :: Int -> Int
double x = x + x

perimeter :: Int -> Int -> Int
perimeter x y = double x + double y
```

Binding parameters

A function definition contains:

- the **declaration** of the parameters
- **references** to the parameters

```
double :: Int -> Int
double x = x + x
```

Q: Where/when are the parameters **bound**?
A: At the **call site**!

```
GHCi> double 5
10
```

References in function definitions

Three kinds of variable names

- parameters
- local variables
- external variables

Where are bindings for ...

- parameter and local names?
  - in current(ish) stack frame!
- external names?
  - good question!

Haskell

```
area :: Float -> Float
area d = let r = d / 2
         in pi * r * r
```

C/Java

```
float area(float d) {
  float r = d / 2;
  return pi * r * r;
}
```

Outline

Static vs. dynamic scope

Static scope: external names refer to variables that are visible at **definition**

Dynamic scope: external names refer to variables that are visible at **call site**

Definition

```
int x = 3;
 ...
int baz(int a) {
  int b = x+a;
  return b;
}
```

Call site

```
int x = 4;
 ...
int y = baz(5);
```

Q: What is the value of **y**?

static scope: 8

dynamic scope: 9

Dynamic scope

References refer to most recent binding **during execution**

Performing a function call

1. push frame with parameters onto the stack
2. run function body, save return value
3. pop frame from stack and resume executing

Tradeoffs:

- easy to implement
- supports ad-hoc extensibility
- all external names are part of the public interface
  - risk of name collision and unintended behavior
  - bad modularity – hard to refactor and understand

Static scope

References refer to most recent binding **in the source code**

Performing a function call

1. save current stack, restore function's stack
2. push frame with parameters onto the stack
3. run function body, save return value
4. restore saved stack and resume executing

Tradeoffs:

- external names are not part of the public interface
    - no risk of name collision – more predictable behavior
    - improved modularity – can change names without breaking clients
- only supports planned extensibility
- harder to implement

Closures

Closure = function + its environment (stack)

Needed to implement static scoping!

Outline

Call-by-value parameter passing

Definition

```
def foo(a,b,c):
  a := b+1
  c := a-b
  return c
```

Call site

```
x := 4
y := foo(3,x,x+1)
```

1. evaluate argument expressions
2. push frame with argument values

Environment: `[(Var,Val)]`

```
[("a",3), ("b",4), ("c",5)]
```

Call-by-name parameter passing

Definition

```
def foo(a,b,c):
  if a > 0 then
    a := a + b
  else
    a := a + c
  return a
```

Call site

```
x := 5
y := 0
foo(x,x+y,x/y)
```

1. push frame with argument expressions

Environment: `[(Var,Exp)]`

```
[("a", Ref "x"),
 ("b", Add (Ref "x") (Ref "y")),
 ("c", Div (Ref "x") (Ref "y"))]
```

This simple approach only works with dynamic scoping – why?

What happens if an argument has a side effect?

Call-by-need parameter passing (a.k.a. lazy evaluation)

Idea: Use call-by-name, but **remember** the value of any argument we evaluate

- only evaluate argument if needed, but evaluate each at most once
- best aspects of call-by-value and call-by-name!

Definition

```
def triple(x,y):
  if x > 0 then
    z := x + x + x
  else
    z := y + y + y
  return z
```

Call site

```
triple (slow(42), crash())
```

1. push frame with argument expressions
2. replace expressions by values as evaluated

Environment: `[(Var, Either Exp Val)]`

Call-by-reference parameter passing

Only relevant in languages with **assignment**

- use a “store” to simulate memory

```
type Store = [(Addr,Val)]
```

Definition

```
def foo(a,b,c):
  a := b+5
  c := a-b
```

Call site

```
x := 2
y := 3
z := 4
foo(x,y,z)
```

Note: only plain variable references allowed as arguments!

1. push frame with argument addresses

Environment: `[(Var,Addr)]`

```
[("a",2), ("b",1), ("c",0)]
```