Lexical Addresses

As we saw in the last lecture, the expression

let x = 1 **y** = 2
 in let f = **proc** (**x**) +(**x**, **y**)
  in (**f x**)

might be compiled to

let _ = 1 _ = 2
 in let _ = **proc** (_) +(<0,0>, <1,1>)
  in (<0,0> <1,0>)

<**n**, **m**> means: **n** frames up in the environment, at position **m**

How can we compute <**n**, **m**> for every bound variable without running the code?

Computing Lexical Addresses

- What creates a new frame?

  let, **letrec**, and (application of) **proc**

- So, to compute the **n** in <**n**, **m**>, count the number of enclosing **let**, **letrec**, and **proc** keywords between the bound variable and its binding
- The **m** in <**n**, **m**> is simply the variable's position in its binding set

Computing Lexical Addresses

Visualize as ***countours*** that separate environment extension from the expressions that use it

proc (**x**) +(**x**, 7)

- Count contour crossings to get **n** + 1
- Cross 1 contour from bound **x** to binding **x**, so first part of address is 0
- Full address is <0, 0>

Computing Lexical Addresses

Visualize as ***countours*** that separate environment extension from the expressions that use it

proc (**y**) **proc** (**x**, **z**) +(**x**, -(**y**, **z**))

- Bound **x**: <0, 0>
- Bound **y**: <1, 0>
- Bound **z**: <0, 1>

Computing Lexical Addresses

Visualize as ***countours*** that separate environment extension from the expressions that use it

proc (**y**) [**proc** (**x**, **z**) [+(**x**, -(**y**, **z**))]]

In general:

proc (<id>$_1$, **...**, <id>$_n$) [<expr>]

Computing Lexical Addresses

Visualize as ***countours*** that separate environment extension from the expressions that use it

let x = 5
in [**x**]

In general:

let <id>$_1$ = <expr>$_1$
... = **...**
<id>$_n$ = <expr>$_n$
in [<expr>]

Computing Lexical Addresses

Visualize as ***countours*** that separate environment extension from the expressions that use it

let x = 5
in [**x**]

- Bound **x**: <0, 0>

Computing Lexical Addresses

Visualize as ***countours*** that separate environment extension from the expressions that use it

let x = 5
y = 7
in [**let x** = **x**
in [+(**x**, **y**)]]

Computing Lexical Addresses

Visualize as ***countours*** that separate environment extension from the expressions that use it

```
let x = 5
    y = 7
  in let x = x
       in +(x, y)
```

- Bound **x**: <0, 0>
- Bound **x**: <0, 0>
- Bound **y**: <1, 1>

Computing Lexical Addresses

Visualize as ***countours*** that separate environment extension from the expressions that use it

```
letrec f = proc (x) +(x, (g 7))
       g = proc (z) -(z, 2)
  in (f 10)
```

In general:

```
letrec <id>1 = <expr>1
         ... = ...
        <id>n = <expr>n
  in <expr>
```

Computing Lexical Addresses

Visualize as ***countours*** that separate environment extension from the expressions that use it

```
letrec f = proc (x) +(x, (g 7))
       g = proc (z) -(z, 2)
  in (f 10)
```

- Bound **x**: <0, 0>
- Bound **g**: <1, 1>
- Bound **z**: <0, 0>
- Bound **f**: <0, 0>

Lexical Addresses are Static

- The contour approach to computing lexical addresses works because they are ***static***
- That's why we can pre-compute them in a compiler

Source Language for Compilation

<expr>	::=	<num>
	::=	<id>
	::=	<prim> ({ <expr> }*(,))
	::=	**let** { <id> = <expr> }* **in** <expr>
	::=	**proc** ({ <id> }*(,)) <expr>
	::=	(<expr> <expr>*)

concrete

Source Language for Compilation

<expr>	::=	(**lit-exp** <num>)
	::=	(**var-exp** <symbol>)
	::=	(**primapp-exp** <prim> (**list** <expr>*))
	::=	(**let-exp** (**list** <symbol>*) (**list** <expr>*) <expr>)
	::=	(**proc-exp** (**list** <symbol>*) <expr>)
	::=	(**app-exp** <expr> (**list** <expr>*))

abstract

Target Language for Compilation

<cexpr>	::=	(**lit-cexp** <num>)
	::=	(**var-cexp** <num> <num>)
	::=	(**primapp-cexp** <prim> (**list** <cexpr>*))
	::=	(**let-cexp** (**list** <cexpr>*) <cexpr>)
	::=	(**proc-cexp** <cexpr>)
	::=	(**app-cexp** <cexpr> (**list** <cexpr>*))

abstract

(no use for concrete)

For implementation: declare a **`cexpression`** datatype with **`define-datatype`**

Compilation Function

```
compile-expression : expr -> cexpr
```

- Mostly trival: create a <cexpr> corresponding to the input <expr>
- Interesting case: **var-exp**
  - Use an environment, almost like evaluation
  - Key difference #1: instead of **apply-env**, we need **lexical-address-in-env**
  - Key difference #2: no closures; instead, compile a **proc** body immediately when we encounter the **proc**

Evaluation Function for the Target Language

- **`eval-cexpression`** is similar to **`eval-expression`**, except:
  - The names in the environment do not matter
  - Use **apply-env-to-lexical-address** instead of **apply-env**

Implementation

(implement in DrScheme)