61A Lecture 29

Monday, November 5

The Structure of an Interpreter

Eval

Base cases:
- Primitive values (numbers)
- Look up values bound to symbols

Recursive calls:
- Eval(operands) of call expressions
- Apply(operator, arguments)
- Eval(sub-expressions) of special forms

Requires an environment for name lookup

Apply

Base cases:
- Built-in primitive procedures

Recursive calls:
- Eval(body) of user-defined proc's

Creates new environments when applying user-defined procedures

Scheme Evaluation

The scheme_eval function dispatches on expression form:

- Symbols are bound to values in the current environment.
- Self-evaluating primitives are called *atoms* in Scheme.
- All other legal expressions are represented as Scheme lists.

```
(if <predicate> <consequent> <alternative>)

(lambda (<formal-parameters>) <body>)

(define <name> <expression>)

(<operator> <operand 0> ... <operand k>)
```

Special forms are identified by the first list element

Anything not a known special form is a call expression

```
(define (f s) (if (null? s) '(3) (cons (car s) (f (cdr s)))))

(f (list 1 2))
```

Demo

Logical Special Forms

Logical forms may only evaluate some sub-expressions.

- **If** expression: (if <predicate> <consequent> <alternative>)
- **And** and **or**: (and <e_1> ... <e_n>), (or <e_1> ... <e_n>)
- **Cond** expr'n: (cond (<p_1> <e_1>) ... (<p_n> <e_n>) (else <e>))

The value of an **if** expression is the value of a sub-expression.

do_if_form

- Evaluate the predicate.
- Choose a sub-expression: <consequent> or <alternative>.
- Evaluate that sub-expression in place of the whole expression.

scheme_eval

Demo

Quotation

The **quote** special form evaluates to the quoted expression.

```
(quote <expression>)
```

Evaluates to the <expression> itself, not its value!

'<expression> is shorthand for (quote <expression>).

```
(quote (1 2))

'(1 2)
```

The scheme_read parser converts shorthand to a combination.

Demo

Lambda Expressions

Lambda expressions evaluate to user-defined procedures.

```
(lambda (<formal-parameters>) <body>)

(lambda (x) (* x x))
```

```
class LambdaProcedure(object):

    def __init__(self, formals, body, env):

        self.formals = formals          A scheme list of symbols

        self.body = body                A scheme expression

        self.env = env                  A Frame instance
```

Frames and Environments

A frame represents an environment by having a parent frame.

Frames are Python instances with methods **lookup** and **define.**

In Project 4, Frames do not hold return values.

g: Global frame	
y	3
z	5

[parent=g]	
x	2
z	4

Demo

Define Expressions

Define expressions bind a symbol to a value in the first frame of the current environment.

```
(define <name> <expression>)
```

Evaluate the <expression>.

Bind <name> to the result (**define** method of the current frame).

```
(define x 2)
```

Procedure definition is a combination of define and lambda.

```
(define (<name> <formal parameters>) <body>)

(define <name> (lambda (<formal parameters>) <body>))
```

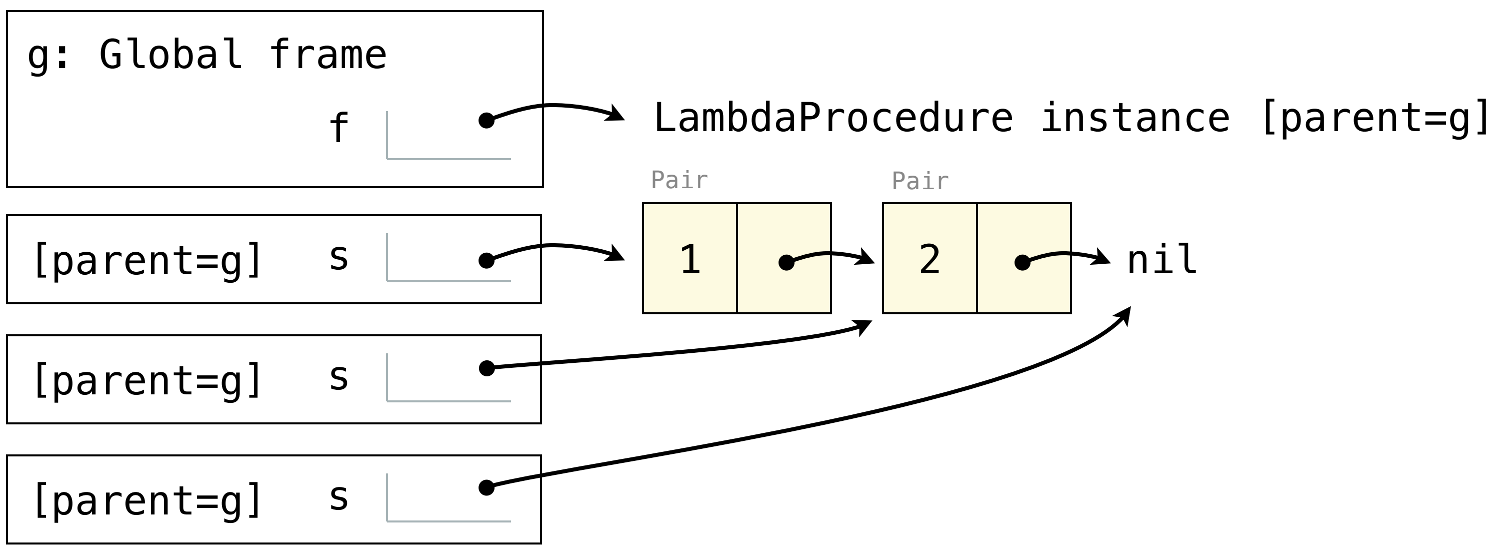
Applying User-Defined Procedures

Create a new frame in which formal parameters are bound to argument values, whose parent is the **env** of the procedure.

Evaluate the body of the procedure in the environment that starts with this new frame.

```
(define (f s) (if (null? s) '(3) (cons (car s) (f (cdr s)))))
```

```
(f (list 1 2))
```



Demo

Eval/Apply in Lisp 1.5

```
apply[fn;x;a] =
     [atom[fn] → [eq[fn;CAR] → caar[x];
                  eq[fn;CDR] → cdar[x];
                  eq[fn;CONS] → cons[car[x];cadr[x]];
                  eq[fn;ATOM] → atom[car[x]];
                  eq[fn;EQ] → eq[car[x];cadr[x]];
                  T → apply[eval[fn;a];x;a]];
     eq[car[fn];LAMBDA] → eval[caddr[fn];pairlis[cadr[fn];x;a]];
     eq[car[fn];LABEL] → apply[caddr[fn];x;cons[cons[cadr[fn];
                                                  caddr[fn]];a]]]
eval[e;a] = [atom[e] → cdr[assoc[e;a]];
     atom[car[e]] →
               [eq[car[e],QUOTE] → cadr[e];
               eq[car[e];COND] → evcon[cdr[e];a];
               T → apply[car[e];evlis[cdr[e];a];a]];
     T → apply[car[e];evlis[cdr[e];a];a]]
```

Dynamic Scope

The way in which names are looked up in Scheme and Python is called *lexical scope* (or *static scope*).

Lexical scope: The parent of a frame is the environment in which a procedure was *defined*.

Dynamic scope: The parent of a frame is the environment in which a procedure was *called*.

Special form to create dynamically scoped procedures

```
             mu
(define f (~~lambda~~ (x) (+ x y)))

(define g (lambda (x y) (f (+ x x))))

(g 3 7)
```

Lexical scope: The parent for f's frame is the global frame.

Error: unknown identifier: y

Dynamic scope: The parent for f's frame is g's frame.

13