61A Lecture 27

Wednesday, November 5

Announcements

- Homework 7 due Wednesday 4/8 @ 11:59pm
  - Homework party Tuesday 4/7 5pm–6:30pm in 2050 VLSB
- Project 1, 2, & 3 composition revisions due Monday 4/13 @ 11:59pm
- Quiz 2 released Tuesday 4/7 & due Thursday 4/9 @ 11:59pm
  - Open note, open interpreter, closed classmates, closed Internet
- Project 4 due Thursday 4/23 @ 11:59pm (Big!)

Interpreting Scheme

The Structure of an Interpreter

Eval

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

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

Requires an environment for symbol lookup

Apply

Base cases:
- Built-in primitive procedures

Recursive calls:
- Eval(body) of user-defined procedures

Creates a new environment each time a user-defined procedure is applied

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Special Forms

Scheme Evaluation

The scheme_eval function choose behavior based on expression form:
- Symbols are looked up in the current environment
- Self-evaluating expressions are returned as values
- All other legal expressions are represented as Scheme lists, called combinations

```
(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

Any combination that is not a known special form is a call expression

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

(demo (list 1 2))
```

Logical Forms

Logical Special Forms

Logical forms may only evaluate some sub-expressions

- **If** expression: (**if** <predicate> <consequent> <alternative>)
- **And** and **or**: (**and** <e1> ... <en>), (**or** <e1> ... <en>)
- **Cond** expression: (**cond** (<p1> <e1>) ... (<pn> <en>) (else <e>))

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

do_if_form

scheme_eval

(Demo)

Quotation

Quotation

The quote special form evaluates to the quoted expression, which is not evaluated

(quote <expression>)   (quote (+ 1 2)) → evaluates to the three-element Scheme list → (+ 1 2)

The <expression> itself is the value of the whole quote expression

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

(quote (1 2))   is equivalent to   '(1 2)

The scheme_read parser converts shorthand ' to a combination that starts with quote

(Demo)

Lambda Expressions

Lambda Expressions

Lambda expressions evaluate to user-defined procedures

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

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

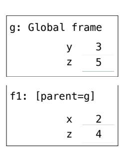
```
class LambdaProcedure:
    def __init__(self, formals, body, env):
        self.formals = formals ........ A scheme list of symbols
        self.body = body .............. A scheme expression
        self.env = env ................ A Frame instance
```


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



(Demo)

Define Expressions

Define Expressions

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

(**define** <name> <expression>)

1. Evaluate the <expression>
2. Bind <name> to its value in the current frame

(**define** x (+ 1 2))

Procedure definition is shorthand of define with a lambda expression

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

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

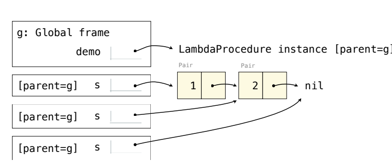
Applying User-Defined Procedures

To apply a user-defined procedure, create a new frame in which formal parameters are bound to argument values, whose parent is the **env** attribute of the procedure

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

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

(demo (list 1 2))



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]]
```