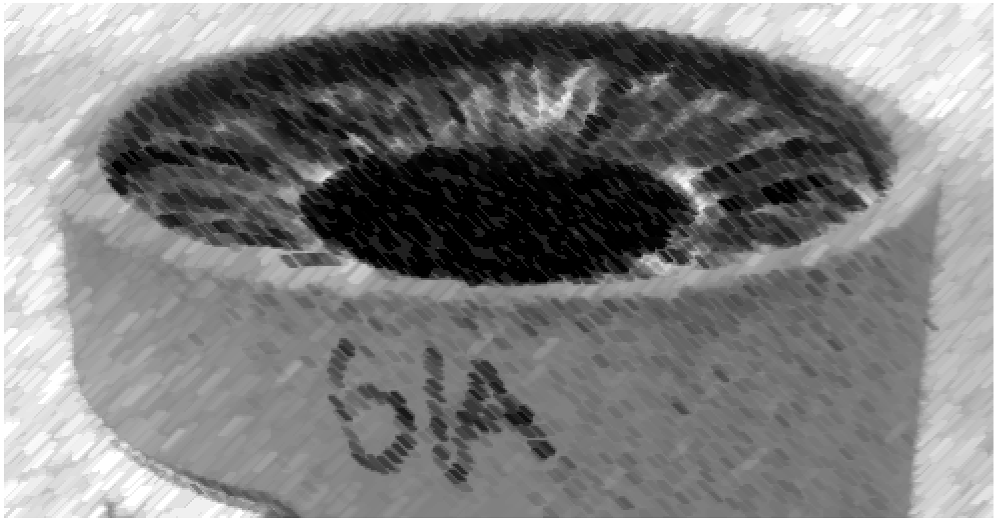

CS61A Lecture 34

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Announcements

- HW10 deadline extended to 11:59pm Thursday
- Scheme project out

Read-Eval-Print Loop

The user interface to many programming languages is an interactive loop, which

- Reads an expression from the user,
- Parses the input to build an expression tree,
- Evaluates the expression tree,
- Prints the resulting value of the expression

The REPL handles errors by printing informative messages for the user, rather than crashing

A well-designed REPL should not crash on any input!

The Structure of an Evaluator

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))
```

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.

- Evaluate the predicate.
- Choose a sub-expression: **<consequent>** or **<alternative>**

do_if_form

- Evaluate that sub-expression in place of the whole expression.

scheme_eval

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

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
```

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>))
```

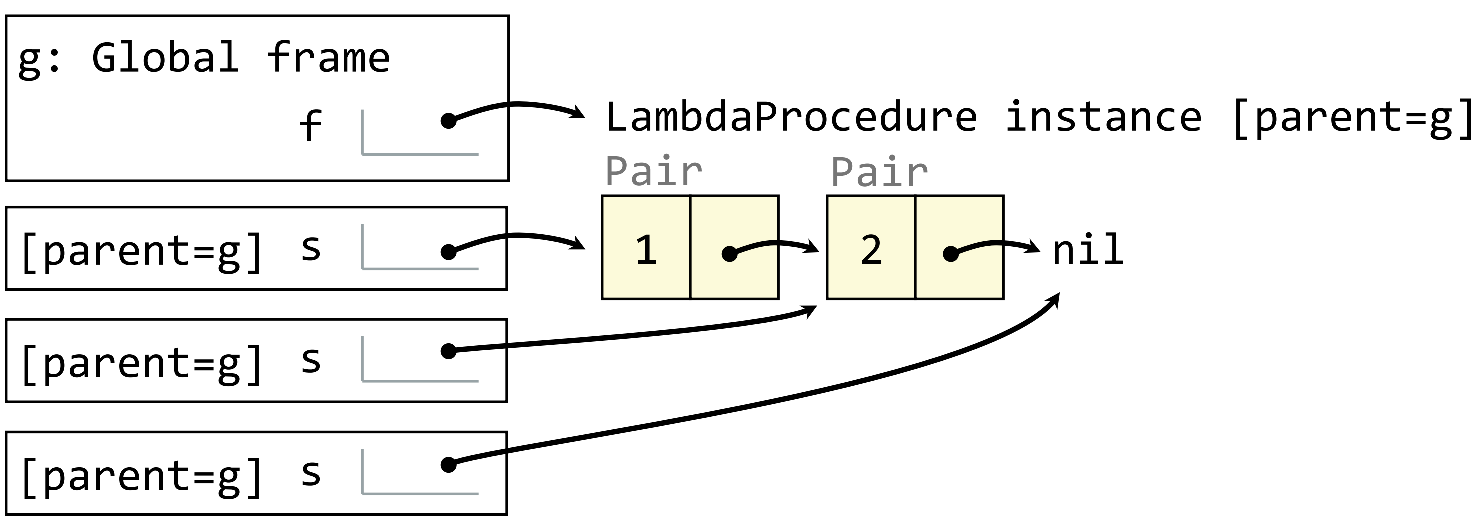
Applying User-Defined Procedures

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))
```



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

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