61A Lecture 23

Wednesday, October 30

Announcements

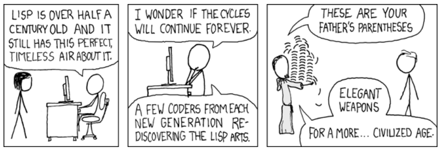
- Homework 7 due Tuesday 11/5 @ 11:59pm.
- Project 1 composition revisions due Thursday 11/7 @ 11:59pm.
- Midterm 2 is graded.
  - (And yes, it was very challenging.)
  - Mean: 30
  - Solutions will be posted and exams distributed soon.

Scheme

Scheme is a Dialect of Lisp

What are people saying about Lisp?

- "The greatest single programming language ever designed."
  -Alan Kay, co-inventor of Smalltalk and OOP
- "The only computer language that is beautiful."
  -Neal Stephenson, DeNero's favorite sci-fi author
- "God's programming language."
  -Brian Harvey, Berkeley CS instructor extraordinaire


LISP IS OVER HALF A CENTURY OLD AND IT STILL HAS THIS PERFECT, TIMELESS AIR ABOUT IT.
I WONDER IF THE CYCLES WILL CONTINUE FOREVER.
A FEW CODERS FROM EACH NEW GENERATION RE-DISCOVERING THE LISP ARTS.
THESE ARE YOUR FATHER'S PARENTHESES
ELEGANT WEAPONS
FOR A MORE... CIVILIZED AGE.

http://imgs.xkcd.com/comics/lisp_cycles.png

Scheme Fundamentals

Scheme programs consist of expressions, which can be:

- Primitive expressions: 2, 3.3, true, +, quotient, ...
- Combinations: (quotient 10 2), (not true), ...

Numbers are self-evaluating; *symbols* are bound to values.

Call expressions include an operator and 0 or more operands in parentheses.

```
> (quotient 10 2)
5
> (quotient (+ 8 7) 5)
3
> (+ (* 3
        (+ (* 2 4)
           (+ 3 5)))
     (+ (- 10 7)
        6))
```

“quotient” names Scheme’s built-in integer division procedure (i.e., function)

Combinations can span multiple lines (spacing doesn’t matter)

(Demo)

Special Forms

Special Forms

A combination that is not a call expression is a *special form*:

- **If** expression: (if <predicate> <consequent> <alternative>)
- **And** and **or:** (and <e_1> ... <e_n>), (or <e_1> ... <e_n>)
- Binding symbols: (define <symbol> <expression>)
- New procedures: (define (<symbol> <formal parameters>) <body>)

Evaluation:
(1) Evaluate the predicate expression.
(2) Evaluate either the consequent or alternative.

```
> (define pi 3.14)
> (* pi 2)
6.28
```

The symbol “pi” is bound to 3.14 in the global frame

```
> (define (abs x)
    (if (< x 0)
        (- x)
        x))
> (abs -3)
3
```

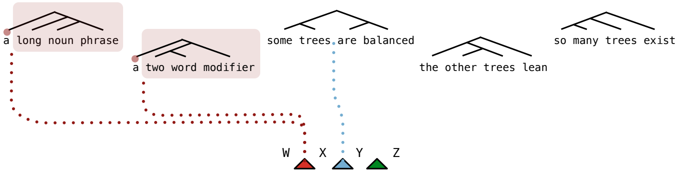
A procedure is created and bound to the symbol “abs”

(Demo)

Counting Trees

Example: Counting Binary Trees

The structure of a sentence can be described by a tree. Each sub-tree is a *constituent*.



The number of trees over n leaves with k leaves in the left and n-k in the right is:
(The number of trees with **k** leaves) * (The number of trees with **n-k** leaves)

(Demo)

Lambda Expressions

Lambda Expressions

Lambda expressions evaluate to anonymous procedures.

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

λ

Two equivalent expressions:

```
(define (plus4 x) (+ x 4))

(define plus4 (lambda (x) (+ x 4)))
```

An operator can be a call expression too:

```
((lambda (x y z) (+ x y (square z))) 1 2 3)
```

Evaluates to the *add-**x**-&-**y**-&-z^2* procedure

Pairs and Lists

Pairs and Lists

In the late 1950s, computer scientists used confusing names.

- **cons:** Two-argument procedure that **creates a pair**
- **car:** Procedure that returns the **first element** of a pair
- **cdr:** Procedure that returns the **second element** of a pair
- **nil:** The empty list

They also used a non-obvious notation for recursive lists.

- A (recursive) list in Scheme is a pair in which the second element is nil or a Scheme list.
- Scheme lists are written as space-separated combinations.
- A dotted list has any value for the second element of the last pair; maybe not a list!

```
> (define x (cons 1 2))
> x
(1 . 2)
> (car x)
1
> (cdr x)
2
> (cons 1 (cons 2 (cons 3 (cons 4 nil))))
(1 2 3 4)
```

Not a well-formed list!

(Demo)

Symbolic Programming

Symbolic Programming

Symbols normally refer to values; how do we refer to symbols?

```
> (define a 1)
> (define b 2)
> (list a b)
(1 2)
```

No sign of “a” and “b” in the resulting value

Quotation is used to refer to symbols directly in Lisp.

```
> (list 'a 'b)
(a b)
> (list 'a b)
(a 2)
```

Symbols are now values

Quotation can also be applied to combinations to form lists.

```
> (car '(a b c))
a
> (cdr '(a b c))
(b c)
```

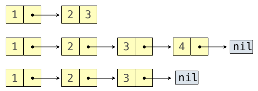
Scheme Lists and Quotation

Dots can be used in a quoted list to specify the second element of the final pair.

```
> (cdr (cdr '(1 2 . 3)))
3
```

However, dots appear in the output only of ill-formed lists.

```
> '(1 2 . 3)
(1 2 . 3)
> '(1 2 . (3 4))
(1 2 3 4)
> '(1 2 3 . nil)
(1 2 3)
```



What is the printed result of evaluating this expression?

```
> (cdr '((1 2) . (3 4 . (5))))
(3 4 5)
```

Sierpinski's Triangle

(Demo)