Lecture #26: Announcements

Project 1 revisions: due April 10.
Hackathon: "There is a hackathon hosted by H@B—Big Hack—vs. Stanford this Weekend. Prizes include: Macbook Airs, Retina iPads, Oculus Rifts, Pebble Smartwatches. You don’t need to have hackathon experience to attend: it’ll be a lot of fun! This Weekend Saturday April 5th to Sunday April 6th (We’ll be back in Berkeley by 6pm). Workshop today that will give you ideas and give you tips about hackathons from previous winners. Please visit the Big Hack facebook page for information on how to register and if you have any questions." – Apoorva Dornadula

Webcast Survey: "Educational Technology Services (ETS) is planning the future of the Webcast program; in particular we will be making choices about "where" we make course webcasts available to you. Your input is valuable! Please take a few minutes to answer the questions using the link (in the Announcements section on the home page.)"

Scheme and Scheme Interpretation

• A little philosophy: why are we talking about interpreters, etc.?
• Idea is to understand your programming language better by understanding common concepts in the design of programming languages
• ...And also to get better mental models of what programs are doing by actually studying how a program might be executed.
• With this, you can perhaps develop better intuitions about what usages are likely to be expensive.
• More directly, many projects can benefit from the introduction of specialized "little languages" and studying interpreters gives you some background in defining and implementing them.

A Bit More Scheme. Standard List Searches: assoc, etc.

• The functions assq, assv, and assoc classically serve the purpose of Python dictionaries.
• An association list is a list of key/value pairs. The Python dictionary {1 : 5, 3 : 6, 0 : 2} might be represented
  (((1 . 5) (3 . 6) (0 . 2))
• The assq functions access this list, returning the pair whose car matches a key argument.
• The difference between the methods is whether we use eq? (Python is), eqv? (handles numbers better), or equal? (more like Python ==).

(define (assq key L)
  (cond ((null? L) #f)
        ((eqv? key (caar L)) (car L))
        (else (assq key (cdr L)))))

• Why caar?
  - L has the form ((key1 . val1) (key2 . val2) ...).
  - So the car of L is (key1 . val1), and its key is therefore (car (car L)) (or caar for short).

A classic: reduce

;; Assumes f is a two-argument function and L is a list.
;; If L is (x1 x2...xn), the result of applying f n-1 times
;; to give (f (f (... (f x1 x2) x3) x4) ...).
;; If L is empty, returns f with no arguments.
(define (reduce f L)
  (cond ((null? L) f)
        ((null? (cdr L)) (car L))
        (else (reduce f (cons (f (car L) (cadr L)) (cddr L))))))

Reduce Solution (1)

;; Assumes f is a two-argument function and L is a list.
;; If L is (x1 x2...xn), the result of applying f n-1 times
;; to give (f (f (... (f x1 x2) x3) x4) ...).
;; If L is empty, returns f with no arguments.
(define (reduce f L)
  (cond ((null? L) (f)) ; Odd case with no items
        ((null? (cdr L)) (car L)) ; One item: apply f 0 times
        (else (reduce f (cons (f (car L) (cadr L)) (cddr L))))))

; E.g.:
; ; (reduce + '(1 2 3 4))
; ; -calls-> (reduce + (5 4))
; ; -calls-> (reduce + (9))
; ; -yields-> 9
Reduce Solution (2)

%; Assumes f is a two-argument function and L is a list.
%; If L is (x1 x2...xn), the result of applying f n-1 times
%; to give (f (f (... (f x1 x2) x3) x4) ...).
%; If L is empty, returns f with no arguments.
(define (reduce f L)
  (define (reduce-tail accum R)
    (cond ((null? R) accum)
          (else (reduce-tail (f accum (car R)) (cdr R)))))
  (if (null? L) (f) ;; Special case
      (reduce-tail (car L) (cdr L))))

Another classic: (two-argument) map

%; Ignore that this is actually built-in.
%; The obvious way goes like this:
%; ; Assumes f is a one-argument function and L is the
%; ; list (x1 ... xn). Returns the list ((f x1) ... (f xn)).
(define (map1 f L) ;; map1 because it takes only one list
  (if (null? L) '()
      (cons (f (car L)) (map1 f (cdr L)))))

Tail-Recursive Map1

%; Previous implementation is not tail recursive.
%; Hint: reverse is built in.
;; Assumes f is a one-argument function and L is the
;; list (x1 ... xn). Returns the list ((f x1) ... (f xn)).
(define (map1-f L)
  ;; The reverse of (map1 f L) prepended to the list sofar.
  (define (map1-tail sofar L)
    (if (null? L) sofar
        (map1-tail (cons (f (car L)) sofar) (cdr L))))
  (reverse (map1-tail '() L)))

Problem: Unknown Argument List Lengths

%; The full map function is like that in Python:
(map + '(1 2 3) '(10 20 30) '(100 200 300))
==> (list (+ 1 10 100) (+ 2 20 200) (+ 3 30 300))
==> (111 222 333)

%; So there must be a step in map where we call its function argument
%; with a list of parameters of arbitrary length.
%; In Python, can do such things with *, as in f(*L).
%; In Scheme, it is a built-in function: apply.

Apply: Controlling Function Evaluation

%; The standard function apply has the effect of allowing one to con-
%; struct and evaluate function calls.
%; To call a function, one generally needs to know how many arguments
%; it takes, and then wire that into the call expression, as in f(x,y)—
%; you may not know what precise function f is, but you must know how
%; many arguments it takes.
%; In Lisp (and Scheme) the function apply handles this:
(define L '(1 2 3))
(apply + L) ===> (+ 1 2 3) ===> 6

Eval

%; From early on, Lisp systems have used the fact that programs are
%; represented as Lisp data that is processed by an evaluator.
%; The eval function has been in Lisp for some time.
%; It treats its argument as a Lisp expression and evaluates it.
%; E.g., (eval (list + 1 2)) produces 3.
%; Only recently added to Scheme officially (since version 5), perhaps
%; in part because it is a little more difficult to define in Scheme than
%; original Lisp.
%; One difficulty is that original Lisp was dynamically scoped, but Scheme
%; (like Python) is statically scoped.
Static and Dynamic Scoping

- The scope rules are the rules governing what names (identifiers) mean at each point in a program.
- We've been using environment diagrams to describe the rules for Python (which are essentially identical to Scheme).
- But in original Lisp, scoping was dynamic.
- Example (using classic Lisp notation):
  ```lisp
  (defun f (x) ;; Like (define (f x) ...) in Scheme
     (g))
  (defun g ()
     (* x 2))
  (setq x 3) ;; Like set! and also defines x at outer level.
  (g) ;; ===> 6
  (f 2) ;; ===> 4
  (g) ;; ===> 6
  ```
  - That is, the meaning of \( x \) depends on the most recent and still active definition of \( x \), even where the reference to \( x \) is not nested inside the defining function.

Eval and Scoping

- Dynamic scoping made eval easy to define: interpret any variables according to their "current binding."
- But eval in Scheme behaves like normal functions, it would not have access to the current binding at the place it is called.
- To make it definable (without tricks) in Scheme, one must add a parameter to eval to convey the desired environment.
- In the fifth revision of Scheme, one had the choice of indicating an empty environment and the standard, builtin environment.
- Our STk interpreter goes its own way:
  ```lisp
  - (eval E) evaluates in the global environment.
  - (eval E (the-environment)) evaluates in the current environment.
  - (eval E (procedure-environment f)) evaluates in the parent environment of function \( f \).```