6.001 Recitation 6: Lists, Data Structures, and Abstractions

RI: Gerald Dalley, dalleyg@mit.edu

23 Feb 2007

New Procedures and Predefined Values

1. `(cons a b)` - makes a `cons`-cell (pair) from `a` and `b`
2. `(car c)` - extracts the value of the first part of the pair.
3. `(cdr c)` - extracts the value of the second part of the pair.
4. `(c`$\frac{a}{d}\frac{a}{d}\frac{a}{d}\frac{a}{d}$`r c)` - shortcuts (*e.g.* `(caddr c)` ≡ `(car (cdr (cdr c)))`).
5. `(list a b c ...)` - builds a list of the arguments to the procedure.
6. `(adjoin a lst)`? - doesn't exist (use `cons`)
7. `(list-ref lst n)` - returns the n^{th} element of `lst`.
8. `(append l1 l2)` - make a new list containing the elements of both lists.
9. The empty list...
   - `'()` - the safe way of specifying the empty list
   - `null` - a DrScheme-specific definition
   - `()` - another DrScheme-specific definition (what DrScheme prints)
   - `nil` - an MIT Scheme-specific definition (what the book uses)
   - `#f` - another MIT Scheme-specific definition (what the tutor prints)
10. Testing for the empty list...
    - `null?` - The only safe way of testing for the empty list.

`car`/`cdr` history...

Which of `cons/car/cdr/list` are special forms?

```
(car (cons (+ 3 4) (/ 4 0)))
```

Box and Pointer Diagrams

Diagramming Rules

1. Any time you see `cons`, draw a double box with 2 pointers
2. Evaluate the stuff inside & point to it
3. Denote `null/'()/`empty list with a slash through a box.
4. Any time you see `list` with n items, draw a chain of n `cons` cells
5. `list` with no items is the empty list

Printing a `cons` structure

1. Each `cons` cell is printed `(` *car-part* `.` *cdr-part* `)`
2. Cross out any ". null"
3. Cross out any ". (" and its matching ")"
4. The empty list is printed as `()` in DrScheme

Practice

```
(define a (cons 1 2))
(define b (list (cons 1 2) (cons 1 2)))
(define c (list a a))
(define d (cons 2 '()))
(define e (cons '() 2))
(define f (list 2))
(define g (list))
(define h (list '()))
(define i (list 1 2 3 4))
(define j (list 5 (cdr (cdr i)) (cons 6 7)))
```

Draw the box-and-pointer diagrams here:

What's the minimum number of `cons` cells needed to store n items?

Write the printed form of the $a - j$ *examples above*

Lis~~p~~t Problems

“cdr-ing down a list”

```
(define (length lst)
  (if (null? lst)
      0
      (+ 1 (length (cdr lst)))))
```

(length (list 1 3 4 7)) → [ ]

(length j) → [ ]

```
;; Write an iterative version...
(define (length lst)
```

“cdr-ing down the input and cons-ing up a result”

```
;; Write cube-neighbor-diff
;;    (cube-neighbor-diff (list 1 3 4 7)) => (8 1 27)
;; Takes the difference between neighboring values then cubes the difference.
(define (cube-neighbor-diff l)
```

biggie-size, Episode 3

In our fictitious consulting firm, we began developing a fast-food order processing system. We built abstractions for combos and orders, but nearly every procedure had to know that our low-level representation used digits 1–4 for non-biggie-sized combos and 5–8 for the corresponding biggie-sized combos. What if we wanted to add salads, baked potatoes, drinks, apple pies, and so forth? We'd have to rewrite nearly *all* of our code! Let's create some better abstractions.

```
;;-------------------------------------------------------------
;; item abstraction
;;    For pricing, assume patties cost $1.17, biggie-sizing a
;;    burger combo costs $0.50, and salads cost $0.99.

;; Constructors
(make-burger-combo num-patties) ; integer   -> item
(make-salad)                    ; void      -> item

;; Accessors,etc.
(get-num-patties item)          ; item      -> integer
(item-price      item)          ; item      -> number
(biggie-size?    item)          ; item      -> boolean
(items-equal?     a b)          ; item,item -> boolean

;; Operators
(biggie-size item)              ; item      -> item
(unbiggie-size item)            ; item      -> item

;;-------------------------------------------------------------
;; order abstraction

;; Special values
empty-order                     ; :order

;; Constructors
; There are none!

;; Accessors, etc.
(order-size order)              ; order -> integer
(order-cost order)              ; order -> number

;; Operators
(add-to-order      order item)  ; order,item -> order
(remove-from-order order item)  ; order,item -> order
```

We'll break up our consulting team into several subteams. For orders-of-growth questions, use I as how many *types* of items there are and N as the number of items in an order.

1. Implement the item abstraction. Do intelligent things for cases like `(biggie-size (make-salad))`. Come up with some additional high-level operations/construstors/accessors that might be useful but don't break the abstraction barrier.
2. Implement the order abstraction by keeping a list of items, sorted by the order they were added. Example: `(item1 item2 item3 ...  itemn)`. What are the orders of growth for each procedure.
3. Implement the order abstraction by keeping a list of items and their counts, *e.g.* `((salad 1) (single 4) (biggie-quad 7))`. What are the orders of growth for each procedure? Why would you ever want this representation?
4. Implement the order abstraction by keeping a list of each item ordered, sorted by price, *e.g.* `(salad single single single biggie-quad)`. What are the orders of growth for each procedure. Why would you ever want this representation?

6.001 Recitation 6: Lists, Data Structures, and Abstractions

RI: Gerald Dalley, dalleyg@mit.edu

23 Feb 2007

Announcements / Notes

- How many of you are taking 8.02 or otherwise have a conflict with the quiz (8 Mar, 7:30-9:30pm)?
- How many would have a conflict with the exam on Wednesday 7 Mar at 7:30pm?
- Anyone with hard conflicts for both times?

New Procedures and Predefined Values

1. `(cons a b)` - makes a `cons`-cell (pair) from `a` and `b`
2. `(car c)` - extracts the value of the first part of the pair.
3. `(cdr c)` - extracts the value of the second part of the pair.
4. `(c`$\frac{a}{d}\frac{a}{d}\frac{a}{d}\frac{a}{d}$`r c)` - shortcuts (*e.g.* `(caddr c)` ≡ `(car (cdr (cdr c)))`).
5. `(list a b c ...)` - builds a list of the arguments to the procedure.
6. `(adjoin a lst)`? - doesn't exist (use `cons`)
7. `(list-ref lst n)` - returns the n^{th} element of `lst`.
8. `(append l1 l2)` - make a new list containing the elements of both lists.
9. The empty list...
   - `'()` - the safe way of specifying the empty list
   - `null` - a DrScheme-specific definition
   - `()` - another DrScheme-specific definition (what DrScheme prints)
   - `nil` - an MIT Scheme-specific definition (what the book uses)
   - `#f` - another MIT Scheme-specific definition (what the tutor prints)
10. Testing for the empty list...
    - `null?` - The only safe way of testing for the empty list.

`car`/`cdr` history...

Which of `cons`/`car`/`cdr`/`list` are special forms?

none – they work like regular combinations

```
(car (cons (+ 3 4) (/ 4 0)))
```

Box and Pointer Diagrams

Diagramming Rules

1. Any time you see `cons`, draw a double box with 2 pointers
2. Evaluate the stuff inside & point to it
3. Denote `null`/`'()`/empty list with a slash through a box.
4. Any time you see `list` with n items, draw a chain of n `cons` cells
5. `list` with no items is the empty list

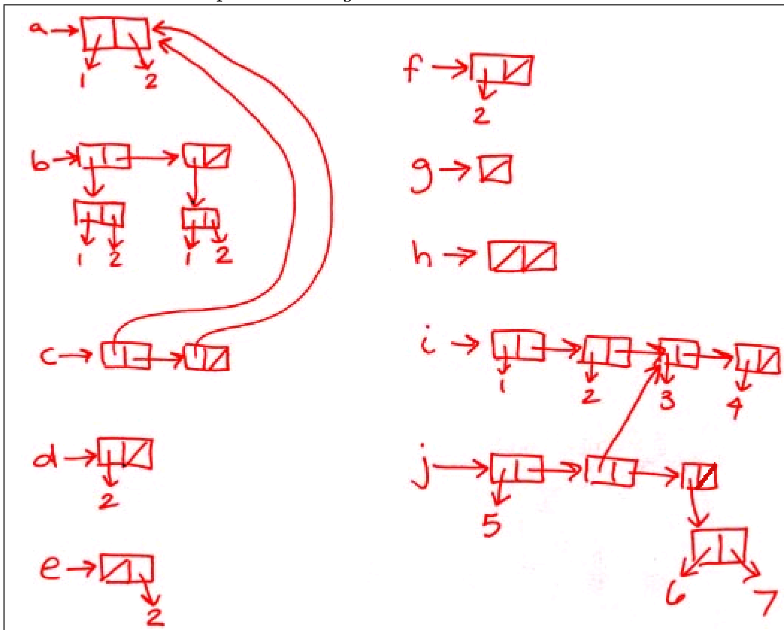
Printing a cons structure

1. Each `cons` cell is printed `(` *car-part* `.` *cdr-part* `)`
2. Cross out any “. null”
3. Cross out any “. (” and its matching “)”
4. The empty list is printed as `()` in DrScheme

Practice

```
(define a (cons 1 2))
(define b (list (cons 1 2) (cons 1 2)))
(define c (list a a))
(define d (cons 2 '()))
(define e (cons '() 2))
(define f (list 2))
(define g (list))
(define h (list '()))
(define i (list 1 2 3 4))
(define j (list 5 (cdr (cdr i)) (cons 6 7)))
```

Draw the box-and-pointer diagrams here:



- Don’t forget to label your diagrams with any defined variables
- Arrows that point to `cons` cells can point to any part of the outer box,
- You can write numbers inside the boxes, or point to them outside the box
- Don’t forget to put something in each box (don’t forget to put a slash in the last box of a list)

What’s the minimum number of `cons` cells needed to store n items? $n-1$

Write the printed form of the a − j examples above

```
a → (1 . 2)
b → ((1 . 2) (1 . 2))
c → ((1 . 2) (1 . 2))
d → (2)
e → (() . 2)
f → (2)
g → ()
h → (())
i → (1 2 3 4)
j → (5 (3 4) (6 . 7))
```

Lis~~p~~t Problems

"`cdr`-ing down a list"

```
(define (length lst)
  (if (null? lst)
      0
      (+ 1 (length (cdr lst)))))
```

(length (list 1 3 4 7)) → 4

(length j) → 3

```
;; Write an iterative version...
(define (length lst)
  (define (helper len remainder)
    (if (null? remainder)
        len
        (helper (+ 1 len) (cdr remainder))))
  (helper 0 lst))

; quick verification (should print 4)
(length (list 1 3 4 7))
```

"`cdr`-ing down the input and `cons`-ing up a result"

```
;; Write cube-neighbor-diff
;;     (cube-neighbor-diff (list 1 3 4 7)) => (8 1 27)
;; Takes the difference between neighboring values then cubes the difference.
(define (cube-neighbor-diff l)
  (cond ((null? l) '())
        ((null? (cdr l)) '())
        (else
         (let ((diff (- (cadr l) (car l))))
           (cons (* diff diff diff)
                 (cube-neighbor-diff (cdr l)))))))

(cube-neighbor-diff (list 1 3 4 7))

; alternative implementation:
(define (cube-neighbor-diff l)
  (cond ((null? l) '())
        ((null? (cdr l)) '())
        (else
```

```
            (cons (cube (- (cadr l) (car l)))
                  (cube-neighbor-diff (cdr l))))))

(define (cube x) (* x x x))
```

`biggie-size`, Episode 3

In our fictitious consulting firm, we began developing a fast-food order processing system. We built abstractions for combos and orders, but nearly every procedure had to know that our low-level representation used digits 1–4 for non-biggie-sized combos and 5–8 for the corresponding biggie-sized combos. What if we wanted to add salads, baked potatoes, drinks, apple pies, and so forth? We'd have to rewrite nearly *all* of our code! Let's create some better abstractions.

```
;;-----------------------------------------------------------------
;; item abstraction
;;    For pricing, assume patties cost $1.17, biggie-sizing a
;;    burger combo costs $0.50, and salads cost $0.99.

;; Constructors
(make-burger-combo num-patties) ; integer   -> item
(make-salad)                    ; void      -> item

;; Accessors,etc.
(get-num-patties item)          ; item      -> integer
(item-price      item)          ; item      -> number
(biggie-size?    item)          ; item      -> boolean
(items-equal?     a b)          ; item,item -> boolean

;; Operators
(biggie-size item)              ; item      -> item
(unbiggie-size item)            ; item      -> item

;;-----------------------------------------------------------------
;; order abstraction

;; Special values
empty-order                     ; :order

;; Constructors
; There are none!

;; Accessors, etc.
(order-size order)              ; order -> integer
(order-cost order)              ; order -> number

;; Operators
(add-to-order      order item)  ; order,item -> order
(remove-from-order order item)  ; order,item -> order
```

We'll break up our consulting team into several subteams. For orders-of-growth questions, use I as how many *types* of items there are and N as the number of items in an order.

1. Implement the item abstraction. Do intelligent things for cases like `(biggie-size (make-salad))`. Come up with some additional high-level operations/construstors/accessors that might be useful but don't break the abstraction barrier.
2. Implement the order abstraction by keeping a list of items, sorted by the order they were added. Example: `(item1 item2 item3 ... itemn)`. What are the orders of growth for each procedure.
3. Implement the order abstraction by keeping a list of items and their counts, *e.g.* `((salad 1) (single 4) (biggie-quad 7))`. What are the orders of growth for each procedure? Why would you ever want this representation?
4. Implement the order abstraction by keeping a list of each item ordered, sorted by price, *e.g.* `(salad single single single biggie-quad)`. What are the orders of growth for each procedure. Why would you ever want this representation?

The solutions are given in `item-1.scm`*,* `order-2.scm`*,* `order-3.scm`*, and* `order-4.scm`*. A script for automatically validating this code is given in* `testdriver.scm`*. These files are embedded in the source* `.zip` *file downloadable from* ***http://people.csail.mit.edu/dalleyg/6.001/SP2007/****.*