MASSACHVSETTS INSTITVTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science
6.001—Structure and Interpretation of Computer Programs
Spring Semester, 1995-96

Problem Set 3

Issued: Thursday, February 15, 1996

Due: Solutions should be sent by email to your tutor by Wednesday, February 28 (odd numbered recitation sections) or Friday March 1 (even numbered recitation sections).

Reading Sections 2.1 and 2.2 (through 2.2.3) of the notes.

Assignment Work tutorial exercises 3.1-3.6 before going to tutorial. Prepare solutions to Problems 1-4 before going to lab.

Tutorial Exercises

Tutorial Exercise 3.1 The printed representation of the value of variable `my-list` is:

```
(2 168.0 ((1 0.37) (2 0.56)))
```

a) Write two different Scheme expressions, one using only procedure `cons` (and `nil`), the other using only procedure `list`, that would create `my-list`.

b) Write expressions (in terms of `car`-s and `cdr`-s) that select the values 168.0 and 0.37 from `my-list`.

Tutorial Exercise 3.2 Work Exercise 2.18 in the notes.

Tutorial Exercise 3.3 Work Exercise 2.21 and 2.22 in the notes.

Tutorial Exercise 3.4 Work Exercise 2.36 in the notes.

Laboratory Assignment

Sequences and Higher Order Procedures

As you may have noticed, 1996 is an election year in the United States of America. During IAP, Ben Bitdiddle and Alyssa P. Hacker decided to form a company that will attempt to predict the results of these elections. They have heard that you are enrolled in 6.001 this semester and have asked you to visit the firm for an interview.

At the interview you learn that Alyssa, having re-read her high school Civics notes, has constructed a national database `edb` to be used to keep track of the results of pre-election polls.

She began by assigning a numerical designator to each party

```
(define republican 1)
(define democrat 2)
(define conservative 3)
(define liberal 4)
(define federalist 5)
(define whig 6)
(define states-rights 7)
(define progressive 8)
(define anti-federalist 9)
```

The database consists of a list of state databases. Each state is represented as a two-item list including a numerical state designator and a list of congressional district data bases. Each congressional district is represented as a three-item list including the numerical district designator, the number of likely voters and a list of statistics. Each statistic is represented as a two-element list including a numerical party designator and the proportion of likely voters that polling indicates favors that party.

For example one poll conducted in state #7, Arkansas, which has two congressional districts, indicated that in the first congressional district there were 323 thousand likely voters, of whom 29% favored the republican party, 11% favored democrats, and 43% favored conservatives. The balnce (17%) expressed no preference (called *undecideds*). In the second district, 37% favored republicans, 56% favored democrats, and 7% were undecided.

Alyssa defined the following *constructors*

```
(define (make-statistic party proportion)
  (list party proportion))
(define make-statistics list)
(define (make-district number voters statistics)
  (list number voters statistics))
(define make-districts list)
(define (make-state identifier districts)
  (list identifier districts))
```

so she could represent ARKANSAS in the database by evaluating

```
(define arkansas-district-1
  (make-district 1
                 323.0
                 (make-statistics
                  (make-statistic republican 0.29)
                  (make-statistic democrat 0.11)
                  (make-statistic conservative 0.43))))

(define arkansas-district-2
  (make-district 2
                 168.0
                 (make-statistics
                  (make-statistic republican 0.37)
                  (make-statistic democrat 0.56))))

(define arkansas
  (make-state
   7
   (make-districts
    arkansas-district-1
    arkansas-district-2)))
```

Tutorial Exercise 3.5. Represent the values of `arkansas-district-1`, `arkansas-district-2`, and `arkansas` using a box and pointer diagram.

For the purposes of this assignment only the states of Georgia, Massachusetts, Illinois, New Hampshire, Oregon, and Rhode Island are to be considered. The databases for those states are included in the code handout.

The national database `edb` is defined as:

```
(define edb
  (list georgia massachusetts illinois new-hampshire oregon rhode-island))
```

Ben insists that you access elements of the database only via the following *selectors*:

```
(define (designator state) (car state))
(define (districts state) (cadr state))
(define (district-number cd) (car cd))
(define (district-population cd) (cadr cd))
(define (district-statistics cd) (caddr cd))
(define (party statistic) (car statistic))
(define (proportion statistic) (cadr statistic))
```

Ben suggests that, rather than writing special purpose procedures to answer specific questions, you should only use higher-order procedures for lists (e.g. `map`, `accumulate`, `filter`, `flatten`) to answer questions based on the database.

Tutorial Exercise 3.6. Show how you can use these higher-order procedures to determine the number of likely REPUBLICAN voters in the congressional district number 2 in the state of GEORGIA.

Laboratory Problem 1. To ensure that his intent is clear, Ben asserts that it is possible to determine the total number of likely voters in a specified state and in `edb` using only these procedures. He asks you to complete the definitions of procedures `state-voters` and `national-voters`:

```
;;; determines the number of likely voters in a specified state
(define (state-voters state)
  (accumulate
    +
    0
    <exp1>))
;;; determine the total number of likely voters in a national database
(define (national-voters database)
  (accumulate
    +
    0
    <exp2>))
```

Test your procedure definitions by determining the number of likely voters in the state of MASSACHUSETTS and the total number of likely voters represented in `edb`.

Alyssa points out that predicting the winner of elections requires determining who is likely to receive the largest number of votes.

Laboratory Problem 2. Alyssa asks you to complete the definition of procedure `pick` that can be used for this purpose. In particular `pick` takes two arguments a comparison operator and a list and returns the value of the item in the list that satisfies the comparison with every other item of the list. Thus to determine the largest number in the list `(5 2 9 4 8 3)` you could evaluate `(pick >= (list 5 2 9 4 8 3))`, whereas to determine the smallest you could evaluate `(pick <= (list 5 2 9 4 8 3))`. You may assume that the list is not empty.

```
(define (pick comparison lst)
  (accumulate <exp1> <exp2> <exp3>))
```

New members of Congress are elected on a district basis. In each district the candidate of the party receiving the largest number of votes in the district wins.

Laboratory Problem 3. a) Define procedure `district-winner` that determines the winning congressional candidate in a given district. It should return a list of the district number and the party of the winner. For example if the predicted winner in the first district were a member of the conservative party, it would return the list `(1 3)`. Ignore uncommitted voters.

```
(define (district-winner district)
  (list (district-number district)
        (map <exp1> <exp2>)))
```

b) Define procedure `state-winners` that determines the winning congressional candidates in a given state. It returns a list of the district winners. For example, in a state with two districts if the predicted winner in the first district were a conservative and the predicted winner in the second were a republican, it would return the list `((1 3) (2 1))`. Ignore uncommitted voters.

```
(define (state-winners state)
  <body>)
```

c) Procedure `house-winners` when applied to a national database (such as `edb`) predicts (ignoring uncommitted voters) the break-down by parties of the new Congress. For example if there were only four parties and the polls predicted that 15 republicans, 18 democrats, 6 conservatives, and 0 liberals would be elected to Congress, `(house-winners edb)` should return `(15 18 6 0)`. This definition can be accomplished within the following structure:

```
(define (house-winners database)
  (let ((winning-reps (flatten (map state-winners database))))
    (map (lambda (x) (accumulate + 0 x))
         (map (lambda (y)
                (map (lambda (z) <exp1>) <exp2>))
              parties))))
```

Test your procedure by applying `house-winners` to `edb`. Turn in the results with your solutions.

The presidential election is conducted by the Electoral College in which each state is represented by electors. The number of electors for each state is two more than the number of congressional districts in that state. All electoral votes for each state are cast for the presidential candidate of the party receiving the largest number of votes in that state.

Laboratory Problem 4. Define procedure `electors` that, when applied to `edb`, predicts the break-down by parties of the new Electoral College. Ignore uncommitted voters. The form of your result should be the same as that produced by the `house-winners` procedure.

Test your procedure by applying `electors` to `edb`. Turn in the results with your solutions.

Turning in your answers

The section on "Feedback" in the *Don't Panic* manual describes how to send Email from the 6.001 lab. Send your answer buffer to your tutor. Do this by starting a mail message and using the Edwin `M-x insert-buffer` command. Don't forget to include a reply email address (or else put your name in the message) so your tutor will know that the message is coming from you.

How much time did you spend on this homework assignment? Report separately time spent before going to lab and time spent in the 6.001 lab.

If you cooperated with other students working this problem set please indicate their names in the space below. As you should know, as long as the guidelines described in the *6.001 Policy on Cooperation* handout are followed, such cooperation is allowed and encouraged.

```
;;; higher-order procedures for lists
(define (filter pred lst)
  (if (null? lst)
      nil
      (let ((item (car lst)))
        (if (pred item)
            (cons item (filter pred (cdr lst)))
            (filter pred (cdr lst))))))
(define (map proc lst)
  (if (null? lst)
      nil
      (cons (proc (car lst))
            (map proc (cdr lst)))))
(define (accumulate combiner init lst)
  (if (null? lst)
      init
      (accumulate combiner (combiner init (car lst)) (cdr lst))))
(define (append s1 s2)
  (if (null? s1)
      s2
      (cons (car s1)
            (append (cdr s1) s2))))
(define (flatten lst)
  (accumulate append nil lst))
```

```
(define georgia
  (make-state 12
            (make-districts
             (make-district 1
                            325.0
                            (make-statistics
                             (make-statistic republican 0.67)
                             (make-statistic democrat 0.13)))
             (make-district 2
                            279.0
                            (make-statistics
                             (make-statistic republican 0.41)
                             (make-statistic democrat 0.37)
                             (make-statistic conservative 0.21)))
             (make-district 3
                            303.0
                            (make-statistics
                             (make-statistic republican 0.52)
                             (make-statistic democrat 0.46)))
             (make-district 4
                            304.0
                            (make-statistics
                             (make-statistic republican 0.1)
                             (make-statistic democrat 0.23)
                             (make-statistic conservative 0.16)
                             (make-statistic liberal 0.38)))
             (make-district 5
                            288.0
                            (make-statistics
                             (make-statistic republican 0.29)
                             (make-statistic democrat 0.05)
                             (make-statistic conservative 0.09)
                             (make-statistic liberal 0.09)
                             (make-statistic federalist 0.4))))))
```

```
(define massachusetts
  (make-state 23
              (make-districts
               (make-district 1
                              303.0
                              (make-statistics
                               (make-statistic republican 0.27)
                               (make-statistic democrat 0.52)
                               (make-statistic conservative 0.12)))
               (make-district 2
                              292.0
                              (make-statistics
                               (make-statistic republican 0.3)
                               (make-statistic democrat 0.46)
                               (make-statistic conservative 0.06)))
               (make-district 3
                              263.0
                              (make-statistics
                               (make-statistic republican 0.62)
                               (make-statistic democrat 0.27)))
               (make-district 4
                              297.0
                              (make-statistics
                               (make-statistic republican 0.46)
                               (make-statistic democrat 0.11)
                               (make-statistic conservative 0.09)
                               (make-statistic liberal 0.31)))
               (make-district 5
                              260.0
                              (make-statistics
                               (make-statistic republican 0.13)
                               (make-statistic democrat 0.36)
                               (make-statistic conservative 0.32)))
               (make-district 6
                              307.0
                              (make-statistics
                               (make-statistic republican 0.22)
                               (make-statistic democrat 0.22)
                               (make-statistic conservative 0.55)))
               (make-district 7
                              252.0
                              (make-statistics
                               (make-statistic republican 0.1)
                               (make-statistic democrat 0.51)
                               (make-statistic conservative
                                               0.37))))))
```

```
(define illinois
  (make-state 15
    (make-districts
     (make-district 1
       240.0
       (make-statistics
        (make-statistic republican 0.39)
        (make-statistic democrat 0.19)
        (make-statistic conservative 0.06)
        (make-statistic liberal 0.16)))
     (make-district 2
       300.0
       (make-statistics
        (make-statistic republican 0.33)
        (make-statistic democrat 0.17)
        (make-statistic conservative 0.3)
        (make-statistic liberal 0.09)))
     (make-district 3
       182.0
       (make-statistics
        (make-statistic republican 0.6)
        (make-statistic democrat 0.25)))
     (make-district 4
       318.0
       (make-statistics
        (make-statistic republican 0.57)
        (make-statistic democrat 0.41)))
     (make-district 5
       340.0
       (make-statistics
        (make-statistic republican 0.39)
        (make-statistic democrat 0.39)
        (make-statistic conservative 0.21)))
     (make-district 6
       321.0
       (make-statistics
        (make-statistic republican 0.05)
        (make-statistic democrat 0.24)
        (make-statistic conservative 0.46)
        (make-statistic liberal 0.24)))
     (make-district 7
       293.0
       (make-statistics
        (make-statistic republican 0.35)
        (make-statistic democrat 0.61)))
     (make-district 8
       267.0
       (make-statistics
        (make-statistic republican 0.64)
        (make-statistic democrat 0.13)
        (make-statistic conservative 0.17)))
     (make-district 9
       306.0
       (make-statistics
        (make-statistic republican 0.34)
        (make-statistic democrat 0.09)
        (make-statistic conservative 0.09)
        (make-statistic liberal 0.01)
        (make-statistic federalist 0.1)
        (make-statistic whig 0.03)
        (make-statistic states-rights 0.23)))
     (make-district 10
       293.0
       (make-statistics
        (make-statistic republican 0.11)
        (make-statistic democrat 0.7))))))
```

```
(define new-hampshire
  (make-state 25
            (make-districts
             (make-district 1
                            264.0
                            (make-statistics
                             (make-statistic republican 0.56)
                             (make-statistic democrat 0.06)
                             (make-statistic conservative 0.14)
                             (make-statistic liberal 0.02)
                             (make-statistic federalist 0.09)))
             (make-district 2
                            263.0
                            (make-statistics
                             (make-statistic republican 0.48)
                             (make-statistic democrat 0.37)))
             (make-district 3
                            160.0
                            (make-statistics
                             (make-statistic republican 0.56)
                             (make-statistic democrat 0.21)
                             (make-statistic conservative
                                             0.17))))))
(define oregon
  (make-state 28
            (make-districts
             (make-district 1
                            286.0
                            (make-statistics
                             (make-statistic republican 0.32)
                             (make-statistic democrat 0.37)
                             (make-statistic conservative 0.01)
                             (make-statistic liberal 0.16)))
             (make-district 2
                            246.0
                            (make-statistics
                             (make-statistic republican 0.31)
                             (make-statistic democrat 0.6)))
             (make-district 3
                            153.0
                            (make-statistics
                             (make-statistic republican 0.29)
                             (make-statistic democrat 0.14)
                             (make-statistic conservative
                                             0.51))))))
```

```
(define rhode-island
  (make-state 32
              (make-districts
               (make-district 1
                              357.0
                              (make-statistics
                               (make-statistic republican 0.64)
                               (make-statistic democrat 0.08)
                               (make-statistic conservative 0.06)
                               (make-statistic liberal 0.01)
                               (make-statistic federalist 0.04)))
               (make-district 2
                              375.0
                              (make-statistics
                               (make-statistic republican 0.1)
                               (make-statistic democrat 0.41)
                               (make-statistic conservative 0.44)))
               (make-district 3
                              212.0
                              (make-statistics
                               (make-statistic republican 0.57)
                               (make-statistic democrat 0.06)
                               (make-statistic conservative
                                               0.31))))))
(define edb
  (list georgia
        massachusetts
        illinois
        new-hampshire
        oregon
        rhode-island))
```