CS 357: Declarative Programming
Homework 3 (Spring '14)

Part I

Exercises 7.2, 7.3, 7.6, 7.7, 7.8, 7.12, 7.18, 7.22, 7.30, 7.31

Part II

1. Consider the following three examples:

```
;; Example 1
(define fact
  (lambda (x)
    (letrec
      ((loop
        (lambda (x acc)
          (if (= x 0)
            acc
            (loop (sub1 x) (* x acc))))))
      (loop x 1))))

;; Example 2
(define reverse
  (lambda (x)
    (letrec
      ((loop
        (lambda (x acc)
          (if (null? x)
            acc
            (loop (cdr x) (cons (car x) acc))))))
      (loop x '()))))

;; Example 3
(define iota
  (lambda (x)
    (letrec
      ((loop
        (lambda (x acc)
          (if (= x 0)
            acc
```

```
            (loop (sub1 x) (cons x acc))))))
      (loop x '())))))
```

The higher-order function *tail-recur* takes the following arguments

- *bpred* - a function of x which returns true if the terminating condition is satisfied and false otherwise
- *xproc* - a function of x which updates x
- *aproc* - a function of x and acc which updates acc
- *acc0* - an initial value for acc

and returns a tail recursive function of *x*. It can be used to write the function, factorial as follows:

```
> (define fact (tail-recur zero? sub1 * 1))
> (fact 10)
3628800
```

(a) Give a definition for *tail-recur*.

(b) Use *tail-recur* to define *reverse*.

(c) Use *tail-recur* to define *iota*.

2. Write a function, *disjunction2*, which takes two predicates as arguments and returns the predicate which returns #t if either predicate does not return #f. For example:

```
> ((disjunction2 symbol? procedure?) +)
#t
> ((disjunction2 symbol? procedure?) (quote +))
#t
> (filter (disjunction2 even? (lambda (x) (< x 4))) (iota 8))
(1 2 3 4 6 8)
>
```

3. Now write *disjunction*, which takes an arbitrary number (> 0) of predicates as arguments.

4. A matrix, $\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$, can be represented in Scheme as a list of lists: *((1 2) (3 4))*. Without using recursion, write a function, *matrix-map*, which takes a function, f, and a matrix, A, as arguments and returns the matrix, B, consisting of f applied to the elements of A, *i.e.*, $B_{ij} = f(A_{ij})$.

```
> (matrix-map (lambda (x) (* x x)) '((1 2) (3 4)))
((1 4) (9 16))
```

5. Consider the following defnition for *fold* (called *flat-recur* in your text):

```
(define fold
 (lambda (seed proc)
   (letrec
     ((pattern
       (lambda (ls)
         (if (null? ls)
             seed
             (proc (car ls)
                   (pattern (cdr ls)))))))
     pattern)))
```

   (a) Use *fold* to write a function *delete-duplicates* which deletes all duplicate items from a list. For example,

   ```
   > (delete-duplicates '(a b a b a b a b))
   (a b)
   > (delete-duplicates '(1 2 3 4))
   (1 2 3 4)
   >
   ```

   (b) Use *fold* to write a function *assoc* which takes an item and a list of pairs as arguments and returns the first pair in the list with a car car which is equal to item. If there is no such pair then *assoc* should return false. For example,

   ```
   > (assoc 'b '((a 1) (b 2)))
   (b 2)
   > (assoc 'c '((a 1) (b 2)))
   #f
   >
   ```

Part III

Using the functions, *apply*, *select*, *map*, *filter*, *outer-product* and *iota*, and without using recursion, give definitions for the following functions:

1. *length* - returns the length of a list.
2. *sum-of-squares* - returns the sum of the squares of its arguments.
3. *avg* - returns the average of its arguments.
4. *avg-odd* - returns the average of its odd arguments.

5. *shortest* - returns the shortest of its list arguments.
6. *avg-fact* - returns the average of the factorials of its arguments.
7. *tally* - takes a predicate and a list and returns the number of list elements which satisfy the predicate.
8. *list-ref* - takes a list and an integer, n, and returns the n-th element of the list.