

## 1 Tail Recursion

- 1.1 For the following procedures, determine whether or not they are tail recursive. If they are not, write why not and rewrite the function to be tail recursive on the right.

```
; Multiplies x by y
(define (mult x y)
  (if (= 0 y)
      0
      (+ x (mult x (- y 1)))))

; Always evaluates to true
; assume n is positive
(define (true1 n)
  (if (= n 0)
      #t
      (and #t (true1 (- n 1)))))

; Always evaluates to true
; assume n is positive
(define (true2 n)
  (if (= n 0)
      #t
      (or (true2 (- n 1)) #f)))

; Returns true if x is in lst
(define (contains lst x)
  (cond
    ((null? lst) #f)
    ((equal? (car lst) x) #t)
    ((contains (cdr lst) x) #t)
    (else #f)))
```

- 1.2 Tail recursively implement **sum-satisfied-k** which, given an input list **lst**, a predicate procedure **f** which takes in one argument, and an integer **k**, will return the sum of the first **k** elements that satisfy **f**. If there are not **k** such elements, return 0.

```
; Doctests
scm> (define lst `(1 2 3 4 5 6))
scm> (sum-satisfied-k lst even? 2) ; 2 + 4
6
scm> (sum-satisfied-k lst (lambda (x) (= 0 (modulo x 3))) 10)
0
scm> (sum-satisfied-k lst (lambda (x) #t) 0)
0

(define (sum-satisfied-k lst f k)
```

```
)
```

- 1.3 Tail-recursively implement **remove-range** which, given one input list **lst**, and two nonnegative integers **i** and **j**, returns a new list containing the elements of **lst** except the ones from index **i** to index **j**. You may assume **j** > **i**, and **j** is less than the length of the list. (Hint: you may want to use the built-in **append** function)

```
; Doctests
scm> (append '(1 2) '(3 4) '(5 6))
(1 2 3 4 5 6)
scm> (remove-range '(0 1 2 3 4) 1 3)
(0 4)

(define (remove-range lst i j)
```

)

**Check your understanding**

- Why aren't all subexpression evaluations tail-recursive? For instance, why isn't the evaluation of `(+ 4 5)` as part of evaluating `(+ 1 (+ 2 3) (+ 4 5))` tail recursive, even though it's the last expression in the summation?
- Given a function `(f lst)` that acts over a list that has a single recursive call of the form `(f (cdr lst))`, what would be a general approach for rewriting it tail-recursively?

## 2 Interpreters

- 2.1 Determine the number of calls to **scheme\_eval** and the number of calls to **scheme\_apply** for the following expressions. Use the visualizer at [code.cs61a.org](http://code.cs61a.org) if you're not sure how an expression is evaluated.

```
> (+ 1 2)
3
```

```
> (if 1 (+ 2 3) (/ 1 0))
5
```

```
> (or #f (and (+ 1 2) 'apple) (- 5 2))
apple
```

```
> (define (add x y) (+ x y))
add
> (add (- 5 3) (or 0 2))
2
```

### Check your understanding

- When a Scheme interpreter evaluates a combination of the form (a b c d e), when does it evaluate a? Does it do so when a evaluates to a user-defined function? What about a builtin procedure? What if it is a keyword for a special form?
- What happens when we redefine a builtin procedure, like #[+]? For instance, if we run (define + -), and then (+ 1 2), what do we get? What about if we overwrite a keyword corresponding to a special form?

### 3 Macros

3.1 What will Scheme display? If you think it errors, write Error

```
> (define-macro (doerror) (/ 1 0))

> (doerror)

> (define x 5)

>(define-macro (evaller y) (list (list 'lambda '(x) 'x) y))

> (evaller 2)
```

3.2 Consider a new special form, **when**, that has the following structure:

```
(when <condition> <expr1> <expr2> <expr3> ... )
```

If the condition is not false (a truthy expression), all the subsequent operands are evaluated in order and the value of the last expression is returned. Otherwise, the entire **when** expression evaluates to **okay**.

```
scm> (when (= 1 0) (/ 1 0) 'error)
okay
scm> (when (= 1 1) (print 6) (print 1) 'a)
6
1
a
```

Create this new special form using a macro. Recall that putting a dot before the last formal parameter allows you to pass any number of arguments to a procedure, a list of which will be bound to the parameter, similar to (\*args) in Python.

```
; implement when without using quasiquotes
(define-macro (when condition . exprs)
  (list 'if _____))

; implement when using quasiquotes
(define-macro (when condition . exprs)
  `(if _____))
```