CMSC 15100 Midterm Exam 2

Ellyn Liu

TOTAL POINTS

90 / 100

QUESTION 1

1 p. 2: list->vector 9 / 9

✓ + 0 pts claimed

✓ + 2 pts The correct type is given: (All (a) (Listof a) -> (Vectorof a))

✓ + 2 pts The function does not crash when the input is an empty list.

✓ + 5 pts The implementation is correct, subject to deductions enumerated below.

+ 0 pts No response.

QUESTION 2

2 p. 3: short evaluations 10 / 10

+ 0 pts claimed

✓ + 1 pts Expression 1 cannot be evaluated. The second argument to build-list needs to be a function.

✓ + 1 pts Expression 2 evaluates to two concentric circles, or two concentric circles with a dot in the middle.

- 0.5 pts Too many circles.

✓ + 1 pts Expression 3 evaluates to (list 5 17 37).

✓ + 1 pts Expression 4 evaluates to (list #f #f #t #f #f).

✓ + 1 pts Expression 5 cannot be evaluated. The outer map must consume a function as its first argument.

✓ + 1 pts Expression 6 evaluates to (list "ccc").

✓ + 1 pts Expression 7 cannot be evaluated. The first argument to foldr must consume two items; b is unbound and appears here out of nowhere.

✓ + 1 pts Expression 8 cannot be evaluated. Since the first argument to foldr, the aggregation operator, returns an integer, the second argument to foldr, the base case, must be an integer (and not a string).

✓ + 1 pts Expression 9 evaluates to 0.

✓ + 1 pts Expression 10 evaluates to -3.

QUESTION 3

3 p. 4: types 7 / 10

✓ + 0 pts claimed

✓ + 1 pts (: v : All (a) (Optional a) a -> a)

✓ + 1 pts The behavior v is correctly described, e.g., v unwraps an optional value and returns either the unwrapped value or a default.

✓ + 0.5 pts A better name for v is suggested, e.g., unwrap or get-value.

+ 0 pts Vague or misleading name for v.

✓ + 1 pts (: smap : All (a b) (a -> b) (Listof (Optional a)) -> (Listof b))

✓ - 0.5 pts The list in smap is a (Listof (Optional a)).

- 0.5 pts Return type of smap is incorrect.

✓ + 1 pts The behavior of smap is correctly described, e.g., smap applied function f to the Some values in a list of optionals, skips the Nones.

✓ + 0.5 pts A better name for smap is suggested, e.g., some-map, map-some, map-values.

+ 0 pts Vague or misleading name for smap.

✓ + 1 pts (: mapp : All (a b) (a -> (Listof b)) (Listof a) -> (Listof b))

✓ - 0.5 pts The functional argument to mapp produces a (Listof b).

+ 1 pts The behavior of mapp is correctly described, e.g., map appends the results of the application of the function f to all the items in the list.

+ 0.5 pts A better name for mapp is suggested, e.g., map-append, flat-map, map-flatten, map-list.

✓ + 0 pts Vague or misleading name for mapp.

✓ + 1 pts (: omap : All (a b) (a -> b) (Optional a) -> (Optional b))

✓ - 0.5 pts The type of omap should include two type variables.

✓ + 1 pts The behavior of omap is correctly described, e.g., omap applies f to Some value, leaves None alone.

✓ + 0.5 pts A better name for omap is suggested, e.g., map-optional, opt-map, map-some.

+ 0 pts Vague or misleading name for omap.

QUESTION 4

4 p.5: compose 9 / 9

+ 0 pts claimed

✓ + 4 pts Compose has the correct type, subject to deductions enumerated below.

- 1 pts Compose has an extra (non-functional) argument in the type.

- 1 pts The type of compose should have three type variables; this type is too restrictive.

- 3 pts The type of compose should be polymorphic; this type includes no type variables.

✓ + 5 pts Compose has a correct implementation, subject to deductions enumerated below.

- 3 pts Compose does not return a function.

- 1 pts Your function definition includes type-incorrect applications.

+ 0 pts There is no response.

- 1 pts The functions should be applied in the other order.

+ 0 pts Incorrect response.

QUESTION 5

5 p. 6: BST sketches 8 / 8

+ 0 pts claimed

✓ + 4 pts Most balanced tree is correct.

- 2 pts Not as balanced as possible

- 2 pts Balanced tree is not a valid BST; elements are out of order.

✓ + 4 pts Most unbalanced tree is correct.

- 2 pts Not as unbalanced as possible

- 2 pts Unbalanced tree is not a valid BST; elements are out of order.

+ 0 pts No response.

QUESTION 6

6 p. 7: LogicalLoc order 7 / 9

✓ + 0 pts claimed

✓ + 3 pts The order type is correct (LogicalLoc LogicalLoc -> Boolean), subject to deductions enumerated below.

✓ + 3 pts The order definition is correct, subject to deductions enumerated below.

✓ - 2 pts The order does not distinguish distinct items. (LogicalLoc 3 4) should not equal (LogicalLoc 4 3).

- 1 pts The ordering doesn't maintain transitivity. If a < b and b < c, then it must be that a < c.

+ 0 pts Incorrect response.

✓ + 3 pts There are three correctly-written tests, subject to deductions enumerated below.

+ 0 pts There is no response.

QUESTION 7

7 p. 8: LogicalLoc hash 9 / 9

+ 0 pts claimed

✓ + 3 pts The type (LogicalLoc -> Integer) is correct.

✓ + 3 pts The definition is correct and distinguishes between (1,2) and (2,1) and (1,11) and (11,1).

✓ + 3 pts There are three correct tests.

+ 0 pts No response.

QUESTION 8

8 p. 9: Alarm data structure 9 / 9

✓ + 0 pts claimed

✓ + 3 pts Can represent either a specific date or a weekly alarm.

+ 1.5 pts Can represent specific dates, but not weekly alarms.

✓ + 3 pts Can represent a time.

✓ + 3 pts Can include an optional reminder.

- 2 pts Did not define an Alarm struct.

+ 0 pts No response.

QUESTION 9

9 p. 10: pass board, count stones on board 8 / 8

✓ + 0 pts claimed

✓ + 4 pts The implementation of pass is correct,

subject to the deductions enumerated below.

- 2 pts Underscores in pass have the effect of discarding necessary information (and are not proper arguments to constructors).

+ 0 pts No response for pass.

✓ **+ 4 pts** **The implementation of stones1 or stones2 is correct, subject to the deductions enumerated below.**

+ 0 pts No response for stones1 or stones2.

QUESTION 10

10 p. 11: retro **8 / 10**

✓ **+ 0 pts** **claimed**

✓ **+ 2 pts** **Correctly populates new structure with board dimension.**

+ 1 pts Correctly populates new structure with next player.

✓ **+ 7 pts** **Correctly populates new structure with locations of black and white stones.**

- 2 pts Does not properly separate black and white stones.

+ 0 pts No response/incomplete response.

+ 0 pts Click here to replace this description.

- 1 pts Board stores (Optional Stone) not Stone

+ 2.5 pts This addresses the inverted problem of building a Go2 given a Go1. You were supposed to consume a Go2 and build a Go1.

- 1 **Point adjustment**

Off by one in your loop termination conditions.

QUESTION 11

11 p. 12: thing **6 / 9**

+ 0 pts claimed

✓ **+ 9 pts** **The drawing is essentially correct, subject to deductions enumerated below.**

- 2 pts The circles are aligned at the bottom rather than in the middle.

- 1 pts There are too many circles in the figure.

- 2 pts There are too few circles in the figure.

✓ **- 3 pts** **The figure is not symmetric around the center.**

- 1 pts There should not be whitespace around the objects.

+ 0 pts No response.

Midterm Exam 2
CMSC 15100 Autumn 2018
Monday, December 3, 2018

Please write your name here:

Ellyn Liu

We do not answer questions from students once the exam has begun. Please read the directions carefully and follow them as best you can. If you have trouble interpreting a question, you can write us a note about your interpretation of it on the test itself along with your response.

You may use the functions you write on this test anywhere on this test. You may not refer to functions you may have written at some earlier time (such as a homework exercise) without rewriting them here. Wherever you design your own helper function, write its purpose and type above its definition.

We will be scanning your exams and grading digital versions of them. Please do your best to write all responses in the given spaces. Write your initials on each page, and please try not to write too close to the margins. Material at the margins may not be successfully scanned. Having said that, all your exams will be read by actual people and we can consult the paper copies if we must.

Some common built-in operations and their types are as follows:

```
cons     : All (A) A (Listof A) -> (Listof A)

first    : All (A) (Listof A) -> A
rest     : All (A) (Listof A) -> (Listof A)

empty?   : All (A) (Listof A) -> Boolean

length   : All (A) (Listof A) -> Integer
reverse  : All (A) (Listof A) -> (Listof A)
```

Throughout the exam, assume

```
(define-struct (Some a)
  ([value : a]))

(define-type (Optional a)
  (U 'None (Some a)))
```

These data definitions are common to project1 and project2.

```
(define-type Stone
  (U 'black 'white))

(define-struct LogicalLoc
  ([col : Integer]
   [row : Integer]))
```

There are various utility functions built in to Racket to convert between one kind of data structure and another. Write the type and definition of the function list->vector, whose name clearly says what it should do.

```
(: list->vector : All(α) (Listof α) -> (Vectorof α))
(define (list->vector lst)
  (match lst
    ['() (vector)]
    [(cons h _)
     (local {(define len (length lst))
             (: vec : (Vectorof α))
             (define vec (make-vector len h))
             (: lp : Integer -> (Vectorof α))
             (define (lp i)
               (if (= i len)
                   vec
                   (begin (vector-set! vec (list-ref lst i) i)
                          (lp (add1 i)))))}
       (lp 1))]))
```

EL

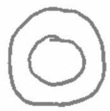
Evaluate each expression, or identify, in a few words, why it cannot be evaluated.

```
(foldr + 0 (build-list 10 20))
```

Error, because build-list expects Integer (Integer -> α) and 20 is not of type (Integer -> α)

```
(foldr overlay
       empty-image
       (build-list 3 (lambda ([i : Integer]) (circle (* i 10) 'outline 'black))))
```

0 1 2



```
(map (lambda ([i : Integer]) (add1 (sqr i))) (list 2 4 6))
```

4 16 36

(list 5 17 37)

```
(map (lambda ([s : String]) (> (string-length s) 2))
     (list "a" "bb" "ccc" "dd" "e"))
```

(list #f #f #t #f #f)

```
(map (map add1 (list 1 2 3)) (list 2 3 4))
```

Error, because this returns (map (list 2 3 4)(list 2 3 4)) and map expects a function in place of

```
(filter (lambda ([s : String]) (> (string-length s) 2))
        (list "a" "bb" "ccc" "dd" "e"))
```

(list "ccc")

```
(foldr (lambda ([a : Integer]) (+ a b)) 0 (list 1 2 3))
```

Error because b is unbound

```
(foldr (lambda ([s : String] [t : Integer]) (+ t (string-length s)))
       ""
       (list "a" "b" "ccc"))
```

Error because (foldr : All(α β)(α β -> β) β (Listof α) -> β) so the "" should be an Integer, not a string

```
(foldr max 0 (list -1 -2 -3))
```

0

```
(foldr min 0 (list -1 -2 -3))
```

-3

Write the type of each function, and explain clearly, in a sentence or two, what each one does. Note that writing the types of these polymorphic functions entails inferring the names of the relevant type variables from the given code. Also, suggest, for each function, a properly descriptive name for it; the names given here are all terse to a fault. None of these functions is ill-typed or does not compile.

(: v : All(a) (Optional a) a -> a)   non-opt

```
(define (v opt def)
  (match opt ['None def] [(Some x) x]))
```

v takes an optional struct and converts it into whatever a was before having a (Some a) around it. If the (optional a) was 'None, then it'll return a designated value def.

(: smap : All(a b)(a -> b)(Listof a) -> (Listof b))   Some-map

```
(define (smap f opts)
  (foldr (lambda ([opt : (Optional a)] [ys : (Listof b)])
           (match opt ['None ys] [(Some x) (cons (f x) ys)]))
       '()
       opts))
```

smap takes a list of optional a and removes any that are 'None and applies f to each element that is (Some _) and puts them in a (Listof b)

(: mapp : All(a b)(a -> b)(Listof a) -> (Listof b))   alt-map

```
(define (mapp f xs)
  (foldr (lambda ([x : a] [ys : (Listof b)]) (append (f x) ys)) '() xs))
```

mapp basically acts like map because it applies the function f to each element in xs and puts them into a (Listof b)

(: omap : All(a)(a -> a)(optional a) -> (Optional a))   apply-f

```
(define (omap f opt)
  (match opt ['None 'None] [(Some x) (Some (f x))]))
```

omap returns 'None if opt is 'None but otherwise will return (Some _) after f has been applied to the x in (Some x)

EL

The built-in compose function takes a variable number of functions and combines them together into a new function. We restrict this question to an implementation of compose that consumes exactly two functional arguments. It should return a function that behaves as the successive application of those two functions, with the function on the right's application first.

These examples show compose in use:

```
((compose sqr add1) 10) --> 121
((compose add1 sqr) 10) --> 101
((compose sqr sqr)   3) --> 81
```

string-length   number -> string

Define compose for two arguments, writing its type and its definition. Do not write a purpose or tests.

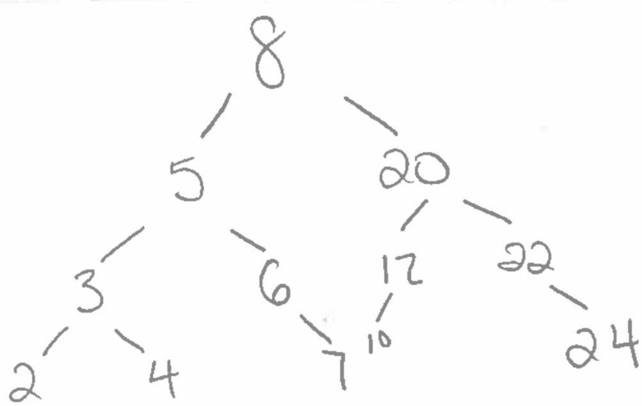
```
(: compose : All(a b c)(b -> c)(a -> b) -> (a -> c))
(define (compose f g)
  (lambda ([x : a]) (f (g x))))
```

Consider this list of numbers:

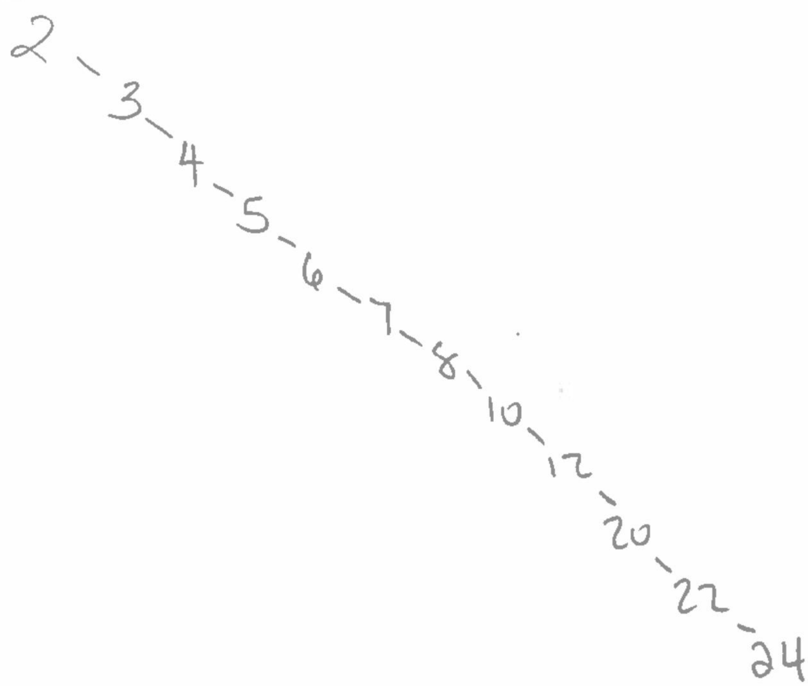
(list 3 5 7 2 4 6 8 10 12 20 22 24)
2 3 4 5 6 7 8 10 12 20 22 24

Draw two binary search trees containing these numbers. In the two drawings, the numbers can be in any legal BST arrangement. One should depict a binary search tree that is as well balanced as possible. The other should depict a binary search tree that is as poorly balanced as possible. Note there is not a single correct response to this question.

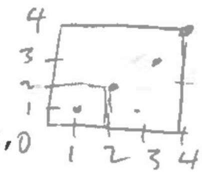
Balanced



Not balanced



EL



Generic BSTMaps were the subject of your most recent lab exercise. Assume that you need to build a BSTMap whose keys were LogicalLoc structs as defined in the Go projects. Write an ordering function that would enable you to use LogicalLocs as keys in a BSTMap. You can choose its name. You need not write a purpose for it, but you must write its type, its definition, and at least three check-expect tests.

```
(: ll<? : LogicalLoc LogicalLoc -> Boolean)
(define (ll<? ll1 ll2)
  (match* (ll1 ll2)
    [(LogicalLoc x1 y1)(LogicalLoc x2 y2)
     (and (< x1 x2)
          (< y1 y2))]))

(check-expect (ll<? (LogicalLoc 0 0)(LogicalLoc 2 2)) #t)
(check-expect (ll<? (LogicalLoc 3 1)(LogicalLoc 2 2)) #f)
(check-expect (ll<? (LogicalLoc 2 2)(LogicalLoc 2 2)) #f)
```

3 +14

6+7

Along similar lines, write a hash function to enable use of LogicalLocs as keys in a hash map. It need not be an industrial-strength hash function, but it should be not obviously bad in the following specific way: it must compute distinct values for (LogicalLoc 1 2) and (LogicalLoc 2 1), and for (LogicalLoc 1 11) and (LogicalLoc 11 1). Write its type, its definition, and at least three check-expect tests.

33 + 7

```
(: hash-ll : LogicalLoc -> Integer)
(define (hash-ll ll)
  (match ll
    [(LogicalLoc x y) (+ (* 3 x) (* 7 y))]))

(check-expect (hash-ll (LogicalLoc 1 2)) 17)
(check-expect (hash-ll (LogicalLoc 2 1)) 13)
(check-expect (hash-ll (LogicalLoc 11 1)) 40)
```

EL

Assume you are working on a team designing a Racket-driven alarm clock. Alarms are scheduled either to happen once at an exact date and time, or weekly on a particular day at some given time. Alarms need to be able to have events associated with them, in which case they can serve as specific reminders (such as "walk the dog" or "call Mom"). If they are associated with no such event, they are pure alarms which just blast a sound at the appointed time.

Define an Alarm data structure that enables these features. You need not write any code for this problem outside of data definitions, but if you refer to other data structures such as Date, etc., please include their data definitions here as well.

```
(define-struct Alarm
  [date : Date]
  [time : Time]
  [weekly : Days]
  [reminder : (U 'None String)]))

(define-struct Date
  ([month : Integer]
   [day : Integer]
   [year : Integer]))

(define-struct Time
  ([hour : Integer]
   [minute : Integer]))

(define-type Days
  (U 'Mon 'Tue 'Wed 'Thu 'Fri 'Sat 'Sun))
```

```
;; === Go from project1, renamed to Go1 (Stone and LogicalLoc are defined on p. 1)

(define-struct Go1
  ([dimension : Integer]
   [black-stones : (Listof LogicalLoc)]
   [white-stones : (Listof LogicalLoc)]
   [next-to-play : Stone]))

;; === Go from project2, renamed to Go2

(define-type Board
  (Vectorof (Vectorof (Optional Stone))))

(define-struct Go2
  ([board : Board]
   [next-to-play : Stone]
   [history : (Listof Board)]))
```

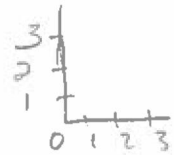
a) Implement a function to pass to the next player. You need only write the definition.

```
(: pass : Go1 -> Go1)
(define (pass go)
  (match go
    [(Go1 d b w next)
     (match next
       ['black (Go1 d b w 'white)]
       ['white (Go1 d b w 'black)])]))
```

b) Write one of these two functions to count the number of stones in play. You need only write the definition.

```
(: stones1 : Go1 -> Integer)
(: stones2 : Go2 -> Integer)
(define (stones1 go)
  (match go
    [(Go1 _ b w _)
     (+ (length b) (length w))]))
```

EL



r : 0
c : 1 2 3
r : 1
c : 1 2 3

c) Write a function "retro" to read a Go2 value and produce the closest possible corresponding Go1 value. In your implementation, you may assume the existence of a function with the following name and type:

```
(: bd-ref : Board Integer Integer -> (Optional Stone))
```

Any other helper functions in your response, you must define as part of your response. No purpose or tests are needed.

```
(: retro : Go2 -> Go1)
(define (retro go2)
  (match go2
    [(Go2 board next _ )
     (Go1 (vector-length board)
          (list-stones 'black b)
          (list-stones 'white b)
          (rev next))]))

(: rev : Stone -> Stone)
(define (rev s)
  (match s
    ['white 'black]
    ['black 'white]))

;; takes a board and returns the LL of stones of the color stone given
(: list-stones : Stone Board -> (Listof LogicalLoc))
(define (list-stones color b)
  (local {(len (vector-length b))
          (: lp : Integer Integer (Listof LogicalLoc) -> (Listof LogicalLoc))
          (define (lp r c acc)
            (cond [(and (= r (sub1 len)) (= c (sub1 len))) acc]
                  [(= c (sub1 len)) (lp (+1 r) 0 acc)]
            else  [(if (symbol=? (opt->sym (bd-ref b r c)) color)
                       (lp r (+1 c) (cons (LogicalLoc r c) acc))
                       (lp r (+1 c) acc))]))}
    (lp 0 0 '())))

(: opt->sym : (Optional Stone) -> Symbol)
(define (opt->sym st)
  (match st
    ['None 'None]
    [(Some s) s]))
```

(thing 81)

t : (thing 27)

(thing 9)

(thing 3)

(thing 1)

```
(: thing : Integer -> Image)
(define (thing i)
  (if (<= i 1)
      (square 1 'solid 'black)
      (local
        {(define t (thing (quotient i 3)))}
        (beside t
                (circle (quotient i 3) 'outline 'black)
                t))))
```

Draw (thing 81).