



Final Exam (Part 1) in Program Design and Data Structures (1DL201)

Teachers: Johannes Borgström, Dave Clarke

2018-01-11 / 08:00–13:00

Instructions

Read and follow these instructions carefully to increase your chance of getting good marks.

- This is a closed book exam. You may use a standard English dictionary. Otherwise, **no notes, calculators, mobile phones, or other electronic devices are allowed.** Cheating will not be tolerated.
- This is a multiple-choice exam. Each question has exactly **one** correct answer.
- You may keep these question sheets. **Only hand in the answer sheet.** Also read the instructions on the answer sheet before you start.
- Johannes or Dave will come to the exam hall around 10:00 to answer questions.

Good luck!



Common Material

Some of the exam questions refer to the following function:

```
{- func a ls
  PRE: ?PRE?
  RETURNS: ?RETURNS?
-}
func :: ?TYPE?
func = funci []

-- funci a b ls
-- VARIANT: ?VARIANT?
funci r _ [] = r
funci r a ((x,y):ls)
  | x == a    = funci (y:r) a ls
  | otherwise = funci r a ls
```

Questions

Please choose a single answer for each question. Read the questions carefully, and watch out for negations (**not**, **except**, etc.).

Question 1: What is the value of `func 3 [(1,'a'),(2,'b'),(3,'c')]` ?

- | | | |
|--|----------------------------------|----------------------------------|
| <input type="checkbox"/> A ['a','b','c'] | <input type="checkbox"/> C ["c"] | <input type="checkbox"/> E "abc" |
| <input type="checkbox"/> B "c" | <input type="checkbox"/> D 'c' | |

Question 2: What is a type (?TYPE?) of `func`?

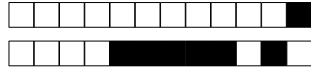
- | | |
|---|---|
| <input type="checkbox"/> A <code>Int -> [(Int,b)] -> [b]</code> | <input type="checkbox"/> D <code>Int -> [(Int,b)] -> [Int]</code> |
| <input type="checkbox"/> B <code>Int -> [(a,b)] -> [b]</code> | |
| <input type="checkbox"/> C <code>Int -> ([a],[b]) -> [b]</code> | <input type="checkbox"/> E <code>Int -> [(a,b)] -> [a]</code> |

Question 3: What is the most appropriate precondition (?PRE?) for `func a ls`?

- | | |
|---|---|
| <input type="checkbox"/> A <code>ls</code> is a list | <input type="checkbox"/> C <code>ls</code> contains no duplicate elements |
| <input type="checkbox"/> B <code>ls</code> contains at most one element matching <code>(a,x)</code> | <input type="checkbox"/> D <code>ls</code> contains a pair <code>(a,c)</code> |
| | <input type="checkbox"/> E <code>True</code> |

Question 4: What is the most appropriate description of the return value (?RETURNS?) for `func a ls`?

- | | |
|---|---|
| <input type="checkbox"/> A a list of all pairs <code>(x,y)</code> in <code>ls</code> where <code>x=a</code> | <input type="checkbox"/> C a list of all <code>y</code> such that <code>(a,y)</code> in <code>ls</code> |
| <input type="checkbox"/> B <code>[b]</code> | <input type="checkbox"/> D <code>y:r</code> |
| | <input type="checkbox"/> E a list of all <code>y</code> such that <code>(y,a)</code> in <code>ls</code> |



Question 5: Which of the following is a variant (?VARIANT?) for the function `func1` `r` a `ls`?

- ☐ A `length ls + length r` ☐ D `2 * length ls`
☐ B `length ls - 1`
☐ C `length r` ☐ E `length ls - length r`

Question 6: Which of the following modifications to the definition of `func` (or `func1`) will reverse the order of the list returned from `func`?

- ☐ A replace `func1 []` by `reverse.(func1 [])`.
☐ B replace `func1 r - [] = r` by `func1 r - [] = reverse r`.
☐ C replace `((x,y):ls)` by `(ls++[(x,y)])`.
☐ D replace `y:r` by `r ++ y`.
☐ E replace `x==a` by `a==y`.

Question 7: Which of the following expressions **does not** evaluate to 15?

- ☐ A `36 'mod' 3 * 7` ☐ C `7 - 3 + 11` ☐ E `11 'div' 3 * 5`
☐ B `9 / 3 * 5` ☐ D `[3,5] !! 1 * 3`

Question 8: Consider the expression

```
let f x y = x + 3 >= y + 3.1 in f 1 1
```

Evaluating this expression will result in ...

- ☐ A `True` ☐ C a type error. ☐ E none of these.
☐ B a syntax error. ☐ D a run-time error.

Question 9: Consider the declaration

```
f x = let f x = x+1 in f (f x)
```

Which of the following is equivalent to the declaration above?

- ☐ A `f z = let g y = z+1 in g (g z)`
☐ B `f x = let f y = y+1 in f (f y)`
☐ C `f x = let g z = z+1 in g (g x)`
☐ D `f y = let g y = y+1 in f (f y)`
☐ E None of these.



Question 10: Consider the function

```
zip (x:xs) (y:ys) = (x,y) : zip xs ys
zip _ _ = []
```

Which of the following expressions is **not** a variant for `zip xs ys`?

- ☐ A `length ys` ☐ D `length xs + length ys`
☐ B `length xs` ☐ E `abs (length xs - length ys)`
☐ C `length xs * length ys`

Question 11: Which of the following evaluates to 11?

- ☐ A `foldr (*) 0 [1,7,3]` ☐ D `foldr (+) 1 [1,5,3]`
☐ B `foldr (+) 0 [1,7,3]`
☐ C `foldr (*) 1 [1,7,3]` ☐ E `foldr (:) [] [1,5,3]`

Question 12: What is the type of `bar`, which is defined as follows:

```
bar f g a = f (g a) a
```

- ☐ A `(a -> b -> c) -> (a -> b) -> a -> c`
☐ B `(a -> b -> c) -> (a -> b) -> a -> c`
☐ C `((a -> b -> c), (b -> a), b) -> c`
☐ D `(a -> b -> c) -> b -> (a -> b) -> c`
☐ E `(a -> b -> c) -> (b -> a) -> a -> c`

Question 13: Which of the following functions is different from the others — that is, which function gives different results when applied to the same arguments?

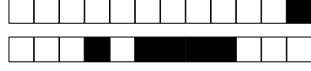
```
f [] = []
f (x:xs) | x > 2 = x + 10 : f xs
```

- ☐ A `| otherwise = f xs`
☐ B `f = map (+10) . filter (>2)`
☐ C `f xs = [x + 10 | x <- xs, x > 2]`
☐ D `f = map (\x -> x + 10) . filter (\x -> 2 > x)`
☐ E `f = filter (>12) . map (+10)`

Question 14: Type τ is an *instance* of type ρ if τ can be obtained from ρ by instantiating ρ 's type variables with other types (which may also be variables). Two types τ and ρ are *related by instantiation* if τ is an instance of ρ or ρ is an instance of τ .

Which of the following types is **not** related to any of the others by instantiation?

- ☐ A `a -> a` ☐ D `(a, a) -> (a, b)`
☐ B `(a, b) -> (a, b)`
☐ C `(Int, a) -> (Int, a)` ☐ E `(a -> a) -> (a -> a)`



Question 15: Recall that $\Theta(n^3)$ is the set of functions bounded both above and below by n^3 , modulo a constant factor, etc. Which of the following is equal to $\Theta(n^3)$?

- ☐ A $O(n^3) \setminus O(n^2)$ ☐ D $(O(n^3) \setminus O(n^2)) \cap (\Omega(n^2) \setminus \Omega(n^3))$
☐ B $O(n^3) \cap \Omega(n^3)$
☐ C $\Omega(n^2) \setminus \Omega(n^3)$ ☐ E All of the above

Question 16: Consider the following function

```
foo :: ([a] -> b) -> [a] -> [b]
foo f [] = [f []]
foo f l@(_:as) = f l : foo f as
```

Assuming that the run-time cost of some function g is given by $T_g(n)$, where n is the *size* of its input, which of the following recurrences describes the run-time cost of `foo g`?

- ☐ A $T(n) = \begin{cases} T_g(0) & \text{if } n = 0 \\ \Theta(1) + T(n-1) + \Theta(n) & \text{if } n \geq 1 \end{cases}$
☐ B $T(n) = \begin{cases} T_g(0) & \text{if } n = 0 \\ T_g(n) + T(n-1) + \Theta(n) & \text{if } n > 1 \end{cases}$
☐ C $T(n) = \begin{cases} T_g(0) & \text{if } n = 0 \\ T(n) + T(n-1) + \Theta(1) & \text{if } n \geq 1 \end{cases}$
☐ D $T(n) = \begin{cases} T_g(0) & \text{if } n = 1 \\ T_g(n) + T(n-1) + \Theta(n) & \text{if } n > 1 \end{cases}$
☐ E $T(n) = \begin{cases} T_g(0) & \text{if } n = 0 \\ T_g(n) + T(n-1) + \Theta(1) & \text{if } n \geq 1 \end{cases}$

Question 17: Which of the following recurrences has the closed form $T(n) = 5n+7$?

- ☐ A $T(n) = \begin{cases} 7 & \text{if } n = 0 \\ T(n-1) + 5 & \text{if } n \geq 1 \end{cases}$
☐ B $T(n) = \begin{cases} 5 & \text{if } n = 0 \\ 2T(n-1) + 7 & \text{if } n \geq 1 \end{cases}$
☐ C $T(n) = \begin{cases} 5 & \text{if } n = 0 \\ 7T(n) + 1 & \text{if } n \geq 1 \end{cases}$
☐ D $T(n) = \begin{cases} 7 & \text{if } n = 0 \\ 5T(n-1) & \text{if } n \geq 1 \end{cases}$
☐ E $T(n) = \begin{cases} 3 & \text{if } n = 0 \\ 5T(n-1) + 4 & \text{if } n \geq 1 \end{cases}$



Question 18: Consider the following datatype declarations.

```
data BTreeA a = Leaf a
              | Node (BTreeA a) a (BTreeA a)
data BTreeB a = Leaf a
              | Node (BTreeB a) (BTreeB a)
data BTreeC a = Leaf
              | Node (BTreeC a) a (BTreeC a)
data BTreeD a = Leaf a
              | Node a (BTreeD a) (BTreeD a)
data BTreeE a = Leaf a
              | Node (BTreeE a) (BTreeE a) a
```

Which of them can represent trees containing an arbitrary non-negative number of data items?

- ☐ A BTreeA ☐ B BTreeB ☐ C BTreeC ☐ D BTreeD ☐ E BTreeE

Question 19: Which of the binary tree datatypes defined above admits insertion of a single new data item in constant time (i.e., $O(1)$)?

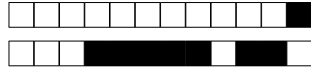
With insertion is meant an operation `insert :: a -> BTreeX a -> BTreeX a`, where `insert x t` returns a tree containing `x` and the data items in `t` (similar to `(:) :: a -> [a] -> [a]`).

- ☐ A BTreeB and BTreeC ☐ D BTreeB only
☐ B BTreeA, BTreeD, and BTreeE
☐ C BTreeC only ☐ E All except BTreeB

Question 20:

Which of the datatype declarations above **cannot** be used with the standard binary search tree invariant and search algorithm as seen in class?

- ☐ A BTreeA ☐ B BTreeB ☐ C BTreeC ☐ D BTreeD ☐ E BTreeE



Do not write above this line!

Answer Sheet — Exam 1DL201 of 2017-01-11

Instructions: Using a **dark** color, fill in **at most one** answer box (A to E) per question. Fill the answer box **entirely** (■)—we will use an optical character recognition (OCR) system that may not recognize ticks, crosses, circles, etc.

If you think that a question is ambiguous or has no correct answer, mark the question number with a ★ and explain **on the backside of this sheet** what the problem is and what assumptions you have made to answer the question.

Transfer your answers from the question sheets to this answer sheet **just before handing in**. If you want to change an answer, then please request a new answer sheet. You may keep the question sheets; at the end of the exam, **only hand in this answer sheet**.

Also fill in your **exam code** in clear handwriting at the bottom of this page.

Grading:	Correct answers	≤ 9	10 – 13	14 – 16	17 – 20
	Grade	U	3	4	5

Question 1: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 2: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 3: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 4: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 5: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 6: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 7: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 8: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 9: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 10: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 11: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 12: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 13: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 14: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 15: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 16: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 17: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 18: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 19: ☐ A ☐ B ☐ C ☐ D ☐ E

Question 20: ☐ A ☐ B ☐ C ☐ D ☐ E

Again: Please fill your chosen boxes **entirely** and in **dark** color!

Your exam code:

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