04IN1023: Introduction to functional programming

Final—Dry run SS 2014

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Prüfungsversuch	☐ 1 ☐ 2 ☐ 3

Hiermit bestätige ich, dass ich zur Klausur angemeldet und zugelassen bin.
Eine falsche Angabe wird als Täuschungsversuch gewertet.

Unterschrift: __________________

Korrekturabschnitt

Aufgabe	**Punkte (0-2)**	**Zusatzpunkt?**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Exam Manual

1. If you have any questions regarding the following items, please ask them during the dry run. You can ask them during the final or the re-sit as well, but this may be less helpful to you.

2. There are 10 assignments with 0-2 points each. 0 means ‘missing’ or ‘wrong’; 1 means ‘arguably appropriate, but significantly incomplete or incorrect’; 2 means ‘appropriate and essentially complete and correct’. You might get an extra point, if you come up with an exceptionally insightful solution.

3. The exam lasts 1 hours. Thus, one can spend more than 5 min per assignment. All assignments only require very few lines of code: 1–5 in the reference solution. Overly long code may receive a reduced score. If text is required, a 140 chars limit applies.

4. The overall topics for the exam are defined with the dry-run; see the section headers. These topics are maintained for the actual final and the re-sit of the given course edition. The topics may be somewhat different in the next edition. The topics leave, of course, much freedom as to the actual assignment.

5. One should be prepared—systematically—that the text of the assignments relates to the (software) *concepts* that are listed for each lecture. Definitions of the concepts are never inquired, but basic understanding of the concepts is assumed and crucial for passing the exam.

6. One is advised to establish familiarity with the *illustrations* given for all concepts. These illustrations are often invoked, perhaps after some modulation, to provide for the exam assignments or to ask code in the assignments.

7. Detailed library knowledge (such as combinators of libraries for parsing or pretty printing) is never assumed; relevant hints would be provided, if libraries are to be used. Familiarity with Haskell’s *Prelude*, though, is assumed—to the extent it is covered in the lecture.

1 “Simple algorithms”

Define a function that tests whether a given list of ints is sorted (in any order you favor).

Reference solution

```
-- Signature is not required
sorted :: [Int] -> Bool
sorted [] = True
sorted [x] = True
sorted (x1:x2:xs) = x1 <= x2 && sorted (x2:xs)
```

2 “Simple data models”

Declare a data type for shapes as follows. One kind of shape is ‘triangle’ described by three points. Each point consists of two ints for the x/y coordinates. Another kind of shape is ‘circle’ described by one point (the centre) and an Int for the radius. Yet another kind of shape is ‘composite’ described by two shapes that are composed in this way.

Reference solution

```
type Point = (Int,Int)
data Shape = Circle Point Int
           | Triangle Point Point Point
           | Composite Shape Shape
```

3 “Local scope”

Consider the following code:

```
f x y = g y
  where
    g z = x + z
```

Transform the code such that no local scope is used, i.e., the function g shall be defined at the top-level as opposed to the local scope of f.

Reference solution

```
f x y = g x y
g x z = x + z
```

4 “Parametric polymorphism”

Define a polymorphic function including its function signature for swapping the two components of a pair.

Reference solution

```
-- Other definitions welcome.
swap :: (a,b) -> (b,a)
swap x = (snd x, fst x)
```

5 “Higher-order functions”

Define a polymorphic function *times* which repeats the application of a given argument function, as demonstrated with the following example:

```
> times 22 (+1) 20
42
```

Reference solution

```
-- Signature is not required
times :: Int -> (a -> a) -> a -> a
times 0 f x = x
times n f x = times (n-1) f (f x)
```

6 “Monoids”

Why is Float not readily defined to be an instance of the Monoid type class? *Please, be concise: 140 characters or less.*

Reference solution

Float could be a monoid for summation and multiplication, but there can be only one instance per type.

7 “Functors”

Consider the following code:

```
-- Sets as lists
data Set a = Set [a]
  deriving Show

-- Construct the empty set
empty :: Set a
empty = Set []

-- Add an element to a set
addTo :: Eq a => a -> Set a -> Set a
addTo x (Set xs) =
  Set $ if elem x xs
          then xs
          else x:xs

-- Functor instance for sets
instance Functor Set
  where
    fmap f (Set xs) = Set (map f xs)
```

The *addTo* function and the functor instance are not perfectly aligned in that an application of *fmap* could lead to a set representation that cannot be possibly reached by a repeated application of *addTo* starting from *empty*. Please explain or give an illustrative sample expression! *Please, be concise: 140 characters or less.*

Reference solution

```
> fmap (const 0) $ addTo 1 $ addTo 2 $ empty
Set [0,0]
```

8 “Unparsing & parsing”

Remember the two horizontal composition operators for unparsing:

```
-- Compose horizontally
(<>) :: Doc -> Doc -> Doc

-- Compose horizontally with extra space for separation
(<+>) :: Doc -> Doc -> Doc
```

Why is the following definition of the latter in terms of the former possibly problematic?

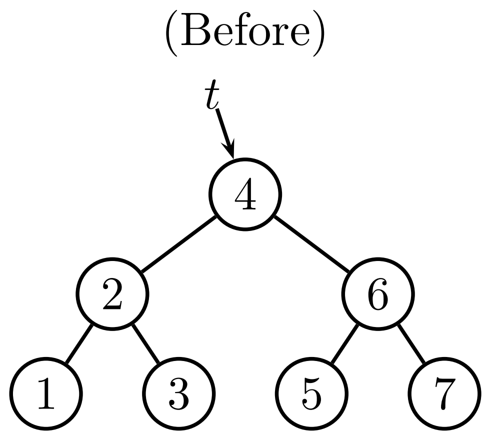
```
x <+> y = x <> text " " <> y
```

Reference solution

We may prefer that “empty” (say, ””) is a unit of both forms of composition.

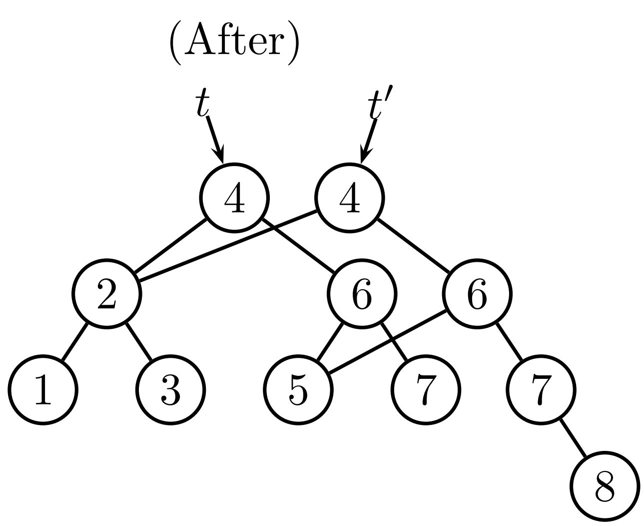
9 "Functional data structures"

Consider the following binary search tree t.



Now, assume that 8 is inserted into t, resulting in a tree t'. Draw the tree t' so that one can see what parts it shares with t.

Reference solution



10 "Reasoning"

How would you test the *head* function for retrieving the head of a list? *Please, be concise: 140 characters or less.*

Reference solution

Construct 2 or more non-empty lists with different heads. Test that the correct head is returned for each list. Test that *head []* throws.