

The University of Melbourne
School of Computing and Information Systems

Semester 1, 2020 Sample Assessment

COMP90048
Declarative Programming

Sample Answers Included

Reading Time: 15 minutes

Total marks for this paper: 100

Writing Time: 2 hours

This paper has 8 pages, including this title page.

Authorised Materials:

Writing instruments (e.g., pens, pencils, erasers, rulers).
No other materials and no electronic devices are permitted.

Instructions to Invigilators:

The exam paper must remain in the exam room and be returned to the subject coordinator.

Instructions to Students:

The marks for each question are listed at the beginning of the question. You should attempt all questions. Use the number of marks allocated to a question as a rough indication of the time to spend on it. We have tried to provide ample space for your answers; do not take the amount of space provided for an answer as an indication of how much you need to write.

This paper must *not* be lodged with the university library.

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Question 1**[12 marks]**

For each of the following Haskell expressions, give its **type** (which may be a function type, may include type variables, and may include type class constraints) or indicate that it represents a type error. You need not write anything other than the type, or that it is an error.

(a) ($<$)`(<) :: Ord a => a -> a -> Bool`

⇐

(b) `map (+3)``Num a => [a] -> [a]`

⇐

(c) `foldr``(a -> b -> b) -> b -> [a] -> b ---or--- Foldable t => (a -> b -> b) -> b
-> t a -> b`

⇐

(d) `Nothing``Maybe a`

⇐

(e) `zip [True,True,False]``[a] -> [(Bool, a)]`

⇐

(f) `flip filter "hello"``(Char -> Bool) -> [Char] —or— (Char -> Bool) -> [Char]`

⇐

Question 2**[12 marks]**

For each of the following Haskell expressions, give its **value**, or explain why it will produce an error or fail to terminate. Assume the `Data.List` library is loaded, which defines the `sort` function.

(a) `map (length < 3) [[1],[1,2,3]]``Type error`

⇐

(b) `filter (not.(==3)) [1,2,3]``[1,2]`

⇐

(c) `let e = head [] in 3``3`

⇐

(d) `map fst $ filter snd $ zip "abcde" [True,True,False,True]``"abd"`

⇐

(e) `head $ sort $ zip [3,0,0,2,0] $ reverse [9,0,0,4,8]`

`(0,0)`

\Rightarrow

(f) `map snd $ sort $ zip "decl" [1..]`

`[3,1,2,4]`

\Rightarrow

Question 3**[30 marks]**

Consider the following Haskell type for ternary trees:

```
data Ttree t = Nil | Node3 t (Ttree t) (Ttree t) (Ttree t)
```

Suppose we have a **Ttree** of Doubles and we want a function to find the average of the numbers in the tree. Write a Haskell function which performs this task. If the **Ttree** is empty, your function should return 0.0. Include type declarations for all your functions. To obtain maximum marks, your code should use a single traversal over the tree and have $O(N)$ worst case time complexity.

Sample Answer to Question 3**Solution using custom fold function for Ttrees**

```
ttreeAverage1 :: Ttree Double -> Double
ttreeAverage1 Nil = 0.0
ttreeAverage1 tt =
  let (sum,count) = foldTtree plusCount (0.0,0.0) tt
  in  sum / count

plusCount :: Double -> (Double, Double) -> (Double, Double)
plusCount n (sum,count) = (sum+n, count+1)

foldTtree :: (a -> b -> b) -> b -> Ttree a -> b
foldTtree _ acc Nil = acc
foldTtree f acc (Node3 n left mid right)
  = let acc1 = foldTtree f acc right
      acc2 = foldTtree f acc1 mid
      acc3 = foldTtree f acc2 left
    in  f n acc3
```

Alternative full-credit solution

```
ttreeAverage2 :: Ttree Double -> Double
ttreeAverage2 Nil = 0.0
ttreeAverage2 tt =
  let (sum,count) = ttAverage' tt
  in  sum / count

ttAverage' :: Ttree Double -> (Double,Double)
ttAverage' Nil = (0.0,0.0)
ttAverage' (Node3 n left mid right) =
  let (suml,countl) = ttAverage' left
      (summ,countm) = ttAverage' mid
```

```
(sumr,countr) = ttAverage' right
in (n+suml+summ+sumr, 1+countl+countm+countr)
```

Partial credit solution using two passes

```
-- Partial credit, two-pass solution. This answer would still get
-- most of the marks.
tttreeAverage3 :: Ttree Double -> Double
tttreeAverage3 Nil = 0.0
tttreeAverage3 tt = ttSum tt / ttCount tt

ttSum :: Ttree Double -> Double
ttSum Nil = 0.0
ttSum (Node3 n left mid right) =
  n + ttSum left + ttSum mid + ttSum right

ttCount :: Ttree Double -> Double
ttCount Nil = 0.0
ttCount (Node3 n left mid right) =
  1 + ttCount left + ttCount mid + ttCount right
```

Question 4

[10 marks]

Give the formal semantics (meaning) of the following Prolog program. Recall that the formal semantics of a logic program is the set of *ground unit clauses* that would give the same answers to all queries as the program itself. English descriptions of the meanings of the programs will receive no credit.

```
p(a).    p(b).

q(X,Y) :- p(X), p(Y).

r(a,c).    r(d,b).

s(X,Y) :- q(X,Y), r(X,_), r(_,Y).
```

Sample Answer to Question 4

⇒

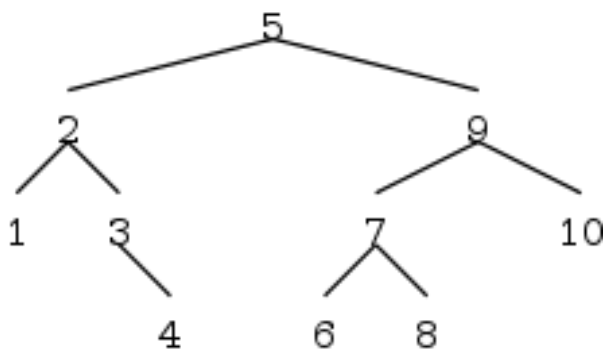
```
p(a).    p(b).
q(a,a).    q(a,b).    q(b,a).    q(b,b).
r(a,c).    r(d,b).
s(a,b).
```

Question 5**[20 marks]**

For this question, we will represent a set of integers as a binary tree in Prolog, using the atom `empty` to represent an empty tree or node, and `tree(L,N,R)` to represent a node with label `N` (an integer), and left and right subtrees `L` and `R`. Naturally, we also insist that `N` be strictly larger than any label in `L` and strictly smaller than any in `R`. We do not require that the tree be balanced. For example,

```
tree(tree(tree(empty, 1, empty),
           2,
           tree(empty, 3, tree(empty, 4, empty))),
      5,
      tree(tree(tree(empty,6,empty),
                  7,
                  tree(empty,8,empty)),
            9,
            tree(empty, 10, empty)))
```

is one possible representation of the set of numbers from 1 to 10. It might be visualized as



Write a predicate `intset_insert(N, Set0, Set)` such that `Set` is the same as `Set0`, except that `N` is a member of `Set`, but may or may not be a member of `Set0`. That is, either `N` is a member of `Set0` and `Set = Set0`, or `N` is not a member of `Set0` and is a member of `Set`, and other than that, `Set` is the same as `Set0`. This predicate must work as long as `N` is bound to an integer and `Set0` is ground.

Hint: Prolog's arithmetic comparison operators are `<`, `>`, `=<` (not `<=`), and `>=`. You can also use `=` and `\=` for equality and disequality.

Sample Answer to Question 5

⇐

```
intset_insert(N, empty, tree(empty,N,empty)).
intset_insert(N, tree(Left,Val,Right), Result) :-
```

```

(   N = Val
->  Result = tree(Left,Val,Right)
;   N < Val
->  Result = tree(Left1,Val,Right),
    intset_insert(N, Left, Left1)
;   Result = tree(Left,Val,Right1),
    intset_insert(N, Right, Right1)
).
```

Question 6**[16 marks]**

Following is a definition of a Prolog predicate to compute the sum of a list of numbers.

```

sumlist([], 0).
sumlist([N|Ns], Sum) :-
    sumlist(Ns, Sum0),
    Sum is N + Sum0.
```

Fill in the blanks in the following transformation of this code to be tail recursive.

```

sumlist(List, Sum) :- sumlist(List, 0, Sum).
⇒
sumlist([], Sum, Sum).
sumlistsumlist([N|Ns], Sum0, Sum) :-
    Sum1 is Sum0 + N,
⇒
    sumlist(Ns, Sum1, Sum).
⇒
```

— End of Exam —