Candidate Number

G6021

THE UNIVERSITY OF SUSSEX

BSc and MComp FINAL YEAR EXAMINATION
January 2021 (A1)

COMPARATIVE PROGRAMMING

Assessment Period: January 2021 (A1)

DO NOT TURN OVER UNTIL INSTRUCTED TO BY THE LEAD INVIGILATOR

Candidates should answer TWO questions out of THREE. If all three questions are attempted only the first two answers will be marked.

The time allowed is TWO hours.

Each question is worth 50 marks.

At the end of the examination the question paper and any answer books/answer sheets, used or unused, will be collected from you before you leave the examination room.

1. Consider the following program written in Haskell syntax:

```
sq x = x*x
twice (f,x) = f(f(x))
inf x = inf (x+1)
```

   (a) Draw the reduction graph for `twice (\x->x,3+4)`. Underline all redexes. [15 marks]

   (b) Describe in one sentence what is meant by the most general type of a function. For each of the functions: `sq`, `twice` and `inf`, give the most general type. [15 marks]

   (c) Are the following statements true? Give a one-sentence justification for each.

      i. `inf` $(\texttt{inf}\ 0)$ is a well-typed expression.

      ii. `inf` $(\texttt{inf}\ 0)$ will terminate with call-by-name strategy.

      iii. `sq` $4 +$ `inf` 4 is a well-typed expression.

      iv. All well-typed Haskell programs terminate. [10 marks]

   (d) Write a PCF function to add two numbers. Include all types in your answer. [10 marks]

2. (a) i. For the following two types, draw the type trees and find the most general unifier, if one exists.

$$(A \to B) \to (B \to C) \to A \to C$$
$$D \to E \to D$$

[10 marks]

ii. Define a function in Haskell that has the most general type:

$$(A \to B) \to (B \to C) \to A \to C$$

[10 marks]

iii. Give the un-curried version of the function in Question 2(a)ii. Include the Haskell code and the type of this function. [10 marks]

(b) Explain why Prolog would fail to find a solution to the following program, and suggest two ways in which this can be resolved.

$$\text{even}(s(s(X))) \leftarrow \text{even}(X).$$
$$\text{even}(0).$$
$$?\text{even}(Y).$$

[10 marks]

(c) What is the *occurs check*? Give an example of the occurs check in both type reconstruction and Prolog evaluation. [10 marks]

3. (a) Consider the following Haskell data type:

```
data Tree = Empty | Node Int Tree Tree
```

Write Haskell functions for the following operations:

i. `mapTree`: apply a function to each element of the tree. Give the most general type of your function. [10 marks]

ii. `flatTree`: Convert a `Tree` into a list. You can use append (++) in your definition. Give the most general type of this function. [10 marks]

iii. `flatTreeAcc`: Convert a `Tree` into a list using an accumulating parameter. You cannot use append (++) in your definition. Give the starting value for the accumulating parameter, and give the most general type of this function. [10 marks]

(b) Write Prolog clauses to convert a Tree data type into a list. You may use the `append` program in your answer. [10 marks]

(c) Write Java classes to represent the Tree data structure. Compare Java, Prolog, and Haskell for 1) representing this data type, 2) writing operations over this data type. [10 marks]

End of Paper