Durham University

EXAMINATION PAPER

Examination Session: May/June	Year: 2014	Exam Code: 1 0 1 0 5 1 / 0 1

Title: **Computational Thinking**

Time Allowed:	2 hours
Examination Material Provided:	None
Additional Materials Permitted:	None
Instructions:	Answer THREE questions. (TWO from Section A and ONE from Section B) ANSWER EACH SECTION IN A SEPARATE ANSWER BOOK Calculators are NOT allowed Erasmus/Visiting students can use a dictionary

Revision:	

Section A Computational Thinking (Professor I.A. Stewart)

Question 1

This question is on problems and problem solving.

(a) What is the Stable Marriage problem? (You should explain the meaning of any concepts you use to define the problem.) Is the Stable Marriage problem a decision, search or optimisation problem? **[6 Marks]**

(b) How would you abstract an instance of the Stable Marriage problem for computational solution? **[2 Marks]**

(c) Show how the Gale-Shapley algorithm proceeds on the following instance of the Stable Marriage problem:

a man's preferences						a woman's preferences					
m_1	:	w_1	w_2	w_4	w_3	w_1	:	m_3	m_4	m_1	m_2
m_2	:	w_2	w_3	w_1	w_4	w_2	:	m_4	m_3	m_2	m_1
m_3	:	w_4	w_3	w_1	w_2	w_3	:	m_1	m_2	m_4	m_3
m_4	:	w_4	w_1	w_3	w_2	w_4	:	m_1	m_3	m_4	m_2

[6 Marks]

(d) What is an independent set in a graph? What is the difference between a maximum independent set and a maximal independent set? **[5 Marks]**

(e) Explain how finding a maximum independent set in a certain graph can help us build (large) sets of codewords of length 5 so that we might undertake 1-bit error detection in any transmitted codeword. **[6 Marks]**

continued

Question 2

This question is on programming and programming languages.

(a) Briefly explain the difference between an algorithm and a program. Suppose that we have an algorithm and that we wish to implement it in Python. How many different implementations are there of this algorithm?**[3 Marks]**

(b) For each of the following descriptions, state the programming paradigm that is being described and give an example of a programming language of that paradigm:

i. programs are characterized by their use of programming instructions to explicitly change a program's state

ii. programs generally consist of a set of axioms and a goal statement, along with some rules of inference

iii. programs are designed to automate frequently used tasks that involve calling or passing commands to external programs.

[6 Marks]

(c) In order to execute a high-level program we must first convert it into machine code so that the CPU can 'understand' it. Briefly explain the difference between compilation and interpretation. Give an example of a programming language that is compiled and one that is interpreted; and give an advantage of compilation over interpretation, and of interpretation over compilation. **[6 Marks]**

this question is continued on the next page

(d) Regular expressions feature strongly in the compilation of programs. A regular expression is defined as follows (below, Σ is a finite alphabet):

- any $a \in \Sigma$ is a regular expression
- $\emptyset$ and ϵ are special regular expressions
- if ω and ω' are regular expressions then so are:
  - $(\omega\omega')$
  - $(\omega|\omega')$
  - (ω^*).

Explain how a regular expression defines a set of strings over Σ.

[7 Marks]

(e) What is the relationship between regular expressions and finite state machines? (You need not define a finite state machine but you should define any other concepts you use.) **[3 Marks]**

continued

Question 3

This question is on algorithms for sorting.

(a) First, give a natural language description of the algorithm **Bubble-sort**, and, next, give pseudo-code for your algorithm. **[8 Marks]**

(b) Describe how your **Bubble-sort** algorithm works on the input list of numbers $4, 5, 3, 2, 5, 2$. **[4 Marks]**

(c) Explain how **Shaker-sort** differs from **Bubble-sort** and show how **Shaker-sort** proceeds on the list of numbers $4, 5, 3, 2, 5, 2$. **[8 Marks]**

(d) What is the time complexity of **Bubble-sort** and **Shaker-sort**? In terms of the number of swaps made, give a worst-case input of a list of 5 input numbers for **Bubble-sort**. **[5 Marks]**

End of Section A

Section B Computational Thinking (Professor I.A. Stewart)

Question 4

(a) Give two different resources used by an algorithm that we might measure. Give two reasons why we usually measure the resources used by an algorithm rather than the resources used by an implementation of an algorithm. **[4 Marks]**

(b) What is the worst-case time complexity of an algorithm? Why is it expressed as a function on the natural numbers? **[3 Marks]**

(c) Define precisely what we mean when we say that two functions $f(n) : \mathbb{N} \rightarrow \mathbb{N}$ and $g(n) : \mathbb{N} \rightarrow \mathbb{N}$ are such that $f = O(g)$. Explain the reasoning behind why we use this notation to express time complexities. Give an objection to the usefulness of the Big-O notation. **[6 Marks]**

(d) Define the complexity classes **P** and **NP**. Give two objections to the definition of a tractable or efficiently solvable problem as a problem in the complexity class **P**. **[6 Marks]**

(e) What is an **NP**-complete problem? What will the consequence be if some **NP**-complete problem turns out to be in **P**? (You should explain your reasoning.). **[6 Marks]**

continued

Question 5

(a) What is a Boolean function? In relation to Boolean functions, what is special about the collective use of NOT-, AND- and OR-gates? **[2 Marks]**

(b) What is a NAND-gate? Show that any NOT-, AND- or OR-gate can be constructed using only NAND-gates. **[9 Marks]**

(c) A computer's hardware is built from gates which are themselves built from transistors. In order to execute a high-level program using hardware, many programs need to be compiled into machine code. What are the 4 phases of the compilation process? In which phase of compilation are context-free grammars used? **[5 Marks]**

(d) Define a context-free grammar and explain how it generates a set of strings. **[4 Marks]**

(e) Give a context-free grammar that generates the set of strings consisting of the symbol a repeated an arbitrary (possibly zero) number of times followed by the symbol b repeated the same number of times (that is, the set is $\{a^k b^k : k = 0, 1, 2, \ldots\}$). **[5 Marks]**

END OF PAPER