COMPUTER SCIENCE TRIPOS Part IB

Thursday 3 June 1993 1.30 to 4.30

Paper 6

Answer **five** *questions.*
No more than **two** *questions from any one section are to be answered.*
Submit the answers in five **separate** *bundles each with its own cover sheet.*
Write on **one** *side of the paper only.*

SECTION A

1 Introduction to Computer Architecture

In what ways has exception handling been designed to impose minimal processing overhead in the MIPS R2000/R3000? [8 marks]

Describe the model of operating system structure assumed by the MIPS R2000/R3000 designers. What hardware support is provided for this structure? [12 marks]

2 Computer Structures

Write short notes on the following methods of improving the performance of a computer system:

(*a*) cache memory [6 marks]

(*b*) pipelining [6 marks]

(*c*) Reduced Instruction Set Computer (RISC) [8 marks]

3 Digital Communication I

Describe the properties of a physical channel which need to be considered when the channel is used for communications. [7 marks]

Describe how the properties of a digital synchronous channel are related to the properties of the underlying physical channel. [7 marks]

Describe three ways in which a protocol entity can provide higher layer channels from lower layer channels. [6 marks]

4 Graphics II

Compare object-space and image-space visibility tests in synthesising an image for display. [12 marks]

Describe one visibility test in detail. [8 marks]

SECTION B

5 Programming in C

Two identical packs of ordinary playing cards (52 different cards in a pack) are shuffled and placed face downwards on a table. Two players then play a game of *Snap*. Each player is allocated one pack and at each turn in the game one card in each pack is turned up and the two upturned cards are compared. If the cards are the same (i.e. match in every respect) a *snap-turn* is declared. A game ends when all 52 pairs have been compared.

Write a C program which will simulate the game for the purposes of determining the probability of there being at least one snap-turn in a game. [20 marks]

Note: you may assume the existence of a random number generator but must state its properties.

6 Programming Language Compilation

Write notes on each of the following topics:

(*a*) the implementation of labels and jumps in a recursive, block structured programming language [7 marks]

(*b*) the implementation of arrays with non-constant bounds [7 marks]

(*c*) problems in the specification and implementation of Algol **own** variables [6 marks]

7 Concurrent Systems

Monitors are often provided in concurrent programming languages to support the interaction of processes by means of shared data.

Discuss the monitor mechanism and its implementation. [10 marks]

How could the monitor mechanism be adapted to allow for many shared data objects of the same type? [2 marks]

What advantages, if any, could be obtained from using an active object instead of a monitor; that is, a monitor-like structure with one or more internally bound processes? [8 marks]

8 Databases

Describe the ANSI-SPARC architecture for managing data, explaining how it enables *data independence* to be achieved. [6 marks]

Outline the CODASYL/DBTG proposals for network database management, showing how they relate to the ANSI-SPARC architecture. [8 marks]

In what ways do the DBTG proposals compromise data independence? [3 marks]

What provision is made for data security in them? [3 marks]

SECTION C

9 Foundations of Functional Programming

Describe David Turner's algorithm for translating λ-terms to combinators, using **S**, **K**, **I**, **B** and **C**. Demonstrate the algorithm by translating $\lambda x\, y\, f.f\, x\, y$. [4 marks]

Prove that $\lambda^T x.R \equiv \lambda^T y.R[y/x]$ holds for every combinatory term R such that y is not free in R. [6 marks]

Describe the graph reduction of $\mathbf{S\,I\,I\,(S\,I\,I)}$. [4 marks]

Describe the graph reduction of $\mathbf{S\,mult\,I}\,(\mathbf{fst}\,(\mathbf{Y}\,(\mathbf{pair}\,3)))$, taking all the constants shown as primitive combinators. [6 marks]

10 Computation Theory

Explain what is meant by the following:

> 'F is a recursively enumerable set each of whose elements is a total recursive function $f : \mathbb{N} \to \mathbb{N}$.' [3 marks]

In each of the following cases state with reasons whether the set is recursively enumerable:

(a) the set A of all total recursive functions $a : \mathbb{N} \to \mathbb{N}$ such that $a(n + 1) \geqslant a(n)$ for all $n \in \mathbb{N}$ [7 marks]

(b) the set D of all total recursive functions $d : \mathbb{N} \to \mathbb{N}$ such that $d(n + 1) \leqslant d(n)$ for all $n \in \mathbb{N}$ [10 marks]

11 Complexity Theory

Explain the relationship between integer and polynomial multiplication. [2 marks]

Show how the latter can be reduced to an interpolation problem which can be solved by matrix multiplication. [4 marks]

Starting from this idea, outline an efficient algorithm for forming the product of two n-bit unsigned integers. [12 marks]

What is the cost of the algorithm that you have described? [2 marks]

12 Formal Languages and Automata

For each of the following languages over the alphabet $\{a, b\}$, say whether or not it is regular. Justify your answers stating clearly any results that you use.

(a) The set of all strings which are not palindromes (i.e. which are not equal to their own reverse) [4 marks]

(b) The union of countably many regular languages $L_1, L_2, L_3, \ldots$ [4 marks]

(c) The set of all strings in which the number of occurrences of the letter a and the number of occurrences of the letter b are both divisible by 3 [4 marks]

(d) The set of all strings which are of the form ww for some string w [4 marks]

(e) The set of all strings such that in each initial substring the number of occurrences of the letter a and the number of occurrences of the letter b differ by no more than 2 [4 marks]