

COMPUTER SCIENCE TRIPOS Part II (General)

DIPLOMA IN COMPUTER SCIENCE

Thursday 6 June 1996 1.30 to 4.30

Paper 13 (Paper 4 of Diploma in Computer Science)

Answer **five** questions.

Submit the answers in five **separate** bundles each with its own cover sheet.

Write on **one** side of the paper only.

1 Distributed Systems

Einstein has established that there is no universal time. For earth-based computer systems discuss how events might be assigned a time stamp which is reasonably close to conventional earth-time.

Describe the constraints on system-wide event ordering and discuss alternative approaches to meeting them. [10 marks]

For a system in which data replicas are maintained:

Either Define *total order* and *causal order* applied to the delivery of update messages to the replicas. Outline an approach to maintaining causal order. [10 marks]

or Describe algorithms and protocols which may be used to achieve consistency of replicas at all times. [10 marks]

2 Computer Architecture

Give the circuit diagram and describe the operation of the following types of memory cell:

(a) bipolar memory cell (static) [5 marks]

(b) MOS memory cell (static) [5 marks]

Give the key characteristics of *each* of the following types of memory: DRAM, ROM, PROM, EPROM and EEPROM. [2 marks each]

3 Digital Communication I

Operations of similar functionality can be performed at different layers of a protocol stack. Discuss this in relation to

- (a) routing [4 marks]
- (b) multiplexing [4 marks]
- (c) error recovery [4 marks]
- (d) flow control [4 marks]
- (e) synchronization [4 marks]

4 Graphics

What are *homogeneous coordinates*? [5 marks]

How can they be used in computer graphics to model

- (a) translation? [5 marks]
- (b) simple perspective? [10 marks]

5 Business Studies

What is meant by *SWOT analysis*? [5 marks]

A small computer company with strong and innovative hardware expertise is considering manufacturing a network interface computer (NIC). The device, which would sell for about half the current price of a PC, is based on games console technology, with a built-in modem. It would allow a user to convert his or her television to a web-browser. Apart from a small amount of parameter storage, the proposed device contains no disc or other long-term memory.

How would you determine the market for such a device? [5 marks]

Perform an analysis of this opportunity. What advice would you give the company? [5 marks]

Comment on changes to the business model that may be expected to be caused by the rapid development of the Internet. [5 marks]

6 Programming in C and C++

A grand debate is being planned by a society that has among its members a large number of computer professionals and working programmers. The motion to be put is “That the languages C and C++ should be consigned to outer darkness and their use banned in all serious computer projects”. Prepare as your answer to this question a briefing document that could explain to people intending to attend the debate what the major points both for and against C and C++ will be, and the lines of arguments that are liable to be used to show how important they are. You are not required to come down either in favour of or against the languages (but may if you wish). [20 marks]

7 Compiler Construction

Programming languages are usually compiled into the machine code of the target computer, but sometimes an interpretive system is used. Discuss the relative merits of these two approaches. [7 marks]

Outline the key features of the design of an interpretive code that would be suitable for an implementation of the C programming language and describe the overall structure of an interpreter for it. [7 marks]

What techniques could be used to improve (a) the space efficiency, and (b) the time efficiency of interpretive codes? [6 marks]

8 Prolog for Artificial Intelligence

Describe how lists that are represented by difference lists may be concatenated (or “appended”) in constant time. [6 marks]

Define a procedure `rotate(X,Y)` where both X and Y are represented by difference lists, and Y is formed by rotating X to the left by one element. [14 marks]

9 Databases

The international conference Extending Data Base Technology has arranged its next meeting in Avignon at the end of March, to coincide with the spring migration through the Camargue. Birders expect to add significant new sightings to the list of birds seen during a major database conference.

Delegates have been arguing for over a decade about the best relational model for the data. It is agreed that the following information should be recorded:

- the names of the major avifaunal regions: nearctic, western palæarctic, Australasia etc.
- for each birding delegate, a level of competence on a scale [1..5] within each avifaunal region
- good bird sites within each region (including all those visited during conferences), specifying the various habitat types occurring within each site
- observations made – by an observer, on a date, in a habitat type at some site, of a species belonging to a particular family of birds

Advise the delegates on a suitable relational schema for this database. [16 marks]

Explain what would be involved in processing the following queries in SQL.

- (a) What species of the kingfisher family have been observed both in a waterside habitat and in arid grassland? [2 marks]
- (b) Which delegate is recorded as having observed the greatest number of distinct species? [2 marks]

10 Natural Language Processing

Describe three significant differences between programming languages and natural languages. [8 marks]

What problems do these differences pose for attempts to construct programs that “understand” a natural language? [12 marks]

11 Introduction to Functional Programming

Give a short explanation (illustrated with examples) of *each* of the following features of ML:

- (a) higher order functions [4 marks]
- (b) polymorphism [4 marks]
- (c) datatypes [4 marks]
- (d) pattern matching [4 marks]
- (e) exceptions [4 marks]

12 Computer Vision

Using appropriate mathematical expressions, define the following operations commonly used in computer vision and briefly explain their function and applications:

- (a) convolution [4 marks]
- (b) correlation [4 marks]
- (c) bandpass filtering [4 marks]
- (d) edge detection by second-derivative zero-crossings [4 marks]
- (e) invariant transform [4 marks]

13 Complexity Theory

One version of the algorithm that uses discrete Fourier Transforms when multiplying integers uses modular arithmetic for much of its internal working. The modulus involved will be chosen to be one greater than a power of two. Explain why this is the case, what power of two is involved, how this relates to the number of digits in the numbers being multiplied and how the basic operations of modular arithmetic are performed. Does it matter that the modulus used is usually not a prime number? [20 marks]

14 Numerical Analysis II

Let

$$p_n(x) = a_n x^n + \cdots + a_1 x + a_0$$

have n_+ positive real roots. If Descartes' rule of signs is expressed in the form

$$0 \leq c - n_+ = 2k,$$

what do c and k represent?

[4 marks]

How many *positive* real roots do the following polynomials have?

(a) $x^6 - x^4 - x - 2$

(b) $x^4 - 2x^3 - 235x^2 - 940x + 10200$, given that $x = 5$ is a root

How many *negative* real roots does the following polynomial have?

(c) $2x^3 - 53x^2 + 316x + 600$

[4 marks]

Given that the polynomial

$$343x^3 - 294x^2 + 32$$

has a double root, find all of its roots.

[6 marks]

Müller's method uses the formula

$$x_{i+1} = x_i - \frac{2f(x_i)}{c_i \pm \sqrt{c_i^2 - 4b_i f(x_i)}}.$$

What is the advantage of having a square root in the formula? How is the sign chosen in the denominator? Describe briefly the idea underlying Müller's method (omitting algebraic details) and comment on the choice of starting values.

[6 marks]