COMPUTER SCIENCE TRIPOS Part IB

Tuesday 1 June 2010 1.30 to 4.30

COMPUTER SCIENCE Paper 4

*Answer **five** questions.*

*Submit the answers in five **separate** bundles, each with its own cover sheet. On each cover sheet, write the numbers of **all** attempted questions, and circle the number of the question attached.*

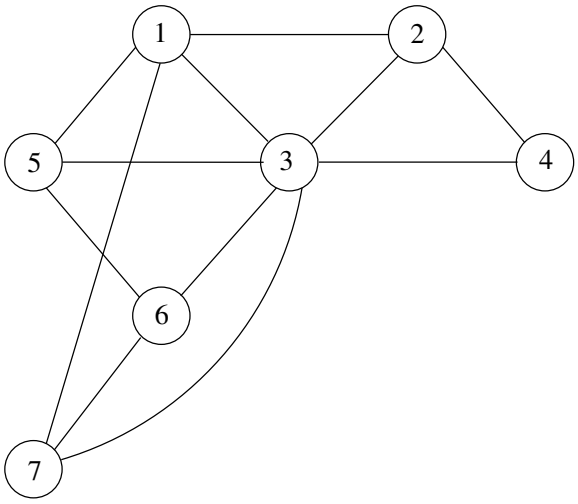
You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

STATIONERY REQUIREMENTS
Script paper
Blue cover sheets
Tags

SPECIAL REQUIREMENTS
Approved calculator permitted

1 Artificial Intelligence I

This question addresses the problem of colouring the following graph using a *constraint satisfaction* approach.



The colours available are amber, black and crimson which we will denote by A, B and C respectively. We want to assign a colour to each node in the graph in such a way that if there is an edge (n_1, n_2) between any pair of nodes then n_1 and n_2 have different colours.

(a) Explain how this problem can be represented as a constraint satisfaction problem. [2 marks]

(b) Explain how we can apply *forward checking* in the process of solving a constraint satisfaction problem. Illustrate your answer using the above graph colouring problem where the initial steps are, in order, $1 = A$, $2 = B$, $6 = B$, $5 = C$. In particular, you should show how the process can *reduce branching* and *induce backtracking*. [8 marks]

(c) Explain how we can apply *constraint propagation* using *arc consistency* in the process of solving a constraint satisfaction problem. Illustrate your answer using the same initial steps in the same order. Determine whether or not backtracking occurs earlier in this case and explain why. [10 marks]

2 Artificial Intelligence I

Evil Robot's creator has sent him on a mission. He must go to the Secret Mountain Hideout, put on an orange boiler suit so that he blends in, then pick up two items called Component 1 and Component 2 and join them together. Finally, he has to press the BIG RED BUTTON (which only works when the two components are joined together) in order to cause something horrible to happen. Evil Robot's internal systems have been constructed using the *situation calculus* and a theorem prover.

(*a*) Give a brief outline of the *situation calculus*, concentrating on the fundamental elements that you would expect to see independently of any specific problem. [4 marks]

(*b*) Suggest **three** logical formulae that might appear in Evil Robot's knowledge base in order to describe the initial state for the above problem. [3 marks]

(*c*) Give an example of a *unique names axiom* that might appear in the knowledge base. Why might such axioms be required? [2 marks]

(*d*) Give an example of a *unique actions axiom* that might appear in the knowledge base. [1 mark]

(*e*) Give **two** examples of a *possibility axiom* that might appear in the knowledge base. [4 marks]

(*f*) Give **two** examples of a *successor-state axiom* that might appear in the knowledge base. One of these should in addition address the *ramification problem*. Explain how it does this. [6 marks]

3 Computer Graphics and Image Processing

(*a*) Give an outline description of the painter's algorithm, z-buffer and BSP tree methods for rendering a set of 3D polygons. [3×4 marks]

(*b*) Compare and contrast the three methods. [8 marks]

4 Computer Graphics and Image Processing

(a) Homogeneous coordinates are often used to represent transformations in 3D:

$$\begin{bmatrix} x'_H \\ y'_H \\ z'_H \\ w'_H \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & b_1 \\ a_{21} & a_{22} & a_{23} & b_2 \\ a_{31} & a_{32} & a_{33} & b_3 \\ c_1 & c_2 & c_3 & d \end{bmatrix} \begin{bmatrix} x_H \\ y_H \\ z_H \\ w_H \end{bmatrix}$$

(i) Explain how to convert standard 3D coordinates, (x, y, z), to homogeneous coordinates, and how to convert homogeneous coordinates to standard 3D coordinates. [2 marks]

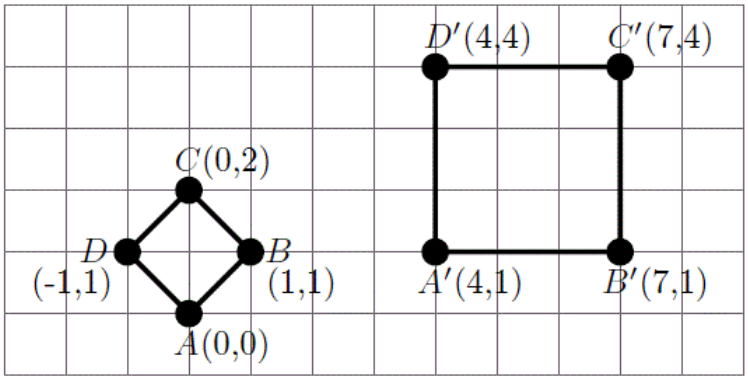
(ii) Describe the types of transformations provided by each of the four blocks of coefficients in the matrix ($a_{11} \ldots a_{33}$, $b_1 \ldots b_3$, $c_1 \ldots c_3$ and d). [5 marks]

(iii) Explain what transformation is produced by each of the following matrices:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \qquad \begin{bmatrix} 1 & 0 & p & -p(1+r) \\ 0 & 1 & q & -q(1+r) \\ 0 & 0 & 1+r & -r(1+r) \\ 0 & 0 & 1 & -r \end{bmatrix}$$

[5 marks]

(b) Consider the following figure:



(i) Give a matrix, or product of matrices, that will transform the square $ABCD$ into the rectangle $A'B'C'D'$. [5 marks]

(ii) Show what happens if the same transformation is applied to $A'B'C'D'$. [3 marks]

5 Databases

(*a*) Suppose that $R(A, B, C)$ is a relational schema with functional dependencies $F = \{A, B \to C, C \to B\}$.

(*i*) Is this schema in 3NF? Explain. [2 marks]

(*ii*) Is this schema in BCNF? Explain. [2 marks]

(*b*) Decomposition plays an important role in database design.

(*i*) Define what is meant by a *lossless-join decomposition.* [2 marks]

(*ii*) Define what is meant by a *dependency preserving decomposition.* [2 marks]

(*c*) Let $R(A, B, C, D, E)$ be a relational schema with the following functional dependencies

$$\begin{aligned} A, B &\to C \\ D, E &\to C \\ B &\to D \end{aligned}$$

(*i*) What is the closure of $\{A, B\}$? [2 marks]

(*ii*) What is the closure of $\{B, E\}$? [2 marks]

(*iii*) Decompose the schema to BCNF in **two** different ways. In each case, are all dependencies preserved? Explain. [4 + 4 marks]

6 Databases

(a) Present **two** advantages and **two** disadvantages of eliminating logical redundancy in database schema design. [4 marks]

(b) What are `NULL` values in SQL, and with what problems are they associated? [2 marks]

(c) We are given a schema $R(\mathbf{X})$ with key $K \in \mathbf{X}$. Suppose that $A, B, C \in \mathbf{X}$ are non-key attributes and we want to verify that the functional dependency $A, B \to C$ is not violated in our database. Consider the SQL query,

```
select S.K, T.K as K1, K2
from R as S, R as T
where S.A = T.A and S.B = T.B and S.C <> T.C
```

Does this query return all key pairs of records that violate the functional dependency

(i) when C is not allowed to be `NULL`? [3 marks]

(ii) when C is allowed to be `NULL`? [3 marks]

(d) Suppose that $R(\mathbf{X}, \mathbf{Y}, \mathbf{Z})$ is a relational schema where $\mathbf{X}$, $\mathbf{Y}$, and $\mathbf{Z}$ are disjoint attribute sets. Prove that the following *mixed transitivity* rule holds:

$$\text{If } \mathbf{X} \twoheadrightarrow \mathbf{Y} \text{ and } \mathbf{Y} \to \mathbf{Z}, \text{ then } \mathbf{X} \to \mathbf{Z}.$$

[8 marks]

7 Introduction to Security

(*a*) Briefly explain the following terms, and for each give **one** example of a technique that implements it:

(*i*) secure commitment; [2 marks]

(*ii*) mandatory access control policy; [2 marks]

(*iii*) perfect secrecy; [2 marks]

(*iv*) message authentication code. [2 marks]

(*b*) You have been hired by CustomWidgets Ltd to secure the web interface to a legacy system. This system is complex, its source code has been lost, and you have been unable to find a precise definition of allowable input values. You have been asked to write input validation procedures, that will identify values which are suspected to be malicious, and flag them for later manual inspection. For each of these input fields, explain **one** validation procedure you could perform, and justify why it is appropriate:

(*i*) the name of a file in a particular directory on the server; [3 marks]

(*ii*) a parameter that you believe will be used on a command-line; [3 marks]

(*iii*) a string that will be loaded into memory and parsed. [3 marks]

(*c*) For **one** of the validation procedures you gave in part (*b*), discuss how a sophisticated attacker could circumvent detection. [3 marks]

8 Economics and Law

(*a*) In a hawk–dove game, doves share food, hawks take food from doves, and hawks fight each other (with a certain risk of death).

(*i*) Write out this game in strategic form. [4 marks]

(*ii*) Under what circumstances will there be an equilibrium with non-zero numbers of hawks and doves? [4 marks]

(*iii*) What will the equilibrium be? Justify your answer. [8 marks]

(*b*) Why might people be more aggressive online than they are in face-to-face encounters? [4 marks]

END OF PAPER