UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 1998

BEng Honours Degree in Computing Part II
MEng Honours Degrees in Computing Part II
BSc Honours Degree in Mathematics and Computer Science Part II
MSci Honours Degree in Mathematics and Computer Science Part II
for Internal Students of the Imperial College of Science, Technology and Medicine

This paper is also taken for the relevant examinations for the
Associateship of the Royal College of Science
Associateship of the City and Guilds of London Institute

PAPER 2.1 / MC2.1

SOFTWARE DESIGN I

Monday, April 27th 1998, 10.00 - 11.30

Answer THREE questions

For admin. only: paper contains 4 questions

Section A *(Use a separate answer book for this Section)*

1a Name and briefly distinguish three kinds of models that are commonly used in software development.

b Why are state-transition diagrams (STDs) unsuitable for modelling in large and complex systems? Describe an adaptation of STDs that addresses some of their weaknesses.

c Normally, a lazy student spends his time either eating, drinking or sleeping. He starts every day sleeping, and when his alarm goes off, he wakes up and starts eating, but only if he has slept ten or more hours. When he is thirsty he drinks, and when he is hungry he starts eating again. Whenever he is sleepy, he goes to sleep.

i) Draw a simple STD that models the above student's behaviour. Include actions, conditions and activities, wherever they are applicable.

ii) Simplify the above STD using "clustering".

iii) During the examination period, the student also spends his time studying, waiting, or sitting exams. When he is in the mood, if he is not sleeping, he studies. When he is ready for his exam, he waits for the exam to start while biting his finger nails. Whether he is studying or waiting, when it is exam-time he sits the exam. While sitting his exam, whenever the student is sleepy, he resists the temptation to sleep.

Using orthogonality of statecharts ("AND-decomposition"), draw a statechart that extends the STD in part (1) to model the student's behaviour during the examination period, noting that if the student is hungry, he can only eat if he is not sitting an exam.

The three parts carry, respectively, 20%, 20%, 60% of the marks.

2a Name a strength and a weakness of the *waterfall model* of software development, and briefly discuss an alternative model that addresses its weakness(es).

b What is “information hiding” and why is it a good principle for software design?

c You have been asked to design the software component for a “stress-o-meter" - a device for measuring stress and analysing various psychological characteristics of people being interviewed for high-pressure jobs. The stress-o-meter analyses a blood sample from a subject, and based on some highly sophisticated algorithms and guidance from an operator, generates a detailed report on the subject, which is automatically sent by post to the company paying for the analysis. The report includes a number form 1 to 10 indicating the stress level of the subject, and a description of the subject's state of mind. Subjects are also asked to provide their name and address to the stress-o-meter.

i) Draw a *Context Diagram* to describe the scope of the stress-o-meter.

ii) The algorithms of the stress-o-meter work in the following way. Based on market research, stored in a database, about people living in different areas, the stress-o-meter generates one of a limited set of pre-defined reports. The blood sample provided by the subject is ignored, and instead a random number from 1 to 10 is generated. The random number and the report are merged into a final report delivered to the customer. The address provided by the subject is stored in a separate database for future use.

Draw an *Overview Data Flow Diagram* (DFD) to elaborate on the functionality of the stress-o-meter. Briefly explain the processes you include, and define the data flows in the diagram using a data dictionary.

d Briefly describe a weakness of DFDs and describe a complementary technique that addresses this weakness.

The four parts carry, respectively, 20%, 10%, 50%, 20% of the marks.

Turn over ...

Section B *(Use a separate answer book for this Section)*

3a i) What is meant by *decorated inclusion* of one schema in another?

ii) Describe the standard usage of the following symbols in specifying operations: ', ?, !, Δ and Ξ.

iii) Suppose the schemas mn, Inc_n and S are defined as follows:

```
___mn _______      __ Inc_n ____      ___S _______
| m, n: ℕ          | n, n': ℕ         | Δmn
|____________      |____________      | Inc_n
|____________      | n' = n+1         |____________
                   |____________      |____________
```

Rewrite S in a form that does not use any inclusions.

b Recall that in traffic lights the three lights (Red, Amber and Green) light in four possible combinations R, RA, G and A, and the sequence of changes is in that order. We define the schema Lamps as follows:

```
____ Lamps________________________
| Red, Amber, Green: boolean
|_________________________________
|_________________________________
```

where the boolean values true and false are to represent on and off.

i) Write schemas *Lights*, to specify Lamps restricted to the four valid combinations, and *Change,* for the operation of Lights changing from one combination to the next. *(Hint:* you may find it convenient to define additional schemas and use schema disjunction and conjunction.)

ii) A particular junction has two directions, NS and WE, and is controlled by two sets of lights, NS.Lights and WE.Lights. Write a schema *Junction* to specify the two sets of lights (treat "NS." and "WE." as decorations) and a constraint that if one is RA, G or A the other must be R.

iii) Write a schema *JunctionChange* to specify the operation on Junction in which one (and only one) of the two sets of lights changes.

iv) What does it mean to say that JunctionChange is a total operation on Junction? *Briefly,* outline the reasons why it is indeed total.

The two parts carry, respectively, 30%, 70% of the marks.

4a For each of the following schemas, describe what its models are. When an interpretation of one symbol in the signature is uniquely determined by the interpretations of the others, mention this fact.

i) Big

$$\begin{array}{|l}
n: \mathbb{N} \\ \hline
n \geq 1000 \\ \hline
\end{array}$$

ii) Ind

$$\begin{array}{|l}
P \subseteq \mathbb{N} \\ \hline
P(0) \\
\forall n{:}\mathbb{N}.\ (P(n) \rightarrow P(n+1)) \\ \hline
\end{array}$$

iii) Pop[X]

$$\begin{array}{|l}
f: X \rightarrow \mathbb{N} \\ \hline
\\ \hline
\end{array}$$

iv) Sample

$$\begin{array}{|l}
Pop[X] \\
S: \mathbb{F}X \\ \hline
\\ \hline
\end{array}$$

v) gSample

$$\begin{array}{|l}
Pop[X] \\
g: \mathbb{F}(X \times \mathbb{N}) \\ \hline
\forall x{:}X.\ \forall n{:}\mathbb{N}.\ ((x,n) \in g \rightarrow n = f(x)) \\ \hline
\end{array}$$

vi) Del

$$\begin{array}{|l}
\Delta Sample \\
\Xi Pop[X] \\
out?: X \\ \hline
\text{pre: } out? \in S \\
S' = S - \{out?\} \\ \hline
\end{array}$$

Explain how there is a 1-1 correspondence between models of Sample and models of gSample.

b i) If Y is a set, what is a *bag* of elements of Y?

ii) By modifying Sample, write down a schema *Bag* whose models are *finite* bags of natural numbers.

iii) Consider the following operation on a bag of natural numbers: take out two elements and put the larger back. (Iterating this gives an algorithm for finding the largest element in the bag – it is the one left at the end.) Write down a schema to specify this operation on Bag.

The two parts carry, respectively, 70%, 30% of the marks.

End of paper

