UNIVERSITY OF EDINBURGH

FACULTY OF SCIENCE AND ENGINEERING

MSc in COMPUTER SCIENCE

MODELLING AND SIMULATION

Tuesday 27 April 1999

09:30 to 11:00

Examiners:

I. Watson (External)

R. Ibbett (Chairman)

INSTRUCTIONS TO CANDIDATES

Answer any TWO questions.

All questions carry equal weight.

1. (a) Explain what a *bottleneck device* is and the role that it plays in performance tuning. *[2 marks]*

   (b) Using operational analysis we can derive the following asymptotic bound on the response time of an interactive system:

$$R \geq \max\{D, ND_{max} - Z\}$$

   For each of the expressions listed below explain what it represents and give an intuitive account of when and how this bounds response time.

   i. D

   ii. $ND_{max} - Z$ *[6 marks]*

   (c) The interactive response time law states that

$$R = \frac{N}{X} - Z$$

   Using this relation, or otherwise, derive the asymptotic bound for throughput, X. Show all your working clearly. *[4 marks]*

   (d) In a database system, the average transaction requires $200ms$ service time at the bottleneck device and $1s$ service time in total. There are 30 users of the system who have an average think time of $2s$. Is a throughput of 6 transactions per second possible in this system? Explain your reasoning. *[3 marks]*

   (e) Draw Petri net fragments which illustrate how a GSPN model can capture each of the features listed below which might be found in a database system. In each case label the places and transitions of the GSPN and give a brief description of how the net structure you have drawn captures the listed feature:

   i. concurrency;

   ii. synchronisation;

   iii. mutual exclusion. *[10 marks]*

2. (a) Consider an $M/M/1$ queue in isolation with arrival rate λ and service rate μ. What is the *stability condition* and what is implied if it is not satisfied? [*2 marks*]

(b) A lecturer holds "office hours" for two hours once a week. During this time, on average, 10 students come to ask questions. On average the lecturer can answer each student's query in 10 minutes.

i. Making Markovian assumptions, explain how this system (lecturer and students) could be represented as an $M/M/1$ queueing model. What other assumptions are necessary?

ii. Draw a state transition diagram for this model.

iii. Calculate the utilisation of the lecturer under steady state assumptions.

iv. In steady state, the average number of customers in an $M/M/1$ queue is $\rho/(1-\rho)$. How many chairs for waiting students should the lecturer place outside her office? Explain your reasoning. [*15 marks*]

(c) Give an example of a feature which cannot be captured by a product form queueing network and explain how you would represent this feature in a DEMOS simulation model. Your explanation should include suitable code fragments. (Minor errors in DEMOS syntax will not be penalised.) [*8 marks*]

3. (a) DEMOS uses a multiplicative linear-congruential, or Lehmer, random number generator.

   i. Explain what is meant by the term *pseudo-random* when applied to a random number generator.

   ii. Give two other desirable features for a random number generator and explain how they can achieved in generators such as the one used in DEMOS. [*6 marks*]

(b) Assume that a communication network has been modelled as a GSPN model and as a DEMOS simulation model. Give an account of how the average residence time of a message within the network would be derived

   i. from the GSPN model;

   ii. from the DEMOS model. [*8 marks*]

(c) *Batch means*, *independent replications* and *regeneration* are three techniques used to increase confidence levels for sample points collected from simulation models. Describe two of these techniques and give an account of their relative strengths and weaknesses. [*6 marks*]

(d) Explain to what extent such variance reduction techniques are necessary

   i. when solving a Markov process;

   ii. when deriving workload parameters from system measurements. [*5 marks*]