UNIVERSITY OF EDINBURGH

FACULTY OF SCIENCE AND ENGINEERING

M.Sc./DIPLOMA IN ARTIFICIAL INTELLIGENCE
M.Sc./DIPLOMA IN COGNITIVE SCIENCE
M.Sc./DIPLOMA IN COMPUTER SCIENCE
M.Sc./DIPLOMA IN INFORMATICS

MODELLING AND SIMULATION

Tuesday 23 April 2002

14:00 to 15:30

Examiners:
N. Chater (External)
N. Jennings (External)
E. Hancock (External)
K. Hawick (External)
R.N. Ibbett (Convener)
J. Oberlander (Co-Convener)

INSTRUCTIONS TO CANDIDATES

Answer any TWO questions.

All questions carry equal weight.

1. (a) A Markov process forms an *analytic* representation of a system whereas a simulation forms an *algorithmic* representation.

   i. Explain what is meant by the terms *analytic* and *algorithmic* in this context.

   ii. Explain how a performance measure such as queue length is derived for each class of models.

   iii. Explain how each of these approaches differ from the calculation for queue length derived using a sampling monitor on an operational system.

[*10 marks*]

(b) In a small software house the manager has determined that the throughput of the programmers (in terms of lines of code) is directly proportional to the throughput in terms of jugs of coffee consumed during the day. There are currently three filter coffee machines, each of which takes $1/\lambda$ minutes to make a jug of coffee. When a jug of coffee has been made it usually lasts $1/\mu$ minutes and when the jug is empty it is immediately returned to the machine to be refilled.

   i. What random variable would you use to characterise the system if you wanted to model it as a Markov process and calculate the throughput of coffee?

   ii. Assume that all times are exponentially distributed. Draw the state transition diagram of the Markov process representing the system in terms of your chosen random variable. Label the states and transitions clearly.

   iii. A bright new graduate has remarked that if an additional jug was purchased the next jug of coffee could be started before the previous ones are finished. Modify your state transition diagram to represent the system consisting of three coffee machines and four jugs. Label the states and transitions clearly.

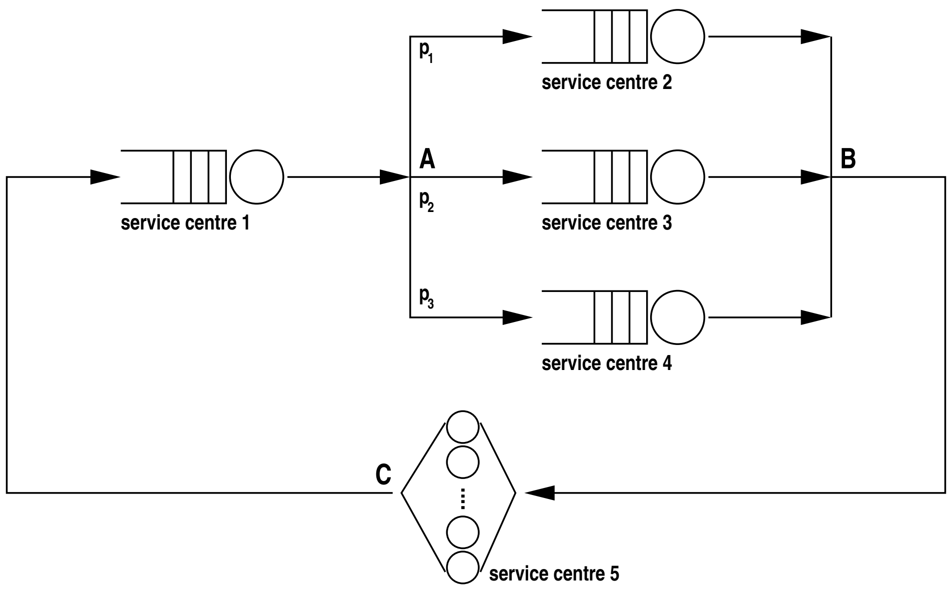
   iv. The cleaner points out that jugs periodically get broken when not on the coffee machine. Modify your state transition diagram again to reflect this. Label the states and transitions clearly. You may assume that the rate at which jugs are broken is r, that broken jugs are not replaced and that the programmers are working and drinking coffee 24 hours a day.

   v. Why is it not possible to calculate a steady state distribution for this last model?

[*15 marks*]

2. (a) What does the term *product form* mean when applied to a queueing network? [*2 marks*]

(b) Consider the queueing network shown below:



i. Explain what is happening to customers at each of the points labelled A, B, and C in the model.

ii. If there are three customers in the system and the service rate at service centre i is μ_i $(i = 1, 2, 3, 4)$, draw a GSPN model of the same system. Label all places and transitions appropriately.

iii. Give an example of an assertion which could be used to verify the GSPN model behaves equivalently to the queueing network.

[*16 marks*]

(c) One of the attractions of queueing networks as a performance modelling paradigm is that for many networks the underlying Markov process does not need to be explicitly constructed in order to derive performance measures. This is not the case for other formalisms. For example, PEPA and GSPN models are used to generate the state transition diagram of the underlying Markov process via their operational semantics or reachability graphs respectively. Nevertheless these high-level modelling formalisms are considered useful for performance modelling. Explain why. To illustrate your answer you should discuss specific features of **either** PEPA **or** GSPN. [*7 marks*]

3. (a) What are the advantages of using a simulation package such as SimJava or DEMOS rather than a general programming language such as C for developing a simulation model intended for performance analysis? [*4 marks*]

   (b) Consider the following excerpt from a SimJava model of a communication channel:

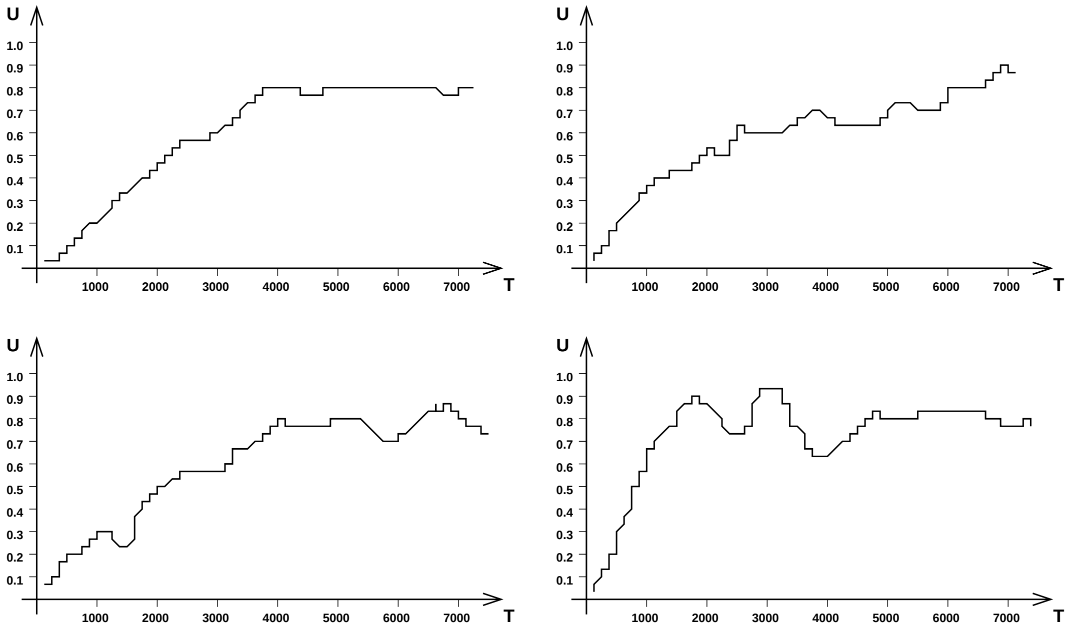
```
int length;
Sim_type_p m_type = new Sim_type_p(2);
Sim_type_p c_type = new Sim_type_c(99);
Sim_event message = new Sim_event();

while (sim_waiting(m_type) > 0) {
   sim_get_next(m_type, message);                (1)
   length = (Integer)message.get_data();         (2)
   sim_hold(length*bwidth);                      (3)
   sim_schedule(delivery_port, 0.0, 2);          (4)
   sim_trace(1,"S delivery_port'');              (5)
}
```

   i. Explain what is happening at each of the lines `(1)`, `(2)`, `(3)`, `(4)` and `(5)`.

   ii. The objective of the model is to determine the utilisation of the channel. Suggest what would need to be added to the code above to allow this measure to be derived. [*14 marks*]

QUESTION CONTINUES ON NEXT PAGE

(c) Consider the four graphs below representing four independent runs of the simulation model of a communication channel considered above.



i. Explain how four such independent realisations of the model might be obtained.

ii. Based on these four graphs what would you set as the warm-up period for subsequent runs of the model? Explain your reasoning. [*7 marks*]