UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 1997

BSc Honours Degree in Mathematics and Computer Science Part III
MSci Honours Degree in Mathematics and Computer Science Part III
MSc Degree in Computing Science
for Internal Students of the Imperial College of Science, Technology and Medicine

This paper is also taken for the relevant examinations for the
Diploma of Membership of Imperial College
Associateship of the Royal College of Science

PAPER M3.35

CONCURRENT AND DISTRIBUTED PROGRAMMING

Wednesday, April 30th 1997, 10.00 - 12.00

Answer THREE questions

For admin. only: paper contains 4 questions

1. Modelling Concurrency:

a. Given two sequential processes P=p1.p2.0 and Q=q.0, briefly explain and indicate how we model concurrent execution P||Q.

b. A special kind of semaphore, DoubleSem, provides two operations, up1 and down2. up1 increments the DoubleSem value by 1 to a maximum value of 2, and down2 suspends the execution of the calling process until the DoubleSem value is 2, and then decrements it by 2. The initial value is 0.

Give the process equation for DoubleSem and draw the corresponding labelled transition diagram.

c. In a factory, a process Monitor reads a value periodically and stores the value in a buffer which can hold up to 4 values. A communications process, Comms, repeatedly sends batches of 4 values to an applications process. The alphabets for the monitoring and communications processes are respectively

αMonitor = {delay, read, store}

and αComms = {batch4, send}

i) Give the process equation for Monitor and Comms.

ii) Modify processes Monitor and Comms (to Monitor* and Comms*) so as to use DoubleSem to provide the necessary synchronization.

iii) Give the specification for the factory system, Factory*.

iv) Your modelling supervisor is unhappy that you had to modify processes Monitor and Comms to provide the necessary synchronisation. She suggests that you rather introduce a separate synchronising process, Synch, which makes use of DoubleSem (in part b) to synchronise between them as required. What is the process description for Synch? Give the new Factory specification.

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

2a. What is a Critical Section?

What mechanism does Java provide to support the programming of Critical Sections?

b. What is a monitor? Explain how it can be used for process synchronisation.

How can Java be used to program monitors?

c. A barrier is an object used to synchronise multiple threads. Each of *n* threads wait at the barrier until all *n* threads are at the barrier, then all *n* threads proceed. Give the Java code for the following class which implements barrier synchronisation, where each thread calls `Barrier.waitAll` in order to synchronise. Note that the Java syntax need not be exact.

```
class Barrier {
...
    Barrier(int n) {...} // n threads
...
}
```

The three parts carry, respectively, 20%, 30%, 50% of the marks.

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3. A student studying anthropology and computer science has embarked on a research project to see if African baboons have an inherent understanding for synchronisation. He locates a deep canyon and fastens a rope across it, so the baboons can cross hand-over-hand. Several baboons can cross at the same time, provided that they are all going in the same direction. If southbound and northbound baboons ever get onto the rope at the same time the baboons will get stuck in the middle. In order to simulate their intended behaviour, the student writes a simulation of Baboon Threads in Java with synchronisation provided at the Rope to preserve the following properties:

Safety: 1. All baboons on the rope are either traveling south, or travelling north.
Liveness: 2. No baboon should be kept waiting if the rope is unoccupied.

a. i) Specify the safety and liveness properties (1 and 2 above) which are to be preserved by your monitor, where n,s indicate the number of baboons travelling north,south respectively; and nw, sw are the number of baboons waiting to travel north, south respectively.

ii) Design a simple Rope monitor that can be used to control the flow of baboons as they **arrive** at the rope, **cross** it, and **depart** on the other side. The monitor should provide four procedures:

Sarrive and Sdepart for south travelling baboons, and

Narrive and Ndepart for north travelling baboons.

and preserve the required invariants. Since the implementation is in Java, your monitor should use only a single condition queue. Note that the Java syntax need not be exact.

iii) Outline the actions and monitor calls that baboon threads must use.

iv) Why is it not possible for the rope to be encapsulated in the monitor?

b. What is the problem with the simple design in part a? What additional liveness property is required?

Briefly describe how you would extend your monitor to satisfy this additional property. If you wish, you may use Sarrive to illustrate your answer.

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

Turn over...

4. Synchronous Message Passing:

a. Outline the behaviour of processes using the following synchronous message passing primitives:

```
channel ! expression
channel ? variable
```

and

```
select
    channel-1 ? variable-1 → statements-1;
or
    channel-2 ? variable-2 → statements-2;
end;
```

b.Environment Control:

Each of the rooms in a building has a control station for monitoring and controlling the environment. Each control station measures and displays the current temperature and humidity. For each room, the desired temperature and humidity is set by a pair of dials. If the current readings are outside the desired setting by more than one percent, then the station can control the heating / ventilation accordingly. A central operator station is able to request the current readings from any control station.

Outline the overall software structure and behavior (using pseudocode) of each of the processes in a room control station assuming a language which provides processes with synchronous message passing and selection primitives as defined in part (a).

The two parts carry, respectively, 20%, 80% of the marks.

End of paper.