UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 1998

MEng Honours Degrees in Computing Part IV
MSci Honours Degree in Mathematics and Computer Science Part IV
MSc Degree in Advanced Computing
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
Associateship of the City and Guilds of London Institute

PAPER 4.81

MODELS OF CONCURRENT COMPUTATION

Friday, May 1st 1998, 10.00 - 12.00

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Answer THREE questions

For admin. only: paper contains 4 questions

1a i) State the three τ-laws of CCS.

ii) Prove the following processes are equal (we omit nils, writing e.g. a.b.**0** as a.b). Mention any laws you use.

$$a.b + a.(b+c+\tau.b)$$

$$a.(c+\tau.b) + a.(b+c+\tau.b)$$

b Let processes P, Q, R, S be defined as follows:

$P = d.e.a.\mathbf{0}$

$Q = b.\bar{d}.\mathbf{0}$

$R = c.\bar{e}.\mathbf{0}$

$S = (P \mid Q \mid R)\backslash\{d,e\}$

Use equational reasoning to obtain a new process T such that T=S and T only uses nil, sum and prefixing, and has no hidden actions.

c Let P be defined by

$P = (a.\bar{d} \mid b.c.d.P) \backslash d$

Obtain a new process Q such that Q=P and Q only uses sum, prefixing and recursion, and has no hidden actions.

2a i) Define *weak bisimulation* and *weak equivalence* ($\approx$) between CCS processes.

ii) Show that for any processes P,Q, and for any formula φ of Hennessy-Milner Logic, if $P \approx Q$ then

$P \models \varphi$ iff $Q \models \varphi$.

(Here $\models$ denotes the satisfaction relation.)

b For each of the following two pairs of processes, state whether they are weakly equivalent (i.e. whether $P_1 \approx P_2$, $Q_1 \approx Q_2$). In each case, if they are weakly equivalent then also prove this. If they are not equivalent, then prove this using Hennessy-Milner Logic.

i) $P_1 = a + \tau(b + a(\tau + c))$

$P_2 = b + a(c + \tau(\tau + c))$

ii) $Q_1 = a(bd+c) + a(b+cd)$

$Q_2 = a(bd+c) + a(b+cd) + a(b+c)$

3a A knife assembly line L repeatedly takes in a blade (event b) and a handle (event h) and fixes them together to produce a knife (event k). L can take in blades and handles in either order. L can store up to 10 blades and up to 10 handles. L can also store up to 10 finished knives.

Define a CSP process which implements L.

b i) What is a process in the Failures Model of CSP?

ii) Define the operators $\|$, $\Box$ and $\sqcap$ in the Failures Model, paying attention to alphabets.

c For each of the following "laws", state whether they are true or false for arbitrary P,Q,R, and give either a proof or a counterexample as appropriate.

i) $P \| (Q \sqcap R) = (P\|Q) \sqcap (P\|R)$

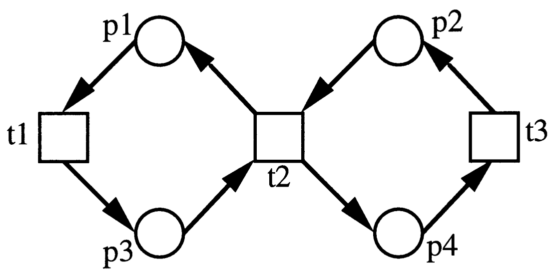
ii) $P \| (Q \Box R) = (P\|Q) \Box (P\|R)$

4a i) Define the following as applied to Petri nets:

(1) sequential
(2) deterministic
(3) safe
(4) live

ii) Give an example of a marked net which satisfies all four properties in (i).

b Here is a net N:



i) Draw the transition system associated with N with initial marking {p1,p2}.

ii) Explain why for any initial marking, N is deterministic.

iii) Explain why for any initial marking, if N is live then N is not sequential.

iv) What are the possible initial markings for which N is safe and live? Justify your answer.

The two parts carry, respectively, 40%, 60% of the marks.

End of paper