UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 2001

BEng Honours Degree in Computing Part III
MSc in Computing Science
MEng Honours Degree in Information Systems Engineering Part IV
MSc 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 Associateship of the City and Guilds of London Institute

PAPER C325=I4.22

PARALLEL PROBLEM SOLVING

Thursday 10 May 2001, 10:00
Duration: 120 minutes

Answer THREE questions

Paper contains 4 questions
Calculators not required

1a In the context of Computational Grids discuss the following:

i) What are the motivations for combining geographically distributed facilities for both the users and suppliers (owners) of such facilities?

ii) What recent developments in computing technology have made such Computational Grids feasible?

iii) Give two similarities and two differences between Computational Grids and closely coupled parallel machines such as the Fujitsu AP3000.

b What are the main functions that have to be performed by the middleware that links geographically distributed computational resources into a Computational Grid? Outline an Object–based architecture that contains the components that are required to provide such a Grid and explain their functionality.

2a In developing applications for both parallel machines and Computational Grids a software technology is required that combines abstraction with the need to be able to specify or achieve efficient implementations. Why is this so? The requirement for abstraction often conflicts with the need for efficient implementations. Discuss how this conflict is reconciled in the following programming systems:

i) The Structured Co-ordination Language, SCL.

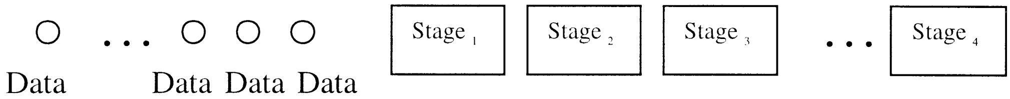
ii) A High-level Component-based application development system.

b An approximation of π can be computed by integrating $4/(1+x^2)$ between 0 and 1

i) Describe a general data parallel technique for computing such an approximation

ii) Outline an SPMD (Single Program Multiple Data) realisation of this program and sketch how this could described using the co-ordination language SCL. Be clear to distinguish between the local and global phases of this calculation.

3 Pipelines are useful and recurring parallel computation structures. A pipeline is formed by chaining together a number of computational stages, $Stage_1$ ... $Stage_n$. Each stage takes in a data element, performs a computation and produces an output, which is then passed as input to the following stage in the pipeline.



For this question assume that:

- The number of input data elements is N.
- The number of computation stages is n.
- The number of available processors is P.
- The execution time for all stages is equal and is given as t_e
- The time required to forward a data element (or result) between two processors is t_c

a)

i) Explain how parallelism can be exploited when many data items are passed through the pipeline.

ii) Derive a performance model (execution time formula) for the operation of the pipeline assuming that that each stage is allocated to a processor (i.e. $n = P$).

iii) What is the speedup for pipeline in this case?

iv) What is the maximum speedup that can be achieved for large values of N when $t_e = t_c$

b) If the number of computation stages, n, is larger than the number of available processors P.

i) Explain a simple method for mapping the computation stages to the available processors.

ii) Derive the execution time and Speedup formulae for this case assuming that the time taken to communicate data between computation stages allocated to the same processor is negligible.

iii) For large values of N and based on your model discuss one case when you would you choose to allocate more than one computation stage to one physical processor.

c) On many computers, the time to transmit a data element of size B bytes can be represented as $t_c = t_0 + t_l B$. where t_0 represents communication start-up time and t_l represents the time to transmit one element between two processors.

i) What would be the effect of a high value of t_0 on the performance of the pipeline computation structure?

ii) Explain a possible optimisation strategy that would overcome the problem and discuss the tradeoffs introduced.

The three parts carry, respectively, 40% (10% for each subpart), 30% (10% for each subpart) and 30% (15% for each subpart) of the marks.

4a i) Describe the difference between the MPI based programming model and the object request broker (ORB) based programming model for programming distributed computing systems.

ii) Describe the JINI model of ubiquitous computing.

b i) Describe the parallelisation methods for the BLAST search.

ii) Outline an efficient parallel implementation model for distance-based clustering

c Given a partial differential equation :

$$\left(\frac{\delta^2}{\delta x^2} + \frac{\delta^2}{\delta y^2} \right) u(x, y) = 0$$

i) Describe the processes of *discretisation* for this partial differential equation.

ii) For the linear equations resulting from this discretisation show how they may be solved and discuss how this solving procedure may be parallelised

The three parts carry, respectively, 40% (20% for each subpart), 30% (15% for each subpart), 30% (15% for each subpart) of the marks.

End of paper