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THE UNIVERSITY
of LIVERPOOL

MAY 2005 EXAMINATIONS

Bachelor of Science : Year 3

Efficient Parallel Algorithms

TIME ALLOWED : Two hours and half

INSTRUCTIONS TO CANDIDATES

Answer **four** questions only.

If you attempt to answer more questions than the required number of questions (in any section), the marks awarded for the excess questions will be discarded (starting with your lowest mark).

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QUESTION 1

a) Describe the notion of scalability and metrics in the context of parallel systems. What is Amdahl's Law?
(5 marks)

b) Describe the Parallel Random Access Machine (PRAM) model of parallel computation.
(5 marks)

c) Is it possible to compute the minimum of n numbers in polylogarithmic time on a mesh-connected computer? Justify your answer.
(5 marks)

d) Describe the Broadcast and Scatter operations in the message passing interface and show the structure of the corresponding operations on a time diagram.
(5 marks)

e) Describe the doubling technique on an example of list ranking.
(5 marks)

QUESTION 2

a) Show the existence of a CRCW PRAM parallel algorithm that can find the maximum of an array $X[1..n]$ in $O(log(log(n)))$ time on n processors.
(10 marks)

b) Describe the Shearsort algorithm on a two-dimensional mesh. Apply it to the following array of elements [3,11,6,16,8,1,5,10,14,7,12,2,4,13,9,15].
(10 marks)

c) How many steps are required to perform broadcasting on a hypercube using store and forward technique? Justify your answer.
(5 marks)

QUESTION 3

a) What is the "Zero-one-principle"? Use it to show that the Shearsort algorithm is correct.
(10 marks)

b) What is a sorting network? Draw a sorting network based on *Bitonic sorter* and *Merging network* for sorting sequences of 16 elements in 10 parallel steps.
(10 marks)

c) What is the balanced binary tree method and why is it convenient to assume the input size is a power of two? **(5 marks)**

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QUESTION 4

a) Explain the difference between fine-grained computation and course-grained computation. Describe the fine-grained and course-grained versions of Warshall's algorithm for the Transitive Closure Problem.
(10 marks)

b) Construct the $O(log(n))$ parallel algorithm computing the depth of each node in a binary tree.
(10 marks)

c) Show the sequence of communications for broadcasting on binary tree topology using cut-through routing technique.
(5 marks)

QUESTION 5

a) Design the $O(log(n))$ parallel time algorithm for the following *compaction problem* using a parallel prefix sum computation:

Input: *An array* $A = A(1), \ldots, A(n)$ *of (any kind) elements and another array* $B = B(1), \ldots, B(n)$ *of bits (each valued zero or one).*

The compaction problem *is to find a one-to-one mapping from the subset of elements of* $A(i)$*, for which* $B(i) = 1$*,* $1 \leq i \leq n$*, to the sequence* $(1, 2, \ldots, s)$*, where* s *is the (a priori unknown) numbers of ones in* B*. The mapping should be order preserving. That is, if* $A(i)$ *is mapped to* k *and* $A(j)$ *is mapped to* $k + 1$ *then* $i < j$*.*
(10 marks)

b) Describe the parallel merge sort algorithm.
(10 marks)

c) What is the complexity class NC?
(5 marks)

QUESTION 6

a) Explain the simulation of CRCW algorithm on the CREW model with a logarithmic slowdown.
(10 marks)

b) Describe the pebbling game technique and apply it to the evaluation of the following arithmetic expression $423 - (((7 + ((2 * 3) + 5)/6) + (4 * 2)) * 7)$.
(10 marks)

c) Explain the difference between MIDM and SIMD in Flynn's Taxonomy.
(5 marks)