The University of Melbourne
Semester 2, 2011 Examination Paper

November, 2011

Department of Computer Science and Software Engineering
COMP90025 Parallel and Multicore Computing
Reading Time: 15 minutes
Writing Time: 3 hours

This paper has 3 pages including this page

Identical Examination Papers: none
Common Content: none

Authorized Materials:
No materials are authorized.

Instructions to invigilators:
No papers may be taken from the exam room.

Instructions to students:
All answers are to be written in the script book(s) provided. Attempt all questions. The examination is worth 60% of the subject assessment.

Paper to be held by Baillieu Library: yes

1. **(4 marks)** Briefly explain what is a *parallel computing model* and why using a parallel computing model is important.

2. **(2 marks)** Describe the PRAM model.

3. **(6 marks)** Suppose we want to simulate a PRIORITY PRAM with n processors, on a COMMON PRAM without any slow down. Show how this can be done with $\mathcal{O}(n^2)$ COMMON PRAM processors.

4. **(4 marks)** Write an *optimal* parallel algorithm to add n numbers on an EREW PRAM. Show why your algorithm is optimal.

5. **(2 marks)** Provide a PRIORITY CRCW PRAM algorithm to determine whether all n elements of an array are distinct or not, using $\mathcal{O}(n)$ processors in $\mathcal{O}(1)$ time.

6. **(8 marks)** Finding the maximum of a list of numbers is a fundamental operation.

   (a) Show how to compute the maximum of n numbers in $O(1)$ time using n^2 processors on a CRCW PRAM.

   (b) Show a recursive algorithm to compute the maximum of n^2 numbers in $O(\log \log n)$ time using n^2 processors on a CRCW PRAM. Your recursive algorithm may make use of your algorithm above.

7. **(2 marks)** Does the OpenMP code below contain a programming error? If yes, then say exactly what it is and write down what the correct code should be.

```
#pragma omp parallel for shared(a)
for(i=0;i<n;i++)
   for(j=0;j<n;j++)
      a[i][j]=0;
```

8. **(2 marks)** In a typical GPU, threads may be scheduled in blocks of a given size, e.g. 16 or 32, where the GPU effectively utilizes a SIMD architecture for thread execution. Assume a thread block of 32 threads is scheduled and a variable `threadID` has been computed. Explain the performance problem encountered for the following code construct:

```
if(threadID<16){
  // do some calculations here
} else {
  // do some different calculations here
}
```

9. **(4 marks)** Explain the technique of *orthogonal recursive bisection*, give a reason for its use and a reason against.

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10. **(6 marks)** Explain the following communication patterns:
    (a) unicast
    (b) broadcast
    (c) gather
    (d) gather/broadcast
    (e) gather/scatter

11. **(4 marks)** Define the following in terms of graph embedding theory as discussed in lectures:
    (a) dilation
    (b) load
    (c) congestion
    (d) expansion

12. **(4 marks)** Consider a 2D mesh of size $n \times n$, where each processor holds an integer. Explain how to sort the integers in $\mathcal{O}(n \log n)$ parallel steps.

13. **(2 marks)** Consider Cannon's algorithm for matrix multiplication on an $n \times n$ torus, where $n = 2^t$. Is it possible to run Cannon's algorithm on a hypercube without slowdown? If yes, what is the minimum size hypercube that would suffice? If no, what is the slowdown?

14. **(4 marks)** Consider a complete binary tree having $2N - 1$ nodes. Show how the tree can be embedded into the hypercube of N nodes with load $\mathcal{O}(\log N)$; give an example for $N = 8$.

15. **(6 marks)** Write a parallel algorithm to compute the prefix sum of n numbers on an n node hypercube in $\mathcal{O}(\log n)$ parallel steps.

END OF EXAMINATION