UNIVERSITI SAINS MALAYSIA

Second Semester Examination
Academic Session 2003/2004

September/October 2003

CCS524 – Parallel Computing Architectures, Algorithms & Compilers

Duration : 3 hours

INSTRUCTION TO CANDIDATE:

- Please ensure that this examination paper contains **FIVE** questions in **FIVE** printed pages before you start the examination.
- Answer **ALL** questions.
- You can choose to answer either in Bahasa Malaysia or English.

ENGLISH VERSION OF THE QUESTION PAPER

1. (a) How are the MIMD machines classified based on the relationship of memory to the processors. Discuss both the types.

(5 marks)

(b) Explain pipelining with the help of a timing diagram and the inferences from it.

(5 marks)

(c) Amdhal law states that the fractional portion, *f*, of a sequential code in a program restricts the speed up to (1/f), no matter how many processors are used. Then how are the large or massively parallel computers in the market justified? Discuss.

(5 marks)

(d) An SIMD computer's vector unit executes at an average rate of 100 MFLOPS and its scalar unit averages 20 MFLOPS. What is the average execution rate of this machine while executing a program that spends 10% of its time executing in scalar mode and the 90% of the time in vector mode?

(5 marks)

2. (a) The program code below is to be executed on a true SIMD architecture. It is known that the values of *b(i)* are equally distributed between zero and one. Comparison of real numbers takes one floating point (fp) operation, and sin() and exp() each take 10 floating point operations.

```
real a(1:N), b(1:N), x(1:N)
If( b(1:N) > 0.75 )
Then x(1:N) = exp( b(1:N) )
Else x(1:N) = sin( b(1:N) ) + exp( a(1:N) )
```

(i) If the SIMD machine has *N* PEs, compute the speedup and efficiency of vector execution over scalar execution of the same computation, counting only floating point operations.

(4 marks)

(ii) If the machine has only 64 PEs, modify the code to represent strip mining the computation when *N* is not necessarily a multiple of 64. Compute speedup and efficiency of the strip mined code.

(6 marks)

(b) What are the important parameters that characterize the multicomputer topology? How do these parameters influence the cost and the performance of the multicomputer?

(4 marks)

(c) Just as a 2-D mesh can be enhanced to a Torus topology, 3-D mesh can also be enhanced. What is the connectivity and diameter of such an enhanced 3-D Mesh with n processors? Explain your answer.

(4 marks)

(d) Given a multicomputer with the hypercube architecture of dimension *'n'*. How many processors does it contain? How many additional processors are needed to make it a hypercube of dimension *'n+1'?*

(2 marks)

3. (a) What is a semaphore? What are the operations that can be performed on them?

(4 marks)

(b) Give all possible final values of the variable `x` in the following parallel program. Briefly explain how you got your answer.

```
INT x = 0;  SEMAPHORE s1 = 1,  s2 = 1

Processes1      Processes2      Processes3
P(s2);          P(s1);          P(s1);
P(s1);          x = x*x;        x = x+3;
x = 2*x;        V(s1);          V(s2);
V(s1);                          V(s1);
end             end             end
```

(4 marks)

(c) A database may be used either for reading or writing. Any number of users may read from it simultaneously, but any user who is writing must have exclusive access to the database. Whenever, a writer is ready to use the database, he should be allowed to do so as soon as possible. Construct a solution to this problem using critical regions and semaphores.

(6 marks)

(d) Three processors in a distributed memory multiprocessor communicate by *send* and *receive* running the code sketched below, where upper case letters represent local activities.

Process P1	**Process P2**	**Process P3**
A	D	G
receive(p3)	send(p1)	receive(p2)
B	E	H
receive(p2)	send(p3)	send(p1)
C	F	I

If both send and receive are blocking, draw a diagram of precedence relation on the local activities. What would happen when this program is executed? Explain your answer.

(6 marks)

4. (a) Discuss 'dependency' and 'alias' with reference to parallelization of sequential programs. Illustrate your discussion with typical examples.

(8 marks)

(b) Discuss the dependencies in the following segment of the code:

```
for  i := 1 step 1   until n
   A(i + 1)  =  B(i - 1)  +  C(i)
   B(i)      =  A(i) * K
   C(i)      =  B(i)  -  1
   End
```

(4 marks)

(c) Explain the concepts of data flow programming.

(3 marks)

(d) Draw a data flow diagram for the following piece of code and explain your answer:

```
f  :=      a;
for   i := 0     step 1     until n-1
      f  :=   1 + 1 / (i + f);
```

where *n* is a constant.

(5 marks)

5. (a) In the program below, written in Hoare's Communicating Sequential Processes language, CSP, there are three processes, *P1*, *P2* and *P3*. Upper case letters represent statements, and lower case letters are variable names.

```
[P1 :: A; P2 ! u; B; P3 ! v; C ||
 P2 :: D; P3 ? w; E; P1 ? x; F ||
 P3 :: G; P2 ! y; H; P1 ? z; K ]
```

(i) The sequential processes of CSP, along with the send (!) and receive (?) commands, impose a partial order on the statements. Diagram the covering relation for the partial order on *A*, *B*, *C*, *D*, *E*, *F*, *G*, *H* and *K*. The covering relation is the order with all relations implied by transitivity removed. No arrows which are implied by transitivity are to be included in the diagram.

(ii) What happens if *P2*!*y* is exchanged with *P1*?*z* in process *P3*?

(10 marks)

(b) What is MPI? Explain as to which classification of Flynn will MPI programs fit?

(4 marks)

(c) Explain with simple examples the MPI functions that enable process to process communication.

(2 marks)

(d) How does OCCAM perform message passing? Explain the appropriate constructs with the help of suitable examples.

(4 marks)