NATIONAL UNIVERSITY OF SINGAPORE

CS3211 - PARALLEL AND CONCURRENT PROGRAMMING
(Semester 2: AY2017/2018)

Time allowed: 2 hours

INSTRUCTIONS TO STUDENTS

This assessment paper contains **FIVE (5)** sections totalling **FORTY (40)** marks, and comprises **ELEVEN (11)** printed pages including this one.

This is an **OPEN BOOK** assessment, and you are to answer **ALL** questions. You may cite any result in the lecture notes or tutorials. Answer **ALL** questions within the space provided in this booklet (write on the backs of pages if you need more room).

Please write your Student Number below. (Do not write your name).

STUDENT NO: ______________________________

This portion is for examiners use only.

Question		Marks	Remark
General topics, short answers	Q1 (6)		
Speedup and analysis	Q2 (6)		
Accuracy and architecture	Q3 (10)		
Programming	Q4 (12)		
Modelling Parallel Systems	Q5 (6)		
Total:	Q1-5 (40)		

Q1 (Short Answer Questions) (6 marks)

In the following short questions, each answer is worth 1 (ONE) mark.

Classify the following four systems (1.1 to 1.4) in the Flynn taxonomy as SISD, SIMD, MISD, or MIMD, and give a one-sentence explanation for your choice.

1.1 A test of five different weather forecasting programs for speed and accuracy, running on five identical servers:

Answer:

1.2 An IBM mainframe built in 1968 running a Fortran program:

Answer:

1.3 A digital camera taking a photo:

Answer:

1.4 The Google search engine processing 40,000 queries per second:

Answer:

Q1 (Short Answer Questions) (Continued)

1.5 In a message-passing system, messages arrive at a processor at an average rate of 5×10^7 bytes per second. The average latency for processing arriving messages is 0.1 seconds. Arriving messages are buffered in a queue. What is the average size of this queue in megabytes? (Show your working)

Answer:

1.6 Image transformation/manipulation is performed repeatedly on a modern CPU, which is storing the image as a 2D array, storing each pixel in one 32 bit word. Each pixel is recomputed in more or less the same time. For a 50×50 image, the computation takes 0.25mS, and as expected, for a 100×100 image, the computation takes 1mS. However when you scale this up to a 2000×2000 image, the computation does not take 400mS. Instead it takes about 5 times longer. Briefly explain the likely reason for this.

Answer:

Q2 (Speedup and analysis) (6 marks)

A multidimensional fast Fourier transform (FFT) with N points runs on a parallel system with P processors in a time given by

$$T(N,P) = 10^{-10} N \log_2 P + 10^{-9} \frac{N \log_2 N}{P} \text{ seconds}$$

Notice that the first term (communication costs) grows with P.

2.1 Find the fixed-size problem speedup for $N = 2^{32}$ and $P = 1024$. (2 marks)

Answer:

2.2 Use a calculator to find a problem size N that is an integer power of 2 and runs in time $T(N, 1024)$, close to what it is for $T(2^{32}, 1)$, the serial time. (2 marks)

Answer:

Q2 (Speedup and analysis) (Continued)

2.3 Use your answer from question 2.2 to find the (approximate) fixed-time problem speedup for $P = 1024$. (2 marks)

Answer:

Q3 (Accuracy and architecture) (10 marks)

In theory, the sum $\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+\ldots$ converges to $\frac{\pi^2}{6}$. To test this, a student writes a C program to compute the sum for the first 10^{10} terms using the float data type. The student then parallelizes it to run on 16 processors. The answers are slightly different, and both only agree with $\frac{\pi^2}{6}$ to four decimals, less than the student expected (since the smallest term in the series is 10^{-20}).

3.1 State a likely reason the parallel result differs from the single-processor result. (2 marks)

Answer:

3.2 Describe an approach that will ensure that both the single-processor and parallel systems return identical results. (2 marks)

Answer:

Q3 (Accuracy and architecture) (Continued)

3.3 State a likely reason why neither result is accurate. (3 marks)

Answer:

3.4 Suggest an approach that would give more accurate answers that is available in C, and explain why it would work. (3 marks)

Answer:

Q4 (Programming) (12 marks)

You are given 33 tasks t_0 to t_{32} that each execute in unit time on a single processor, and eight processors P_0 to P_7 that can execute in parallel with no communication costs or other sequential overhead. You want to allocate a nearly equal subset of tasks to each processor.

4.1 Find a closed-form expression for $j = \text{start}(i)$, the t_j index that processor P_i has as its first element, and $k = \text{length}(i)$, the number of tasks assigned to processor P_i. (2 marks)

Answer:

4.2 What is the maximum possible speedup for the eight-processor system? (2 marks)

Answer:

Q4 (Programming)

(Continued)

4.3 Suppose you have a processor with three multipliers and one adder that can function in parallel and complete an operation in one clock cycle. Find a way to evaluate

$$ax^3 + bx^2 + cx + d$$

in as few clock cycles as possible, describing what happens in parallel in each clock cycle. Assume all values are in registers and take no time to load or store, and that the laws of algebra hold so that you can rearrange the formula without altering the answer. (4 marks)

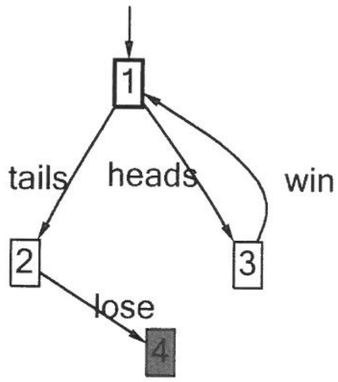
Answer:

4.4 Now suppose you only have one multiplier and one adder, and they cannot operate in parallel. Minimize the total number of multiplies and adds and describe the sequence of operations. (4 marks)

Answer:

Q5 (Modelling Parallel Systems) (6 marks)

The following LTS describes completely the behaviour of Eric as a process `Eric()`, playing "heads-you-win, or tails-you-lose" (if he wins he can keep on winning).



5.1 In CSP, specify `Eric()` and a coin `Coin()` (each using a single process in CSP), and `Game()`, the parallel composition of `Eric()` with `Coin()`. (2 marks)

Answer:

5.2 What would be the outcome of the following assertion on the above model? Explain your answer. (1 mark)

```
#assert Eric() deadlockfree;
```

Answer:

Q5 (Modelling Parallel Systems) (Continued)

5.3 When using a model-checker for CSP, you construct a model $\mathscr{M}$ in CSP, and a property ϕ to be checked (not in CSP). Briefly explain the relationship between $\mathscr{M}$ and ϕ if the property holds in the model. (3 marks)

Answer:

=== END OF PAPER ===