Mohammad Atif Faiz Afzal
50059438

Mid-term Examination
HPC1 Fall 2014
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20/20 **Problem 1:** Compare and contrast shared memory and message passing programming models, giving at least four attributes for each.

List of Attributes: Memory, Ease, Data parallelizing, Data Handling, Speedup & scalability, Implementation, Data communication, Data modification, Examples.

Attribute	Shared Memory Programming	Message Passing Programming
1. Memory →	Shared memory	→ distributed memory.
2. Use →	for Parallel programming	→ for parallel programming.
3. Ease of Use →	Relatively easy when compared to Message passing programming ok	→ Will have to re-engineer the whole code generally ok
4. Data ~~pall~~ → parallelizing	Used generally for data parallelizing ok	→ Used generally for task parallelizing. ok
5. Data ~~communicati~~ on	Workers have access to same data ok	→ Workers can have different data and cannot generally modify each other's data ok
6. Communication →	No, because same data ok	→ communicate by passing the message ok
7. Data Handling →	~~No~~ Less control on data location	→ Full control on ~~and~~ data and its location
8. Speed up & Scalability →	speedup is good compared to Message Passing but not have good scalability (due to limited core counts/node)	→ Scalability is good. Can be used for very large parallel computing. ok
9. Implementation →	Different on different platforms	→ General programming method for all the platforms.
10. Examples →	Open MP, HPF, Pthreads ok HPF → High Performance Fortran Pthreads → Used for Windows	→ ~~Cluster OpenMP~~, MPI, PVM, CAF, UPC ok → PGAS, not really message passing MPI → Message Passing Interface PVM → Parallel vector Machine CAF → Co-Array Fortran, UPC → Unified Parallel C.

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Problem 2: A sequential program depends on data of size N and has performance of $\mathcal{O}(N^2)$. It also takes $\tau_i + N$ time units to execute the serial portion of the code (input, output, setup, etc.). The program's parallelizable portion executes in $100N^2$ time units.

a. Derive an expression for the parallel speedup, $S(N, P)$, in terms of N and the number of processors, P.

b. Similarly express the parallel efficiency, $\mathcal{E}(N, P)$, assuming $\tau_i << N$.

c. Express in terms of P the maximum speedup for this program for $N = 10^5$, again assuming $\tau_i << N$. For what value of P does the parallel efficiency drop to 50%?

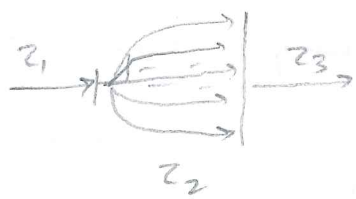
d. Now suppose that $\tau_i = N^2$. For what value of P does the parallel efficiency now drop to 50%?

Serial code (τ_s) $\rightarrow$

here, $\tau_1 + \tau_3 = \tau_i + N$ (given)

$\tau_2 = 100N^2$.

Parallel code (τ_p) $\rightarrow$



here, $\tau_1 + \tau_3 = \tau_i + N$ (given)

$\tau_2 = \dfrac{100N^2}{P}$.

(a) 10/10 $S(N,P) = \dfrac{(\tau_i + \tau_2 + \tau_3) \text{ for } S}{(\tau_i + \tau_2 + \tau_3) \text{ for } P} = \dfrac{\tau_i + N + 100N^2}{\tau_i + N + \dfrac{100N^2}{P}}$

(b) 5/5 $\mathcal{E}(N,P) = \dfrac{S(N,P)}{P} = \dfrac{\tau_i + N + 100N^2}{P(\tau_i + N) + 100N^2}$

if $\tau_i << N$ $\quad \mathcal{E}(N,P) \approx \dfrac{N + 100N^2}{PN + 100N^2} = \dfrac{1 + 100N}{P + 100N}$.

(c) 10/10 for $\tau_i << N$ $\quad S(N,P) \approx \dfrac{1 + 100N}{1 + \dfrac{100N}{P}}$, if $N = 10^5$ $\quad S(N,P) = \dfrac{1 + 100 \times 10^5}{1 + \dfrac{100 \times 10^5}{P}}$.

$\Rightarrow S(N,P) = \dfrac{1 + 10^7}{1 + 10^7/P}$

for this case $\quad \mathcal{E}(N,P) = \dfrac{1 + 10^7}{P + 10^7} = 0.5 \Rightarrow 2 + 2 \times 10^7 = P + 10^7$.

$\Rightarrow P = 2 + 10^7 \approx 10^7$.

(d) 5/5 $\mathcal{E}(N,P) = \dfrac{\tau_i + N + 100N^2}{P(\tau_i + N) + 100N^2} = \dfrac{N^2 + N + 100N^2}{P(N^2 + N) + 100N^2} = \dfrac{N(1 + 101N)}{N(P(1+N) + 100N)} = 0.5$.

$\Rightarrow 2 + 202N = P(1+N) + 100N \xrightarrow{2} \Rightarrow P = \dfrac{(2 + 102N)}{(1+N)}$

for $N = 10^5$, $P = \dfrac{2 + 102 \times 10^5}{1 + 10^5} \approx \dfrac{102 \times 10^5}{10^5} = 102$ $\quad \Rightarrow P \approx 102$