Parallel Program Performance Analysis

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CS 499: Spring 2016 GMU

Logistics

Today

- Final details of HW2 interviews
- HW2 timings
- HW2 Questions
- Parallel Performance Theory

Special Office Hours

- Mon 2/29 3:30-4:30
- Don't wait until the last minute to start HW2

Reading: Grama Ch 5

- Performance Analysis
- Performance Metrics

Schedule

Tue 2/23	PageRank & MPI
Thu 2/25	Performance Analysis
Mon 2/29	HW 2 Due 11:59pm
Tue 3/1	Performance Analysis
Thu 3/3	Guest Lecture, Mini-Exam 2
3/1-3/4	HW 2 Interviews

HW2 Interview Logistics

Will post a means to sign up for GTA interview time shortly.
Synopsis:

- 20-minute interview
- Demonstrate compiling and running a parallel program interactively on medusa
- Demonstrate submitting a parallel job on the batch queue with a certain number of processors
- Outline how the Problem 1: Heat program was parallelized
- Give a brief walk-through of code for Problem 1: Heat
- Explain some MPI calls as they appear in the Heat program
- Outline how the Problem 2: Pagerank program was parallelized
- Explain some MPI calls as they appear in the Pagerank program
- Describe timing results associated with parallel Pagerank runs with different numbers of processors and input sizes
- For groups of 2, interviewer may direct a question at individual group members to assess that both members understand the content

Specific Sample Interview Questions

- "Here you called `MPI_XXX(...)` in your Pagerank code. What is being accomplished there and why is it necessary?"
- "What kind of decomposition did you use for your parallel Heat code? What kind of communication did it require?"
- "Show me the timing results for running your Pagerank code on 4, 8, and 16 processors for the `notredame-8000.txt` graph."
- "Show me how you would run your parallel Heat program with 8 processors and width 64 interactively."
- "Submit a job to the batch queue which runs your parallel Heat program with 8 processors and width 64 and puts the output in `testout.txt`."
- "At the end of your Pagerank program, where are is the entire array of Pageranks stored? Show me where this happens in your code."

Other similar questions possible.

Warm-up / Review

Draw pictures or show examples of the following collective communication operations

Operation	MPI Function
Broadcast	`MPI_Bcast`
Scatter	`MPI_Scatter`
Gather	`MPI_Gather`
All-Gather	`MPI_Allgather`
Reduce	`MPI_Reduce`
All-Reduce	`MPI_Allreduce`

PageRank Planning

- Overview Matrix-vector multiplication and parallel decomposition
- Discuss Vector Versions of Collective Comm Ops
- Spend more time planning/coding for PageRank
- Determine specifically which collective comm operations are needed at which parts of the program

Evaluating Parallel Algorithms

- Model problem: adding N numbers
- T_s: Serial execution time
- T_p: Parallel execution time
- Parallel Metrics
  - Speedup: $S = T_s / T_p$
  - Efficiency: $E = S / P$
  - Cost: $C = T_p * P$
- Amount of work W = time for best serial algorithm to complete, akin to problem size

Amdahl's Law

Speedup is limited by the portion of the program that can be parallelized and the degree to which that portion can be parallelized

- $W = W_{ser} + W_{par}$
- Supposing W_{par} can be reduced to near 0 through parallelism
- Speedup $S = W / W_{ser}$: upper bound on speedup
- More refined versions of Amdahl's law exist (see Wikipedia)

Exercise: Expensive Summing

- Adding N numbers on $P = N$ processors can be done in $2 * \log_2 N$ steps. How?
- Standard serial algorithm takes N steps to sum N numbers.
- For 8, 32, and 1024 processors, calculate
  - Speedup: $S = T_s / T_p$
  - Efficiency: $E = S/P$
  - Cost: $C = T_p * P$
- What happens to efficiency as N increases
- Give an analytic expression for the Efficiency of this algorithm for any N
- Is this algorithm worth the cost in terms of processors?

Exercise: Realistic Summing

- Adding N numbers on $P < N$ processors can be done in $N/P + 2 * \log_2 P$ steps. How?
- Standard serial algorithm takes N steps to sum N numbers.
- Fill in the following table
  - Speedup: $S = T_s/T_p$
  - Efficiency: $E = S/P$
  - Cost: $C = T_p * P$

P	N	Speedup	Efficiency	Cost
4	64			
8	64			
8	192			
16	192			
16	512			

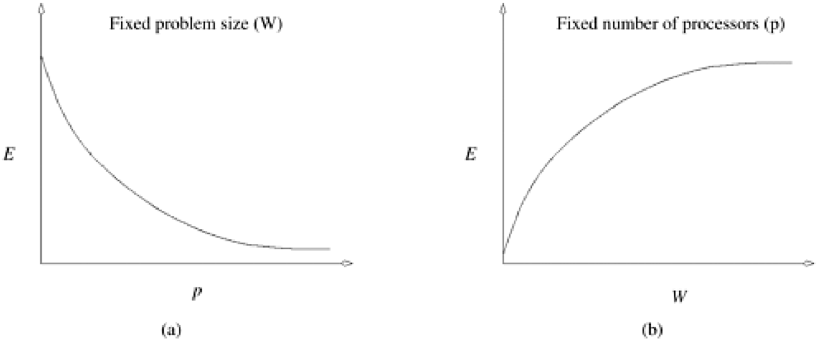
- What happens to efficiency as N increases
- Give an analytic expression for the Efficiency of this algorithm for any N and P
- How fast does N need to increase to maintain efficiency?

Answers from Textbook (Grama Ch 5.4)

Table 5.1. Efficiency as a function of N and P for adding N numbers on P processing elements.

n	p=1	p=4	p=8	p=16	p=32
64	1.0	0.80	0.57	0.33	0.17
192	1.0	0.92	0.80	0.60	0.38
320	1.0	0.95	0.87	0.71	0.50
512	1.0	0.97	0.91	0.80	0.62

Observations about Efficiency



- E Decreases as number of processors increases while work remains fixed
- E Increases as number of processors remains fixed while work increases

Isoefficiency and Parallel Overhead

- Isoefficiency: to go from P processors to $P + K$ processors, amount that work needs to increase to keep efficiency constant; a function of processors and problem size
- Isoefficiency: W = K T_o(W, P)
  - K = E/(1-E): constant based on target efficiency
  - T_o(W, P): parallel overhead based on algorithm/system
- Smaller isoefficiency is better, indicates more processors can be added
- Parallel overheaad: $T_o = PT_p - T_s$
- For adding N numbers on P processors

$$T_o(N, P) = N - P * (\frac{N}{P} + 2\log_2(P))$$

$$T_o(N, P) = N - N + 2P\log_2(P)$$

$$T_o(N, P) = 2P\log_2(P)$$

- For adding N numbers on P procs
  - Increase P to $2 * P$
  - Increase N by $2 * (2 * P) * \log_2(2 * P)$
  - Stay at the same efficiency E