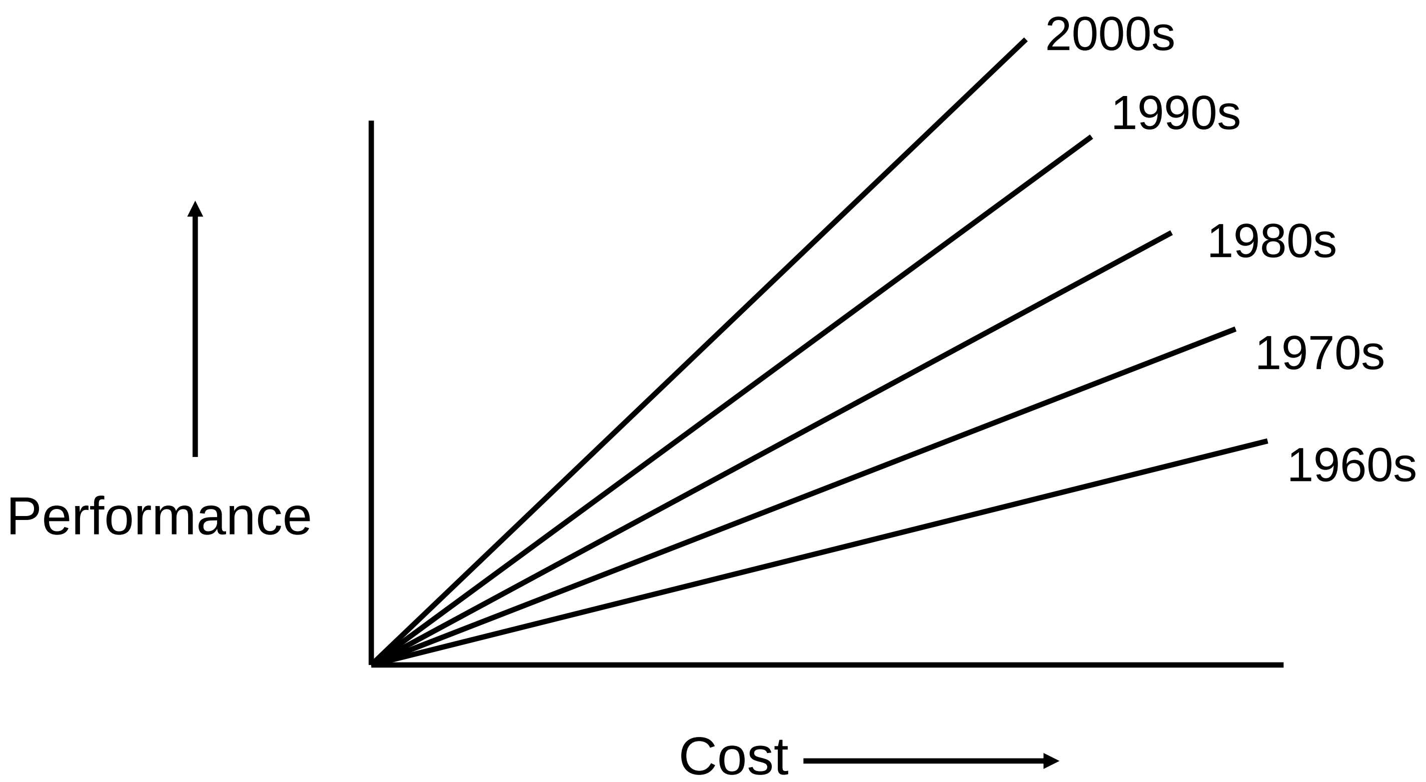
Parallel Computing

Outlines - Introduction

- ***Cost versus Performance***
- ***What is Parallel Computing?***
- ***The Scope of Parallel Computing***
- ***Issues in Parallel Computing***

Cost versus Performance

Cost versus Performance curve and its evolution over the decades.



What is Parallel Computing?

- **Example:** Library and workers to distribute books

1) **Dividing** a task among workers by assigning them a set of books is an instance of task partitioning.

2) **Passing** books to each other is an example of communication between subtasks.

The Scope of Parallel Computing

- Applications such as **weather prediction** and **pollution monitoring**.

- Satellites collect billions of bits per seconds of data relating to **pollution** level and the **thickness of ozone** layer.

Example: Weather Modeling & Forecasting

- **Assumptions:**
  1) Modeling of weather over an area of 3000 x 3000 miles.
  2) Area is being modeled up to a height of 11 miles.
  3) 3000 x 3000 x 11 cubic mile domain is partitioned into segments of size 0.1 x 0.1 x 0.1 cubic miles which is approximately 10^{11} different segments.
  4) Modeling the weather over a <u>two-day period</u> and the parameters need to be computed <u>once every half hour</u>.

$$3000 \times 3000 \times 11 = 99000000 \text{ cubic miles}$$

$$99000000 / (0.1 \times 0.1 \times 0.1) = 99000000000 \approx 10^{11} \text{ Segments}$$

Assumptions: Weather … Continues

5) The computation of parameters inside a segment uses initial values and values from neighboring segments.
   - Assume that this computation takes 100 instructions, then a single updating of parameters in entire domain requires
     - 10^{11} segments x 100 instructions = 10^{13} instructions
   - Since this has to be done approximately 100 times (two days every half hour, that is 96), then total number of operations (instructions) is 10^{15}.

24 Hours x 2 x 2 days = 96 ≈ 10^2 times

10^{13} instructions x 10^2 times= 10^{15} instructions

Example: Weather Modeling … (Continues)

- On serial supercomputer capable of performing one billion instructions per second, this weather modeling would take approximately 280 hours that is: 1000000000 instructions per second = 10^9 instruction per second
  - 10^{15} instructions / 10^9 = $10^{(15-9)}$ = 10^6 seconds
  - 10^6 seconds / 60 second = 16,666.7 minutes
  - 16,666.7 minutes / 60 minute = 280 hours
  - 280 hour / 24 hour = 11.67 days

Example: Weather Modeling … (Continues)

- Taking 280 hours (11.67 days) to predict weather for next 48 hours (2 days) is unreasonable.

- Parallel processing makes it possible to predict weather not only <u>faster</u> but also more <u>accurate.</u>

Example: Weather Modeling … (Continues)

- If we have parallel computer with 1000 workstation class processors, then we can partition 10^{11} segments of domain among these processors.
- Each processor computes parameters for 10^8 segments
  - 10^{11} segments / 10^3 processors = 10^8 segments for each processor
- Assuming that the computing power of this computer is 100 million instructions per second, the problem can be solved in less than 3 hours:
  - 100000000 instructions per second = 10^8 is the power of each processor
  - 10^8 segments x 100 (instructions per segment) = $10^{8} \times 10^2 = 10^{(8+2)} = 10^{10}$ instructions for each processor
  - 10^{10} instructions x 100 (2 days) = $10^{(10+2)} = 10^{12}$ instructions
  - 10^{12} instructions / 10^8 instruction per second = $10^{(12-8)} = 10^4$ seconds
  - 10^4 seconds / 3600 (60 second x 60 minute) sec. ≈ 2.7 hours.
  - So, the whole process takes 2.7 hours because processors are working in parallel

Issues in Parallel Computing

1) Design of Parallel Computers:
   - Large number of processors.
   - Supporting fast communication.
   - Supporting data sharing.
2) Design of Efficient Algorithms:
   - Issues in designing parallel algorithms are very different from those in designing their sequential computers
     - Partition: Decompose task into several parallel tasks
     - Load Balancing: Distribute load on processors as evenly as possible
     - Communication: How processors can communicate efficiently to perform the whole parallel task

Issues in Parallel … (Continues)

3) Methods for Evaluating Parallel Algorithms:
   - Given a parallel computer and a parallel algorithm running on it, we need to evaluate the performance of the resulting system.
   - Performance analysis allows us to answer questions such as:
     a) How fast can a problem be solved using parallel processing?
     b) How efficient are the processors used?

Issues in Parallel … (Continues)

4) Parallel algorithms are implemented on parallel computers using a programming language.
   - Examples: Pthreads, High Performance Fortran (HPF)
5) Parallel Programming Tools:
   - To facilitate programming of parallel computers.
   - Examples: MPI and PVM (using Fortran, C/C++, C#, and Java).

Issues in Parallel … (Continues)

6) Portable Parallel Programs
   - In a sense that the parallel program can be executed under different operating systems and different architectures

7) Automatic Programming of Parallel Computers:
   - Parallel compilers are expected to allow us to program a parallel computer like a serial computer.