Why Parallel & Distributed Computing?

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What is Parallel & Distributed Computing?

- Multiple Processing Units solving a large problem together
  - Parallel Computing: *shared common memory.*
  - Distributed Computing: *Local memory*
  - communication via messages.

- Common Theme: (Parallel = Distributed)
  - *Task division*
  - *Coordination among processors*
I. Who Needs High Performance Computing?

Grand Challenge Problems

- Biology: Genome Sequencing
- Materials Design: Superconductivity
- Computers: Language Processing
- Medicine: Modeling Organs
- Climate Modeling: Global Warming

  • To study how the southern oceans transport heat to the south pole, a 100 MFLOPS computer will require about six months to simulate a years worth.
FIGURE 1-1 Sample output of a southern ocean circulation model developed at Oregon State University by Andrew F. Bennett and Boon Chua. The image shows ocean pressure (elevation) between the latitudes 32° S and 75° S. (Courtesy John A. Gregor.)
Global Weather Modeling

- Study how the southern oceans transport heat to the south pole
- Grid 4000 X 1000 X 12 east-west X north-south X layers of depth
- 50 Million cells each requiring 600 floating point operations
- A single iteration simulates for 10 mins.
  - uses 30 billion instructions (50Million x 600)
- A 100 MFLOPS computer will require about six months to simulate a years worth
  - use computers to simulate within an hour
II. Physical Limits

Conventional Sequential Circuits

- Heat Generation
  - Possible Solution: Superconductivity
  - Partial Solution: Liquid Nitrogen

- Speed of Light: Limit on clock rate
  - Time for a multiplication [Foster 95]
  - Performance of Various Computers [Quinn 94]
  - No Solution (yet!)
Figure 1.2  Trends in computer clock cycle times. Conventional vector supercomputer cycle times (denoted “o”) have decreased only by a factor of 3 in sixteen years, from the CRAY-1 (12.5 nanoseconds) to the C90 (4.0). RISC microprocessors (denoted “+”) are fast approaching the same performance. Both architectures appear to be approaching physical limits.  

[IAN FOSTER]
Figure 1-2

Supercomputers
Mainframes
Minicomputers
Microprocessors

Performance


III. Increasing integration in VLSI chips

1980
- 8086 50K transistors

1992
- 30 times more transistors, 1000 times better performance (clock & better architecture)
- Dec's Alpha has 1.68M transistors

2000
- 1M transistors was enough for full mainframe functionality on a chip
- 50M transistors on a chip

Next factor of ten must go into some form of parallelism (even in PCs)
- Dual and quad-processor micros are here!!
IV. Parallel Architectures are more Cost Effective

- A faster chip is far more costly than a collection of many slower chips connected together
  - 1 pentium chip $200-300
  - 1 80286 chip $10 *(probably free!)*

- Mainframes: Price/Performance differential is even more steep
  - Steady increase in Processor Count [Foster].
  - Multiprocessors and multicomputers are cheaper to build, and are better performers.
Figure 1.3  Number of processors in massively parallel computers ("o") and vector multiprocessors ("+"). In both cases, a steady increase in processor count is apparent. A similar trend is starting to occur in workstations, and personal computers can be expected to follow the same trend.  [Foster]
V. Idle Cycles

- Dozens of workstations and PCS are idling most of the time
- Why not use those idle cycles to perform parallel/distributed computation?
- Public Domain Packages - **MPI/PVM**
  - Parallel Virtual Machine package (PVM) from Oak Ridge National Lab
- *Companies have a vested interest in utilizing those idle resources!*