Global Address Space Applications

Kathy Yelick

NERSC/LBNL and U.C. Berkeley
Algorithm Space

- Reuse
  - Grobner Basis ("Symbolic LU")
  - Asynchronous discrete even simulation
  - Sparse direct solvers
- Regularity
  - Search
  - Sorting
  - Sparse iterative solvers
  - One-sided dense linear algebra
  - Two-sided dense linear algebra
  - FFTs
Scaling Applications

• Machine Parameters
  - Floating point performance
    - Application dependent, not theoretical peak
  - Amount of memory per processor
    - Use 1/10th for algorithm data
  - Communication Overhead
    - Time processor is busy sending a message
    - Cannot be overlapped
  - Communication Latency
    - Time across the network (can be overlapped)
  - Communication Bandwidth
    - Single node and bisection

• Back-of-the envelope calculations!
- 1 GHz * 8 pipes * 8 ALUs/Pipe = 64 GFLOPS/node peak
- 8 Address generators limit performance to 16 Gflops
- 500ns latency, 1 cycle put/get overhead, 100 cycle MP overhead
- Programmability differences too: packing vs. global address space
Effect of Memory Size

- Low overhead is important for
  - Small memory nodes or smaller problem sizes
  - Programmability
Parallel Applications in Titanium

- Genome Application
- Heart simulation
- AMR elliptic and hyperbolic solvers
- Scalable Poisson for infinite domains
- Genome application
- Several smaller benchmarks: EM3D, MatMul, LU, FFT, Join
MOOSE Application

- Problem: Microarray construction
  - Used for genome experiments
  - Possible medical applications long-term
- Microarray Optimal Oligo Selection Engine (MOOSE)
  - A parallel engine for selecting the best oligonucleotide sequences for genetic microarray testing
  - Uses dynamic load balancing within Titanium
Heart Simulation

• Problem: compute blood flow in the heart
  - Model as elastic structure in incompressible fluid.
    - “Immersed Boundary Method” [Peskin and McQueen]
    - Particle/Mesh method stress communication performance
    - 20 years of development in model
  - Many other applications: blood clotting, inner ear, insect flight, embryo growth,…

• Can be used for design of prosthetics
  - Artificial heart valves
  - Cochlear implants
Scalable Poisson Solver

- MLC for Finite-Differences by Balls and Colella
- Poisson equation with infinite boundaries
  - arise in astrophysics, some biological systems, etc.
- Method is scalable
  - Low communication
- Performance on
  - SP2 (shown) and t3e
  - scaled speedups
  - nearly ideal (flat)
- Currently 2D and non-adaptive
- Point charge example shown
  - Rings & star charges
  - Relative error shown

-6.47x10^{-9}
1.31x10^{-9}
• Developed by McCorquodale and Colella
• 2D Example (3D supported)
  - Mach-10 shock on solid surface at oblique angle

• Future: Self-gravitating gas dynamics package
UPC Application Investigations

- Pyramid
  - 3D Mesh generation [Shewchuk]
  - 2D version (triangle) critical in Quake project
  - Written in C, challenge to parallelize
- SuperLU
  - Sparse direct solver [Li,Demmel]
  - Written in C+MPI or threads
  - UPC may enable new algorithmic techniques
- N-Body simulation
  - “Simulating the Universe”
Summary

• UPC Killer App should
  - Leverage programmability: hard in MPI
  - Use fine-grained, irregular, asynchronous communication

• Libraries
  - Must allow for interface to libraries
  - MPI libraries, multithreaded libraries, serial libraries

• Compilation needs
  - High performance on at least one machine
  - Portability across many machines