The Performance and Productivity Benefits of Global Address Space Languages

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- Titanium: GAS dialect of Java
  - Compiled to native executable
  - No JVM or JIT
  - Highly portable & high performance
- High productivity language
  - All the productivity features of Java
  - Automatic memory management
  - Object oriented programming, etc
  - Built-in support for scientific computing
  - N-D arrays, data types, arrays
  - N-D domain calculus operators
  - Flexible & efficient multi-core arrays
  - High-performance templates
  - User-defined immutable native classes
  - Explicitly unrolled N-D loop iteration
  - Operator overloading
  - Efficient cross-language support
  - Allows for elegant and concise programs

Productivity

- Highly portable & high performance
- Titanium reduces code size and development time
- Language features and libraries capture useful semantics

Global Address Space Languages

- Languages: UPC, Titanium, Co-Array Fortran
- Productivity benefits of shared-memory programming
- Competitive performance on distributed memory
- Use Single Program Multiple Data (SPMD) control
- Fixed number of compute threads
- Global synchronization, barriers, collectives
- Explicit fast one-sided communication
- Individual accesses and bulk copies
- Berkeley implementations use GASNet

GASNet Portability

- Native network hardware support
  - Quadrics QNet (Elan/Elan4)
  - Cray X1 - Gray shmem
  - SGI - SCI
  - IBM - InfiniBand
- Portable network support
  - Ethernet - UDP: works with any TCP/IP
  - MPI 1: portable impl. for other HPC systems
  - Berkeley UPC, Titanium & GASNet highly portable
  - Runtimes and generated code all ANSI C
  - Uses tree-based team reduction library
  - Tunable based on network characteristics

PARALLEL BANDWIDTH OF 512KB MESSAGE FOR 15 PROCESSORS

- Performance is comparable to HPL / MPI
- UPC code less than half the size
- Uses some Berkeley UPC extensions
- All competitive with best MPI versions, even on shared networks

LU Decomposition

- High ratio of computation to communication
- Scales very well to large machines: Top500
- Non-trivial dependence patterns
- HPL code uses two-sided MPI messaging
  - and is very difficult to tune
- UPC implementation of LU uses
  - one-sided communication in GAS model
  - lightweight multithreading atop SPMD
  - memory-constrained lookahead to manage amount of concurrency at each processor
  - highly adaptable to problem size
  - natural latency tolerance
- Performance is comparable to HPL / MPI
  - UPC code runs 10x faster on 2 cores

Conjugate Gradient

- Solves Ax = b for x, where A is a sparse 2-D array
- Computation dominated by Sparse Matrix-Vector Multiplications (SPMV)
- Key communication for 2-D (NAS) decomposition
  - team-sum-reduce-to-all (vector&scalar)
- Need explicit synchronization in one-sided model
  - Uses tree-based teams reduction library
  - Tunable based on network characteristics
- Overlap the vector reductions on the rows of the matrix with the computation of the SPMV
- Outperform MPI implementation by up to 10x

Unified Parallel C

- 3-D FFT with 1-D partitioning across processors
- Computation is 1-D FFT using PSTT library
- Communication is a add-up finalize
- Traditionally a bandwidth-limited problem
- Optimization targeted in GAS languages
- Aggressively overlap transpose with 2-D FFT
- Send more, smaller msgs to maximize overlap
- Pre-target slabs or individual 1-D slabs
- Use low-overhead one-sided communication
- Consistently outperform MPI based implementations
- Improvement of up to 2x even at large scale

Titanium

- Aggressively overlap transpose with 2nd FFT
- All the productivity features of Java
- Titanium: GAS dialect of Java
  - Compiled to native executable
  - No JVM or JIT
  - Highly portable & high performance

Performance

- Immersed Boundary Method Simulation
  - Human Heart
  - Cockcha
- Adaptive Mesh Refinement (AMR)
  - AMR Poisson Multigrid Solvers
  - 2D AMR: Gas Dynamics Hyperbolic Solver
  - AMR with Line Relaxation (row aspect ratio)
- Bioinformatics: Microarray oligonucleotide selection
- Finite Element Benchmarks
- Tree-structured n-body kernels
- Dense Linear Algebra: LU, MatMul

Applications

Armed Forces: Energy Conversion

http://titanium.cs.berkeley.edu

http://gasnet.cs.berkeley.edu

http://upc.lbl.gov