CMSC 714
Lecture 17
Runtime Parallelization

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Notes

- Midterm exam in 2 weeks, on Thursday, Nov. 10
  - on readings through previous week
- Group Project interim report due Nov. 7
- Still working on grading OpenMP project – will be done this week

Outline

- Overview
- Compiler-driven: Multiblock Parti
- Library-driven: Global Arrays
- Conclusion

Overview

- Writing good parallel programs for distributed memory systems is hard.
- Idea: abstraction on top of message passing to get results
  - We can do this where communication is regular: block-structured applications
  - Trade off: (somewhat) reduced performance for reduced effort

Multiblock Parti

- Provide High Performance Fortran-like language enhancements to support block-structured applications
- Treat things statically, where we can
  - Like Fortran D, High Performance Fortran, etc.
- Use run-time support where we can't establish compile-time bounds

Runtime Support

- Regular_Section_Move_Sched
  - Schedule a regular section move
  - Accommodates block, cyclic, and block-cyclic distributions when the bounds & strides are known at run-time
- Overlap_Cell_Fill_Sched: schedule moves for overlap / ghost cells

Compiler Support

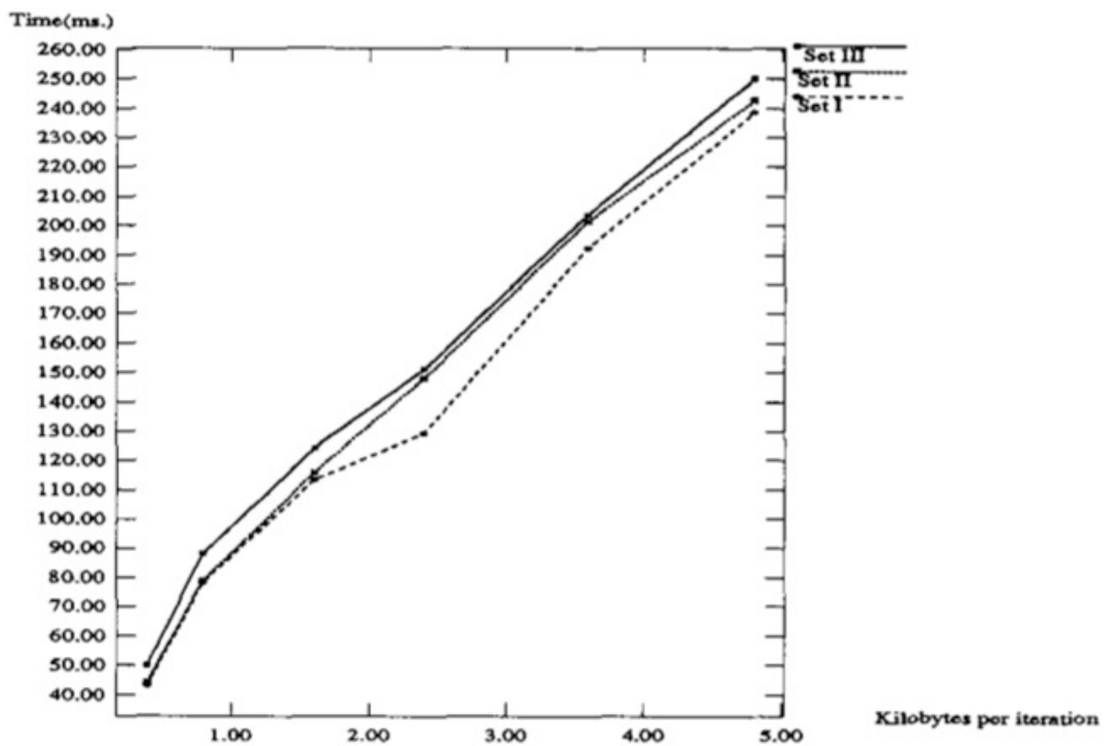
- Additional HPF-like directives
- Static analysis for data distribution
- Insert calls for runtime workload partitioning based on data distribution

Static Analysis

- Done on for_all loop parameters
- Categorize one of three ways
  - No communication necessary
  - Copy overlap (ghost) regions
  - Copy regular sections

Experiment: Overhead

- Extra time from library calls and schedule building isn't too bad



Set I : Communication (Max. message aggregation)
Set II : Communication and copying
Set III : Communication, copying and schedule building

Experiment: Multiblock Code

- Within 20% of hand-parallelized F77
- Difference between compiler-parallelized & hand-parallelized F90 is mostly in computing loop bounds and searching for previously-used schedules

One Block: 49 × 9 × 9 Mesh (50 Iterations)

Number of Processors	Compiler Parallelized	Hand Parallelized F90	Hand Parallelized F77
4	6.99	6.88	6.20
8	4.17	4.06	4.00
16	2.47	2.35	2.28
32	1.55	1.45	1.41

Fig. 5. Performance comparison for small mesh, one block (sec).

Two Blocks: 49 × 17 × 9 Mesh (50 Iterations)

Number of Processors	Compiler Parallelized	Hand Parallelized F90	Hand Parallelized F77
8	7.49	6.69	6.17
16	4.64	4.07	4.03
32	2.88	2.32	2.30

Fig. 6. Performance comparison for larger mesh, two blocks (sec).

Experiment: Multigrid Code

- Within 10% of hand-parallelized code

No. of Proc.	Compiler: First Iteration	Compiler: Per-subsequent Iteration	By Hand: First Iteration	By Hand: Per-subsequent Iteration
8	4.80	2.29	4.60	2.14
16	3.84	1.38	3.41	1.35
32	3.03	.95	2.48	.88

Fig. 7. Semicoarsening multigrid performance (sec).

Experiment: Compiler Optimizations

- Performance stinks if schedules are not saved (Version I)
- Hand-implemented reuse improves over runtime reuse (II vs. III)
- Un-implemented optimization for loop-bounds in subroutines also improves (Version IV)

Two Blocks: 49 × 9 × 9 Mesh (50 iterations)

No. of Proc.	Compiler Version I	Compiler Version II	Compiler Version III	Compiler Version IV	Hand F90
4	13.45	7.63	7.41	7.33	6.79
8	15.51	4.78	4.58	4.54	4.19
16	11.72	2.85	2.71	2.62	2.39
32	8.01	1.85	1.79	1.66	1.47

Version I: Runtime Library does not save schedules
Version II: Runtime Library saves schedules
Version III: Schedule reuse implemented by hand
Version IV: Loop bounds reused within a procedure

Fig. 8. Effects of various optimizations (sec).

Global Arrays

- Library for parallelization abstraction
  - On distributed memory systems (clusters)
  - SPMD model
- Idea is to program as if shared memory, but move data between distributed memory and local memory as needed
  - Only operate on local data within each process
- Compatible with MPI, so can mix GA calls with MPI calls as needed
  - Built on top of ARMCI (Aggregate Remote Memory Copy Interface) library for one-sided communication (put/get) – portable and efficient
  - One-sided can be more efficient than send/receive, as shown for some applications, since less synchronization

Global Arrays

- Programmer can map both ways between global and local views of data objects (arrays)
  - But only compute on local view
- GA is also aware of SMP (multi-core) nodes
  - To support "mirrored view" – caching distributed memory data in shared memory for multiple processes to use
- Also has direct support for ghost cells
  - To avoid distributed to local copies for structured grid applications
  - And for periodic boundary conditions
- Paper also talks about sparse data management
  - But not clear how efficient GA is for computing with sparse matrices/vectors

Global Arrays

- Data parallel interfaces to operate on global arrays
  - To interface with other libraries like BLAS, SCALAPACK to perform data parallel collective operations
- Disk Resident Arrays allow extending global arrays to out-of-core
  - Basically distributed memory stored on (local) disks
  - With operations to move data between disks (instead of distributed memory) and local memory in each process
- Support for mapping global arrays onto subsets of processors
- Many similarities to Multiblock Parti, but also supports copies from global to local view
- Performance results show good scaling on several applications for parallel systems available at that time
  - All the applications employ large, dense, multi-dim data grids
  - And can take advantage of both low-latency and high-bandwidth networks (through ARMCI)

Overall Conclusion

- We can get close to hand-coded performance with these systems
- Are they easier to use?
- Current status:
  - Multiblock Parti no longer supported, other than inside applications and other parallel libraries
  - Global Arrays still supported by PNNL, latest release in Dec. 2021, and now uses ComEx (Communication Runtime for Extreme Scale) for communication, which by default uses MPI (and uses shared memory across processes on the same node)