Compilers and Runtime Systems for Dynamically Adaptive Applications (a.k.a. autotuning?)

Rudi Eigenmann

Purdue University

Why Autotuning ?
my bias

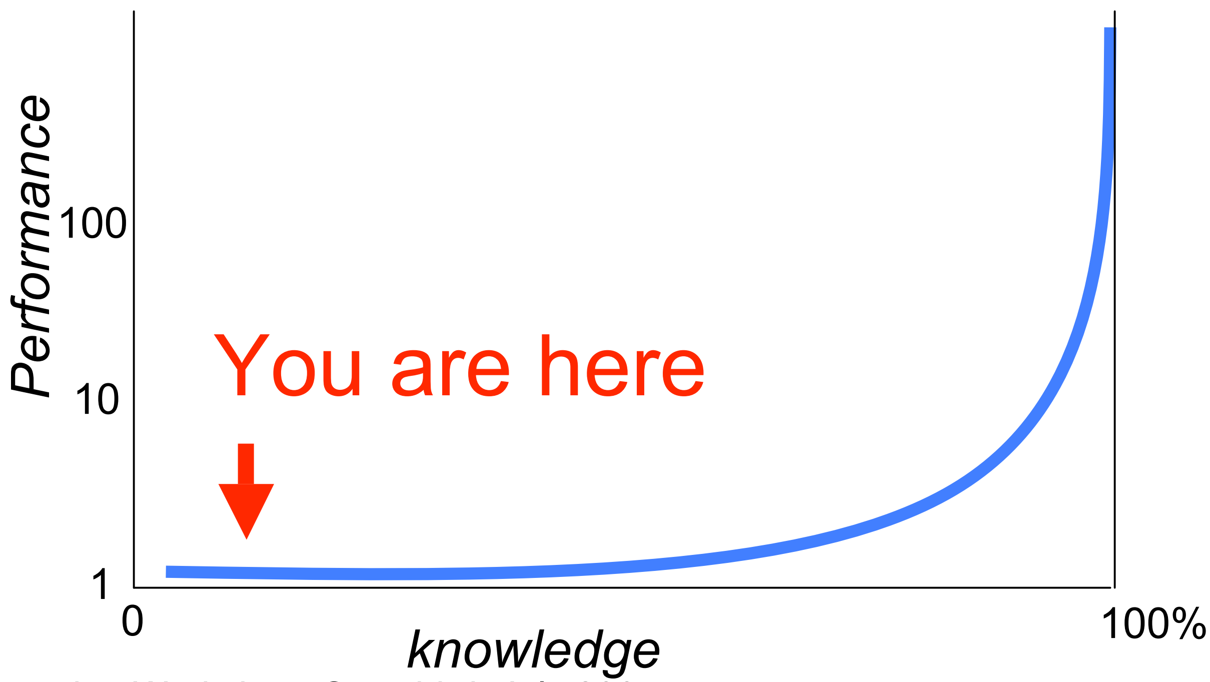
- Runtime decisions for compilers are necessary because compile-time decisions are too conservative
  - Insufficient information about program input, architecture
  - When to apply what transformation in which flavor?
  - Polaris compiler has some 200 switches

    Example of an important switch: parallelism threshold
  - Early runtime decisions:
    - Multi-version loops, runtime data-dependence test, 1980s
- Idea for dynamic adaptation dates back to DARPAs HPCC program, early 1990s
- My goals:
  - Looking for tuning parameters and evidence of performance difference
  - Go beyond the “usual”: unrolling, blocking, reordering
  - Show performance on real programs

Is there Potential

You bet!

- Imagine you (the compiler) had full knowledge of input data and execution platform of the program



"Amdahl's law" of Autotuning

Early Results on Fully-Dynamic Adaptation

- ADAPT system (Michael Voss - 2000)
- Features:
  - Triage
    - tune the most deserving program sections first
  - Used remote compilation
    - Allowed standard compilers and all options to be used
  - AL - adapt language
- Issues:
  - Scalability
  - Shelter and re-tune

Recent Work

Offline Tuning - “Profile-time” tuning

Zhelong Pan

Challenges:

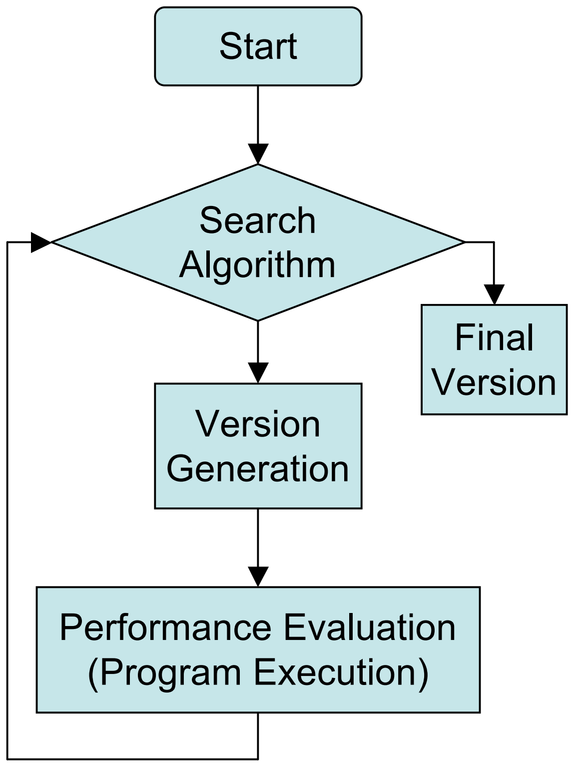
1. Explore the optimization space
   (Empirical optimization algorithm - CGO 2006)
2. Comparing performance
   (Fair Rating methods - SC 2004)
   - Comparing two (differently optimized) subroutine invocations
3. Choosing procedures as tuning candidates
   (Tuning section selection)
   - Program partitioning into tuning sections

Two goals : increase program performance and reduce tuning time

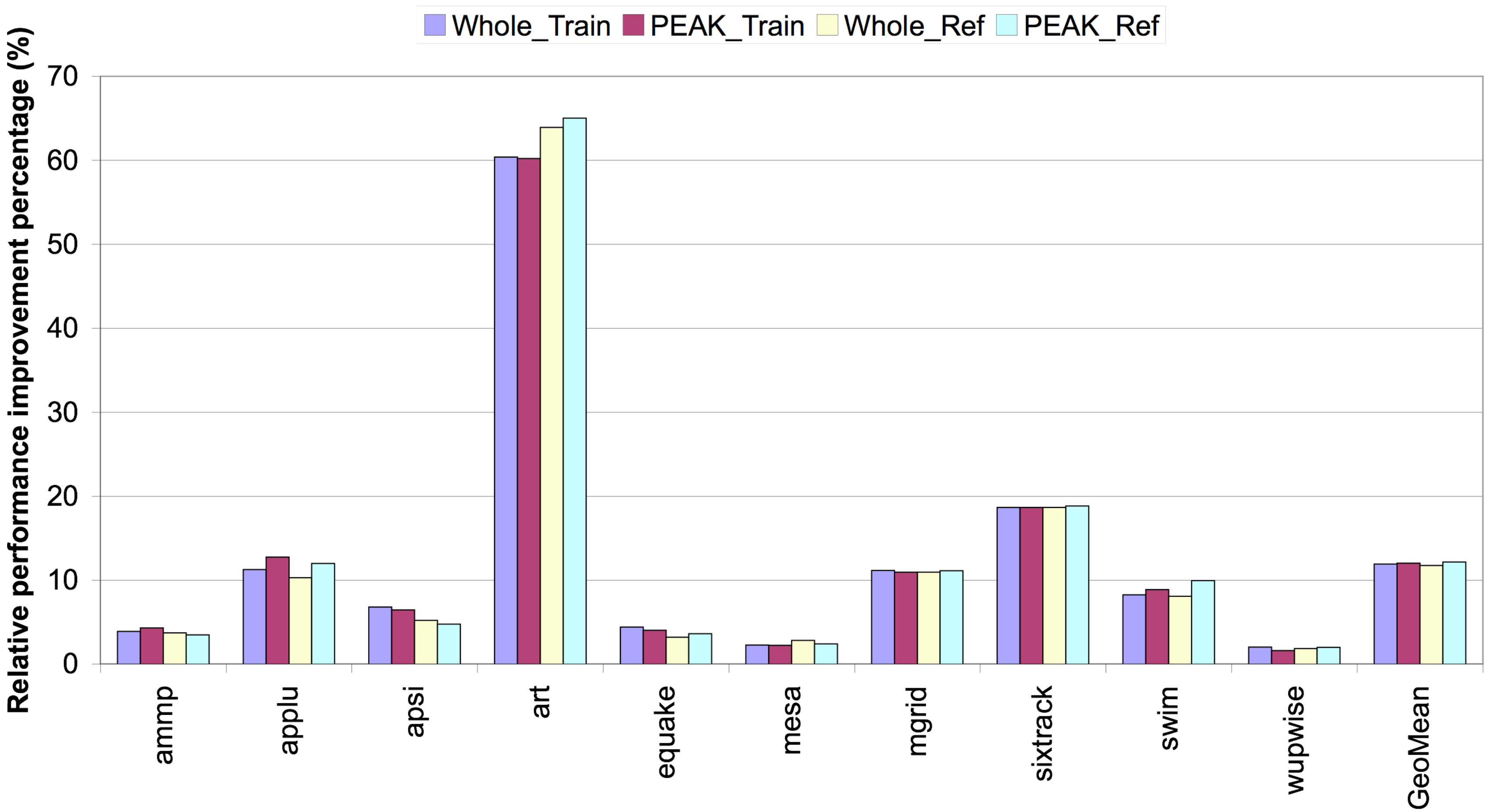
Whole-Program Tuning

Search Algorithms

- BE: batch elimination
  - Eliminates “bad” optimizations in a batch => fast
  - Does not consider interaction => not effective
- IE: iterative elimination
  - Eliminates one “bad” optimization at a time => slow
  - Considers interaction => effective
- **CE: combined elimination (final algorithm)**
  - **Eliminates a few “bad” optimizations at a time**
- Other algorithms
  - optimization space exploration, statistical selection, genetic algorithm, random search



Performance Improvement

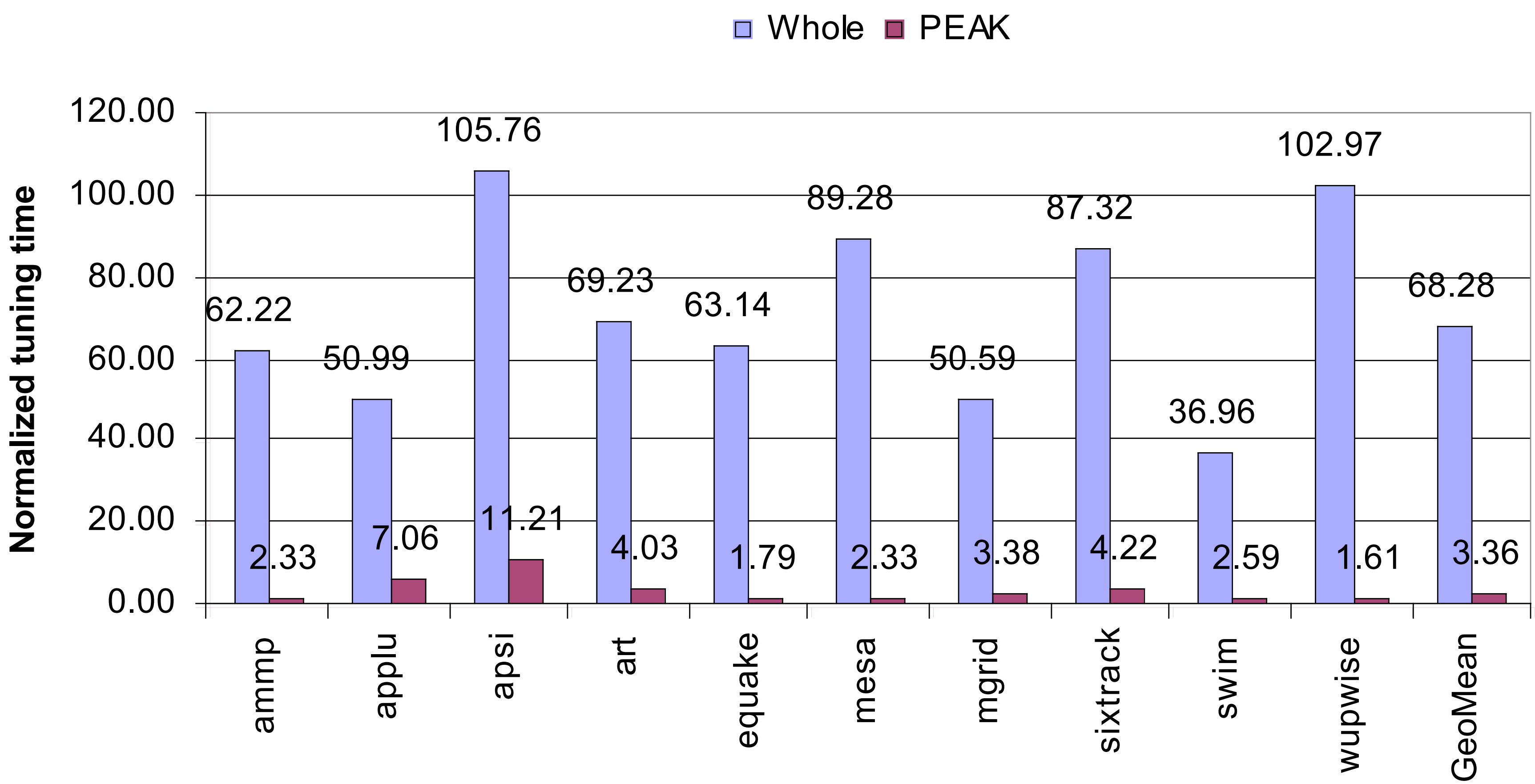


Tuning Goal: determine the best combination of GCC options

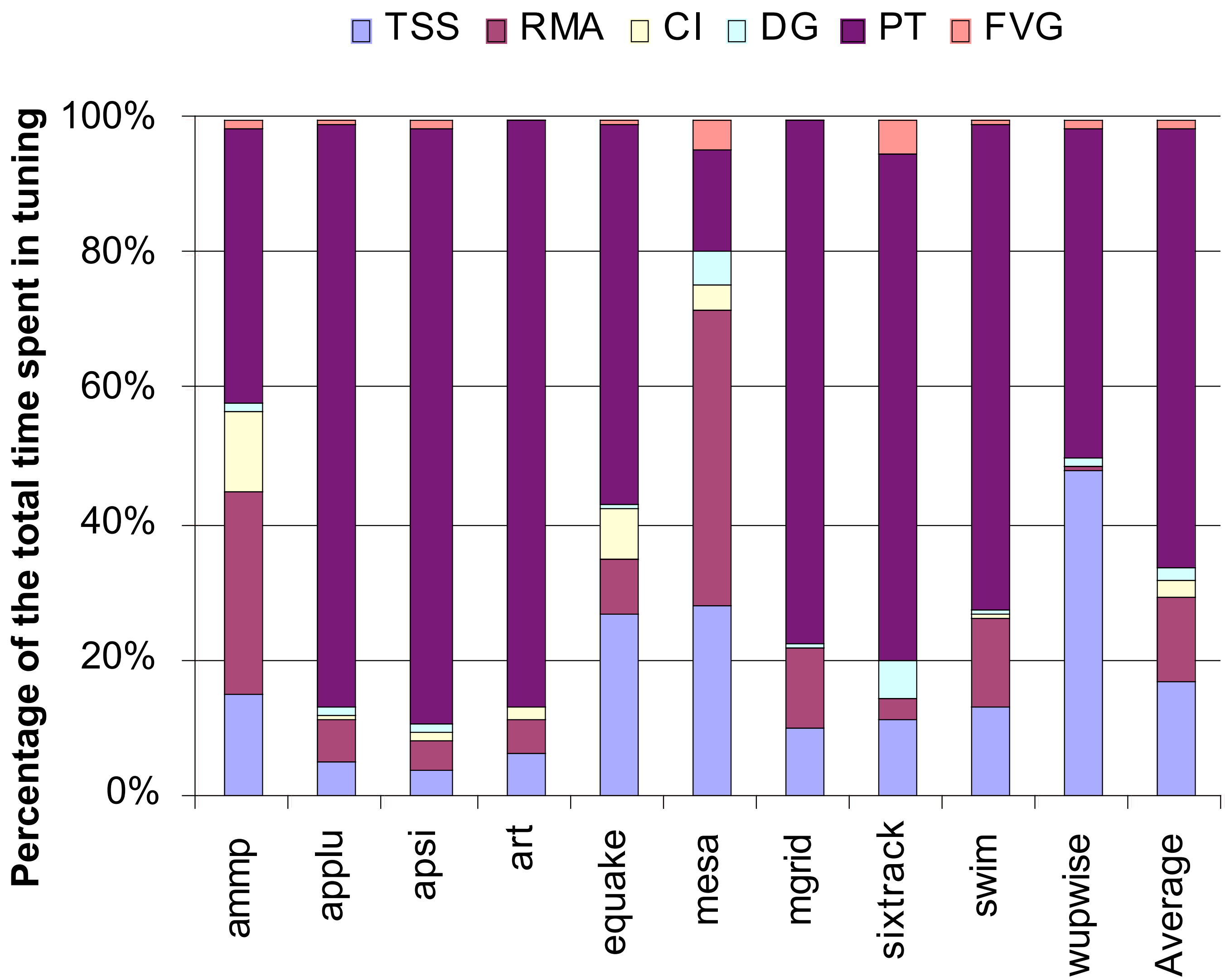
Tuning at the Procedure Level

(1) Tuning Section Selection (TSS)	Pre-Tuning
(2) Rating Method Analysis (RMA)	
(3) Code Instrumentation (CI)	
(4) Driver Generation (DG)	
(5) Performance Tuning (PT)	During Tuning
(6) Final Version Generation (FVG)	Post-Tuning

Reduction of Tuning Time through Procedure-level Tuning



Tuning Time Components

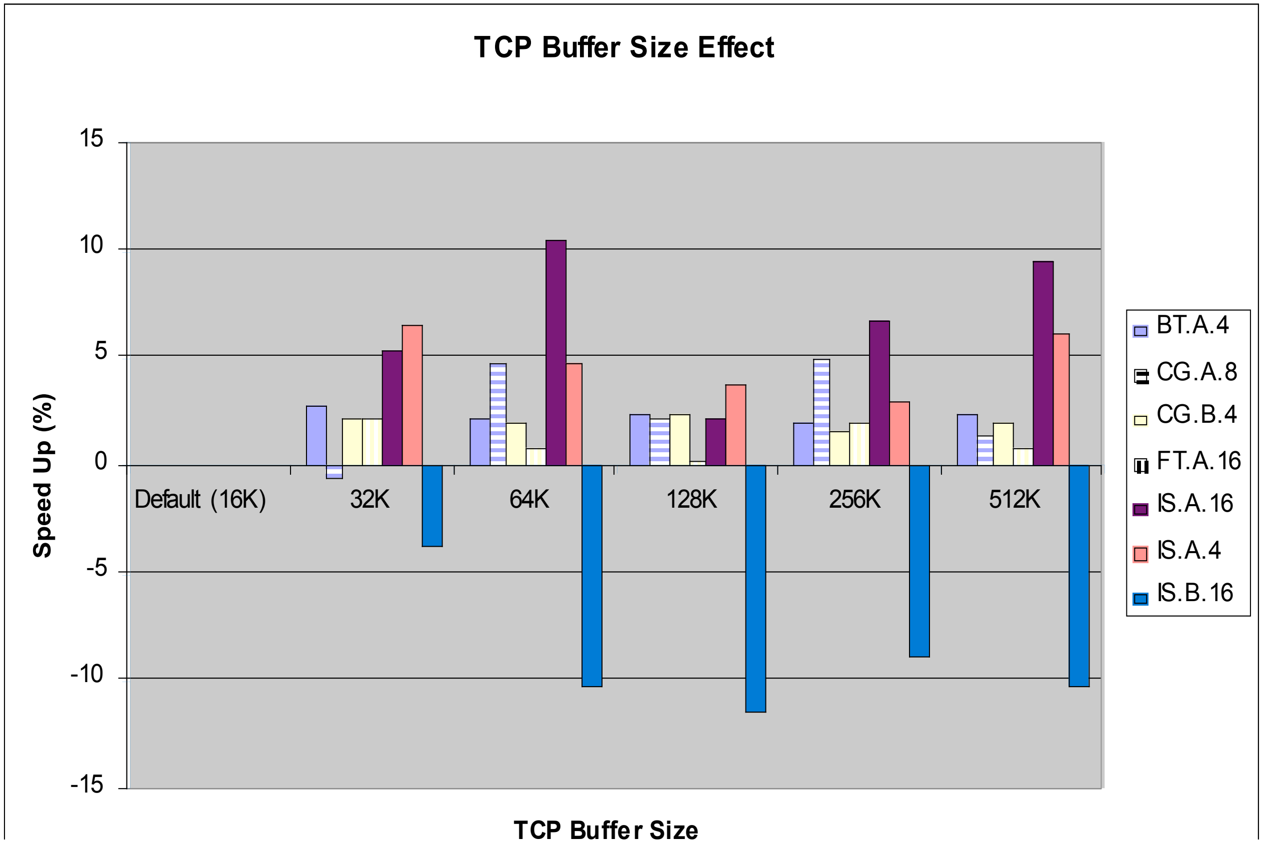


Ongoing Work

Seyong Lee

- Biggest part of the tuning system is runtime
  - Compiler was just the first application
- New applications of the tuning system
  - MPI parameter tuning
  - Tuning library selection - (ScalaPack, ...)
  - OpenMP to MPI translator

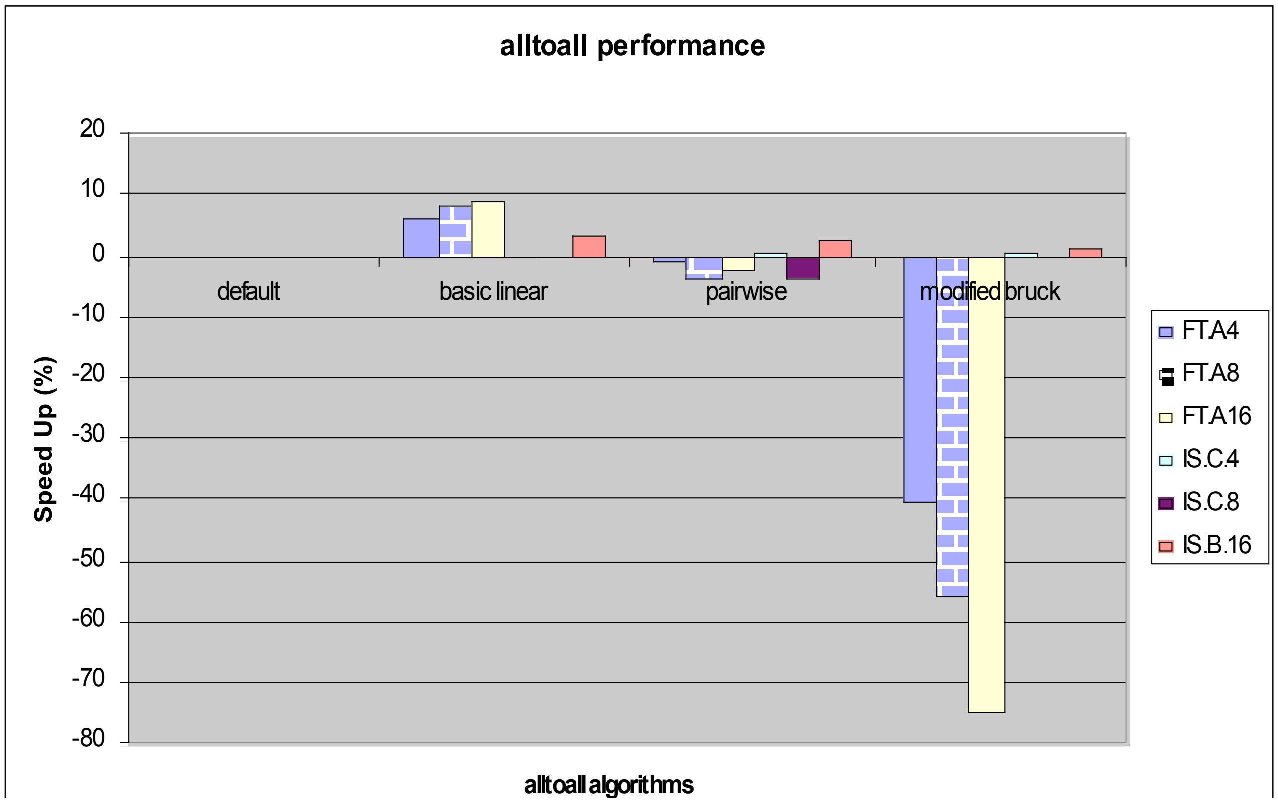
TCP Buffer Size Effect on NPB



Target system: Hamlet (Dell IA-32 P4 nodes) clusters in Purdue RAC

Used MPI: MPICH1

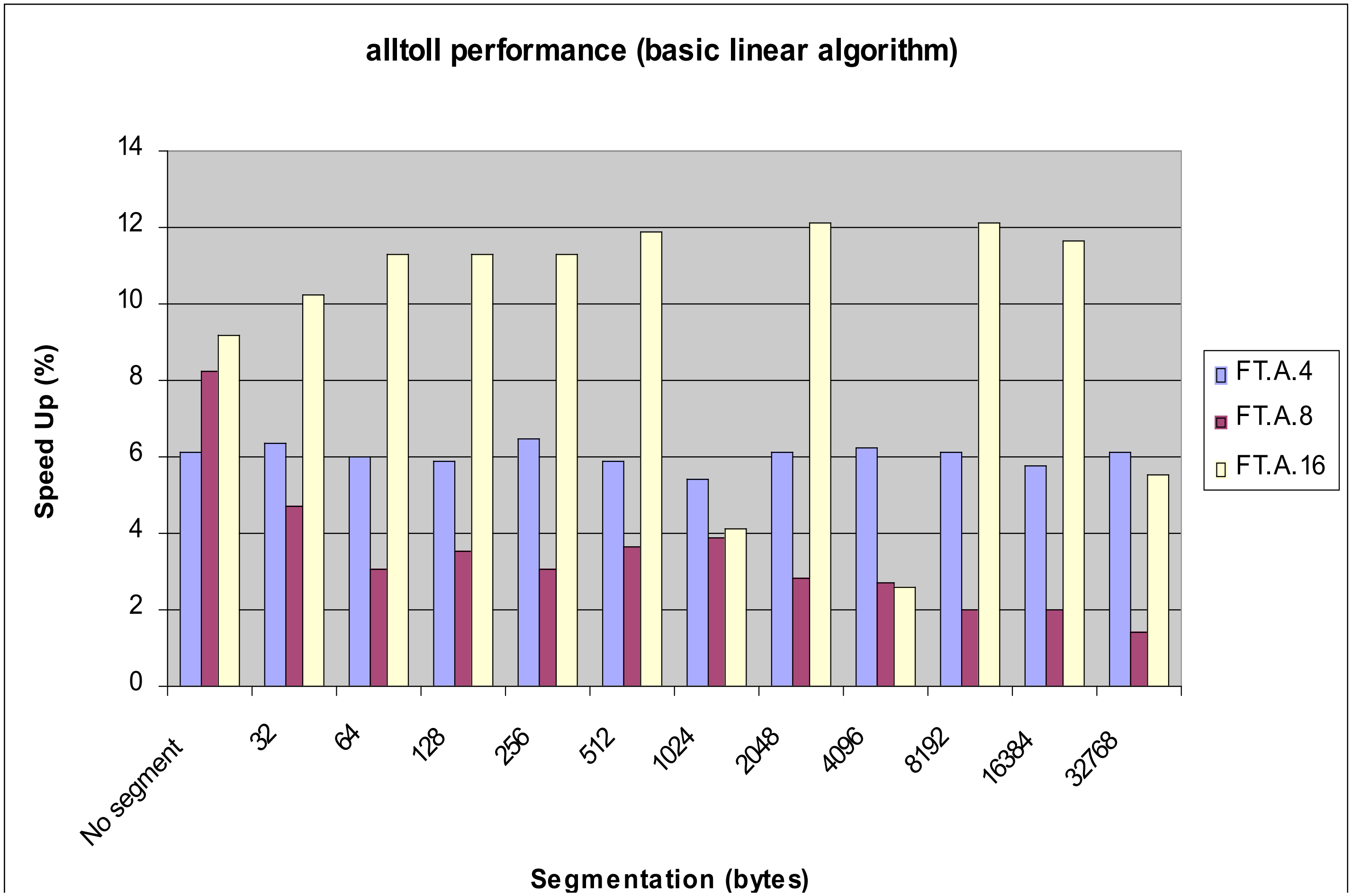
Alltoall collective call performance (without segmentation)



Target system: Hamlet (Dell IA-32 P4 nodes) clusters in Purdue RAC

Used MPI: Open MPI 1.2.2

Segmentation Effect on Basic Linear Alltoall Algorithm



Target system: Hamlet (Dell IA-32 P4 nodes) clusters in Purdue RAC

Used MPI: Open MPI 1.2.2

OpenMP to MPI Reduction Translation

OpenMP code

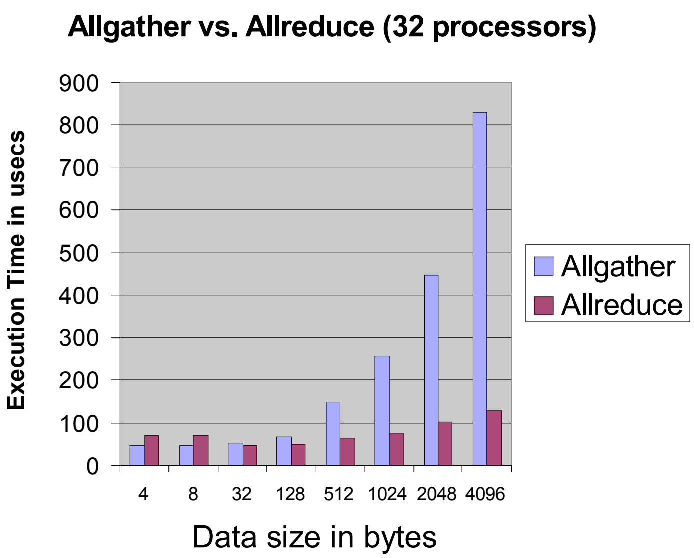
```
!$OMP PARALLEL DO PRIVATE(J, K)
        DO J=1, nrows
           w(J) = 0.0
           DO K=row(J), row(J+1)
              w(J) = w(J) + a(K)*p(colidx(K))
           ENDDO
        ENDDO
```

Translation w/o reduction

```
Call MPI_AllGather(…)
DO J=s_index, e_index
   w(J) = 0.0
   DO K=row(J), row(J+1)
     w(J) = w(J) + a(K)*p(colidx(K))
   ENDDO
ENDDO
```

Reduction Translation

```
DO J=1, nrows
   w(J) = 0.0
   DO K=row(J), row(J+1)
     IF (colidx(K) is local)
        w(J) = w(J) + a(K)*p(colidx(K))
     ENDIF
   ENDDO
ENDDO
Call MPI_AllReduce(…)
```



Variants of Communication Libraries for Sparse Matrix Vector Multiplication

- Simple Translation

  - without SMVM recognition

```
Call MPI_AllGatherv(…)
DO J=1, NA
   DO K=row(J), row(J+1)
      …
   ENDDO
ENDDO
```

- OPT1 (w/ SMVM recognition)

```
DO J=1, NA
   DO K=row(J), row(J+1)
      …
   ENDDO
ENDDO
Call MPI_AllReduce(…)
```

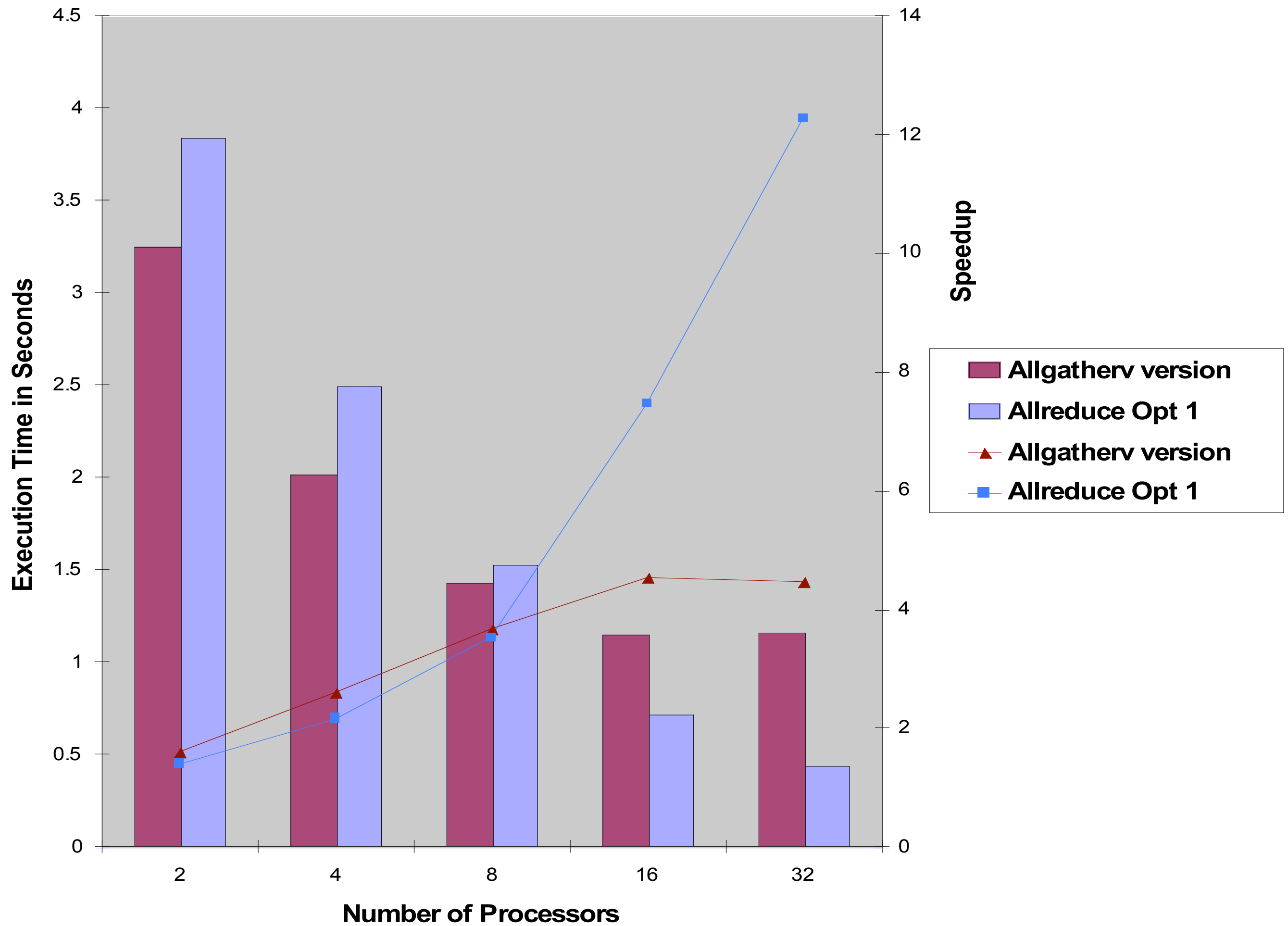
- OPT2 (w/ SMVM recognition)

```
DO J=1, NA
   DO K=row(J),
row(J+1)
      …
   ENDDO
ENDDO
DO PID=1, NPROCS
   Call MPI_Reduce(…)
ENDDO
```

- OPT3 (w/ SMVM recognition)

```
DO J=1, NA
   DO K=row(J),
row(J+1)
      …
   ENDDO
ENDDO
DO I = 1, LOG2NPROCS
   Call MPI_IRecv(…)
   Call MPI_ISend(…)
ENDDO
```

SPMUL



Execution Time in Seconds
Speedup
Number of Processors
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
2
4
6
8
10
12
14
2
4
8
16
32
Allgatherv version
Allreduce Opt 1
Allgatherv version
Allreduce Opt 1

A Related Project

- Autotuning in iShare - an Internet Sharing System

Publish - Discover - Adapt

1. *Published autotuner (available)*
2. *Tuning upon matching disvovered application and platform (current work)*

Conclusions and Discussion

Dynamic Adaptation is one of the most exciting research topics, but there are still

issues to Sink your Teeth in

- Runtime overhead: when to shelter/re-tune
- Fine-grain tuning
- Model-guided pruning of search space
- Architecture of an autotuner
  - If we could agree, we could plug-in our modules
- AutoAuto - autotuning autoparallelizer
- How to get order(s) of magnitude improvement
  - Wanted: tuning parameters and their performance effects