NPB-MPJ: NAS Parallel Benchmarks Implementation for Message-Passing in Java

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Java is a Competitive Alternative for HPC in the Multi-core Era

- Java is a (the most) popular language.
- Interesting features:
  - Built-in networking
  - Built-in multi-threading
  - Portable, platform independent
  - Object Oriented
  - Main training language
- Many productive parallel/distributed programming libs:
  - Java RMI
  - Java Threads (high level facilities: Futures, ThreadPools...)
  - ProActive
  - Message-Passing in Java (MPJ) libraries
  - Java OpenMP implementations
  - ...

Java Adoption in HPC:

- HPC developers and users want to use Java in their projects, but they are highly concerned about performance.
- Java is no longer slow (Just-In-Time compilation)!
- But there is no suitable benchmark to assess this in HPC!

Message-Passing in Java

- Message-passing is the main HPC programming model
- MPJ (MPI-like bindings for Java) Implementations
  - mpiJava. MPJ Java wrapper library over native MPI implementations (e.g. OpenMPI, MPICH).
  - MPJ Express. MPJ pure (100%) Java library.
  - MPJ/Ibis. MPJ pure Java library.
  - Parallel Java, Jcluster, P2P-MPI... (15 more –older–)
- Our goal: Implement a suitable benchmark to evaluate Java performance for HPC, particularly for MPJ

Java Benchmarks in HPC. The Java Grande Forum Benchmark Suite gathers most of the benchmarks in Java for HPC

- Four groups:
  - Sequential Benchmarks
  - Language comparison benchmarks (sequential C vs Java)
  - Multi-threaded codes
  - MPJ benchmarks
- Three levels:
  - Micro-benchmarks (e.g. ping-pong, bcast, threads sync.)
  - Kernel benchmarks (e.g. LU fact., Sparse matrix mult.)
  - Applications (e.g. N-body simul., Montecarlo, Ray tracer)

Java NPB Implementations.

- NPB-JAV: Java Multi-threaded (CG, FT, IS, MG, SP)
- NPB-PA: Java ProActive (CG, EP, FT, IS, MG)
- MPJ NPB
  - JavaMPI (2001): EP and IS (1050 SLOC)
  - MPJava (2003): CG (1000 SLOC)
  - P2P-MPI (2006): EP and IS (1050 SLOC)

NPB-MPJ allows:

- the comparison among MPJ implementations (>15)
- the evaluation of MPJ against other Java parallel libraries (ProActive)
- the assessment of MPJ versus MPI
- example of best Java programming practices for performance in HPC

NPB-MPJ Design

- NPB-MPI based (Fortran except IS and DT –C–)
- SPMD
- “Plain Objects” Design
  - Instead of complex number Object, 2 double array
  - One class per benchmark
  - C-like implementation
  - Less “object orientation” in heavy loaded methods

NPB-MPJ Implementation: 11.000 SLOC (Source LOC)

- CG (Conjugate Gradient) 1000 SLOC
- EP (Embarrassingly Parallel) 350 SLOC
- FT (FFT) 1700 SLOC
- IS (Integer Sort) 700 SLOC
- MG (MultiGrid kernel) 2000 SLOC
- DT (Data Traffic) 1000 SLOC
- SP (Scalar Pentadiagonal) 4300 SLOC

NPB-MPJ Implementation Issues:

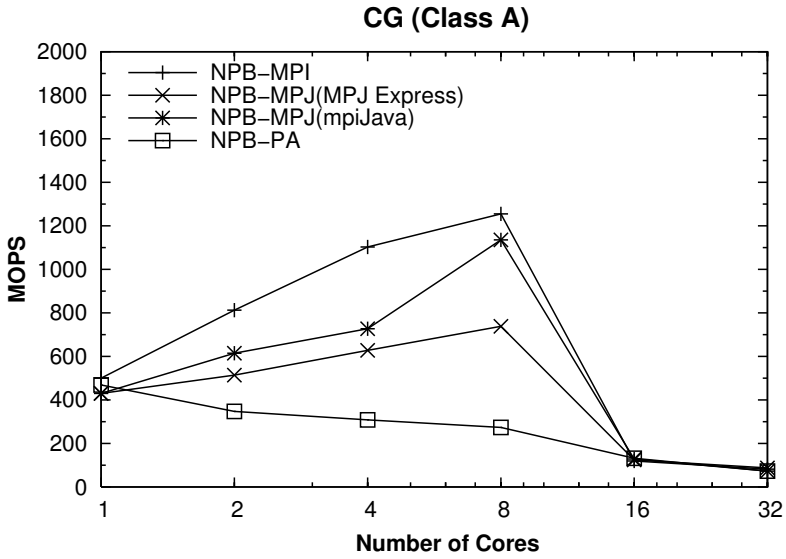
- No multi-dimensional arrays support in Java.
  - NPB uses 5 dims arrays → Java defined arr[v][w][x][y][z]
  - MPI C can send contiguous elements (2 rows from a 2 dimensinal array)
- "Array flattening" Technique. Mapping an n-dimensional array in a 1-dimensional array.
  - Positioning method (position3D(x,y,z,d1,d2,d3))
  - Example: complex number array compArr[2][N]
    - Defined compArr[2*N]
    - Access compArr[REAL][x] → compArr[position2D(REAL,x,2,N)]
    - Hides array layout

NPB-MPJ Optimization

- JVM JIT compilation of heavy methods with runtime information
- JVM JIT paradoxes:
  - An “optimized” code is slower than an “unoptimized” code
  - Method inlining reduces performance
- Structured programming is the best option
  - Small frequent methods are better. E.g. compArr[position2D(REAL,x,2,N)] is better than compArr[REAL+2*x]
  - NPB-MPJ code refactored, obtaining significant improvements (up to 2800% for SP)

Testbeds:

- Gigabit Ethernet cluster (8 dual dual-core nodes)
  - 2 x Intel Xeon 5060 dual-core at 3.2 GHz
  - 4 GB RAM
  - Linux, gcc 4.1.2
  - Sun JDK 1.6.0_02, MPICH2 1.0.7 (ssm)
- InfiniBand cluster (4 HP Integrity rx7640 nodes)
  - 8 x Montvale Itanium2 dual-core (IA64) at 1.6 GHz
  - 128 GB RAM
  - Linux, C compiler Intel icc 9
  - BEA JRockit 5.0 (R27.6), HP MPI 2.2.5.1
- MPJ Express 0.27, mpiJava 1.2.5x, ProActive 3.2


CG (Class A)
NPB–MPI
NPB–MPJ(MPJ Express)
NPB–MPJ(mpiJava)
NPB–PA
MOPS
Number of Cores
0
200
400
600
800
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1200
1400
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2000
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16
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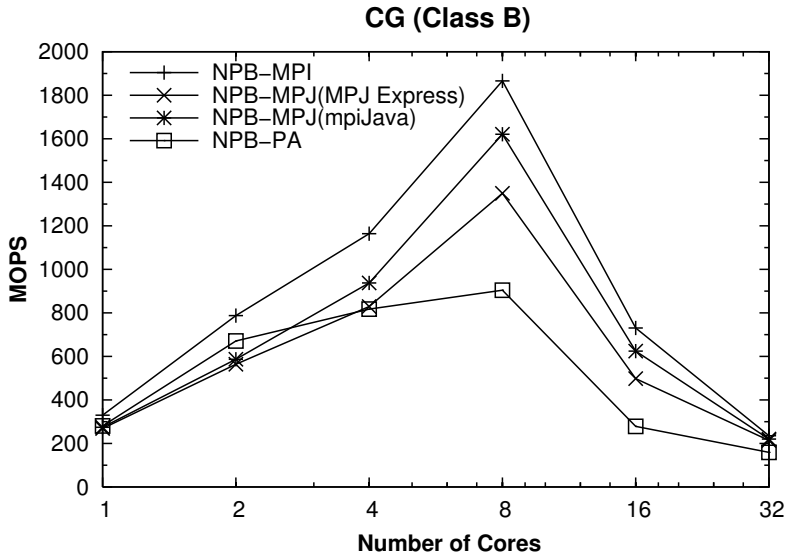
CG (Class B)
NPB–MPI
NPB–MPJ(MPJ Express)
NPB–MPJ(mpiJava)
NPB–PA
MOPS
Number of Cores
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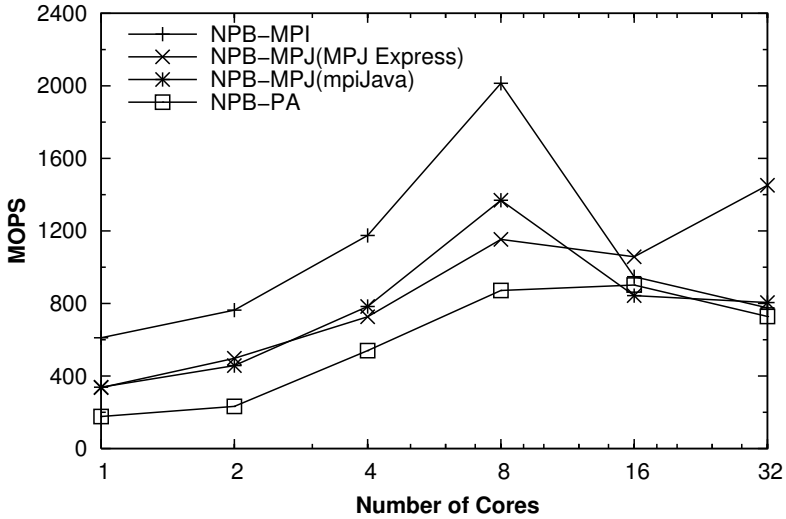
FT (Class A)
NPB–MPI
NPB–MPJ(MPJ Express)
NPB–MPJ(mpiJava)
NPB–PA
MOPS
Number of Cores
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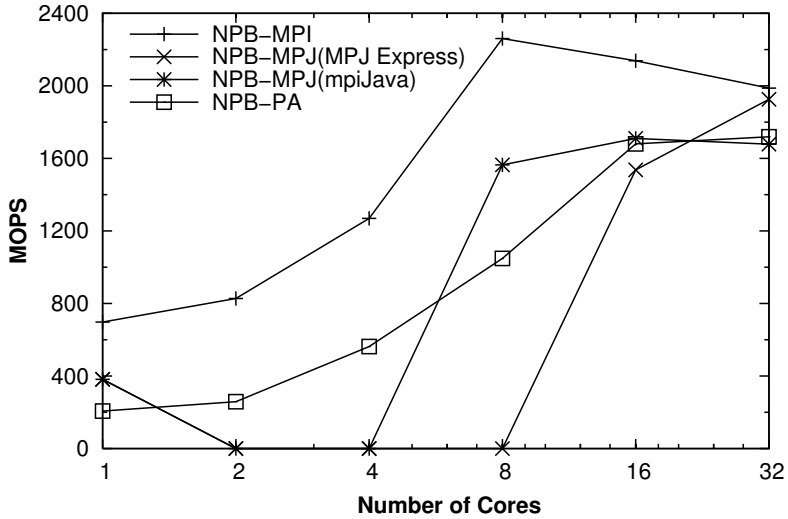
FT (Class B)
NPB–MPI
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NPB–MPJ(mpiJava)
NPB–PA
MOPS
Number of Cores
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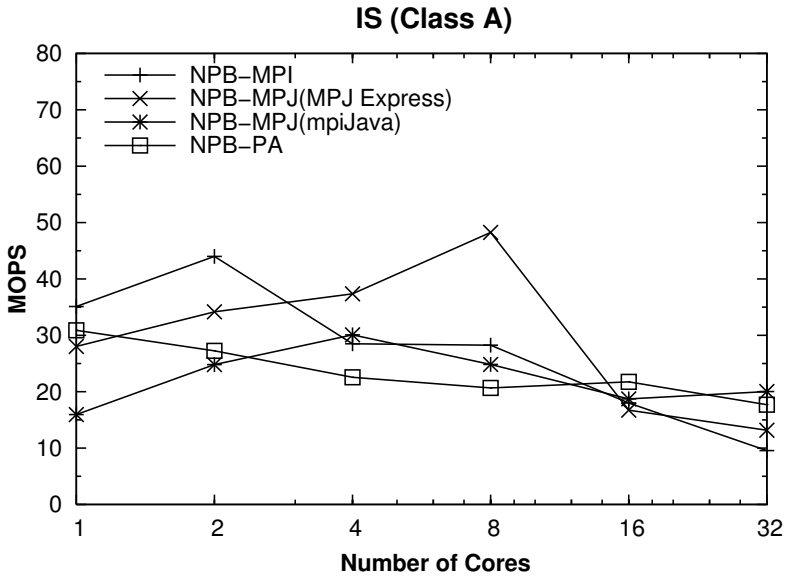
IS (Class A)
NPB–MPI
NPB–MPJ(MPJ Express)
NPB–MPJ(mpiJava)
NPB–PA
MOPS
Number of Cores
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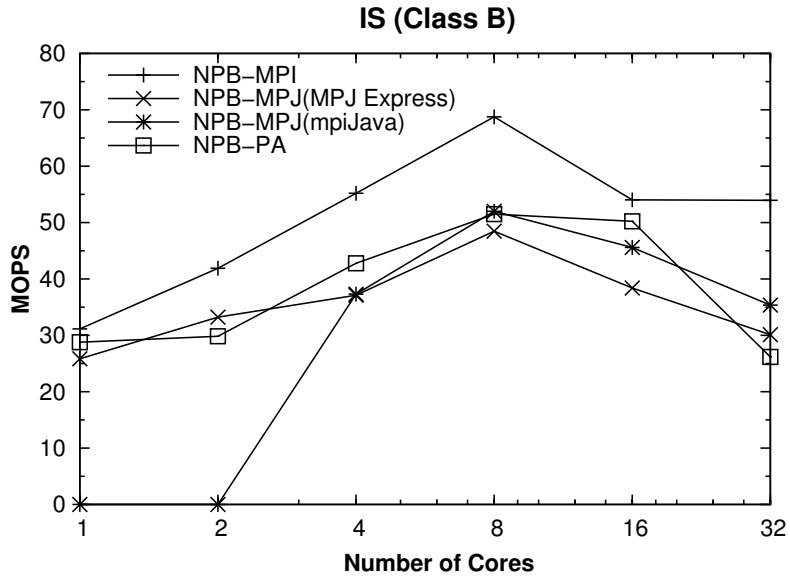
IS (Class B)
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NPB–MPJ(MPJ Express)
NPB–MPJ(mpiJava)
NPB–PA
MOPS
Number of Cores
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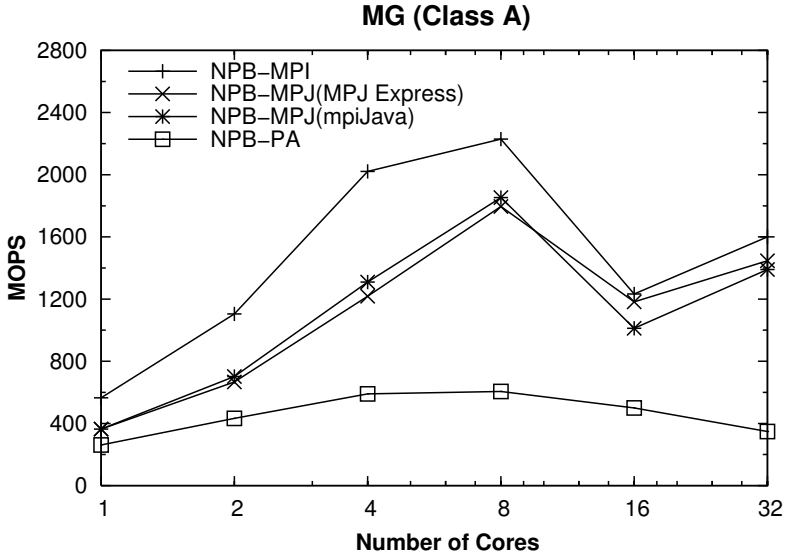
MG (Class A)
NPB–MPI
NPB–MPJ(MPJ Express)
NPB–MPJ(mpiJava)
NPB–PA
MOPS
Number of Cores
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2800
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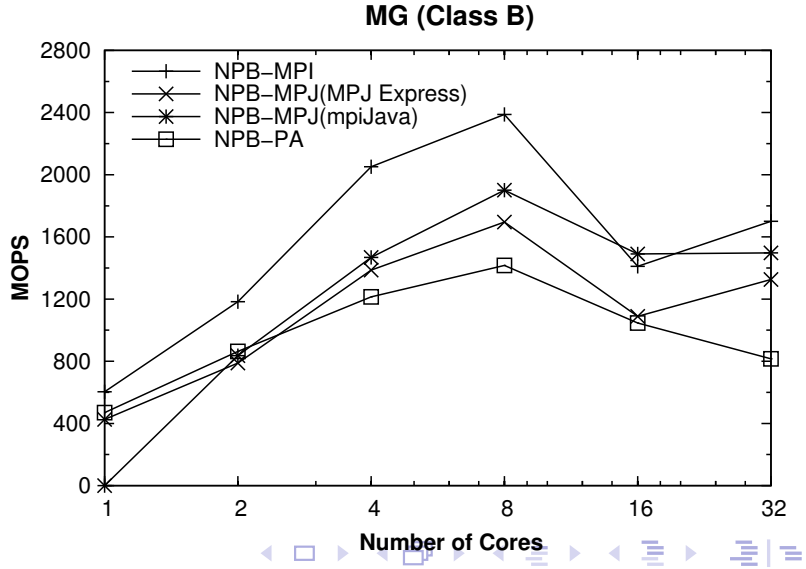
MG (Class B)
NPB–MPI
NPB–MPJ(MPJ Express)
NPB–MPJ(mpiJava)
NPB–PA
MOPS
Number of Cores
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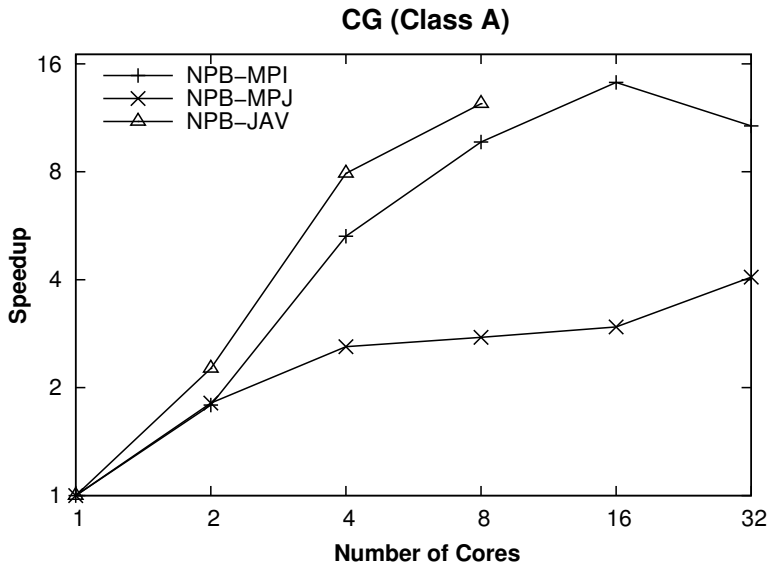
CG (Class A)
NPB–MPI
NPB–MPJ
NPB–JAV
Speedup
Number of Cores
1
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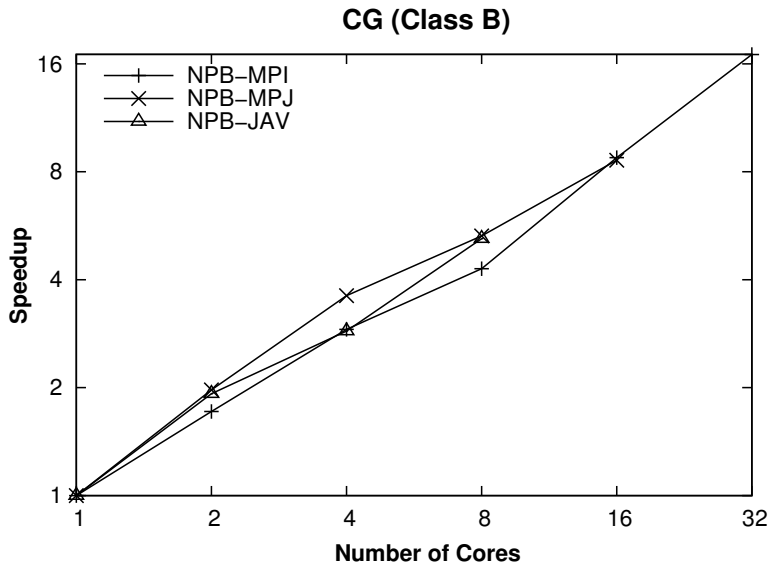
CG (Class B)
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NPB–MPJ
NPB–JAV
Speedup
Number of Cores
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16
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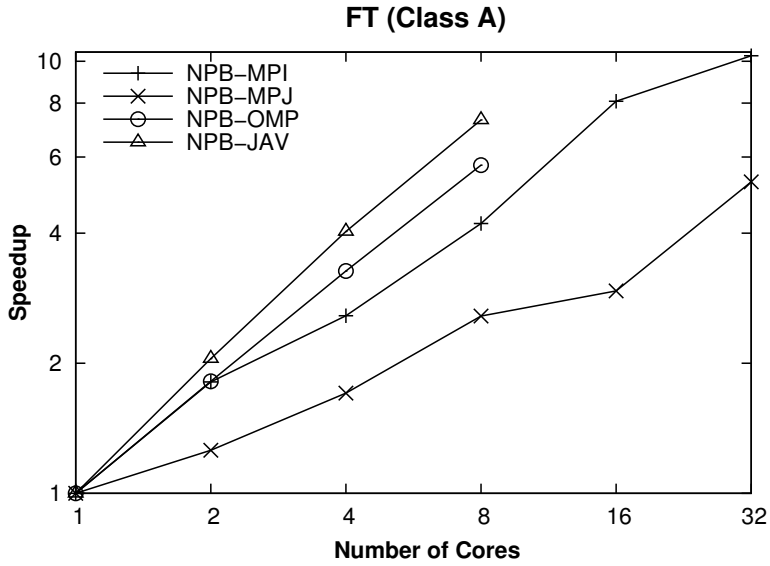
FT (Class A)
NPB–MPI
NPB–MPJ
NPB–OMP
NPB–JAV
Speedup
Number of Cores
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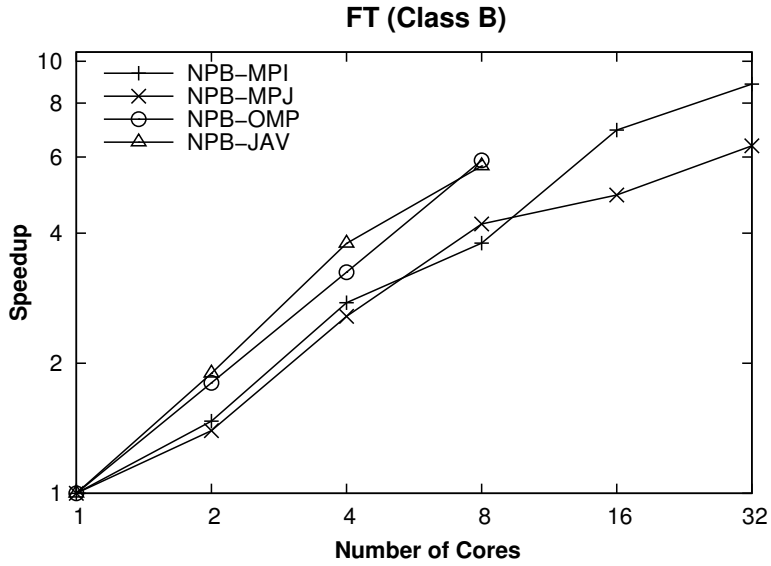
6
8
10
16
32


FT (Class B)
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NPB–MPJ
NPB–OMP
NPB–JAV
Speedup
Number of Cores
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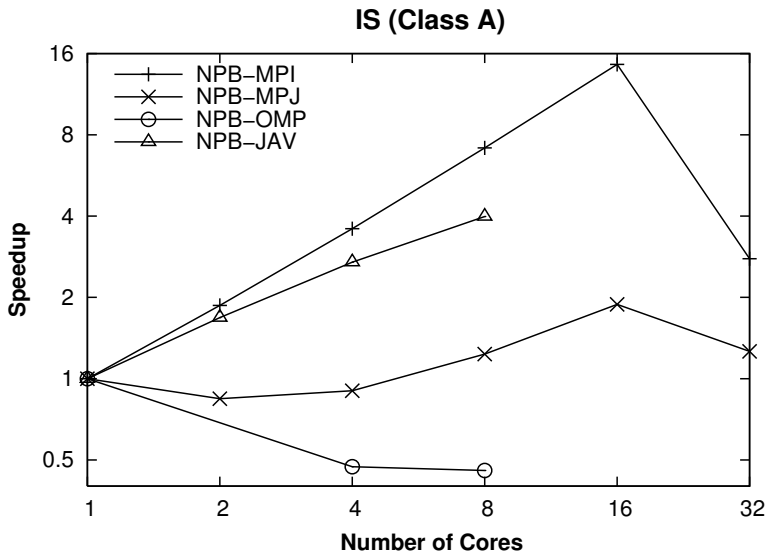
IS (Class A)
NPB–MPI
NPB–MPJ
NPB–OMP
NPB–JAV
Speedup
Number of Cores
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0.5
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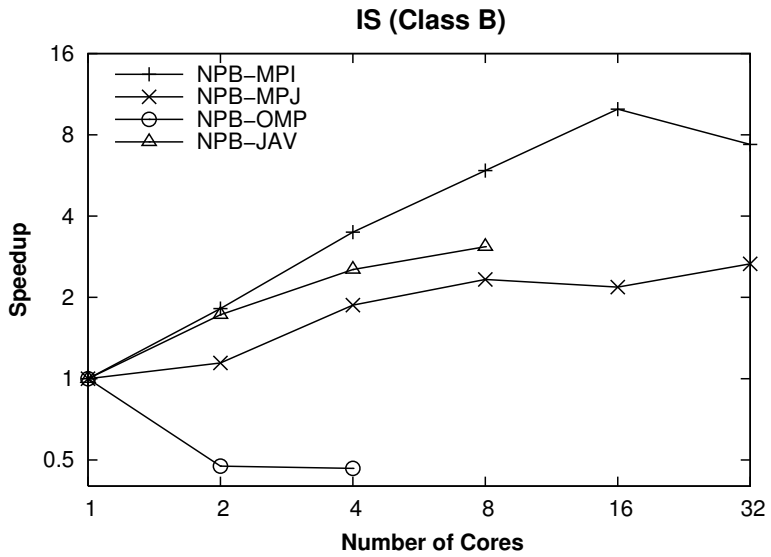
IS (Class B)
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NPB–MPJ
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NPB–JAV
Speedup
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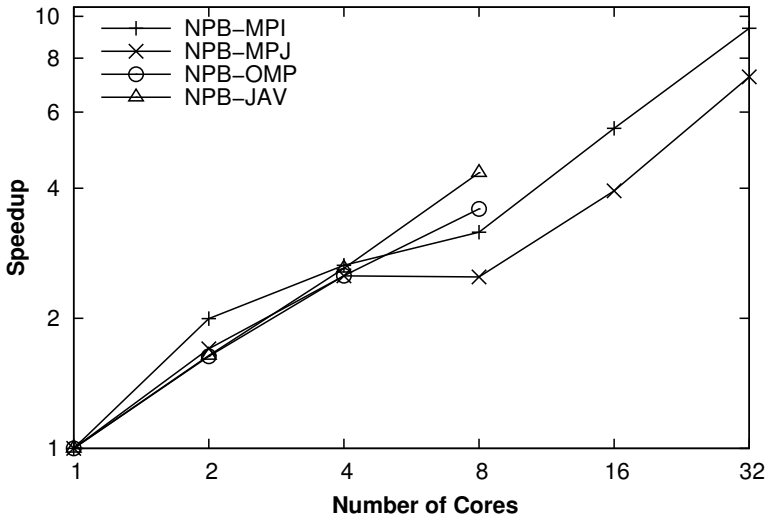
MG (Class A)
NPB–MPI
NPB–MPJ
NPB–OMP
NPB–JAV
Speedup
Number of Cores
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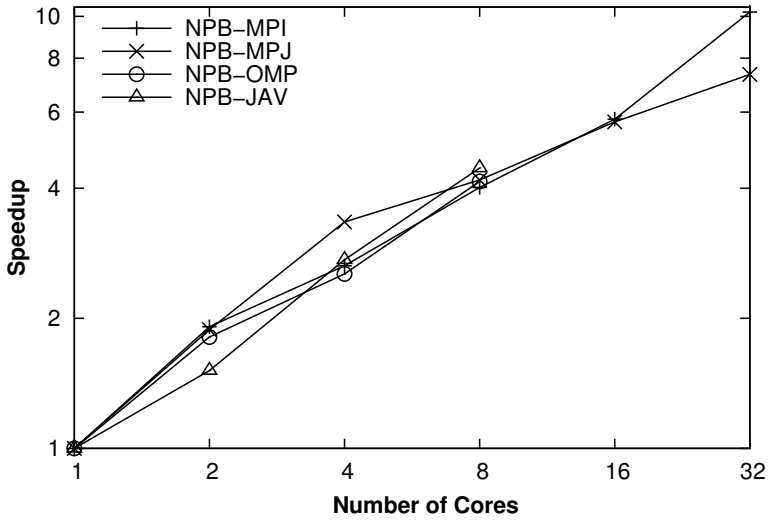
MG (Class B)
NPB–MPI
NPB–MPJ
NPB–OMP
NPB–JAV
Speedup
Number of Cores
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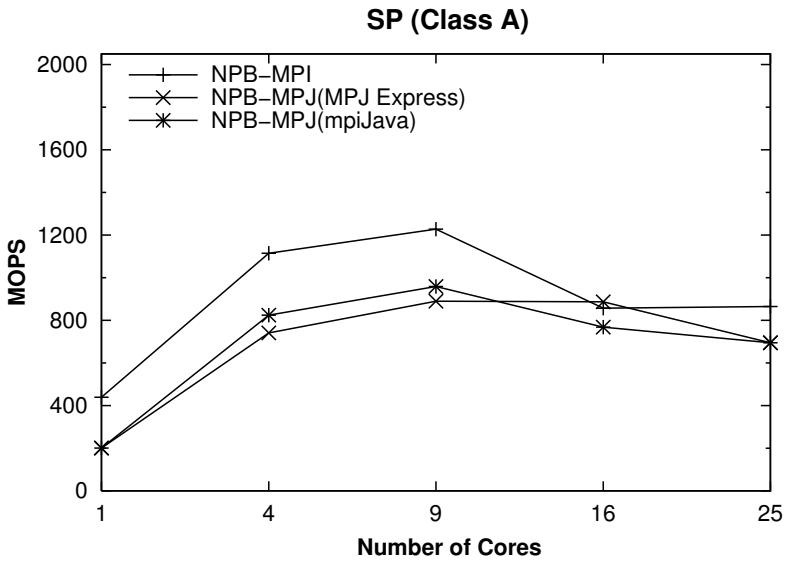
SP (Class A)
NPB–MPI
NPB–MPJ(MPJ Express)
NPB–MPJ(mpiJava)
MOPS
Number of Cores
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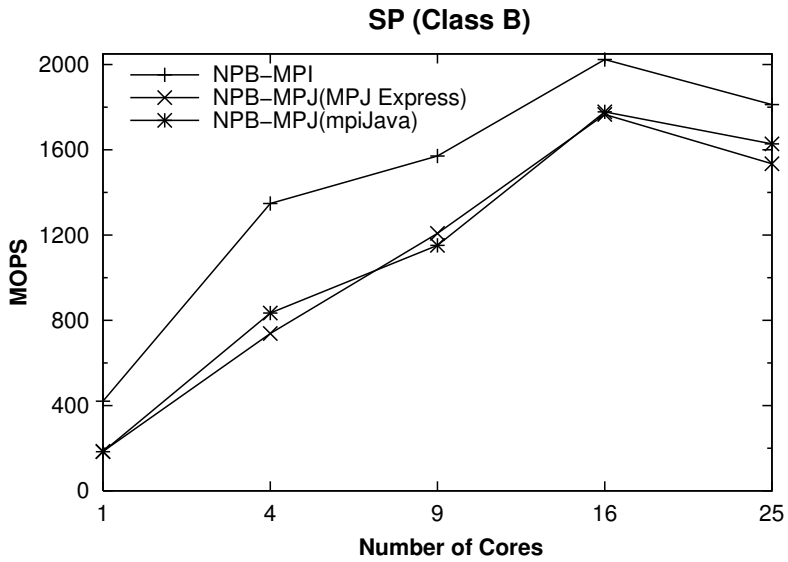
SP (Class B)
NPB–MPI
NPB–MPJ(MPJ Express)
NPB–MPJ(mpiJava)
MOPS
Number of Cores
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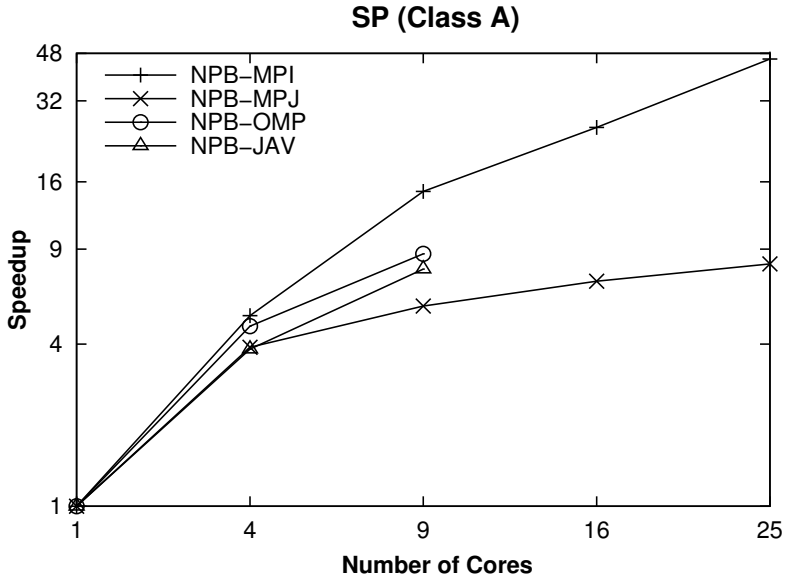
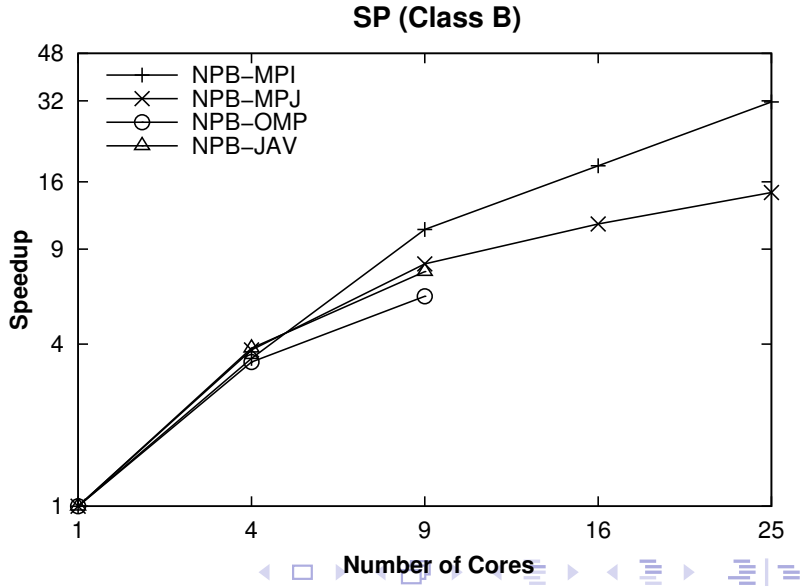

SP (Class A)
NPB–MPI
NPB–MPJ
NPB–OMP
NPB–JAV
Speedup
Number of Cores
1
4
9
16
32
48
1
4
9
16
25


SP (Class B)
NPB–MPI
NPB–MPJ
NPB–OMP
NPB–JAV
Speedup
Number of Cores
1
4
9
16
32
48
1
4
9
16
25

Summary

- NPB-MPJ is the complete NPB MPJ implementation
- NPB-MPJ allows the performance comparison of MPJ against MPI, OpenMP and other Java solutions for HPC (Threads, ProActive).
- NPB-MPJ serves to evaluate MPJ implementations ($>$10).

- Analysis of the Results
  - MPJ can compete in performance with MPI.
  - It is feasible to increase Java performance.

Questions?

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University of A Coruña, Spain

For Further Reading I


B. Amedro, V. Bodnartchouk, D. Caromel, C. Delbé, F. Huet, and G. L. Taboada.
Current State of Java for HPC.
In *INRIA Technical Report RT-0353*, pages 1–24, INRIA Sophia Antipolis, Nice, France, 2008, http://hal.inria.fr/inria-00312039/en/.


B. Amedro, D. Caromel, F. Huet, and V. Bodnartchouk.
Java ProActive vs. Fortran MPI: Looking at the Future of Parallel Java.
In *Proc. 10th Intl. Workshop on Java and Components for Parallelism, Distribution and Concurrency (IWJacPDC'08), Miami, FL, USA*, page 134b (8 pages), 2008.