# OpenPOWER HPC Performance Insights

## Industry Applications & Benchmarks

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IBM

# OpenFOAM Overview

- **O**pen Source **F**ield **O**peration and **M**anipulation
- C++ Toolbox for Simulation of Mechanical Problems
  - Solvers
  - Pre-/post processing utils
  - MPI parallelized
  - NO OpenMP
  - NO vector intrinsics
- Widely used in industry and academics
  - Computational Fluid Dynamics (CFD)
    - Aerodynamics simulations
    - Pharmaceutical industry
  - Electromagnetism
  - Combustion
  - …
- Many different modules
  - simpleFoam – static analysis
  - pisoFoam – dynamic analysis
- Known to be memory bandwidth limited

OpenFOAM

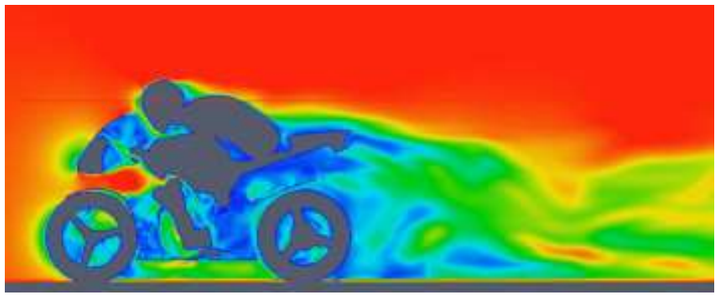
http://www.openfoam.com

Credit to: Dr. Markus Bühler, IBM **P**OWER **A**cceleration and **D**esign **C**enter

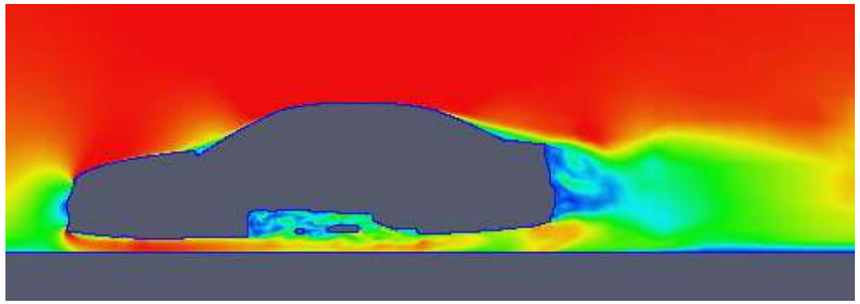
# OpenFOAM on POWER8

- OpenFoam 2.3.0 compiled on x86 and POWER8
  - Only minor configuration changes to compile on POWER8
  - Optimizations see next slide

- Benchmark 1: Motorbike Example
  - Provided with OpenFoam examples: incompressible/simpleFoam
  - Different problem sizes by changing grid: 1k – 100M points



- Benchmark 2: Car
  - Car model
  - Morphed from two real cars
  - Several problem sizes



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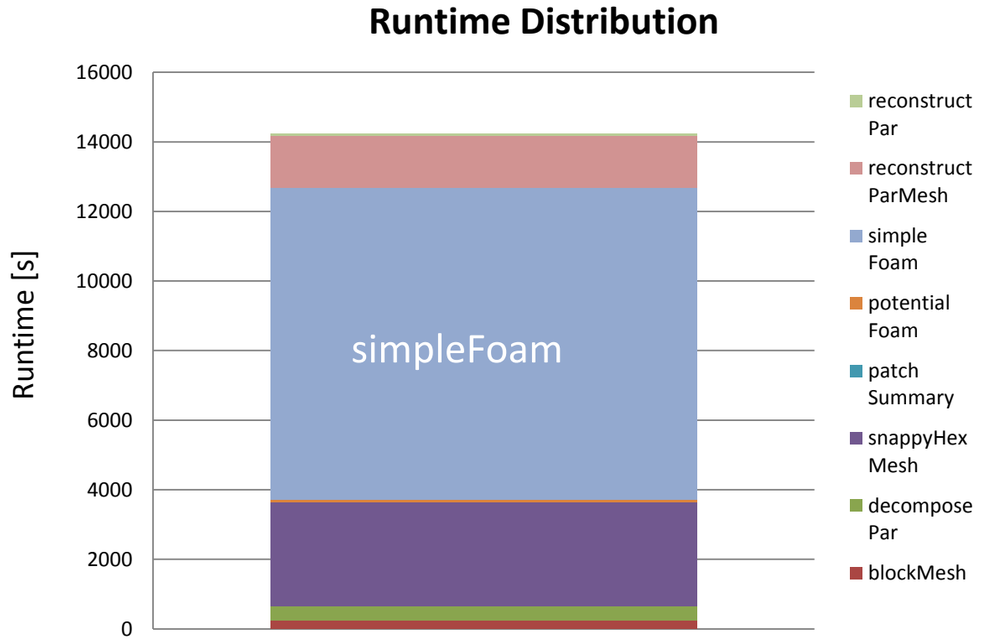
# OpenFOAM – MotorBike Benchmark Overview

**9 Steps**

1. surfaceFeatureExtract
2. blockMesh
3. decomposePar
4. snappyHexMesh
5. patchSummary
6. potentialFoam
7. **simpleFoam**
8. reconstructParMesh
9. reconstructPar




- simpleFoam dominates runtime
- other steps are not always required
- ➢ concentrate on simpleFoam

Credit to: Dr. Markus Bühler, IBM **P**OWER **A**cceleration and **D**esign **C**enter

Results are based on IBM internal testing. Individual results will vary depending on individual workloads, configurations and conditions.

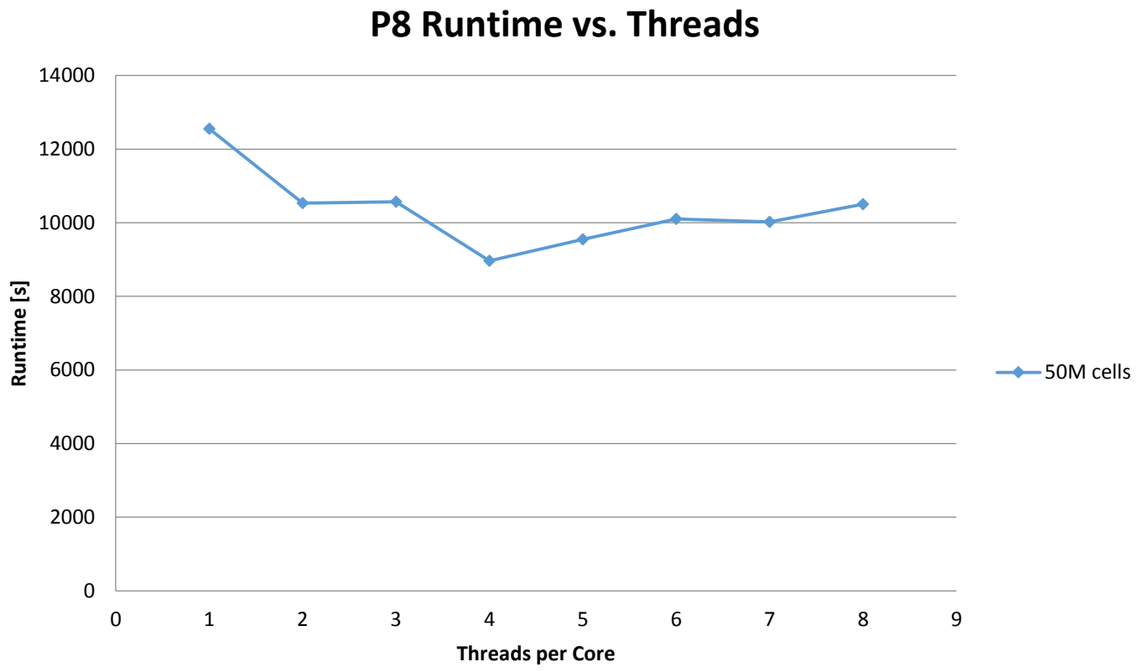
# OpenFOAM – Hardware Configurations

| | Power 8 – S822LC (one socket) | Intel (one socket) |
|---|---|---|
| Processor | P8 | Haswell E5-2680v3 |
| Clock | 3.49 GHz | 2.5-2.9 Ghz |
| Cores / Threads (max) | 10 / 80 | 12 / 24 |
| Memory / Node | 512 GB | 256 GB |
| Memory BW / socket | 115 GB/s | 68 GB/s |
| Caches L1 / L2 / L3 | 640k / 5M / 80M | 64k / 256k / 30M |

Credit to: Dr. Markus Bühler, IBM **P**OWER **A**cceleration and **D**esign **C**enter

# OpenFOAM – Optimizations for POWER8

- Compiled with -O3
- Link with tc_malloc instead of standard malloc
  - simpleFoam: almost no impact
  - recomposeParMesh: up to 2x speedup
- Threads per core
  - P8 offers up to 8 threads per core
  - Runtime impact




- choose 4 threads per core unless stated otherwise
- x86: little impact on runtime → use 1 thread per core

Credit to: Dr. Markus Bühler, IBM **P**OWER **A**cceleration and **D**esign **C**enter

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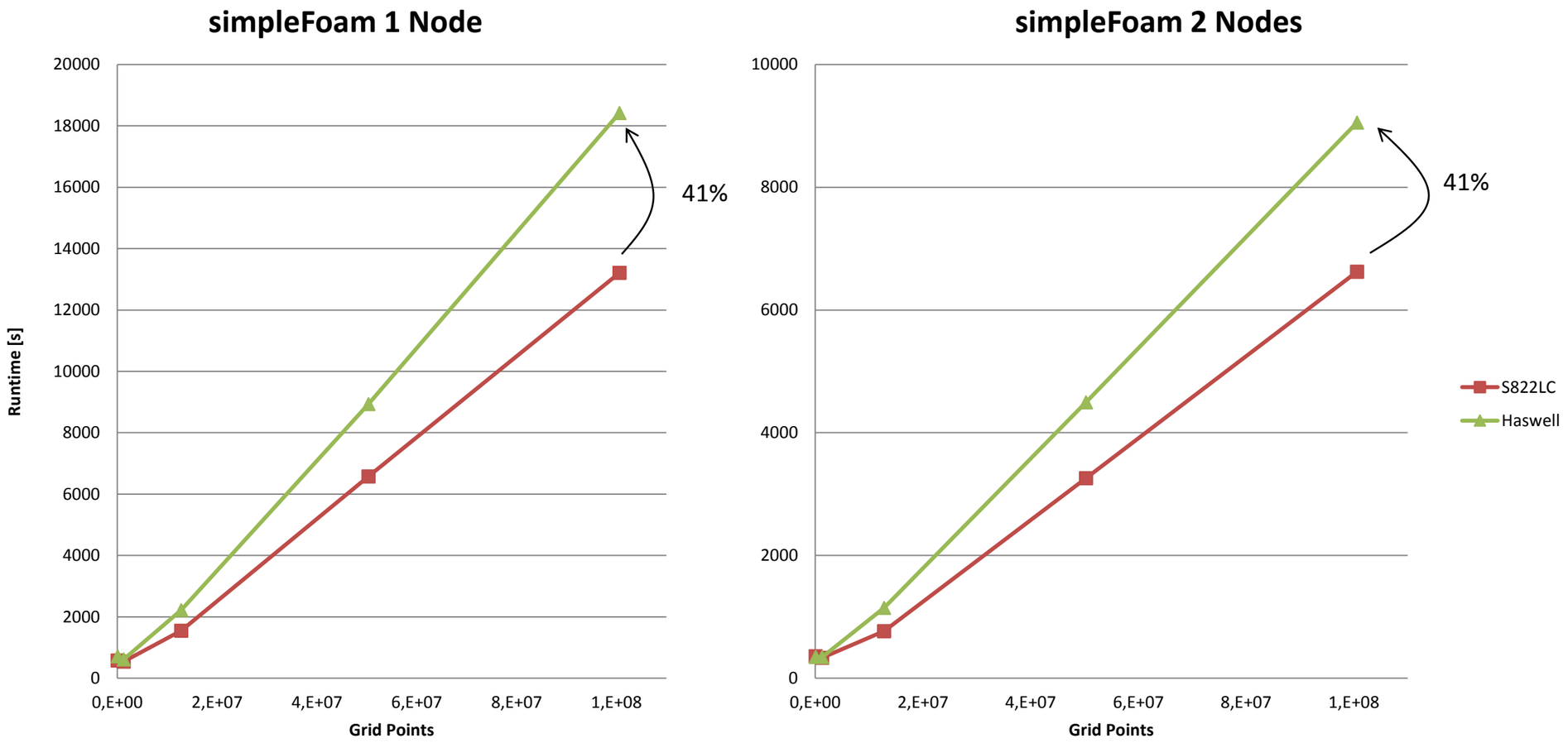
# OpenFOAM – Benchmark Results (two sockets per node)




Credit to: Dr. Markus Bühler, IBM **P**OWER **A**cceleration and **D**esign **C**enter

Results are based on IBM internal testing. Individual results will vary depending on individual workloads, configurations and conditions.

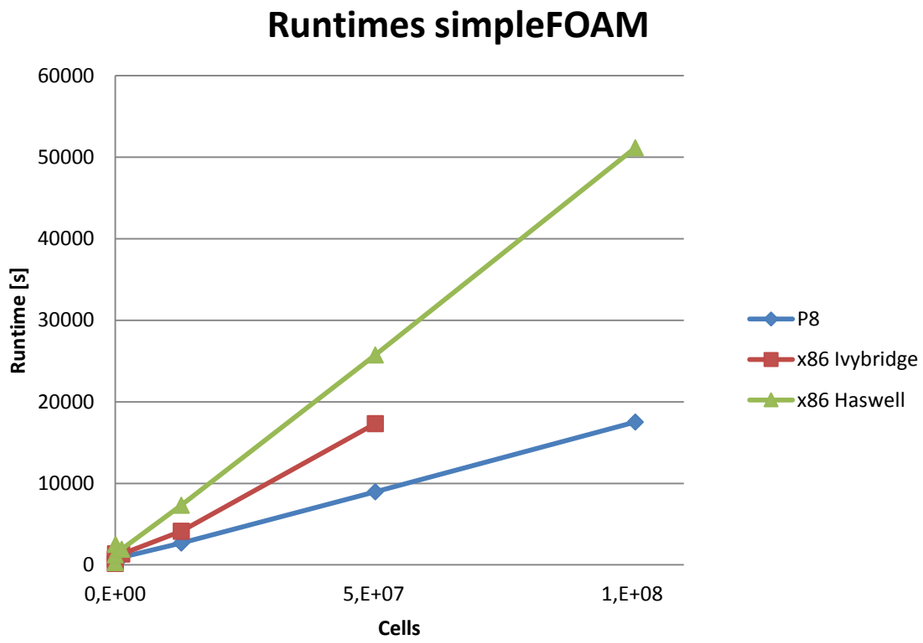
# OpenFOAM – Hardware Configurations

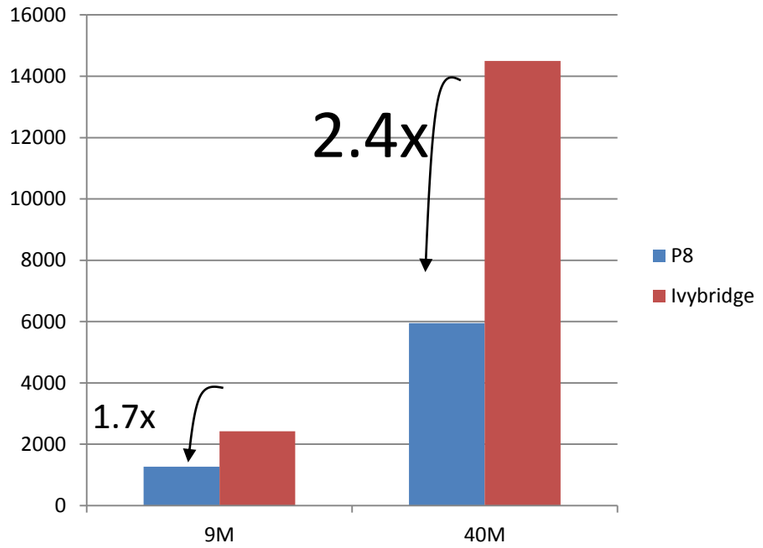
| | IBM S824L (one socket) | Intel Ivybridge (one socket) | Intel Haswell (one socket) |
|---|---|---|---|
| Processor | P8 | E7-4890V2 | E5-2699V3 |
| Clock | 3.4GHz | 2.8Ghz | 2.3GHz |
| Cores / Threads (max) | 10 / 80 | 15 / 30 | 18/36 |
| Memory | 128 GB | 96 GB | 384 GB*) |
| Memory BW | 230 GB/s | 85 GB/s | 68 GB/s |
| Caches L1 / L2 / L3 / L4 | 640k / 5M / 80M / 128M | 480k / 3.75M / 37.5M / n/a | 576k / 4.6M / 45M / n/a |
| Linux | Ubuntu 14.04 | Red Hat 6.5 | Red Hat 7.1 |
| Compiler | GCC 4.8.2 | GCC 4.7.2 | GCC 4.8.3 |

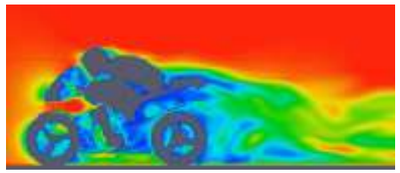
*) 3 dimms/channel: considerable performance penalty

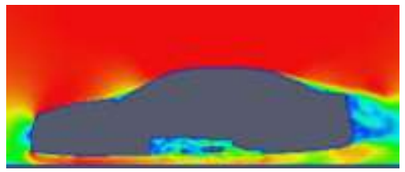
Credit to: Dr. Markus Bühler, IBM **P**OWER **A**cceleration and **D**esign **C**enter

# OpenFOAM – Benchmark Results





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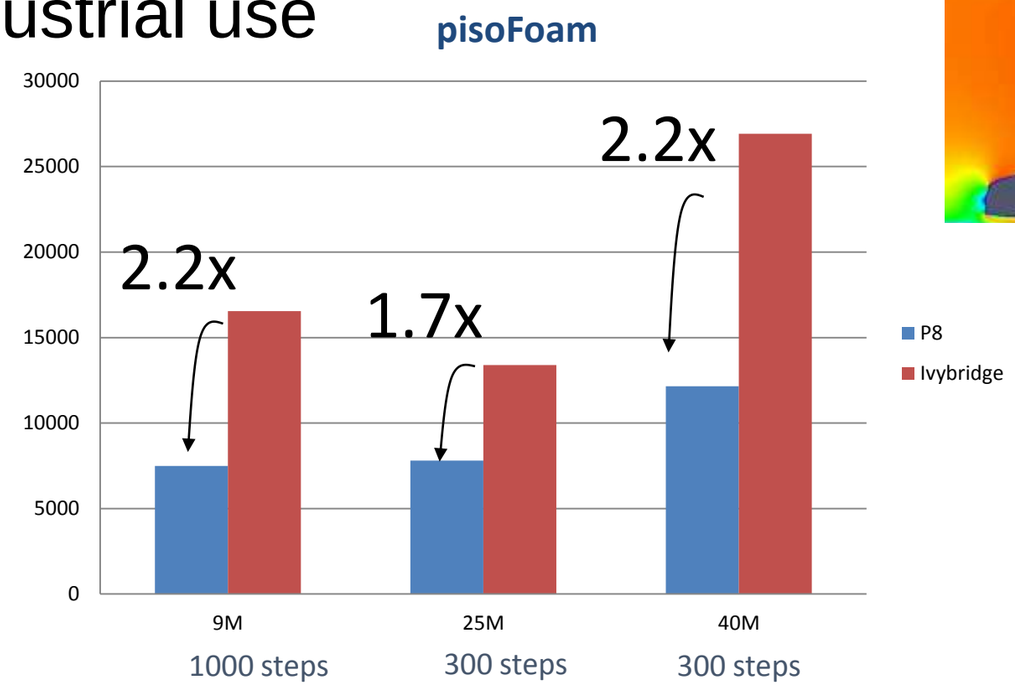
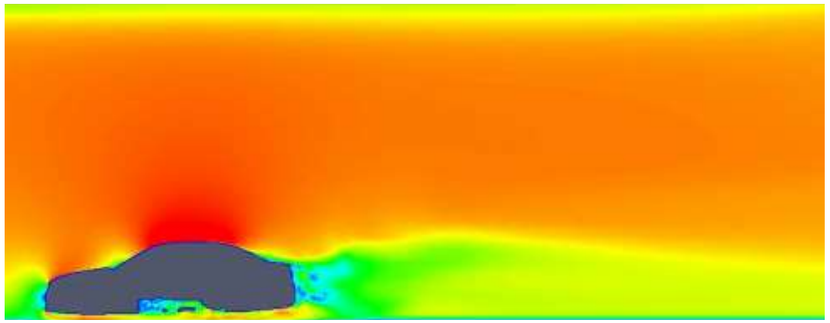
Results are based on IBM internal testing. Individual results will vary depending on individual workloads, configurations and conditions.

# OpenFOAM – Dynamic Simulation

- pisoFoam: simulates transient behaviour
- Runtimes even longer than simpleFoam
  - ➢ hinders industrial use



**Conclusion**

- Similar speedup as simpleFoam

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# Backup slides

# OpenFOAM – MotorBike Benchmark Overview

OpenFoam Example

① Start

② blockMesh

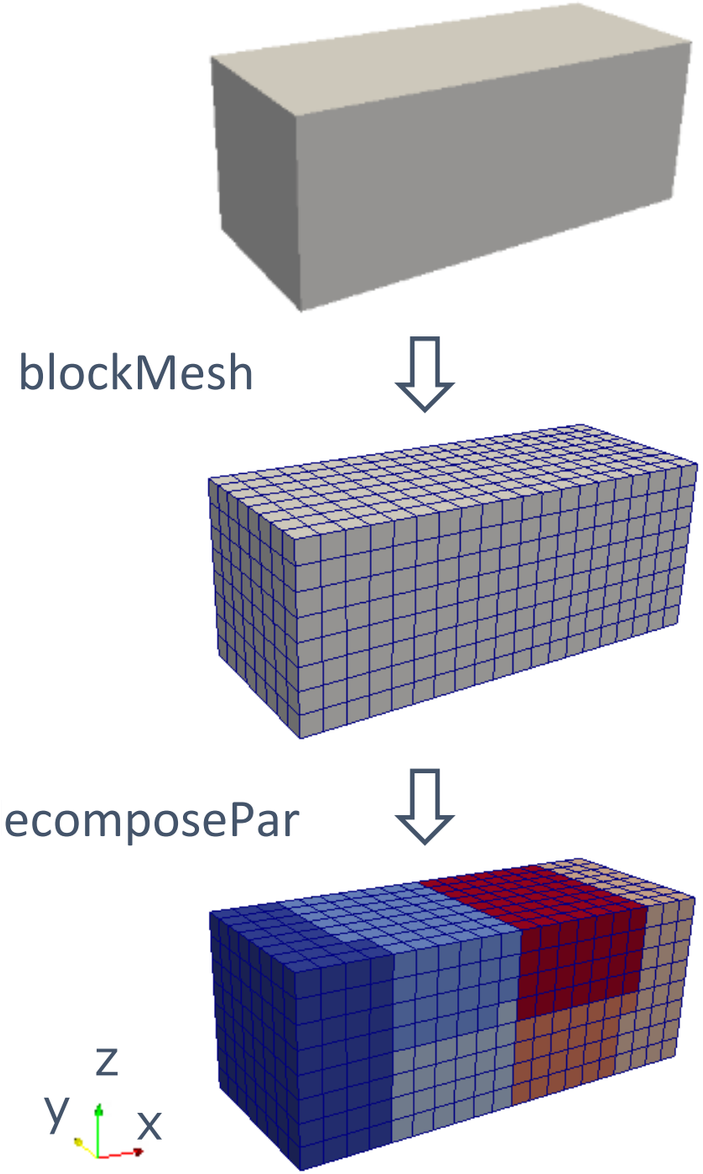
Mesh the 3D space

- 20 x 8 x 8 = 1280 cells (default)

  …
- 857 x 343 x 343 = 100M cells

③ decomposePar

➢Divide into submeshes

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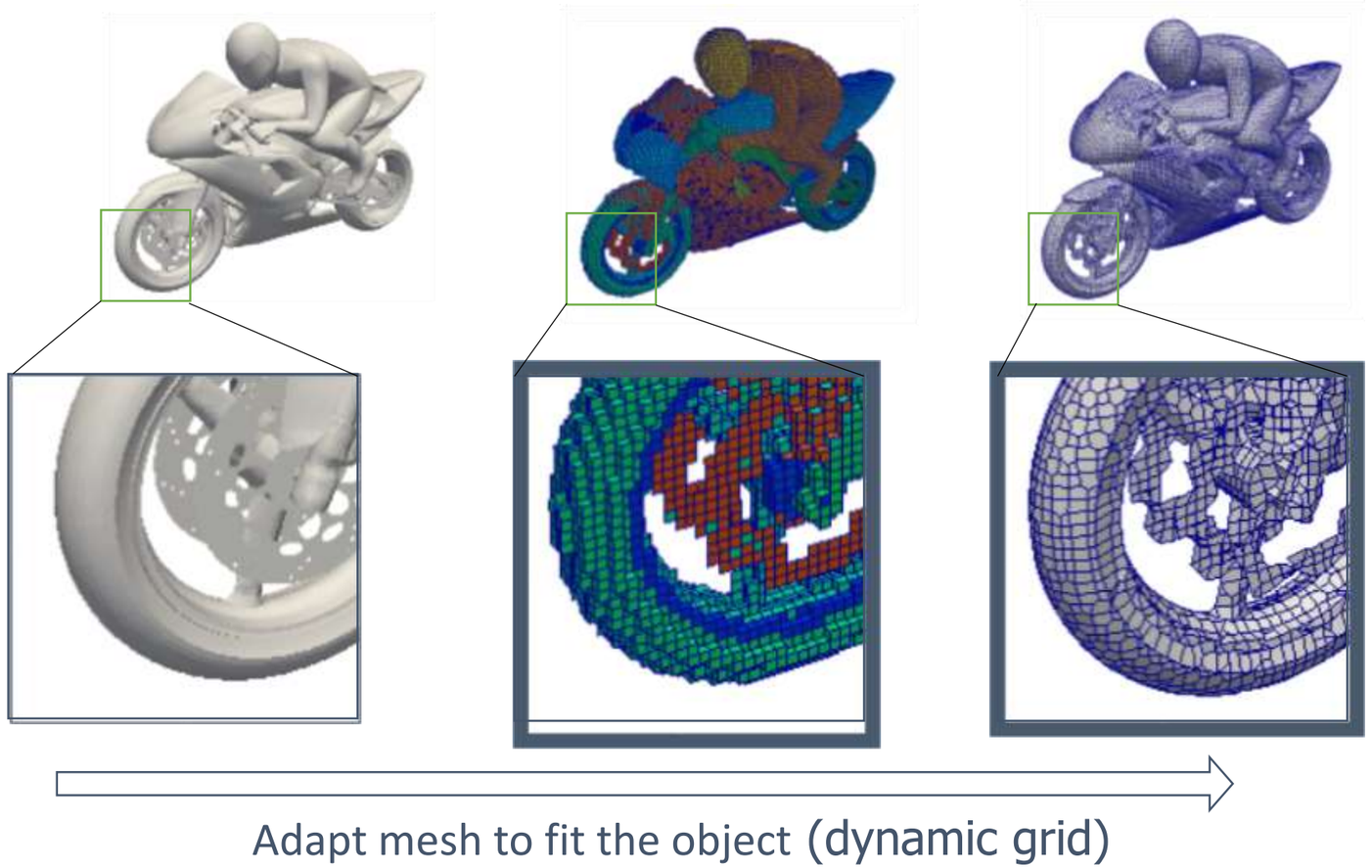
# OpenFOAM – MotorBike Benchmark Overview

④ snappyHexMesh




(Reference) http://www.rccm.co.jp/icem/pukiwiki/index.php?SnappyHexMesh

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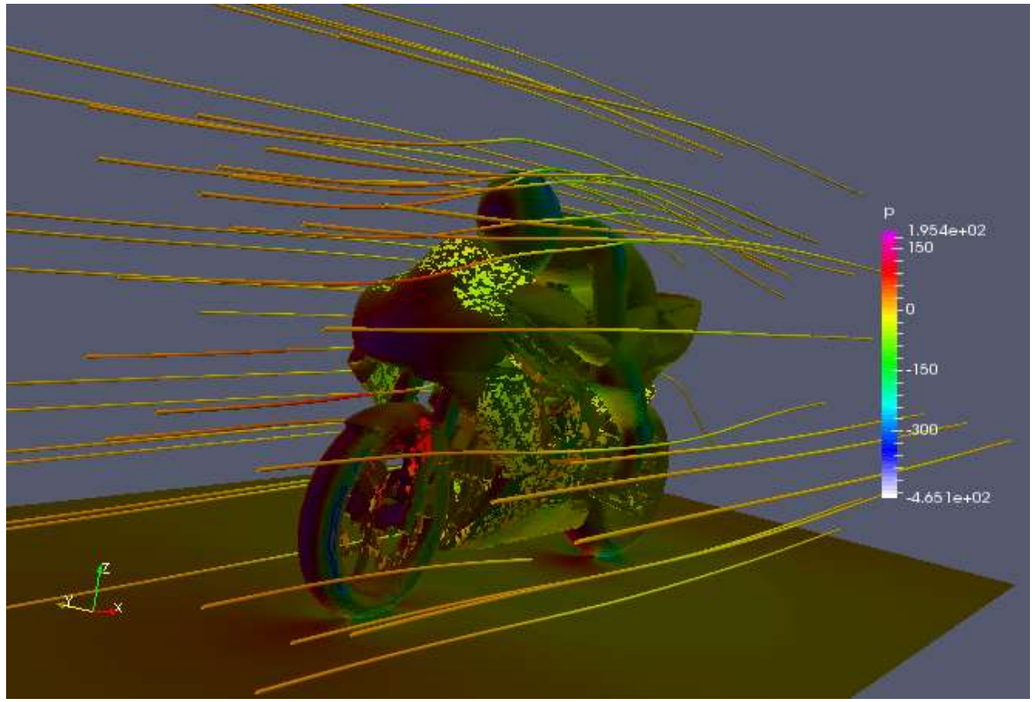
# OpenFOAM – MotorBike Benchmark Overview

⑦ simpleFoam

- One of the main solver included in OpenFOAM.
- **S**emi-**I**mplicit **M**ethod for **P**ressure-**L**inked **E**quation: calculate velocity and pressure by iterative calculation
- Benchmark: run 500 iterative steps
- Outcome: aerodynamic coefficients

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# POWER8 – Choice of SMT modes

*Table A-3 NPB: Favorable modes and options for applications from the NPB suite*

| | -O2 | -O3 | -O4 | -O5 |
|---|---|---|---|---|
| **ST** | — | — | — | mg.C |
| **SMT2** | — | bt.C, is.C, sp.C | — | lu.C |
| **SMT4** | — | ua.C | — | ft.C |
| **SMT8** | — | cg.C | ep.C | — |

Implementing an IBM High-Performance Computing Solution on IBM Power System S822LC

http://www.redbooks.ibm.com/abstracts/sg248280.html

# POWER8 – Thread binding

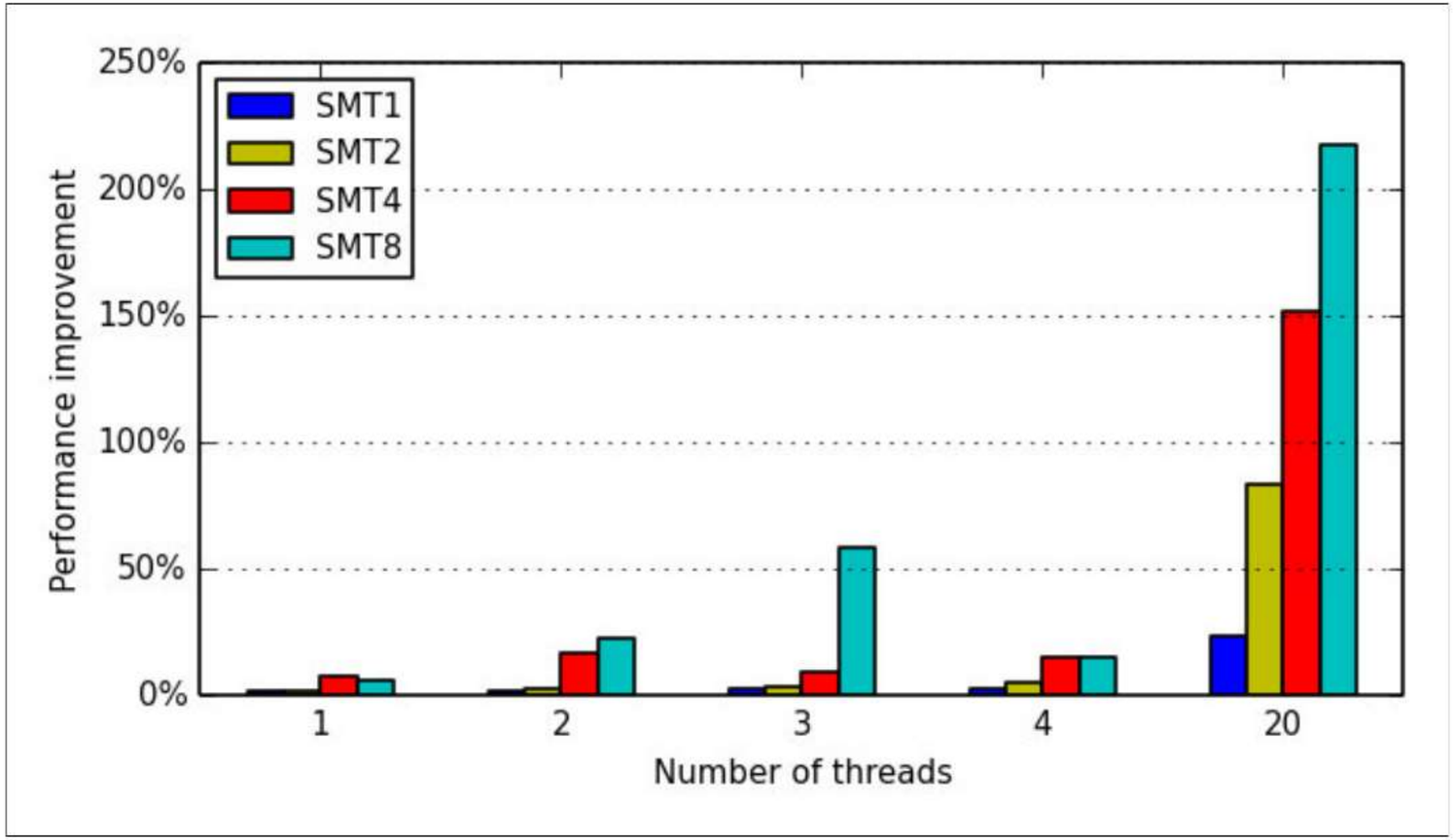


*Figure A-27 Performance improvement for an application when thread binding is used*

Implementing an IBM High-Performance Computing Solution on IBM Power System S822LC

http://www.redbooks.ibm.com/abstracts/sg248280.html