Running PEPPHER benchmarks on top of the StarPU runtime system

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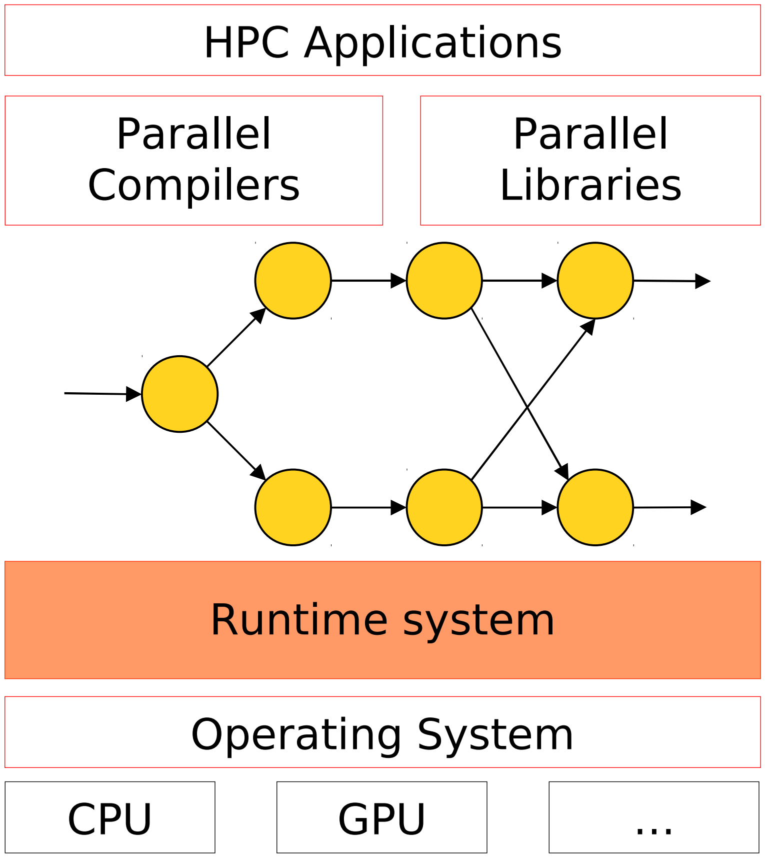
The StarPU runtime system

Motivations

- “do dynamically what can’t be done statically”

- Typical duties
  - Task scheduling
  - Memory management

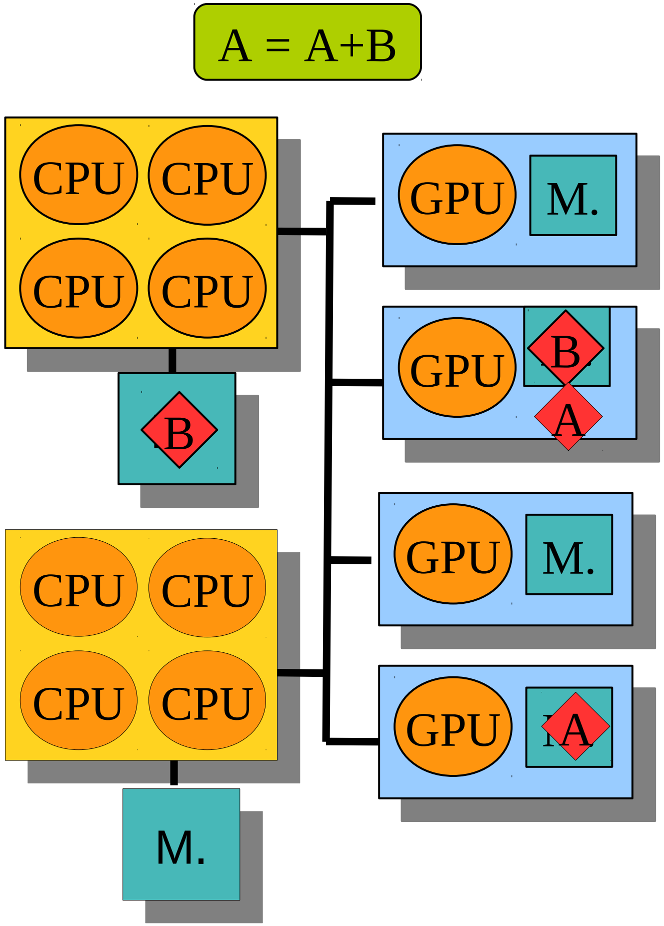
- Compilers and libraries generate (graphs of) parallel tasks
  - Additional information is welcome!



The StarPU runtime system

Motivations

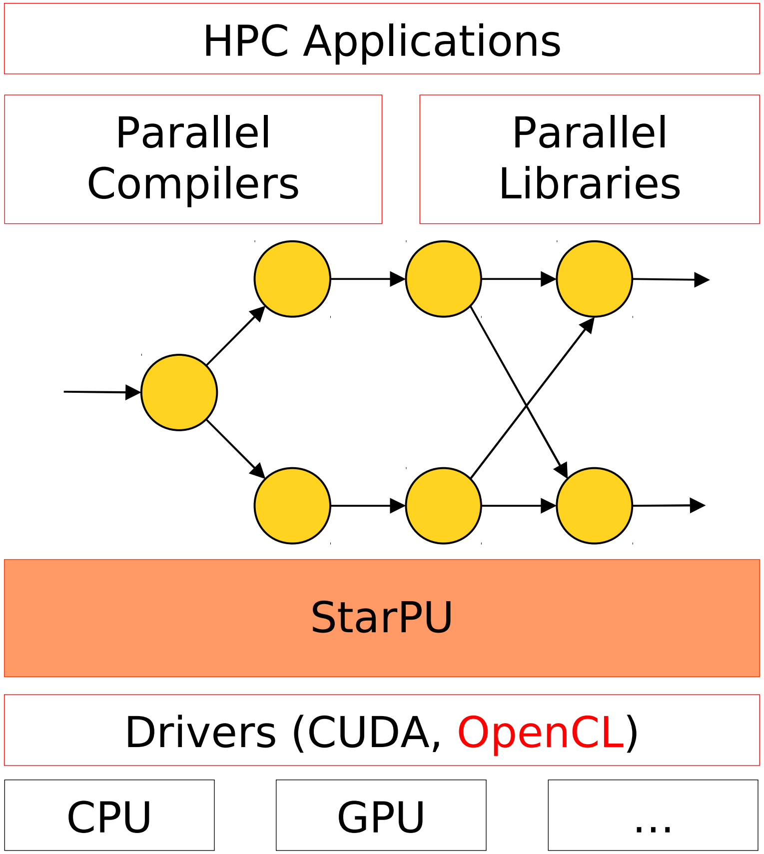
- Main Challenges
  - Dynamically schedule tasks on all processing units
    - See a pool of heterogeneous cores
    - Scheduling ≠ offloading
  - Avoid unnecessary data transfers between accelerators
    - Need to keep track of data copies



The StarPU runtime system

Memory Management

- StarPU provides a Virtual Shared Memory subsystem
    - Weak Consistency
    - Replication
    - Single writer
    - High level API
- Application registers data
- Input & ouput of tasks = reference to registered data

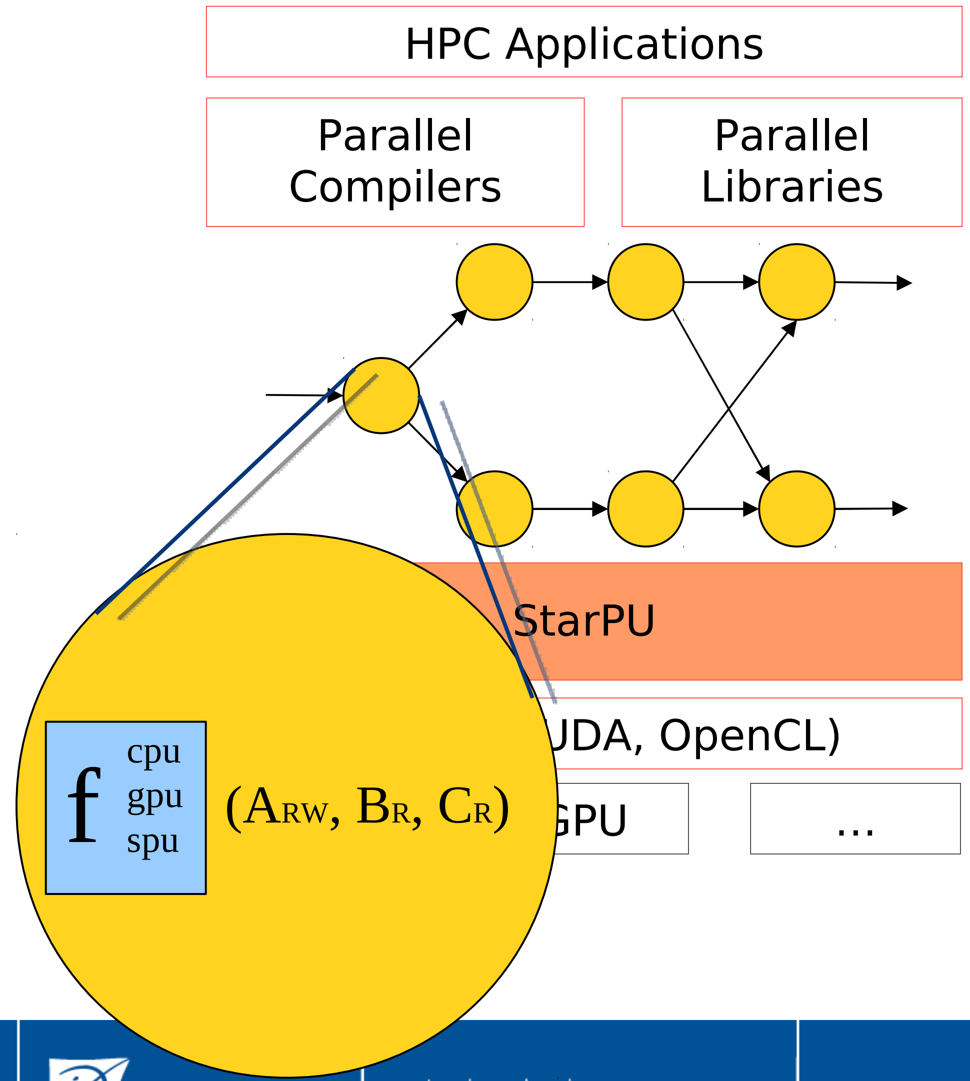


The StarPU runtime system

Task scheduling

- Tasks =
  - Data input & output
  - Dependencies with other tasks
  - Multiple implementations
    - e.g. CUDA and/or CPU
  - Scheduling hints

- StarPU provides an Open Scheduling platform
  - Scheduling algorithm = plug-ins



Pepphe Benchmarks

- Fast Fourier Transform (FFT)
  - Mixing FFTW and CUFFTW
- Dense Linear Algebra
  - Mixing PLASMA and MAGMA
- Computational Fluid Dynamic (CFD)
  - Porting Rodinia's CFD

Dense Linear Algebra

Mixing PLASMA and MAGMA

(Collaboration with UTK)

Mixing PLASMA and MAGMA with StarPU

Background

- Background
  - Cholesky/LU/QR: Solve dense linear systems
  - UTK : ~ leaders for Dense Linear Algebra for 20 years
  - Need performance portability

- State of the art libraries
  - PLASMA (Multicore CPUs)
  - MAGMA (Multiple GPUs)

- Our approach
  - Use PLASMA algorithms
  - PLASMA kernels on CPUs, MAGMA kernels on GPUs
  - Schedule tasks with StarPU

Mixing PLASMA and MAGMA with StarPU

Productivity

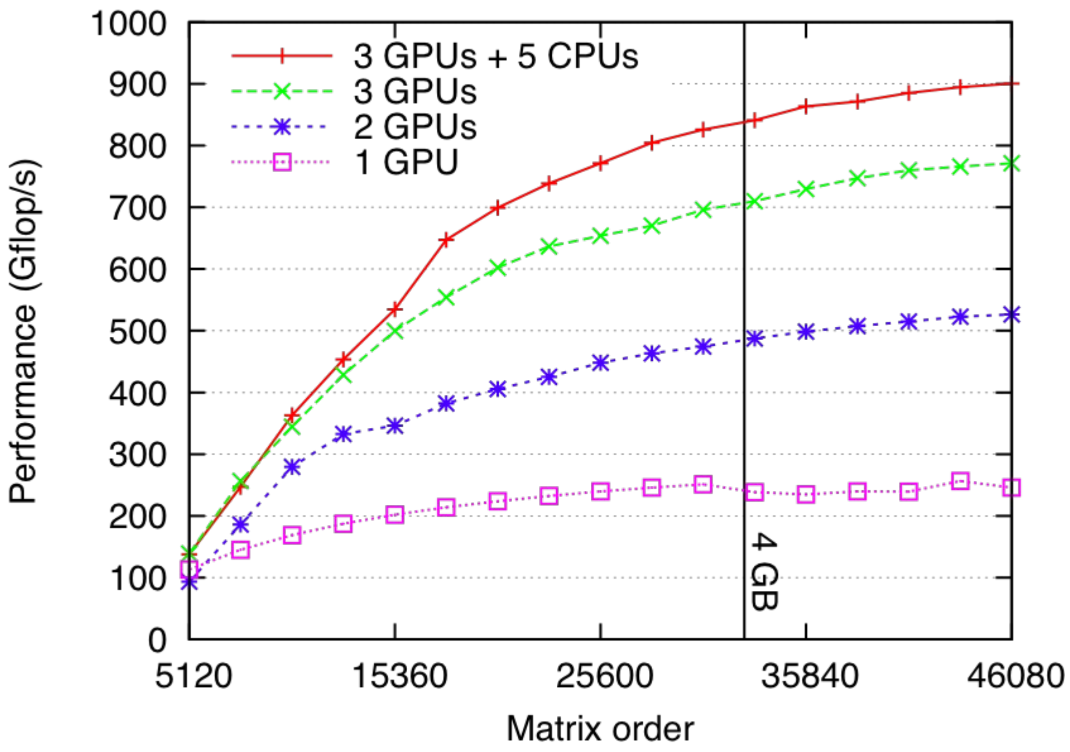
- Programmability
  - Cholesky: ~half a week, QR: ~2 days of works, LU : ~time to write new kernels
  - Quick algorithmic prototyping

```
// Sequential Tile Cholesky
FOR k = 0..TILES-1
  DPOTRF(A[k][k])
  FOR m = k+1..TILES-1
    DTRSM(A[k][k], A[m][k])
  FOR n = k+1..TILES-1
    DSYRK(A[n][k], A[n][n])
  FOR m = n+1..TILES-1
  DGEMM(A[m][k], A[n][k], A[m][n])
```

```
// Hybrid Tile Cholesky
FOR k = 0..TILES-1
    starpu_Insert_Task(DPOTRF, ...)
    FOR m = k+1..TILES-1
      starpu_Insert_Task(DTRSM, ...)
    FOR n = k+1..TILES-1
      starpu_Insert_Task(DSYRK, ...)
   FOR m = n+1..TILES-1
      starpu_Insert_Task(DGEMM, ...)
```

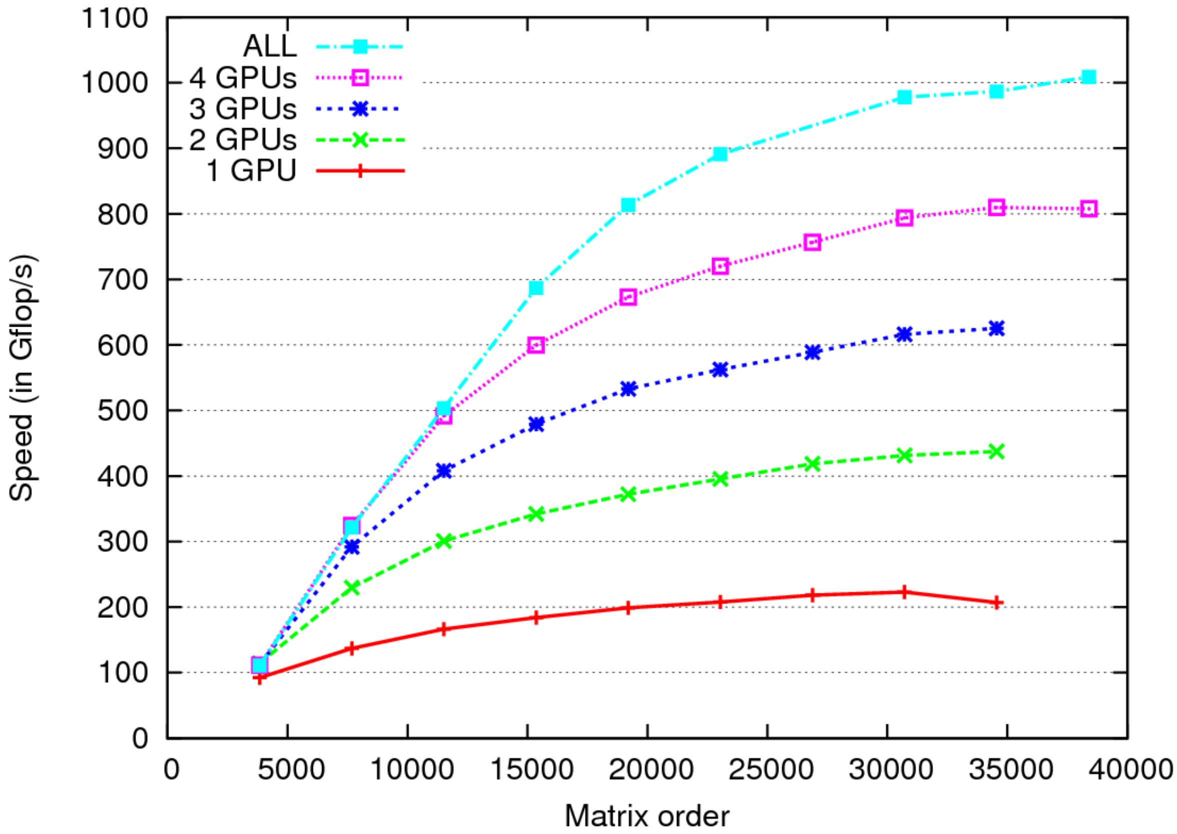
Mixing PLASMA and MAGMA with StarPU

- Cholesky decomposition
  - Hannibal: 8 CPU cores (Nehalem) + 3 GPUs (NV FX5800)



Mixing PLASMA and MAGMA with StarPU

- QR decomposition
  - Mordor8 (UTK) : 16 CPUs (AMD) + 4 GPUs (C1060)



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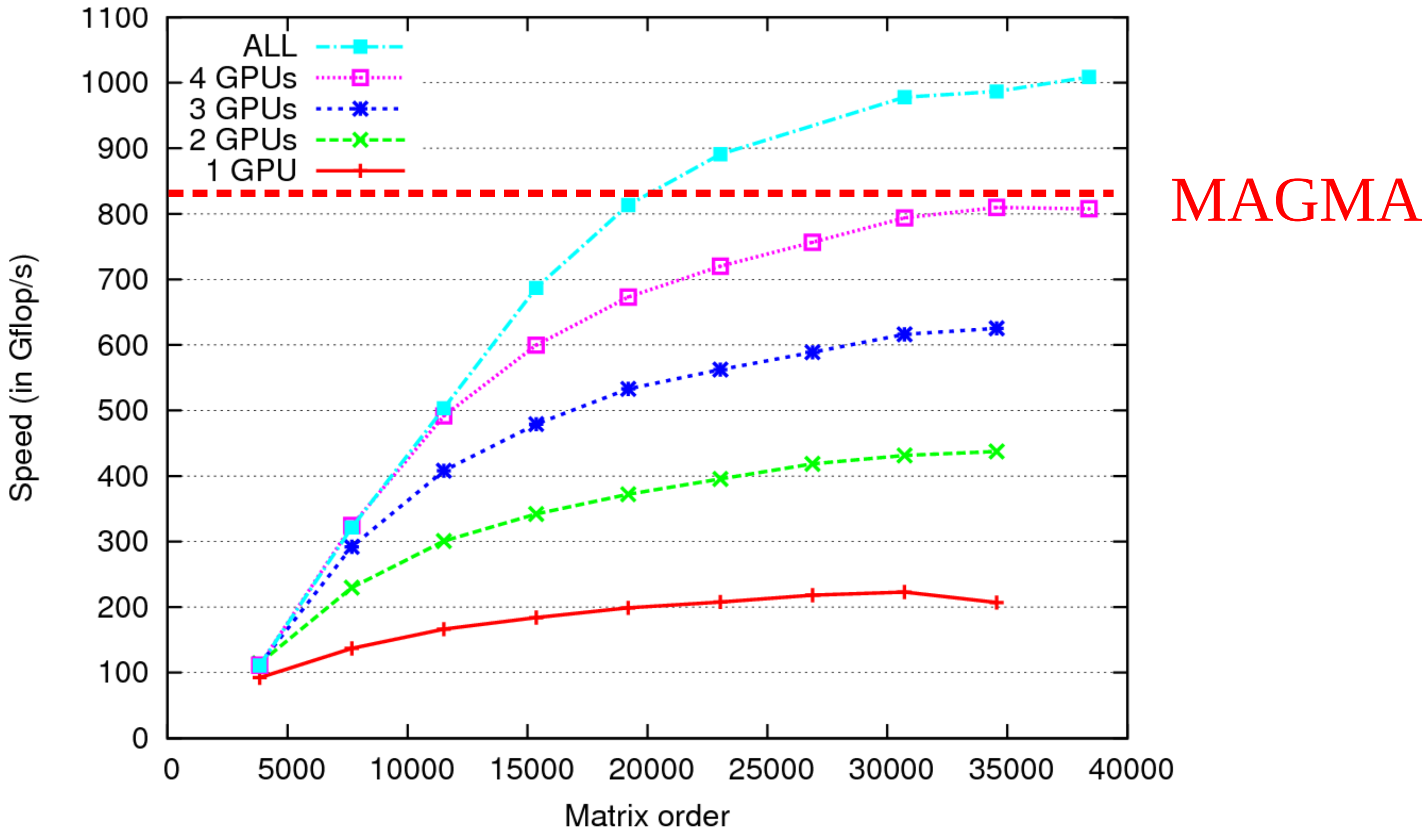

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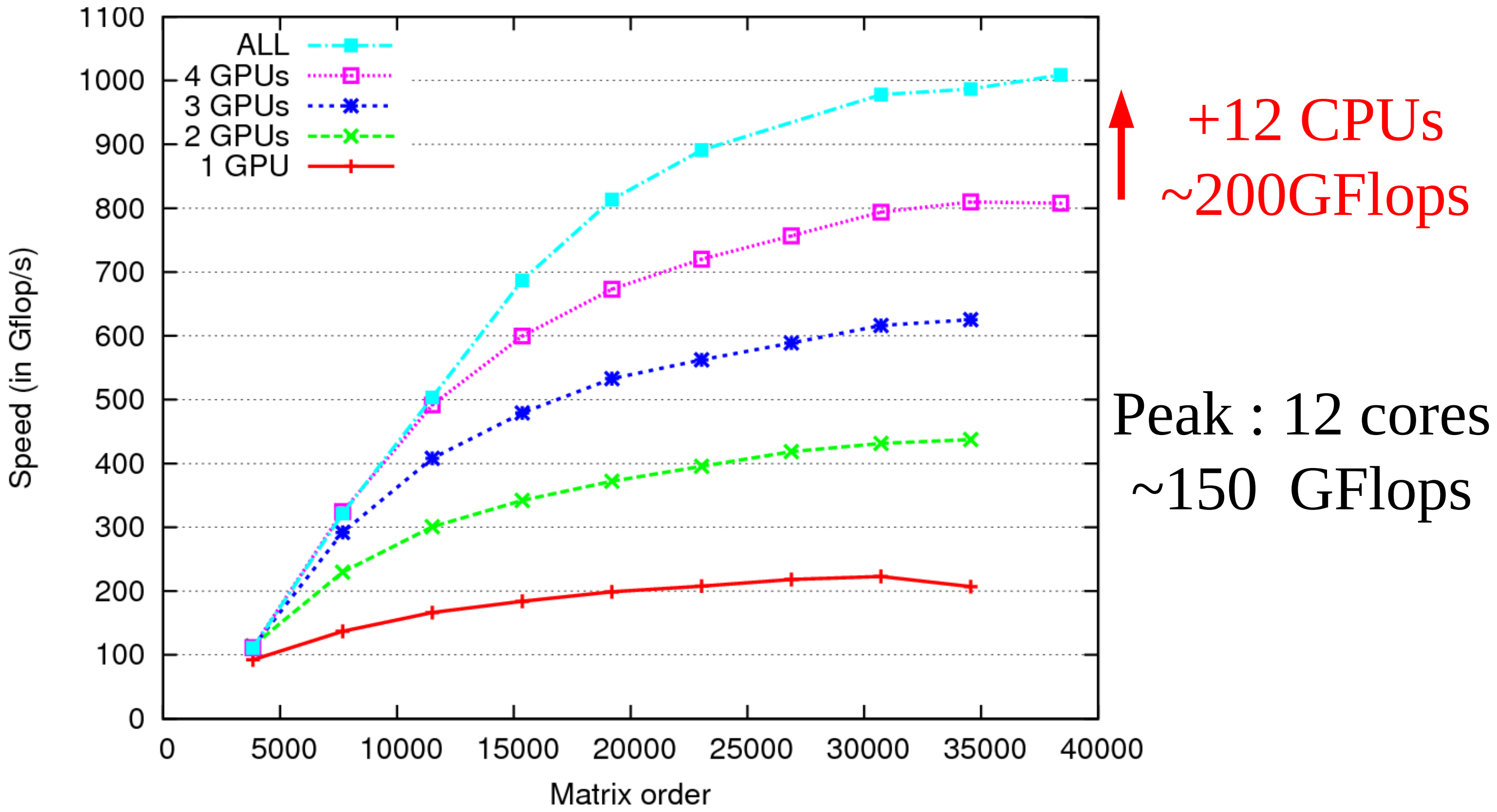
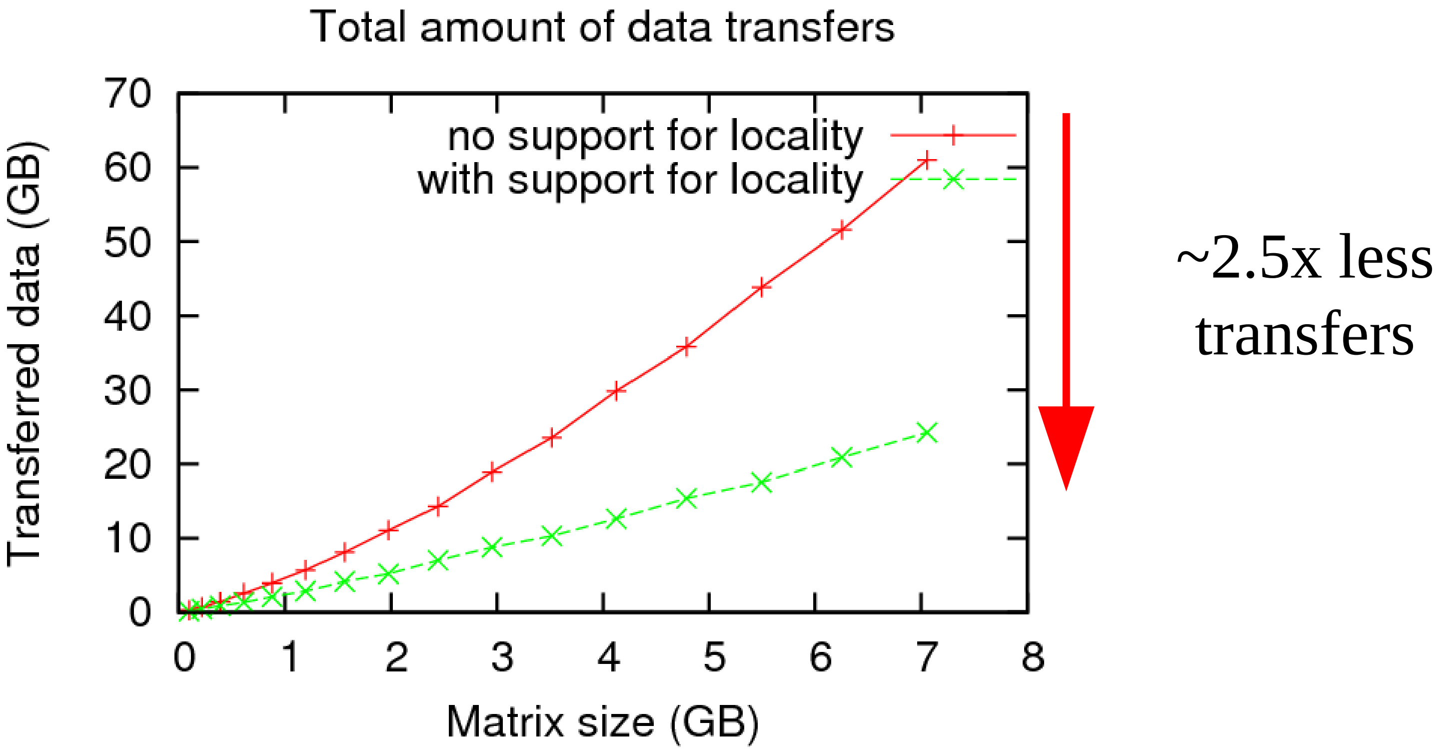


Mixing PLASMA and MAGMA with StarPU

- Memory transfers during Cholesky decomposition



Mixing PLASMA and MAGMA with StarPU

Perspective

- Add more algorithms
  - 2-sided Factorizations (eg. Hessenberg)
  - Solvers
- Going to be released as a standalone library
  - Toward a complete LAPACK implementation for hybrid computing
  - Need autotuning facilities!
- Next step: integrate MPI
  - On-going work
  - Accelerated SCALAPACK ?

Rodinia's CFD Solver

Rodinia's CFD Solver

Background

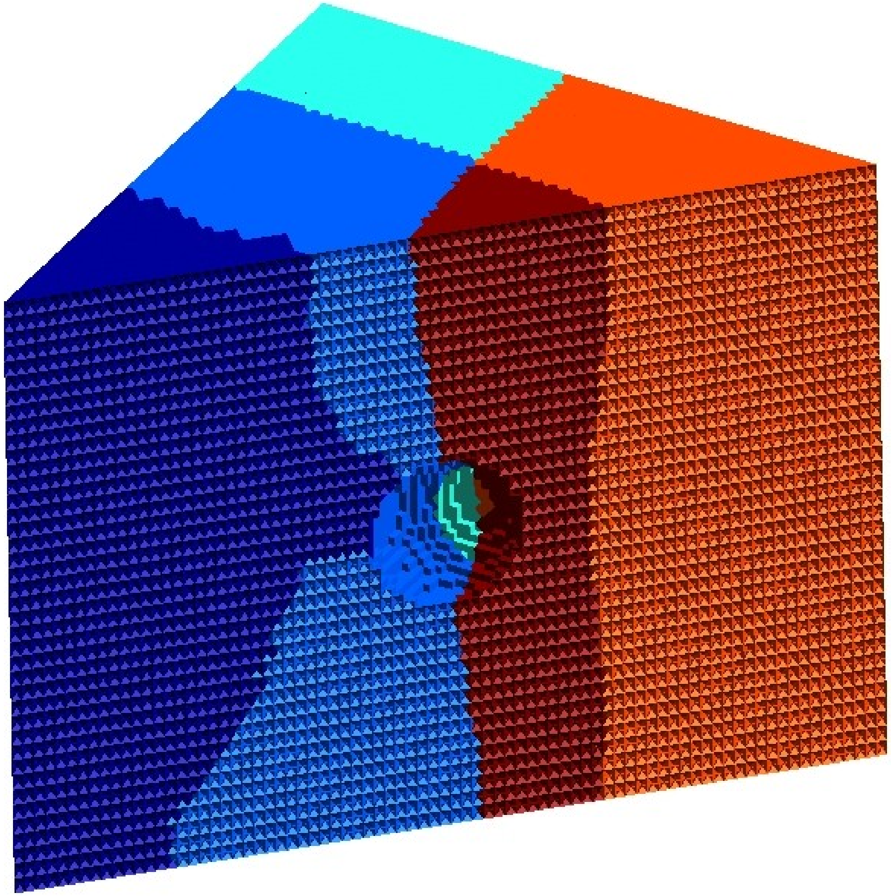
- The Rodinia benchmark suite
  - Cover the different « Berkeley Dwarves »
  - Available either in OpenMP or in CUDA
  - Neither multi-GPU nor hybrid systems

- Rodinia's CFD Solver benchmark
  - 3D Euler equations for incompressible flow
  - Unstructured Grid Finite Volumes
  - Memory intensive kernel
  - Pre-processing and Post-processing are not available
    - Need to create our own input meshes

Rodinia's CFD Solver

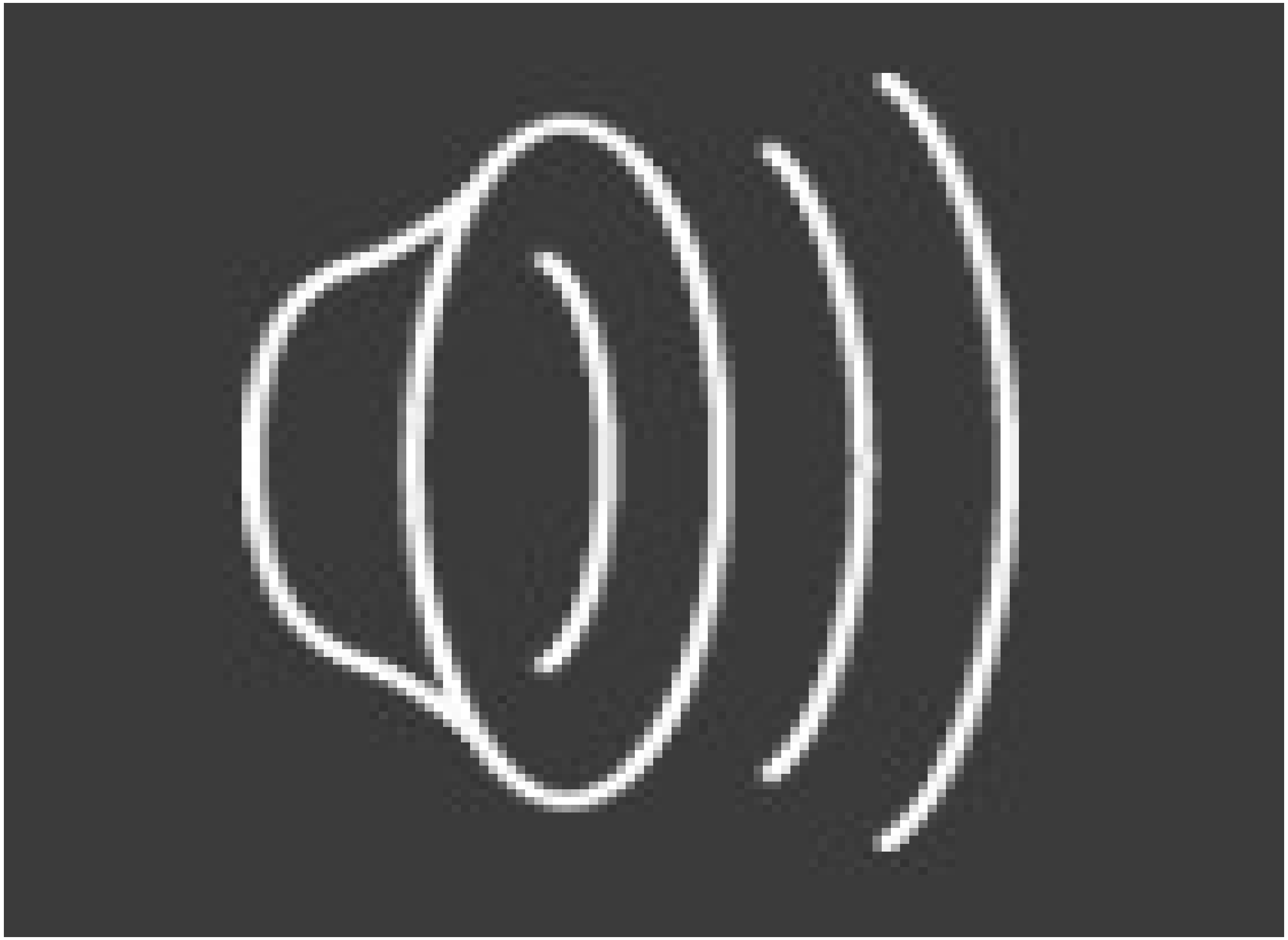
Methodology

- Pre-processing
  - Generated a mesh of the air around a sphere
  - Very simple yet !
- Parallelizing the problem
  - Partition the mesh using SCOTCH
  - 1 task = update 1 part
  - Redundant computation
  - Exchange part boundaries



Rodinia's CFD Solver

Post-processing



Rodinia's CFD Solver

Preliminary results

- Problem size
  - 64x64x64 grid, 1.3 Millions tetrahedrons
- Reference CPU performance
  - 1 core (Intel Westmere X5650)
    - 1.4s per iteration
  - 12 cores
    - 0.15s per iteration
- Preliminary performance with StarPU
  - 1 NVIDIA C2050
    - 53ms per iteration
  - 2 NVIDIA C2050
    - 28ms per iteration
  - We need large problems !

Rodinia's CFD Solver

Perspective

- Port in OpenCL
- Use hybrid platforms
  - GPUs are much faster than CPUs
    - Memory bound
    - Rather few tasks
  - Parallel CPU tasks
    - large granularity
- Heterogeneity-aware data layout
  - CPUs : Arrays of Structures (cache friendly)
  - GPUs : Structures of Arrays (SIMD friendly)

Conclusion

- StarPU
  - Data management & Task scheduling
  - Freely available under LGPL on Linux, Mac and Windows
- Adapted 3 PEPPHER benchmarks
  - FFTW + CUFFTW
  - MAGMA + PLASMA
  - Rodinia's CFD Solver

Conclusion

- Productive approach
  - Rely on existing kernels for CPU/GPU
  - Architecture independent task model
  - Higher-level front-ends would help
    - StarSs, HMPP, Codeplay's Offload

- Autotuning will be required
  - Need to find optimal granularity
    - Parallel tasks
    - Divisible tasks
  - Select code variants
    - eg. with SkePU