Scheduling Cholesky Factorization on Multicore Architectures with GPU Accelerators

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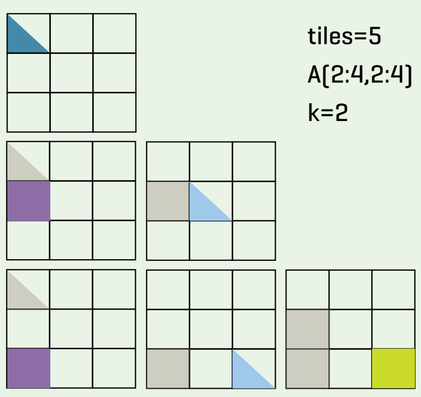
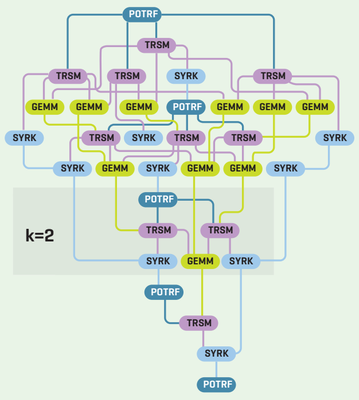
Although the hardware has dramatically changed in the last few years, nodes of multicore chips augmented by Graphics Processing Units (GPUs) seem to be a trend of major importance. Previous approaches for scheduling dense linear operations on such a complex node led to high performance but at the double cost of not using the potential of all the cores and producing a static and non-generic code. We schedule dense linear algebra operations on multicore architectures with GPU accelerators thanks to a runtime system capable of using the full potential of the node and that handles the data coherency. High-level algorithms – such as the Tile Cholesky Factorization – are represented as collections of tasks/kernels with a data-driven execution order. The kernels are taken from the PLASMA and MAGMA libraries and their execution scheduled through the StarPU runtime.

Tile Cholesky Factorization

For k=0..tiles-1
  A[k][k]<- **POTRF** (A[k][k])
  For m=k+1..tiles-1
    A[m][k] **TRSM** (A[k][k],A[m,k])
  For n=k+1..tiles-1
    A[n][n]<- **SYRK** (A[n,k],A[n,n])
    For m=n+1..tiles=1
      A[m][n]<- **GEMM** (A[m,k],A[n][k],A[m][n])



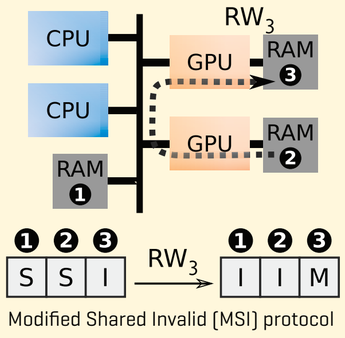


- Fine granularity
- Tile layout
- Asynchronism
- DAG to schedule

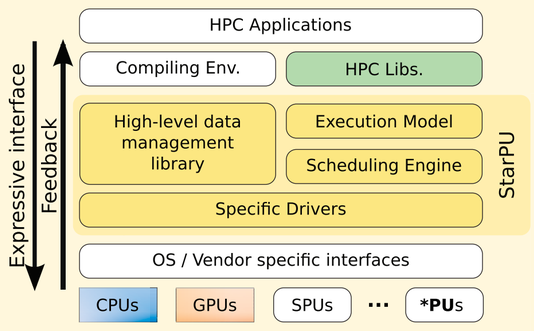
StarPU Runtime System

Download at http://runtime.bordeaux.inria.fr/StarPU/

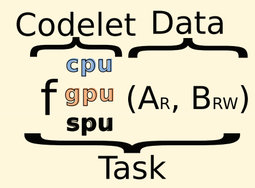
Transparent data management



A Unified Runtime System for Heterogeneous Architectures

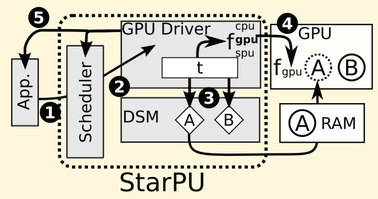


A Unified Task Abstraction



1. Asynchronously submit tasks
2. Schedule tasks onto processing units
3. Ensure data availability & coherency
4. Offload computation
5. Notify task termination

A Unified Execution Model



- Exploit all resouces
- Hide low-level complexity
- Performance portability

PLASMA CPU BLAS

Download at http://icl.cs.utk.edu/plasma/

Principle
- New BLAS (for QR and LU)
- Triangular on top of square

Cholesky Factorization
- Standard BLAS
- Wrapper on top of vendor

MAGMA GPU BLAS

Download at http://icl.cs.utk.edu/magma/

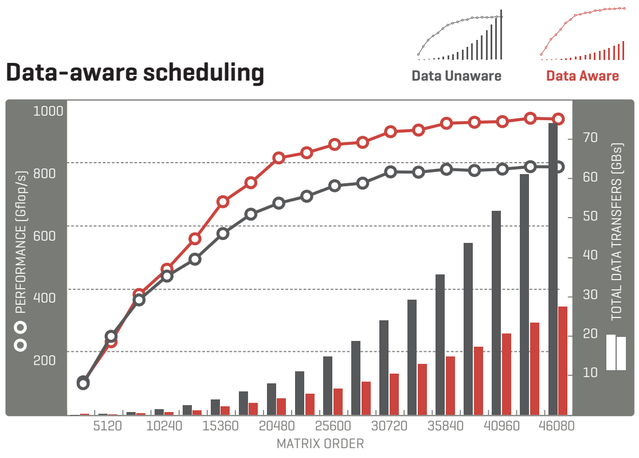
Principle
- CUDA BLAS
- Possibly hybrid CPU/GPU
- Auto-tuned

Cholesky Factorization
- Optimized SYRK and GEMM
- Special handling for TRSM
- Hybrid Kernels (magma_spotrf)

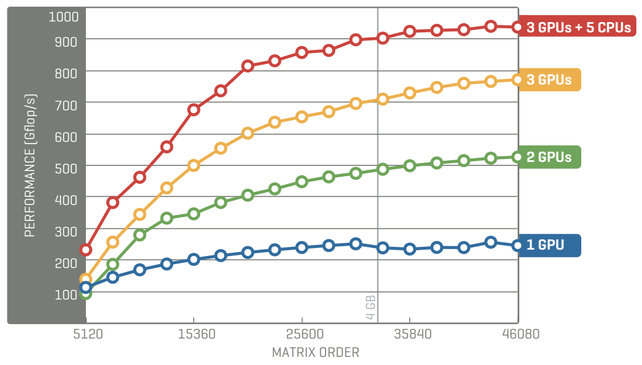
Performance Results

CPU Intel Nehalem X5550 @ 2.67 GHz, 8 cores - sgemm peak 20 GFlop/s per core
3 NVIDA FX5800 GPUs @ 1.30 GHz - sgemm peak 333 GFlop/s per CPU

Data-aware scheduling



Scalability



On-going Work

QR/LU Factorization
- Use of PLASMA CPU kernels
- Needs for new GPU kernels
- Coherency of Hybrid CPU/GPU kernels

Communication-Avoiding QR
- New high-level algorithm
- Needs for new GPU and CPU kernels

Distributed Memory
- Step1: One StarPU instance per node
- Step2: Distributed shared memory

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