Towards the Automatic Generation of Efficient Geometric Multigrid Solvers for Exascale Computing

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Project ExaStencils
- Generation of efficient, robust and exa-scalable geometric multigrid solvers

ExaStencils

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HHG data structures [1] and a 3D FD discretization on uniform grids

References:

Geometric Multigrid
- Smoothing of high frequency errors
- Coarsened representation of low frequency errors

Prototype Solvers and Generated Codes
- Prototype solvers for a 2D FD discretization of Poisson’s equation with HHG data structures [1] and a 3D FD discretization on uniform grids
- Both codes feature a broad spectrum of tunable options and are used to ensure scalability and to collect important data
- Generated solvers are examined as well

Convergence Prediction with LFA
- Local Fourier Analysis is used to predict the convergence rates of a given setting
- Allows the study of various parameter configurations

Performance Prediction and Optimization with SPL
- Apply techniques from the Software Product Line domain to predict the performance of multigrid solver configurations [2]

Code Generation with Scala
- Necessary due to the high variance of the multigrid domain
  - Hardware - CPU, GPU or both? Number of nodes, sockets and cores?
  - Cache characteristics? Network characteristics?
  - Software - MPI, OpenMP or both? CUDA or OpenCL? Which version?
  - MG components - Cycle type? Which smoother(s)? Which coarse grid solver? Which inter-grid operators?
  - MG parameters - Relaxation? Number of smoothing steps?
  - Optimizations - Vectorization? Temporal Blocking? Loop transformations?
  - Problem description - Which PDE? Which boundary conditions?
  - Discretization - Finite Differences, Finite Element or Finite Volumes?
  - Domain - Uniform or block-structured? How to partition?

Low-Level Optimizations
- Performance analysis and comparison of known techniques on different hardware architectures [3]
- Basic optimizations: explicit address precalculation, register blocking and vectorization
- Spatial and temporal blocking as well as a combination (overlapped tiling)

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