Comparing different graph models for partitioning tetrahedral grids on distributed-memory computers

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At RWTH Aachen University the finite element solver DROPS is being developed within the SFB 540 “Model-based experimental analysis of kinetic phenomena in fluid multi-phase reactive systems.” This parallel software package is designed to simulate two-phase flow problems arising from studying the behavior of droplets or falling films with a free surface. Typically, the analysis of such three-dimensional phenomena that are close to reality involves a high demand of both memory resources and computing time. To cope with these problems, we pursue two strategies: adaptive mesh-refinement and parallel computing. First, the refinement algorithm aims for locally refining the tetrahedral mesh in domains of interest. The output of this algorithm is a hierarchy of tetrahedral grids representing the computational domain. While evolving in time during the course of the simulation, the domains of interest may change, and thus, the hierarchy of tetrahedral grids may change as well. Second, the tetrahedra of the finest grid are distributed among several processes. In this domain decomposition setting, each process is responsible for a subdomain, which is represented by a subset of tetrahedra. Finding an appropriate distribution of the tetrahedra among the processes is generally done by graph partitioning techniques that decompose a graph into “equally-sized” subgraphs while minimizing edges connecting vertices in different subgraphs.

In this work, we present and compare graph models representing the tetrahedra hierarchy in DROPS. These models allow to distinguish between “computationally expensive” and “computationally inexpensive” tetrahedra. Therefore, algorithms for graph partitioning may find a distribution offering a good balance of the computational work while minimizing communication among processes. To augment the graph with information about computational effort, we utilize the degrees of freedom to weight each tetrahedron. This is of particular importance in the context of two-phase flow problems where the computational cost of tetrahedra may vary dramatically.

We conclude by giving detailed results when using different graph models. The numerical results are obtained by investigating several problems occurring in two-phase flow simulations performed by DROPS.

References:

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