Abstract

The research and analysis of partial differential equations is the basis for fundamental understanding of natural phenomena, practical science procedures and industrial applications. The numerical solution of such applications based on partial differential equations on unstructured grids in two or three dimensions is one of the most important problems in mathematical computation and simulation nowadays. To obtain reasonable solutions the approximation usually involves a large number of unknowns. Thus, it can only be solved in a reasonable amount of time by utilizing (massively) parallel computer systems with large memory space in a reasonable amount of time.

One of the main problems of numerical simulation software running on parallel computer systems is scalability and efficient usage of such a system. Therefore, a distributed data and object model especially designed for massively parallel finite element applications is presented in this thesis. The main characteristic of this object and data model is a local namespace usage for all elements within a partition of a distributed mesh. Mesh consistency on partition boundaries is automatically maintained by the distributed object model itself.

The object and data model of a distributed mesh is a key component for a simulation environment, because it connects the three main modules of a numerical simulation software, namely the numerical module, the (geometric) adaptation module and the workload balancing and data migration module. All these modules work on their own data model. Thus, an efficient conversion technique between these data models is required. The distributed object and data model developed in this thesis, offers an efficient and scalable approach for this important requirement in parallel simulation applications. The utilization of this mechanism is presented in detail for all three modules.

Mesh modifying modules like the adaptation and the migration module represent bottlenecks for the efficiency of the data structure in the object model. For this reason, two algorithms for these modules, both especially developed for massively parallel usage and working on the distributed data and object model, are introduced in this thesis. The geometric adaptation algorithm is based on irregular refinement and extended with an additional set of rules for quality conservation of element shapes. The migration algorithm works efficiently on large distributed meshes and provides an automatic scalable partition boundary reconstruction, which maintains the local namespace consistency requirement.

To evaluate and verify the object model and the algorithms working on it, a practical implementation in the framework *padfem*^{2} has been carried out. Several artificial benchmark sets are used for analysis of the three main modules and the results are presented in this thesis. Finally, a comprehensive numerical simulation benchmark for computational fluid dynamics is evaluated within the *padfem*^{2}-environment to proof the efficiency of the developed framework including object model, data structures and algorithms.