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Betreff: Dissertation of Aizhan Abylkasymova

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Report on the Dissertation

“Potential of hybrid OpenMP/MPI parallelization strategies for HPC software”

written and submitted by Mrs. Aizhan Abylkasymova

to obtain the scientific degree of a Doctor of Philosophy in Computer Science

Aizhan Abylkasymova submitted a dissertation with the title "Potential of hybrid OpenMP/MPI parallelization strategies for HPC software". The dissertation is devoted to the development of a dynamic load balancing (DLB) scheme that improves the performance of complex coupled simulations with non-trivial domain decompositions. The doctoral dissertation consists of 5 chapters devoted to the study of mathematical models for various large-scale problems and parallel numerical algorithms that solve the model equations. These chapters are briefly summarized in the following.

Chapter 1 discusses the main features and characteristics of high performance computing. This chapter summarizes the techniques used for the parallel execution of a simulation and explains the idea and benefit of a hybrid OpenMP/MPI parallelization.

Chapter 2 presents the analytical models used to determine the main characteristics of a parallel algorithm. The parallel efficiency of an algorithm is defined and strong and weak scaling tests are explained.

Chapter 3 introduces a mathematical model for the simulation of a flow in or around a body with complex geometric shape and the appropriate numerical methods for the solution of the fluid dynamical problem. This chapter provides the basic equations of fluid mechanics, which are the conservation for mass, momentum and energy. It also shows, how non-dimensional equations are obtained by choosing suitable reference values. The discretization of the conservation equations and the numerical solution method is described in detail.

Chapter 4 includes numerical studies to determine the computational efficiency of the simulation method for a backward facing step test problem. The necessary boundary conditions for the mathematical model are formulated first, before a detailed description of the parallel numerical algorithm is presented. The chapter also includes the evaluation of the efficiency of the parallel algorithm.

Chapter 5 contains the results of numerical studies of the efficiency of high-performance computing using a hybrid OpenMP/MPI parallel algorithm for the simulation of the flow in a human respiratory tract. In

more detail, the flow inside the nasal cavity is predicted, where the complex geometry of the interior part of the nose is determined from computer tomography data of a patient with impaired breathing capabilities. The large scale simulations of the flow through the nasal cavity also demonstrate the effectiveness of the DLB scheme. A detailed performance analysis showed the DLB method to be necessary to reduce the load imbalances, which are caused, e.g., by various boundary conditions which generate different workloads on the individual subdomains. Such imbalances are difficult to avoid by using a static domain decompositioning based on a priori estimated computational weights. Therefore, the DLB method is a key ingredient to achieve a high parallel efficiency. The strong scaling tests performed showed an increasing performance improvement with increasing degree of parallelism when a DLB method is used. All major results presented in the dissertation have been published in peer-reviewed international and local scientific journals.

During her research, Aizhan Abylkassymova conducted two scientific internships at the Institute of Aerodynamics of the RWTH Aachen University. During the time she spent in Aachen, she studied the strategies of parallel computing for various large-scale related problems that were executed on the computing cluster of RWTH. During her internship at the Institute of Aerodynamics, Aizhan Abylkassymova proved that she can independently conduct scientific research at the highest level.

The results of the dissertation work of Aizhan Abylkassymova are new and at a high international level. Therefore, her doctoral dissertation definitely meets all requirements for a high level dissertation in the field of computer science.

To summarize, there is definitely no doubt that Aizhan Abylkassymova's dissertation with the title "Potential of hybrid OpenMP/MPI parallelization strategies for HPC software" should be accepted for the defense of the scientific degree of Doctor of Philosophy in 6D060200 – Computer Science.

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