A Novel Approach to Interactive, Distributed Visualization and Simulation on Hybrid Cluster Systems

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Abstract

The introduction of hybrid cluster systems, which consist of several heterogeneous groups of homogenous nodes (e.g. computing nodes, visualization nodes, hardware-accelerated nodes) marks a paradigm shift in the usage of cluster systems. For the first time, the powerful hardware is open to applications other than classical high performance computing (HPC) applications, such as number crunching and massively parallel simulations. Various new fields of science and industry could use it as a powerful new tool for simulation and visualization. Interactive simulations and their visualization as well as Virtual Reality applications are areas where HPC on hybrid cluster systems can bring significant benefit in many aspects, as for example realism, multiple comparative simulations, multiuser-support etc.. But, to enable and to later-on ease the utilization of the complex cluster systems for such simulations, tools to orchestrate and access these resources are needed. Existing applications should be quickly able to run on and to benefit from the new hardware with only little effort and changes in source code. Currently there are only few systems that (partially) fulfill these tasks. Most of the existing ones for traditional HPC applications lack important features to provide the desired interactivity and flexibility.

This thesis addresses two main aspects of this problem and introduces concepts for the computational steering (CS) and the remote visualization (RV) of interactive simulations and Virtual Reality (IS/VR) applications on hybrid cluster systems. The main focus is to conserve the interactivity and user-integration of these applications and, at the same time, dramatically extend their features by harvesting the power of the hybrid cluster architecture. Thus, the main contribution of this thesis is the introduction of two new subsystems, one for the steering and orchestration of the application's distributed components (CS) and one for the remote access to the interactive graphical applications running on the cluster (RV). The concept for the CS framework bases on three new models for the steering of IS/VR applications that significantly differ from the model used for traditional CS. Besides the original idea that a running simulation is observed and controlled by a connected visualization, many parts of traditional CS needed to be redesigned and adapted to the needs of IS/VR. Especially interactivity and flexibility play a big role during the conceptual design of the system. The

proposed framework and its implementation is tested and evaluated by realizing distributed versions of two existing IS/VR applications and is further showing that these applications greatly gain on flexibility, performance and quality for the users. Thereafter, the introduction of a framework for RV gives the users graphical access to the applications running on the cluster system. Again, the developed system takes the idea of traditional RV (e.g. for remote administration purposes) and transfers it to the domain of IS/VR, where interactivity and high quality are of highest importance. To achieve these goals, the developed system, as the first of its kind, makes use of powerful graphics cards for image compression. Until now, these GPUs (Graphics Processing Unit), built into most of the existing hybrid clusters, were almost exclusively used for the rendering of the results of HPC simulations. But, only recently these processors have become available for general purpose computing through the introduction of new and universal APIs. By different benchmarks it is shown that the performance of the remote visualization is thereby improved in many cases. Additionally, the framework is able to use the flexibility that clusters provide, to allow the remote access to multiple, simultaneously running applications on the cluster by multiple users.

All in all, a novel approach to effectively use hybrid clusters for interactive simulations and VR applications is presented, and the findings are manifested by exemplary applications and various benchmarks.