Design of a Multi-modal Interactive Simulation Framework

by

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ABSTRACT

Multimodal interactive simulations (MIS) are increasingly finding applications in highly realistic virtual environments as well as in engineering analysis such as computational steering. However, as computational capabilities have increased over the years, so have the complexity of the simulated scenes. It is not unusual to demand a MIS that involves heterogeneous scenes composed of different states of matter; complex geometry and material properties of the objects within the scene; multi physics interactions and multimodal (visual, auditory and haptic) rendering of the results to the user. Moreover, users may be geographically separated and may have different connectivity and hardware platforms. Developing a MIS has traditionally been a highly demanding task that usually requires a multidisciplinary research team that must be proficient in physics-based computing, software management, and network architecture and computer graphics.

In this thesis we present the design, development and optimization of a novel **Software Framework for Multimodal Interactive Simulations** (**SoFMIS©**) that substantially automates the process of generating domain-specific custom MIS by using some or all of its modules. Techniques to overcome long standing MIS performance issues including multi-core support for simulation execution, decision-based resource management to adaptively adjust the simulation performance under varying loads based on hardware counters, and simulation using modern graphical processing units (GPU) have been proposed. Benchmarks tests have been performed to quantify the performance of SoFMIS© which show that the framework successfully utilizes the hardware resources and improves the performance of multiple components running with different frequencies with increasing load.

A logical extension to **Platform Independent SoFMIS© (Π-SoFMIS©)**, albeit with necessary modifications in architecture, is presented which allows **SoFMIS©** to run on a variety of hardware platforms ranging from desktop PCs to mobile devices. However, the cost of accessibility and portability is reduced performance compared to native SoFMIS© applications and difficulty to maintain consistent simulation for

different hardware devices. Therefore, an optimization model has been proposed for Π-SoFMIS© that substantially automates the customization of the complex interactive environments that satisfy visualization and simulation execution constraints on the user hardware. In order to achieve real-time rates and simulation constraints, a novel parallel language and compiler has been developed. Realistic applications, particularly in the area of medical simulations, have been provided to demonstrate the effectiveness of the frameworks.