

Preface

The ever increasing complexity of sophisticated technical and mechatronical systems demands for highly optimized development processes. With the ongoing computer hardware evolution, simulation systems became an indispensable part in research and development, particularly in robotic applications. These systems have to simulate a large number of sub-systems and their collaboration in different domains, which are known under the term "Multi-Domain Simulation Systems". In early systems the focus was put on numerical results with rather functional representations. With the emergence of Virtual Reality (VR) technology in the early 1980s, VR simulation systems firstly allowed a more intuitive representation of the generated results to gain insight into corresponding systems and their operation. In particular, the evolution of graphics hardware and the advances in real-time rendering have made a key contribution to the increasingly realistic virtual worlds we know today. While current entertainment domains fully exhaust the technical possibilities of modern graphics hardware and state of the art rendering approaches, many simulation-centric domains still rely on purely functional graphics. Apart from different goals and target groups of both domains, this development is due to technical reasons. While computer graphics applications demand for highly specialized, rendering-centric data and system structures in order to grant real-time performance and efficiently adapt novel rendering techniques, simulation applications may be optimized for other purposes that rely on completely different structures. These structural differences, which define the gap between rendering- and simulation-centric frameworks, have not yet been closed in a sustainable manner.

In this thesis, concepts for system and data structures that allow to realize a unifying approach are proposed and evaluated, which are capable of facing the arising challenges when expanding to new domains or adapting to novel technical trends. Modern software design patterns, as well as the concepts of semantic world models and graph databases provide new opportunities for the development of modern "Multi-Domain VR Simulation Systems". These holistic systems offer new chances through the combination of complex numerical simulations at scientific level with attractive real-time computer graphics that consider aesthetic aspects. Attractive imagery is not only an important form of support to understand complex mechanisms and correlations, it also drastically increases acceptance of simulation technologies. Last but not least, the vital role of high quality demonstrations of project ideas and results in attractive virtual worlds as a sales argument for possible follow-up projects must not be neglected. By closely tailoring together simulation and rendering, arising synergy effects can not only be used to create and render close-to-reality virtual environments with little effort; moreover, advanced rendering techniques can also be applied to directly support certain simulation tasks like interactive data visualization or optical sensor simulations. The resulting benefits will be demonstrated by a broad range of applications and projects, which have been realized with the presented multi-domain VR simulation system as a result of bridging the gap between simulation and rendering frameworks in a sustainable and intuitive way.

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people. Yet, I hope that all of them know, how deeply I appreciate what they have done for me.

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