Interactive Exploration in Virtual Environments

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Chapter 7

Summary and concluding remarks

7.1 Summary

Over the last years, computers have become increasingly powerful. As a consequence, researchers are now able to study increasingly large and complex problems. However, this development has led to a situation where the size and complexity of the data spaces that are generated by these problems have increased as well. Often, it turns out to be quite difficult to analyse this data using computer algorithms, either because suitable algorithms do not exist, or because existing algorithms would take too long to find an acceptable result. In these cases, interactive exploration environments may be the only suitable alternative. This thesis makes a distinction between static and dynamic exploration environments. In static environments, the data under study has been generated at an earlier time and will, therefore, not change during exploration. In dynamic environments, the data under study is generated by a computer process that is active *while* the exploration takes place. This would make it possible to not only study the running process, but also alter its course.

In an interactive exploration environment, the data under investigation should be represented to the researcher in an understandable and accurate way. Within the area of scientific visualization, several methods have been developed to accomplish this, but in some cases the complexity of the data can be such that the resulting images are still insufficient to obtain insight in the phenomena under study. In these cases, Virtual Reality (VR) may provide a suitable alternative.

The aim of a a Virtual Environment (VE, the environment that is generated by a VR system) is to immerse the researcher in a representation of his data. To achieve this, the data is represented as a collection of virtual objects in a computer generated artificial world. As in the real world, interaction with these objects enhances the experience of "presence" in the environment, thereby breaking the conventional barrier of a flat computer screen, keyboard and mouse and increasing a researcher's involvement with his data.

Three case studies were built to obtain a better understanding on the available technology, the applications and scientific issues involved in the construction of a usable exploration environment (Chapter 2). These showed that there were still significant challenges that inhibit the productive use of these environments. The experiences did show that for some applications a VE can help in obtaining a better insight in large and complex data sets.

Until recently, the use of VR required a significant financial investment that was hard to overcome by many. At the end of the Nineties, the performance and price of commodity-of-the-shelf personal computer (PC) hardware was such that it would, in principle, be possible to build a low cost VR system out of easily available components. Chapter 3 describes the design and construction of a PC hardware based VR system and shows that these systems can compete with commercially available solutions.

Essential building blocks were still missing that hampered the construction of a successful interactive exploration environment for scientific research. Chapter 4 describes a number of techniques and interaction methods that address these problems. SCAVI allows the application developer to include existing scientific visualization algorithms into VEs, including methods that allow the researcher to interact directly with these visualizations in an intuitive manner. XiVE bridges a gap by enabling existing 2D desktop applications and graphical user interface toolkits to be used in virtual environments. Automatic speech recognition provides a powerful alternative over graphical interaction methods and, through the use of environment context, the performance of speech recognition can be improved. GEOPROVE allows the researcher to perform measurements on visual entities presented in the virtual environment.

A dynamic environment can benefit from a design where the process under study is separated from the component that represents the data and the component from which the exploration is coordinated. This would allow these different components to execute on dedicated hardware if that could make them perform more efficiently. However, as a consequence, some means of communication must be established between the distributed components. Chapter 5 addresses the issues involved in the design of dynamic environments and describes several architectures that allow these environments to exploit specialized computing resources through a distributed design. Because the exploration environments that are of concern to this research are intended for the exploration of *large* data and problem spaces, the communication performance of these architectures was described in some detail and a number of techniques was described to increase performance.

Based on the design issues addressed in the previous chapters, Chapter 6 describes a test-case environment that has been designed and built for an application from a medical domain: simulated vascular reconstruction. Here, a virtual environment for the representation of 3D angiography scans is connected to a computational fluid solver to simulate blood flow through vascular structures. Interactive scientific visualization techniques allow the researcher to explore the morphology of the structures and the flow behaviour through these structures. Additional interaction techniques allow the researcher to modify the vascular morphology. This environment allows human-in-the-loop simulations through which the researcher can simulate the influence of a proposed treatment on blood flow for a particular patient.

7.2 Concluding remarks

Our description of the construction of conglomerate applications out of distributed executing components in Chapter 5 is currently under review within the Section Computational Science. Several research initiatives are being explored that can help in the development of collaborative interactive dynamic exploration environments for the construction of generic Problem Solving Environments (PSEs). One such initiative is the "Open Grid Services Architecture" (OGSA) that builds on concepts and technologies of the Grid and Web services community in order to define an architecture that provides uniform exposed service semantics [82, 83].

The description of the medical application in Chapter 6 primarily focuses on the software architecture of an environment that can assist a surgeon in his decision process. Although we addressed some of the user interface issues in this design, we have not looked in detail at the usability issues of the particular VR configuration that is most suitable for this application. Clearly, one particular VR configuration will not be suitable for every imaginable application. Current work in our research group includes initiatives to design and build alternative displays, interaction devices and interaction methods that provide a more intuitive interface to the application at hand.