Chapter 16
Visualization:
Future Technology and Practices for Computational Science and Engineering

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ABSTRACT

This chapter focuses on state of the art at the intersection of visualization and CSE. From understanding current trends it looks to future applications for these technologies. Some background is provided into visualization and its relation with CSE as well as with software and hardware frameworks that visualization systems depend on. Important emerging research areas are identified, including: interactive simulation and computational steering; collaborative, remote visualization and visualization services; VR technologies for visualization; user experience and assessment; teaching and serious gaming; communicating science to the public; ultra-scale visualization; and computational aesthetics. This should present the readers with real possibilities for CSE no matter what their disciplinary background.

INTRODUCTION

Visualization is a technology that provides pictorial descriptions of results from computations and simulations and as such it is a vital component of CSE. It is a fairly mature technology providing not only an ever widening set of presentational techniques but also, among other things, a framework for visualization systems that can be extended to remote/distributed visualization services, techniques for handling and rendering large data and the more efficient exploitation of high performance computing (HPC). Though visualization is very prominent in Computational Science and Engineering (CSE) it can be applied to many other areas such as data mining and infor-

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matics. Just as computational science is divided into separate communities interested in specific application areas or mathematical/programming approaches so too is visualization.

This chapter focuses on the general area of visualization. Just as there are many distinct mathematical approaches to developing computational simulations each with their own dedicated communities, visualization also divides itself amongst different application areas and/or mathematical approaches. Here, however, we will use application areas or programmatic issues only to illustrate more general trends, except when discussing special cases that are part of the current research scene. Interested readers should consult textbooks referenced for more balanced and wide ranging examples.

Who Should Read This Chapter

Researchers with a variety of backgrounds and job roles will have an interest in visualization. This chapter starts with the general to build the reader's understanding of pertinent issues (the background of visualization; its relation to computer graphics and computer science departments; the visualization pipeline and how this abstraction relates to the general frame work of visualization systems as well as its dependence on hardware; ending with the background to CSE). The chapter then looks at seven visualization research areas relevant to CSE:

- Interactive simulation and computational steering;
- Collaborative, remote visualization and visualization services;
- VR technologies for visualization;
- User experience and assessment;
- Teaching and serious gaming;
- Communicating science to the public;
- Ultra-scale visualization;
- And computational aesthetics.

All readers should get some benefit from these, but we have mainly aimed at three kinds of readers:

- **Visualizers,** who are often specialized in one area of visualization, may find the discussion of more general issues useful as well as finding interest in issues in other areas of visualization research.
- **Practitioners of CSE with interests in a specific area of visualization** will have a variety of needs, skills and knowledge. They will benefit from the general issues and also from selecting relevant topics from those discussed in more detail.
- **CSE managers and policy makers:** in general, this group needs to be aware of the hardware and software needs the visualization professionals require to do their jobs. The CSE manager needs to understand the separation and intertwined nature of CSE and visualization and the way their needs differ with the CSE problems under consideration.

BACKGROUND

Visualization is an integral part of computational science and so during the relatively short history of their relationship there have been several attempts to understand the benefits visualization offers. The National Science Foundation in the United States of America (USA) commissioned an extensive report entitled "Visualization in Scientific Computing" (McCormick et al, 1987). The report brought together experts in computer graphics via the Association for Computing Machinery's Special Interest Group on Computer Graphics (ACM-SIGGRAPH) to define and highlight computer generated visualization. The report defined visualization as "a method of computing... a tool both for interpreting image data fed into a computer, and for generating images from complex multi-dimensional data sets". The importance