ACM SIGGRAPH 99 Course #21 Notes

Internetworked 3-D Computer Graphics: Overcoming Bottlenecks and Supporting Collaboration

Introduction:

The concept of Internetworked Graphics is used here to describe the merger and dependencies of computer graphics applications and the networking infrastructure. During this course, we will provide an overview of network infrastructure issues relating to interactive 3-D graphics. Relevant networking capabilities, available to all users, will, hopefully, be demonstrated in real time. We show how the Mulitcast Backbone (MBone) functions to support real time video and audio. Collaborative work tools that incorporate computer graphics functionality across the Internet are also be discussed and demonstrated. The relationship of OpenGL, VRML, X3D, Java/Java3D, MPEG, Chromeffects, HTML, and XML, to Internet, streaming and Distributed Interactive Simulation (DIS) protocols is reviewed. We also cover High Level Architecture (HLA) applications.

We will highlight how the development of the next generation of Web software is dependent on effective implementation of Internetworked Graphics concepts. Those developing networking protocols and MBone capablities will need to factor in the impact that the next - generation Virtual Reality Modeling Language (VRML), interactive visualization, and large scale virtual enviroments (LSVE) methods have on future bandwidth and latency requirements. Those creating interactive graphics tools for the Web and the Internet will want to understand the underlying networking standards and infrastructure in order to build effective 3-D collaborative applications. This is especially true with regard to efforts to create content with the next generation VRML which is entitled "Extensible 3D" (X3D). X3D will be compatible with the Extensible Markup Language (XML) for the Web. Integrated approaches allow us to move beyond the bottlenecks and roadblocks of Internetworked Graphics.

This course begins with an overview of 3-D Interactive Graphics using the Internet. Next, we discuss the concepts behind the Internet Protocol (IP) and other telecommunications components for interactive graphics. In the afternoon, we provide a practical viewpoint on integrating Internet Engineering Task Force (IETF) standards with 3-D programming paradigms. Finally, we focus on human-computer interaction issues and a taxonomy for distributed networked graphics. Throughout this course, we will provide real time demonstrations of collaborative networked 3-D graphics applications and distributed virtual environments.

We hope you enjoy participating in this course and reading these notes.

Theresa Marie Rhyne, Bob Barton, Don Brutzman, and Mike Macedonia

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Internetworked 3-D Computer Graphics Course Outline:

I. Introductory Remarks -- Rhyne

Motivation and expected outcomes. Organization of course and demos. (5 minutes)

II. Overview of 3-D Interactive Graphics using the Internet -- Rhyne (45 minutes)

A big-picture description of the key issues and practical aspects of internetworked graphics and collaborative visualization across the Internet are reviewed. Six components of Internetworked Graphics are highlighted: connectivity, content, interaction, economics, applications and personal impacts. Several examples of information visualization and virtual reality are presented that illustrate how 3-D graphics can be used to help solve key problems in global networking. We show that interactive graphics and visual information retrieval can provide new insight into key web and network problems such as topology visualization, web searching, performance optimization and network monitoring. Internetworked graphics is a two-way collaboration that can significantly benefit by cooperative work between the computer graphics and networking communities.

MBone and Internet based Virtual Environment Demonstration - Rhyne and all instructors. (30 minutes)

Java, MPEG and VRML applications that demonstrate collaborative exploration of 3-D graphics will be shown. We will also demonstrate 3DML (a 3-D XML type language) content. Internet-Multicast applications (e.g. the MBone) will also be introduced.

Morning Break

III. Internetworked Graphics: Capabilities, Shortfalls, Frontiers -- Brutzman (45 minutes)

Networking and graphics are two halves of an interlocking whole: large-scale virtual environments (LSVEs). Concepts to be presented include the Internet Protocol (IP), unicast/broadcast/multicast, http, streaming protocols, MBone audio/video/whiteboard/image streams, the Distributed Interactive Simulation (DIS) protocol, behavior protocols, etc. Recent work to support the integration of DIS-Java-VRML along with real time demonstrations of applications that use this DIS-Java-VRML pubic domain software will be highlighted. The notion of a Virtual Reality Transfer Protocol (vrtp) will be introduced and described. The proposed concept of vrtp is designed to support VRML in the same manner that http supports HTML. (See: http://www.stl.nps.navy.mil/~brutzman/vrtp/). We will show how to tie network bottlenecks to performance just as we evaluate graphics bottlenecks.

MBONE and Virtual Environment Demonstration - Brutzman and all instructors. (30 minutes)

A series of example programs of immediate practical use for networking graphics are demonstrated. We use the DIS-Java-VRML library (www.stl.nps.navy.mil/dis-java-vrml) to show how ordinary VRML scenes can be easily composed and internetworked. We compare and contrast Java+VRML with a Java3D example. If possible, we will continue to collaborate, in real time, with remote sites via the Multicast Backbone (MBone), showing public domain audio, video and behavior streams together with 3D VRML. Source code and web pointers will be provided throughout.

Lunch

IV. Integrating IETF Standards with 3D Programming Paradigms & Issues in Distributed Virtual Environments-- Barton (45 minutes)

Activities of the Internet Engineering Task Force (IETF) and how they integrate with 3-D programming paradigms will be discussed. Here we present how the IPv6 suite from the IETF impacts developers and content creators using OpenGL, Java3D, OpenGL++/Fahrenheit, VRML and Chomeffects. After discussing these integration efforts, issues and applications relating to distributed visualization and virtual environments are discussed. This allows us to see how network infrastructure issues integrate with real time internetworked 3-D graphics applications.

Collaborative Virtual Reality Demonstration - Barton (30 minutes)

A real time demonstration of a case study and results of remote collaborative design work between U.S. and Germany by Fraunhofer Center for Research in Computer Graphics will be presented. Key issues for usability and effectiveness: bandwidth, latency, multiple users, integrating multimedia with 3-D graphics will also be discussed and highlighted. The "nuts and bolts" process and the bottlenecks associated with implementing this Internetworked 3-D Computer Graphics application will be revealed.

Afternoon Break

V. Human-Computer Interaction Issues and A Taxonomy of Distributed Virtual Environments -- Macedonia (45 minutes)

Building upon the IETF discussion and the collaborative virtual environment demonstration, we then provide an overview of human-computer interaction issues and a taxonomy of distributed virtual environments (DVEs). The tradeoffs between bandwidth, latency, frame rate, packet loss, and router congestion, will be reviewed. Current efforts of military and government researchers to develop a High Level Architecture (HLA) for DVEs and the importance of interaction with the entertainment community will be discussed.

MBONE and Virtual Environment Demonstration - Macedonia and all instructors. (30 minutes)

Practical demonstrations of networked simulators used for skill-based and cognitive level learning will be shown. High Level Architecture (HLA) applications will be demonstrated and reviewed in real time. We will include computer games examples and build up to training on distributed networked simulators. These demonstrations are intended to show human-computer interaction issues and skill development.

VI. Closing Remarks -- Rhyne (5 minutes)

Instructors' Biographical Information:

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