COURSE NOTES

18

Beyond Bottlenecks and Roadblocks: Internetworked Computer Graphics

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ACM SIGGRAPH 97 Course #18

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Internetworked Computer Graphics

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Abstract: Although networking and computer graphics are considered to be distinct disciplines, they have begun to converge. For example, both graphics and networking must be considered together when using 3D for collaborative exploration, information visualization and large-scale virtual environments (LSVEs). This course presents an introduction to networking concepts for using and developing interactive Internet-based graphics applications.

Software and tools associated with the Multicast Backbone (MBone), hypertext transfer protocol (http) and the Virtual Reality Modeling Language (VRML) will be demonstrated. Collaborative remote design projects will be presented as case studies. We will show first-hand examples of the capabilities and tradeoffs involved when interactive 3D graphics are combined with the World Wide Web and live information streams across the Internet. Finally we discuss how the SIGGRAPH community is affected by (and can likewise influence) Internet Engineering Task Force (IETF) standards, the ACM Special Interest Group on Communications (SIGCOMM), the VRML Consortium and other standards-related organizations.

I. 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 examine how telecommunication breakthroughs provide new opportunities for interactive three-dimensional graphics across globally interconnected dissimilar networks. 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 Virtual Reality Modeling Language (VRML) and interactive visualization 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 integrated approach allows us to move beyond the bottlenecks and roadblocks of Internetworked Graphics.

This course begins with an overview of 3D 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 will discuss human interaction issues and focus on a specific global remote collaboration case study. Next, Internet Engineering Task Force (IETF) standards and their impact on computer graphics will be highlighted. We conclude our course with a discussion on how 3D graphics and information visualization can help solve key problems in global networking. Real time demonstrations will be presented throughout our course.

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

Theresa Marie Rhyne
Bob Barton
Don Brutzman
Mike Macedonia

ACM SIGGRAPH Course #18: Beyond Bottlenecks and Roadblocks: Internetworked Computer Graphics
Course Outline - (August ?, 1997)

I. Introductory Remarks -- Rhyne

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

II. Overview of 3D Interactive Graphics using the Internet -- Rhyne

A big-picture description of the key issues and practical aspects of internetworked graphics. (45 minutes)

MBone and Virtual Environment Demonstration - Rhyne and all instructors. Introduce remote participants and explain basic audiovisual setup.
(30 minutes)

For all demonstrations, remote collaboration will include off-site participants and applications shown in the Electric Garden. We will multicast audio and video globally throughout. We will also use GraphicsNet and SIGGRAPH TV to provide high-bandwidth streams to the convention site.

Morning Break

III. Internetworked Graphics: Capabilities, Shortfalls, Frontiers -- Brutzman

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. We will show how to tie network bottlenecks to performance just as we evaluate graphics bottlenecks. (45 minutes)

Concepts are described in "Internetworked Graphics: Bottlenecks and Breakthroughs," chapter in Digital Illusions, editor Clark Dodsworth, Addison Wesley, to appear 1997. Available at http://www.stl.nps.navy.mil/~brutzman/breakthroughs.html

MBONE and Virtual Environment Demonstration - Brutzman and all instructors. Discuss the usefulness of live audio/video and Web connections with remote participants who are following the presentation. Demonstrate basic operation of MBone software tools, note strengths and weaknesses as they are encountered. (30 minutes)

Lunch

IV. Human-Computer Interaction Issues across Local and Global Networks -- Macedonia

Present case study and results of remote collaboration design work between U.S. and Germany by Fraunhofer Center for Research in Computer Graphics. Discuss key issues for usability and effectiveness: bandwidth, latency, multiple users, integrating multimedia with 3D graphics. (45 minutes)

MBONE and Virtual Environment Demonstration - Macedonia and all instructors. Demonstrate the tradeoffs between bandwidth, latency, frame rate, packet loss, router congestion, etc. Demonstrate an example collaborative work session. (30 minutes)

Afternoon Break

V. Internet Engineering Task Force (IETF), SIGCOMM, VRML Consortium Overview -- Barton, (with Macedonia & Brutzman)

What are the IETF standards under development that will impact the computer graphics community? We will describe the standards process and how to access information regarding Internet Protocol design and employment. Explain the goals and activities of ACM SIGCOMM. Discuss participation opportunities and related organizations such as the VRML Consortium, World Wide Web Consortium (W3C), International Standards Organization (ISO), others. (45 min)

MBone Discussion - questions and dialog by local and remote participants, moderated by instructors. (Barton, facilitator)

VI. Information Visualization and Virtual Reality across global networks: how close are we to smooth surfing? Where do we go next? -- Rhyne

Several examples of information visualization and virtual reality are presented that illustrate how 3D graphics can be used to help solve key problems in global networking. We show that interactive graphics can provide new insight into key network problems such as topology visualization, performance optimization and network monitoring. Internetworked graphics is a two-way collaboration that can significantly benefit by cooperative work between SIGGRAPH and SIGCOMM members. (45 min)

MBone Discussion - all instructors, local and remote audience (30 minutes)

Instructors' Biographical Information:

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Robert J. Barton III has recently joined the staff of Fraunhofer Center for Research in Computer Graphics (in Providence, Rhode Island) as an Engineer and Project Leader for the Transatlantic Research and Development Environment (TRADE). His engineering career has included included engineering billets on US Naval Surface ships, instructor duty at the Naval Academy, and systems engineering branch head for the Trident Missile Program of Strategic Systems Programs Office, Sunnyvale, CA. His areas of research include VLSI High-radix arithmetic circuits, computing the average number of nodes of Ordered Binary Decision Diagrams (OBDDs), and the modeling and analysis of multicast network protocols. For this course, Bob will be presenting the SIGCOMM - networking viewpoint and will handle logistics issues for the real time networked demonstrations.

Don Brutzman
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Don Brutzman is a computer scientist working in the Interdisciplinary Academic Group at the Naval Postgraduate School. His research interests include underwater robotics, real-time 3D computer graphics, artificial intelligence and high-performance networking. He has highlighted networking issues in panel presentations at SIGGRAPH 94 & 95 and organized the "VRML: Prelude and Future" panel at SIGGRAPH 96. Recently, he was the chair of the VRML 97 Symposium. He is a member of the Institute of Electrical and Electronic Engineers (IEEE), the Association for Computing Machinery (ACM) Special Interest Group on Graphics (SIGGRAPH), the American Association for Artificial Intelligence (AAAI) and the Virtual Reality Modeling Language (VRML) Consortium.

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Michael R. Macedonia is Vice President in charge of developing global virtual environments for commerce, government and education at the non-profit Fraunhofer Center for Research in Computer Graphics (CRCG). He has worked extensively with the multicast networking community and has written one of the most often referenced publications in that area. He also contributed to the National Academy of Sciences report entitled "Virtual Reality: Scientific and Technological Challenges" detailing the networking and communications research needed to continue the development of virtual reality systems. At SIGGRAPH 96, he was a panelist on the "Global Multi-User Virtual Environments" panel. He is a member of both ACM SIGCOMM & SIGGRAPH.

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Theresa Marie Rhyne is currently a Lead Scientific Visualization Researcher employed by Lockheed Martin Technical Services at the U.S. EPA Scientific Visualization Center. From 1990-1992, she was the technical leader of the U.S. EPA Scientific Visualization Center and was responsible for building the Center since its founding in 1990. She was the SIGGRAPH 96 Panels Chair and currently serves as a Director at Large on the SIGGRAPH Executive Committee. Her research interests include visualization toolkit development, collaborative computing in a networked environment and the integration of geographic information systems with scientific visualization methods.