

Research Statement

Ganesh Sankaranarayanan

April 30, 2007

Overview

Undoubtedly, these are exciting times for the field of Haptics, clearly seen by the number of scholarly articles published in both journals and conference proceedings in the past few years; a figure that is still on the rise and which showcases the exploding growth of this field. Haptics is an interdisciplinary research field that encompasses and appertains to psychologists, and robotics and computer scientists. Therefrom, to become a great researcher in this area, one should be adept in Robotics as well as virtual reality interfaces and at the same time possess the ability to design human subject experiments and methodologies, coupled with the knowledge of associated psychophysical techniques. Being a research associate at the *Biorobotics Laboratory* and at the *Human Interface Technology Laboratory (HITLab)* at the University of Washington, I have had the unique advantage of working on diverse aspects of haptic technology and its applications, such as **collaborative haptics**, **surgical simulators**, **surgical robot technology**, **bilateral teleoperation** and **scientific data visualization**. Moreover, the collaboration with the **Boeing company** for my research project capacitated me in the industry aspects of haptic technology. In this document I have outlined my current and past research activities and my future research goals in this field.

Current Research

My primary research area is **Collaborative Haptics**, where multiple users collaborate on a shared virtual space and at the same time experience force feedback. It has considerable potential applications, such as in surgical training, maintenance procedure training, and multi-player networked games. I am interested in analyzing the position coherency of the virtual objects that multiple users share in a haptic virtual environment, which is particularly important since any divergence in the positions of the virtual objects will make the collaboration meaningless beyond certain time. Given that a collaborative haptic system could be implemented using a distributed (peer-to-peer) or centralized (client-server) architectures, choosing a centralized architecture appears to be the best option to maintain position coherency, and the distributed architecture seems to be the best for scalability. Furthermore, in the distributed architecture the users experience only half of the delay compared to the centralized architecture. In [1], I have proposed virtual coupling schemes for maintaining position coherency in haptic virtual environments. In particular, two of the schemes were used to represent distributed architectures and the other one a centralized architecture. Ultimately, I have built an experimental collaborative haptic system to measure objective performance metrics based on human subject studies, and thus compare the performance of the distributed and centralized architectures. This was the **first work of its kind** on the comparison of the two architectures using objective performance measures in collaborative Haptics. I have demonstrated that a distributed architecture could be used to maintain position coherency in a collaborative haptic system.

In the first part of my work I had used constant delays, simulated using buffers for testing the virtual coupling schemes. Afterwards, in [2], I tested the virtual coupling schemes for time varying delay using the actual Internet. For the **first time** in collaborative Haptics, packet reflector networks were established at the servers of our collaborators in Canada, Italy and USA. With this unique setup I was able to conduct human subject studies using my experimental collaborative haptic system with the subjects located in the same laboratory and at the same time experience time varying delay. UDP was used for haptic data transmission across the Internet. I also tested the architectures at various packet transmission rates. I showed that a distributed architecture could be used in a collaborative haptic system for maintaining position coherency even in the presence of time varying delay. In addition, I demonstrated that at low packet transmission rates both the distributed and centralized architectures exhibited a larger position error and the force rendered to the user increased as well.

Additionally, I've strived to peruse network emulators, which are pieces of software that can emulate real Internet-like networks on a local network inside a laboratory. Such emulators can be helpful in testing collaborative haptic system since the network delay, jitter, bandwidth and dropped packets could be changed to mimic a wide spectrum of network conditions. In [3], I carefully studied the performance of NISTNet –a popular network emulator– specifically in the conditions required for testing a collaborative haptic system. I found that with network emulators it is often difficult to recreate exact network conditions like those which exist in the Internet due to the relatively high packet transmission rates required for collaborative haptic systems. I am currently implementing an experimental study to objectively compare the performance of the network emulator to the data obtained using the actual Internet[4].

I am also actively involved in the development of a surgical robot at the *Biorobotics laboratory*, specifically, in the design and building of a portable robot-assisted surgery master station, which consists of a light-weight system with two commercial haptic devices connected to the Internet and can operate the surgical robot from anywhere in the world [5]. My contribution to this research project includes kinematic mapping, haptic feedback and delay compensation techniques for latency and jitter experienced on the Internet. Patent application process is currently undergoing through the UW Techtransfer.

Previous Research

My previous research in Haptics has been on medical and scientific visualization. My masters thesis work addressed voxel-based haptic rendering techniques for direct haptic rendering of anatomical datasets [8]. This work significantly enhanced the diagnosis capabilities of surgeons during preoperative procedures. During this time, I also collaborated in the research and development of a laparoscopic inguinal hernia surgery simulator. My work focused on the physically-based modeling of tissues for accurate haptic rendering in the simulator. To this end, I used a visible human database to create a virtual model of the inguinal area and applied FEM-based modeling techniques for soft tissue deformation and accurate rendering of haptic feedback.

During the first two years of my doctoral research, I worked at the Human Interface Technology Laboratory at the University of Washington on two different projects. In the first project –in joint collaboration with the Scripps Research Institute and funded by the National Institute of Health (NIH)– I developed a haptic interface for augmented tangible model of protein structures to be able to feel the molecular bonding forces using a PHANToM premium haptic device[7]. The augmented protein model consisted of a physical model of the protein with specialized markers used for tracking and rendering of enhanced virtual model of the protein using augmented reality. I developed different methods to synchronize the haptic and graphic workspace in an augmented reality system and produced fast haptic rendering techniques for CPK representations of protein structures. This interface was found to greatly ameliorate learning experiences in structural molecular biology.

In the second project –titled Next Generation Two-handed Suturing Simulator and funded by the Washington Technology Center– I developed a graphic processor (GPU)-based fast collision detection algorithm for the two-handed suturing simulator. I also developed the graphic model of a hand with a wound, needle driver, forceps and scalpel for the simulator in which FEM based modeling techniques were applied for deformation and force rendering [6].

Future Research

My long-term research plans include the further investigation of collaborative haptic systems in implementing adaptive control algorithms to mitigate effects due to delay and jitter. I am also greatly interested in applying the results from the collaborative haptic system experiments to networked robots, given their similarity in some of the control problems concerned.

Given my research experience in medical robotics and surgical simulators, I am particularly interested in working on medical applications of haptic technology. Current surgical robots do not provide force feedback to surgeons which can be critical for some surgical procedures. Therefore, I plan to investigate force feedback technologies for surgical robots as well as quantify the effects of surgeon performance with and without force feedback during actual procedures. I also seek to investigate the usefulness of haptic technology in rehabilitating stroke and accident victims.

In addition, my previous research experience in augmented protein models unveiled its usefulness as a great teaching tool. In this regard, I plan to investigate haptics as dimension in visualization, analysis and teaching of scientific data, which could bring a whole new dimension to the understanding and analyzing data in this field.

References

- [1] Sankaranarayanan, G. and Hannaford, B. Virtual Coupling Schemes for Position Coherency in Networked Haptic Environments. In *Proc. BioRob 2006, The First IEEE/RAS-EMBS International Conference on Biomedical Robotics and Biomechatronics*, Pisa, Italy, pp. 853- 858, 2006.
- [2] Sankaranarayanan, G. and Hannaford, B. Experimental Internet Haptic Collaboration Using Virtual Coupling Schemes. In *review for IEEE/RSJ International Conference on Intelligent Robots and Systems*, San Diego, California, USA, 2007.
- [3] Sankaranarayanan, G. and Hannaford, B. Measurement and Emulation of Time Varying Packet Delay With Applications To Networked Haptic Virtual Environments. In *submission for ROBOCOMM, the first International Conference on Robot Communication and Coordination*, Athens, Greece, 2007.
- [4] Sankaranarayanan, G. and Hannaford, B. Comparison of performance of virtual coupling schemes for haptic collaboration using real and emulated internet connections. In *submission for ROBOCOMM, the first International Conference on Robot Communication and Coordination*, Athens, Greece, 2007.
- [5] Lum, MJH., Rosen, J., Sankaranarayanan, G., et al. Teleoperation of a Surgical Robot via Airborne Wireless Radio and Transatlantic Internet Links. To appear in *Proc. FSR 2007, The Sixth International Conference on Field and Service Robotics*, Chamonix, France.
- [6] Lindblad, A.J., Turkiyyah, G.M., Sankaranarayanan, G., Weghorst, S.J. and Berg, D. Two-handed Next Generation Suturing Simulator. In *J.D. Westwood et al. (Ed.), Proceedings of Medicine Meets Virtual Reality (MMVR)*, pp. 215- 220, 2004.
- [7] Sankaranarayanan, G., Weghorst, S.J., Sanner, M. and Gillet, A. Role of haptics in teaching structural molecular biology. In *Proceedings of 11th Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems, 2003*, Los Angeles, CA, pp. 363- 366, 2003.
- [8] Sankaranarayanan, G., Devarajan, V., Eberhart, R. and Jones, D.B. Adaptive Hybrid Interpolation Technique for Direct Haptic Rendering of Isosurfaces. In *J.D. Westwood et al. (Ed.), Proceedings of Medicine Meets Virtual Reality (MMVR)*, pp. 448- 454, 2002.