Proceedings of EuroHaptics 2004, Munich Germany, June 5-7, 2004.

The Haptic Kymograph: Towards Transmission of Diagnostic Vital Signs

Youngseok Kim and T. Kesavadas

Virtual Reality Laboratory
809 Furnas Hall, Department of Mechanical Engineering
State University of New York at Buffalo
Buffalo, NY 14260, USA
{ykim5, kesh}@eng.buffalo.edu
http://www.vrlab.buffalo.edu/research.html

Abstract. The kymograph is the art of measuring pressure-based attributes, such as human pulse and blood pressure. The Haptic Kymograph is one of the advanced haptically-enhanced virtual reality medical applications. It transforms human vital signs into sensible, scalable and ubiquitous media so that a user can easily comprehend subtle and ambiguous signals. The development of the system faced some common challenges faced in tele-haptics, such as the data acquisition, digitalizing, network transmission of pulsation data, and synchronization and replication of real-time haptic sensation. The research also explores several human factor issues often required in sophisticated man-machine interfaces, such as multivariate environment and haptic distortion. This innovative technology has immediate applications in Tele-medicine and training.

1 Introduction

The complexity of human body and multivariate situations of medical diagnostics usually make symptoms very hard to recognize. This is especially true in physical examination with vital signs, such as touching and feeling pulsation of artery. Because patients often have weak pulses in their body, the ambiguity and subtlety often gives doctors problems during capturing and evaluating conditions of a patient. The Haptic Kymograph is a new haptically-enhanced virtual reality medical applications that captures and transforms human vital signs into sensible, scalable and ubiquitous media so that doctors can easily comprehend subtle and ambiguous signals from human body.

Recent medical haptic applications are mostly about replicating three-dimensional polygon model for human organ and its behavior for diagnostic palpation or surgical simulation, such as cutting and suturing human skin. Such studies have been often implemented with commercial force-feedback haptic devices, such as Sensable Technology's PHANToM® or Immersion's CyberGrasp®. Tele-haptic sensation has been

demonstrated before in various fields, however most applications have been replications of polygon models in master-slave or intent transmission.

Haptic Kymograph is unique in that it measures sensible signs (such as dynamic beats, pulsation and graphs) and converts it to haptic sensation. For example, instead of only watching an oscilloscope-thinking-evaluating, a doctor can directly see-hear-touch-feel the frequency and magnitude of the patient's pulse, shortening the perception time and contributing to decision support.

The technical advances over current active haptics research such as haptic-visual synchronization [1], [2] and haptic-network implementation [3], [4] are; (i) measuring dynamic pulsed data and synthetically generating proprioceptive cues based on haptics technology, and (ii) synchronization of haptics, visual, auditory sensation to recreate a full experience of medical diagnostics.

2 Method

The system of the Haptic Kymograph acquires and transforms abstract data (pulses, for example) into various human sensations in a real-time remote environment. The separation of haptic and graphical rendering loops makes the real-time interface possible (1kHz for haptic, 30fps for visualization). Further predictive algorithms are being developed to makeup for loss of data in the network. Also the special algorithms for synchronization processes are being expanded to haptic-visual-auditory-network environments.

For the readiness in data acquisition, distribution and replication, the system adopts relatively inexpensive sensor and hardware, and common platform-independent software: A piezo sensor for pulse sensing, a data processor board of Texas Instrument, Labview as a data controller, PHANToM Desktop for haptic interface, GHOST SDK for haptic device control, TCP/IP network interfaces, OpenGL for real-time graphics, Microsoft Visual C++ 6.0 for integrative software development in two Pentium III 1.0GHz in Microsoft Windows2000 operating system (Fig. 1).

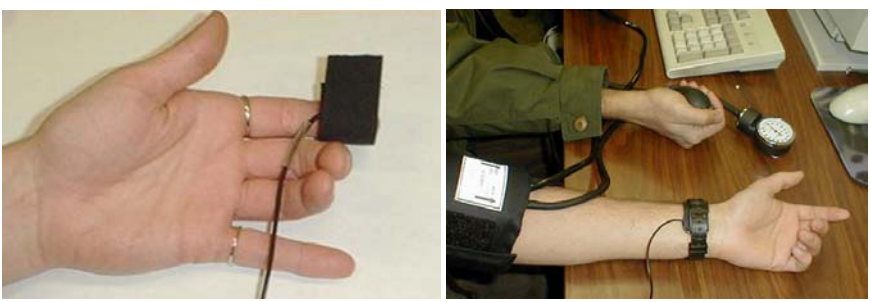

Fig. 1. A piezo pulse sensor is used for catching human pulse, attached on various position of human body, such as finger tip and wrist.

3 Results

The Haptic Kymograph simulation was implemented in a network environment (Fig.2). The sensor was attached on the wrist of the patient for capturing the pulse. A set of sphygmomanometer and stethoscope were used for simulating the use of human auditory channel. This served as a supplementary cue and will be replaced by sound recreation device in the future.

Fig. 2. The Haptic Kymograph can be used either via TCP/IP network PCs (left) or a local machine. A doctor sees, hears and touches the pulse of a patient in a remote site.

To achieve smooth feeing along with digitized step pulses, digitized data was processed at 200 Hz [5], [6], and transmitted via LAN, and it was successfully replicated in the remote site within our research institution. By placing the virtual hand on the leaping disk, the remote user could feel the patient's pulse (Fig. 3).

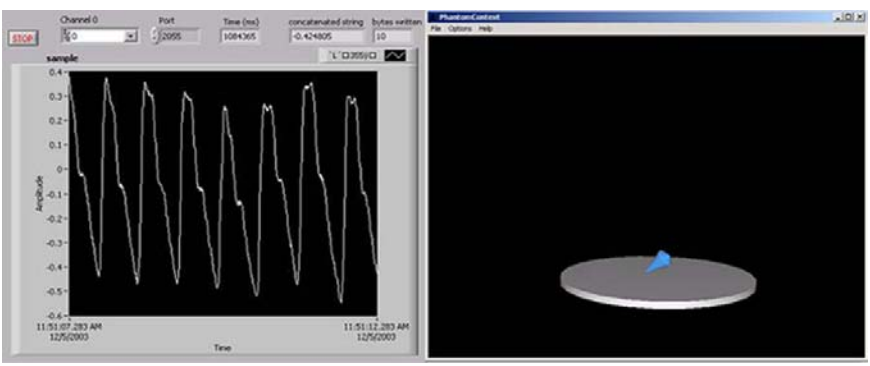

Fig. 3. Human pulse is captured, digitized and represented by replicated pulse (left). The haptically rendered leaping disk represents touch point where the pulsation is captured.

4 Conclusion and Future Works

The digitally captured human pulse were successfully processed, transferred, and replicated at the remote site haptic device. The scalability also gave the user a clear and agreeable haptic sensation despite the subject's weak pulse. The performance of the system, however, should be evaluated in the future, because the additional algorithm for dealing with various sensation data (i.e. visual, auditory and force feedback) may consume computational resources to the limit, and consequently risk the haptic distortion at the remote site. We plan to test the system performance across the country and between continents in the near future.

Overall, the core technology of the Haptic Kymograph will help in manifesting the ambiguities of vital signs in a human body for more precise diagnostics. In a sense, the technology can be expended to many other diagnostic applications of complex signals, that use oscilloscope in the future. Tele-haptic can lead to the dissemination of the benefit of the technology to people irrespective of their location. Furthermore, the ability to manifest subtlety and ambiguity can also provide new insights into the mysteries of the oriental medicine, because the touching and feeling a patient's pulsation is regarded as one of the most fundamental diagnostic technique in the oriental medicine.

References

1. Mark, W. R., Randolph, S. C., Finch, M., van Verth, J. & Taylor, II, R. M. (1996). *Adding force feedback to graphics systems: Issues and solutions*. Computer Graphics Proceedings. Annual Conference Series, ACM SIGGRAPH (pp. 447-452).

2. Sensible Technologies Inc. (2001). GHOST SDK Programmer's Guide & API Reference. Sensible Technologies Inc. Woburn, MA.

3. Fukuda, I., Matsumoto, S., Iijima, M., Hikichi, K., Morino, H., Sezaki, K. & Yasuda, Y. (2002). A *robust system for haptic collaboration over the network.* Touch in Virtual Environments; Haptics and the Design of Interactive Systems. Andrew Tesher. Ed. IMSC. (pp. 137-157). Prentice Hall, Upper Saddle River, NJ.

4. Hespanha, J. P., McLaughlin, M. L. & Sukhatme, G. S. (2002). *Haptic collaboration over the Internet.* Touch in Virtual Environments; Haptics and the Design of Interactive Systems. Andrew Tesher. Ed. IMSC. (pp. 158-168). Prentice Hall, Upper Saddle River, NJ.

5. Burdea, G. C. (1996). Chapter 2. Haptic sensing and control. Force and Touch Feedback for Virtual Reality. (pp. 13-39). John Wiley & Sons, New York, NY.

6. Burdea, G. C. and Coiffet, P. (2003). Virtual Reality Technology. 2nd Ed. (pp. 98–110). John Wiley and Sons, Hoboken, NJ.