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A Network-ready Multi-lateral High Fidelity Haptic Probe

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ABSTRACT

We describe a system comprising two or several haptic probes each having a sensor, an actuator, and circuitry. The inputs and outputs can be connected to audio channels of standard audio equipment and hence be networked via computers. When a user manipulates a probe to scratch and tap surfaces, the other users can share her haptic experience.

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Keywords: Vibrotactile displays, haptic devices, telepresence and virtual reality

1 INTRODUCTION

In bilateral teleoperation a slave manipulator is controlled so as to track the movements of a master manipulator which is held by a human operator [1]. When the slave encounters an object located in its workspace, the master arm reflects to the operator the interaction forces experienced by the slave arm, creating the impression of working at distance. This applies identically when exchanging the terms 'master' and 'slave'. Many have recognized that much of the haptic experience is contained in the contact transients and high frequency components for *telepresence* [4].

Given the present interest for haptics over the internet [2, 5, 3], we propose a low-complexity, yet high-quality, multi-lateral system able to provide an uncannily realistic experience of interaction with objects at distance. Referring to Fig. 1, two or more actuated and sensorized probes are connected to each other via a computer network. Since the probes are hand-held, users can manipulate them, say, to scratch and tap surfaces. While any particular user will experience of the results of her own actions through the probe she is holding, all other users holding connected probes will experience similar sensations because the same vibrations and transients will be transmitted. Typically, the result is greatly enhanced when the operator performing a task is watched via a video channel, and when the results are heard via an audio channel. The greater is the fidelity of these channels (resolution, delay) the more realistic is the experience.

To design the system, we have adapted the results of previous research, where is was shown that only acceleration had to be measured and transmitted, and that measuring and transmitting the interaction force was unnecessary [6]. The haptic probe senses surfaces by measuring the acceleration of the tooltip and reproduces it as acceleration at the handle.

The system may be used in a variety of applications including training and teaching, remote diagnosis in medecine, teleconferencing, and other fields. It can also be employed to recording multimedia documents involving video, sound, and tactile information.

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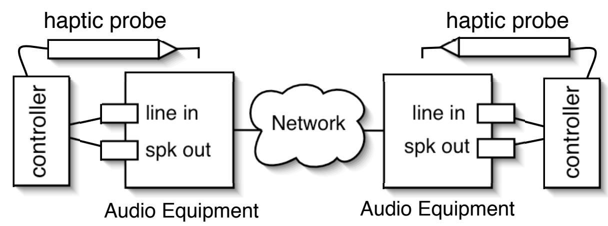

Figure 1: Connecting probes via audio.

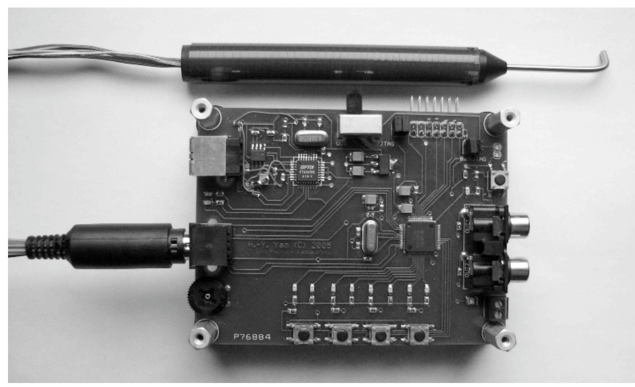

Figure 2: A complete probe system.

2 PROTOTYPE DESCRIPTION

2.1 Haptic Probe

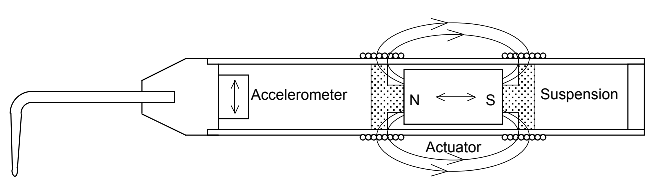

Figure 3: The Haptic Probe.

A solid state accelerometer (ADXL210E, Analog Devices), was bonded to the tip. This device gives a pulse-width modulated signal, which can be directly processed by a micro controller in "input-capture" mode.

A custom-made actuator was embedded in the handle. It consists of a magnet suspended inside a pair of coils in an open magnetic circuit arrangement. With proper design of the mass of the magnet relative to that of the handle, of the suspension damping coefficient, and of the resonant frequency, this system could accelerate the handle powerfully over a wide frequency range [6]. The actuator (6 Ω impedance) is sufficiently efficient to be driven by a 5 W audio amplifier.

2.2 Controller Circuitry

An optional custom-made controller supports the implementation of user-defined filters for various purposes such as echo removal, frequency-specific enhancement or attenuation, or time-domain processing.

The micro-controller (MSP430F1612, Texas Instrument), has on-chip analog-to-digital and digital-to-analog converters. The clock frequency was set to 8 MHz which is sufficient to sample the inputs and perform some filtering with the aid of an internal Multiply and Accumulate unit. This processor is very power efficient, consuming only 4 mA of current, allowing hundreds of hour of operation powered with batteries. A USB-UART chip (FT232BM, FTDI) provides USB connectivity (and auxiliary power selected via an on-board switch). This interface can be used to collect surface data or to transmit signals in digital form to the probe.

2.3 Portability

The haptic probe is light-weight and pleasant to use. It is made of carbon-fiber tubing and weights approximately 48 g, like an ordinary pen. The total system is portable with a total system weight of 134 g including batteries. The only wires are those connected to the amplifier, and to the audio equipment, or the external USB device if it is used.

2.4 Network Connectivity

In a teleconference setting, one possible scenario is to use an audio channel as illustrated in Fig. 1. Haptic signals, having a narrower bandwidth than audio signals, can be transported using the audio transport layer of teleconferencing equipment. Alternatively, data can be passed back and forth via the USB port. Using an audio channel, however, eliminates any special hardware or software.

3 Conclusions

A haptic probe was designed to be used directly for network transmission in a multi-lateral configuration. The whole device is light-weight, portable and network-ready either through an audio channel or USB connectivity.

We are investigating the possibility of using class-D amplifiers on-board to drive the actuator. It would then be feasible to employ radio-frequency wireless data connections.

4 Acknowledgment

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