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Design of a Wireless Tactor System for Haptic Feedback in Virtual Reality

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ABSTRACT

We present recent results we have obtained in the design of a wireless tactor system for use in virtual as well as real environments. We describe a system we have designed that uses vibration motors wired to a body-worn control box, which in turn communicates with a host computer using a wireless connection. Though we have successfully integrated this system into an existing VR-based dismounted infantry simulator, it is clear that expanding the body coverage and number of vibration points requires a solution that is completely wireless. To this end, we describe a working prototype we have built that, though still somewhat large and feature-limited, has convinced us of the merit of our approach.

CR Categories: H.5.2 [User Interfaces]: Haptic I/O; H.1.2 [User/Machine Systems]: Human factors; I.3.6 [Methodology and Techniques]: Interaction techniques.

Keywords: Haptics, wireless, vibrotactile, full-body, guidelines.

1 INTRODUCTION

For the past several years, we have been working to develop the necessary technologies and techniques for deploying wearable, scalable systems for delivering haptic cues. These cues are typically used to convey some sense of touch to the user when, for example, the user's hand comes into contact with a virtual object. Support for touch cues has potential application in both real and virtual worlds, including situational-awareness systems for pilots [10, 5] and road vehicle drivers [11], guidance systems for firefighters [8] or blind individuals [1], motion-following systems for sports and fitness, such as for learning Tai Chi [4], and non-verbal communication [13]. Applications for virtual environments include providing force and torque information for molecular-docking tasks [2], creating a sense of motion using sensory saltation [12], and delivering cues when a user comes into contact with virtual objects [6], such as collision reaction vibrations in video games, rumble vibration for driving simulators, and high-frequency surface properties during active touching [3].

Many technological approaches to providing high-fidelity haptic cues require a significant portion of the apparatus to be mounted on the floor [2] or fixed to a desk, while others place a substantial weight burden on the user for untethered operation. Several researchers have proposed the use of low-cost vibration motors, called *tactors* (devices that provide some form of tactile sensation), as a means of providing haptic cues in virtual environments [10, 5, 7]. Identical to mobile phone vibration units, such systems trade high fidelity and precise control for simplicity, modest power consumption, and reduced cumber on the user.

Current systems have limited flexibility in placing tactors due to mechanical and/or power constraints. In this paper, we describe a prototype system for controlling a potentially large number of vibration-type tactors that imposes few restrictions on tactor placement. This system has the potential to provide benefits to both the VR and wearable computer communities.

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2 FIRST-GENERATION WIRELESS HAPTIC FEEDBACK SYSTEM

Current approaches to providing vibrotactile feedback use simple control boxes connected to a standard serial or parallel port to interface with the tactors. Providing the ability to control the intensity of the vibration [7], as opposed to simply turning the motors ON or OFF [5], can increase the fidelity of the cues. A single source, AC or battery, typically provides power to the tactors. For communication between the control box and the host computer, Bluetooth-serial-bridge devices can be used, providing a range of about 100m. The control box regulates the power to each tactor individually based on commands from the host, and delivers the corresponding power over lightweight cables. We have successfully used this setup in several applications, including 2-tactor armbands for sending signals to soldiers during obstacle course training [8], and a 16-tactor upper-body garment for training Marines in building-clearing exercises in VR [9].

3 WIRELESS TACTORS

A natural evolution would attempt to increase the number of tactors, in order to cover a larger area of the body. With the current approach, however, adding more tactors means adding wires from each one to the control box. One solution to this is to use additional control boxes deployed at different locations on the body (*e.g.*, one on the torso for tactors on the upper body, one on the abdomen for tactors on the legs). While feasible, the added cumber limits scalability. A better solution would be to use a wireless connection from the tactor to the control box. This would allow tactors to be easily mounted at any location on the person, or on hand-held props, and would remove the cumber associated with the addition of more tactors.

In undertaking the design of wireless tactor units, we have first been concentrating on building a system that incorporates basic functionality, so as to better understand the nature of the problem. Since getting the prototype working, we have now begun optimizing size and weight characteristics, as well as increasing functionality. The entire system consists of a host computer to send control commands, a wireless base unit, and multiple tactor units. The base unit receives control commands from the host via a RS-232C serial (or Bluetooth-serial bridge) channel, and broadcasts to all wireless tactor units (**Figure 1**). One of the drawbacks of the use of wireless technologies is the additional communications delays that are incurred. We are currently evaluating the magnitude and variation in this delay to better assess the characteristics of our system.

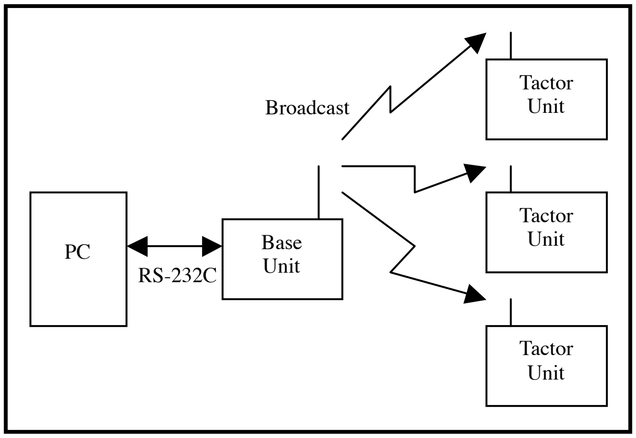

Figure 1: Configuration of the wireless tactor system.

Each tactor unit (**Figure 2**) is an all-in-one package consisting of a vibration motor, an amplifier circuit, a microcontroller (4-bit CPU: Mitsubishi Electric M34518M4), a wireless receiver circuit module, a chip antenna, and a coin-type lithium battery (CR2025). We use a Fujikura FMIU-005 as the vibration motor, which measures 8.0mm (0.31") in diameter, 3.7mm (0.15") in thickness, weighs 0.95g, and spins at 10,000 rpm at 3.0 V. The motor draws 24 mA of current at 3.0V, and the vibration quantity is 10 m/s^2 for a 60g chassis. The size of a tactor unit package (**Figure 2, inset**) is 26mm (1.0") × 26mm (1.0") × 45mm (1.8") (H × W × D), and weighs 30g including the battery. The battery lifetime is approximately 3 hours when the vibration motor is always ON. As the period that the motor is switched ON is usually much less than this case, the lifetime is expected to exceed a whole day.

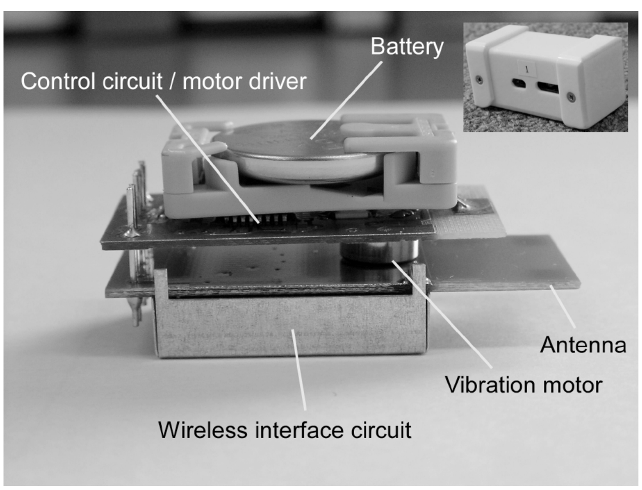

Figure 2: A wireless tactor unit. (Inset: hard-plastic tactor case)

We use a 315MHz-band weak radio wave for communication between the base unit and the tactors, and the effective range is four meters, which is considered to be sufficient for coverage of the human body, assuming the base unit is attached somewhere near the waist. Each tactor unit has a wireless receiver unit with a unique ID, and the base unit sends a command that contains bits corresponding to ON/OFF for each tactor, allowing each tactor unit to find if it should activate itself or not.

4 Conclusions and Future Work

We have followed the natural progression from a fully wired system to one that provides much more flexibility in terms of tactor placement, coverage, and ease of donning/doffing. We are now in the process of continuing to miniaturize the tactor units further, and are looking at how the overall mass of the tactor package affects the choice of the vibration motors. In addition, we have identified several candidate hardware options for bi-directional communication, as well as for batteries. Also, a round tactor shape would lend itself better to mounting on the body. The current system only allows the tactor units to be switched ON and OFF, but intensity control of the tactors will also be addressed in future systems. Finally, we will conduct empirical and field tests to better assess the characteristics of the system.

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