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The Chair as a Novel Haptic User Interface

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Abstract

Our work focuses on the chair that is involved in virtually all human-computer interactions. Surface-mounted pressure sensors are placed on the seatpan and backrest to monitor the pressure distribution pattern resulting from the contact between a user and a chair. A real-time seating posture classification system has been developed by applying pattern recognition techniques (especially those developed for face recognition in our lab) to the pressure distribution data. A physics-based human seating model is being developed. Vibrotactile transducers have been implemented in the back of the chair to deliver directional and simple geometric patterns to the user. The use of such a display has been explored in the context of navigation guidance and traffic situation awareness during driving simulation. Future work will investigate the use of the chair as a general haptic human-machine interface.

1. Introduction

Discussion on user interface design has largely focused on visual and audio channels. Haptic interfaces such as the TrackPoint ("the little red button") for the IBM ThinkPad laptop computer allow the user to control a cursor more accurately and to "feel" icons, window borders, etc. Such devices can enhance the functionality of standard computer displays (i.e., monitor and speaker) and input devices (i.e., keyboards, mice and joysticks). Recent advances in computer vision and speech recognition technology are adding visual and audio perceptual capabilities to human-computer interfaces. However, relatively little work has been reported in the area of providing *haptic* perceptual capabilities to user interfaces.

The term *haptics* refers to sensing and manipulation through the sense of touch. At the Perceptual Computing Section of the MIT Media Lab, we are developing new haptic interfaces using contact sensors and haptic displays. Our work focuses on an object that is involved in virtually all human-computer interactions but has so far remained sensory-deprived — the chair. With proper sensors, it is possible to track a person's postures and movements in the chair as well as joint positions of the lower body. With vibrotactile transducers and carefully designed signals, it is possible to deliver meaningful information to the user's back with minimal amount of training on how to interpret these signals.

2. The Chair with Sensors

To make the chair "smart", surface-mounted pressure-sensitive transducers are used to monitor the pressure distribution in both the seatpan and the backrest. The hardware consists of two identical Tekscan sensor sheets, their interface electronics, and a PC-compatible board (Tekscan Inc., South Boston, MA). Each sheet is 0.10 mm in thickness and is printed with an array of 42-by-48 sensing units (force-sensitive resistor units spaced 10 mm apart). Each unit outputs an 8-bit pressure reading. The pressure distribution data from the seatpan and the backrest are spliced together; the resulting 84-by-48 pressure map is analogous to an 8-bit gray scale image and lends itself very nicely to image modeling and classification algorithms. The current version of our real-time seating posture classification system is trained on data collected with N=10 samples per posture for a total of M=21 postures (e.g., seated upright, leaning forward, right/left leg crossed, etc.). A total of M separate eigenspaces are calculated, each capturing the variation of the N samples in a common posture. This approach is very similar to the "view-based" representation used by Pentland, Moghaddam & Starner for face recognition [5]. For each new pressure distribution map to be classified, the "distance-from-feature-space" (DFFS, see [6]) for each of the M postures are calculated and compared to a threshold. The posture class that corresponds to the smallest DFFS is used to label the current pressure map, except when all DFFS values exceed the threshold, the current posture is declared unknown. Our algorithm runs on a Pentium PC in Windows 3.11 environment (required by the Tekscan hardware driver).

Current work is progressing in two directions: a multi-user seating posture classification system and a physics-based model for posture tracking. Data are being collected from a group of users for the M postures. Multivariate Gaussian density functions will be learned from these data, and a Bayesian framework will be used for classification [3]. A physics-based seating model representing the torso and legs as deformable masses will also be developed. The model will explicitly specify the seating constraints in terms of the connectivity between body parts and stability. It is expected that with this model, real-time tracking of a user's seating postures and movements as well as joint positions of the lower body can be achieved.

Future work will look at how the posture classification and tracking system perform with reduced spatial resolution of pressure distribution data. A low-cost and low-resolution pressure sensing system will then be developed to facilitate the widespread use of smart chairs.

3. The Chair with a Display

To make the chair an active part of human-machine interaction, vibrotactile stimulators are embedded in the back of the seat to display haptic information to the user. Historically, systems such as the TVSS (Tactile to Vision Substitution System, [7]) have been developed to directly map an array of image pixels to a corresponding array of stimulators on the user's back. Performance with such systems, however, rarely matches that with a computer monitor unless, of course, that the user is visually impaired [7]. Other systems such as the palmtop display for dextrous manipulation developed at ATR Communication Systems Research Laboratories in Japan use force feedback to facilitate human-computer interaction [4].

Our display has been developed based on several considerations. First, it delivers stimulation to the user's back that is hardly engaged by any other interfaces. It thereby works in concert, rather than in competition, with exiting user interfaces. Second, we focus on ways of displaying haptic information that exploit the special properties of and are particularly suited for the human somatosensory system. For example, a tap on the shoulder grabs one's attention much more effectively than a string of letters on a computer screen. We believe that information such as pictures and speech are still best conveyed through visual and auditory displays. Third, we make use of sensory illusions to achieve greater information content with reduced hardware complexity. Of particular interest to us is a haptic sensory illusion called "sensory saltation" [2]. It allows the delivery of directional and simple geometric information through a coarse (e.g., 3-by-3) vibrotactile array. By sending multiple pulses to each one of a set of vibrators sequentially, a vivid sensation of taps along the locus occupied by the vibrators can be perceived. What's more, the multiple taps seems to be equally spaced between the location of two adjacent stimulators, rather than localized at the actual stimulation sites. In other words, finer spatial resolution can be achieved than the actual spacing of stimulators, and the sensation mimics that produced by a veridical set of stimulators with the same higher-density spacing [1]. We have constructed a set of demonstration signals (e.g., up, down, left, right, circular, etc.) for first-time observers and found that the sensation is salient and intuitive and the interpretations are highly consistent among these novice observers. Another added benefit of displaying directional information on the user's back is that the information is always in the local coordinates of user's body, thereby eliminating the need for coordinate transformation that is often associated with visual displays.

4. A Haptic Driver's Seat

One application of our sensing and reactive chair is a haptic driver's seat. It is possible to determine whether the driver intends to shift lane, speed up or slow down by classifying pressure distribution patterns associated with such actions. The vibrotactile display embedded in the chair can then give the user appropriate warnings based on surrounding traffic conditions. For example, a sudden pulsing on the driver's back can indicate something fast approaching from the back. An increased pulsing on the right side of the seat can indicate an "obstacle" in that direction and can therefore discourage the driver from changing to the right lane. With carefully designed vibrotactile patterns, a driver can react subconsciously to such warnings. The vibrotactile array can also be used as a haptic navigation display. By sensing the car's relative position on a map using a GPS system, appropriate signals (such as "turn right at next intersection") can be sent to the driver's back.

5. Summary

We have described a novel haptic interface developed around a familiar object — the chair. We have implemented this system in the context of driving simulation. In the future, we will investigate the use of the office chair as a novel human-computer haptic interface.

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