Haptic Radar / Extended Skin Project

Alvaro Cassinelli*
University of Tokyo

Carson Reynolds†
University of Tokyo

Masatoshi Ishikawa‡
University of Tokyo

Abstract

We present a device whose goal is to allow wearers to perceive and respond to range information from multiple sensors using haptic cues. It uses an array of modules, each of which senses range information and transduces it as vibro-tactile cues on the skin directly beneath the module. Moreover, this modular interface can cover precise skin regions, be distributed in a discrete manner over the skin surface, or span the entire body surface (and then function as a sort of double skin). Among the numerous applications of this interface are visual prosthetics for the blind, augmentation of spatial awareness in hazardous working environments, as well as enhanced obstacle awareness for car drivers. In an experiment, a significant proportion (87%, p=$1.26 * 10^{-5}$) of subjects moved to avoid an unseen object. On a questionnaire, subjects reported the system as more of a help, easy, and intuitive.

CR Categories: H.5.2 [Information Interfaces and Presentation (e.g., HCI)]: User Interfaces—Haptic I/O

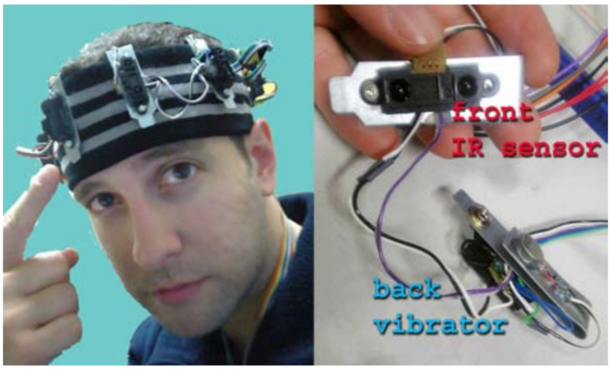
Keywords: haptics, sensory substitution, visual prosthetics

1 Range Sensors as Hair

While visual-to-tactile sensory substitution has already been studied [Kaczmarek et al. 1991], this project explores the use of multiple sensors for range-to-tactile sensory substitution. Haptic Radar is a prototype which converts range information into convenient tactile cues. One analogy for our artificial sensory system in the animal world would be the cellular cilia, insect antennae, as well as the specialized sensory hairs of mammalian whiskers. There is evidence that insects can very rapidly use flagellar information to avoid collisions [Camhi and Johnson 1999].

The prototype presented here is configured as a headband, which provides the wearer with 360 degrees of spatial awareness. Each module contains an infrared proximity sensor (SHARP GP2D12) with a maximum range of 80 cm (giving the user a relatively short sphere of awareness). Vibro-tactile stimulation is achieved using cheap off-the-shelf miniature off-axis vibration motors, and tactile cues are created by simultaneously varying the amplitude and speed of the rotation, in direct proportion to the range-finder output. The system is controlled using an ATMEGA128 microcontroller that also communicates with a PC for monitoring. The GP2D12 proximity sensors have a maximum sampling rate of about 5ms, so our interface is limited to a sampling rate of around 200Hz.

*e-mail: alvaro@k2.t.u-tokyo.ac.jp
†e-mail: carson@k2.t.u-tokyo.ac.jp
‡e-mail: ishikawa@k2.t.u-tokyo.ac.jp



2 Proof-of-Principle Experiment

We hypothesized that participants using the Haptic Radar prototype could avoid an unseen object approaching from behind. A pilot experiment with N=10 participants was performed testing avoidance of a Styrofoam ball stimulus. The experimental made use of a Haptic Radar prototype with 6 sensors facing along the back of a flexible headband. A control task without Haptic Radar was also conducted. In each task, the experimenter moved the stimulus toward blindfolded participants' head three times from randomly-ordered angles (either 240, 270, and 300 degrees). The participants' movement was recorded. Finally a questionnaire asked participants on an 8-point Likert scale the following questions: "For avoiding the object the system is a: (Help...Hindrance)," "Using the system is: (Difficult...Easy)," "The system is: (Intuitive...Confusing)," "The system is: (Uncomfortable...Comfortable)."

In 26 out of 30 trails participants moved to avoid the stimulus. A simple proportion test confirms that this is a significant proportion (p=$1.26 * 10^{-5}$). A Wilcox test comparing against a hypothetical even split of opinion found that participants viewed the system as more of a help (p=0.005), easy (p=0.005), and intuitive (p=0.005).

These results show that the Haptic Radar device can be successfully used to cause untrained users move in response to unseen objects approaching from behind. Video of Haptic Radar may be viewed at: http://www.k2.t.u-tokyo.ac.jp/fusion/HapticRadar/

References

CAMHI, J. M., AND JOHNSON, E. N. 1999. High-frequency steering maneuvers mediated by tactile cues: antennal wall-following in the cockroach. *J Exp Biol 202*, Pt 5 (March), 631–643.

KACZMAREK, K. A., WEBSTER, J. G., BACH-Y RITA, P., AND TOMPKINS, W. J. 1991. Electrotactile and vibrotactile displays for sensory substitution systems. *IEEE Trans Biomed Eng 38*, 1 (January), 1–16.