Flutter

Halley P. Profita/Nicholas Farrow/Nikolaus Correll
Department of Computer Science
University of Colorado at Boulder
Boulder, CO USA
{Halley.Profita, Nicholas.Farrow, Nikolaus.Correll}@colorado.edu

Abstract— Hearing is one of the fundamental sensory inputs that permits us to respond to and navigate our surrounding environment. Without intact hearing, the inability to detect warning signals such as fire alarms, police sirens, and honking horns can place individuals with impaired hearing at a significant disadvantage while navigating their environment. Common assistive technologies such as hearing aids, cochlear implants, and hearing dogs provide a means for individuals to respond to their environment more intuitively, however, the situation or context can render these aids inappropriate. Developing a wearable system to tactilely relay information can empower an individual with a hearing impairment to move confidently throughout their environment without the extraneous need of having small pieces of technology that can easily get lost (hearing aid) or the need of a canine escort (supervision can increase cognitive demand and requires one hand to maintain control of the dog). Flutter integrates function and fashion to relay information about the auditory environment for a holistic feedback system. If a sudden or lou alert is detected, such as the honk of a horn or the blare of a fire truck, the leaflets of the garment will begin to flutter in the direction and with the intensity of the signal for haptic notification.

Keywords –haptic; hearing impairment; collaborative robotics.

I. Introduction

Approximately 36 million Americans suffer from a varying degree of hearing impairment [1]. The sense of hearing is considered essential for performing tasks such as navigating one's environment, responding to warnings, cries, and alarms, and basic interpersonal communication. While a plethora of assistive technologies exist to supplement this disparity, hearing aids still prove to be the number one rejected assistive technology on the market as only 20% of the hearing impaired population are willing to wear one [2]. Other common aids include cochlear implants, hearing dogs, and visual or vibrotactile alerts. However, for a number of individuals the technology itself may be unappealing due to social stigma, may be cumbersome or non-portable, or in the case of the hearing dogs, may be an added responsibility and unsuitable for many situational contexts.

A. Haptic Feedback: Unmapped Territory

Even the most successful hearing aids can only achieve 6-8 frequency channels of information across the spectral range, making fine grain speech resolution difficult for the user [3]. Flutter is able to achieve the same level of frequency capture, and can serve as a less invasive method of information communication for the hearing impaired. This garment lends to the potential for users to adapt to a new method of hearing. By internalizing the vibrotactile feedback, the user can in essence, learn how to hear in a new way. Flutter serves as an elegant medium to internalize the external environment.

II. Design Concept

Flutter was designed to assist those with hearing impairments with the many challenges that they face when navigating one's external environment. Such challenges include being able to effectively detect warning notification systems such fire alarms, the blare of fire truck sirens, or the horn of an on-coming car. Typical assistive devices such as alarm beepers or hearing dogs are programmed/trained to respond to common alerts in the home, such as a fire alarm, the buzzer of a microwave, or an alarm clock. Once an individual leaves the home, the personal beeper becomes unserviceable, and the dog is no longer responding to an accustomed array of alerts. Instead, in an external environment

Figure 1. Flutter (front view)

canines react natively to their surroundings and the user is trained to respond based on the dogs actions. Designed to be worn in public, Flutter picks up where many home tuned alert systems and hearing dogs leave off.

In the United States, all public establishments are required to permit hearing dogs. However, this does not translate globally, and can at times be inconvenient when extensive traveling is involved. By making Flutter a hands free wearable system, it can more seamlessly remain with the user and reliably communication information in a consistent manner. Flutter is a dedicated system that can pick up localized auditory cues that it then translates into vibrotactile feedback for the user to respond to intuitively. Flutter uses a natural mapping to keep the feedback consistent with the directionality of the auditory signal, giving the user an accurate representation of the sound environment. The haptic feedback materializes through vacillating leaflets on the front exterior of the garment (designed to look like mere ornamentation when at rest), as well as embedded vibrotactile motors in the back of the garment.

III. THE FLUTTER TECHNOLOGY

Flutter relies on a coordinated network of microphones, microcontrollers, and vibrotactile motors that work together to detect and relay auditory information throughout the garment. Miniature microphones instrumented within the garment send auditory information to the microcontrollers which amplify the signal and attempt either a time-of-flight (TOF) differential or sound intensity differential to detect the directionality and proximity of the respective noise. The microcontrollers then interpret the signal and instruct the appropriate vibrotactile motors to actuate. Each microcontroller can be thought of as a miniature robot that extracts sound from the environment, communicates with its neighboring robot, and responds in a coordinated fashion to deliver tactile feedback at the localized point of the auditory signal. The shirt is adorned with decorative leaflets that, when at rest, appear to be just ornamentation. However, the leaf network actually responds to the auditory cue by starting to flutter (using vibration motors sized 6 mm by 10 mm) in the direction of the sound. The fluttering leaflets will move with the sound as the auditory signal moves in space. For rear auditory feedback, coin vibration motors (8 mm diameter) are instrumented throughout the back of the shirt and actuate against the skin when a posterior sound is detected, indicating the direction and proximity of the auditory alert. Thus, vibrotactile feedback on the upper right shoulder blade indicates an alarm coming from the rear right. The louder the signal - the more intense the vibration.

B. Design Execution

Flutter uses embedded electronic technology consisting of microphones, microcontrollers, and vibrotactile motors. Operational amplifiers coupled with microcontrollers affixed to small printed circuit boards integrated into the garment perform the acoustical analysis and signal processing. Each circuit board is responsible for actuation of up to four vibration motors, as well as processing the signal from a single

Figure 2. Flutter (close view)

microphone. The signal from the microphone is first amplified and filtered using a gain stage before being fed directly into an analog-to-digital converter port of the microcontroller. The microcontroller is continually sampling the data stream as it fills a buffer. Once the buffer has been loaded the microcontroller performs a fast Fourier transform (FFT) on the sample and begins to load another sample. The FFT transforms the auditory signal from the time domain to the frequency domain which permits identifying the signature of the signals of interest. The microcontrollers also convolve the auditory samples of neighbor microcontrollers to attempt TOF analysis for localizing the acoustic signal in space. Once the microcontroller network selects the proper motors for actuation, the microcontroller(s) responsible for those motors will be notified to actuate, providing the haptic feedback to the user. The network sampling rate is sufficient to permit the fluttering leaflets to move with the sound as the auditory signal moves in space.

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REFERENCES

[1] National Institute on Deafness and Other Communication Disorders. National Institutes of Health. March 14, 2012. < http://www.nidcd.nih.gov/health/statistics/Pages/quick.aspx>.

[2] Hearing Review. BHI Study Suggests Thin-Tube BTEs Appeal to Younger Audience. Ascend Media, LLC. November 2006. <http://www.hearingreview.com/insider/2006-11-09_2270.asp>.

[3] Gantz, B.J., Turner, C., Gfeller, K.E., Lowder, M.W., 2005. Preservation of hearing in cochlear implant surgery: advantages of combined electrical and acoustical speech processing. Laryngoscope 115, 796–802.