Wearable Communicator Badge: Designing a New Platform for Revealing Organizational Dynamics

Daniel Olguín Olguín[1], Joseph, A. Paradiso[2], Alex (Sandy) Pentland[1]
MIT Media Laboratory, [1]Human Dynamics Group, [2]Responsive Environments Group
20 Ames St. Room E15-386
Cambridge, MA 02139
{dolguin, joep, sandy}@media.mit.edu

Abstract

We are developing a new wearable electronic badge that will enable people working in large organizations to communicate, find information, and interact in more efficient and intelligent ways. The badge will perform speech analysis and speech recognition using a microphone and state-of-the-art micro-power electronics. It will be capable of playing audio messages and reminders through a speaker. An accelerometer will allow us to study how people move and behave throughout the day: Are they walking to a meeting? Are they talking to someone? Are they sitting in front of their computers? An infrared sensor will be used to capture face-to-face interactions and study social networks. A 2.4 GHz radio transceiver will send and receive information from base stations distributed along a specific area and a Bluetooth module will enable it to interface with cell phones, PDAs, portable computers, and other Bluetooth-enabled sensors and devices.

1 Introduction

The vision that Mark Weiser and his colleagues at Xerox PARC had in the early 1990's of ubiquitous computing has become a reality [9]. Pervasive cell phones, PDAs, personal computers, and other portable electronic and wearable devices are commonplace in the workplace.

Wearable badges are common gadgets that employees wear in large organizations to identify themselves to others or to gain access to certain locations or information. The Active Badge developed at Xerox PARC was one of the first attempts to augment inanimate nametags with electronics. Containing only a small microprocessor and an infrared transmitter, this badge could broadcast the identity of its wearer and trigger automatic doors, automatic telephone forwarding, and computer displays [8].

We are currently developing the first prototype of a *Wearable Communicator Badge* that will allow us to integrate different research efforts at MIT Media Lab. This new research platform will allow us to study how members of different teams interact, exchange information, communicate their ideas, and form social networks within large organizations.

2 Related Work and Motivation

More complex badge platforms have been developed after the first Active Badge. One example is the SocioMeter, a wearable sensor package designed at MIT Media Lab to measure face-to-face interactions between people with an infrared transceiver, a microphone, and two accelerometers [1]. This badge was used to learn social interactions from sensory data, and model the structure and dynamics of social networks.

The UbER Badge is the most recent research platform developed at MIT Media Lab for facilitating interaction in large groups of people. This badge has both RF and IR communication, a 5 x 9 LED display capable of presenting graphics and scrolling text that users in the vicinity can read, an onboard microphone for 12-bit audio sampling, a 12-bit audio output available at a headphone jack, a pager motor for vibratory feedback, 3 onboard processors, capacity for up to 256 MB of flash memory, provisions for connecting LCD displays, and connectors that allow a variety of different sensors to be integrated [4]. It measures 8.25 x 10.5 cm and weights 100 grams. Its average current consumption is 100 mA and batteries last for about 15 hours of continuous usage.

The best known commercially available badge system is the 802.11-based Vocera communications system. With it, users interact through wearable badges that can be clipped to coat pockets, worn as pendants, or carried in holsters. The system architecture centers on a server that maintains voice dialing phrases, badge session identifiers, email addresses, telephone numbers, and names. The Vocera badge provides a voice-controlled user interface and enables instant, hands-free conversations among people throughout the workplace. It weighs 53.9 grams and measures 10.6 x 3.5 x 1.5 cm. The standard battery (Li-ion 600 mAh) lasts for 2 hours of talk time and 44 hours of standby time, and it is rechargeable through a single bay or 8-bay charger [7].

In addition to some of the main features offered by previous badge platforms, we want to add social intelligence to the *Wearable Communicator Badge* so that it will be capable of:

- Recognizing common daily human activities in real time using a single accelerometer [3].
- Performing speech feature analysis in real time to measure non-linguistic social signals and identify the social context [5].
- Interacting with the user through voice commands to find resources and information in a timely fashion.
- Communicating with radio base stations in the 2.4 GHz radio band for sending and receiving information from different users, and processing data.
- Performing indoors tracking and user localization by measuring the received signal strength and implementing triangulation algorithms.
- Communicating with Bluetooth enabled cell phones, PDAs, and other devices to study user behavior and routine through proximity sensing [2].
- Capturing face-to-face interactions using an infrared sensor to determine how much time users spend talking face to face [1].

The new badge must have a small form factor, be comfortable to wear for long periods of time (at least 8 hours a day), and have a long battery life so that it doesn't need to be charged every day. To achieve this, the badge is designed for very low power wake-up directly from sensor stimuli. We are currently evaluating the total power consumption and battery life.

3 Functional Description

In this section we present the concept of the *Wearable Communicator Badge* and describe the choice of electronic components that will be used in the first prototype implementation.

The output of an omnidirectional electret condenser microphone (currently evaluating a MEMs microphone) is connected to the non-inverting input of a micro-power single-stage non-inverting operational amplifier (AD8542), with a high-pass filtering cutoff frequency of 85 Hz realized via its feedback loop. The amplified microphone signal is then applied to an array of micro-power single-op-amp Sallen-Key band-pass filters with constant Q. A diode-capacitor peak detector is used after each band-pass filter to obtain the spectral envelope in each frequency band. These four spectral envelopes (85 to 222, 222 to 583, 583 to 1527, and 1527 to 4000 Hz) are applied to A/D inputs on the microcontroller and will be used for extracting different speech features such as energy and pitch. The output of a full audio band-pass filter also feeds an A/D input on the microcontroller directly for digital audio applications.

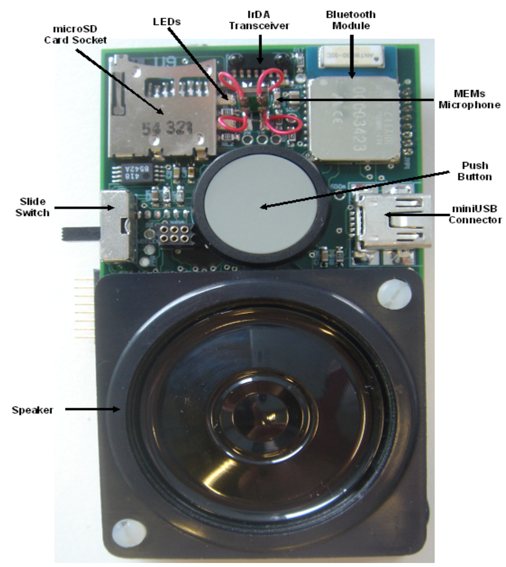

Figure 1. PCB front view

A microcontroller wake-up is also provided by a passive inertial component conditioned by a micro-power comparator. A 3-axis MEMS accelerometer (ADXL330) and infrared transceiver module (TFDU4300) are also powered up by the processor's power gate to save energy. All sensor electronics are powered up only when a significant sound is detected (indicating a possible conversation) or the passive inertial components detect significant motion. A bridged-output audio power amplifier (SSM2211) drives an electromagnetic speaker on the badge.

A 2.4GHz radio transceiver (CC2500) together with an ARM microcontroller (AT91SAM7S64) are being evaluated. A Bluetooth module (BR-C29A) has also been incorporated. A trans-flash memory card socket has been included for storing data when the user is out of range or when the badge is used as a self contained sensor package. The badge will be powered by a 1950 mAh Lithium-ion battery (CGA103450A) that measures 3.4 x 5.0 x 1.0 cm, weights 40 grams, and will be rechargeable through USB (BQ25010). The dimensions of the printed circuit board (PCB) are 4.2 x 6.5 cm. Figures 1 and 2 show the front and back views of our first prototype's PCB.

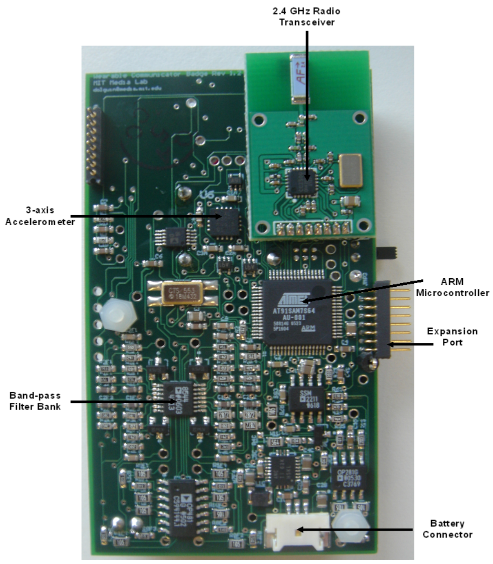

Figure 2. PCB back view

4 Applications

Sensible Organizations This is a new concept of social sensor network technologies that will help improve organizational practices. The *Wearable Communicator Badge* will allow us to quantitatively and qualitatively measure, analyze, and reveal organizational dynamics by closely looking at interactions and social behavior among employees of an organization. Companies will have a better understanding of how they work and how they can improve their daily routines in order to increase productivity, innovation, and job satisfaction.

Personal Sales Coach Recent experiments in the Human Dynamics Group at MIT Media Lab have shown that it is possible to measure how persuasive a person is being when talking to others, how interested a person is in a conversation, how much attention a person is paying to someone, and how effective someone is at negotiating all by measuring different voice features and body motion [5]. The *Wearable Communicator Badge* will be used to track individual and global sales performance in retail stores and give advice on how to make interaction with clients more effective.

Healthcare The *Wearable Communicator Badge* will also be used for a variety of healthcare monitoring applications, such as depression state tracking, eldercare, triage in the emergency room, and others. Sung et al [6] showed that non-invasive behavioral measures such as voice features and body motion are correlated to depression state and can be used to classify emotional state and track the effects of treatment over time.

5 Conclusions and Future Work

The first version of the badge is currently under revision. We are building ten of them for our initial studies. We will then make it as efficient as possible and reduce power consumption to a minimum by adding a nano-power comparator to detect the presence of significant audio and wake up the microcontroller. A vibration sensor will also indicate when there is significant motion. Migration to a low power microcontroller is also being considered in case the battery life needs to be significantly extended.

We plan to build several hundred badges and use them in real organizations both to study everyday social dynamics and to experiment with the different applications described in this paper. We will attempt to measure variables such as creativity, efficiency, productivity, and innovation using this research platform, with the goal of redefining current management practices.

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References

[1] T. Choudhury. *Sensing and Modeling Human Networks*. PhD thesis, MIT Media Lab, Feb 2004.

[2] N. Eagle and A. Pentland. Eigenbehaviors: Identifying structure in routine. Submitted to *Ubicomp'06*, Sep 2006.

[3] D. M. Karantonis, M. R. Narayanan, M. Mathie, N. H. Lovell, and B. G. Celler. Implementation of a real-time human movement classifier using a triaxial accelerometer for ambulatory monitoring. *IEEE Transactions on Information Technology and Biomedicine*, 10(1):156–167, Jan 2006.

[4] M. Laibowitz, J. Gips, R. Aylward, A. Pentland, and J. A. Paradiso. A sensor network for social dynamics. In *Proceedings of the 5th International Conference on Information Processing in Sensor Networks*, pages 483–491, Apr 2006.

[5] A. Pentland. Socially aware computation and communication. *Computer*, 38:33–40, Mar 2005.

[6] M. Sung, C. Marci, and A. Pentland. Wearable feedback systems for rehabilitation. *Journal of NeuroEngineering and Rehabilitation*, 2:17–28, Jun 2005.

[7] Vocera. Vocera communications system. http://www.vocera.com.

[8] M. Weiser. The computer for the 21st century. *IEEE Pervasive Computing*, pages 19–25, Jan-Mar 2002. First published in *Scientific American*, September 1991, pp. 94-104.

[9] M. Weiser, R. Gold, and J. S. Brown. The origins of ubiquitous computing research at parc in the late 1980s. *IBM Systems Journal*, 38(4):693–696, 1999.