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Ambient Intelligence and Wearable Computing: Sensors on the Body, in the Home, and Beyond

Diane J. Cook and
School of Electrical Engineering and Computer Science, Washington State University

WenZhan Song
School of Engineering and Computer Science, Washington State University Vancouver

Abstract

Ambient intelligence has a history of focusing on technologies that are integrated into a person's environment. However, ambient intelligence can be found on a person's body as well. In this thematic issue we examine the role of wearable computing in the field of ambient intelligence. In this article we provide an overview of the field of wearable computing and discuss its relationship to the fields of smart environments and ambient intelligence. In addition, we introduce the papers presented in the thematic issue highlighting a number of research projects which are defining the state of the art in wearable computing and ambient intelligence.

Keywords

wearable sensors; wearable computing; body area networks; health monitoring

1. Introduction

Ambient intelligence is an emerging discipline that infuses the settings in which we live with intelligence. Ambient intelligence is frequently associated with systems that are sensitive to individuals [1], responsive to the presence of persons [9], in existence all around us [12], nonintrusive [17], ubiquitous [21], and intelligent [18]. Ambient intelligence is often associated with intelligent sensors and software embedded in our everyday environments. However, wearable sensors and wearable computing systems also exhibit the features of ambient intelligence and play an important role in the field of AmI. Here we provide a brief overview of wearable computing research and highlight the research contributions that are offered in this special issue on *Ambient Intelligence and Wearable Sensors*.

As Huang defines wearable computers, they are computers that people can wear effortlessly [8]. While Thorp [20] self-reports the first wearable computer as a cigarette pack-sized device that was designed in 1955 to predict roulette, wearable computing became a recognized area of study in 1997 when IEEE sponsored the first symposium on Wearable Computers and Pentland hosted the first Smart Clothes Fashion Show [14].

2. Wearable Sensors

Complex systems such as smart environments require a large number of software components. Each of these components, when containing some autonomy and driven by an intelligent design, can be viewed as an intelligent agent. In order to ensure that the collection of software agents is robust, transparent, and seamless, these embedded agents need to communicate and cooperate with each other.

A main factor that distinguishes wearable computing from other ambient intelligent applications such as smart environments is the nature of the sensors that are used. Smart environment sensors are embedded into the environment themselves. They typically consist of wired or wireless sensors for detecting or measuring motion, light, temperature, humidity, and other conditions that are descriptive of the environment.

In contrast, wearable sensors are positioned directly or indirectly on the body. They need to run continuously and be operated hands-free [16]. As a result, they monitor features that are descriptive of the person's physiological state or movement. These sensors can be embedded into clothes, eyeglasses, belts, shoes, wristwatches (as is shown in Fig. 1), or positioned directly on the body. They can be used to collect information such as body position and movement, pulse, and skin temperature.

3. Wearable Computing Research

The unique features of wearable sensors create unique challenges for creating wearable computing systems. In addition, the unique features of wearable sensors create novel and important applications for research in wearable computing.

The first new research challenge that is introduced with wearable computing is the creation of wearable sensor network, or BodyNets, technology. For example, Yoo et al. [22] are designing on-body and near-body networks that use the human body itself as a channel. Other researchers are investigating MAC protocols for BodyNets [15] and are devising creative mechanism for conserving power in such networks [6]. Researchers in the textile industry are considering how best to design conductive materials to support sensors within clothing [13].

With the advent of wearable systems comes the design of new algorithms that take advantage of the information provided by the wearable sensors. For example, researchers such as Harms et al. [7] have designed algorithms to identify body posture based on information gathered by a smart garment, while Deyle at al. [5] and Kim et al. [10] use wearable sensors to recognize gestures.

Researchers have discovered new and exciting applications of ambient intelligence through the use of wearable sensors. For example, Madan et al. [11] characterize a person's social context by evaluating a user's proximity, speech, head movements and galvanic skin response. The collected information is propagated to others in the social group to facilitate distance communication and support teamwork.

There are also a number of health-based applications that have emerged in the area of wearable computing, such as the work by Sung et al. [19], who monitor the body temperature of soldiers to detect hypothermia. Others use wearable computers to design and evaluate assistive devices including wheelchairs [4] and smart walking sticks [3].

4. Introduction to the Special Issue

The papers that appear in this special issue represent significant innovations in the areas of wearable computing devices, systems, algorithms, and applications. In their paper "Rapid prototyping of smart garments for activity-aware applications", Harms et al. make use of novel wearable devices to analyze data. In particular, they collect data from garments and use the information to recognize postures. Bulling et al. also introduce a new wearable device: wearable EOG goggles. In their paper "Wearable EOG goggles: Seamless sensing and context-awareness in everyday environments", researchers use the goggles to measure eye movement. Tracking eye movement is beneficial for detecting gaze-intensive activities such as reading and focus-based gestures.

A necessary component of wearable computing is the sensor network that collects and disseminates sensed data. Jayaraman et al. describe an exciting new approach to sensor networks in their paper “Wearable sensor network: A framework for harnessing ambient intelligence”. Here the authors extend existing work on sensor network and smart clothes technologies to make use of a wearable motherboard, where the textiles themselves as part of the sensor network.

Partnered with the wearable systems technologies are algorithms that process and learn from the collected data. This special issue features two approaches to learning movement models from wearable sensors. Krishnan et al., in their paper “Recognition of hand movements using wearable accelerometers”, use the hand movement information to label the data with the corresponding activity that the individual is performing. Yang et al. also perform activity classification from wearable sensor data. Their paper, titled “Distributed recognition of human actions using wearable motion sensor networks”, describes how the authors perform the activity labeling in a distributed manner. These authors also make their collected data available for comparative analysis.

The last segment of the special issue is devoted to applications of wearable computing and ambient intelligence. Curtis et al. use wearable sensors to monitor physiological state of patients in a hospital waiting room. The reaction of participants toward this type of monitoring is detailed in their paper “Using ambient intelligence for physiological monitoring”. Chen et al. embed sensors in a child’s toy to monitor the health of preterm babies. In their paper titled “Design of power supply for neonatal monitoring with wearable sensors”, these authors describe the design of a device that is designed to bring power to the wireless sensor device. While medical assistive applications provide a vast source of uses for wearable sensors, other applications are also compelling. For example, Ghasemzadeh and Jafari describe how wearable sensors can be used to monitor athletic performance in their paper “Design of a wearable virtual coach: Quantitative analysis of golf swings”.

5. Conclusions

As demonstrated by the work found in this thematic issue, wearable sensors and wearable computing systems play an important role in the design of ambient intelligence. As more uses for the technology emerge, additional challenges arise that need to be addressed. One direction for continued research that we would like to stress is the integration of wearable sensing and environment sensing technologies. To date, research in wearable computing and research in smart environments has been pursued independently. However, these disciplines have much to offer each other. For example, fusing data from worn sensors and from passive environmental sensors can facilitate the creation of more comprehensive and more accurate models of resident behavior and well being. In addition, information collected in the environment can be used to predict resident physiological response (validated by wearable sensors) and information collected from wearable sensors can be used to initiate appropriate responses and changes in the environment.

The fields of ambient intelligence, smart environments, and wearable computing are all in their infancy and are all growing quickly. By taking a holistic look at these technologies, researchers can identify opportunities for continued growth and development. The goal of this thematic issue is to provide such a unifying look at the field.

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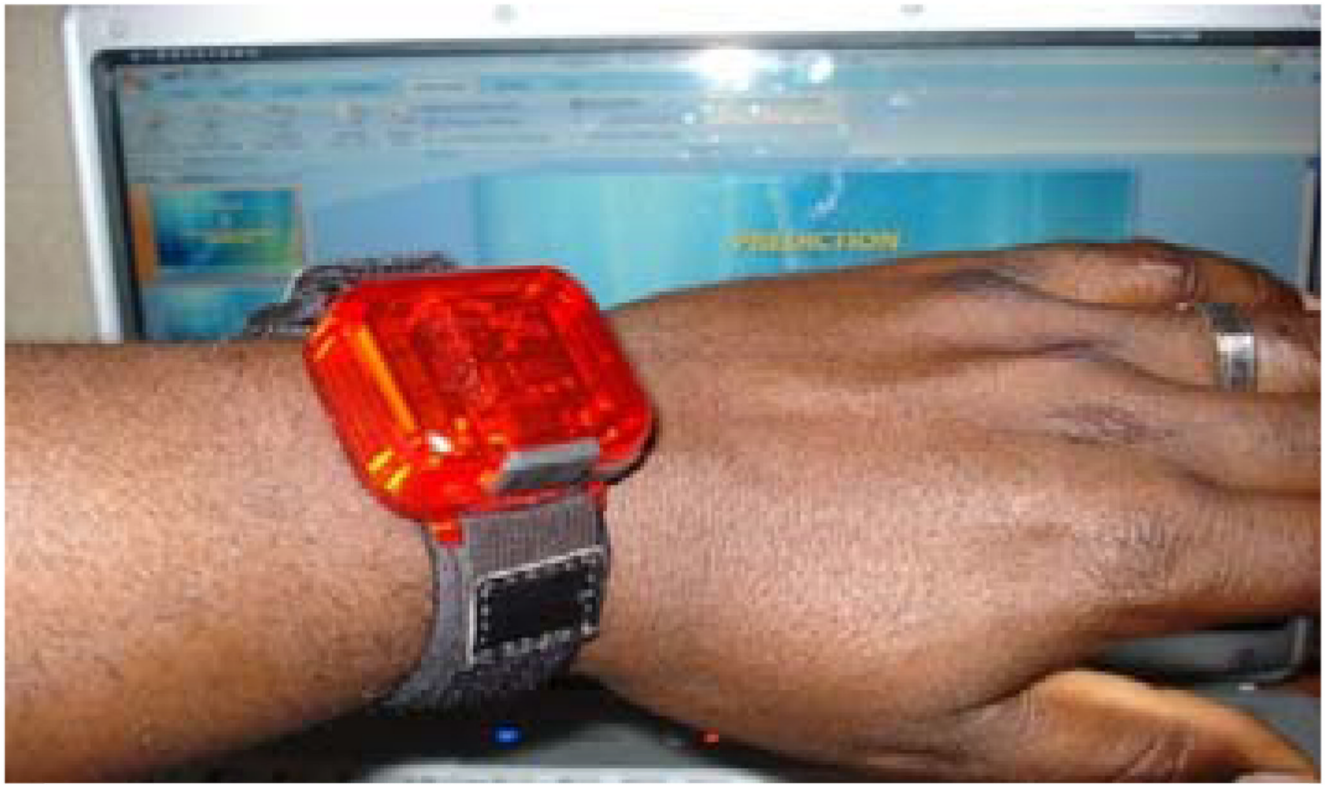

Fig. 1.
The Actigraph [2] accelerometer watch.