Recognizing Handheld Electrical Device Usage with Hand-Worn Coil of Wire

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Abstract. This paper describes the development of a new finger-ring shaped sensor device with a coil of wire for recognizing the use of handheld electrical devices such as digital cameras, cellphones, electric toothbrushes, and hair dryers by sensing time-varying magnetic fields emitted by the devices. Recently, sensing the usage of home electrical devices has emerged as a promising area for activity recognition studies because we can estimate high-level daily activities by recognizing the use of electrical devices that exist ubiquitously in our daily lives. A feature of our approach is that we can recognize the use of electrical devices that are not connected to the home infrastructure without the need to equip them with sensors. We evaluated the performance of our approach by using sensor data obtained from real houses. We also investigated the portability of training data between different users.

Keywords: Activity sensing, Electrical devices, Wearable sensors.

1 Introduction

Problems closely related to our daily lives such as the aging of society and adult diseases have become serious in modern society. Therefore, such pervasive computing applications as supporting the care of the elderly, fitness monitoring, and lifelogging are attracting attention [1,2] and various technologies have been studied to realize these applications. In particular, human activity recognition using sensors is one of the most important tasks in relation to the pervasive computing applications. Two main approaches are used for activity recognition studies: environment augmentation and wearable sensing. Many environment augmentation approaches use ubiquitous sensors such as RFID tags and/or switch sensors installed in the environment [3,4,5]. The wearable sensing approach attempts to recognize a user's activities by employing such sensors as body-worn accelerometers to capture characteristic body movements and postures adopted for certain activities [6,7,8,9]. On the other hand, sensing the usage of home electrical devices has recently emerged as a promising area for activity recognition because we live surrounded by large numbers of electrical devices, and frequently use them when we perform daily activities. Therefore, we can estimate high-level daily activities by recognizing the use of electrical devices. For example, when

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we detect that a user is using a hair dryer, we can know that she is drying her hair. Environment augmentation and wearable sensing approaches have been employed to recognize the use of electrical devices. Some studies employ ubiquitous sensor nodes attached to each electrical device to detect its use [10,5]. However, this distributed sensing approach requires large numbers of sensor nodes for electrical devices. Therefore, its deployment and maintenance costs, e.g., battery replacement costs, are high. Several studies have attempted to monitor the use of electrical devices with small numbers of sensors. For example, the system proposed in [11] employs a single central sensor to monitor the total electrical load of a home's power meter and then separates the individual loads of electrical devices in the home with statistical signal processing methods. Also, the systems proposed in [12,13] recognize the use of electrical devices by monitoring noise on the home infrastructure (home electrical systems).

The above systems focus on electrical devices connected to home electrical systems via outlets. On the other hand, we attempt to recognize the use of portable electrical devices such as digital cameras, cellphones, electric shavers, video game players, and music players with the wearable sensor approach. Our previous work [14] also focuses on portable electrical devices and employs Hall effect magnetic sensors [15] attached to a user's hands to monitor the magnetic fields emitted by the permanent magnets and relatively large motors incorporated in portable electrical devices. However, the system requires multiple Hall effect sensors (four or more sensors) attached to different parts of the hands to achieve high recognition accuracies. (See section 2 for more detail.) By contrast, in this paper, we describe our attempt to capture the magnetic fields emitted by sources different from those described in [14] and attempt to achieve high recognition accuracies with a single sensor on the hand. In detail, we try to develop a new hand-worn sensor device with a coil that can capture (sense) small time-varying magnetic fields emitted by, for example, electrical circuits, motors, boost converters, and conductive wires, included in portable electrical devices. Then, we extract the characteristic frequencies of the magnetic fields emitted by electrical devices and recognize which electrical device the wearer is using with machine learning techniques. Note that, because wearing several sensors places large burdens on a user in her daily life, sensing with small numbers of sensors is important. Here, we focus on the wearable sensor approach because it allows us to sense users' activities in both indoor and outdoor environments. Portable electrical equipment such as digital cameras and cellphones are frequently used out of doors. Also, with the wearable sensor approach, we can recognize the use of electrical devices that are not connected to the home's electrical systems. In addition, the approach does not require any sensors installed in the user's environment, e.g., ubiquitous sensors attached to each electrical device.

In the rest of this paper, we first introduce work related to detecting the use of electrical devices. Then, we describe the design of our prototype sensor device and show example sensor data obtained from the device when a wearer performs several activities (the use of electrical devices). After that, we introduce a machine learning-based method that identifies which electrical device a