Standalone Sound-Based Mobile Activity Recognition for Ambient Assistance in a Home Environment

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Abstract. Developments of ambient assistance systems and energy consumption optimization in home environments are one of the main goals of ambient intelligent systems. In this work we propose a wearable standalone solution, which combines the assistance task and the energy optimization task. For this purpose we develop a real-time mobile sound-based device and activity recognizer that senses the audible part of the environment to support its owner during his daily tasks and to help him optimize them in terms of resource consumption.

Keywords: Smart home · Sound-based recognition · Wearable · Ambient intelligence · Ambient assistance · Power optimization

1 Introduction

In our daily life we perform activities using devices, which consume resources like electricity and water. A way to optimize the resource consumption is to perform our tasks in efficient ways such that we utilize the devices in optimal way, like avoiding leaving them idling unsupervised or forgotten. Ambient Intelligent Systems support us for that purpose in various ways. To do so however, such systems should first sense us and our environment to recognize our actions and guess our intentions.

Sound-based context recognition is a natural way of environment sensing by anticipating its ambient sounds. First sound-based recognition systems date from roughly 10 years ago and use both wearable [1] and static [2] microphone placements. Recently, there are developments done with different sound setups and sensing aspects of the environment, like distress event detection [3] and device recognition [4] in a home environment or general context mobile recognition [5].

In this work we synthesize the mentioned approaches with an implementation of a standalone system for smartphones. We advance the research state by not only recognizing devices, but their states too, as well as other audible user activities in a home environment. The application further lists the different activities recognized during its execution and also issues various notifications to the user concerning its observations, including popping up warnings for electrical devices left running for long periods of time. The latter is of special interest for users with hearing impairments, while other users can profit from such application by receiving vital device usage information and use it to optimize their electrical or other resource consumption.

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2 Architecture and Environment

The process from an activity to its corresponding device recognition starts with the environment where some activity occurs. Its sounds are captured by a smartphone and used to extract a desired set of features to classify the ongoing activities and their corresponding devices (see Fig. 1).

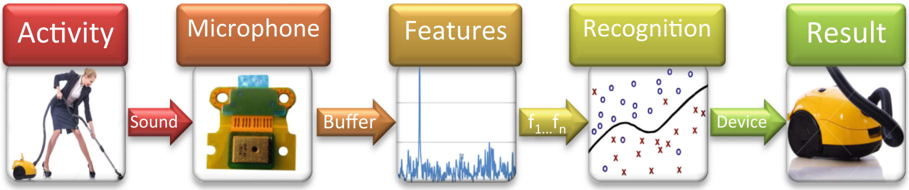

Fig. 1. Illustration of the process from activity to its corresponding recognition.

This study seeks to provide wearable activity recognition in a smart home so the architecture and the implementation are centralized on a home environment (see sample setup in Fig. 2). Our design requires a mono recording functionality – a capability of all smartphones, and if more audio input channels are present, we mix their input into a single processing channel. The latter enables switching between different on-body positioning setups without computational overhead. We assume there is only one activity running at a time, performed by a user with or without device, or the device doing its periodic miscellaneous tasks alone. Due to the nature of our design that exploits existing smartphone hardware, we consider our installation to be low cost and feasible for every user.

Fig. 2. Illustration of a sample usage scenario in a home environment – a user with hearing impairment receives sound-based recognition ambient assistance during his daily routines.

3 Sound-Based Activity Recognizer Implementation

Our implementation of a sound-based activity recognizer consists mainly of two components. The first one is a sound processing component, which records a mono sound with 32 bit depth at 44100 Hz and uses Fast Fourier transformation with Hamming window, to extract 8 features as described in [6]. The second one is a machine learning component, which classifies the different activities according to their sound-based fingerprint using the Nearest Neighbor algorithm. Both of the components require only standard smartphone hardware and are implemented in a highly optimized way in order to allow a real-time recognition combined with a low-battery consumption. We also implement a model of an incremental learning system, which relies on user input to build its activity database and to receive feedback about the recognition accuracy while running.

Fig. 3. On-body placement of the smartphone (left) with the application running (middle) and a sample alert (right) after leaving electrical device running longer than desired.

The application itself is capable of running in live recognition mode and provides its recognition results (see Fig. 3) at different possible rates starting at 10 Hz. It enumerates the different activities, which it recognizes and can also display both power/time and frequency/power representations of the sound, so that if the user has hearing impairment he can see the sound picture of his home. This graphical representation of the sound is also useful for a user to decide whether some activity can be captured by the device clear enough so that it makes sense to add it to its activity list. The application can also issue different warnings via vibration on different events like leaving the vacuum cleaner or blender running for too long, or notifications for washing machine or coffee pot ready. The latter might be crucial since one can forget his coffee on the heating element for long periods of time and thus expose themselves to potential danger. Furthermore, notifications about various possible misuses of electrical and other devices are important for several reasons, including electrical and other resource usage optimization, and extending the lifetime of those devices.

4 Conclusion and Future Work

Our main contribution in the field of sound-based context recognition is creating a wearable standalone system for device and activity recognition. It further can recognize the states of some devices, which allowed us to explore application opportunities beyond the recognition-only task. On top of the recognition functionality we implemented an ambient assistance application, which issues different activity-related notifications, besides the automatic creation of an activity schedule.

We plan to extend our working prototype with a communication interface to make the application accessible by other sensor nodes and to increase its intelligence in terms of being integral part of a wireless body sensor network for activity recognition. The latter is also an important step for evaluating and comparing the implementation with other ambient recognition techniques.

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[1] EASY-IMP is a European research project aiming to develop methodologies, tools and platforms for the design and production of personalized meta-products, combining wearable sensors embedded into garment with mobile and cloud computing (www.easy-imp.eu).