Acoustic Presence Detection in a Smart Home Environment

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INTRODUCTION

Rapid research progress in the field of Information Communications Technology (ICT) has an important influence on everyday life, with an increasing number of devices present in the human environment. Existing communication networks and their successors, like 5G, enable the development of a smart home environment, where all these devices communicate and integrate into one system, with the objective to ease and support human life. The population in developed countries is aging fast. This will result in an increased ratio of elderly persons who will need additional care. The smart home environment can provide one of the solutions to prolonging the independent life of the elderly and, in addition, simplify the organization for caregivers from the point when they can't live independently anymore onwards.

A broad set of various services can be implemented in a smart home environment, with the objective to improve the quality of life of the inhabitants. A basic set of services is oriented toward establishing a fully automated and energy-efficient home environment. An extended set of smart home services includes fusion of different information and media content sources into a common platform, which serves as a virtual assistant . The interaction with the assistant can be carried out in an almost natural way if embodied conversational agents (Rojc et al., 2017) are implemented in this role. One of the key pieces of information needed for successful operation should answer the question if users are present in the environment. A smart home environment must be able to monitor the users inside the home, to be aware of their presence and movements in particular rooms.

The presence detection systems in a smart home environment can be implemented in various ways. The basic concept behind presence detection is to measure some of the biological, technical or environmental conditions, which are influenced or generated by the users who are present in the smart home. From the quality of experience point of view, users prefer those presence detection systems which are non-invasive. In the opposite case, users have to carry with them a presence device, which reduces the perceived smart home experience significantly. The presence device can be a dedicated hardware module, which is, typically, using one of the in-door positioning methods to sense the user's presence. Wireless systems like RFID, NFC, Bluetooth, Bluetooth Low Energy (BLE), etc. have been applied successfully for this task. Another approach is to use some terminal equipment that users are carrying with them as a presence device. Nowadays, a smartphone is best suited for this task, although it still has to be carried by the users all the time to fulfill the role of the presence device, which reduces the comfort of smart home inhabitants.

The non-invasive methods for presence detection in a smart home can be classified according to the modality which is being measured or monitored to detect the user's presence. A frequently used approach is based on Passive Infra-Red (PIR) motion detection sensors. The PIR sensor is a small electronic device, which operates locally and detects the increased level of infra-red light radiation emitted by humans. Another solution is based on acoustic presence detection, which estimates the users' presence based on uttered words and other sound produced by the speakers during their presence and activities in the environment of a smart home. In this case, the audio signal is captured by a single microphone or by a microphone array, and processed to detect users' presence with audio and speech classification algorithms. A similar approach can be carried out using the visual modality, where a video camera captures a signal and the user's presence is detected with visual object recognition algorithms. An example of the non-invasive presence detection method, which is measuring technical conditions, is based on estimating the change in the electromagnetic field using IEEE 802.11 Wi-Fi access points.

The objective of the proposed encyclopedia article[1] is to present the approach of acoustic presence detection in a smart home environment, analyze the modules which are building the complete system, and propose the key elements for the given context. The acoustic presence detection solution benefits greatly from Human-Computer Interfaces, which are part of intelligent ambient. The usage of acoustic presence detection in a smart home environment is one of the building blocks which is a prerequisite for establishing a natural user-interface for human users.

BACKGROUND AND LITERATURE REVIEW

In the area of presence detection for the smart home environment, passive infra-red sensors are the method which has been applied most frequently for a user's presence detection (Monaci and Pandharipande, 2012). The main reason is its low technical complexity and low costs. The methods based on video modality (Ahvar et al., 2016) were used successfully for presence detection in different smart home set-ups, despite their computational complexity. The third method for sensing a user's presence in the environment is based on acoustic signals. Acoustic presence detection can be carried out with different algorithms. One of the simplest is based on measuring loudness in the smart home environment (Brgulja et al., 2010). More robust and accurate are methods based on low-level features, like the ones extracted by the openSMILE toolkit (Eyben et al., 2013). The most sophisticated acoustic presence detection systems are using classification or recognition algorithms, which are processing acoustic signals captured in a smart home environment by microphone arrays.

Smart environments contain various electronic devices that allow us to interact with human and machine. For detection of the acoustic presence we need a microphone for capturing an acoustic signal in such environments. The installation of the selected microphone in the room is not self-evident, because we need to know the acoustics of the room. The book (Virtanen et al., 2018) provides an overview of the methods for computational analysis of sound scenes and events for different environments, while sound environment analysis in a smart home was provided in (Sehili et al., 2012). The main approach for capturing sound in a smart home environment is microphone array. The study and implementation of microphone arrays are explained in detail in (Brandstein & Ward, 2001). The audio signal captured with microphone arrays is the basis for further steps of acoustic presence detection in smart home environments that can contain different types of acoustic signals, from speech, music, various noises from the environment, and, of course, also a signal of pure silence. If the goal is to detect the presence of a human, then pre-processing techniques must be used to remove the noise from the captured audio signal,

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