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SmartGreeting: A New Smart Home System Which Enables Context-Aware Services

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Abstract. Home automation systems are expected to develop a new trend, as they embed new technologies and low-cost devices making them suitable for any budget. Nowadays, the researching efforts are dedicated to designing low-power and low-cost smart home systems that offer personalized services considering multiple scenarios that cover usual daily activities. The main goal of the paper is to analyse the digital output signal of passive infrared sensors used in a configuration of smart home entrance called SmartGreeting. The system can be used to enable personalized services in an entire smart home environment.

Keywords: Persons' counting · Personalized services · Smart home
Passive infrared sensors

1 Introduction

Currently, in home-design systems area, the research is focused on designing low-cost and energy smart home systems [1–5], on finding solutions for solving compatibility issues concerning products under different licences [6, 7] and establishing efficient communication between smart devices [8–10] from the privacy point of view [11], energy consumption [5] and complexity [1, 3]. There is also an increased interest for human usual activities recognition [12, 13], interest motivated by the need to offer context or person-aware services [14]. Moreover, there can be observed the preference for using either low-cost sensors like passive infrared sensors (PIR) [14], either signals or sensors from users' devices instead of increasing the system's infrastructure [15, 16]. Throughout this paper we propose a sensor system that greets a more complex home automation design and enables scenario-aware and person-aware services. The paper is organized as follows: In Sect. 2 we present SmartGreeting system diagram explaining its functioning, including mentions regarding the features that may be extracted and processed. Section 3 presents the methodology of features extraction and analyses the experimental results and, finally, Sect. 4 comprises our conclusions and future intentions.

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2 SmartGreeting System: PIR-Based Subsystem Analysis

SmartGreeting system consists in 4 sensor nodes types: *PIR* nodes (*PIRx*) based on motion sensors [17] that detect thermal energy of human bodies (presence in the environment); *window sensors (WSx)* nodes consisting in piezoelectric sensors mounted on door and windows responsible for sensing intrusive actions; *light sensors (LSx)* nodes measuring the luminance and adjusting the indoor lighting conditions, temperature and relative humidity sensors (RHT) that monitors environmental conditions and *door sensor (DS)* node with magnetic contact switch and smart lock.

From systems' workflow (Fig. 1a) it can be noticed that the system continuously determines home occupancy and for Presence detection we implement a *Presence Detection* (PD) block using an improved sensors emplacement that, in contrast to previous person's detection and counting system [18], uses data acquired from 2 digital PIR sensors to increase the performance when multiple persons enter simultaneously the residence. The entrance has l = 100 cm and = 208 cm. Preliminary tests proved that 3 persons can enter simultaneously. This worst scenario represents the main challenge when counting the persons and determining occupancy.

PIR1 and PIR2 sensors were placed at a height h = 75 cm on two parallel walls with an offset of 35 cm between them to give information about target detection and direction. We determined 5 detection areas in which the targets may pass. The 100-cm entrance was first divided in 3 equal regions (I–III) and the middles of these regions formed other two regions (IV–V). There are two possible directions: Left-Right or Right-Left. Thus we considered 34 scenarios that cover all possible combinations of these variables and we succeed in extracting features from 28 of them. When PD detects a scenario, *Person Counting* (PC) block increments or decrements the number of persons (PN) which determines one of the following contexts (Fig. 1b):

NOT@Home context: active when $PN = 0$. The system assumes that no occupants are inside and enables *House Breaking Protection* (HBP) which improves residence security. *Presence Simulation* (PS) simulates presence in home by turning on/off the lights and speakers based on an algorithm that follows occupants' habits. PS receives information from Luminosity Sensors through HBP which picks Door and Window vibration sensors signals and turns on alert loudspeaker. *Door lock status* (DLS) is verifies the magnetic contact switch at certain intervals established.

HomeAlone context: active when $PN = 1$ and therefore DLS and HBP are enabled. Unlike NOT@Home scenario PS is no longer required. Still *Physical Activities Monitoring* (PAM) function oversees monitoring daily activities that reflect the status of the person: sleeping, cooking, bathroom using, etc. The main challenge resides in using only PIR sensors to detect these activities. PAM block will control lighting, i.e., dependent on luminosity conditions and the detected tasks; it will turn light on/off.

Smart4Family context: available when the number of persons >1 but $<N$ (previously set by the user; it reflects the maximum number of residence occupants). In this case, enabled functions are DLS and *Lighting Control* (LC). The lighting is controlled by luminosity sensor and PIR sensors data. Unlike HomeAlone scenario, PIR sensor data processing is less complex, activities monitoring being disabled.

Oxy+ context is designed to improve residence air quality when environment parameters like temperature, humidity or CO_2 are exceeding comfort thresholds or when a high number of persons is detected. It is stated that a high occupancy rate will determine environmental changes that decrease home comfort. Our system averts such situation through *Person Counting* function and RHT monitoring and activates Oxy+ before persons' number has an impact on air quality.

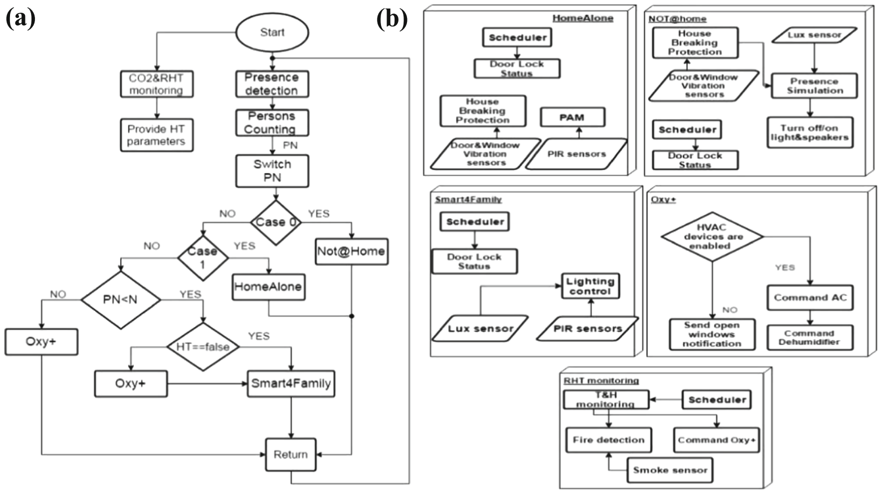

Fig. 1. **a.** SmartGreeting system diagram **b.** Functional blocks

3 Experimental Results: Extracted Features

To identify the number of persons that enter or exit the residence, we acquired the signals of the two digital sensors of PD subsystem when one (scenarios 17–26), two (scenarios 1–16) and three persons (scenarios 27–28) were walking in all possible directions (L-R/R-L) and regions (I–V). For two persons-scenarios, we provided all the possible combinations of directions and regions. Scenarios 17 to 21 imply L-R walking and regions I–V (in this order), while in scenarios 22 to 26 one person walked from R-L also in regions I–V. In scenarios 1–4 two persons were walking L-R/R-L, L-R/L-R, R-L/R-L, R-L/L-R, in regions I–II. Scenarios 5–8 were dedicated to II–III regions, 9–12 to I–III regions and 13–16 to IV–V regions. In 27 two persons were walking R-L and one R-L, while in 28 all persons were walking R-L. All persons walked with normal speed. Due to technical issues two or three people were asked to pass almost in the same time, in a row (not one after the other). Each scenario was repeated 6 times. We represented digital output of the two PIR sensors when one person passes L-R in regions I and III (Fig. 2) and regions II and IV (Fig. 3).

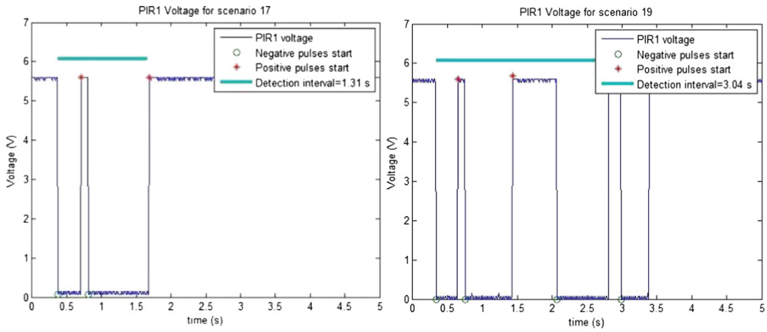

Fig. 2. PIR1 output when one person walks L-R in region I (left) and III (right)

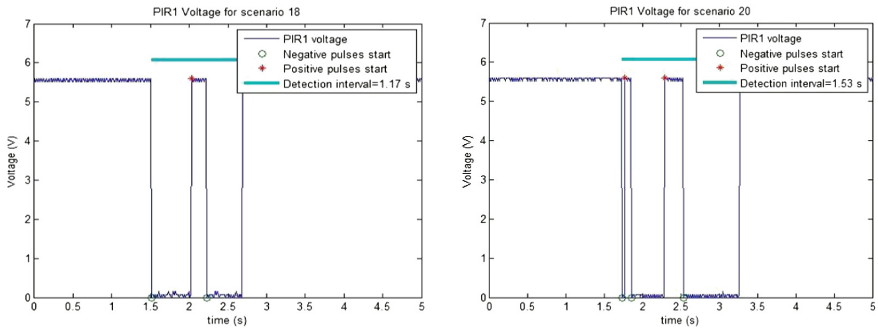

Fig. 3. PIR1 output when one person walks L-R in region II (left) and IV (right)

Digital PIR has two levels: logical 0 (motion is detected) and logical 1 (no detection occurs). Detection start and final are also marked. We observed that features like detection duration (μd), signal variance (Var), number of negative pulses (NPN), pulses width (μPN, μPP), the percentage of negative pulses duration from total duration (μ(X)) for both PIR signals (1 and 2) differentiate the scenarios. Each feature was obtained through averaging sets of values for which we computed the variance to test their reliability. Next, we analyse the importance of two features, detection duration and pulses number, in discriminating between one person and two persons scenarios.

Thresholds are set to identify the scenario. From Fig. 4 it can be seen that through regions I, II and IV L-R has duration of 1.4–1.65 s in the case of single person. New feature can be found to identify more accurately the scenario. Looking to negative pulses number (Fig. 5) we find that only for region I $PN_1 = 1$ (#17) due to the high thermal energy emitted by the very close human body. For one person Region III L-R (#19), duration threshold is irrelevant. If we analyse negative pulses number duration of PIR2 signal, we notice that only #3, #6 and #11 may be confounded with #19, but if we analyse number of negative pulses in Fig. 5, we clearly distinguish #19.

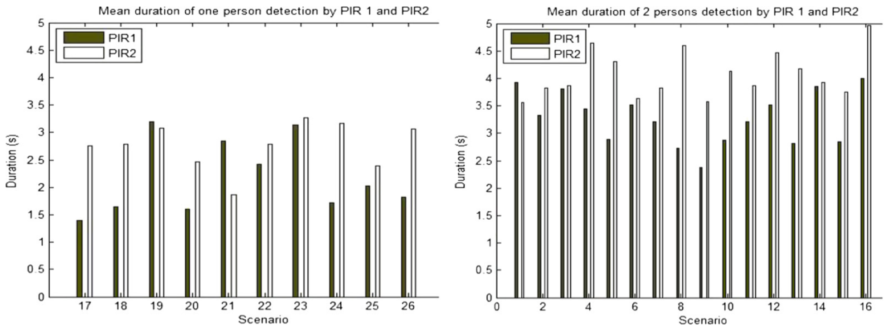

Fig. 4. Mean duration for one (left) and two persons detection (right)

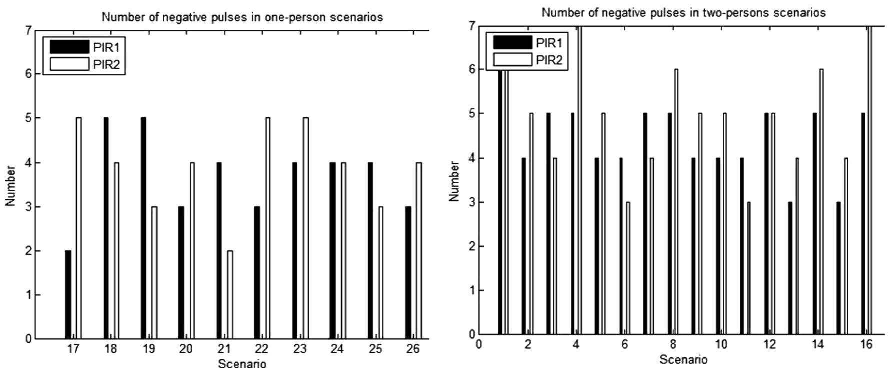

Fig. 5. Number of negative pulses for one (left) and two persons scenarios (right)

When two or more scenarios will be confounded, another feature must be analysed. When two persons walk in the same direction, the PIR that was first triggered will end the first, too. When the persons walk in different directions the PIR that was first triggered will end the last. This helps in achieving more accurately the number of persons that must be incremented or decremented. If our system recognises a scenario in which two persons walk in the same direction, it will decrement/increment with 2.

4 Conclusions and Future Research

The novelty of the system consists in the activation of system tasks according to the continuously updated occupancy detected. Moreover, we succeed in designing a new low-price (under 35€) and low-complexity configuration that gives important information about residence occupancy using two digital PIR sensors output and scenario recognition. In future, we intend to compare other features (pulses durations and signal variation) and their performance in discriminating between all three types of scenarios (one, two and three persons). Future efforts will be dedicated to the walking of the persons one after the other, building and training a classifier for scenario recognition that uses the features extracted. Also, we intend to embed in our system acoustic sensors and test new audio features.

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