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Presence detection and person identification in Smart Homes

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Abstract
In the paper, several systems and solutions for presence detection and person identification in smart home environments are reviewed and advantages and disadvantages of different solutions are derived. As a consequence, multi-sensor scenarios are promoted. Several detectors developed for the SmartHOME at the University campus site are presented.

Introduction

Smart Home environments have become an important research topic in recent years (e.g. [1-6]). They consist of a large number of networked sensors and actuators for decentralised indoor climate control and remote access to different functionalities and comfort functions.

A basic condition for smart environments are systems for the detection, localisation and identification of persons. There are 3 primary goals for such systems:

1. security issues (intruder detection)
2. economical and environmental issues (occupancy-driven lighting, heating and ventilation)
3. comfort issues (effective, off-the desktop interaction of the users with the smart environment)

For smart home scenarios (esp. demand-driven HVAC systems and user interaction, the following have to be extracted [7,8]:

- number of occupants,
- identification of occupants,
- physical activity of occupants,
- localisation of occupants in a room.

In the following, various known methods and devices for presence detection and for person identification are reviewed and there usefulness for Smart Homes is assessed. As a consequence from the review, a multi-sensor scenario is promoted. In the sequel, some solutions applied in the SmartHOME at the University campus site are discussed.

Detection of persons

In order to detect that a person / intruder is entering the home environment, numerous technical solutions based on a large variety of physical phenomena are available and are still refined. Apart from the widespread passive infrared

(PIR) detectors, glass-break sensors and vibration shock sensors, active systems using infrared light, ultrasound or microwaves are used. Also video cameras are widely applied in security systems.
Various access control systems including electronic keys (transponders, touch memory (iButton®) and systems for biometrical identification (fingerprint recognition, handwriting recognition, etc.) are developed.
For the user a maximum sensitivity and reliability is most important since missing alarms question the purpose and alarms false alarms are costly and reduce the system's credibility. In a later section it will shown, that with a multi-sensor approach the false-alarm probability can be reduced significantly. Other important issues are the detection range of the devices, their ability to distinguish object due to their size, form or distance to the sensor and, last but not least, their cost.
In Table 1, a summary of the most perspective sensors and their comparison is given.

Table 1. Comparison of presence detection sensors

Type of sensors	**Information grade/ Resolution**	**Information**					**Price**	**Main problems**
		Movement detection	**Number of occupants**	**Persons identification**	**Persons localisation**	**Physical activity**		
Passive-IR	Low	+	-	-	-	+/-	low	low resolution
Light barriers	Low	+/-	+	-	-	-	low	low resolution
Microwave detectors	Low	+	-	-	-	-	medium	low resolution and relative high price
Ultrasonic (simple)	Low	+	-	-	-	-	low	Low resolution
Ultrasonic (intelligent)	Relative low	+	+/-	-	+/-	+/-	medium	Low price/ information grad relation
Shock sensors	High	+	-	-	-	+/-	medium	Relative complexity installation
IR Camera	Very high	+	+	-	+	+	very high	Very high price
360° PIR	Very high	+	+	-	+	+	medium	Mechanic noise
Trans-ponder	Low	-	-	+	-	-	medium	Low information grade, low range

Video camera	Very high	+	+	+/-	+	+	high	Complexity of algorithms, psychological factors, critical to insufficient light
Biometric systems	Low	-	+	+	-	-	high	Low information grade, psychological factors

Identification of users

Transponder systems allow the identification of a person, however inherit some grave disadvantages: the user has to take the ID batch (key) always with him (partly this problem can be solved by embedding of transponders in watches, ornaments or keys to the house) the range is restricted to some centimetres and it is impossible to detect the direction of motion (whether the user enters or leaves a room). Nevertheless, it is the most simple, cheap and reliable way of the person identification. In combination with a light barrier (using two beams to detect the direction of motion) at any entrance to all rooms the necessary information about the number of occupants and their identity is provided. The system structure and a simple realisation are shown in Figs. 1,2.

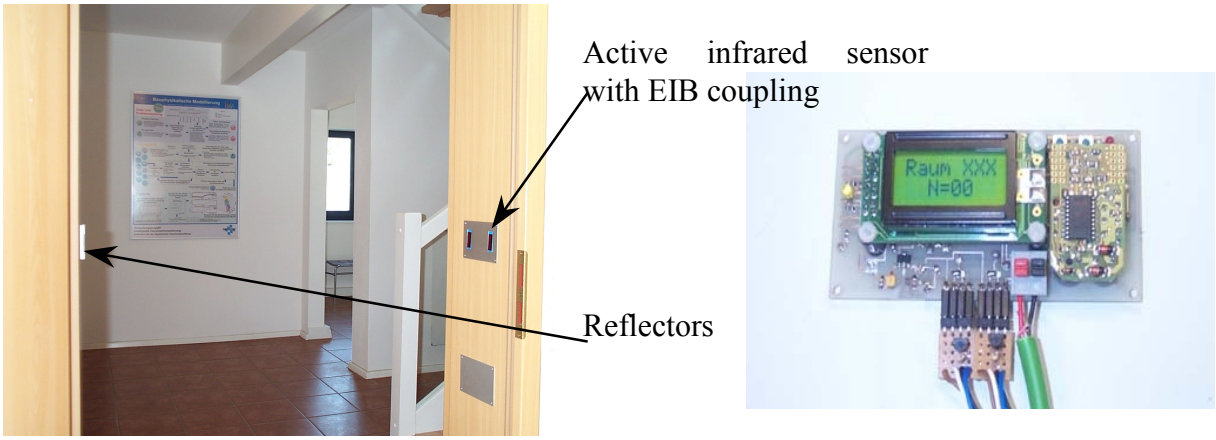

Figure 1: The functional model of the active infrared sensor

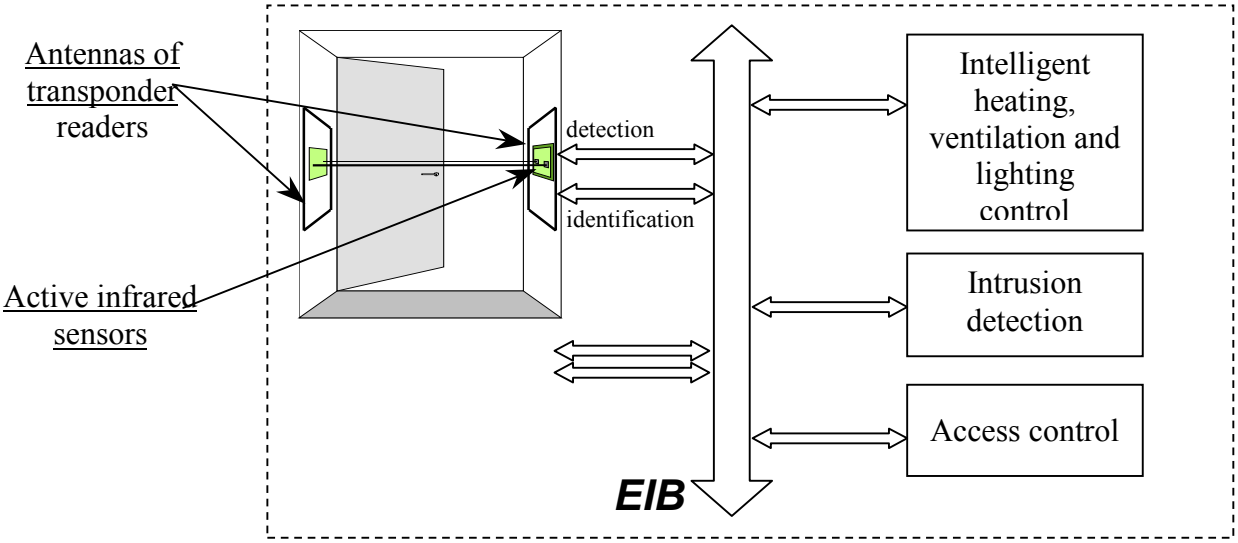

Figure 2: Structure of the simple multi-sensor system on the basis of the EIB

Sophisticated systems for user identification which detect several biometric properties (face detection, speech recognition) have become important research issues (e.g. [9-12]). However, the reported solutions are still far from satisfying regarding flexibility, learning time and recognition rate.

Localisation and tracking of objects

On the basis of the information about the position of persons in a room, the appropriate heaters or ventilators close to the person can be chosen and, generally, the activity level (metabolic rate) of the users can be determined[1]. To support natural user-interaction a microphone or a camera can steered to the user.

Two interesting systems will be presented in more detail. In [14], a motion detection and localisation system based on vibration shock sensors is described. The operation principle of this system is based on the fact that every moving person induces vibro-acoustical waves propagating along the surface where they are detected by sensors placed at different points of the floor surface. The data processing algorithm is based on application of neural networks. The system allows to define a trajectory of the person's movement, remaining itself absolutely imperceptible.

The omnidirectional passive infrared human information sensor described in [15] can be regarded as a reasonable alternative to both video and infrared cameras. The sensor module consists of a one-dimensional array detector, an infrared transparent lens, a 360° rotary scanning mechanism and a 3° chopping mechanism. The array detector rotating mechanism allows the sensor to have a wide view (10m diameter). The schematic concept of the 360° direction type sensor is shown in Fig. 3.

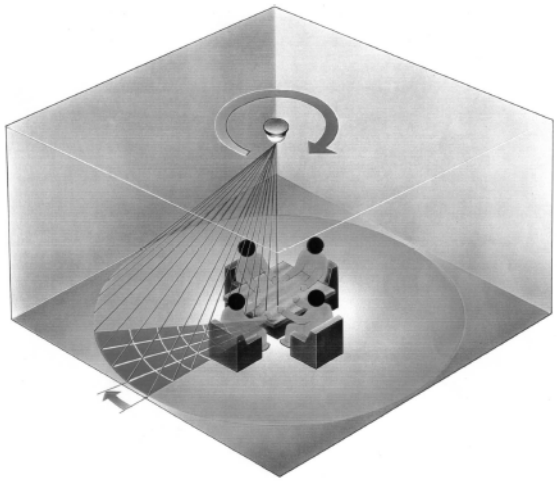

Figure 3: Schematic concept of measurement by a 360° direction type human information sensor.

Image recognition

For the localisation and tracking of persons in rooms, video cameras can be applied. Main problems with video systems are the strong dependence on lighting conditions and overlapping objects in different distances from the

[1] The predicted mean vote PMV, essential to predict the thermal comfort, is usually determined by 6 parameters: air temperature, humidity, air velocity, mean radiation temperature, metabolic rate and clothing [13]

camera [16-18]. To arrive at a flexible reliable system, the camera should be used primarily in combination with other systems (e.g. light barriers, PIR sensors).
In Fig 4, the block diagram of the image recognition algorithm is represented, and in the Fig. 5 - stages of this operation.

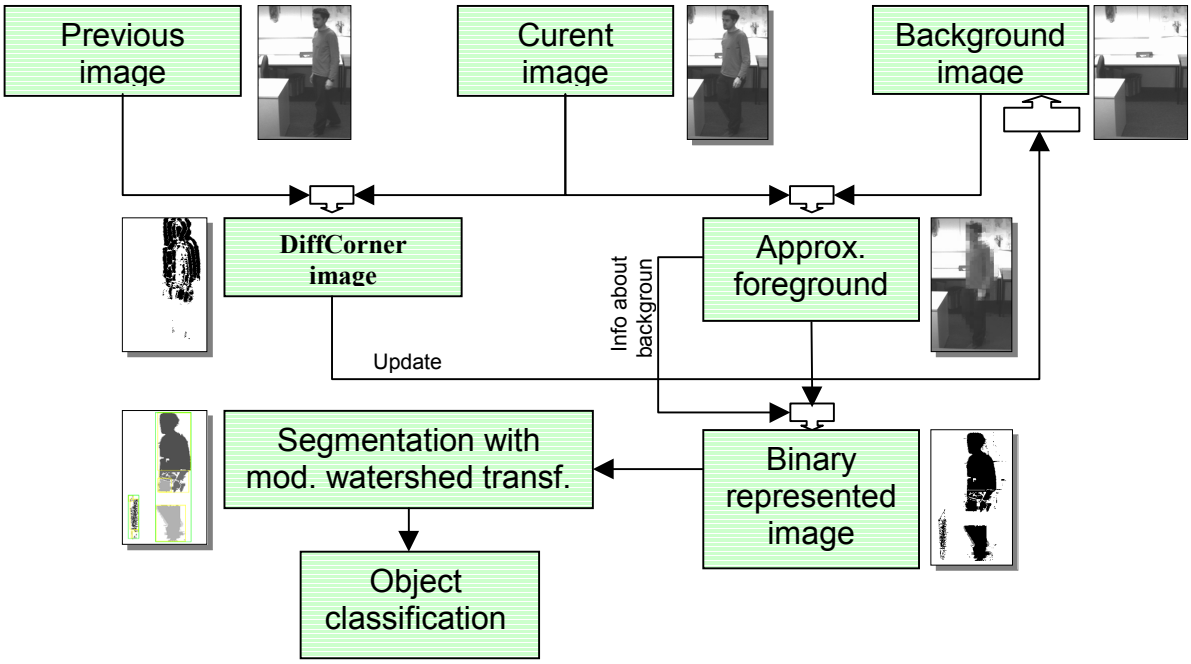

Figure 4: Image recognition algorithm

The original picture in Figure 5a differs from Figure 5b at the places in which an approximation of the background picture supplies "bad" values to the foreground. This was executed about the whole picture in 8x8 blocks what explains the faded blocks in picture 5b. The result of the adaptive threshold on the blocks is represented in Figure 5c. The extracted boxes (Fig. 5d) are used for object tracking.

a) curent image | b) approximation to the background | c) binary represented image | d) segmentation and excepting of small segments

Figure 5: Separate steps of the image recognition algorithm

Problems with a reliable detection of objects are still encountered due to suddenly changing lighting relations (e.g. clouds) as well as too weak illumination of the considered region. Furthermore, a comprehensive knowledge about the expected form of the objects is expected to support the distinction between several object and the background.

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