Bathroom telemonitoring system with alerting function for independent life of elderly

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Abstract. Population ageing is tending to become one of the most significant social challenges of the twenty-first century. World’s population is ageing, and this fact is noticeable in every country in the world. Telemonitoring is a way of responding to new needs of home care in an aging population. With the current technology, it is possible to implement solutions that until recently seemed to be a distant vision of the future. Telemonitoring technologies in home environment is still under development, but this method appears to be one of the most promising approaches to facilitate independent living for elderly. This paper presents a fully independent and autonomous bathroom telemonitoring device for emergency situations detection.

1. Introduction
The world’s population aging is a global phenomenon. According to the World Health Organization website the number of people over 65 years will outnumber children under 5 in the next 5 year and that means the age pyramid will be turned upside down.

Between 2015 and 2030 the number of people with age 60 years or over is projected to grow by 56 % that means an increase from 901 million to 1.4 billion. By 2050 the global population of older persons is projected to reaching nearly 2.1 billion, which means more than double its size since 2015. By 2050, 1 in 6 people in the world will be over the age of 65, up from 1 in 11 in 2019. [1] There are many issues associated with ageing and the healthcare systems are already under pressure in most countries. Elderly people with complex needs are limited to perform their basic daily activities due to mental, psychological, and physical challenges. The number of people with multiple diseases increasing dramatically above the age of 75 years.

The well-being and health of the elderly generation is more than ever a major challenge for our society. Living at home for elderly is equal with well-being because it allows them to maintain their lifestyle and remain in contact with their family and friends.

2. Telemonitoring
Technological tools provide the possibility for elderly to remain at home and maintain an acceptable quality of life [2], [3]. The use of information technology to monitor people at distance is named TELEMONITORING. Telemonitoring is a way of responding to the special needs of home care in an ageing population and allow monitoring elderly people in the environment of their choice and can provide the possibility of independent living.
In the recent years the number of research from telemonitoring filed has increased. The [4] study shows that the most important functionality of a telemonitoring system in accordance to the Maslow’s pyramid is the alarm function. The key needs expressed by older people are:

- to feel secure and safe and to live independently;
- to be able to care for themselves and also for their homes;
- to enjoy fulfilling life at home and outside the home as well [5];

In the following section we introduce some telemonitoring projects from European researchers.

Vital Assistance for the Elderly (VITAL): researchers from [6] aimed at empowering elderly to take care of themselves and provide access for them to information. With the developed platform they would like to satisfy the following functions: the ability to move safely, personal advice, interpersonal communication, and edutainment. [7]

Networked Multisensor System for Elderly People: Healthcare, Safety, and Security (NETCARITY): The main goal of this project is to provide wellbeing, security, and confidence to elderly living alone at home. It uses smart cameras in the ceiling combined with pressure sensors in the floor which are able to recognize emergency situations and automatically alerts primary contacts for support. In bathrooms to detect falling incidents the researchers used motion sensors. [7]

Service-oriented Programmable Smart Environments for Older Europeans (SOPRANO): aims at allowing older people to be more independent while living in their home. The developed system beside that can provide support in problematic and emergency cases, helps to improve the everyday life quality of elderly being able, through a set of sensors, to sense the current state of elderly. [7]

PIR (passive infrared) sensors are commonly used to build smart environments such as healthcare centres, security systems, smart energy systems, etc. Due to their simplicity PIR sensors have recently been gaining increasing attention. One of the biggest advantages of using PIR sensors for movement detection is the fact that they are well accepted by users because of their appearance in numerous places and can be easily attach to any indoor environment. Many researchers have been working on systems with PIR sensors for movement detection and for counting people entering/leaving the room. In their study [8] the researchers used PIR sensor nodes to locate human targets. The scope of sensor nodes is to detect the angular displacement of a moving target and by using multiple sensor nodes the researchers enhanced the localization accuracy. In their study [9] the researchers declared that their system can track up to eight persons with high accuracy, for that they used binary infrared PIR sensors attached to the roof of the room. Researchers from [10] proposed a method for abnormal behaviour detection with PIR sensors.

A PIR sensor based wireless network system for detecting the direction of movement and identifying the number or people walking (in line as well as side by side) was built by the researchers from [11]. According to the test results their system showed a 100% correct detection of movement direction and an 89% correct detection of number of people. Researchers from [12] presented a wireless distributed PIR system for identifying and tracking multiple humans based on their gait and heat of body radiation.

3. PIR based bathroom emergency detection device

Based on our research, the most important non-functional requirements for telemonitoring domains are: the use of non-wearable sensors, ease of use, validity of information, durability and reliability. Beside these requirements the telemonitoring system should be ubiquitous, that means the monitored person would not need to remember to enable the equipment [13].

In this section we will introduce a PIR sensor based telemonitoring system for bathroom emergency situations detection with SMS alerting function. The scope of the developed device is to support the independent life of elderly in home environment by ensuring them if they need support in bathroom emergency situations their request will be sent automatically. The developed device detects if the monitored person spends too much time (more than usual) in the bathroom, it is a sign of potential emergency situation, and automatically alerts primary contacts for support. The device detects when someone enter into the bathroom and start a countdown from a predefined value. If the
person leaves the bathroom the countdown turns off. If the countdown reaches 0, trigger the alarm for one minute. The monitorized person can stop the alarm by pressing the reset button during this one-minute period. If the monitorized person does not push the reset button, after one minute the device send massages to predefined numbers (ex.: “Too much time in the room, maybe something wrong happened”). Figure 1 shows the functional logical scheme of the developed device.

Figure 1. Functional logical diagram
Figure 2 shows the general components and the schematic diagram of the bathroom telemonitoring device. The device’s “brain” is an Arduino Uno from the Arduino board family. It is a microcontroller board based on the ATmega328P, it has 14 digital input/output pins, 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button.

Figure 2. PIR-based bathroom emergency detection device.
For movement direction detection we use two PIR sensors (HC-SR501), it is based on infrared technology with high sensitivity and reliability and ultra-low voltage operating mode. In emergency situation to be able to notify predefined persons we use the SIM900 GSM module. It is an ultra-compact and reliable GSM/GPRS module, which works on frequencies of 850/900/1800/1900MHz and can be used for oral communication, SMS notification and internet access. For visual and auditory local notifications we use three LEDs and an active buzzer. To obtain 100% autonomy as power supply we use 9V rechargeable UPS batteries and to avoid any possible low battery issues we use a voltage sensor to measure continuously the batteries charge level.

4. Experiment
The developed bathroom emergency situation detection device was tested in laboratory environment. Figure 3 presents the developed device prototype.

![Figure 3. Bathroom emergency situation detection device – prototype.](image)

Six different scenarios, described below, were tested, where the device was positioned according to the layout detailed in figure 4; table 1 summarize the tests results.
- Scenario 1: one person entered the room, waited and after 30 seconds left the room;
- Scenario 2: one person entered the room waited until the alarm triggered and reset the alarm by pressing the reset button;
- Scenario 3: one person entered the room wait until the alarm triggered and waited the one-minute resetting countdown (waited until the message was sent);
- Scenario 4: two persons entered the room (30 seconds delay between them) and after one minute both left the room (30 seconds delay between them);
- Scenario 5: two persons entered the room (30 seconds delay between them) and just one left after 30 seconds. The alarm triggered and the alarm was reset by pressing the button;
- Scenario 6: two persons entered the room (30 seconds delay between them), after 30 seconds one person left the room and the other one waited until the alarm triggered and the message was sent;

![Figure 4. Test installation layout.](image)
Table 1. Prototype testing - Results.

| Scenario  | No. of tests | Number of correct detection | False detection | Test result |
|-----------|--------------|-----------------------------|-----------------|-------------|
| Scenario 1 | 50           | 50                          | 0               | Passed      |
| Scenario 2 | 10           | 10                          | 0               | Passed      |
| Scenario 3 | 10           | 10                          | 0               | Passed      |
| Scenario 4 | 10           | 10                          | 0               | Passed      |
| Scenario 5 | 5            | 5                           | 0               | Passed      |
| Scenario 6 | 5            | 5                           | 0               | Passed      |

5. Conclusion
In this paper we studied the existing telemonitoring solutions for independent life of elderly and we have presented a bathroom telemonitoring system with alerting functions. The scope of the presented device is to support the independent life of elderly in home environment by ensuring them if they need support in bathroom emergency situations their request will be sent automatically. We identified the crucial features of the developed device in: ease of use, 100% autonomy, the use of non-wearable sensors, durability and reliability. These features have been tested in laboratory environment. We tested six different scenarios, more than 90 simulations with 100% accuracy. The next step will be to test the developed device in real home environments and to validate the expected benefits by user experiences.

6. References

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