Asian Journal of Pharmaceutical Research and Health Care, *Vol 9(3), 131-137, 2017*
ISSN (Online) : 2250-1460
DOI: 10.18311/ajprhc/2017/14970

Bedroom Monitoring System for Isolated Elderly People and Patients

Atika Arshad[1*], Ahmad Fadzil Ismail[1], Sheroz Khan[1], Wahidah Hashim[2] and Mohammad Kamrul Hasan[1]

[1]Department of Electrical and Computer Engineering, International Islamic University Malaysia, Malaysia; atikaarshad@hotmail.com, af_ismail@iium.edu.my, sheroz@iium.edu.my, hasankamrul@ieee.org
[2]Department of System and Networking, Computer Science and Information Technology, Universiti Tenaga Nasional, Malaysia; Wahidah@uniten.edu.my

Abstract

With the rapid growth of a number of elderly people around the world, an increasing need has arisen in providing physical security to them. Researchers have been working in developing such monitoring systems for the past decades. However, the needs of elderly people and their families are yet to be fulfilled, especially since the developed existing systems need their users to change their lifestyles. This work aims at suggesting a system for monitoring the occupancy of an elderly person on the bed. Capacitive proximity sensing system has been proven to be a probable solution for indoor localization, which senses the presence of a human body. Nevertheless, the requirements for installation are many, which make the integration costly. In this paper, a flexible and integrated solution is proposed that makes use of inexpensive, open source hardware, allowing indoor localization and fall detection. The bed monitoring system is made up of aluminum sheets sensor electrodes installed under the bed sheets to detect the sleeping patterns of the subject. An alarm system has been integrated into the room to enable the elderly to call for help during an emergency. Presence detector and light controlling device are installed on the floor surface to detect the mobility of the elderly and turn ON/OFF the room lights automatically. The proposed system allows elderly people to live independent living at homes with all amenities.

Keywords: Bed Occupancy Sensor, Capacitive Proximity Sensing, Elderly Monitoring, Independent Living, Indoor Monitoring System

1. Introduction

This work describes the design of a real-time sensing system which aims to make lives of elderly people safer and more reliable. Monitoring and safety make two major regions of concerns in health care homes establishments. Monitoring parameters include their daily activities, social interactions, sleep patterns, and other health indicators[1-4]. Safety is related to falling incidents, one of the biggest issues about the elderly homes[5]. An elderly person accidentally falls may have terrible medical conditions, which deteriorate the quality of life besides being costly expenditures. Monitoring a subject in bed can reduce the falling incidents or going into the toilet as a huge number of fallings occur in such conditions[6].

Several ongoing research works have been reported[7-13] giving a comprehensive description of the existing such systems. Some of such monitoring systems include video/camera, passive infrared sensors (PIR), motion sensors, Doppler sensors, radars, capacitive sensors, floor sensors, and so on as listed in Table 1.

All the mentioned technologies serve a good purpose on monitoring the elderlies daily life activity, but an essential point to be noted is that capacitive methods for human monitoring applications are drawing the most interest because they offer a technique to protect individual privacy, their sensing electrodes are not required to be noticeable to the user, they can be used to distinguish between both the static and moving subjects, and they can be deployed with sizeable electrodes covering large

** Author for correspondence*

areas, and yet less[14-16]. This paper has reported the design and development of a monitoring system, which will aid in monitoring the elderly at home. The monitoring of the elderly in the bedroom is analyzed. The quality of sleep can indicate the wellness of the elderly. When he/she gets sound sleep, sensors will give stable signals. On the contrary, when the person lacks from enough sleep or moves ceaselessly during sleep, the signals will not be stable. Accordingly, irregular activities can be identified. If the person leaves the bed at night, that time duration for which the bed is unused is also monitored.

2. Motivation and the Need for Bed-Sensor

In the development phase of an elderly monitoring system, essentialities for integrating a bed check monitoring system with the existing system have been realized. The target behind using this kind of sensor is to observe the time used in bed by an old person who lives on his own in a house. The person may require an urgent medical need or an abnormal situation might occur. The developed system presented in this work can provide a preventive solution to avoid any sudden accidents in the home environment in absence of a caregiver.

Let us assume two different types of circumstances, which a person can face while living unaccompanied.

- A person is habituated to get up from bed every morning at a specific time. However, on a particular day, that person may not feel like getting up from bed at that specific time. This indicates that the person may have a severe health issue or he/she is not capable of moving out of the bed due to ill feelings.
- A person is habituated to use the bed at a definite time every night. If on a particular night he/she doesn't go to bed according to his schedule, it may indicate that the person might have severe health issue or he/she fell down somewhere in the house which is why he/she is not able to use the bed at that time and also he/she needs medical aid.
- In these kinds of circumstances, the bed monitoring sensor can be effective. By analyzing the data from its database, the system will be able to decide whether to trigger an alarm signal or stay quite. If the need to trigger the signal is felt, it will alert the caregiver as well.

3. Capacitive Sensing Overview

Capacitive proximity sensor operates on the basis that human body is made up of ionized water; thus contain some electrical properties including conductivity. By applying an electric field[17,18], the human body can easily be influenced. Usually, with an application of a specific

Table 1. Overview of the existing monitoring technologies

Technology	Advantage	Disadvantage
Video cameras[7]	- Provides direct information	- Raises privacy concern - High cost of installation - Requires high computing powers - Affected by lighting and shadowing - Line-of-sight requirement from the user to the camera
Passive Infrared Sensors[7]	- Compact in size - Cost effective - Less power consuming	- Not very accurate as they are sensitive to temperature - Unable to monitor motionless or slow moving human body
Sound/Audio sensors[7]	- No privacy issue raised	- High cost - Consumes more power - Complex structure - High level of interference by the environment - Extensive cabling is required - Need to carry a device by the user
Wearable device[7]	- Increase efficiency in health monitoring - Increases research scope in nanotechnology	- Uncomfortable, need to be worn at all times
Electric Field Sensing[7]	- Non-intrusive - Low cost	- affected by humidity and temperature

voltage to the sensor, a uniform electric field is generated. A capacitance is generated animatedly when a human body is in contact with the sensor. The capacitive sensor controller can determine any change in the electrical field due to the presence of any human or conductive object coming close to the sensor. Therefore, any change in capacitance formulates a decision of human proximity; thus making the system appropriate for being installed under the carpeting in a room[19]. In addition, through signal processing, different types of human activities can be identified. The capacitive behavior existing between two conductive parallel plates can be formulated analytically.

$$C = \frac{Q}{V} \quad (1)$$

$$C = \varepsilon_O \varepsilon_r \frac{A}{d} \text{ and thus } C \propto \frac{1}{d} \quad (2)$$

The equation states the proportional relationship between capacitance and the plate area A; and the anti-proportional relationship between capacitance and the distance d between the plates. The relative permittivity of the dielectric between the plates is expressed as relative premitivity, εr. Sensor electronics are made grounded with the body behaving as the ground itself. By applying a constant voltage V, the sensor plate is charged. A large value of capacitance makes the system hold a large charge Q. The conductive object behaves as the second plate, thus enhances the capacitance C by reducing the distance d.

Figure 1 shows the basic setup for human localization using proximity sensing sensor setup[20-21]. The sensor forms a parasitic capacitance Cp with the surrounding ground, and an electric field fringe is formed on top of the sensor area. If any human walks above this sensor, it changes the electric field lines and adds a human body capacitance Cbody to the sensor. This enhances the value of sensor capacitance from Cp to Cp + Cbody. By incessantly calculating the sensor(s) capacitance and looking for an abrupt change in capacitance, a microcontroller can determine whether a human body came in contact with the sensor. Here, the parasitic capacitance of the sensor is not taken into account. The microcontroller keeps on looking for an abrupt variation in capacitance and if this variation is more than a specific threshold, a human body presence is identified and reported.

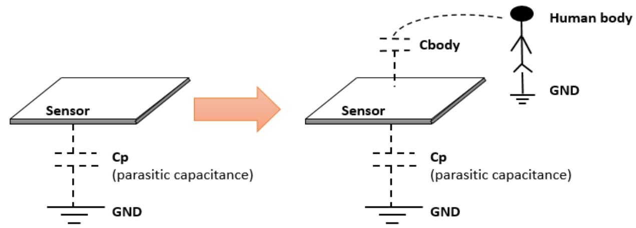


Figure 1. When a conductive object (human body) comes near the sensor, a capacitance Cbody is introduced which is parallel to the parasitic capacitance CP.

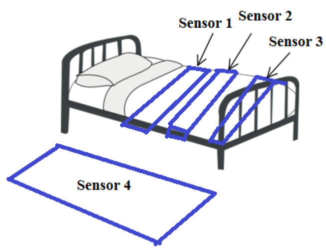


Figure 2. Placement of the sensors.

4. Implementation of the Proposed Design

The proposed system is developed for senior citizens who live alone, with the aim to monitor their sleep routine. Sensors are integrated under the bed cover (S1, S2, and S3), on the floor surface (S4) as seen in Figure 2 and a manual switch (M1). The sensors are made from capacitive elements (aluminium sheets), three capacitive sensors (Sensor 1, Sensor 2, Sensor 3) are set to be placed underneath the bed covers which will monitor the position of the subject on the bed, either the patient is lying down or sitting up. Sensor 4 is placed on the floor beside the bed, which will monitor the leaving state of the person, hence controlling the room lighting device. A flow chart is illustrated in Figure 3 demonstrating its working principle. The algorithm of the system is divided into two parts, the first part is based on the detection of an elderly being present on the bed, and the other part of the algorithm is based on turning ON/OFF of a lighting device when the elderly steps out of the bed.

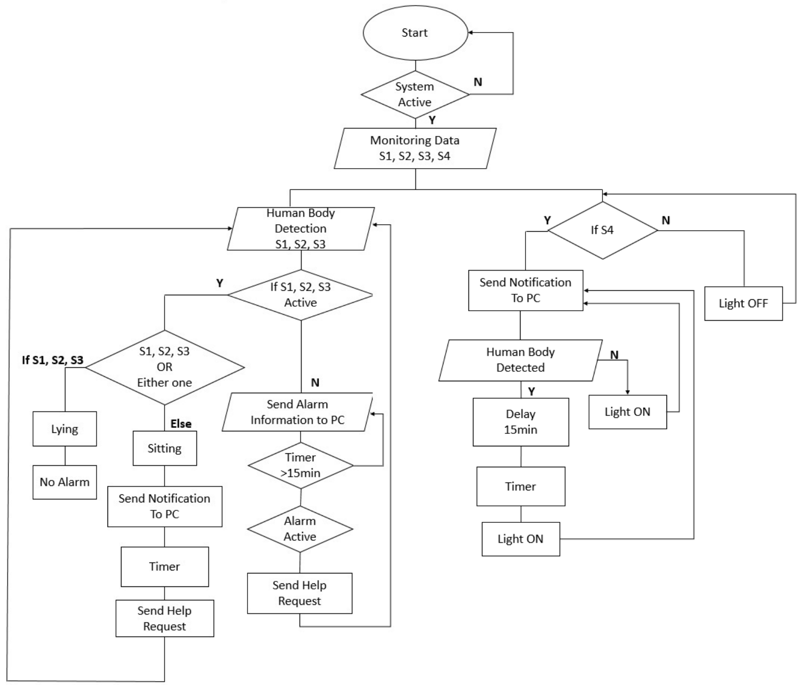


Figure 3. Workflow algorithm of the bed monitoring system.

In order to detect the occupancy of the bed, the system checks whether the three sensors S1, S2 and S3 are activated. If the system finds that all three sensors S1, S2 and S3 are in the active state, it will be notified that a person is in the lying down position. However, if any other combination is detected, it will be notified that the person is in the sitting down position and a timer will be activated for a certain time and monitor the length of time a person is taking to sit. If the time taken is more than 15 minutes, an alarm will activate as well as a help request is sent to caretakers.

When the three-bed sensors including the floor sensor detect nothing, the system senses an inactive state of all the three sensors, and after 15 minutes of the waiting time, an alarm will activate to notify the caretakers about the unusual occurrence.

Sensor 4 is activated in the presence of a person. Once activated a lighting device (green LED) will turn ON. However, if the person wanders off to the bathroom for too long, that is more than 15 minutes, an alarm will be triggered.

Figure 4 shows the complete circuit diagram for the bed monitoring system. The connection is integrated with the Arduino UNO microcontroller. The receiver pins and the send pins of the sensors S1, S2, S3, and S4 are connected to the microcontroller's digital pins (4, 2), (4, 3), (4, 5) and (4, 8) respectively.

Then the Arduino is programmed for turning ON a relay, turning ON and OFF when Sensor 4 is activated uses the relay to control the lighting device in the room. The ground of the relay is connected to the receiver pin of Sensor 4, and channel 1 of the relay is connected to digital pin 7 of the Arduino.

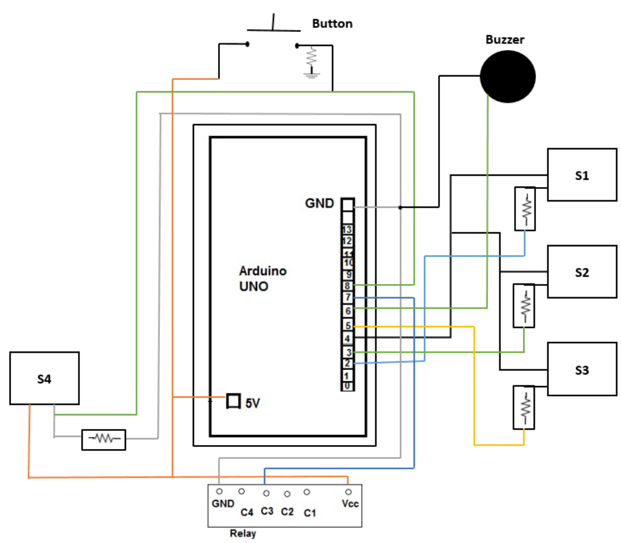


Figure 4. Complete circuit diagram of the bed monitoring system.

Furthermore, a manual switch button M1 is connected to the Arduino, for the purpose of manually controlling the lighting device. The switch button has three connection, +5V, GND and digital pin 8 of the Arduino. Again this manual switch can be used as a manual reset button for the caretakers to manually reset the system. The buzzer is connected to digital pin 6 and a red LED will blink when the buzzer is trigged by the Arduino.

5. Results and Discussion

The proposed device illustrates a combination of several results which are shown below. When the person is detected as lying down position, the system will show normal state which is no alarm or LED light remains turned on as seen in Figure 5.

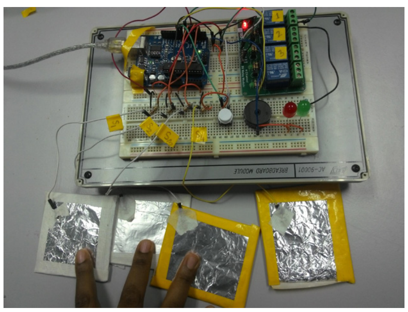
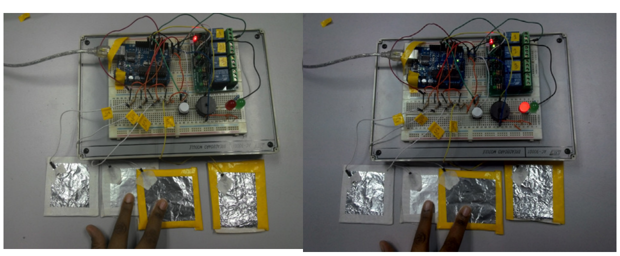


Figure 5. S1, S2, and S3 are active indicating the patient in lying down position.

If the patient is sitting down on the bed only, with the combination of any one or two sensors being active, the device will detect as sitting down position of the patient, see Figure 6(a). But if the sitting down position exceeds 15 minutes, an alarm will be trigged with buzzer and red LED indicator will be shown as in Figure 6(b).



(a) (b)

Figure 6. (a) Any one or two sensors are activated, the system notifies as sitting down position. (b) When sitting position is exceeded.

Furthermore, if the patient activates sensor 4 while sitting, it would mean "the patient wanting to go to the bathroom" or anywhere else. Then the room light system will be turned on through a relay. The green LED as seen in Figure 7 represents the room light.

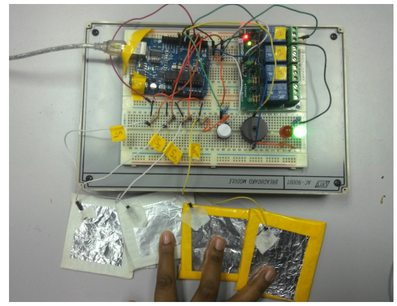
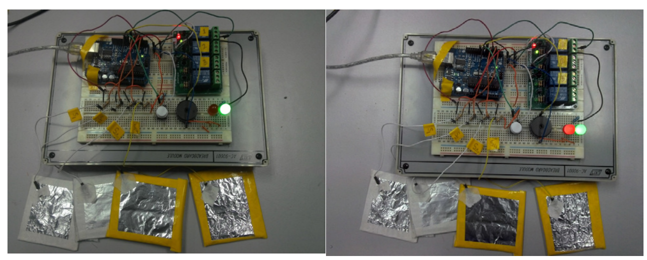


Figure 7. Any one or two sensors are activated, along with sensor 4, given an indication of the person ready to leave the bed.

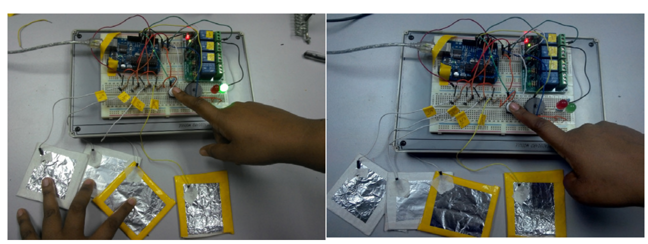
If the person gets off the bed, the room light will remain turned ON, see Figure 8(a). When the person does not return back to the bed after 15 minutes the red LED will turn ON. An alarm is activated to notify to staff on duty hat the person has wondered off.



(a) (b)

Figure 8. (a) Rooms light turned ON, when the person leaves the bed. (b) When the person does not return to bed within 15 minutes.

Finally, the manual button function is shown in Figure 9. If the person decides to manually turn off the lighting device or turn off the alarm, he or she can do so by pushing the manual button M1.



(a) (b)

Figure 9. (a) Manually turning off the lighting device. (b) Turning off the alarm manually.

6. Conclusion and Future Work

A reliable bedroom system has been proposed and implemented for monitoring the sleeping pattern of a person, based on which health conditions can be predicted, possible namely restless sleep, and fast change in scheduled activities or atypical changes in the regular routine chores of a person. Furthermore, the proposed system is able to monitor the availability of the person on the bed; the exit/entry of the person from the bed as well as the system is able to turn on the light automatically. It can be concluded that the system is low cost since it is based on capacitive sensing. The presented system is easily extendable and a new sensor can be added and removed at any time. The system is capable of storing a patient's physiological data for an entire day and also for a week as well. However, there is one major drawback in this system that is the system can be only implemented in homes using raised flooring system in order for the system to be unobtrusive. Additionally, the proposed system's precision and reliability could not be fully ascertained, as the experiment is not conducted using an arbitrary bed. The bed monitoring system offers an inexpensive measurement device, as the designed system is implemented using basic laboratory components, likewise, the power intake of the hardware system is also less since fewer components are being used. The proposed system can be viewed to be absolutely safe for the human beings since the formed electric fields in the human body are below the International Commission on Non-Ionizing Radiation Protection (ICNIRP) set reference restriction level[22]]. Here a 5V excitation is supplied which will produce an electric field lower than 4.32 V/m, that is, the maximum limit set by ICNIRP for human safety. In future the presented system can be extended to include more sensors that can measure more added parameters like the usage of the bathroom, this can be determined by the usage of the toilet flush, and the water usage of the bathroom sink by placing the capacitive electrodes at the watering pipe system.

7. References

1. Wang SW, Chen WH, Ong CS, Liu L, Chuang YW. RFID applications in hospitals: A case study on a demonstration RFID project in a Taiwan hospital. In Proceedings of the Annual Hawaii International Conference on System Sciences; 2006; p. 1–10. https://doi.org/10.1109/HICSS.2006.422
2. Gentili GB, Dori F, Iadanza E. Dual-frequency active RFID solution for tracking patients in a children's hospital. Design method, test procedure, risk analysis, and technical solution. Proceedings of the IEEE. 2010; 98(9):1656–62. https://doi.org/10.1109/JPROC.2010.2053330
3. Pitta F, Troosters T, Spruit MA, Decramer M, Gosselink R. Activity monitoring for assessment of physical activities in daily life in patients with chronic obstructive pulmonary disease. Archives of Physical Medicine and Rehabilitation. 2005; 86(10):1979–85. PMid:16213242. https://doi.org/10.1016/j.apmr.2005.04.016
4. Ducatel K, Bogdanowicz M, Scapolo F, Leijten J, Burgelman J. Scenarios for ambient intelligence in 2010. Technical Report; 2010. http://cordis.europa.eu/ist/istagreports.htm
5. Gill J, Moore M. The state of aging and health in America; 2013.
6. Pung H, Gu T, Xue W, Palmes P, Zhu J, Tang C, Chung N. Context-aware middleware for pervasive elderly homecare. IEEE Journal on Selected Areas in Communications. 2009; 27(4):510–23. https://doi.org/10.1109/JSAC.2009.090513
7. Arshad A, Khan S, Alam AHMZ, Ahmad FI, Tasnim R. A study on health monitoring system: Recent advancements. International Islamic University Malaysia Engineering Journal. 2015; 15(2):89–99.
8. Arshad A, Alam AHMZ, Khan S, Tasnim R. Passive monitoring techniques for elderly: A review on recent development and prospective. Proceedings of the World Congress on Engineering and Computer Science (WCECS 2015); San Francisco, USA. 2015 Oct.
9. Aud MA, Abbott CC, Tyrer HW, Neelgund RV, Shriniwar UG, Mohammed A, Devarakonda KK. Smart carpet: Developing a sensor system to detect falls and summon assistance. Journal of Gerontologic Nursing. 2010 Jul; 36(7):8–12. PMid:20608585. https://doi.org/10.3928/00989134-20100602-02
10. Rimminen H, Linnavuo M, Sepponen R. Human tracking using near field imaging. International Conference on Pervasive Computing Technologies for Healthcare; 2008.
11. Ropponen A, Linnavuo M, Sepponen R. LF indoor location and identification system. Int J Smart Sensing and Intelligent Systems. 2009; 2(1):94–117.
12. Rimminen H, Linnavuo M, Sepponen R. Human tracking using near field imaging. 2nd International Conference on Pervasive Computing Technologies for Healthcare; 2008. p. 148–51.
13. Arshad A, S. Khan, Alam AHMZ, Tasnim R, Gunawan TS, Ahmad R, Nataraj C. An activity monitoring system for senior citizens living independently using capacitive sensing technique. International Instrumentation and Measurement Technology Conference (I2MTC 2016); Taipei, Taiwan. 2016 May 23-26. https://doi.org/10.1109/i2mtc.2016.7520405

14. Valtonen M, Vuorela T, Kaila L, Vanhala J. Capacitive indoor positioning and contact sensing for activity recognition in smart homes. Journal of Ambient Intelligence and Smart Environments. 2012; 4(4):305–34. https://doi.org/10.3233/AIS-2012-0158
15. Braun A, Heggen H, Wichert R. CapFloor - A flexible capacitive indoor localization system. Communications in Computer and Information Science. 2012; 309:26–35. https://doi.org/10.1007/978-3-642-33533-4_3
16. Adami A, Pavel M, Hayes T, Singer C. Detection of movement in bed using unobtrusive load cell sensors. IEEE Transactions on Information Technology in Biomedicine. 2010; 14(2):481–90. PMid:19171523. https://doi.org/10.1109/TITB.2008.2010701
17. Zimmerman TG, Smith JR, Paradiso JA, Allport D, Gershenfeld N. Applying electric field sensing to human-computer interfaces. CHI'95 Human Factors in Computing Systems; 1995.
18. Smith JR. Electric field imaging [Dissertation]. Massachusetts Institute of Technology; 1999.
19. Valtonen M, Vanhala J. Human tracking using electric fields. IEEE International Conference on Pervasive Computing and Communications; 2009. p. 1–3. https://doi.org/10.1109/percom.2009.4912795
20. Baxter L. Capacitive sensors: design and applications. IEEE Press Series on Electronics Technology. John Wiley and Sons; 1996. https://doi.org/10.1109/9780470544228
21. Foster KR, Lukaski HC. Whole-body impedance–what does it measure? The American Journal of Clinical Nutrition. 1996; 64(3).
22. Guidelines for limiting exposure to time-varying electric and magnetic fields (1 kHz- 100 kHz). International Commission on Non-Ionizing Radiation Protection, Health Physics Society; 2010.