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Daily Activity Monitoring of an Elderly Person for Determining Their Wellness

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Abstract

The work carried out in this paper aims to present a model based on elderlies daily activities to determine their wellness status. A wellness function is delineated to estimate the health condition of the aged individuals while carrying out their day-to-day routine. The proposed model can also be used to monitor the mobility parameters, such as entry and exit of a room and bed occupancy of an elderly. Simple sensors such as capacitive sensors are equipped into their homes to monitor their behaviour and identify their daily activities via non-contact means. The device will allow extracting daily behavioral patterns of the elderly person. Thus the device will help in providing information to build behavioral model of the person which can foresee the anomalies in their behaviour. In case the elderly is distressed, an alarm can be sent to a receiver unit. The cost effectiveness of the device will ultimately lower the total cost of wellness monitoring of an elderly person. A prototype of the device can be fabricated and broadly tested for extracting precise results.

Keywords: *Elderly care, home monitoring, daily activities, wellness, capacitive sensor*

1. Introduction

Aging population and dealing with problem in improving their lifestyle has become an important issue in health monitoring field. According to a survey [1] the number of elderly population are aged over 65 years, which is approximately 7% of the world's population. This number has been projected to rise nearly by 20% by the year 2050. With the present rise in demography, there is an increasing challenge for both government and individual families to effusively support the healthcare expenditures and social care systems. The health care budget can be reduced by lessening the number of elderly people in clinics through detecting health issues and saving those people from any worse situation using smarter technology. For instance, smart home allow elderly people to be in their individual homes comfortably instead of being in a hospital or institution. Over the last decade, various methods have been proposed for monitoring elderly behavior in smart home. Technologies like video surveillance, wearable devices, smart home monitoring applications have been able to significantly diminish the possibility of such risks or accidents by making it possible to keep an eye on the elderly people and notify their respective contacts or care takers whenever such mishap occur. However, several shortcomings have been observed in prior technologies. For instant invasion of privacy and expensive infrastructure are a major drawback in the realm of video surveillance systems. Wearable devices are uncomfortable as they need to be worn on the body. The existing monitoring systems are not user friendly and most of them have complicated design. Hence the aforementioned shortcomings

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should be overcome. A smart monitoring system will allow elderly to take control of their personal health and wellbeing. The use of daily monitoring system will reduce overall costs, increase freedom of movement, and change the traditional care giving system which was limited to healthcare settings in hospitals or nursing homes. Most of the existing products in the traditional system require the elderly people to buy special devices. Sometimes the system will require the user to pay a recurring fee for using proprietary technology.

However, it is recognized that modern technologies have immensely contributed towards the advancement of healthcare. Smart home environments have become a noteworthy research topic in recent years. It can improve the standard of living of the elderly people by keeping their privacy and allowing them to stay in their own homes rather than living at care homes or hospitals.

This paper proposes an intelligent home monitoring system for the care of elderly. To perceive and recognize the behavioral changes of an elderly person on daily basis, integrated sensors are designed and developed. Due to old age or physical illness of elderly people, some risk factors are there. The elderly's activity is monitored by observing patterns of their regular actions, simple parameters such as movements, falls, sleep patterns, exit and entry to bathroom, kitchen or rooms are examined. For example records of data pattern can support with the identifying of urinary tract infections through the regularity of bathroom visits during the day. The system uses capacitive sensors to observe the elderly person in a house and identify if any particular safety measure is required. In accordance with this analysis, physical parameters such as entrance and exits of a room, or occupancy of bed or chair can be sensed to provide early warning if the elderly person does not return in determined time. Moreover, the proposed system can be used in an existing home of the senior citizen or on a newly built house. The developed system is non-invasive, cost effective and helps in continuous monitoring, tracking of normal behavior of elderly living alone. Any variation in normal actions can possibly be detected by the developed home monitoring unit, which triggers messages to the caregiver regarding any functional alterations in the capabilities of elder people.

2. Related Work

Human monitoring and day-to-day activity recognition systems proposed in the literatures can be categorized into active non-contact sensors and passive non-contact /ambient sensors. The active based systems require users to have a physical device or an attached device to the person namely global positioning system (GPS), ultrasonic system, infrared (IR), radio frequency identification (RFID) tag *etc*. Therefore, active systems can be conspicuous and bothersome for uninterrupted usage. From the perspective of an aged person living at home [2], these methods are not practical or user-friendly owing to the hassle of remembering to carry the device at all times. If one does not pay attention to the device, monitoring does not take place.

To overcome the problem of active systems, an alternating method is the use of automatically functioning passive device that would allow users to continue their everyday activity without being monitored. Passive sensing systems allow the users to roam without the necessity for sticking any tags to the person. Such monitoring systems can be embedded in the environment. Several shortcomings have been observed in these technologies. For instant invasion of privacy and expensive infrastructure are a major drawback in the realm of video surveillance systems. Wearable devices are uncomfortable as they need to be worn on the body. A detailed review on the advantages / disadvantages of some of the systems is presented in [3].

The most important factor in modeling the design for the elderly is that the technology should not interfere with normal activities. Therefore, the devices should completely operate independently. To control the devices independently without human interference, objects inside the house would be attached with sensors to collect data on their active state, for instance on stoves and refrigerators, domestic objects such as bed and chairs, and temperature conditioning units such as air conditioners and radiator. By studying the habits of a person, anomalies from their daily activities, such as mobility, sleep patterns, entry and exist of a room, use of cooking, washing and lavatories facilities can be reported.

3. Capacitive Sensing

Capacitive sensors utilizes electric field to distinguish human activities. Using the unique differentiating features of human touch, one can uniquely identify individuals. This is due to the fact that every human body has different levels of bone density, blood volume, muscle mass, and touching patterns, and so on. So, if one can precisely measure the electrical properties of a person, it should be possible to recognize, or at least distinguish, the person. Zimmerman et al. and Smith in [4] presented the first-generalized approaches to proximity sensing for locating humans. As elaborated in [4], they discussed three modes of operation: 1) transmit mode, 2) shunt mode, and 3) loading mode. In this work the focus is on the loading mode of capacitive sensing as it is the simplest and most flexible mode. The moment a human body comes in contact with an electrode, the capacitance between the electrode and the human body increases, in which typically only a single electrode is required in this setup.

4. Activity Annotation Process

Anomaly detection process is known as the system of discovering trends in relevant data that follows expected behavior [5]. Clustering techniques, information theoretic methods and statistical methods are anomaly detection techniques which are widely used to integrate emergency detection algorithms into video surveillance, home monitoring, or fall detection systems integrated to smart homes. Anomaly detection technique was previously for recognizing patterns or dangerous situations using several types of heuristic methods on the basis of spatiotemporal information [6], classification [7], and goal analysis [8].

The anomaly detection function in this paper is developed based on the work established by Mukhopadhyay *et al.*, [9]. The author determines the wellness of a person by finding the number of times a certain household appliance is being used in a day, thus a behavioral model is developed. The behavioral model in this work is defined based on individual elderlies performing their daily habitual routines. For instance an elderly may get up during night-time to use the toilet, then may begin wandering in the room without going back to sleep, hence, keeping track of such activity is referred as the behavioral pattern.

Two wellness functions have been defined β1and β2 to estimate the wellness of the aged people being monitored. The function β1 denotes the inactive period of the appliances, whereas β2 denotes the over-usage period of the household applications.

The wellness functions can be derived as follows;

$$\beta 1 = 1 - t/T \tag{1}$$

Where,

β1 = Wellness function of the elderly person on the inactive period of duration of application.

t = Inactive period of appliances, that is when no appliance were being used at all.

T = Maximum duration of inactive period when no appliances were used, hence, resulting in an irregular state.

If $\beta 1 = 1.0$, this shows that the elderly is in a good health state. If $0.5 < \beta 1 < 1.0$ then this denotes that the elderly person is in irregular state and if $\beta 1 < 0.5$ then help is necessary.

$$\beta 2 = 1 + (1 - Ta/Tn) \quad (2)$$

Where,
β2 = Wellness function of the elder person on the basis of over usage or over active measurement of appliance.
Ta = Exact active period of any appliance.
Tn = Maximum active duration for the use of appliances in regular state.

It is well-defined that under regular state when no irregularities occurs, Ta < Tn. However, if Ta > Tn then β2 can be deliberated using Eq. (2). Furthermore, when the value of β2 falls between the range 1 to 0.8, it is considered to be in the regular state and if the value of β2 falls below 0.8, then this indicates that the appliance is being over used, thus, resulting in an irregular state.

This work proposes the anomaly detection algorithm for determining the wellness of an elder, a related work conducted by Mukhopadhyay et al. [9], however, Mukhopadhyay determined the wellness of a person using time duration, whereas in this work, the welfare of the elderly is identified by finding out the number of times a specific sensor has been activated.

For instance bed occupancy sensor, a capacitive based sensor embedded on the surface of the bed to monitor the presence or absence of the person on bed. Monitoring changes in sleep pattern can act as a precautionary health monitoring system, if an elderly person leaves their bed often at night, this can indicate that the elderly is suffering from some discomfort. Here by knowing the number of times the sensor is trigged to be active can determine the wellness of the elderly.

Take a case scenario, a healthy elderly gets off from the bed twice at night to use the washroom. This activity is assumed to be a fixed number of times per unit duration for a healthy condition, which is denoted by **N**. The number of times the elderly gets off the bed while being monitored for the same activity during the same unit duration is denoted by **n**. In order to indicate the wellness of the elderly, it is hypothesized that if the bed sensor is activated more than 75% or has not been active for more than 75%, then the wellness factor, **W** can be derived as follows:

$$\text{Wellness factor, } (\boldsymbol{W}) = 1 - (\mathbf{n}/\mathbf{N}) \quad (3)$$

Where,
n = number of times the sensor has been activated during monitoring,
N = fixed number of time the sensor is activated during when an elderly is healthy.

A threshold value of 75% is set for the algorithm to generate an alarm signal. Suggesting, that when n is 75% more or 75% less than N, an alarm will be triggered to inform the care takers or family members of an unhealthy condition.

Two sets of threshold value can be set; upper threshold value and lower threshold value as follows;

Upper threshold	Lower threshold
$n = N - 0.75N$ $n = 0.25N$ $W = 1 - (n/N)$ $W = 1 - (0.25N/N) = 0.75$	$n = N + 0.75N$ $n = 1.75N$ $W = 1 - (n/N)$ $W = 1 - (1.75N/N) = -0.75$

It can be concluded that during unhealthy condition $W > 0.75$ or $W < -0.75$, and during healthy condition $-0.75 < W < 0.75$.

5. Description of the System

The system entails two basic components; Wireless sensor network, a ZigBee based module and a software module. ZigBee module is integrated with a mesh topology structure to collect the sensor information depending on the number of times a sensor is activated, and stores this information in the computer for processing further. The collected sensor information is able identify the sensor as well as notify the sensor's active or inactive state. For sensing the motion pattern of the elderly concurrently, the software module will evaluate the composed information by using an intellectual instrument at numerous level of data generalization grounded on sensor usage behavior. Fig. 1 shows the block diagram of the monitoring system.

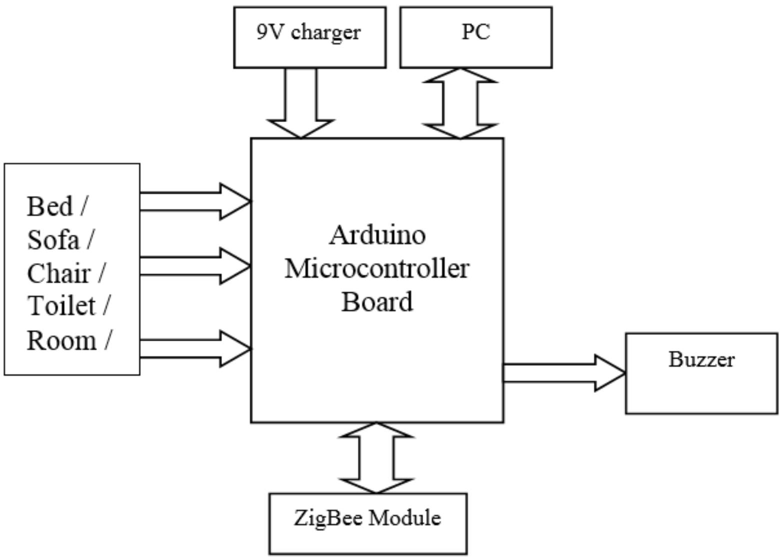

Figure 1. Block Diagram of the Monitoring System showing the Interfacing Sensors and the ZigBee Module

The monitoring system monitors the frequency of daily usage of the sensors by attaching capacitive sensors to bed / sofa / chair or any such objects present in the room. The capacitive sensors are also positioned on the floors near the entrances of the toilet and the room. The sensors placed on the floor surface are covered with a carpet to make it invisible to the users. Capacitive sensors was selected because of its ease of integration, cost-effectiveness, and reliability [10]. A detailed explanation on the sensing algorithm and an overview of the capacitive sensing technique is given in [11]. Based on the values for each sensors received by the microcontroller, the system will be able to identify the frequency of use of these devices as active or inactive. Each time the elderly person encounters the embedded sensors, the developed system will monitor and record the event efficiently for additional data processing.

By detecting the status of bed entry and exit patterns one can indicate the status of the elderly whether they have left the bed, hence, any unfamiliar change in their routine can be recognized.

6. Results and Discussion

The experimental setup (Figure 2) for elderly monitoring system consists of three capacitive sensors, an Arduino microcontroller unit and an alarm button connected in the home to monitor elderly conduct and provide help for independent living. Furthermore, any asymmetrical behavior is identified at any specific time. The microcontroller unit is connected to a laptop via a USB cable. The software programing for data procurement and welfare determination is written using Microsoft Visual Studio.

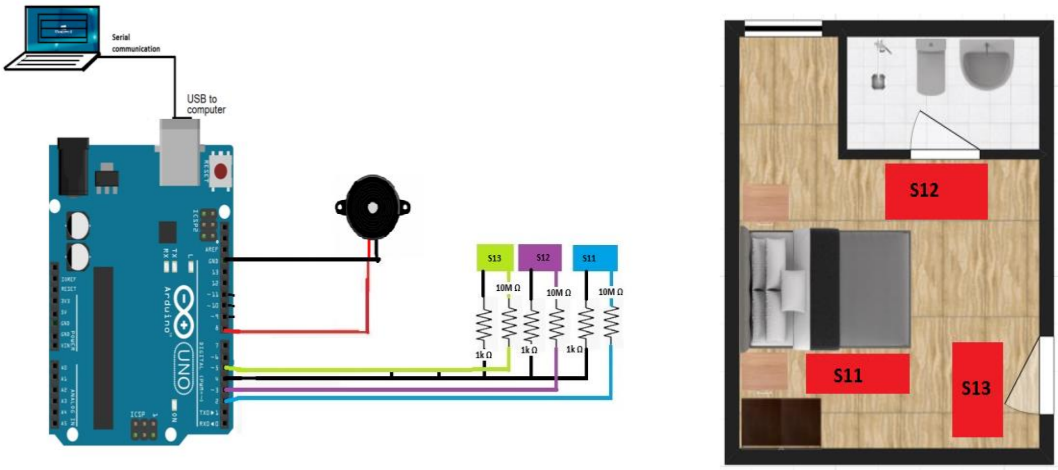

Figure 2. Circuit Diagram of the Experimental Setup (Left) and 3-D view of the Bedrooms Layout and the Sensor Placement (Right)

Sensors are labeled as S11, S12 and S13. The sensor placed at the bed is denoted by S11, sensor for monitoring the number of times a person uses the toilet is labelled as S12 and S13 for sensor monitoring the entering and exiting pattern to the room. The activities of the elderly can now be documented on the basis of sensor ID status, whether the sensor is active or inactive.

Furthermore, status of real-time activity of any elderly can be observed using the proposed system. This system allows the caregiver to be informed about any activity status of the elderly at any instant. The interface will emphasize the icon showing the position of the elderly. The system is capable of storing the information on sensor and analyzes the wellbeing indices. An additional benefit of the interface is that remote monitoring of the elderlies can be carried out.

The alarm can be set based on value of the wellness, which will vary from person to person. When the alarm is set, the system will buzz a sound to notify the elder person that an alert is being sent to the person who is caregiver. Considering the future normal condition, the alarm can be reset to normal when the elder actually press the reset button. The wellness functions were useful in comprehending the active and inactive state of the sensor used by the elder person at their homes. These are also useful in forecasting the early abnormal condition of an elderly person performing.

Figure 3 depicts the software monitoring window system signifying which sensor is active or inactive. The daily activity status of the sensors is stored in a computer. These data are used for activity annotation and determining wellness level. The developed user interface shows the status of sensor with corresponding icons and information about the use of each individual sensor, for example, the amount of times the sensor has been used, the active and inactive state of the sensor with the representation of 1 and 0 respectively. The message window shows the sequence of sensors usage.

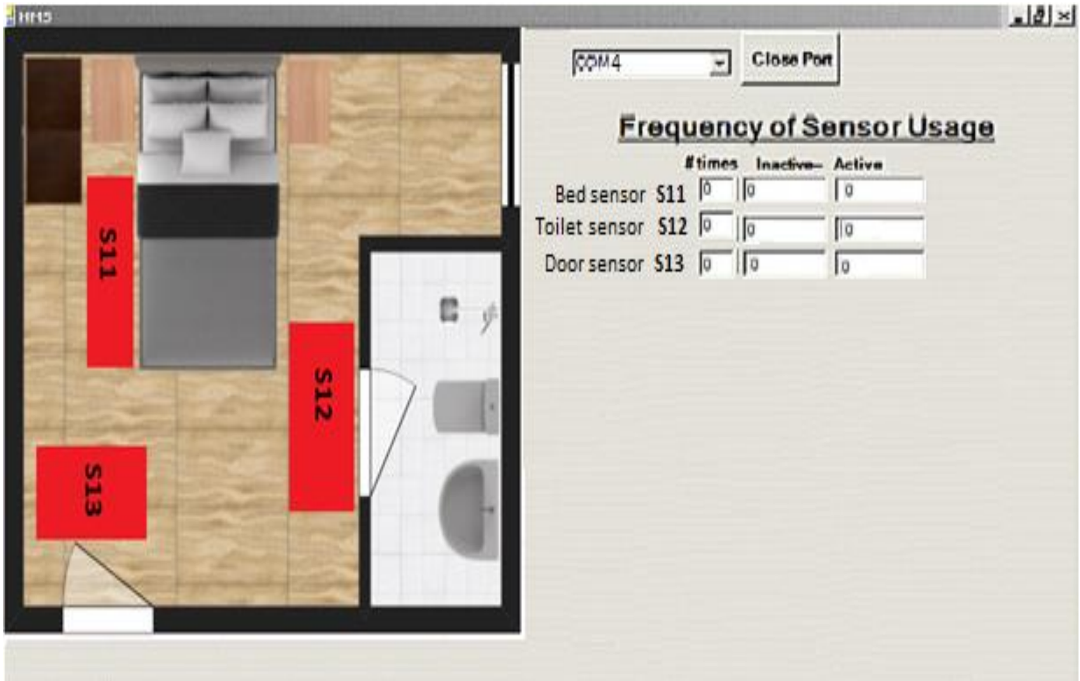

Figure 3. The GUI Output showing the Active or Inactive Status of the Sensors

7. Conclusion and Future Work

The research work presents an elderly monitoring system for determining the wellness of any elderly performing daily activities. This will allow facilitating the caregivers in evaluating the performance of the elderly activities. The real-time activity recognition and wellness determination of the elderly is done making use of sensors. In future, the system can be added to the physical factor monitoring sub-system for collecting information regarding basic health parameters like body temperature, heart rate *etc*. The combined elderly health observation and daily action recognition system can be used to decide on the wellness of the elderly. The system proposed is considered as cost effective, the sensors used for monitoring elderly are built using capacitive sensors, which can be effortlessly made from aluminium kitchen foil, which is available at any grocery store. Furthermore, the monitoring systems are inexpensive to install because extensive wiring is no longer required between sensors and the data acquisition system. It is also easy to implement since no drilling is necessary, it can be basically placed under a floor mat, hence, making the system cost-effective. Additionally, the proposed system causes no effect on the health of the elderly, as the system only measures the change in capacitance as a human body approaches the sensor. An advantage of this system is that more sensors can be added when required as each pin on the Arduino microcontroller works independently, additionally the system is reflected to be portable.

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