Abstract—A non-intrusive design for monitoring everyday activities of an elderly person is presented. The proposed system is intended to be used in the bedroom, allowing the elders to stay at home in a safe environment. The required hardware design is simple in structure and cost effective. The sensor design is implemented by using capacitive sensors and an Arduino microcontroller unit. And a real time graphical user interface is implemented to monitor the elderly person. The performance analysis shows that the sensor design is able to differentiate between a human body and a house pet.

Index Terms—Arduino, elderly home, sensors, senior citizens.

1. Introduction

The ageing population in the world has gradually increased, as well as their dependence and their care cost [1]. Fig. 1 presents a statistical plot showing the percentage of dependent people by age group [2]. Accordingly, the percentage of dependent people is approximately 31.2% in the aged 80 to 84 years old group and that is 49.5% in the over 85 years of age group. In the elder age categories, an increasing number of aged people require supports to perform their day-to-day activities. Furthermore, it is also estimated that around 10% of the aged population are over 65 years old suffering from cognitive deficits, affecting their ability to live a life on their own. The aged population is constantly increasing, and it is predicted that the aged population will reach 20% by the year 2050. This rise is related primarily to the increase in the number of elderly people and decline in the fertility rate.

With the advancement of technology, researches and developers have started to focus on home and personal monitoring systems for the elders. Numerous ongoing studies have been reported, the work documented by [3] and [4] giving a detailed report on existing elderly monitoring technologies. The monitoring systems can be categorized into using active sensors and using passive sensors. The active based systems require users to carry a physical device or a device to be attached to a person such as the global positioning system (GPS) unit [5], radio frequency identification (RFID) tag [6][7], ultrasonic system [8], infrared (IR) [9], and a wearable device. Hence, active systems are considered to be obtrusive and troublesome for continuous use. From the view point of an aged person living at home [10], these techniques are not practical or user-friendly because one must pay attention to the device and remember to carry it all the time, otherwise monitoring does not takes place. An alternative method to overcome the problem of active systems is the use of automatically functioning passive devices that would allow the users to perform their daily activities freely without being monitored. Passive sensing systems allow the users to move freely without the need for attaching any tags or devices. Such monitoring systems include the camera, passive infrared (PIR) sensors, pressure sensing systems, and capacitive sensors. One of the advantages of using passive systems is that tracking can be done without wearable tags or badges. But the use of surveillance cameras for monitoring the patients in most cases has already been ruled out entirely [11][14] due to the issues on privacy. Generally people do not prefer to install cameras in private places like their homes.

Fig. 1. Statistics on percentage of dependent people by age and the dependency ratio over the age group [2].

Pressure sensors have known to be the most traditional existing monitoring system technology available. One of the techniques for measuring pressure is by utilizing electromechanical film (EMFi) [15] that is a thin and flexible
polypropylene film coated with metal electrodes. EMFi is able to store huge permanent charges. If an external force affects the EMFi surface, a variation in the charges becomes obvious between electrodes, detected as a voltage. The EMFi system operates well for locating purposes. Nevertheless, the disadvantage of using EMFi sensing is that EMFi only reacts to pressure variations, it cannot be used to sense static or a stationary person.

PIR sensors are used commonly for monitoring motions, they can be fixed in the ceiling of a room, allowing the evaluation of movements and activities\cite{16,17}. PIR sensors are compact in size, cost-effective, and easily installable, and consume very little power. However, PIR sensors are relatively inaccurate as they are sensitive to temperature and cannot monitor stationary or slow moving human body.

Capacitive sensing methods for human monitoring applications has been in the rise, as capacitive sensing technique\cite{18-24} offers to raise no concerns on privacy unlike camera based systems. Furthermore, the capacitive sensing electrodes can be placed underneath the floor surface of a room, which will allow them to be hidden from the users. More importantly, the capacitive sensing technique is able to distinguish between both the static and moving people, and the sensors can be deployed with big and low-cost electrodes to cover large sensing areas. In this work, capacitive sensing is proposed to be used as a suitable passive sensing system. The required hardware is quite simple in structure and cost-effective as well. The sensing electrodes can be made from the very thin, inexpensive, scalable, and durable material, which can be constructed from a simple aluminum foil that is purchasable at any grocery store and possible to be cut into proper pieces at the installation site.

2. Overview of the System

The block diagram of the proposed system is shown in Fig. 2. The elderly bedroom monitoring system mainly comprises a wireless module and sensing module. Capacitive sensors are used to monitor the elder’s activities and a ZigBee unit is employed to transmit the measured data to a PC. In this work, the focus is given to the method on sensing module. A microcontroller unit is responsible for directing the devices and sensors. Here the microcontroller is the hub of the system, which controls and processes all the information.

Monitoring the quality of sleep for an elder can predict his/her wellness level. For instance, when a person leaves the bed often during their sleep more than the usual times, this could indicate that the person is having some sort of health issues. Considering the lifestyle of an elder, a bed is initiated to be used as a health monitoring system design, since this is a device that an elder has already used frequently in their daily living and hence, which does not require any additional effort from the elder to learn and use. Furthermore, the sensor platform can be integrated easily into the existing device the elderly person is familiar and frequently using. The processor components and the vast sensor modules can be fabricated and positioned on the bed handle.

The basic idea of the proposed system is to recognize the real world and respond accordingly by providing significant data and/or services to the end-user. The work proposes to integrate the sensing components into the elder’s bedroom.

<table>
<thead>
<tr>
<th>Quantity measured</th>
<th>Sensors</th>
<th>Sensor part names</th>
</tr>
</thead>
<tbody>
<tr>
<td>External relative humidity</td>
<td>Humidity sensor module</td>
<td>HSM-20G</td>
</tr>
<tr>
<td>External temperature</td>
<td>Temperature sensor</td>
<td>LM35</td>
</tr>
<tr>
<td>Sleep pattern</td>
<td>Capacitive sensor</td>
<td>Aluminium foil</td>
</tr>
</tbody>
</table>

The main components of the hardware are the sensors, which allow the measurement of the data for sleep patterns and environmental conditions. These include ambient temperature, relative humidity, and capacitive sensors. For the experimental setup various sensors are connected to the central microprocessor using breakout wires, a PCB can be then designed to make the circuit smaller and more compact. The sensors used for measuring each desired condition are listed in Table 1.

3. Measurement Principle and Analysis

Capacitive sensors employ electric field as sensing measurand to identify human body. By means of the electrical properties of a human, one can differentiate and identify them. An ideal capacitor is given by $C = \varepsilon_0 \varepsilon A / d$, where $\varepsilon_0$ is the permeability of free space, $A$ is area, and $d$ is the separation between two capacitive plates. When a human body is exposed to the capacitive sensor, the sensor will measure the disturbance in the electromagnetic field. The capacitor charging and discharging time is measured. The time it takes to charge/discharge to a certain level is
related to the change in capacitance. This change in capacitance can be measured by a time constant \( r \). The larger the capacitance, the longer it will take to charge. The Arduino UNO microcontroller unit will be used to record the time the circuit takes to charge/discharge.

The capacitive sensor Arduino library\(^{25}\) will read the sensor value, which is the library routine where the delay between pulse transmitting time and pulse receiving time is measured. The measured delay is proportional to the time constant \( \tau = R_C C \). Since \( R_C \) is a constant, the timer delay varies only depending on the capacitance \( (C_X) \). If a human body enters the proximity of the sensor, the total capacitance will be varied causing a higher RC time-constant. This will increase the capacitor’s charging/discharging time. Thus it can be determined whether the sensor is in the direct contact with the human body through interpreting the value of the timer.

### A. Bed Sensor

A bed equipped with capacitive sensors can identify the presence and the movement of the person on a bed. The capacitive sensors are positioned beneath the bedsheets where the head (B1), back (B2), and the feet (B3) rests (see Fig. 3). When all three sensors become active, the bed monitoring system will activate immediately and notify that a person is present on the bed. By using three sensors, the lying down and sitting down positions of a person can be distinguished. Through monitoring the sleeping pattern of a person, the detection of the wellness level can be determined, namely the restless sleep, or a typical change in regular routine of a person. When a person sleeps well, the sensor will give stable signals, while a nonstable signal can mean that the person lacks sufficient sleep or moves nonstop during sleeping.

Fig. 4 illustrates the experimental circuit design of the bed-monitoring sensors. Table 1 presents the test measurement output. The measured values are obtained from the Arduino serial monitor. The numbers in the first column represent the time when each sensor changes the voltage. The second column demonstrates the capacitive sensor reading for sensor 1 (B1), the third and the fourth columns show the sensor reading for sensor 2 (B2) and sensor 3 (B3), respectively. These sensor reading values returned are a long integer containing the absolute capacitance, in arbitrary units (a.u.).

Here, we notice marked changes in the behavior of the reading values. The reading begins from low, then increases, and later starts to reduce again. The low reading shows that the sensor had no human contact, and the high reading value is due to the presence of a human contact. And as shown in Table 1, a threshold value is noted; the threshold value is about 200000, when the sensor reading reaches 200000 or above, it means that a sensor has been active. In this way, the location of the person can be identified easily, if an alarm goes on at any point. By measuring baseline values and fluctuations detected when a person stands on the sensor, the threshold value can be established. Furthermore, the proposed system will also be able to differentiate if a house pet (dog or a cat) steps on the sensor.

A human body is much larger than a house pet and will thus generate a much larger threshold value. For a non-conductive object such as chairs and tables, it is known that they do not provide grounding/parasitic capacitance unlike human bodies, thus the system can easily distinguish between a human body and an object.

<table>
<thead>
<tr>
<th>Time (ms)</th>
<th>Sensor 1 reading</th>
<th>Sensor 2 reading</th>
<th>Sensor 3 reading</th>
<th>Presence/absence indication</th>
<th>Presence/absence indication</th>
<th>Presence/absence indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>116</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>S1 untouched</td>
<td>S2 untouched</td>
<td>S3 untouched</td>
</tr>
<tr>
<td>119</td>
<td>862</td>
<td>0</td>
<td>0</td>
<td>S1 untouched</td>
<td>S2 untouched</td>
<td>S3 untouched</td>
</tr>
<tr>
<td>120</td>
<td>783</td>
<td>0</td>
<td>0</td>
<td>S1 untouched</td>
<td>S2 untouched</td>
<td>S3 untouched</td>
</tr>
<tr>
<td>108</td>
<td>309</td>
<td>0</td>
<td>0</td>
<td>S1 untouched</td>
<td>S2 untouched</td>
<td>S3 untouched</td>
</tr>
<tr>
<td>109</td>
<td>212581</td>
<td>467</td>
<td>28</td>
<td>S1 touched</td>
<td>S2 untouched</td>
<td>S3 untouched</td>
</tr>
<tr>
<td>679</td>
<td>212714</td>
<td>469</td>
<td>0</td>
<td>S1 touched</td>
<td>S2 untouched</td>
<td>S3 untouched</td>
</tr>
<tr>
<td>678</td>
<td>212680</td>
<td>467</td>
<td>130</td>
<td>S1 touched</td>
<td>S2 untouched</td>
<td>S3 untouched</td>
</tr>
<tr>
<td>550</td>
<td>169465</td>
<td>125</td>
<td>125</td>
<td>S1 untouched</td>
<td>S2 untouched</td>
<td>S3 untouched</td>
</tr>
<tr>
<td>108</td>
<td>193</td>
<td>0</td>
<td>123</td>
<td>S1 untouched</td>
<td>S2 untouched</td>
<td>S3 untouched</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
<td>46</td>
<td>753</td>
<td>S1 untouched</td>
<td>S2 untouched</td>
<td>S3 untouched</td>
</tr>
<tr>
<td>100</td>
<td>234</td>
<td>60</td>
<td>0</td>
<td>S1 untouched</td>
<td>S2 untouched</td>
<td>S3 untouched</td>
</tr>
</tbody>
</table>

Fig. 3. B1-B3 denotes the bed monitoring sensors placed at the head, back, and feet resting position.

Fig. 4. Experimental setup of the monitoring sensor.

Table 1: Experimental output when sensor encounters human body
The process flow of the bed detector sensor system is shown in Fig. 5. For the bed sensor to be in the active state, all three sensors should be activated at the same time. And once all the three sensors are in the active state, the microcontroller will indicate if there is a person laying on the bed or sitting down. An alarm system has also been integrated in the room to enable the elder to call for help during an emergency. If the microcontroller encounters all three sensors to be inactive, which indicates that a person has left the bed. Then an alarm notification will be sent to PC, and after 15 minutes of the waiting time, an alarm will activate and notify the caretakers about the unusual occurrence. If the time taken is more than 15 minutes, an alarm will activate, as well as a help request is sent to caretakers.

The timer will compute for 15 minutes, the user can adjust this timer value as desired. When the detector cannot sense the presence of the person even after 15 minutes, the microcontroller will send the “help request” notification to the monitoring system and the people concerned, such as the caretakers or a family member of the elder.

Additionally, the microcontroller will also activate the buzzer for notifying others regarding any unusual occurrence. After leaving the bed for a toilet trip or any other motive, if the person returns to the bed within the preset time “15 minutes”, the state of the microcontroller will be back to “normal”.

B. Ambient Temperature Sensor

Ambient temperature is a vital measurement parameter for the elders, as in summer the environment temperature can rise very high and most elderly people are vulnerable to high temperatures. This system monitors the surrounding temperature and sends an alert message to the caretakers in case the temperature upsurges to a precarious level.

For human comfort, the environmental temperature should be around 21 °C to 24 °C. The temperature sensor used in this work is the LM35 sensor[26], which is designed to produce the output voltage which is linearly proportional to the measured celsius temperature. Fig. 6 gives the associated program flowchart.

C. Humidity Sensor

Humidity often raises health concerns among elderly population. During the summer, a high humidity level is experienced raise concern among the elderlies. The specific humidity sensor chosen for this work is HSM-20G, an analog humidity and temperature sensor that provides analog output voltage with respect to relative humidity and temperature. The relative humidity is measured as the percentage of moistures in air for a specific temperature[27].

The connection of the humidity sensor to the microcontroller can be seen in Fig. 7. The output voltage is actually the input signal for the microcontroller unit. As soon as the sensor gives signal to MCU, it will compute the humidity rate of an area and will inform the user.

Fig. 5. Flow chart of the bed monitoring sensor.

Fig. 6. Flow chart of the temperature monitoring sensor.

Fig. 7. Circuit diagram for HSM-20G humidity sensor module.
4. Results and Discussion

In this work, the graphical user interface (GUI) is used to indicate the monitoring results and alarm the emergency notification. Here each sensor is connected to the MCU (Arduino Uno) that is connected to control room’s computer. The MCU will write the values from sensors and the line computers will read the values through serial communication and exhibit those to the monitoring box. Fig. 8 illustrates the diagram of serial communications with the MCU and computer.

In this research, GUI has been used to monitor various features namely sleep pattern, temperature, humidity recognition and security alert. The subsequent design illustrates three windows, which shows various facets and two controlling buttons for safety reasons. The GUI interface is real-time, which monitors the elderly user’s activity by displaying the status of the sensors in the bedroom.

Fig. 8. Illustration of GUI output showing various windows of the bedroom monitoring system.

5. Conclusions and Results

An interactive embedded measurement system is presented to monitor the daily activities and environmental parameters through the implementation of a bed device. The sensor values are used for the prediction of the behavior of the elder. A software module was programmed to read the data from the sensors and send emergency notifications when needed. An advantage of this system is that more sensors can be added when required as each pin on the Arduino microcontroller works independently. And, the proposed system can differentiate a house pet (dog or a cat) from a human body, as well as a non-conductive object such as chairs and tables.

In order to implement a real-time monitoring system a GUI interface is carried out. In addition to monitoring the sleep pattern of a person, the system also proposes to investigate the elderly person’s environmental issues, such as the room’s humidity level and temperature. The research area can be widened to other areas with the ever-emerging new applications for different ranges of users.

References


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