HealthBand for Dementia Patients: Fall and Scream Detector and Caretaker Helper

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Abstract: The ratio of dementia patients is escalating with time and requires proper attention to help the people suffering from it to continue their activities of daily living (ADL). Such patients suffer from the symptoms like irregular sleep patterns, restlessness, wandering, screaming, falling, sadness and depression. Assistive Technology facilitates caretaker to aid the patient efficiently with minimum effort. Advances in technology have made possible state of the art and innovative methods of health care delivery. Home telecare; in which the patient’s health is monitored remotely at home, is one such method. This paper is proposing a cost effective and user friendly wearable product based solution (i.e. HealthBand) that monitors patient’s activities (specifically fall and scream) and notifies the caretaker in case of emergency to take appropriate action(s). These notifications are sent to the caretaker on the basis of predefined threshold and time span over Bluetooth and GSM mediums to android based application. The android app also keeps patient’s medicines’ intake record and reminds caretaker regarding medicine dosage and timings.

1. Introduction
Dementia especially Alzheimer’s is a heart breaking disease that causes the loss of cognitive functions affecting the patient’s daily life activities. Such patients suffer from the symptoms like irregular sleep patterns, restlessness, wandering, shouting, higher rates of falls, sadness and depression [1]. The higher fall rate is quite dangerous as it causes injuries in such patients thus adversely affects their health. People with dementia may shout, moan or use abusive language and their speech rate is also high. The caretaking of such patients becomes quite difficult for the caretakers and causes physical as well as emotional strain for them. The adoptions of assistive technology for detecting the fall and shout can help improve the caretaking process and quality of patient’s life.

The use of wearable device (i.e. HealthBand) in order to monitor the day to day activities of a person for the health care is quite of importance. The use of technology like accelerometer plays a vital role in this regard. The use of wearable device (i.e. HealthBand) in order to monitor the day to day activities of a person for health care is quite of importance. The use of technology like accelerometer plays a vital role in this regard. Conventional fall detection systems propose the usage of MEMS accelerometers and tri-axial accelerometer in wireless adhoc networks in order to detect the fall of a person and transfer the fall information through the networked infrastructure; in the form of RF Signals; to the caretaker in order to take appropriate action[2]. The tri-axial accelerometer; in waist mounted systems; is used to measure the parameters like patient’s posture, energy expenditure and movement[3]. In order to distinguish the actual fall from activities of daily living (ADL), some systems also propose usage of gyroscopes along with tri-axial accelerometers. For this purpose, human activities are divided into two categories of static postures like standing, bending, sitting, and lying and dynamic transitions are the movements and motions between
the different static postures. The accelerometers are used to detect static postures and gyroscopes are used to detect dynamic transitions[4]. A number of smart phone and smart watch based fall detection systems; using built in sensors; have also been presented that monitor the patient’s movements for recognizing fall [5][6]. Some systems also apply machine learning algorithms in order to classify the two categories of fall in order to increase the accuracy of actual fall detection[7]. While others evaluate the data gathered from the accelerometer with threshold based algorithms.

Along with the position and fall detection sensors, the use of sound detection sensors plays a vital role in providing assistance to the patients. A number of systems; attached with the remote monitoring systems; dealing with speech analysis and classification of sounds have been presented. Such systems perform the task of speech recognition to distinguish a distress situation from a normal one[8]. A number of systems present the idea of health smart home having microphones installed as an activity recognition system in order to detect environmental sounds[9, 10]. In order to detect scream, audio features like sound energy; specifically log energy and pitch are used. The system categorizes sound as a scream when there is continuity in it for a longer interval than a normal sound. [11]

A number of systems using ultra-sonic technology have also been presented. The ultra-sonic sensors are connected to devices like Arduino microcontroller or field programmable gate array (FPGA) processor in order to send the signal to the main processing unit using a networked architecture. The signal is analyzed by sensing the distance and detecting the actions like standing and falling etc. [12-14]

The main contribution of this paper is to present a unified solution “HealthBand” for fall and scream detection and medication and emergency alert. The product can monitor the patient’s activities at home and unfamiliar surroundings as compared to the solutions that are limited to certain boundary. The product will also monitor occurrence of hyper activity of the patient to check the effectiveness of the medication he is taking and also keeps medicine and activity record. This project also detects the fall duration to check the severe condition of the injury.

Section 2 of the paper discusses in detail the method and materials of the product that is being presented, Section 3 outlines the implementation of hardware, Section 4 provides an insight on hardware testing and finally the last section i.e. Section 5 concludes the paper.

2. Method and Materials
HealthBand uses the 3-axis Accelerometer and Microphone sensors to sense the fall and hyperactivity of the patient based on a threshold approach to detect falls and motionless periods. The following are the details of the materials used to develop the HealthBand.

2.1 Arduino Nano
Arduino is an open source computer hardware and software company for building intelligent electronic projects. It consists of physical programmable circuit board and an Integrated Development Environment (IDE), which is used to write and upload code from computer to the physical board. Wide range of entry level, enhanced features, Internet of Things (IoT) and educational Arduino boards are available in market. Board can be chosen according to specifications of each microcontroller. For this research, Arduino Nano is used because of its smaller size, optimum number of I/O pins and its compatibility with accelerometer. [15]

2.2 Accelerometer
ADXL-345 is a small and low power 3 axis accelerometer with high resolution measurement up to ±16g. Several special sensing functions are provided in ADXL-345, i.e. double and signal taps, activity and inactivity detection and free fall detection. In this research ADXL-345 is used to detect human fall. When the subject falls, the acceleration is rapidly changing and the angular velocity produces a variety of signals along fall direction. The lower and upper fall thresholds for these signals are used to identify the fall. [16]
2.3 Microphone Sensor
Microphone sensor module KY – 038 is used to detect patient’s screaming. This sensor simply converts analog sound to electrical signal. Thresholds for these electrical signals are set to identify screaming. Once signals from microphone exceed threshold, alarm is generated. [17]

2.4 Bluetooth Module
In this research, Bluetooth module is used for communication between HealthBand and Android application. Variety of Bluetooth serial interfaces are available such as; HC05 and HC06. Bluetooth module (HC05) is used as it can act as both master and slave whereas HC06 functions only as slave. [18]

2.5 GSM Module
GSM Module (900A) is used to provide long range communication between HealthBand and caretaker.

2.6 Android Application
The product contains a module of android application for remote monitoring of the patient by caretakers. The application receives signals from the HealthBand worn by dementia patient and notifies the caretaker in case of emergency. The application processes the signals for both fall and screams and generates alerts accordingly. In order to make the caretaking process easy, the application also contains the module for medicine intake reminder. With the help of medicine reminder module, one can maintain the pill dosage schedule and medicine intake history of the patient.

2.7 Fall Detection
Figure 1 explains the process of patient’s fall detection. Accelerometer (ADXL345) detects movements along X, Y and Z axis (if any) and passes the data to microcontroller, where body acceleration is calculated. This calculated acceleration is compared with the pre-defined threshold, if this calculated value exceeds threshold, accelerometer further checks Y and Z axis for activity to reduce the possibility of false alarm. If activity is not sensed on Y and Z axis “fall” is detected.

![Figure 1: Fall Detection Data Flow Diagram](image1)

![Figure 2: Scream Detection Data Flow Diagram](image2)
2.8 Scream Detection

Figure 2 explains the process of patient’s scream detection. Microphone sensor (KY-038) detects sound (if any) and passes the data to microcontroller, where analog to digital conversion of data takes place. This converted digital data (calculated value) is compared with the pre-defined threshold, if this calculated value exceeds threshold for 5 seconds “Scream” is detected.

3. Hardware Implementation

Figure 3 shows the connections amongst Arduino Nano, 3- Axis Accelerometer (ADXL-345), Microphone (KY-038), Bluetooth Module (HC-05) and GSM Module (900A).

4. Hardware Testing

4.1 Fall Detection

Human body experience weightlessness during free fall and vector sum of acceleration on three axes tends towards 0 gram. The duration of weightlessness depends on the height of freefall. Furthermore it’s noteworthy that the weightlessness during a normal fall is not as significant as a freefall i.e. vector sum of acceleration for normal fall is greater than 1 gram while for freefall is considerably less than 1 gram. Therefore, the first condition to detect freefall is weightlessness. When human subject experience weightlessness (Figure 4a) (Blue: X Axis, Red: Y Axis and Grey: Z Axis) and hits the ground; the vector sum of acceleration curve shows a large shock (Figure 4b) (Blue: X Axis, Red: Y Axis and Grey: Z Axis). This shock is identified by the ACTIVITY interrupt of ADXL345. Therefore, the second condition to detect fall is the ACTIVITY interrupt right after freefall. After fall and making impact to the ground human subject cannot rise immediately and remains motionless for short period of time. This motionlessness is identified by the INACTIVITY interrupt of ADXL345. Therefore, the third condition to detect fall is the INACTIVITY interrupt right ACTIVITY interrupt. Due to change in position after fall as compared to initial position accelerometer reading also changes. The acceleration data in all axes after the INACTIVITY interrupt is compared to the threshold, if vector sum of acceleration of the final status exceeds a certain threshold, an ACTIVITY interrupt occurs, since the static of the acceleration has changed after determining a fall to normal situation. Figure 4b and Figure 5 (Blue: X Axis, Red: Y Axis and Grey: Z Axis) shows acceleration change curves during the fall of human subject.
4.2 Scream Detection

Occasionally (sometimes frequently) dementia patients scream, moan or use abusive language. The patient may become hyper due to pain, discomfort, under/over stimulation, loneliness, anxiety and an unaccommodating environment (hot, cold or dark). Figure 6 (Blue: threshold magnitude and Red: detected magnitude) shows the frequency detected by microphone when patient suddenly gets hyper and starts screaming. If the value exceeds the threshold continuously for 5 seconds, scream is detected and alert signal is sent to caretaker on Android application to take required action.

5. Conclusion

The main focus of the paper is to present wearable product that is Hardware and Smartphone based solution to help the patients suffering from Dementia. The product monitors the fall and hyperactivity of the patients and alerts caretaker in case of emergency. The product also includes an android application to facilitate the caretaker to keep a check on patient’s medicine intake, history and its effectiveness. It helps the patient/caretaker in any environment (Indoor/outdoor) not limiting to the surroundings of home only, with assistance. In future, we also want to include the fall direction detection and perform different analytics on the patient’s medicine intake history as well as on the fall and hyperactivity durations in order to facilitate the doctors to check the effectiveness of the treatment and medicine intake.

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