Eurasian Journal of Analytical Chemistry
ISSN: 1306-3057 OPEN ACCESS 2017 12 (3): 127-135

Fall Detection System for Elderly Person Monitoring using Sensors, GSM/UMTS/LTET Ele-Communication and GPS

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Received: 08 November 2016 ▪ Revised: 11 December 2016 ▪ Accepted: 10 January 2017

Abstract: This work was intended to develop and integrate a system that can successfully detect falls in real-time. The system enables autonomous monitoring and reporting of falls in geriatric patients. The system is designed in such a way that it satisfies the number of requirements ranging from the electronic communication protocols to ergonomic sensors. The system required an algorithm that can evaluate an event based on some pre-determined calculations to classify it as a fall or non-fall. Therefore, an effective integration of hardware and software tools was also needed that provides a real-time detection and reporting of falls successfully to the doctors and medical staff.

Keywords: Electronic Communication Protocols, Fall Detection System, Geriatric Patients.

INTRODUCTION

The proportion of elderly people in the world is demonstrating a remarkable increase every year. By the year 2050, 1 in 5 person of the world will be age 60 or older. With the increase of elderly people population Rising Health Care Costs. Many elderly people choose to stay at home for privacy/dignity issues. A majority of older adults are challenged by chronic and acute illnesses and/or injuries. More investment is needed for elderly care. The growing insufficiency of traditional family care i.e., decreased care by relatives. Decrease in the working population will cause a shortage of skilled caregivers.

Definition of a Fall

First of all, it is necessary to understand the meaning of the term fall. Once the understanding of the phenomenon is established, it will be easier to grasp the content of this thesis work. Different people have different ways of defining a fall. Some define it as the event when a knee touches the ground, whereas few define it as a sudden movement of the human body resulting in an injury. However, in simple words, a fall can be considered as an unintentional and uncontrolled movement of a human body causing it to lie down on the floor. Moreover, it may also be known as an unintentional and sudden change in position of an individual, causing him/her to land at a lower level, on an object, the floor or the ground.

Therefore, the individual would not necessarily end up lying on a horizontal floor in order to call it a fall. They may come to rest on an inclined floor, stairs or an object after the sudden and unintentional movement. However, if an intervention or a support during the unintentional movement prevents the human body from lying down on the ground, it is termed a stumble. Moreover, if a person is found on the floor, the event may still not be a fall unless it was unintentional. The activity of bending down or being in the process of sitting on the floor should not be confused with a fall even though the person might end up lying on the floor. Falls may not be always injurious; however, they often result in injury and pain for the elderly person and stumbles serve as sign of future falls.

Causes of a Fall

Over the years, research has been conducted to find the causes of falls. Knowing the causes of the fall may lead to the successful prevention and detection of these events. Though many reasons for a fall have been found, they are not specific enough to generate a successful preventive model. Factors that are often associated with falls are: improper balance, medication effect, gait inconsistency, cardiovascular diseases,

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weakness/loss of strength, and impaired vision. Though the causes of falls seem to be entirely different from each other, they share one common feature: all of them have an adverse effect on the gait of the person.

Once the effect on the gait can be detected and identified, treatment is possible, based on the medical history of the person, to prevent the imminent fall. Improper balance and gait inconsistencies may be the result of fatigue or a pre-existing injury. Moreover, elderly patients suffer from weakness and loss of strength in muscles due to inactivity or low physical activity. However, if these symptoms are detected before the mishap, the person can be rescued by providing the appropriate physical therapy or treatment for the injury. Furthermore, an abnormality in the gait of a person can be due to the effect of high medication. The person might feel dizzy after consuming a high dose of daily medicines. However, there may be a possibility of reducing medication to prevent falls if the effect is identified on time.

Challenges in Detecting and Predicting Falls

As emphasized, observing the inconsistency and abnormality in a person's gait may help in preventing the fall. However, it is rather challenging to develop a system that can successfully identify the anomalies in different people. Different people have different walking styles. In fact, everyone has unique ways of making a movement. For example, some people do not use their heel while walking and land straight on the entire foot while taking a step, whereas some do not shift their weight onto the tip before lifting it off. Therefore, it becomes very challenging to come up with a model that conforms to each and every person.

Furthermore, different people might react to these problems, like fatigue, in completely different ways. One person may start dragging his leg along the ground, while other may just take shorter steps with a higher swing of the body in left/right direction. Similarly, falls are also of several types and can be very different from one another. Falls can occur in any direction and at any speed.

For example, Faint falls are the ones where a person loses his/her consciousness before the fall and, hence, is not able to seek any support on their own. These are one of the most unexplained of the falls. Faint falls generally occur at high speed and are often dangerous. On the other hand, there may be a Crumble fall where a person goes down slowly and sometimes take support of a wall or other objects. To detect this wide variety of falls, an algorithm is needed that utilizes the unique and common feature(s) of these events that separates them from other daily living activities.

Different systems on fall detection and/or fall prevention

Medical monitoring systems have become an important area of research and development due to the possibility of allowing improved quality of life and care while reducing overall medical costs. A number of systems have been proposed and sometimes tested. A few of these systems are discussed in this section to allow our proposed system to be put in context. Micro sensors are now integral parts of many technologically advanced healthcare systems used for monitoring elderly people at the risk of falling.

The sensors commonly used for fall detection and prevention systems include, but are not limited to, tri-axial accelerometers, pressure sensors, gyroscopes, heart rate sensors, sound sensors, vibration sensors, visual sensors and infrared sensors. A number of theories have been established that relate inconsistency in the gait phases of a person to the possibility of a fall in his/her future. Moreover, a number of systems have been proposed and developed that detect and predict falls successfully.

PROJECT DESCRIPTION

The K-SVD aims at formulating the image by utilizing a few linear amalgamations drawn from an astronomically immense and redundant dictionary. Through an over consummate dictionary, the pristine image is decomposed into a sparse coefficients matrix populated primarily with zeros. Only a few nonzero coefficients reveal the nature of the image, greatly reducing the intricacy of the pristine image. After several iterations, the algorithm ceases when there is no vicissitude in the MSE. All atoms are updated and a better dictionary is found. The K-SVD is pristinely designed for Gaussian noise abstraction. It cannot be directly applied to ultrasound images with the Rayleigh distribution noises. Here, the K-SVD is modified in our processing steps.

Cardiac tumors are aberrant growths in the heart or heart valves. There are many types of cardiac tumors. But, cardiac tumors, in general, are recherche. The tumors can be cancerous (malignant) or noncancerous (benign). Tumors that commence growing in the heart and stay there are called primary tumors. Tumors that start in another part of the body and pergrinate to the heart (metastasize) are called secondary tumors.

Most cardiac tumors are benign. But, even benign tumors can cause quandaries because of their size and location. Sometimes, scintillas of tumor fall into the bloodstream and are carried to distant blood vessels and obstruct blood flow to vital organs (embolism).

A diminutive percentage of patients with cardiac tumors have a family history of the condition. Sometimes, the tumors can be a component of another health condition, such as NAME Syndrome, LAMB Syndrome or Carney Syndrome. Most often, the tumor develops without any of those conditions or family history. They are the result of cell overgrowth that either commences in the heart or pergrinates to the heart.

Primary tumors affect only 1 in 1,000 to 100,000 people. The most mundane type of primary cardiac tumor is myxoma. Most of these are benign. Patients of any age can develop a myxoma. They are more prevalent in women than men. Most times, the tumor grows in the left upper chamber of the heart (left atrium) at the atrial septum, which divides the two upper chambers of the heart. Myxomas can grow in other areas of the heart or in the heart valves, but such magnification is recherche. About 10 percent of myxomas are hereditary or develop as a result of other diseases (visually perceive above).

Other types of benign primary tumors are papillary fibroelastomas, fibromas, rhabdomyomas, hemangiomas, teratomas, lipomas, paragangliomas and pericardial cysts. Malignant primary tumors include pericardial mesothelioma, primary lymphoma and sarcoma.

Secondary cardiac tumors are much more prevalent than primary tumors. They do not commence in the heart. Instead, they pergrinate to the heart after developing in another area of the body. Most often, these tumors start in the lungs, breasts, stomach, kidneys, liver or colon. They can withal be tumors cognate to lymphoma, leukemia or melanoma.

Echocardiography uses standard two-dimensional, three-dimensional, and Doppler ultrasound to engender images of the heart. Echocardiography, additionally called an echo test or heart ultrasound, is a test that takes “moving pictures” of the heart with sound waves. You don’t have to stay in the hospital. It’s not surgery and doesn’t hurt.

METHODS

System Analysis

Existing System

The evaluation of Sensors has been done to improve the detection Performance. The design method used to analyze the Health Condition. The traditional monitoring system can only monitor fewer type of Signals, and the Speed of the transmission also slow.

Proposed System

We therefore designed a multi-parameter physiological signal monitoring system which is characterized by the low power, high precision and high-capacity. The system can obtain ECG, EEG, EOG, EMG, pulse and respiration signal at low operating frequency. At the same time, it can also handle both SD card storage and USB data transmission. The system reduces its power consumption under the premise of ensuring the realization of a number of function. We added 16 bit controller to monitoring and to send the signals to web server as fast without any collision. It is designed by using MOD bus protocol where the transmission loss is very low.

Can Bus

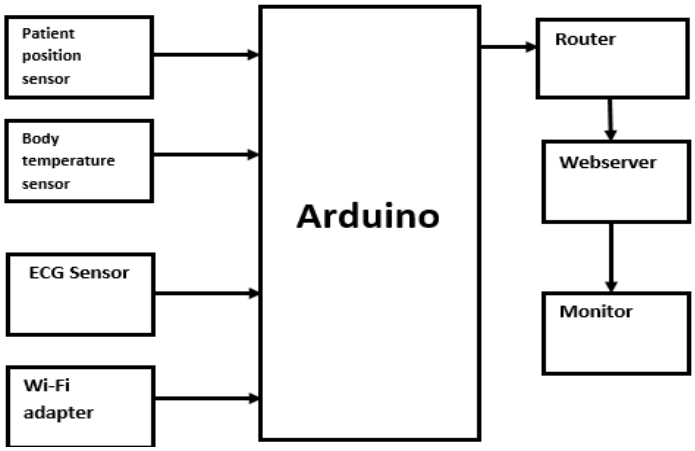
It is a network protocol which is used for communication between the micro-controllers or any other devices without the use of any master computer. CAN is basically designed for industrial networking but now a days it finds wide use in automation, mobile machines, military and other harsh environment monitoring application. CAN bus does not hold any address between the transmitter and the receiver.

Instead it holds the unique identifier which is a numeric value used to label the message throughout the network. Each of the receiving nodes provides the acceptance or uses the filtering to check whether the message is relevant to the particular node or not. If the message is relevant to the particular node the message is received and processed or else the message gets distorted.

MOD Bus

It is an Application layer messaging protocol for client/ server communication between device connected on different types of buses or networks. In this bus the transmission loss is very less compared to the transmission loss in CAN bus.

Block Diagram



Arduino

The Arduino hardware was very skillfully designed to reduce the complexities arising in the circuitry. It has an In System Programmer (ISP), which allows users to transfer the software inside the microcontroller without removing it from the circuit. The basic model of an Arduino board consists of an 8-bit AVR microcontroller along with some other necessary components like a 5 volt linear regulator IC, a 16 MHZ crystal, ceramic resonator, output connectors, direct adaptor input, etc.,

The IO ports on boards are positioned in a way that it can be easily attached with the interchangeable add-on modules, known as shields. Shields are daughter boards that can be externally attached/ plugged with the arduino boards to extent the board's capabilities. For example an xbee shield can be attached with the arduino board to establish a wireless communication. A motor control shield can be attached on the top of Aurdino board to run the motors or to provide an ease to control the speed of motors. The Arduino Board can easily interface with external sensors, circuits or other peripherals.

LM 35:

LM35 is a precision IC temperature sensor with its output proportional to the temperature (in °C). The sensor circuitry is sealed and therefore it is not subjected to oxidation and other processes. With LM35, temperature can be measured more accurately than with a thermistor. It also possess low self-heating and does not cause more than 0.1 °C temperature rise in still air. The operating temperature range is from -55°C to 150°C. The output voltage varies by 10mV in response to every °C rise/fall in ambient temperature, i.e., its scale factor is 0.01V/ °C.

ECG Sensor

The electrocardiogram (ECG or EKG) is a diagnostic tool that is routinely used to assess the electrical and muscular functions of the ear.

The electrocardiogram (ECG) has grown to be one of the most commonly used medical tests in modern medicine. Its utility in the diagnosis of a myriad of cardiac pathologies ranging from myocardial ischemia and infarction to syncope and palpitations has been invaluable to clinicians for decades.

Web Server

A Web server is a program that, using the client/server model and the World Wide Web's Hypertext Transfer Protocol (HTTP), serves the files that form Web pages to Web users (whose computers contain HTTP clients that forward their requests). Every computer on the Internet that contains a Web site must have a Web server program.

Two leading Web servers are Apache, the most widely-installed Web server, and Microsoft's Internet Information Server (IIS). Other Web servers include Novell's Web Server for users of its NetWare operating system and IBM's family of Lotus Domino servers, primarily for IBM's OS/390 and AS/400 customers.

Wi-Fi Adapters

Wi-Fi adapters provide wireless connectivity to the local area network (LAN) in the home or office. Typically used to add Wi-Fi to desktop computers, they can also retrofit older laptops that never came with Wi-Fi. See Wi-Fi and Ethernet.

Sensors Evaluation for Fall Detection

As part of this thesis work and to ensure a highly reliable system, a lot of work was done with 24eight and AT&T over the past year to refine and test a number of pre-production versions of these sensors. The first and most important task in the beginning of the project was to identify and suggest the sensors that can be used adequately for detecting falls and determining gait instability of a person. Doctors and the team at Texas Tech had a very reasonable concern of not loading the elderly person with too many body-worn sensors. Insoles, because of their ability to measure and transmit pressure from four different parts of the foot, was an obvious and unanimous choice among Texas Tech and the entire corporate team involved in the project. The insoles were considered very important to analyze pressure distribution across the foot of a person so as to determine stability during different gait phases. However, it was really necessary to identify the strengths and weaknesses of the insoles to understand if they can serve the purpose of fall detection and prevention all by themselves. During the initial testing it was found that the data coming out from the insoles may not be adequate in distinguishing falls from daily living activities all the time. The acceleration observed by the insoles at the time of fall was not big enough to separate it from other activities like sitting on a chair and keeping your foot at foot-rest. This is primarily due to the reason that when a person falls, the feet are always close to the ground and do not see a big acceleration on impact. Moreover, pressure on all the four pressure sensors is supposed to go down to zero in both the events. Therefore, the signatures that were received in the data from the insoles suggested that it may generate a lot of false fall alarms. These results can be seen in the graphs shown below.

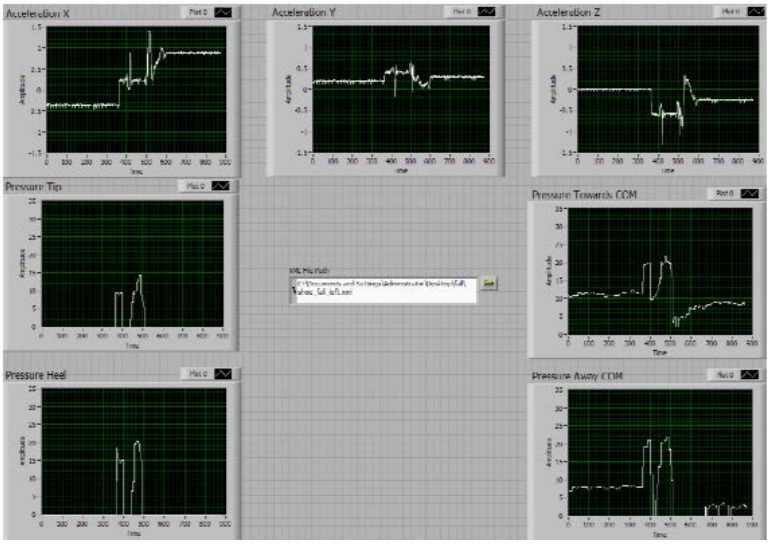


Fig. 1(a): Data for falling in the left (peak resultant acceleration =1.70g)

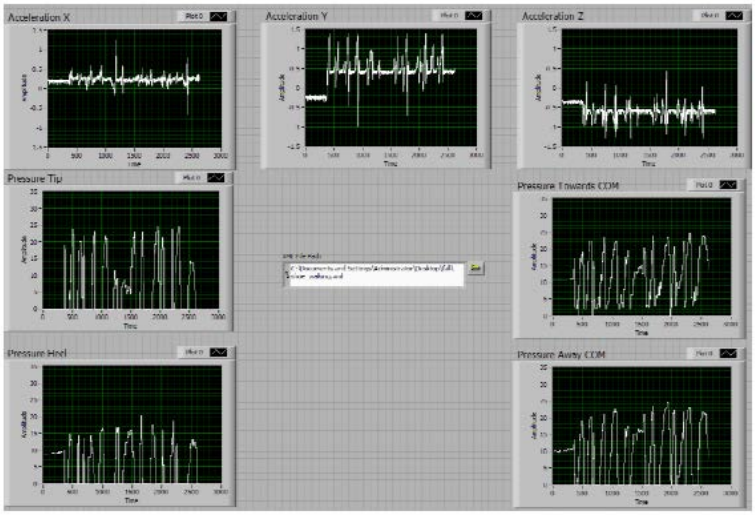


Fig. 1(b): Data for normal walking (peak resultant acceleration =1.82g)

Therefore, there is a need of an additional sensor that can effectively distinguishing a fall from daily living activities without generating many false alarms. Tri-axial accelerometer, as also used in other devices like laptops and notebooks for fall detection (free-fall detection), was the first in the list to be

considered as the additional sensor. As the acceleration experienced by the insoles in the three orthogonal directions was not too much of help in fall detection, a suitable body-position was to be identified for the sensor. The position of the sensor on the body should be comfortable for the wearer, should have the least artifacts (due to different activities) and must be able to show the motion of the entire body effectively. Due to these reasons, few body positions were short-listed for further experiments. A Z-Star (tri-axial accelerometer from Freescale) was then attached on these body positions one-by-one and different daily living activities and different types of falls were simulated. The body positions that were shortlisted for this particular experiment were:

1. Wrist
2. Upper-back
3. Waist

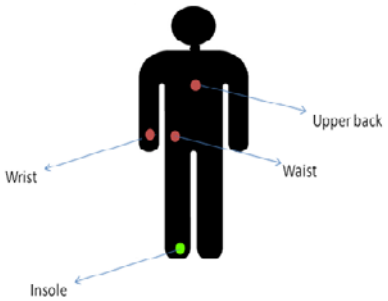


Fig. 2: Displaying the position of sensors

Each activity was repeated four times in different styles and at different pace to gather data for analysis. Activities performed for the Analysis were:

1. Walking – 5 minutes of walk for each body position.
2. Sitting
3. Kneeling Down
4. Falling

The results showed that the data from the wrist can be very unpredictable and may raise false alarms. Data collected while holding an object or taking support of a railing during walking displayed orientation results similar to that of a person lying down on a floor. The data from upper-back showcased fidelity while evaluating orientation during different activities. However, the acceleration observed during these activities was observed to be amplified or reduced causing resolution problems. The results of these experiments showed that the waist of a person to be the best available position to fit the accelerometer. The waist showed best results in reflecting the actual acceleration of the body during different activities. Moreover, the waist is also the closest to the centre of mass (COM) of the human body. Furthermore, it is very comfortable for a person to wear the sensor on the waist and perform all the activities without any problems and interference from the device. A person can easily remove the sensor or replace the batteries without needing support from anyone else. Also, having the sensor on the waist keeps it more than six inches away from the heart (and pacemaker), an important requirement for any wireless medical sensor. The results of the experiments are as shown in the table 1.

Table 1: Results of Acceleration from four different body locations

Body Location	Comments	Results
Feet	1. Poor sensitivity. 2.Poor orientation reliability.	1.Acceleration observed is too small in most cases. 2.Cannot determine true orientation of body at all time.
Wrist	1. Lots of artifacts due to random movement of hands. 2. Poor sensitivity 3.Poor orientation reliability.	1. Hard to distinguish if person is walking or sitting. 2.Cannot determine true orientation of body at all time.
Upper Back	1. Fair Sensitivity 2. Good orientation	1.Resolution problems during some activities. 2. Provides true orientation of
Waist	1. Good sensitivity 2.Good orientation reliability	1.Good resolution during all activities as also near the COM. 2. Provides true orientation of body

Sensor Testing

Once the sensors and their body positions were identified, the devices provided by 24eight were tested to analyze if they are fit for a robust system. Testing was done for different parameters and functionality that will be critical in real environment. A test plan was made that covered a range of tests leading to the discovery of following problems in the first version of insoles:

1. Information in the packets
2. Range of the devices
3. Transmission consistency
4. Battery life (power consumption)
5. Repeatability
6. Reproducibility
7. Ability to share the network

The initial testing of the devices showed that though the insoles are sampling pressure values of all the four pressure sensors, only one of them is being transmitted to the receiver at a time. However, to perform any kind of analysis on the gait and pressure distribution, pressure values of all the four pressure sensors was needed. Moreover, when the raw data was captured using Labview, some malformed packets were observed at the receiver end. These packets were either containing incorrect information or were only partially formed at the time of transmission. Number of malformed packets transmitted by the insoles was calculated to be 2%, after analyzing packets received over a long period of time (~6 hours). Transmission of the packets from the devices was inconsistent and one of the main reasons aggravating the problem was repeatability issue of the insoles. The insoles showed irregularity in transmitting the data even when all the external conditions were unaltered. On the repeatability issue, the insoles at times required the subject to press hard on any of the pressure sensor for resuming the transmission, which was not very desirable. This particular problem could lead to many activities not getting reported to the system. Moreover, the data and results from one set of insoles were not very reproducible from the other set of insoles and hence were bound to make gait analysis difficult during the trials. Another interesting finding from the testing of the devices was that when two devices were communicating simultaneously in a network, packets with higher power were overriding the packets with low power. The problem was noticed when two fresh batteries were used in the insoles and few packets from the insole that was powered up late were not received at the local computer. To analyze the phenomenon more deeply, one of the two insoles was used with a relatively older battery and up-to 90-95% packets of that insole were observed to be lost in the network.

CONCLUSION

The system was tested on the data-set shown above where the data was recorded after repeating each activity in different way and different style. Though the system was not tested for all the possibilities where the system might fail, the system showcased very good results for the ones that were performed. The system was able to report all the non-fall activities correctly. Therefore, fake alarm was never generated and specificity of system was 100 %. Moreover, all the simulated stumbles were accurately reported as stumbles. The acceleration peaks observed during the falls and stumbles are as shown in figure 19. However, few falls were wrongly reported as stumble and not fall. In these cases, though the uncontrolled/unintentional movement was detected, alarm was generated for stumble instead of a fall. Here, the orientation of the body after the big acceleration was not as expected for the fall (lying on the ground with most of the gravity on either X or Y axes) and therefore caused the failure. Upon analysis, it can be said that the system might fail in the conditions where the body (accelerometer) stays at higher.

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