SMART SHOE FOR HUMAN FALL DETECTION AND PREVENTION

This project report is submitted to

Yeshwantrao Chavan College of Engineering

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In partial fulfillment of the requirement for the award of the degree

of

Bachelor of Engineering in Electronics & Telecommunication Engineering

by

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CERTIFICATE OF APPROVAL

This is to Certify that the project report entitled "**Smart Shoe for Human Fall detection and Prevention**" has been successfully completed by **Dhanshri Narse , Harshita Nedunuri , Priya Sawarkar and Vrushali Talkhande** under the guidance of **Dr. Prabhakar D. Dorge** in recognition to the partial fulfillment for the award of the degree of Bachelor of Engineering in Electronics & Telecommunication Engineering**, Yeshwantrao Chavan College of Engineering** ***(An Autonomous Institution Affiliated to Rashtrasant Tukdoji Maharaj Nagpur University)***

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Signature of External ExaminerName:-

Date of Examination:

DECLARATION

We hereby declare that

a. The work contained in this project has been done by us under the guidance ofmy supervisor(s).

b. The work has not been submitted to any other Institute for any degree ordiploma.

c. We have followed the guidelines provided by the Institute in preparing theproject report.

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e. Whenever we have used materials (data, theoretical analysis, figures, and text)from other sources, we have given due credit to them by citing them in the textof the report and giving their details in the references. Further, we have taken permission from the copyright owners of the sources, whenever necessary.

Signature & Name of the Students

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Contents	Page No.

LIST OF TABLES:

LIST OF FIGURES:

ABSTRACT

Falls are a major health risk with which the elderly and disabled must contend. Scientific research on smartphone-based gait detection systems using the Internet of Things (IoT) has recently become an important component in monitoring injuries due to these falls. Analysis of human gait for detecting falls is the subject of many research projects. Progress in these systems, the capabilities of smartphones, and the IoT are enabling the advancement of sophisticated mobile computing applications that detect falls after they have occurred. This detection has been the focus of most fall-related research; however, ensuring preventive measures that predict a fall is the goal of this health monitoring system. By performing a thorough investigation of existing systems and using predictive analytics, we built a novel mobile application/system that uses smartphone and smart-shoe sensors to predict and alert the user of a fall before it happens. The major focus of this dissertation has been to develop and implement this unique system to help predict the risk of falls. We used built-in sensors --accelerometer and gyroscope-- in smartphones and a sensor embedded smart-shoe. The smart-shoe contains four pressure sensors with a Wi-Fi communication module to unobtrusively collect data. The interactions between these sensors and the user resulted in distinct challenges for this research while also creating new performance goals based on the unique characteristics of this system. In addition to providing an exciting new tool for fall prediction, this work makes several contributions to current and future generation mobile computing research. Our modern societies are suffering the increase of elderly population while at the same time social security and health costs must be cut down. In order to avoid the need for special care centers, the actual trend is to encourage elderly to stay living autonomously in their own homes as long as possible. This project contributes to this objective, since it provides user localization, automatic fall detection and activity monitoring both for indoors and outdoors activities, associated with a complete call centre for medical monitoring of the patient as well. Normal walking is the coordination of balanced muscle contraction, joint movement, and sensory perception. Limbs, hips, and systemic illnesses will have an effect on a person's gait. Healthy people stroll on legs, usually capable of automatically regulating their function to

obtain stability and balance. The pelvis is stricken by the arm swing, resulting in periodic rotation and incline. Also, ankle, knee and hip angle change in the manner of movement for coordination. So the normal gait is periodic, with the traits of coordination and stability. Walking speed decreases as human beings age. This speed decline influences quicker strolling speeds, greater than comfortable walking speeds. Quantitative evaluation of gait balance and gait symmetry has acquired a sequence of parameter results. On this foundation and gathered other factors, we've proposed to assemble an early warning system that predicts the subject's chance of fall while taking walks.

CHAPTER 1 - INTRODUCTION

The following specification particularly describes the invention and the way it is to be performed. Injuries due to gait abnormality are a major health problem all over the world.These injuries are associated with significant mortality, disability, and a decrease in quality of life. Analysis of the human gait for predicting falls is the subject of many current research projects. By 2050, it is estimated that more than one in five people worldwide will be age 65 or over. Falls in the elderly are very common occurrences as approximately one third to one-half of the population repeatedly experience falls on a yearly basis. For people 70-75 years old, the estimated incidenceof falls is over 30% per year

Due to increase in age risk of unintentional falls occurs which is a matter of concern.Falls not only cause physical injuries but it may also have a psychological impact on elderly people that it will reduce their independence. Once the fall happens it's necessary to take immediate medical care before the injury becomes severe. So this system helps to convey the message to the caregiver that fall has been happened and the medical care should be provided as soon as possible.

The problem of accidental falls among elderly people has substantial social and economic impacts as well as health consequences. In 2009 the elderly population in the world reached 737 million, accounting for 10.8% of the total population. In the year 2025, it is projected to account for 15% of the total population. Among elderly people who live at home, almost half of all falls take place near or inside the house. Nearly half of nursing home patients fall each year, with 40% falling more than once. Most falls happen during the activities of daily living (ADL) that involve a small loss of balance during an activity such as standing or walking.

Falls not only cause physical injuries, but also have dramatic psychological consequences that reduce the independence of elderly people because falls can lead to an avoidance of activity that results in a pattern of increased isolation and health deterioration. These incidents can also result in significant economic expenses, including the cost of hospitalization and rehabilitation therapy.We built a novel mobile application/system that uses smartphone and smart-shoe sensors to predict and alert the user of a fall before it happens.

Current research on automatic fall detection methods can be classified into three main categories in terms of the sensors they use: video-based methods , acoustic-based methods and wearable sensor-based methods . Many systems also rely on significant installation and training times. This increases the obtrusiveness of the intervention and contributes to poor acceptance of the system. Smartphone-based fall detection systems can function almost everywhere, since mobile phones are highly portable. Our system detects a high-risk gait pattern and enables a warning to the subjects through an audio message and vibration, to alert him or her about an imminent fall.

In wearable sensors-based gait analysis, motion sensors are worn or attached to various parts of the patient's body, such as the foot, wrist and waist. Such sensors are accelerometers, gyro sensors, force sensors, strain gauges, inclinometers, goniometers, and so on. These sensors can measure various characteristics of the human gait. The various signal recorded by these sensors can be used to perform the gait analysis in humans. In this project, a smartphone-based gait analysis system using shoe-worn sensors has been presented. Since mobile phones are highly portable, smartphone-based gait detection systems have the potential to function almost everywhere. With the recent development in mobile technology, the smartphone-based gait detection systems have become more popular as their computational abilities have increased. Ideally, the pressure sensor shoes (smart shoe) can automatically analyze gait. Therefore, we focus on smart gait detection for preventing fall injuries and assessing gait in general. To address these issues, we propose a smartphone-based gait detection system that can alert the user as well as a person's caregivers about their abnormal walking patterns.

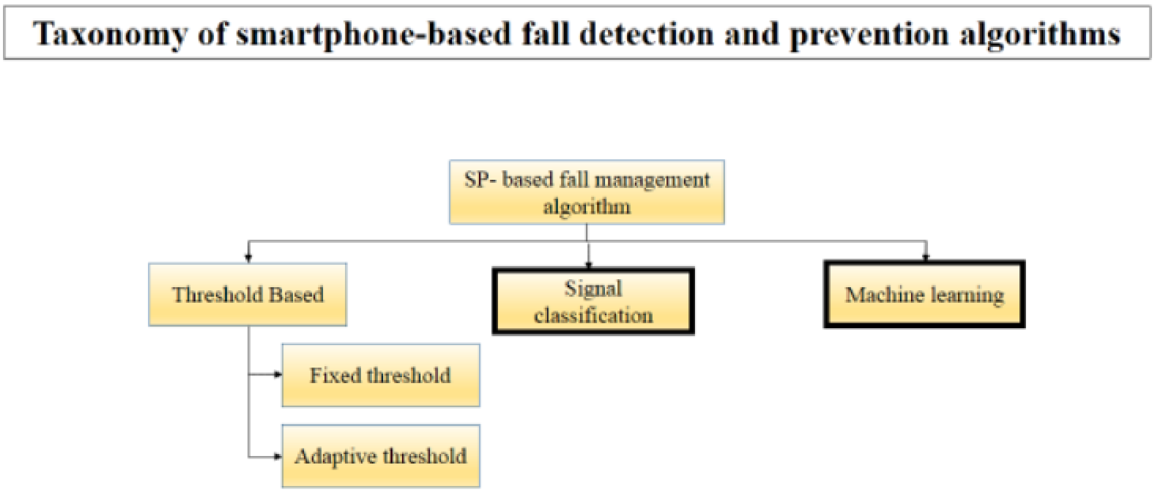


Figure 1.1: Taxonomy of smartphone-based fall detection and prevention algorithms

THEORY OF WALKING

To determine abnormal gait patterns, we must first establish criteria for normal walking. Normal walking is the coordination of balanced muscle contraction, joint movement, and sensory perception. Limbs, trunk, and systemic diseases will affect a person's gait. Healthy people walk on two legs, generally able to automatically adjust their position to achieve balance and stability. The pelvis is affected by the arm swing, resulting in periodic rotation and incline. Also, ankle, knee and hip angle change in theprocess of motion for coordination. So, the normal gait is periodic, with the characteristics of coordination and balance. Walking speed decreases as people age. This speed decline affects faster walking speeds more than comfortable walking speeds. Quantitative analysis of gait stability and gait symmetry has obtained a series of parameter results. On this basis and other factors, we have proposed to construct anearly warning system that predicts the subject’s risk of fall when walking.

FALL RISK FACTORS

A fall can be triggered by several factors that can be characterized in multiple categories. Some researchers categorize these into intrinsic and extrinsic factors, while others describe them in various interaction terms. Below is the combination of both categories-

Physical: Biological attributes, poor vision, gait and balance problems, muscle, orthostatic, postural hypotension, postural instability.

Behavioral: Fear of falling, medications, sleep deprivation, hygiene, lack of exercise,mental state.

Demographic: Age, gender, history of falls. Environmental: Surface, wet floors, obstacles,

climate.

Factors are not limited to those listed above, there are additional interrelated factors that may also need to be considered. A proper understanding of the factors is vital to the definition of a solution that addresses them effectively. Current clinical practices to assess an individual's fall risk mostly rely on fall history, medication review, physical examination, and functional and environmental assessments. Clinical assessments by healthcare providers, in conjunction with individual treatment for self-care fall assessment, have been shown to reduce falls by 24%. A similar result was found by the US Preventive Services Task force, which emphasizes follow-up with clinical caregivers. The American Geriatrics Society supplied a recommendation guide for physicians to screen older patients, which includes multicomponent/multifactorial intervention, medication assessment, exercise schedule, vision evaluation, foot and footwear assessment that establish the clinical assessment. They recommend regular annual screening of adults 65 and above to perform fall risk assessment.

MECHANISMS OF FALL

Elderly people rarely have a single cause for falls. A fall is usually caused by a complex interaction among the following:

Intrinsic factors (age-related decline in function, disorders, and adverse drug effects)Extrinsic

factors (environmental hazards)

Situational factors (related to the activity being done, e.g., rushing to the bathroom)

1. Intrinsic Factors

Age-related changes can impair systems involved in maintaining balance and stability (e.g., while standing, walking, or sitting). Changes in muscle activation patterns and ability to generate sufficient muscle power and velocity may impair the ability to maintain or recover balance in response to perturbations (e.g., stepping onto an uneven surface, being bumped). In fact, muscle weakness of any type is a major predictor of falls.

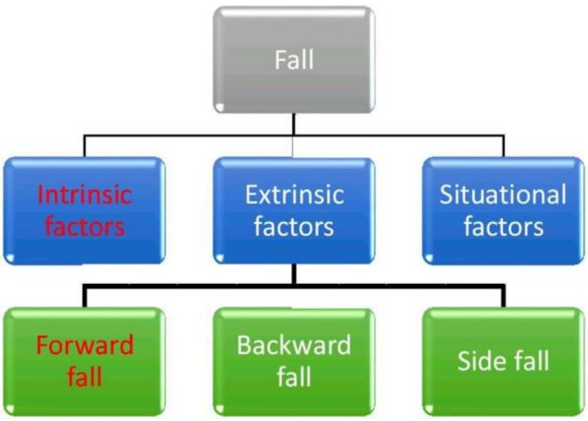


Figure 1.2. Taxonomy of most common falls in elderly

Chronic and acute disorders and use of drugs are major risk factors for falls. The risk of falls increases with the number of drugs taken. Psychoactive drugs are the most commonly reported as increasing the risk of falls and fall-related injuries.

2. Extrinsic Factors

Environmental factors can increase the risk of falls independently or, more importantly, by interacting with intrinsic factors. Risk is highest when the environment requires greater postural control and mobility (e.g., when walking on a slippery surface) and when the environment is unfamiliar (e.g., when relocated to a new home).

3. Situational Factors

Certain activities or decisions may increase the risk of falls and fall-related injuries. Examples are walking while talking or being distracted by multitasking and then failing to notice an environmental hazard, rushing to the bathroom, and rushing to answer the telephone.

Advantages Of the Innovations Are as Follows:

- Predict a fall through real-time abnormality detection in users' gait patterns.
- The user does not need to wear any special device, their operation is limited tothose places where the sensors have been previously placed.
- To inform and seek help from caregivers or for forewarning the users about an imminent fall.

- Easy to use
- Simple to handle
- Compact

Disadvantages Of the Innovations Which Are Present in Market Areas Follows:

- The users are required to keep their smartphones close to their body as the smartphone-based system, proposed so far, are body-worn systems.
- If the user does not respond within that time, the system will consider theevent a fall.
- A major weakness of this smartphone-based system is the limited battery life of smartphones.
- Usually, the battery life of a smartphone in normal use is about one day.

CHAPTER 2 - CONSTRUCTION AND WORKING OF MODEL

BASIC ARCHITECTURE

Fall detection and fall prevention systems have the same basic architecture as shown in figure. These systems follow three phases of operation: sense, analysis, and communication. The main difference between these systems lies in their analysis phase, which varies in their feature extraction and classification algorithms. Fall detection systems try to predict the occurrence of falls accurately by extracting the features from the output 12 data of the sensors and then identifying falls from other activities of daily living (ADL). Fall prevention systems can predict fall events early by analyzing the outputs of the sensors. The necessary steps needed for both fall detection and prevention systems are data/signal acquisition, feature extraction and classification, and communication for notification. The number and type of sensors and notification techniques, on the other hand, vary from system to system (some examples are shown in figure 1). In conventional systems, discrete hardware components are used for the implementation of each unit, whereas in smartphone-based systems, all required units may already be in-built within a smartphone.

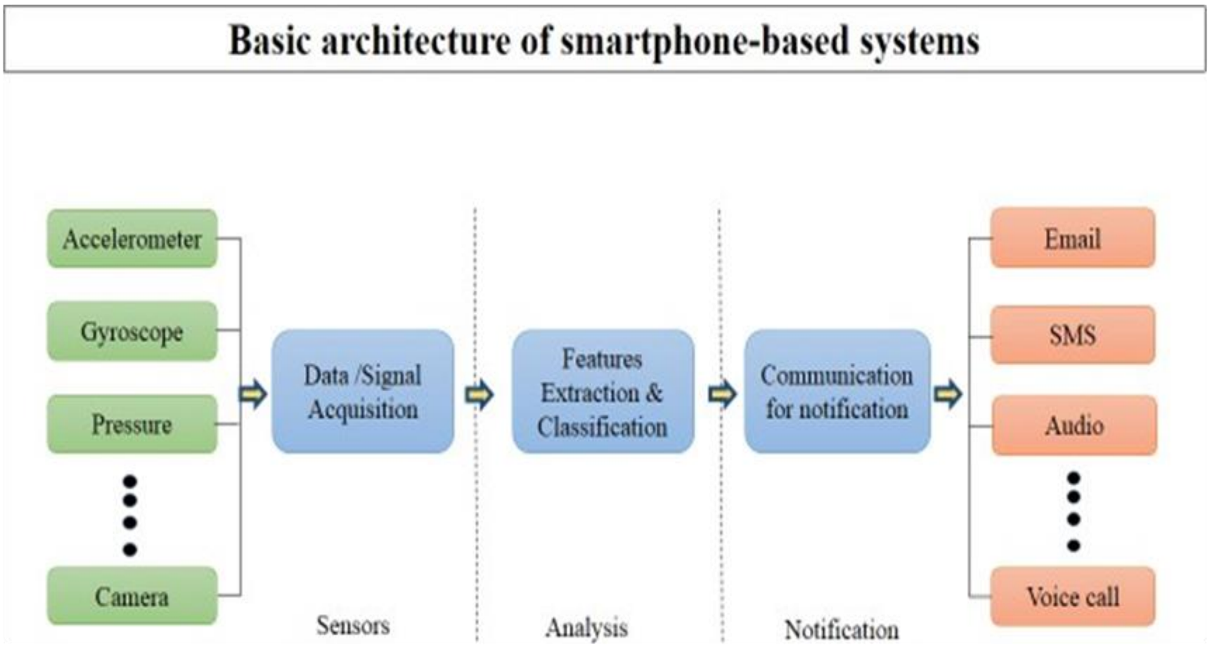


Figure 2.1; Basic Architecture of smartphone - based systems

1. Sensing

The first phase of any fall detection and prevention system is sensor data collection. In this phase gait quantities, like stride length and stride frequency are measured using sensors. Smartphones come with built-in sensors and these are one of the reasons for choosing smartphones as an alternative for conventional fall detection and prevention platform. Moreover, the users of smartphone-based systems are more likely to carry smartphones (with built-in sensors) throughout the day since mobile phones are seen as important in daily life. This use is in contrast to the users of conventional systems who may not always to wear the special micro sensors. There are many types of sensors now available for smartphones. These sensors include accelerometers, gyroscopes, temperature sensors and magnetic field sensors. These are used in variousways in smartphone- based solutions. Some solutions use only one of the aforementioned smartphone sensors for fall detection or prediction. The tri-axial accelerometer is the most used sensor for smartphone-based fall detection and prevention. Another benefit to smartphone-based solutions is they can use combinations of two or more smartphone sensors during this sensing phase. Some solutions use both smartphone sensors and external sensors for detection and prediction of falls. It is also possible to use smartphones for analysis and communication in addition to sensing. An uncommon type of solution proposed, they used a smartphone for sensing only, and external systems to perform the analysisand communication tasks of a fall prediction system.

2. Analysis

After measuring the physical quantities by using sensors, obtained data are analyzed. In this phase, the features are extracted from the sensor outputs and initial decisions about the abnormal gait are made by classifying and analyzing these extracted features. Most of the fall related solutions are based on Threshold-Based Algorithm (TBA). The reason it is useful to choose TBAs is that these algorithms are less complex and thus require the lowest computational power, which helps to reduce battery consumption [20]. To make preliminary decisions about a potential fall, these algorithms generally compare the sensor's data with predefined threshold values. TBAs may use more than one threshold and threshold values that could be either fixed or adaptive. The users of any fall prediction system provide some physiological data and the system obtains the corresponding threshold that is not re-calculated during system operation. For example, the algorithm proposed in uses an adaptive threshold which changes with user-provided parameters such as height, weight and level of activity. Most solutions employ the tri-axial accelerometer for sensing which measures acceleration simultaneously in three orthogonal directions. TBAs use these acceleration values for calculating a Signal Magnitude Vector by using the following relation: □□□□□□□ □□□□□□□□□ □□□□□□= √|□□| 2 + |□□| 2 + |□□ | 2 (1) Where Ax, Ay, and Az represent accelerometer signals of the x, y, and z-axis respectively. If the value of signal magnitude vector for a particular incident exceeds a predetermined threshold value, then the algorithm preliminarily identifies that incident as a fall event. To makethe final decision about a risk of fall, algorithms usually depend on the next communication phase. The processing power of smartphone has increased dramatically over the past few years. The computational power of the smartphone has

become comparable to that of former workstations and, thus, even complex machine learning and statistical classification algorithms for fall detection and prevention can easily be implemented in smartphones. Authors implemented three machine learning algorithms, namely C4.5, Decision Tree, Naïve Bayes Classifier and Support Vector Machine, on smartphones and compared their recognition accuracy. In, the authors employed a combined algorithm of Fisher’s Discriminant Ratio (FDR) criterion and J3 criterion.

3. Communication

When a smartphone-based solution detects a fall event, it communicates with the user of the system and caregivers. Most fall detection solutions carry out the third phase communication, in two steps. First the system attempts to obtain feedback from the user by verifying the preliminary decision about the user's gait patterns and thus improve the sensitivity of the system. The second step depends on the user's response. If the user rejects the predicted fall, then the system restarts. Otherwise, a notification is sent to the users and caregivers to ask for immediate assistance. Some systems may not wait for user's feedback and will instantly convey an alert message to their caregiver. Moreover, instead of alerting the users, fall prevention systems can also activate other assistive systems (e.g., wearable airbag, intelligent walker, intelligent cane, and intelligent shoe) for protecting the user from the adverse effects of fall. Theuser's feedback can be collected automatically by analyzing the sensors' data. For example, the algorithm proposed generates the final decision by automatically analyzing the difference in position-data before and after the suspected falls. Other systems required manual feedback from the user. Combinations of alarm systems and graphical user interface of smartphones are also used for collecting user feedback. After requesting a response from the user, the system waits for a predefined period (typically $\leq$ 1 min). If the user does not respond within that time, the system will consider the event a fall. However, fall detection systems may fail to detect a real fall event. In such cases, some systems provide help (or panic) buttons and thus allow users to seek outside help manually.Smartphone-based systems generate several types of notifications to seek help from caregivers or for forewarning the users about an imminent fall such as audible alarms vibrations, Short Message Service (SMS), Multimedia Messaging Service (MMS), and even automatic voice calls. E-mails and Twitter messaging have also been described as a means of notifying users and caregivers about a fall. Notification messages may contain information on time, Global Positioning System (GPS) location (coordinates), and location map. Smartphone-based solutions can also support streaming of phone data from microphones and cameras for further analysisof the situation.

DETAILED ARCHITECTURE

The architecture of the system is shown in Figure. The main parts of this system are a smart shoe and a smartphone. Smart shoe consists of piezo-resistive pressure sensors and a communication module. In this system, the piezo-resistive pressure sensor is used to measure the pressure exerted on the foot while walking. Here four piezo-resistive pressure sensors are placed on shoe insoles to assess the pressure distribution, out of which two are placed in the forefoot region and the remaining two in the rear foot region.

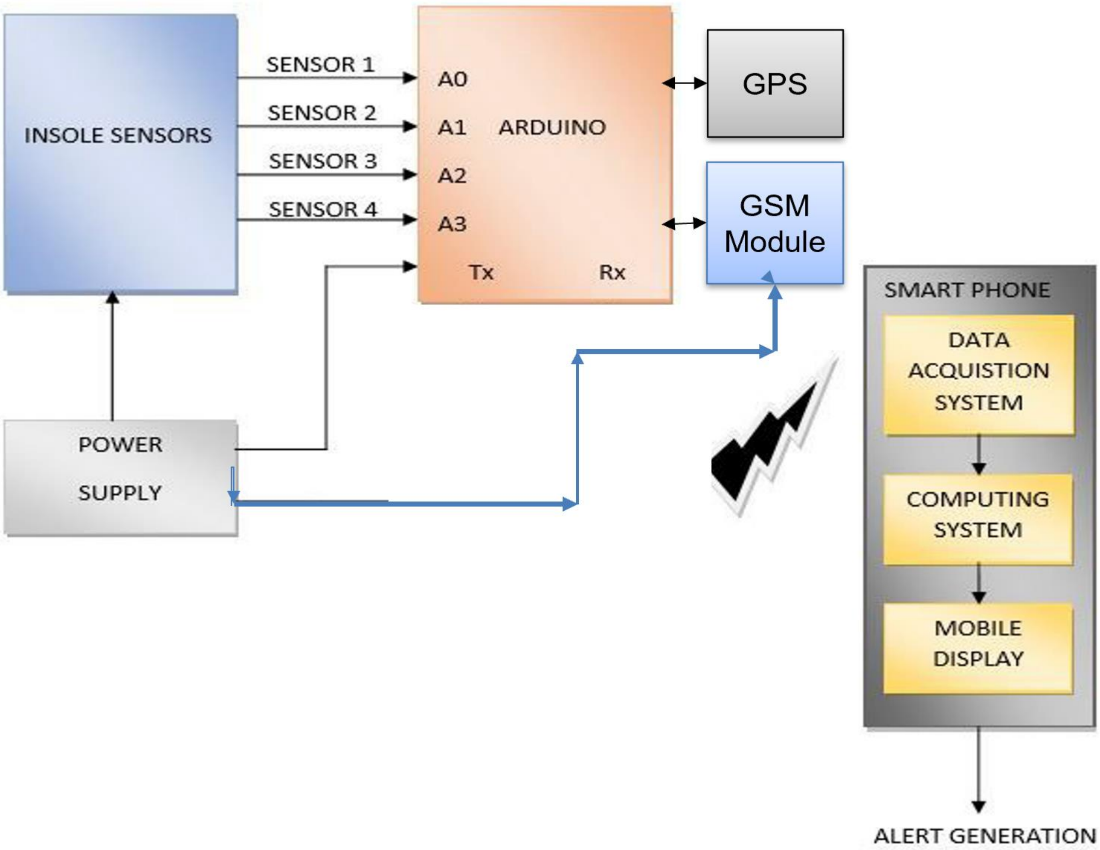


Figure 2.2. Block diagram of proposed system

The communication module comprises of an Arduino Uno with a battery power supply. The Arduino is an open-source physical computing platform based on a simple I/O. This module amplifies the signal and transfers the amplified signal to the smart phone through a Wi-Fi communication network. In order to process the pressure data, the communication module has two different software tasks. One is for the Arduino and another is for the Android. The Arduino is programmed to read analog signals from the shoe sensors and to create a data packet that converts the signal into digital form. Subsequently, Arduino sends those packets to the smart phone in response to the data sending request. Smartphone collect pressure data over a period of time and different walking patterns for the same subject will be recorded. After receiving the data through the Wi-Fi communication network, it is processed inside the mobile phone to identify the abnormality in a walking pattern. In order to identify whether the gait is cautious or not, Decision tree algorithm is used. This algorithm classifies the gait into normal and cautious gaits by analyzing the available sensor data. The moment the abnormality is detected in the walking pattern, the system enables a warning alarm to the subject through an audio message and vibration, to alert them about an imminent fall related injury and also the system will send a message to the caretaker saying that the patient is having walking abnormality.

Classification Algorithm

Classification algorithm used in this project is the Decision tree. Decision tree is a popular type of machine learning algorithm. It consists of nodes and branches. Branches are used for connecting the nodes. The top node of the tree is called the root, including all the training data, which are finally split to classes. The bottom nodes of the tree are called the leaves, and which indicating classes. All nodes except the leaves are defined as decision nodes, where training examples are split into distinct classes based on one attribute. In the testing progress, every new testing data goes into a specific branch from the root, following a matching path to a particular leaf.

Use Of Smartphone For Sensing, Analysis And Communication

The benefits of using a smartphone as a pervasive fall detection and prevention system have already been discussed in the literature. Smartphone-based systems experience some critical challenges with certain issues remaining open to further research. These challenges and open issues in smartphone-based fall management systems have been identified; this section presents the most relevant ones.

Quality of Smartphone Sensors

It is still an open research question whether the qualities of built-in smartphone sensors in existing smartphones are adequate to develop fall detection and prevention systems with acceptable performance. When choosing a smartphone for a particular application (fall detection or fall prevention) adequate attention should be paid to the quality of the sensors. Specifications of the sensors should satisfy theminimum requirements of the applications.

Energy Consumption and Battery Life

A major weakness of smartphone-based solutions is the limited battery life of smartphones. Usually, the battery life of a smartphone in normal use is about one day, but no smartphone battery will last more than a few hours with heavy usage. The battery life is also directly proportional to the recording time and activities of the user.

Gait Abnormality Detection Using Smartphone Sensor Data

After measuring the physical quantities by using sensors, obtained data should be analyzed. In this phase, the significant features are extracted from sensor output and preliminary decisions are made by classifying and analyzing the extracted features. Most smartphone-based solutions, especially solutions for fall detection, use a Threshold-Based Algorithm (TBA). The most vital reason for choosing TBAs is that these algorithms are less complex and hence require the lowest computational power, which helps to reduce battery power consumption. In order to make preliminary decisions about a potential fall, these algorithms usually compare the sensor’s outputs with predefined threshold values. TBAs may use more than one threshold and these threshold values are either fixed or adaptive. It should be noted that the adaptive threshold values are not calculated dynamically while using the system. Instead, users provide physiological data and the system obtains the corresponding threshold that is not re-calculated during system

operation. The algorithm proposed in uses an adaptive threshold which changes with user-provided parameters such as height, weight and level of activity. As mentioned before, the computational power of the latest smartphones has become comparable to that of former workstations and, thus, even complex machine learning and statistical classification algorithms for fall detection and prevention can easily be implemented in smartphones. Some fall detection and prevention solutions include external sensorsand processing units, using the smartphone for sensing and communicating with the users or their caregivers.

Development of a Wi-Fi Communication Network for Smart-Shoe and Integration of Different Smart-Shoe Hardware Module

For data collection from the smart-shoe, the most important challenge is to establish a dedicated communication framework. When choosing the device, we considered the popular data transmission technologies. The three most popular wireless technologies are Bluetooth, ZigBee, and Wi-Fi protocols. They correspond to the IEEE 802.15.1,
802.15.4 and 802.11a/b/g standards, respectively. Bluetooth communication has covered a relatively short range. Considering all the limitations, we developed a custom Wi-Fi communication module for the smart-shoe. The Wi-Fi communication module is able to wirelessly send smart-shoe sensors data to the smartphone. We also had to develop a means of communication between the smartphone and smart-shoe which required different hardware modules. Putting these modules together and having them function properly was another challenge we encountered in our research.

Alert Generation Using Processed Data

Existing and potential smartphone-based fall detection and prevention systems communicate with the users and caregivers by sending alert messages to obtain the user's feedback. Prediction systems are only concerned with pre-fall data, but detection systems deal with pre-fall, post-fall and intermediate data. Finally, detectionsystems notify caregivers of fall events and ask for help, whereas prediction systems attempt to prevent impending falls with the help of other assistive systems. Some smartphone-based solutions require external sensing units that may or may not have built-in processors. These external units may transmit either raw data or results after primary analysis.

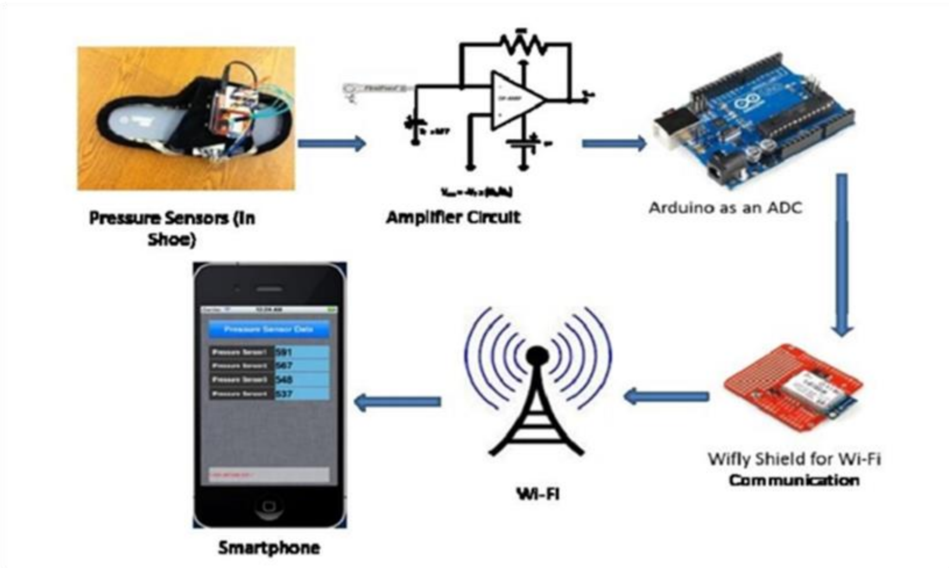


Figure2.3. Data collection process from a smartshoe

REQUIREMENT ANALYSIS AND SYSTEM DESIGN

When studying fall risk variables, the maximum significant feature to focus on is the gait. In general, a fall happens when normal balance is disturbed. Among the reasons for imbalance, in a study of 1042 people aged 65 and over, tripping was mentioned in 53% of cases, dizziness in 8% and blackouts in 6%. Tripping typically happens in association with foot imbalance or foot movement disparity. Hence, the study of gait is important and must get hold of the maximum emphasis to identify fall risk due to tripping.

1. Gait Cycles

A gait cycle is measured from heel strike to some other heel strike among steps. The cycle includes a stance section and a swing section . The stance section is the length of time the foot is on the ground. 60% of one gait cycle is spent on this section. The next section, Swing section, is the period the foot is off the ground, proceeding towards the stance

2. Foot Balance

In general, the foot swing in taking a step while taking walks or running is related to 8 phases: Initial Contact > Loading Response > Midstance > Terminal Stance > Pre swing > Initial Swing > Initial Swing > Mid Swing > Late Swing. During these phases, an effect of Minimum Foot Clearance (MFC) determines the moving velocity and is a sign of chance of fall due to foot imbalance.

3. Gait Analytics In Fall Risk Assessment

Causes for falls are multifactorial, however the majority of falls share one common feature- they occur during stepping or walking. Stride length and stride-to-stride distance variation are the two most important metrics in gait, and researchers have found significant correlations with these in predicting falls. There are also correlations between stride time and swing time variation and fall risk. Even a small number of variations in gait can lead to a greater risk of falls. Maki showed a stride length variation of just 1.7cm had an odds ratio for falling of 1.95 with 95% accuracy

4. Features Extraction

For the gait analysis-based system to work, a few vital gait features need to be extracted using sensory systems. Based on the literature, the most vital metrics and features directly correlated to a fall hazard are follows -

i. Steps (stride length, frequency)

ii. Supination/Pronation (L & R stride symmetry)

iii. Pressure Points

iv. Timing (L & R stance/swing, double stance)

v. Balance

Supination and Pronation are vital features to research in gait analytics. Supination is when a foot reports body weight at the outdoor of the foot, while an inward roll of the foot with weight shifted to the forefoot is referred to as pronation.

5. Design Overview

The design of a realistic fall risk assessment tool must encompass numerous modules, each wearable, and stationary. To accumulate gait information, an insole with sensors is most convenient. The information needs to be accumulated both in the insole, or in a separate device such as a Smartphone. A computer with a large screen might presentthe best analytical information with some visible graphics. Justifications for the design modules and instruments are

a. **InSole –** A digital sensory insole with pressure sensors, and an accelerometer can seize gait information during activities. A pressure sensor would prompt when force isapplied from the planar system. Locomotion would prompt the accelerometer, which could seize the movement in three axes. The combination of data types would provide gait parameters favored for the system.

b. **Smartphones** – An insole sensor can seize the information, however a triggering tool is needed to begin and stop the information capture. A smartphone is excellentfor this task. Subject profiling also can be finished within the smartphone application.

c. **Computer** – A computer with a large display might be used to show the give up results, publish calculation of the gait parameters. The computer can be minimally configured. Once information arrives in the laptop, it would be capable of exhibiting the calculations visually with graphics.

6. User Friendliness

The user interface should be designed considering the target population, especially elderly. Their familiarity with certain technology, and physical capabilities should be considered during the design of the system.

7. Cyber Physical System

Our objective is to enable the efficient development of distributed cyber physical systems (CPSs) whose nodes operate in a proven and correct manner in terms of functionality and timing, leading to predictable behavior of the entire system.

8. Mobility

One key characteristic of the system is to maintain the mobility of the users and caregivers. Caregivers are expected to monitor a user's real time data using their mobile phones and receive alert messages in case of emergency.

9. Continuous Data Collection

Continuous gait longitudinal data collection is one of the problems in monitoring the elderly. Data should be continuous and regular to have accurate information of the user's current status. Once the system is deployed, it should be able to collect data for a period of time and update the caregiver by sending an alert message in case of emergency.

10. Quality Over Quantity

Data collected using a smartphone-based system can be biased by different factors.For example, when a user went to bed or sat down for a long time, the caregiver or loved one might not get accurate data for that period of time. The user's response isinfluenced by their current status of mobility. So the quality of the gait data varies with the time and with daily activities. The way to increase the quality of the data is to record the data when it matters most. For example, recording gait parameters when the user is walking or doing simple or complex activities increases the quality of data.

CHAPTER 3 - DETAILS

TOOLS USED:-

1.FORCE SENSITIVE RESISTOR

Interlink Electronics FSR 400 series is part of the single zone Force Sensing Resistor TM family. Force Sensing Resistors, or FSRs, are robust polymer thick film (PTF) devices that exhibit a decrease in resistance with increase in force applied to thesurface of the sensor. This force sensitivity is optimized for use in human touch control of electronic devices such as automotive electronics, medical systems, and in industrial and robotics applications. The standard 406 sensor is a square sensor 43.69mm in size. Custom sensors can be manufactured in sizes ranging from 5mm to
over 600mm.

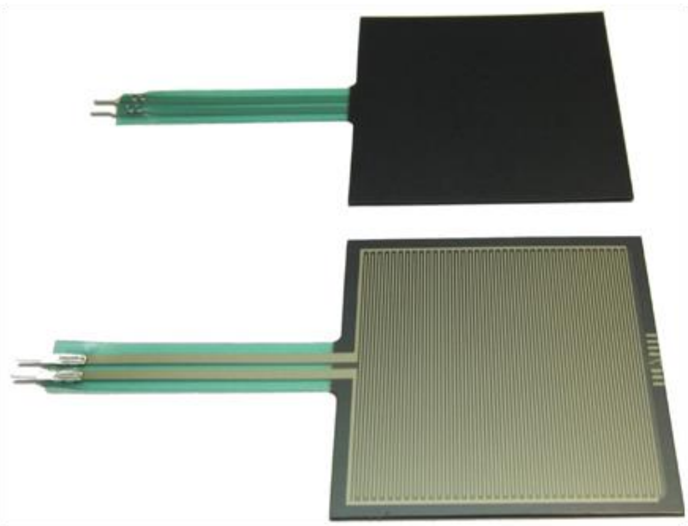


Figure 3.1: Sensor

Application Information

FSRs are two-wire devices with a resistance that depends on applied force. For a simple force-to-voltage conversion, the FSR device is tied to a measuring resistor in a voltage divider configuration .

The output is described by the equation:

$$V_{OUT} = \frac{R_M V+}{(R_M + R_{FSR})}$$

In the shown configuration, the output voltage increases with increasing force. If RFSR and RM are swapped, the output swing will decrease with increasing force.

The measuring resistor, RM, is chosen to maximize the desired force sensitivity range and to limit current. Depending on the impedance requirements of the measuring circuit, the voltage divider could be followed by an op-amp.

A family of force vs. VOT curves is shown on the graph below for a standard FSR in a voltage divider configuration with various RM resistors. A (V+) of +5V was used for these examples.

FEATURES AND BENEFITS

•Actuation Force as low as 0.1N and sensitivity range to 10N.

•Easily customizable to a wide range of sizes.

•Highly Repeatable Force Reading: As low as 2% of initial reading with repeatable actuation system

•Cost effective

•Ultra thin; 0.45mm

•Robust; up to 10M actuations

•Simple and easy to integrate

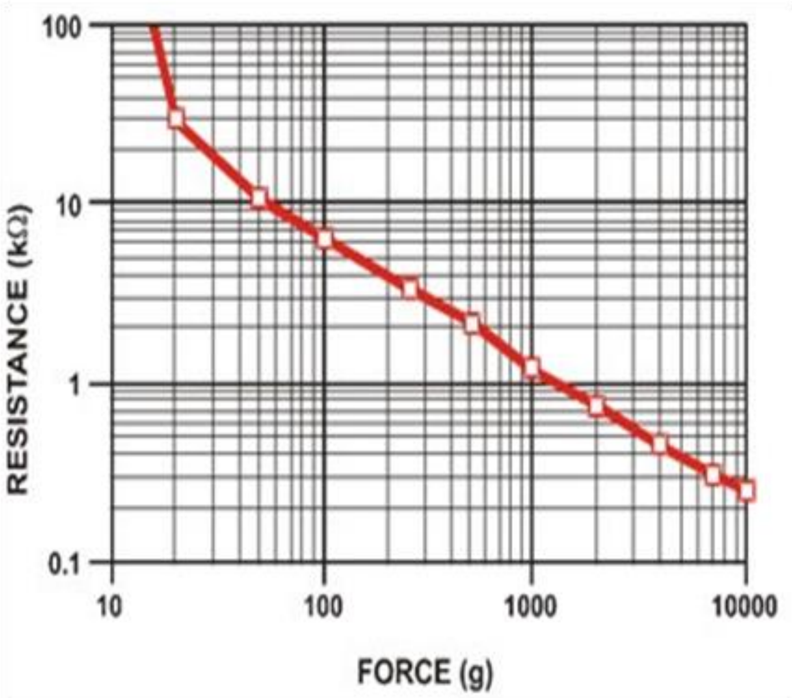


Figure 3.2: Force vs Resistance Graph

APPLICATIONS

1. Detect & qualify press- Sense whether a touch is accidental or intended by reading force

2. Use force for UI feedback- Detect more or less user force to make a more intuitive interface

3. Enhance tool safety -Differentiate a grip from a touch as a safety lock 4.Find centroid of force- Use multiple sensors to determine centroid of force

5. Detect presence, position, or motion-Of a person or patient in a bed, chair, or medical device

6. Detect liquid blockage-Detect tube or pump occlusion or blockage by measuring back pressure

7. Detect tube positioning

Feature Condition Value*Notes

Actuation Force

Force Sensitivity Range

Force Repeatability[3] (Single part)

Force Resolution[3]

Force Repeatability[3] (Part to Part)

Non-Actuated
Resistance Size
Thickness
Range
Stand-Off
Resistance

Switch Travel
(Typical)

Hysteresis[3]Device RiseTime Long Term Drift

0.1 Newtons

0.1 - 10.0[2] Newtons

± 2%

continuous

±6
% 10
MW
43.69 x 43.69mm0.2 - 1.25mm

>10M ohms

0.05 mm

+10%

<3 microseconds

<5% per $\log_{10}$(time)

-30 - +70 °C

Unloaded,
unbent
Depends on
design (R_{F+} -
R_{F-})/R_{F+}.

measured w/steel ball 35
days test, 1kg load

Temp Operating Range **(Recommended)**	**10 Million tested**	**Without failure**
Number of Actuations **(Lifetime)**		

Table 3.1 Device Characteristics

2. ARDUINO UNO

Arduino/Genuino Uno is a microcontroller board based on the ATmega328P (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.. You can tinker with your UNO without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again. The Arduino/Genuino Uno can be programmed with the (Arduino Software (IDE)). Select "Arduino/Genuino Uno from the Tools > Board menu (according to the microcontroller on your board). The Arduino/Genuino Uno board can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the GND and Vin pin headers of the POWER connector.

The board can operate on an external supply from 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may become unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

Each Component In Detail

ATmega328 Microcontroller- It is a single chip Microcontroller of the ATmel family. The processor code inside it is of 8-bit. It combines Memory (SRAM, EEPROM, and Flash), Analog to Digital Converter, SPI serial ports, I/O lines, registers, timer, external and internal interrupts, and oscillator.

ICSP pin - The In-Circuit Serial Programming pin allows the user to program using the firmware of the Arduino board.

Power LED Indicator- The ON status of LED shows the power is activated. When the power is OFF, the LED will not light up.

Digital I/O pins- The digital pins have the value HIGH or LOW. The pins numbered from D0 to D13 are digital pins.

TX and RX LED's- The successful flow of data is represented by the lighting of these LED's.

AREF- The Analog Reference (AREF) pin is used to feed a reference voltage to the Arduino UNO board from the external power supply.

Reset button- It is used to add a Reset button to the connection.

USB- It allows the board to connect to the computer. It is essential for theprogramming of the Arduino UNO board.

Crystal Oscillator- The Crystal oscillator has a frequency of 16MHz, which makes the Arduino UNO a powerful board.

Voltage Regulator- The voltage regulator converts the input voltage to 5V.

GND- Ground pins. The ground pin acts as a pin with zero voltage. Vin- It is the input voltage.

Analog Pins- The pins numbered from A0 to A5 are analog pins. The function of Analog pins is to read the analog sensor used in the connection. It can also act as GPIO (General Purpose Input Output) pins.

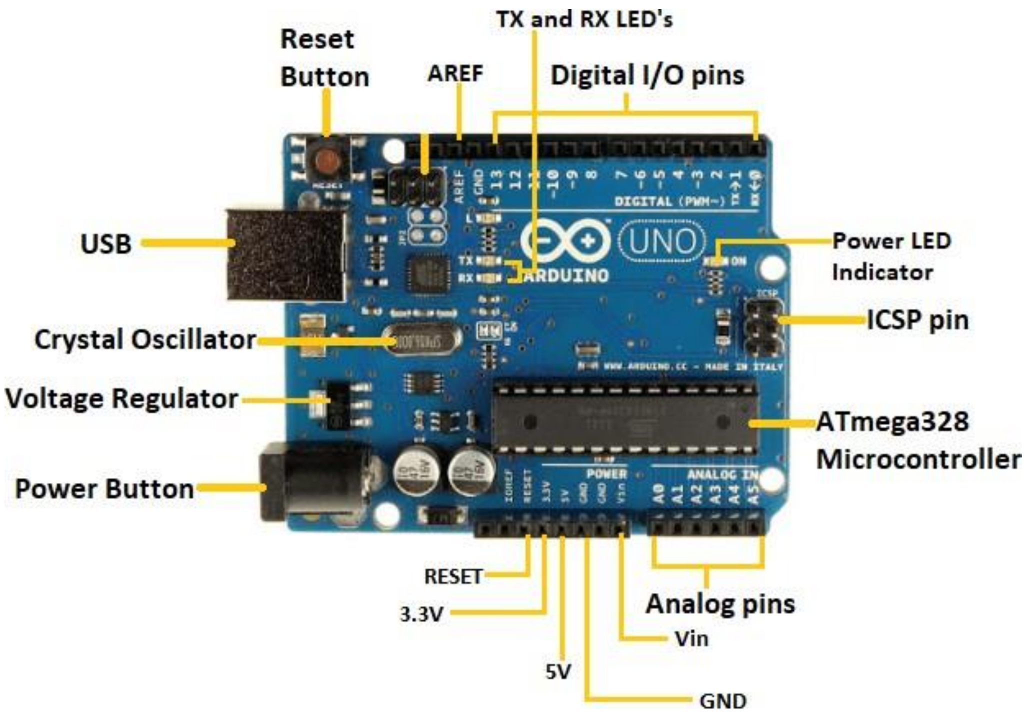


Figure 3.3: Arduino

The technical specifications of the Arduino UNO are listed below:

There are 20 Input/Output pins present on the Arduino UNO board. These 20 pis include 6 PWM pins, 6 analog pins, and 8 digital I/O pins.

The PWM pins are Pulse Width Modulation capable pins.

The crystal oscillator present in Arduino UNO comes with a frequency of 16MHz.

It also has a Arduino integrated Wi-Fi module. Such Arduino UNO board is based on the Integrated Wi-Fi Module and ATmega328P microcontroller.

The input voltage of the UNO board varies from 7V to 20V.

Arduino UNO automatically draws power from the external power supply. It can also draw power from the USB.

LIMITATIONS OF SMARTPHONE SENSOR-BASED ANALYSIS

The accelerometer of smartphones was used in all the previous solutions, and the GPS receiver is the second most commonly used sensor, followed by the gyroscope. Over the past few years, the number of studies on smartphone-only solutions for gait detection is higher than that of other smartphone-based solutions. However the use of external devices in smartphone-based fall detection and prevention systems is increasing gradually. The smartphone sensor that is used by all smartphone-onlysolutions is the accelerometer and the usual dynamic ranges of these built-in accelerometers are insufficient for accurate fall incident detection . Acceptable dynamic ranges for accelerometers from ±4 g to ±16 g have already been researched (where, 1 g = 9.8 m/s2) . Smartphones typically contain accelerometers with dynamicranges of ±2 g or less , but higher dynamic ranges can be found in high-end smartphones . The issue of energy consumption should be considered when designing a smartphone-based system. The battery life of the smartphone is dependent on the number of sensors used, data sampling rate , data recording time , features of algorithm and mode of operation . The battery life of a particular smartphone (Samsung Galaxy S II) was reduced to 30 hours when only one sensor was used, to 16hours if three sensors were used simultaneously. When developing the right algorithm, care should be taken to incorporate a minimal number of features, as fewer features decreases the usage of the processor and saves energy. Experimental results show that the use of the battery per hour for foreground 31 execution mode and background execution mode are 2.5% and 2.25% respectively. However, energy saving measures could negatively impact accuracy and usability. People with cognitive disabilities face great difficulty using the complicated interfaces of modern smartphone-based applications [80-81]. A recent study has revealed the myth that older people avoid new technologies as a fallacy. Older people have been found to be willing to accept new technologies to support their independence and safety. As mentioned earlier, all smartphone-only solutions use the accelerometer as a sensor which requires fixed placement of the smartphone. Various fixed positions on the body including the shirt pocket, waist and trouser pocket. This placement limits the usability of smartphone-based solutions because not everyone carries their smartphone in a fixed position and it may be difficult to convince them to do so. In order to overcome this obstacle, researchers have proposed the use of external body-worn sensors in combination with smartphones. This solution is also not accepted universally because these external devices expose the frailty of the user and many users forget to put on such external devices.

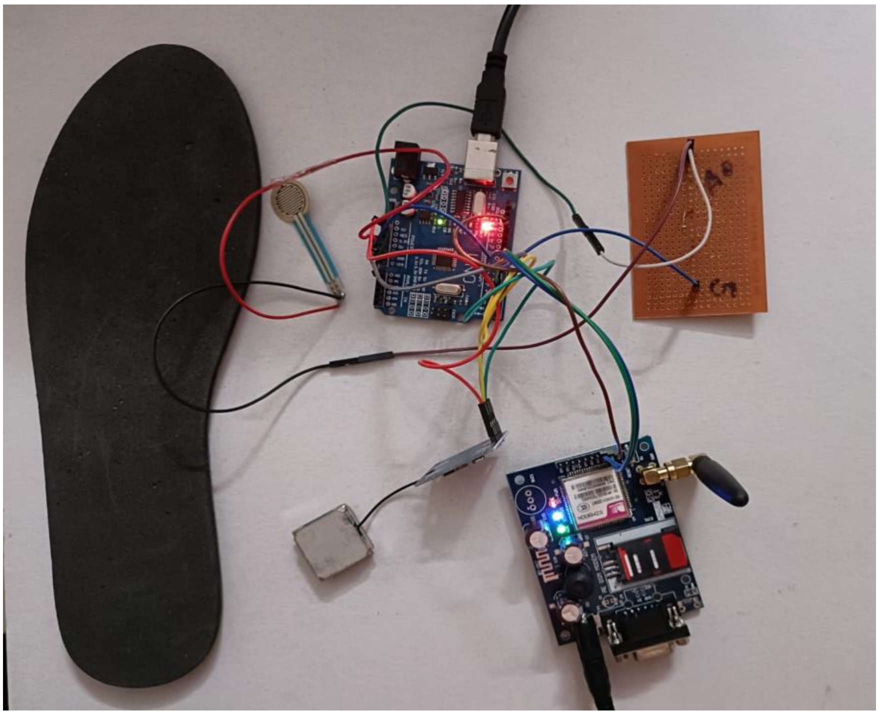
SMARTPHONE PLACEMENT AND USABILITY ISSUES

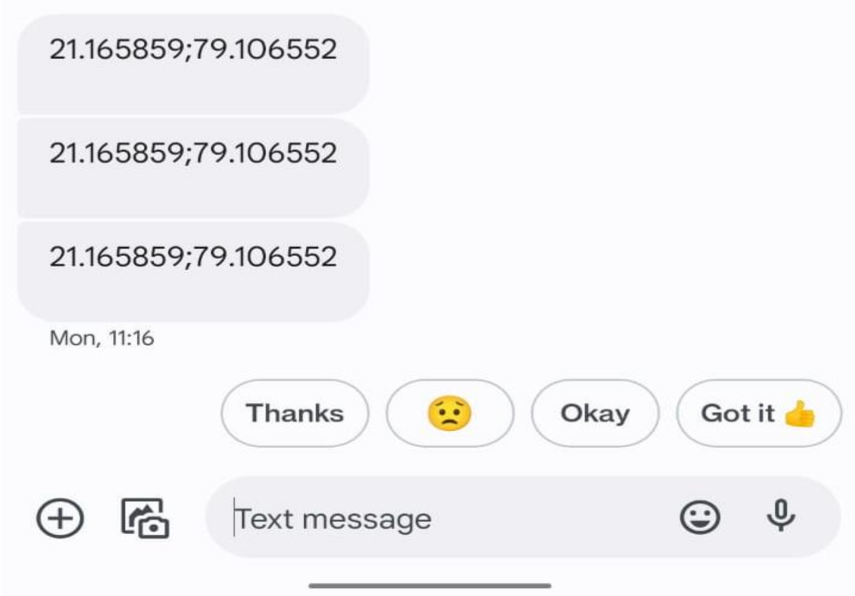
Smartphone-based fall detection and prevention systems are mostly designed for older people and individuals with neurodegenerative disorders. However, the acceptability of these solutions among older individuals has been suggested as a limiting factor. Older people may also prefer to have a single phone with self-contained fall detection functionality rather than wear a separate fall detection device. Therefore, while designing new smartphone-based solution, smartphone placement and usability issues should be handled carefully.

CHAPTER 4 – RESULTS, DISCUSSIONS and CONCLUSIONS

Results And Discussion

Pressure measurement is carried out by using FSR 402 force sensor. The output from sensor is connected to analog input of Arduino Uno and corresponding values are analyzed using serial monitor. After that Arduino sent these values to smartphones through the Wi-Fi communication network created by GSM module. Next, pressure values corresponding to different walking patterns are stored and which is then classified using the Decision tree method. This algorithm classifies different gait patterns to cautious and normal. Whenever a cautious gait happens then smartphone warns the older adult and also provide a feedback to caregivers.





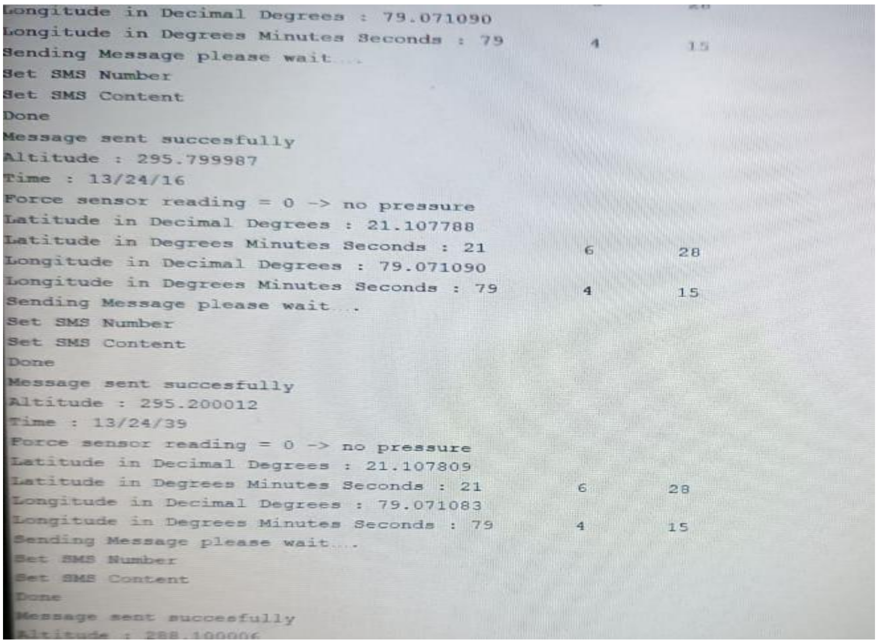


Fig .4 Working of Project

Conclusion

In this project, a wireless system is developed that is used to analyze gait using smart-shoe sensors through a real time detection of abnormality in users gait patterns. The proposed system can detect and predict cautious gait that can lead to a fall in older adults. Gathering the results from gait analysis are useful in medical programs, fall prediction in the elderly, physical therapy, and sports training. Through detailed gait feature analysis, therapists can quantify the rehabilitation progress of the patients after surgery, and the corresponding treatment and training can be customized according to an individual's status.

CHAPTER 5 - APPENDIX

Weight Testing of Insole Feedback

In order to test the accuracy of the fall prediction, we conducted weight testing to show the applicability of this system to a range of subjects and the stable calibration of the pressure sensors. Using smartphone sensors as the testing weights, it was found that the output voltage from the in-sole sensor approximately linearly increased with the testing weight as shown in figure . However, there was residue output voltage even though there was no weight on the sensors.

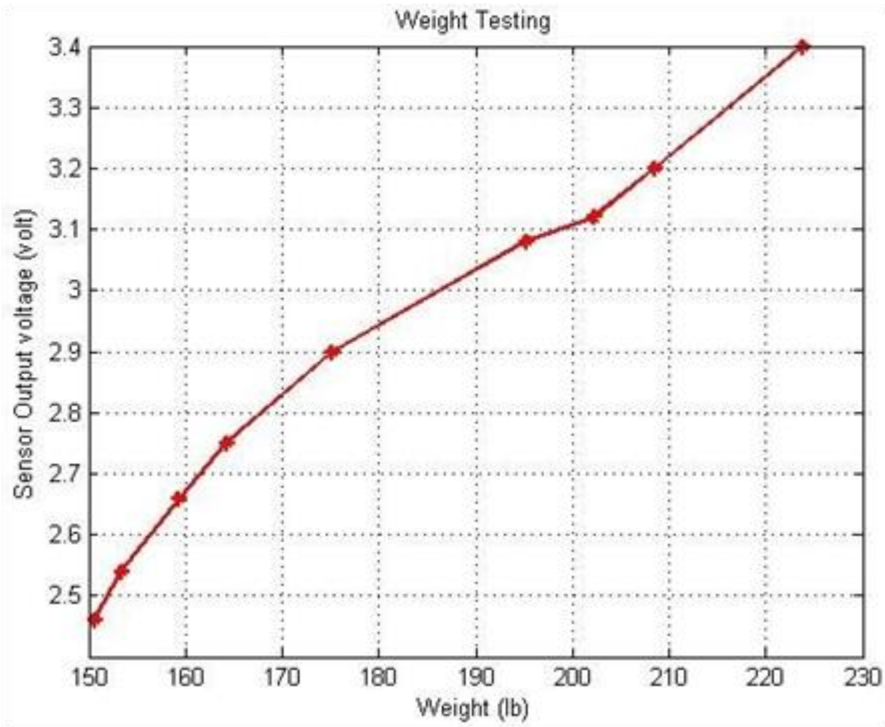


Figure 5.1: Weight vs Sensor output voltage(volt)

We have programmed the Arduino with four sensors. We read the analog input data and sent it serially to the Bluetooth device of smartshoe. Smartphone Bluetooth has received these data as string. Then we displayed the data on the Android device with corresponding sensors. As we have described earlier the application started with saving individual patient personal information. We have recorded the sensor data with respect to individual patient. We saved the data in order to train out system for individual patient. Later on by analyzing these information of individual patient we could identify their walking pattern or classify between normal and abnormal gait pattern. Raw data on foot pressure distributions were collected with the developed foot pressure sensing shoe (smart-shoe). The pressure level represents the output value of analog information into which voltage is converted. The experiment was conducted to develop an automatic measuring system for revealing the relations between human motions and collective foot pressure characteristics. With the power supply unit, foot pressure signal was gathered by piezoresistive flexi force sensors in a time span and transmitted to the smartphone through a Bluetooth communication network.

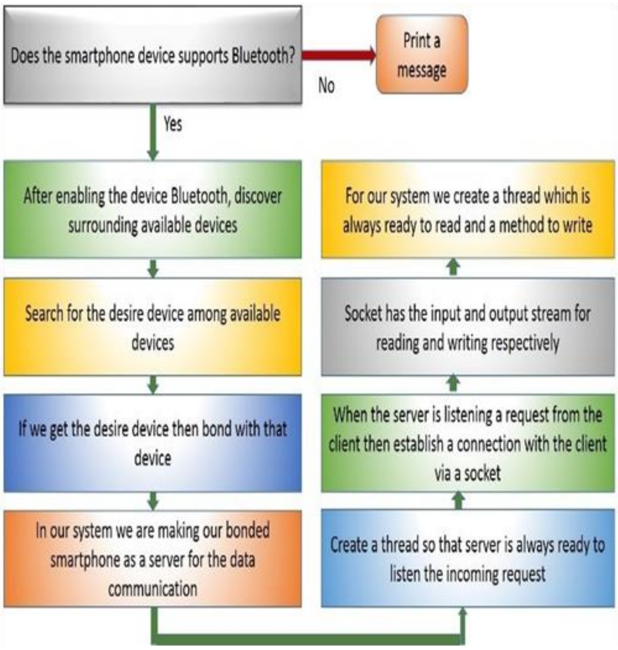


Figure 5.2: Algorithm on smartphone for low energy communication

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CAPTER7-SOCIETAL RELEVANCE

Injuries due to gait(walking) abnormality are a major health problem all over the world because of gait abnormality people may tend to fall. Falls are major health risk with which elderly and disabled have to face. These injuries are associated with significant mortality, disability, and a decrease in quality of life and also many health centers have to deal with a large number of patients due to unintentional falls, resulting in huge cost to the society and lot of time-consumption which leads to risk of life. Thus, there is a critical need for the development of cost-effective systems to reduce the injuries of a fall and to give faster assistance if fall occurs.

Several risk factors for falling can be identified and specific interventions can be designed in low cost and quick responses can be given to reduce injuries, which helps in maintaining independence of people who are suffering. Accurate and reliable knowledge of one’s gait characteristics at a given time and, even more importantly, monitoring and evaluating them over time, will enable early diagnosis of abnormality in gait(walk) to predict falls.

SEM VII **ET 2409 : Mini Project**

	CO Statement	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
1	Identify, formulate and analyze complex engineering problems through literature survey.	3	3	2	2	3	2	2	3	3	3	2	3	3	3
2	Apply Knowledge to assess health, social ,safety and environmental issues.	3	3	2	2	3	3	3	3	3	3	2	3	3	3
3	Implement core/multidisciplinary / industrybased electronics projects in cost effective manner.	3	3	2	2	3	2	2	3	3	3	2	3	3	3
4	Communicate technical details effectively	3	3	2	2	3			3	3	3	2	3	3	