

# Gait Disturbances in Geriatric Patients based on Activity Recognition and Footstep Monitoring

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## Abstract

The main aim of this research work is to design and implement a system for Health monitoring and fall detection in elderly people i.e, Geriatric patients accompanied by a system to perform Gait Disturbance Analysis. Health monitoring involves continuous monitoring of health conditions of disabled, elderly patients using many measures and parameters based on Remote Patient Monitoring (RPM) technologies. Gait Analysis involves conveying important information about one's physical and cognitive conditions using inertial sensors. Health monitoring provides a platform for monitoring health conditions like temperature, heartbeat rate of elderly citizens using an intelligent and a versatile health monitoring system that could help the elderly and individuals with disability, live independently in their own homes. If the monitored health conditions are abnormal, a message can be sent via GSM to the people concerned. It serves as a cost effective approach for personal care. An unobtrusive system capable of detecting accidental falls is also designed. The parameters obtained from the above mentioned systems are transmitted via GSM to the concerned health care professionals for smooth monitoring of gait disturbances in the elderly patients.

**Keywords: Gait Disturbance Analysis, Fall Detection, Health Monitoring, Geriatric Patients, Remote Patient Monitoring (RPM) Technologies, Foot Step Monitoring**

## I. INTRODUCTION

Many previous and current research works in the area of fall detection of elderly patients used medical sensor networks to identify and track human activities in daily life. In order to monitor, detect and report time-critical events, the urgency of the situation can be evaluated and coordinated in a number of ways and in a timely manner.

And, Health monitoring provides a platform for monitoring health conditions like temperature, heartbeat rate of elderly citizens using an intelligent and a versatile health monitoring system that could help the elderly and individuals with disability, live independently in their own homes. If the monitored health conditions are abnormal, a message can be sent via GSM to the people concerned. It serves as a cost effective approach for personal care.

The Signal Vector Magnitude (SVM) parameter, trunk angle and the person's heart rate after fall are used to determine if it is a serious fall or not. If the fall is serious then a message is sent via GSM to the concerned person in order to provide immediate medical assistance.

### A. Types of Gait Disturbance in Old Age

The neurological diseases that arise mainly in old age and have a gait disturbance as their major clinical manifestation, along with the basic components of the treatment for each. Gait disturbances in old age are often of multifactorial origin. The treatment consists of specific therapy for each of the identified components and may include physiotherapy, medications, behavioral therapy, and, in rare cases, surgery. Although physiotherapy is an important part of treatment for nearly all types of gait disorders, its efficacy has not been demonstrated in controlled studies, even for common disorders. Particular varieties of physiotherapy can be applied specifically only when the patient's deficits have been appropriately diagnostically categorized; sensory exercises, balance and coordination training, and biomechanical training can then be used as indicated. Fall prevention measures for patients at risk of falling include patient education, training, and instruction (e.g., regarding suitable shoes). Patients at very high risk of falling should be given appropriate mechanical aids.

Gait abnormality is a deviation from normal walking (gait). Watching a patient walk is the most important part of the neurological examination. Normal gait requires that many systems, including strength, sensation and coordination, function in an integrated fashion.

Specific vestibular disorders in older adults. Of all vestibular disorders, benign paroxysmal positional vertigo (BPPV) is one of the most common in older adults. BPPV causes vertigo, dizziness, and other symptoms due to debris that has collected within a part of the inner ear.

Gait and balance problems can be a result of pain, muscle weakness, muscle tightness or spasticity, loss of balance, or poor posture. Other causes include limited range of motion, numbness (sensory deficit), and fatigue. Muscle weakness can occur in one leg or both, and make walking difficult.

## B. Gait Detection

Walking is one of the more frequently performed sensorimotor tasks in everyday life. It relies on a complex, simultaneous interaction of the motor system, sensory control, and cognitive functions. The diagnostic assessment of gait disturbances in old age requires a clear distinction of pathological findings from the normal, physiological changes of aging. Spontaneous walking speed normally decreases by about 1% per year from age 60 onward, and the observed decline of maximum walking speed is even greater. On the other hand, a gait disturbance in old age is said to be present when the patient walks even more slowly than expected for age, or when there are qualitative abnormalities of locomotion, such as disturbances of the initiation of gait or of balance while walking. The patient's gait should be observed in standardized fashion, and the findings should be compared to age-specific norms. Gait disturbances in old age should be clinically classified in purely descriptive terms at first; deficits should be recorded as deviations of the main quantitative parameters of gait—speed, step size, and breadth of stance—from the corresponding age-specific norms. (Figure:1)

Gait disturbances are among the more common symptoms in the elderly. Reduced mobility markedly impairs quality of life, and the associated falls increase morbidity and mortality. To promote safety and prevent injuries among older adults, many technology developers are focusing their attention on Remote Patient Monitoring technologies that detect and ultimately prevent falls and wandering. The incidence of falls among older adults is high, as are the associated health care costs. Additionally, older adults with dementia are at increased risk of both falling and wandering. In a study of 100 people with dementia, patients fell over 400 times per year<sup>19</sup> and estimates of wandering ranged from 6 to 100%.<sup>20</sup> Unsafe wandering and elopement have many negative consequences, including injury to oneself or others and even death.

Falls are the most common cause of nonfatal injuries and of hospital admissions for trauma among older adults. Falls are a major issue among older adults. Of those who fall, many suffer serious injuries such as hip fractures and head traumas. This project proposes a simple and an unobtrusive method for detecting falls in the homes of older adults. This system uses the values obtained from accelerometer and gyroscope.

## C. Gait Analysis

Gait analysis has been investigated as an indicator of both physical and cognitive condition. Gait analysis can be used to help diagnose and assess the severity of neurological conditions such as Parkinson's disease and stroke. Wearable inertial sensor systems can be used to continuously and unobtrusively assess gait during everyday activities in uncontrolled environments. An important step in the development of such systems is the processing and analysis of the sensor data. The clinical gait analysis does not reflect the patient's every day activities. In addition, the frequency of the assessments may not be high enough to detect short-term variations. Continuous gait monitoring in uncontrolled environments is, therefore an important complement to traditional clinical gait assessment. Our work presents continuous gait monitoring system.

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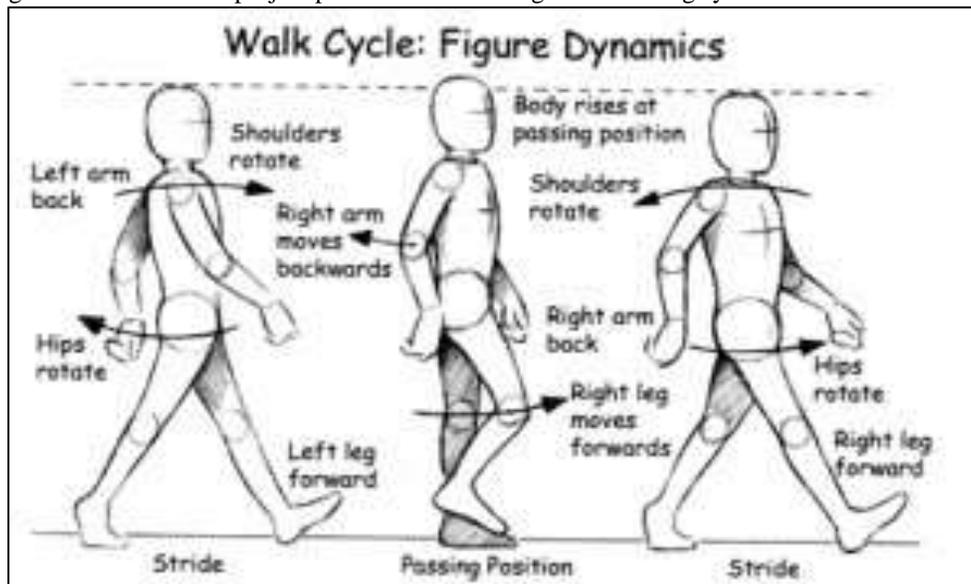


Fig 1: Gait Dynamics-Stride and Stance

## II. LITERATURE REVIEW

According to Jin Wang, Zhongqi Zhang, Bin Li, Sungyoung Lee, and R. Simon Sherratt(2014, IEEE), various fall-detection solutions have been previously proposed to create a reliable surveillance system for elderly people with high requirements on accuracy, sensitivity and specificity. An enhanced fall detection system was proposed for elderly person monitoring that is based on smart sensors worn on the body and operating through consumer home networks.

With treble thresholds, accidental falls can be detected in the home healthcare environment. By utilizing information gathered from an accelerometer, cardio tachometer and smart sensors, the impacts of falls can be logged and distinguished from normal daily activities.

From a test group of 30 healthy participants, it was found that the proposed fall detection system can achieve a high detection accuracy of 97.5%, while the sensitivity and specificity are 96.8% and 98.1% respectively. Therefore, this system can reliably be developed and deployed into a consumer product for use as an elderly person monitoring device with high accuracy and a low false positive rate.

Yu-Liang Hsu, Pau-Choo (Julia) Chung, Wei-Hsin Wang, Ming(2014, IEEE) suggested that despite patients with Alzheimer's disease (AD) were reported of revealing gait disorders and balance problems, there was still lack of objective quantitative measurement of gait patterns and balance capability of AD patients. Based on an inertial-sensor based wearable device, this paper develops gait and balance analyzing algorithms to obtain quantitative measurements and explores the essential indicators from the measurements for AD diagnosis.

The gait analyzing algorithm is composed of stride detection followed by gait cycle decomposition so that gait parameters are developed from the decomposed gait details. On the other hand, the balance is measured by the sway speed in anterior-posterior (AP) and medial-lateral (ML) directions of the projection path of body's center of mass (COM).

Alexander Rampp, Jens Barth, Samuel Schulein, Karl-Gunter Gaßmann, Jochen Klucken and Bjorn M. Eskofier (2015, IEEE) stated that a detailed and quantitative gait analysis can provide evidence of various gait impairments in elderly people. A mobile gait analysis system, which is mounted on shoes, can fulfill these requirements. Therefore, an accelerometer and a gyroscope were positioned laterally below each ankle joint Temporal gait events were detected by searching for characteristic features in the signals. The presented method was validated using GAITRite-based gait parameters from 101 patients (average age 82.1 years). Subjects performed a normal walking test with and without a wheeled walker. The parameters stride length and stride time showed a correlation of 0.93 and 0.95 between both systems. The absolute error of stride length was 6.26 cm on normal walking test. The developed system as well as the GAITRite showed an increased stride length.

## III. PROPOSED SYSTEM

In our proposed method, we have developed a system to monitor health conditions, detect accidental falls and perform gait analysis for the Geriatric patients. The resultant parameters from these sensors are processed and displayed on LCD and transmitted via GSM.

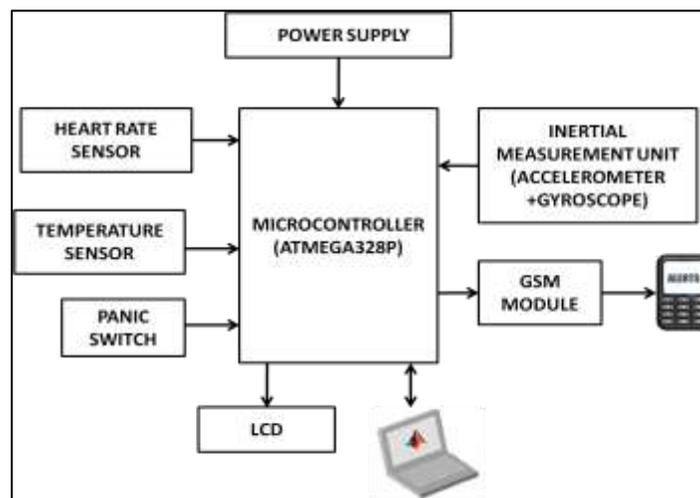


Fig. 2: Proposed System for activity based monitoring.

The temperature and the heart beat rate measured from the respective sensors are processed and their values are displayed on the LCD. If the sensed values are abnormal, they can be transmitted via GSM to the members concerned to alert them and to save the lives of the elderly individuals.

GSM is an open, digital cellular technology used for transmitting and receiving the data. GSM operates in the 900MHz and 1.8GHz bands. GSM supports data transfer speeds of up to 9.6kbps. In our proposed project, GSM technology is used for transferring the information to the health care professionals and family.

- The Proposed device to perform gait analysis comprises of an inertial measurement unit MPU6050 that consists of a triaxial accelerometer and triaxial gyroscope.
- The accelerometer senses the acceleration signals of walking in all the three axes. The gyroscope measures the trunk angle, which is an indicator of body balance.

#### A. Stride Detection Algorithm

- Step 1: Calculation of SVM (Signal Vector Magnitude).
- Step 2: Finding starting point of the stride.
- Step 3: Finding the ending point of the stride.
- Step 4: Gait cycle decomposition:
- Step 5: Finding the Heel Strike (HS) and Toe-off point.
- Step 6: Percentage of swing period in gait cycle.

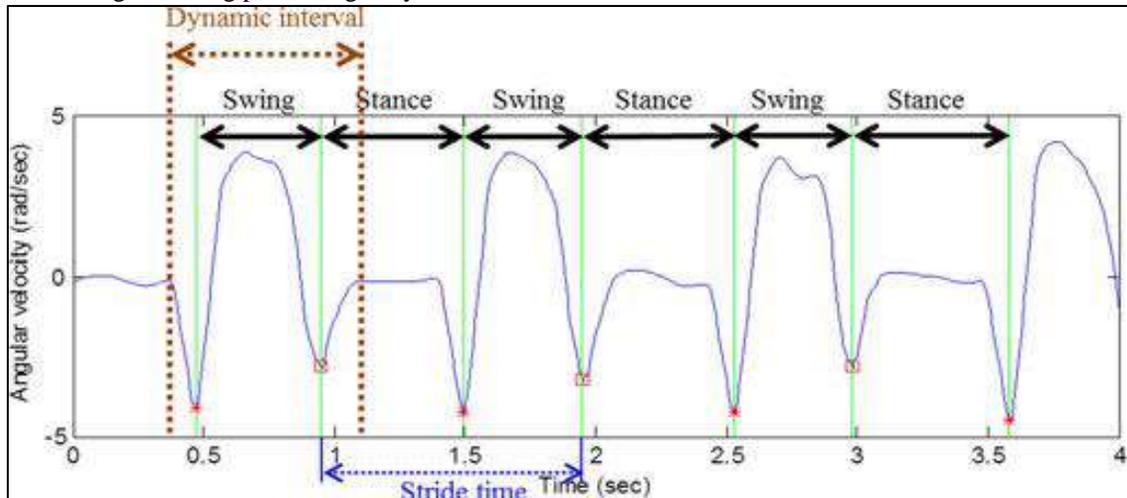


Fig. 3: Gait cycle decomposition

Falls are a major public health concern, particularly in the elderly population. Approximately 25% to 35% of people aged 65 years or older experience falls each year, and the epidemiology of falls shows that more than 50% of the falls occur during some form of locomotion.

Although significant changes in gait parameters may render one third of the community-dwelling elderly population at risk for falls, most gait studies of elderly people focus on gait risks for falls in clinical populations and often are limited to the evaluation of stride parameters.

For example, in individuals older than 70 years, average gait speed declines 12% to 16% per decade, stride frequency (STF) increases, stride length (STL) decreases at a given walking speed, and double-support duration increases from 18% (in young people) to 26% (in elderly people).

Possible explanations for changes in walking speed and stride parameters with aging include reduction of energy cost, compensation for muscle weakness, balance impairments, and coping with increased variability in walking.

#### IV. EXPERIMENTAL SET UP AND SIMULATION

The Health and Gait care system implemented is shown above. It consists of a series of switches to perform the assigned functions. Switch 1 displays temperature and pulse rate.

Switch 2 displays accelerometer and gyroscope values to detect falls. Switch 3 is used to connect Arduino to the MATLAB and calculate the Gait parameters. A panic switch is used in case of emergency conditions to immediately attend the patient's needs.

Specifications for SMS via GSM/ GPRS

- Point-to-point MO and MT
- SMS cell broadcast
- Text and PDU mode.

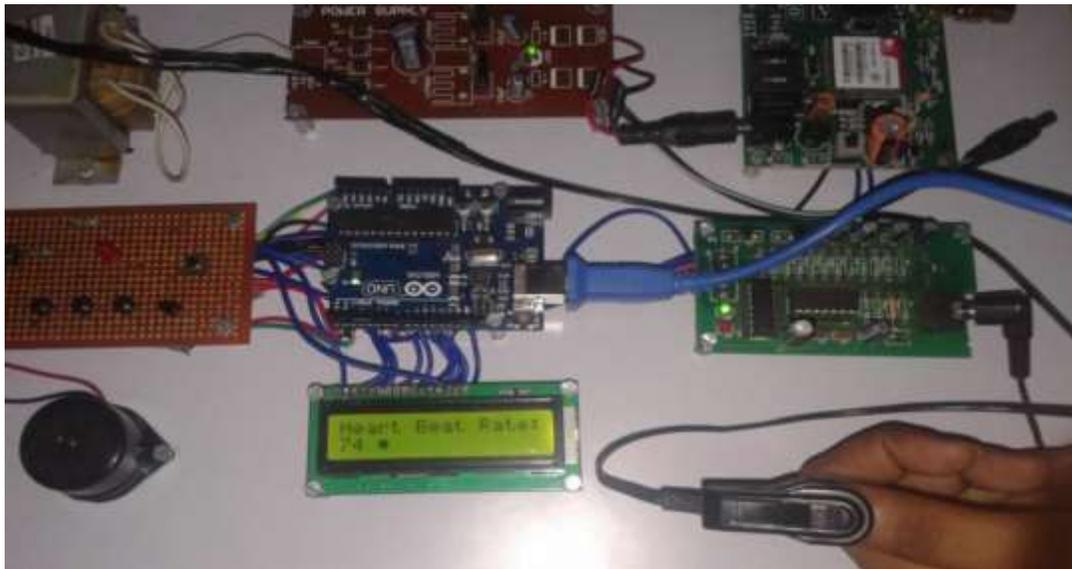


Fig. 4: Displaying warning message when pulse rate is high

### B. Fall Detection

A typical fall event ends with the person lying on the ground or leaning on walls, or furniture that will cause significant change in trunk angle. In this case, it is desirable to consider changes on the trunk angle to detect whether the detected acceleration was due to a fall event. Trunk angle ( $\theta$ ) can be defined as angle between the SVM and positive z-axis and can be calculated by inverse trigonometric function as in equation (2). The threshold for  $\theta$  has been given as:  $60^\circ$

In addition to health monitoring a panic switch is included in this work, which helps the elderly persons call anybody nearby for help when they are facing an emergency situation. If the person is not able to talk or move due to any medical emergency then he has to press the panic switch. When the panic switch is pressed, the buzzer produces sound to make the persons nearby aware of the emergency situation.

Passive fall detection technologies utilize a variety of sensors, including motion and pressure sensors, accelerometers, and gyroscopes to monitor location, position, immobility, speed of motion, and distance covered. Passive sensor technologies automatically detect falls and promptly alert the appropriate parties.

Different types of sensors can be used to detect movement, including motion sensors affixed to the walls of users' homes, accelerometers and gyroscopes attached to the user, and pressure sensors in the floorboards underneath carpet. Few algorithms are utilized to set thresholds for alert notification tailored to each older adult by monitoring patterns of movement and behavior. For example, a data pattern can assist with detecting urinary tract infections through frequency of bathroom visits at night or throughout the day. Such technology also can signal that individuals may need to move to a higher acuity setting or that they should consider using mobility assistive technologies if patterns change and mobility begins to deteriorate. System dashboards integrate individual and multiple user data in an easy-to monitor format. Dashboards can stratify alert notifications based on severity, which can be particularly valuable for assisted or independent living communities that monitor several people at once.



Fig. 5: Display of warning message, in Mobile phone, when pulse rate is high

### C. Classification for Fall Detection

The emergency case can be classified into four levels:

#### 1) Caretaker Level

When the system is setup, it will check whether the SVM and temperature is beyond the threshold. If it does not, it would frequently check the heart rate. Once the heart rate gets beyond a threshold value, the system will assume an emergency event has occurred and would request the caregivers to check out the condition of the elderly.

#### 2) Relatives Level

Once the system notices that acceleration is beyond the threshold in the first decide loop, the system will then examine the value of heart rate. If it is higher than the preset threshold, the call will be forwarded to the relatives and they contact the elderly person's home.

#### 3) Caretaker and Relatives Level

In addition, in case the acceleration, pressure, heart rate values get higher than the preset thresholds, then system can contact the caregivers and relatives irrespective of the trunk angle as a distinct floating in heart rate coupled with high acceleration is a significant warning.

The parameters that need to be calculated to determine a serious fall are,  
Acceleration in x, y and z axis. Gyroscope angle in x, y and z axis. Signal Vector Magnitude for Acceleration

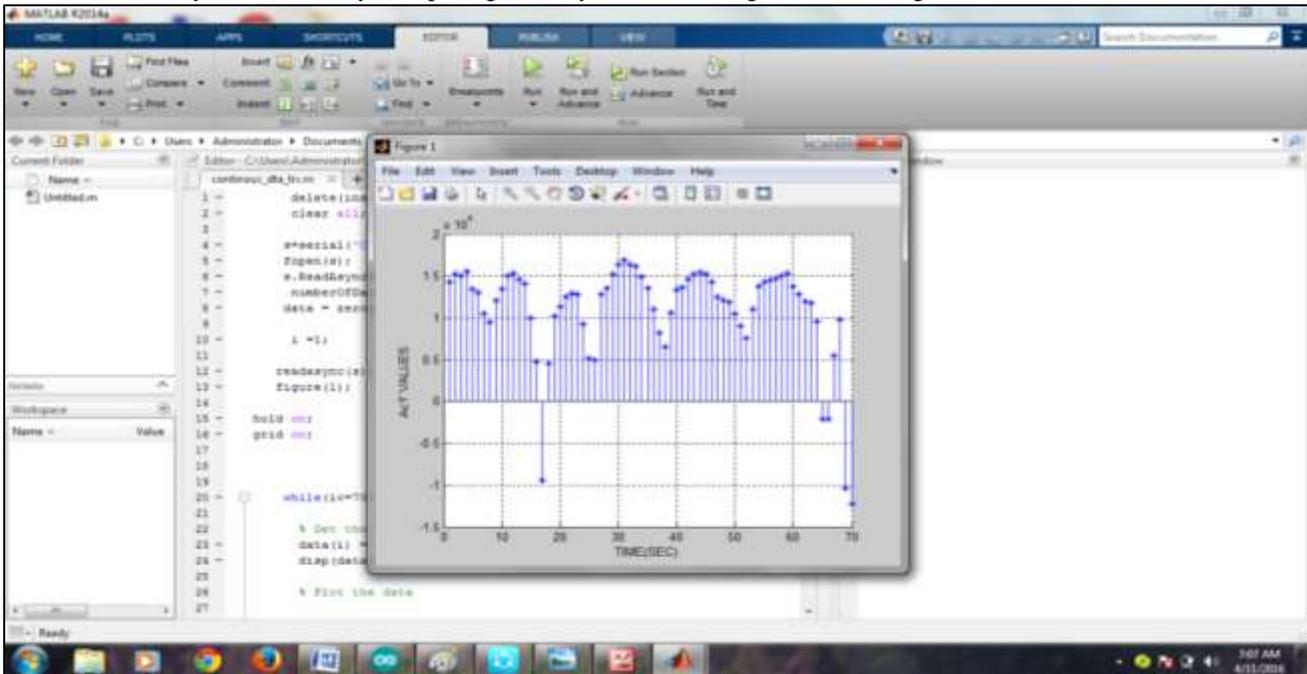


Fig. 6: Capturing Motion

The Arduino is interfaced to the MATLAB using hardware support packages. The above plot is obtained from the accelerometer & gyroscope values and it is a plot between the acceleration of y-direction and time. From the above plot, the heel-strike and toe-off points are determined and given as input to obtain the following Gait parameters.

Table – 1  
Measured Gait Parameters

Parameter Measured	Measured Value	Normal Value
Stride time	1.58	1.00 ± 0.08
Stance time	0.62	0.55 ± 0.06
Swing time	0.65	0.45 ± 0.03
Coefficient of variation of stance time	2.5	3.13 ± 1.07
Percentage of swing period in gait cycle	43.5	45.3 ± 2.04
Percentage of stance period in gait cycle.	55.5	54.70 ± 2.04

### V. CONCLUSION & FUTURE WORK

This research work incorporates a number of issues like health monitoring, fall detection and Gait Analysis which can be of great help to the geriatric or elderly people living independently in their homes. The health monitoring system monitors the elderly anytime, anywhere and automatically alarm to the emergency center in the emergency situation.

Also, by using the information from the accelerometer and other smart sensors, the impacts of falls can successfully be distinguished from the activities of daily lives thereby reducing the false detection of falls. In addition to that, we have presented a method that is able to calculate clinically relevant gait parameters from inertial sensor data of gait sequences. The entire setup proves to be simple, cost effective and portable. This work will be user friendly and helpful to the elderly people and will prove to be a promising health monitoring system.

#### **A. Future Work**

In future, the sensor can be integrated in the elderly patient's shoe to give the possibility of a data recording over at least a complete day. This would give the possibility for a detailed long term gait monitoring. Apart from the proposed method of using sensors to monitor the Gait parameters, Neuro Fuzzy Logic based methods could be used for this work.

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