Gait Analysis for Fall Prediction

Aditi Khawase, Nidhi Bomanwar, Tarini Wate
Department of Electronics and Telecommunication
Yeshwantrao Chavan College of Engineering, Nagpur, Maharashtra.

Abstract- 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. The product presented in this paper 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.

Keywords - fall, gait analysis, risk assessment, primary prevention, wearable technology, health technology, Smartphone, for elderly people

INTRODUCTION

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.

FACTORS AND PARAMETERS

The gait analysis is modulated or modified by many factors, and changes in the normal gait pattern can be transient or permanent. The factors can be of various types:

1. Extrinsic: such as terrain, footwear, clothing, cargo
2. Intrinsic: sex, weight, height, age, etc.
3. Physical: such as weight, height, physique
4. Psychological: personality type, emotions
5. Physiological: anthropometric characteristics, i.e., measurements and proportions of body

Mechanisms of Fall

Elderly people do not often have a single purpose for falls. A fall is generally due to a complicated interaction among the following:

1. INTRINSIC FACTORS

Age-associated changes can impair systems involved in maintaining balance and stability like standing, walking, or sitting. Changes in muscle activation patterns and capacity to generate enough muscle strength and pace may also impair the capacity to preserve or get better stability in response to perturbations like stepping onto an uneven surface, being bumped. In fact, muscle weakness of any kind is a prime predictor of falls.
2. EXTRINSIC FACTORS

Environmental factors can increase the threat of falls independently or, more importantly, by interacting with intrinsic factors. Risk is maximum when the environment requires more postural control and mobility like walking on a slippery surface and when the environment is unfamiliar like relocating to a new home.

3. SITUATIONAL FACTORS

Certain activities or decisions may increase the risk of falls and fall-related injuries. For example, 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.

CLINICAL ASSESSMENT TOOLS

The most common clinical fall assessment tools currently used include the following

i. Morse Fall Scale (MFS)
ii. St. Thomas Risk Assessment Tool in Falling Elderly Inpatients (STRATIFY)
iii. Hendrich II Fall Risk Model
iv. John Hopkins Fall Risk Assessment Tool
v. Stopping Elderly Accidents, Deaths, and Injuries (STEADI) Algorithm

All five tools are heavily dependent on some form of questionnaire. A patient is verbally asked questions from the forms, and answers are recorded. Subsequent scores provide a risk assessment. Often patients do not need further follow-up since results from the tests are satisfactory. A common feature of the current clinical tools is to analyze the cause of past fall experiences, which then can be addressed by providing counselling or medication to avoid such circumstances in future. In addition to the common tools in an office-based timed assessment, Mayo Clinic providers perform the following tests under their guideline, which tests are more functional than the above –

a. 5X STS – Five Times Sit to Stand – this test assesses physical strength
b. SLS – Single Leg Stance – this test assesses balance
c. TUG – timed up and go – this test assesses gait

The popular clinical fall risk assessment tools are demonstrated below with the actual models used for evaluation.

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 section. 40% of one gait cycle is spent on this section.

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 present the best analytical information with some visible graphics. Justifications for the design modules and instruments are

1 InSoLe –
A digital sensory insole with pressure sensors, and an accelerometer can seize gait information during activities. A pressure sensor would prompt when force is applied 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.

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

3 Computer – A computer with a large display might be used to show the given 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.

IMPLEMENTATION DETAILS

1. COMPONENTS
A specific smart insole is proposed. The insole top is made with rubber texture, and bottom hard-shell. These insoles are size dependent, and gender independent. Both insoles have embedded sensors in them. Since sensors are significantly small and low cost, it is convenient to insert 5 pressure sensors, and 1 accelerometer inside each insole. A small microcontroller is also placed inside the insole which interfaces with all the sensors. The microcontroller has a Bluetooth module that broadcasts data when any of the sensors is activated, and data is retrieved programatically.

The insoles have 5 pressure sensors, placed according to human foot placement dynamics. They are located under the- toe, forefoot, mid-foot, back-foot, and heel. When pressure is applied on any of the pressure sensors, this is recorded as a value of 1 which is passed to the microcontroller. The insoles also have a 3-axis accelerometer. It is placed under the forefoot. When foot locomotion occurs, the accelerometer detects the yaw, roll, and pitch of the movement. When activated, it sends data continuously to the microcontroller.

The interfacing control unit for the sensors is a small microcontroller which is supplied by the vendor of the insole. The API is also supplied, using which the data from the sensors can be collected programatically. It also comes with a Bluetooth module and a battery. The Bluetooth does not require pairing, as it broadcasts the data with an encryption key.

The insole has a lithium-ion battery built into it. It has roughly 400mAh capacity which can keep the insoles active for approximately 24 hours. The battery is rechargeable and utilizes a micro-USB port located on the side of the insoles. A full charge takes 1 hour to complete.

2. METHODOLOGY
An android application has been developed that can interface with the insole to read and collect data. The application records an ID of the subject, to uniquely identify the study and then proceeds with a set of instructions directing the test subject to perform certain activities that generate the gait data. After completion of the activities, the mobile application can send the captured data to a cloud web server for storage.

The API implements a Bluetooth module which can correctly name and retrieve all of the close by gadgets which might be broadcasting at the precise channel. The tool identifier denotes whether or not it’s far towards or proper insole. The mobile utility then determines to have slots for the insoles and establishes a Bluetooth connection.

Once connection is established, the textbox asking
for a Subject ID displays and requests input. The acceptable input is A-Z, and 0-9 with no special character or spaces allowed. The subject ID is stored as the file name, and also displays on the next screen. Duplicate entry replaces the existing file in the mobile device.

Four buttons are displayed in the next view, combining labels for instructions and buttons to start and end the capture window. Clicking on any of the buttons triggers a capture session to the insole. Insole data is recorded, and immediately sent to the mobile device real time along with timestamp.

After the collection of data according to the various activities instructed, when the submit data button is pressed, the file that was created in the beginning of the session is closed and is sent to a web server.

After proceeding with the instructions provided in the mobile application, following performance of 4 categories of activities, a file is generated with all the raw sensor data. At this stage the file is ready for transmission to the web server. An HTTP transmit call is made in the app which ships the file to a container in the destination Apache server. Any file storage capable server can be used for this stage. The credential for the storage system is stored within the app, in order to authenticate and be able to write to the destination. The server is protected with HTTPS and TLS protocol, so data remains encrypted for its duration in the remote location.

An alternate route for the data transmission is to manually retrieve the TXT file from the mobile device using a USB cable. The mobile application makes the call to the insole to send data as per the designed algorithm. The sampling is set to 10Hz, so data is recorded every 1/10th second and transmitted to the mobile device from all sensors. This has proven to be sufficient for sampling. Accurately capturing changes in gait for the sampling rate have been suggested in various research reports.

APPLICATIONS

1. CLINICS AND PRIMARY CARE PROVIDERS

The primary equipment for the proposed platform is a pair of insoles, a smartphone, and a computer connected to the internet. The patients would follow the instructions from the app with or without assistance. The app can be used by the patient or by someone assisting the patient. The data is available in real-time and fed into the platform and is then displayed for a doctor or caregiver to make further assessments.

2. GAIT DETECTION

This tool is maximum beneficial in evaluation and detection of gait styles and abnormalities. A caregiver can right away see numerous metrics to decide whether or not the affected person has any gait abnormalities. Foot fractures, damaged bones, osteoarthritis, strain arthritis, and foot disorders, may be effortlessly located from use of the device. The visible interactive information analytics can display and discover numerous gait patterns.

3. PLATFORM INDEPENDENT

Since the designed tool does not depend on a specific platform, as it is more internet browser based than a native operating system based, this can prove very useful when caregivers would like to use a handheld portable device such as a tablet.

4. REALTIME ASSESSMENT

The time it takes for a complete gait assessment is less than 10 minutes in total starting from inserting the insoles, to collecting data and transmission over the internet, to the application of the fall risk assessment tool. This is actual patient performance evaluated in real time.

5. EXTENDED CAPABILITIES

One of the design objectives is to make this tool as flexible as possible, so that further sensor-based facts may be accommodated. This tool can effectively house the improved competencies with its extra scalability feature. Not only insole data, however some other sort of data may be incorporated easily into the tool and visually represented collectively with gait facts. For example, if a blood pressure display or a glucose display can export uncooked facts then PowerBI can effortlessly import the data and comprise those with gait data.
LIMITATIONS

This fall risk assessment tool comes with certain limitations in its architecture and usability. The limitations do not affect the performance of the designed tool but instead suggest enhancements for future. 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 the event 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.

CONCLUSION

The work reported here demonstrates a gait analytics tool that can successfully display details of a person’s real-time gait and allows a user to analyze the gait using a slicing and dicing approach, by tweaking various parameters. Using a pair of sensory insoles, a smartphone, and a computer equipped with the tool a medical caregiver can easily visualize a person’s gait balance, and any gait impairment, and make an educated judgment on the potential and probability of a fall in the near future.

REFERENCES


