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MEMS Based Wireless Sensor for Real Time Gait Feedback System

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Abstract*:* This paper describes a MEMS sensor and a feedback system, to find out the gait abnormalities. The device are based on wireless transmission of the gait data for real-time sensory feedback to help the healthcare centre. Vibration rate piezo sensor was designed, using embedded that were sampled using a microcontroller, which then transmitted the data to an android smart phone. Different sensory methods of feedback were tested to determine their individual efficiency of the gait subject under study. Without the help of supervision of a rehabilitation specialist, the feedback system are capable of influencing the gait of the user. A statistical analysis was performed to establish the reliability and repeatability of the system. The proposed feedback method designed a novel, inexpensive and effective method for the people with gait abnormalities.

Keywords*:* MEMS vibration sensor, Smart phone, Gait rehabilitation, Sensory Feedback component.

I. INTRODUCTION

MEMS are small, integrated devices, which combines electronics, electrical as well as mechanical element on a single chip. The combination of microelectronics and mechanical components make MEMS more versatile than the other conventional sensors.Microelectromechanical Systems technology is used to make micro sensors and actuators. This process senses its environment and uses a microcircuit control, to change its environment. MEMS are also used for activation or adjustment of a variable capacitor, switches, and filters. Micro systems are fast, more reliable, cheaper, and have more complex functions. MEMS technology is used to developed chemical sensors, gas sensors, optical sensors, bio sensors, thermal sensors and mechanical sensors. Micro components make the system faster, more reliable, cheaper and capable of incorporating more complex functions. The resistance of the piezoresistive sensor is varied by applying external force and it is used to measure the physical parameters such as pressure, force and flow rate. The way of walk is an important function for normal human. Hence consideration must be given to the treatment and remediation to walk properly without any difficulty for a person [1].Due to the severity of the gait disorders, different method and different evaluating and diagnosing method were introduced for the gait problem [2].The aim of rehabilitation is to raise the functional walking ability of the patient to a normal level. Rehabilitation techniques are high cost, which is commonly used in gait rehabilitation, which includes force plates, force mats, motion capture systems, instrumented treadmills and insole sensor systems [3]. Force plates and force mats are high accuracy but it is use in stationary settings [5]. The required training is large and expensive for implementing it outside the clinic. Instrumented treadmills are large to be considered. Force sensors are visual-auditory feedback systems, but it required the monitor feedback. Other research in gait rehabilitation includes visual auditory feedback, use of on board processing and vibrotactors. The insole sensor system titled by LEAFs (Lower Extremity Ampulatory Feedback Systems), LEAFs uses a net book, to provide a auditory alert [8].

The main aim of this paper is to develop, design and verification of an inexpensive portable gait feedback device use by patients outside the clinical environment. The main goal is to develop a system which reduces the cost of the rehabilitation person. The patient shoes are implemented with a custom insole sensor. The sensor are embedded with FSRs(Force sensitive resistors),which are able to determining the common gait parameters. Ankle-mounted microcontrollers are used for sampling and data collection, as well as to transmit the real time gait data via a Bluetooth serial connection.

The LEAFs systems are replaced by a smart phone and it was developed by android mobile phone operating system. Android smart phone give the result of gait data by using phones functionality, to provide the effective feedback systems. There are three types of alert, such as auditory alert, vibrotactile alert, and visual display. These mobile applications are advantageous that it reduces the cost of the overall system, ease of installation and it provides the effective method of gait modification without use of physician.

II. DEVICE DESIGN

The feedback device is designed with a simplified wireless communication protocol. The proposed design is more robust and it can be deployed in smart phone applications. The proposed device has three feedbacks, it is easy to pack, and it is reliable and inexpensive for the

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gait rehabilitator. The individual system provides high efficiency.

A. *Embedded Vibration Sensor*

Embedded vibration sensor was designed and the vibration data's were sampled using a micro controller. Four piezoresistive sensors were used. In left side one sensor were placed under the forefoot and one sensor under the hind foot. The position of the sensors decreases the amount of data that are collected and analyzed. It also reduces the entire data size of the device and increasing the sampling rate. Fig 1. shows the embedded vibration sensor. Two sensors are enough to calculate the gait timing and provide feedback on abnormalities. It is used to find out the user's gait values whether the gait value is abnormal or normal. The gate value can be effectively calculated without losing any data or unnecessary data being sampled. Feedback system is used to give the effective gait value. The vibration sensors are immediately depressed upon heel strike, and released upon toe off. Embedded vibrating sensors are arranged in voltage divider circuit that converts the resistance changes caused by sensor activation into a change in electrical voltage.

Fig. 1 Embedded Vibration Sensor

B. *Microcontroller and Wireless Data Transmission*

The insole sensor data's are sampled by microcontroller, using PIC16F877A 4MHz microcontrollers. The FSR data are transmitted using six analog input pins, which can be lead simultaneously. The board is connected to a Bluetooth serial pipe for data transmission in android smart phone. The Bluetooth wireless serial data transmission and reception are carried out. They are paired with the feedback application while running on the smart phone. Bluetooth are applicable for modern smart phone system. Instead of Zigbee radio transmission, Bluetooth with the smart phone are established for low power consumption.

Bluetooth data transmission using Zigbee radio communication can be done for long distance communication. The wireless transmission needs more power and it also supports the android hardware. In addition to reduce the lower limb implementation, embedded insole sensors and feedback system are used. The main aim is to reduce the size with a prototype cost of $ 225 USD.

C. *Smart phone and Feedback Development*

The previous method used gait analyses system and provides feedback to the stationary user and the cost of the system is too high. In addition the system requires supervisor such as rehabilitative therapist or a specialized operational trainer. The advantage of gait rehabilitation and therapy are numerous and effective. It will not be suitable for the feedback system in home or other non clinical settings. The main motivation to develop this research is to provide a effective wearable instrumentation system. In order to increase and support rehabilitation the previously work used the insole sensors which relied on laptops and computers with MATLAB or LABVIEW.

The major specification was carried out for the development of complete system and for the development of highly portable feedback device. In the design phase, a literature survey was performed to determine the different type of sensory feedback which can be included in the next generation feedback device. There are three different feedback methods such as visual, audible and vibrotactile methods. These three feedback system where redesigned for the insole gait system. This redesigned device provides different methods of feedback from a integrated systems, which can be used to communicate and support the wireless insole sensors. A smart phone is selected for feedback system. Smart phone offer many useful and effective methods for conveying data to the user, it is applicable for fast process, large storage capacities and more number of wireless communication. Thus it was decided to use an android smart phone in the system for development purposes. The reason for choosing android smart phone is that, it has a highly competitive platform, which is used to develop control open handset. The entire operating system has an open source and has a free platform, which is able to change according to the situations. The android systems are directly related to the peripheral systems. These peripheral systems includes speakers, vibrating motors, touch sensitive display screens, input keyboards, internal GPS and an accelerometer units. In addition to, it Bluetooth is activated for wireless communication. A customized feedback system was implemented in android smart phone so as to provide the feedback cues such as visual, Audible or vibrotactile.

Fig. 1 ANDROID Application

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III. DATA LOGGING

In addition to the feedback tabs that are available in the layout, feedback system application includes context menus for the users to specify their individual details. This is a valuable component for researchers, it allows them to use the application easily to log and study the data regarding the influence of the sensory feedback on the user. Once the user enters applications that are needed, then their performance can be saved and all the information can be easily retrieved from the external secure digital (SD) card.

A. Visual Feedback

The visual feedback system was designed for the users to help them to easily identify and monitor their current gait details. Fig 3.shows the screen shot of the visual display system. There are three lines in the visual feedback system. The first two lines denotes the acceptable gait range and graphical representation of the gait rating. The numerical display updates the gait ratio at each time. The graphical display was designed to be simple and intuitive, so as to allow the user to receive their current gait status at their display.

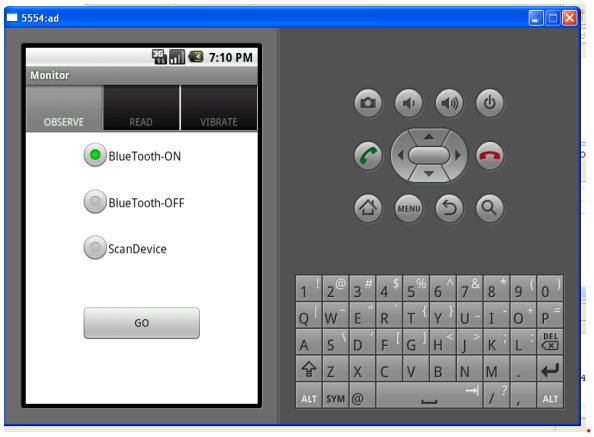

Fig. 3 Visual Display

B. Audible Feedback

The audible feedback tab is provided with simple instructions, which are used to start the application of audible feedback. The user can alter the feedback parameters, so that the gate value can be adjusted. Before starting the audible feedback system the user has to be alerted. Once the audible feedback is initialized it will change the tone according to the gait value. So the user can know about their own gait value using the audio alert.

C. Vibrotactile Feedback

Vibrotactile feedback similar to the audible feedback tab system. Vibrotactile instructions were initialized and depending on the users gait value, a vibrotactile could be received. The phone vibrates in correspondence to the received gait value (outside parameters or inside parameters). If the gait value is too high, the user takes more time for each step. So vibration produce long buzz. If gait value is too low, the vibration will be a short buzz. The vibrotactile feedback allows the feedback system to receive silent low level feedback cues; sensory stimulation is not used or ineffective due to the user environment.

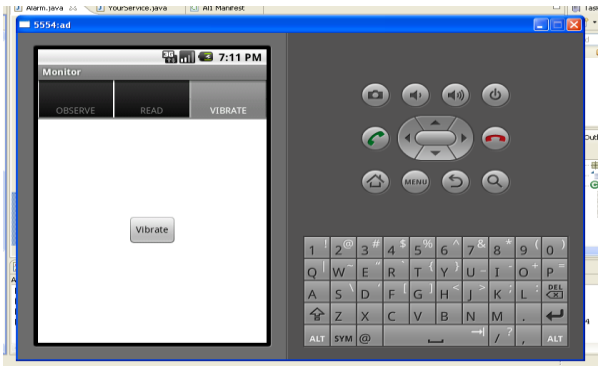

Fig. 4 Embedded Vibration Sensor

D. Software Implementation

The feedback system has been developed to provide a various user gait values. Generally a standard clinical test are conducted to determine the gait value (normal or abnormal).It can be achieved by using a microcontroller in the ankle box. The microcontroller samples the sensor data with a frequency of 1000Hz. In feedback, the stance times were calculated. Stance time expressed as

$$\text{Stance time}=T\_HS / T\_TO$$

Here T_HS and T_TO are the heel strike and toe off respectively. Once complete pair of heel strike and toe off times has been received, every present measurement of stance time is transmitted continuously to the smart phone. Gait timing parameters on the left foot and right foot were implemented in the smart phone. The symmetry ratios are computed using the stance time of left and right foot.

$$R=ST\_R / ST\_L$$

Where the ST_L and ST_R are the stance times measured on the right and left feet respectively. The symmetry ratio is calculated in the smart phone application. The target ratio is ±1.0 is specified and used.

IV. EXPERIMENTAL METHOD

MEMS sensor (Insole sensors) are used to measure the pressure and vibration of the human locomotion. Depending upon the motion of the human being, the pressure applied on sensor gets differed on both legs. A sensor calculates the pressure and vibrations of human foot based on the angular velocity of the foot while walking. Output voltage of sensor are amplified and given to the controller. Amplifying circuit consists of high pass filter, low pass filter and amplifier IC, to provide the amplified output. Fig 5. shows the circuit diagram the method proposed.

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High pass filter are used to filter the low frequency noise signals and to allow the high frequency signal to pass through it. The value of cut off frequency is 0.3 Hz. Low pass filter are used to allow the low frequency signal to pass through it and to attenuate the high frequency signals. Cut off frequency of low pass signal are 1 kHz. Outputs of the sensors are fed to the micro controller to estimate the value of gait.

Pic 16F877a microcontroller is fed by the output of the MEMS sensors. Analog port of the controller gets the input and converts it to the respective digital value and it can be compared with the normal value of the gait and produce the final output. Fig 6. shows the hardware implementation of the proposed method.

LCD display is connected with the digital port of the controller and to display ADC values of each sensor. Controller uses the UART serial communication to transmit the values to the Bluetooth module. Bluetooth module receives the data from the controller and sends it to the android mobile phone and stored the data to the database.

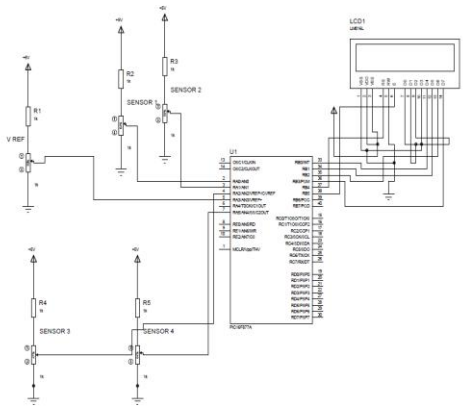

Fig. 5 Circuit Diagram

Fig. 6 Hardware Implementation

V. RESULTS AND DISCUSSION

Most of the elderly people have gait abnormality. These persons are identified by their posture and gait movement. Depends upon the gait value, these person can be characterized into two types, one with a gait normal value and the other with a gait abnormal value. From the gait value, we can check whether the user has Parkinson's disease or not. Parkinson's disease is generally a neurodegenerative disease which affects a person slowly. Brain controls the entire movement of the body. The degeneration disease affects the whole movement of the body, it also affect the gait of the human. Therefore, this result causes the abnormal movement. The symptoms of the disease are mostly seen in person above 40 years. Parkinson's diseases affect the body of a person in different stages; finally it will affect the entire body movement. In the United States over 1 million people are affected with Parkinson's disease. For every year 50,000 people are affected with Parkinson disease.

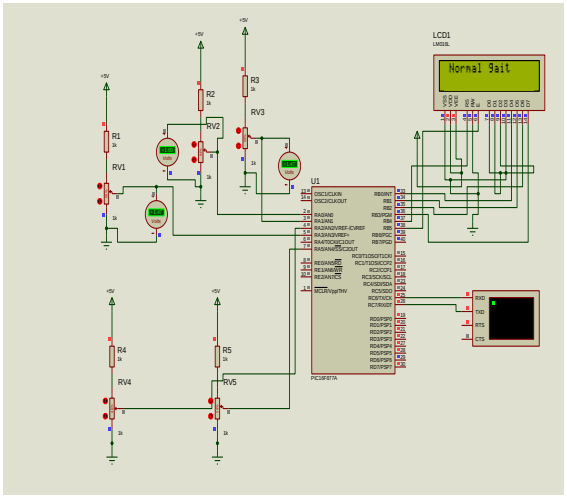

Fig. 7 Simulation output1

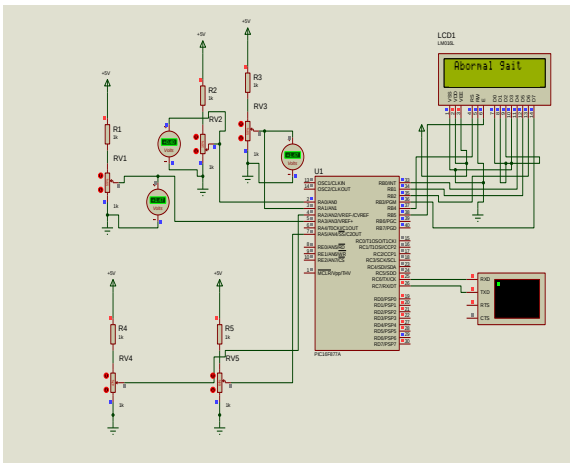

Fig. 8 Simulation output2

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Nowadays Parkinson diseases are increasingly seen in average age people. The symptoms of the Parkinson disease are tremor, trembling or shaking in the limb. The symptoms are collectively called Parkinsonism or a Parkinsonism syndrome. The Parkinson disease also has a genetic origin. It can also cause neuropsychiatric disturbances which can varies from mild to severe. This disorder can affect the speech, cognition, mood, behavior and thought of a person.

TABLE I.

Gait value	Visual	Audible	Vibrotactile	Status of a Person
1.00	1.00	Normal	Short buzz	Not affected
1.95	1.95	Normal	Short buzz	Not affected
1.98	1.98	Abnormal	Long buzz	Affected
2.68	2.68	Abnormal	Long buzz	Affected

The feedback system succeeds in knowing the gait subjects of walking pattern. This process is an extremely short training process compared to a gait rehabilitation program. It is shown that the three feedback systems have high level of effectiveness in influencing the gait of the subject.

VI. CONCLUSION

Effective, inexpensive and a novel hardware was designed for a persons with gait abnormalities. The MEMS based vibration sensor along with the three feedback system, were able to achieve and analysis a satisfactory gait values. The circuit is simulated by using Embedded C and PROTEUS Design suite and result were successfully obtained. The system has potential for use in the rehabilitation and training of subjects who have undergone lower limb amputations, suffered from Parkinson's disease.

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