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Wireless IoT System towards Gait Detection in Stroke Patients

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ABSTRACT

Gait analysis using the Internet of Things (IoT) is an important medical diagnostic process and has many applications in rehabilitation, therapy and exercise training. We have designed and implemented an IoT-shoe with a Wi-Fi communication module and the smartphone or personal computer to discreetly monitor insole pressure of the patient's motion. The objective of this study is to present a multisensory system that explores walking patterns to predict a cautious gait in the stroke patient. This portable sensing system serves as a walking aid for rehabilitation training or permanent use in a wide range of gait disabilities. The proposed system can notify the user about their abnormal gait and possibly save the analysed data of the gait variations in the cloud. Experimentation and verification are conducted on multiple subjects with different gait including free gait.

Key Words: *IoT, Stroke, Gait, Smartphone, Personal computer, Sensor.*

1. INTRODUCTION

At the present time, gait analysis is primarily carried out in one of two ways: in a motion laboratory, with full analysis of the motion of all body segments using highly accurate optical systems, or in a doctor's office with the physician making visual observations. The first method is expensive, requires the maintenance of a dedicated motion lab, and uses cumbersome equipment attached to the patient, but produces well-quantified and accurate results for short distances. The second method is inexpensive and does not require anything to be attached to the patient, but the results are qualitative and difficult to compare across multiple visits. There is a need for a low cost device that falls in between these two methods, one that can provide quantitative and repeatable results. Analysis of the human gait for predicting falls due to cautious gait is the subject of many current research projects. Accurate 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 to predict falls. This diagnosis will also help to predict and prevent users from an injury. Stroke is one of the leading causes of morbidity and mortality in adults, accounting for 17.3 million deaths per year. So, the automatic detection of cautious gait in stroke patients would help reduce the arrival time of a medical caregiver and, accordingly decrease the mortality rate. One criticism of the available risk indicators has been the lack of consideration of fall-related factors and loading conditions, which may considerably affect the predicted fall risk. Thus, much attention has been directed towards gait prediction using smart phone and Internet of things (IoT) devices. To the best of our knowledge, we are the first to use subject-specific IoT-based gait evaluation implemented on smart phones to accurately detect abnormality in gait events in predicting injuries in a stroke patient. IoT has created an explosion of sensor data due to the increased number of devices with embedded sensors. With recent developments, smartphones have increased their processing capabilities and have been equipped with a number of built-in multimodal sensors. As self-contained devices, smart phones present a mature hardware and software environment for developing various health monitoring systems. Smartphone-based gait monitoring systems can function almost everywhere, because mobile phones are highly portable. Ideally, integrated sensors along with the pressure sensor shoes (IoT-shoe) can automatically detect gait patterns. Researchers have already developed some smart phone-based gait detection systems, especially for stroke patients. However, in all of these previous studies, the system detects a gait related injury only after it has already occurred. We believe the best way to reduce the number of injuries is to alert users about their abnormal gait and the possibility of falling due to cautious gait. Therefore, our focus is on gait detection (followed by patient awareness) which will help to predict injuries due to cautious gait in stroke patients. To address the issue of gait detection, the aim of this study is to determine if the gait of stroke patients changes significantly over successive gait trials using smart phones or computers. Data from a pressure-sensor embedded shoe and smart phone or personal computer were used to validate the proposed approach.

1.1 Major Contributions

The contribution of this paper is to concentrate on the development of a wireless IoT-shoe for user gait abnormality identification. Foot pressure signals can identify the behavior of human gait and posture as reflected in foot pressure distribution. Many studies describe foot pressure as a detection system, but few have used smart phone and a smart-shoe for the analysis. We report on a new smart phone and smart-shoe used for gait analysis. Our major contributions are as follows:

- Developed an IoT system for gait detection in stroke patients
- Proposed a smart phone or computer and Iot shoe-based system to analyze gait in common environment
- Designed and developed a Wi-Fi communication generic framework between IoT-shoe and smart phone or personal computer
- Storing of analyzed data in the cloud
- Provide users, health care professionals and caregivers with highly personalized health feedback

Our system, targets gait detection among people with impairments that affect balance, predisposing individuals to falling. These include stroke patients, common rehabilitation diagnostic groups and elderly populations, but also may eventually help identify gait disorders among children, behavior analysis, and be helpful in environment monitoring.

2. RELATED WORK

Gait pattern detection using embedded IoT sensors has been the subject of many studies over the past decade. Most of the previous approaches regarding gait recognition utilize accelerometers attached to the subject for gathering data. Therefore, they have very limited accuracy in predicting abnormal gait, like cautious gait for a specific individual. Past studies have shown that stroke patients exhibit great fatigability during gait. These studies have established that, after a stroke, walking performance declines over relatively short periods of functionally-relevant ambulation. In addition, there are several research projects within mobile ECG recording using Internet solutions, Bluetooth technology, cellular phones, and wireless local area networks, Wireless and WLAN Sensor Networks . A gait monitoring system has been proposed based on mobile platform which transmits abnormal walking identified in a patient-worn unit. Later, a smart phone based gait detection system that can alert the users about their abnormal walking patterns was developed. The authors validated their system using a decision tree with cross validation and found 99.8% accuracy in gait abnormality detection using smart phone sensors data. They also have developed the system which equips an IoT-shoe with smart phone sensors to analyze the data using the same method to show the fall prediction accuracy. They did not consider predicting cautious gait that can lead to a fall. To address the drawbacks of the above-mentioned research, in this paper, we propose a gait assistant system using IoT. Our system is designed to address directly some of the drawbacks of the existing systems and potentially yield good prediction results. To the best of our knowledge, our system is the first IoT-based gait assistance for predicting cautious gait, especially in stroke patients with the involvement of cloud for storage and accessing the data through both smart phone and personal computer.

3. METHODOLOGY

1.1 Hardware

Arduino is an open-source physical computing platform based on a simple i/o board and a development environment that implements the Processing/Wiring language. Arduino can be used to develop stand-alone interactive objects or can be connected to software on your computer (e.g. Flash, Processing, MaxMSP). The open-source IDE can be downloaded for free (currently for Mac OS X, Windows, and Linux). The Arduino Mega is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, 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. The Mega 2560 R3 also adds SDA and SCL pins next to the AREF. In addition, there are two new pins placed near the RESET pin. One is the IOREF that allow the shields to adapt to the voltage provided from the board. The other is a not connected and is reserved for future purposes. The Mega 2560 R3 works with all existing shields but can adapt to new shields which use

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these additional pins. ESP8266EX (simply referred to as ESP8266) is a system-on-chip (SoC) which integrates a 32-bit Tensilica microcontroller, standard digital peripheral interfaces, antenna switches, RF balun, power amplifier, low noise receive amplifier, filters and power management modules into a small package. It provides capabilities for 2.4 GHz Wi-Fi (802.11 b/g/n, supporting WPA/WPA2), general-purpose input/output (16 GPIO), Inter-Integrated Circuit (I^2C), analog-to-digital conversion (10-bit ADC), Serial Peripheral Interface (SPI), I^2S interfaces with DMA (sharing pins with GPIO), UART (on dedicated pins, plus a transmit-only UART can be enabled on GPIO2), and pulse-width modulation (PWM). A force-sensitive resistor (alternatively called a force-sensing resistor or simply an FSR) has a variable resistance as a function of applied pressure. In this sense, the term “force-sensitive” is misleading – a more appropriate one would be “pressure-sensitive”, since the sensor's output is dependent on the area on the sensor's surface to which force is applied. When external force is applied to the sensor, the resistive element is deformed against the substrate. Operationally, an FSR is very similar to a strain gauge, the main difference being that a strain gauge's backing deforms with the resistive element, while an FSR's does not. This fact is important to consider when mounting an FSR against a support, as discussed below. The same applied force will result in a wider output swing in a FSR than a strain gauge. Strain gauges, however, have higher accuracy than an FSR. Depending upon the particular needs of the application, one may choose one or the other. Ultimately, a major consideration in the choice of a sensor is cost; a major advantage of FSRs is their low cost. One of the most common circuits implemented to utilize an FSR's output is the voltage divider. A voltage (usually +5 V) is applied to one of the leads, while the other is grounded. FSRs are not polar, meaning it does not matter which side receives the voltage. One lead from a second resistor (with fixed value) is then connected to the voltage side, while the other lead of the second resistor is also connected to ground. In this way the FSR is able to measure the “voltage drop across a resistor”. The resistance value of the second resistor determines the output range of the sensor. Typically, 100 KΩ will yield a sensor output suitable for common ADCs used for musical applications.

3.2 Experimental setup

The strength of our proposed IoT system is dependent on existing wireless communication technologies to provide a low cost solution with maximum freedom of movement. In addition, we have used smart phone, computer and a sensor embedded IoT-shoe that are user friendly. The architecture of the system is shown in Figure 1. To test the effectiveness of our proposed system, we collected data from the IoT-shoe sensor with the help of Arduino, which is programmed to read an analog signal from the shoe sensors and send it to the cloud using Wi-Fi communication module. The stored data is accessed using the personal computer or the smart phone. We used multiple subjects and collected data for different events of a gait cycle. Pressure data was collected for the users over a period of time and every time a subject was tested with different types of walking.

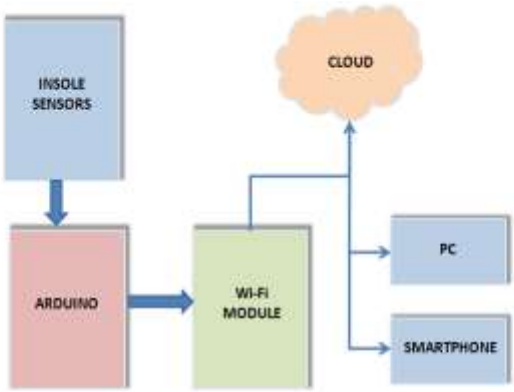

Figure 1: System architecture

3.3 Data analysis

For the data analysis, we have developed a prototype application. The screenshots of the prototype application with visualization of pressure variation in different sensors are shown in Figure 2. The interface is shown, which is used to visualize the 2-axis pressure variations while walking for a period of time. We also have developed the interface for graphically picturing all four insole sensors. The graphical data is effectively analysed by comparing the pressure variations with the standard pressures. The recorded data is stored in the cloud and it can be accessed by the patient when needed. There is a provision for viewing the data through the smart phone or personal computer. Moreover, the doctor can also access the sensor data for the treatment.

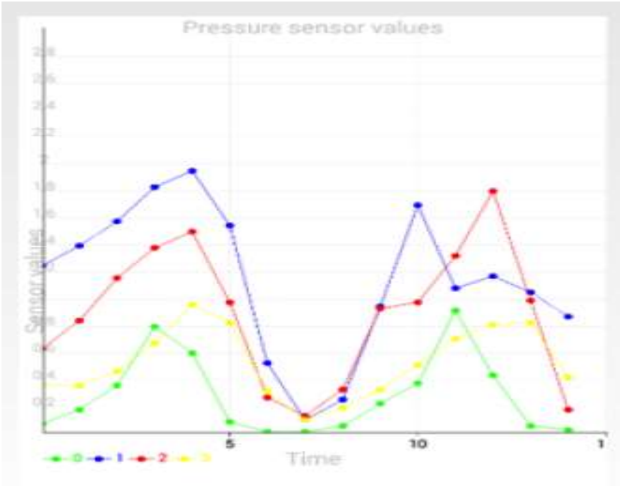

Figure 2: Sensor data

4. CONCLUSION

In this paper, we presented a wireless system to analyze gait using pressure sensors along with the IoT system for the real-time detection of abnormality in users' gait pattern. There is a clear need for a device which can provide quantitative analysis of gait in conditions outside of the motion lab. While this work is continuing to be developed, it shows great promise as a future contributor to clinical gait analysis. Also, we are planning to compare healthy and stroke patients' data where the pairs are closely comparable based on weight, height, age, and gender.

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