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Foot Neuropathy Analyzer and Blood Flow Stimulator Embedded in Smart Motion Sensing Shoes Designed for Diabetic Patients

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Abstract: Diabetes is one of the important reasons for illness and premature death worldwide. Diabetes causes neurovascular complications, due to this it can increases high pressure areas in the feet and hands. Diabetic neuropathy causes nerve damage which can severely lead to amputation or ulceration. Vascular and neural diseases are closely related and intertwined. Blood vessels depends on normal nerve function as well as nerves depend on adequate blood flow. A person with diabetic neural dysfunction can also have Microvascular dysfunction and it is a complex one. As a remedy, sending imperceptible vibrations through the feet of diabetics and neuropathy patients significantly improves the damaged nerves and stimulates blood flow. Although equipment to measure foot pressure distribution is available in all places, these are still not readily accessible for huge segment of the population, are too expensive to own and are too bulky to be portable. The foot pressure monitors are not readily available in some poorly developed countries which are home to many communities with a high prevalence of diabetes. The goal of this paper is to design and build a low-cost foot neuropathy analyzer and blood flow stimulator system, embedded within smart footwear which a patient can wear at any place to monitor his or her foot pressure distribution.

Key words: Microvascular · Neural Dysfunction · Vascular and neural diseases · Pressure distribution

INTRODUCTION

Foot Neuropathy is a serious neurodegenerative disease requiring close monitoring and regular evaluation. It affects a large group of population [1]. It is estimated that worldwide 4 million people are living with Foot Neuropathy. The disease affects a part of the brain called as [2] "Substani Nigra". Substani Nigra is the part which controls movement in the body. Essentially there is a lack of Neurotransmitter in the brain when Foot Neuropathy is present. It is a progressive disease that affects people over 50 years of age however younger people can also be diagnosed with this disease [3]. There are a number of features associated with the disease making diagnosis difficult. Persons with diabetes may require frequent and time consuming visits to specialist medical centeres for assessment and eveluation.

The untidiness is intolorable [4], but treatments can be very helpful [5]. The most important thing to find whether foot neuropathy is the result of a significant underlying condition. Foot neuropathy is a disorder that occurs when these nerves crash because they're damaged or spoiled. This disrupts the nerves' normal functioning. They might pass signals of pain when there's no pain, or they might not send a signal of pain even if something is harming you. Nerve damage caused by diabetes is one of the most important forms of neuropathy. This leads to numbness [6], pain and a loss of sensation in the extremities. The danger of neuropathy increases for people who are overweight, high blood pressure, over the age of 40. Home based monitoring of PD is a laudable aim that has the potential to reduce the necessity to attend frequent deliberation with specialist personnel in addition to offering potentially more precise and

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continuous monitoring paradigms sensitively assessing disease continuation and medication effects. The Timed Up and Go (TUG) test is a mostly used medical test to assess balance, mobility and fall risk in the elderly and in patients with Parkinson's disease (PD). The Timed Up and Go test (TUG) is a simple form of test used to assess a patient's mobility function and requires both static and dynamic balance [7]. The test is Electromyography. Electromyography can show problems with how the body's nerve signals move to your muscles. For this test, the doctor will place a small needle into muscle. Then doctor will move your muscle slowly. Probes will measure the amount of electricity moving through your muscle [8]. This test may feel like receiving a shot in the body. Sometimes the area becomes sore for a few days afterward.

Block Diagram: The foot neuropathy analyzer consists two units named foot wear unit and handheld unit. The block diagram for the foot wear unit is shown in the Figure 1. The footwear unit consists accelerometer and flexi force sensors.

Accelerometer is used to monitor the force applied by the patients. Flexi force sensors are used to measure the pressure distribution in foot [9]. The pressure distribution under the foot of the patients is given as input to inertial sensors which includes accelerometer gyroscope measures the pressure sensor outputs and transmits the information by using IEEE 802.15.4 wireless transceiver to the handheld monitoring unit.

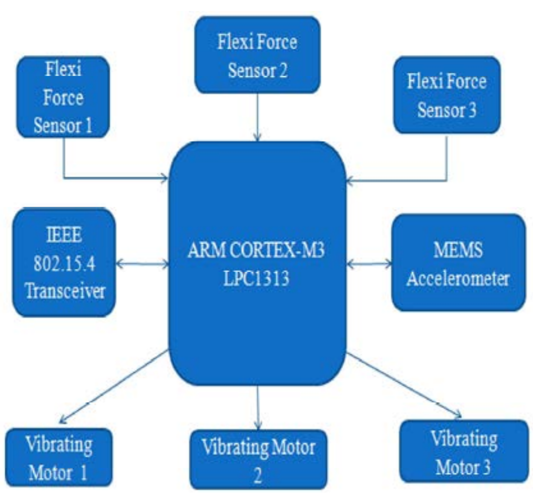

Fig. 1: Block Diagram of Foot Wear Unit

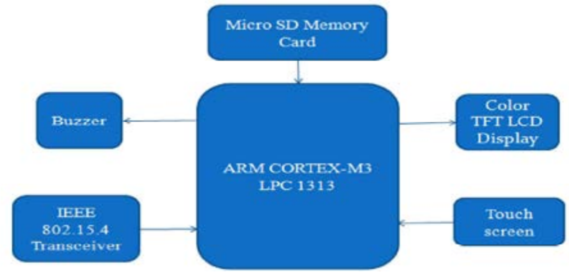

Fig. 2: Block Diagram Of Hand Held Unit

The block diagram of the handheld unit is shown in Figure 2. The monitoring device is equipped with a 65K Color Touch screen TFT Display that receives the wireless data and displays the foot pressure distribution on color bar graph and also stores that data in the memory card.Both the footwear unit and the handheld [10] display unit use LPC1313. LPC1313 is a 32-bit ARM Cortex-M3 Microcontroller. The microcontroller runs the application software and the device driver firmware and also runs software such as a Graphics Library, a FAT-32 File System and an IEEE 802.15.4 Wireless Networking Protocol Stack.

Hardware Description

Arm Cortex: The LPC1313 is ARM Cortex-M3 based microcontrollers are used for embedded applications featuring a high level of amalgamation and low power consumption. The ARM Cortex-M3 is a next generation core that offers system intensification such as enhanced debug attributes and a higher level of support block integration. The LPC1313 operates of up to 72 MHz CPU frequencies, the ARM Cortex-M3 CPU have a 3-stage pipeline and uses Harvard architecture with separate local instruction buses and data buses and also a third bus for peripherals. The ARM Cortex-M3 CPU has an internal pre-fetch unit.This unit will supports speculative branching. The peripheral complement of the LPC1313 includes flash memory up to 32kB, data memory up to 8 kB, one Fast-mode I2C-bus interface, UART, four general purpose timers and up to 42 GPIO pins.

Flexi Force Sensor: Flexi Force load sensors are used to measure the force applied by the patients under the foot. The force measurement systems provide a low cost solutions and OEM tools for an economical solution to the force sensing needs. Flexi Force sensors are adaptable, user-friendly solution for test and measurement, because they can be used with the existing electronics, such as a calibre multi meter, or with an ELF system, which includes data acquisition electronics and software.

Motor Driver: The motor driver is used to regulate the blood circulation.The L293D is designed to provide bidirectional drive currents of up to 600-mA and the voltage range is from 4.5 V to 36 V.These devices are designed to drive inductive loads such as relays, dc and bipolar stepping motors and also other high-current or high-voltage loads in positive-supply applications. When an enable input is high, the corresponding drivers are enabled and their outputs are in phase and active with their inputs.

When the particular input is low, those drivers are disabled and their outputs are off and in the high-impedance state. With the desired data inputs, each pair of drivers configures a full- bridge reversible drive suitable for solenoid and motor applications. The L293D is assembled in a 16 lead plastic package which has 4 center pins connected jointly together and used for heat sinking. The L293DD is arranged in a 20 lead surface mount which has 8 center pins connected jointly together and used for heat sinking.

Accelerometer: The LIS302DL is a radical compact low-power three axes linear accelerometer. It includes a sensing element and an IC interface able to provide the acceleration to the external world through I2C/SPI serial interface. The sensing element have the capability to detect the acceleration, is manufactured using a dedicated process developed by ST to produce inertial sensors and actuators in silicon.

SD Card: The Micro SD Memory Card is practically compatible with the SD Memory card but is smaller in sizes. It can be fitted into a passive SD memory Card Adapter and operate as an SD Memory Card. TwinMOS Micro SD Card TM is supreme for some digital devices designed to use Micro SD Card. It is fully convenient to a new consumer standard, called the Micro SD system standard and have SDC Physical Layer specification V1.10 and provides error correcting code reliability to detect and correct errors automatically.

Software Description: The software tool which is used for the arm cortex M3 is LPCXpresso. LPCXpresso is a new, low-cost development platform which is available from NXP. This software consists of Eclipse-based IDE, a GNU C compiler, linker, libraries and an enhanced GDB debugger. The hardware unit has the LPCXpresso development board which has an LPC-Link debug interface and an NXP LPC ARM-based microcontroller target. LPCXpresso is an end-to-end solution to develop the applications from initial evaluation to final production. LPCXpresso's IDE is a highly integrated software development environment for NXP's LPC Microcontrollers having all the necessary tools which are necessary to develop high quality software solutions in a timely and cost effective fashion.

Proposed Work: The main idea of this proposal is to design and build a low cost foot pressure analysis and blood flow simulation system, embedded within smart footwear.The main use of this footwear is that the patient can wear at any place to monitor their foot pressure distribution. To improve the blood flow circulation the smart footwear has a set of small-scale vibrating motors that restorative the nerves by vibrating in different amplitude that can be configured separately started and stopped by the user.

The microcontroller used for pressure detection and handheld system is ARM CORTEX M3. The foot unit consists of ARM microcontroller, transceiver, flexi force sensors, accelerometer and vibrating motors. The flexi force sensor outputs are connected to Analog to Didital Converter pins of the microcontroller to convert the analog pressure data values into digital data values. The motor driver used to spin the vibrating motors.

The hand held unit consists of SD card, ARM microcontroller, Touch screen unit, LCD display and transceiver. The data pins of the LCD display unit are connected to the microcontroller. The Buzzer which is used to indicate the injury detection is connected to ADC pin. MIWI transceiver is connected to data pin of microcontroller. The touch screen controller consists of serial clock, serial data in and serial data out that are used to communicate with external peripheral units. In this system, the foot pressure distribution of the patients is measured by a set of flexi force pressure sensors located on the inner sole of the shoe. These sensors are based on force-sensing resistors so resistance varies inversely with the applied pressure force. The footwear unit measures the pressure sensor outputs and transmits the information using wireless transceiver to the handheld device.

RESULT AND DISCUSSIONS

This chapter deals with the various experimental results that are obtained by implementing the foot neuropathy analyzer and blood flow stimulated systems. The ARM Cortex Microcontroller monitors the foot pressure values using flexi force sensors and stores the values in the SD card for future references or analysis by the doctor. The measured values are transmitted to the handheld device using wireless transceiver. If there is any difference in the pressure distribution the buzzer will be ON. The user can also select and rotate the particular motor driver to stimulate the blood flow.

The flexi force sensor A is connected to analog channel AN0 and the flexi force sensors B and C is connected to analog channel AN1 and AN2.The flexi force sensors are denoted by FSR1,FSR2 and FSR3.L293D is the motor driver used to spin the vibrating motor. The speed of the vibrating motor is displayed in a bar graph and the speed will be adjusted by the user. Since there is a difference in average pressure value of these three FSR sensors then the vibrating motor starts to rotate which is driven by patients.

The foot unit consists of pressure sensors, 3 axis MEMS accelerometer, vibrating motors, wireless transceiver and ARM microcontroller. Figure 3 shows the hardware of handheld unit. The hand held unit consists of LPC1313 microcontroller, touch screen unit, LCD display unit and MIWI transceiver.

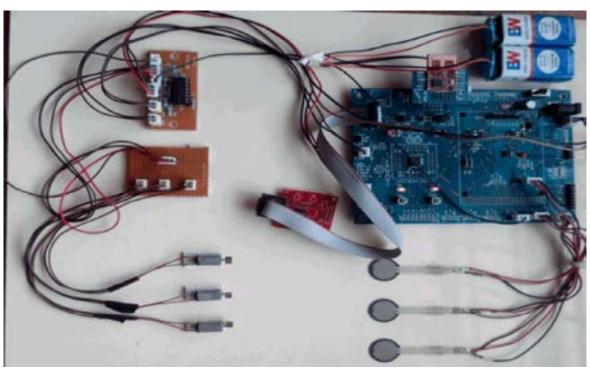

Fig. 3: Foot Wear Unit

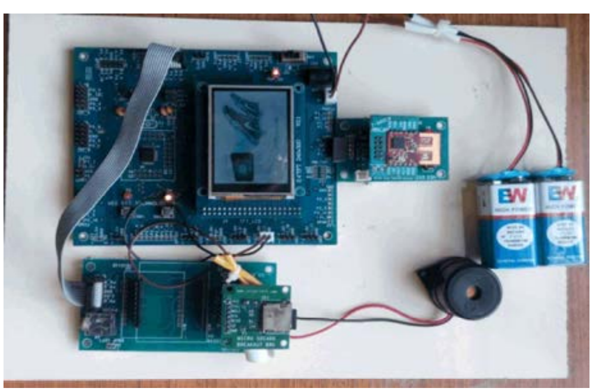

Fig. 4: Hand Held Unit

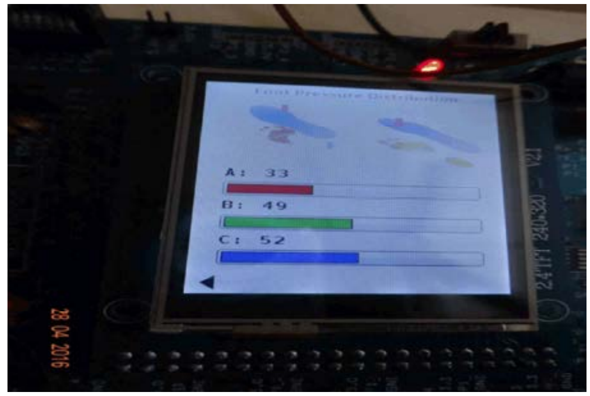

Fig. 5: Pressure Values Storage

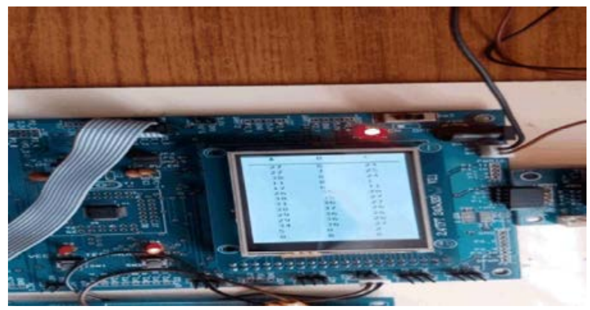

Fig. 6: Mode To List the Pressure Values

Fig. 7: Bar Graph Result

Mode Selection: Initially we have to give power supply to both the hand held unit and foot wear unit. In the hand held unit shows two modes called DATA LOGGER and Vibrating Motor. If want to know the pressure distribution under the foot then enter into the data logger mode.

Inside the data logger it has another two modes named START_RECORD and VIEW_RESULT. First enter into the START RECORD mode to store the pressure values given by the user.

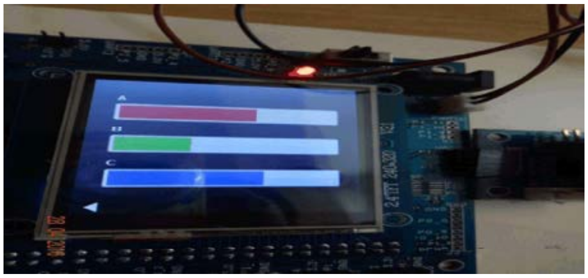

Fig. 8: Vibrating Motor Speed Variation

Depending upon the pressure values the bar graph display will be varied.The results are viewed by using two modes BAR GRAPH and LISTING modes. This Phase consists another two modes named LISTING and BAR_GRAPH.In the LISTING mode the recorded pressure sensor values are listed. The pressure values are started to record once given the power supply. It shows the three pressure sensors named A, B and C values. The BAR_GRAPH mode shows the average and maximum pressure values.

Vibrating Motor: If there is any anomaly in the pressure distribution then the patients enter into the vibrating motor mode. There are three vibrating motors are used to stimulate the blood flow. The user can vary the speed of the motor. Depending upon the speed given by the user the motor start to rotates. The rotating motors stimulate the blood flow.

CONCLUSION AND FUTURE WORK

This paper discussed about the identification of foot neuropathy disorder as early as possible in a home based environment. Flexi force pressure sensors are used to measure the pressure in patient's foot and if any difference is detected in the foot pressure distribution it is displayed on the users hand held device. The user can stimulate the blood flow by rotating vibrating motors. In future the system enhanced to automatically rotate the motor when if there is any anomaly is detected in pressure values and sending messages to the doctor for analysis.

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