Foot Pressure Mapping System Using Strain Gauge Pressure Sensors

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Abstract- The pressure measurement of the interface between the shoe soles and foot is an important aspect in analysis of gait and many other health diagnoses. The abnormal pressure may indicate health related complications like instability in gait pattern, postural distortions, risks of ulcers development or callus formation especially in diabetic foot as well as have many other biomedical analytical applications. Only the proper orthotics can be made to redistribute the pressure evenly on the foot. In this study, strain gauge pressure sensors (sensing device) are integrated on the insole of footwear which indicates the pressure exerted by its corresponding value of output voltage. The system consists of 8 tiny strain gauge sensor elements. The voltage is then amplified by the amplifier unit. The data from the amplifier section is then sent to data acquisition section. Lab VIEW software is then employed for processing the data for normalization and representation in computer. The system software indicates the strain in every small sensor element of the insole in actual time and then saves that data to a file. The system is easy to use, accurate and inexpensive. This project helps in the monitoring of the pressure distribution underneath the foot to obtain the knowledge of the functioning of normal and abnormal feet in numerous situations, such as, if the subject is standing, walking or running etc. It also helps the doctors to relate the distribution of pressure to the affected person's medical conditions and therefore, special shoes for patients with leprosy or diabetics will be designed.

Keywords- **Plantar pressure, strain gauge pressure sensors, gait analysis.**

1. INTRODUCTION

The feet are the basis of the human frame and it provides balance to the body while standing, running and walking. The important parameters related to plantar pressure are the foot structure, posture control and proper functioning of the foot. The main functions of the foot is to provides support for the body, to adapt to uneven ground, to act as shock absorber for the body during gait, to absorb transverse leg rotation and to provide leverage for propulsion [1]. Measurement of human foot pressure distribution is helpful in diagnosing improper functioning of foot [2]. Patients with diabetes mellitus are more prone to foot problems due to pedal plantar fat pad and muscular atrophy, peripheral neuropathy and vascular insufficiency. More than 1/2 of the lower limb amputation is executed on diabetic sufferers because ankle and foot injuries fail to be healed and the sequences of events leading to amputation are initiated by ulceration of skin and loss of sensation [4]. The interface pressure between plantar surface of and insole of the shoes is an important parameter frequently measured during gait analysis. Abnormal pressure may indicate gait instability, risks of ulceration development and many other biomedical diagnostic applications. Therefore, accurate analysis of distribution of plantar pressure laid the foundation for the characterizing of individual's walking strategies and it additionally provides important information for modeling the dynamic equilibrium of the body [8].

Because of the reasons stated above, different plantar pressure distribution techniques have been developed. The high pressure zones are heel, metatarsal head 1, metatarsal head 3, metatarsal head 5 and the toe [10]. The mean pressure values are observed to be as 305±25 K Pa at heel, 257±25 K Pa at 1st MTH, 270±23 K Pa at 3rdMTH, 75±17 K Pa at arch and 235±24.5 K Pa at toe [3].

The load distribution beneath the foot may be calculated both with the aid of making the subject walk over the stress sensitive surface/place or by placing a skinny transducer among the foot and the insole of shoes [6]. The pressure distribution monitoring under the foot is carried out to obtain the knowledge of functioning of normal and abnormal feet in diverse conditions like if the subject is in the standing position, is walking or running etc. It can also be used to calculate and manipulate aid by determining the particular regions underneath the foot which can be prone to ulcer development that is a form of diabetic neuropathy, and also in arthritis detection. Moreover, it will also help any person to correct his/her abnormalities in the gait [5].

2. MEASUREMENT SYSTEM

The measurement system consists of an insole sensor, amplifier electronics, data acquisition system and real time software for data evaluation on PC[9].

The requirements of the system are defined based on the chiropody applications. The important part of the system design is the sensor selection. Excitation and/or signal conditioning circuits are almost always needed to interface the device and supply adjustable standardization, amplification, linearization, and degree transformation capabilities. Although there are numerous differing types with different technologies of pressure sensors are available but strain gauge pressure sensors are utilized in this project.

Compared to other types of pressure sensors, strain gauges are relatively inexpensive, highly sensitive, have small physical size and mass, better accuracy and are moderately affected by temperature changes.

3. SYSTEM BLOCK DIAGRAM

The system block diagram is shown in Figure 1.

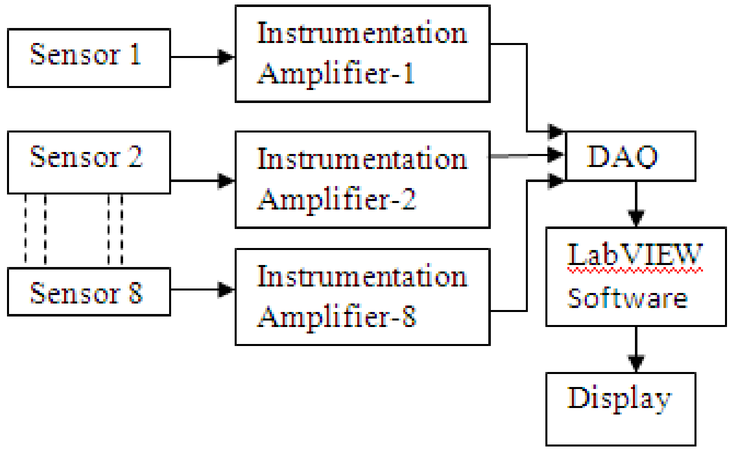


Figure 1: Block Diagram

A. SENSORS

The sensor selection and its characterization is the most essential part of system design. Once the number of sensors which are to be placed on the insole of shoes and their location is finalized, the development of shoe can begin. Eight pressure points (toe, fingers, metatarsal head1 (MTH1), metatarsal head2 (MTH2), the lateral arch of foot, heel1, heel2, heel3) have been chosen for the current work. Each strain gauge sensors are placed on these pressure points of the insole. For installing the sensors, surface of the insole must be properly cleaned and made uneven by using emery paper. It is then marked with a fine pencil at the pressure points where strain is to be measured. The sensor wire is then soldered with the silk wire and finally the sensor is pasted using 'anabond' on the marked area. Because of the various advantages strain gauge sensors offers, it is selected. These sensors are very thin, hence, it doesn't cause any discomfort to the patient. Also, it doesn't develop any additional pressure due to the bulging at the sensor site. A strain gauge is a sensing element whose resistance varies with applied pressure; it converts force, stress, anxiety, weight, and many others, into a change in electric resistance which would possible then be measured.

Figure 2 shows the strain gauge sensors embedded on the insole of foot that was utilized for this work.

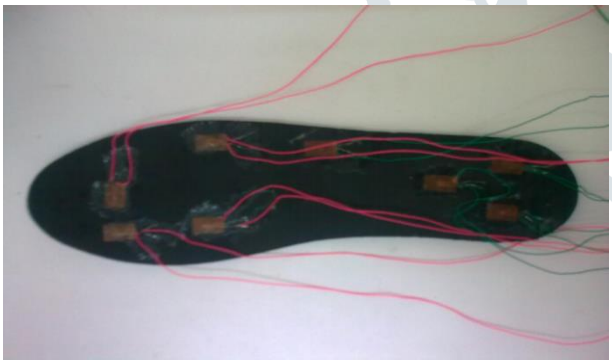
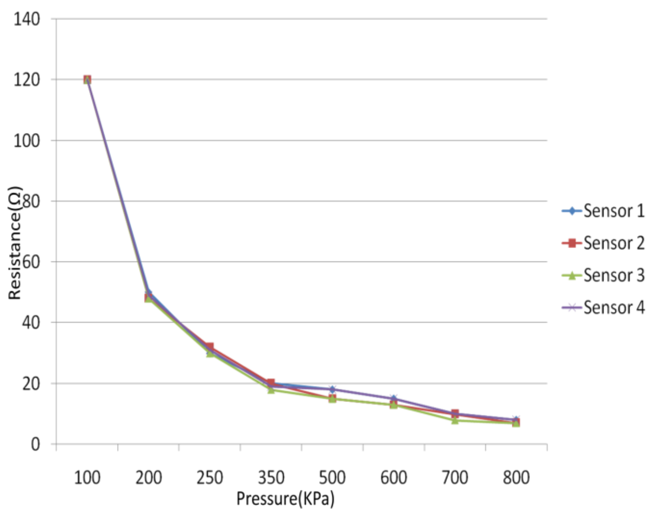


Figure: 2

B. SENSOR CONDITIONING

Each sensing tool is needed to be conditioned earlier than standardization and testing so as to deliver accurate effects. This is often done by applying a hundred and twenty of a check weight inside the range for a few instances and letting the device stabilize. Moreover, the interface (foam plates that protects the devices from sheer force effect) between the sensor and test subject material used was same throughout conditioning as during standardization and actual trying out [7]. The resistance exchange with relation to carried out force is shown in graph 1.



Graph: 1 Response of sensors with relation to applied pressure

C. SENSOR CALIBRATION

To calibrate the sensors, a load that is about the implemented load throughout testing and system use was applied equally, and consequently, the output is recorded 5 times for 5 absolutely unique forces or weights. However, since it was needed to acquire a linear relationship between the implemented pressure and the output voltage, the sensitivity become modified every time to get this linearity and therefore, the above method was repeated for every sensitivity value, or the feedback resistor value, until a detailed approximation of linearity was obtained. The same is repeated for every device on an individual basis.

4. SIGNAL CONDITIONING

A. WHEATSTONE BRIDGE CIRCUIT

Due to their outstanding sensitivity, Wheatstone bridge circuits are very advantageous for the measuring of resistance, inductance and capacitance. These are wide used for strain measurements. This circuit is employed as a pick up circuit and output is detected by a separate amplifier. Wheatstone bridge circuit was initially balanced with all resistances equal. In reality, this is often not the case due of inherent irregularities between even the most accurate of strain gauges or dummy resistances. As a result, the bridge output voltage, e, is not zero but rather may additionally show a preliminary unbalance. In strain gauge bridges, a much larger resistance may be added in parallel with an arm to lesser its effective resistance and consequently to balance the bridge.

B. INSTRUMENTATION AMPLIFIER (INA122)

After obtaining micro volts from the bridge circuit the signal is fed into instrumentation amplifier (INA122) to amplify the signal strength. Each sensor has its separate amplifier and therefore eight amplifiers are used in the system.

C. DATA ACQUISITION SYSTEM

Data from the sensors is sent to a signal conditioner integrated circuit for compensation and amplification. The outcomes are then sent to DAQ card that has an Analog to digital converter to digitalize the analog voltage information received from the sensors. These data are then interfaced to the computer through the USB interface of the DAQ card. Additionally, an easy to use software program was established in LABview to read the procured data from the DAQ card, perform the specified computations and averaging, and after that give a graphical illustration of the manipulated data for an improved understanding of where a large portion of the weight is applied on the foot.

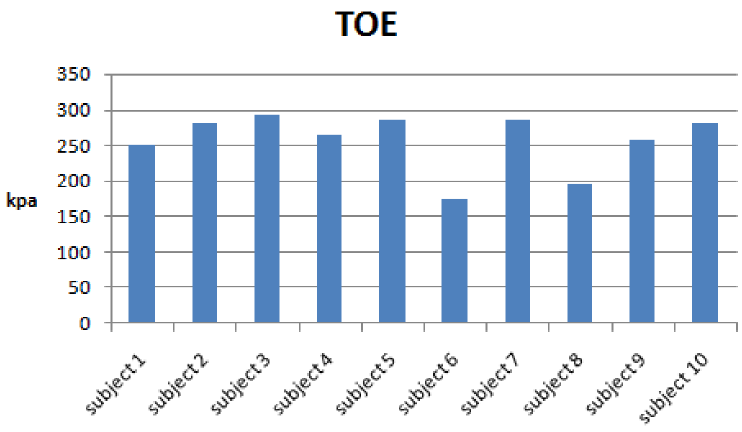
5. SOFTWARE DESIGN

A. REAL-TIME READING OF SENSORS

Every sensor’s yield is associated to an analog input channel inside the DAQ card that exchanges the information to the PC. Utilizing LabVIEW, each sensor’s circuit yield is read continuously at a sampling rate of five hundred samples for every second.

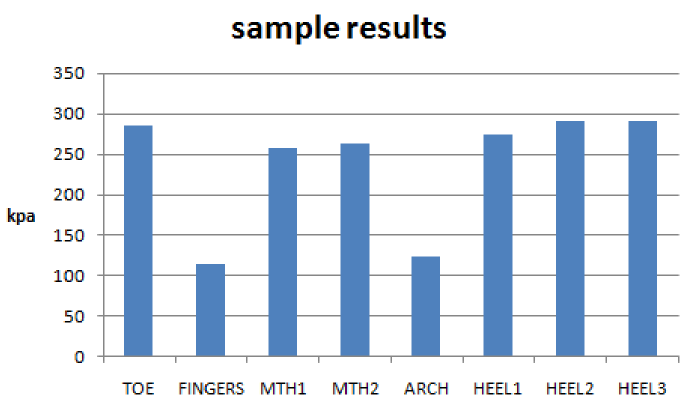
B. RESULTS

Readings were observed from 10 numbers of subjects and the insole foot pressure was analyzed. The graph 2 shows the toe pressure of 10 subjects. Similarly, the pressure was mapped for all the other 7 pressure points discussed above.



Graph 2 – The toe pressure of 10 subjects

Graph 3shows that there is comparatively high pressure recorded on the heel followed by toe and metatarsal respectively, on an average. The rest of the pressure points in the foot have been recorded for comparatively low pressure.



Graph 3 shows the sample results

6. APPLICATIONS AND FUTURE WORK

This system is ideal for measuring plantar pressure distribution. It could be used as a cost effective alternative by doctors to diagnose various pressure related problems and prescribe the orthotic insole that is custom made for each patient based on his/her needs and requirements. In future work, we can make this system portable for accurate measurement of plantar force distribution in course of dynamic activities.

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