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Podiatric Gait Analysis and Posture Correction using Embedded Systems

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Abstract: Every day, an average individual takes thousands of steps, placing extremely significant pressure on their feet. Many biomechanical issues arise as a result, which have terrible consequences. As a result, it's important to keep an eye on foot pressure and appropriately manage these conditions. Yet, everyone has varied and distinctive walking styles. In this project, we show a flexible and universal in-shoe sensor that can record data as you walk in real-time. The resulting clear and understandable graphics will allow the patient and the doctor to view what happens when walking. We created an Android application that is used to display the visuals on the smartphones. It uses technology that is wireless, portable, and user-friendly and also stores data or history for a podiatrist to analyse the patient's stride. The foot strikes will be dynamically shown as a movie, frame by frame, in the user-friendly application. Graphics showing before-and-after comparisons of the therapy can be used by a podiatrist or the subject to assess effectiveness or recommend adjustment.

Keywords: measures, indicates, responds, active and passive sensors, third party applications, analog and digital sensors, posture or movement, heel, toe mounds, inner arch, outer arch and android application interface.

I. INTRODUCTION

A sensor is a device which detects or is sensitive to particular stimulus or sensitive to more than one stimulus (stimuli) and responds to the same by change in its physical, chemical or electromagnetic properties which is further processed by a signal processing unit into a more usable and readable form. A sensor can be used alone or as an array (in an array). An array of sensors is a series of similar or different sensors connected/monitored simultaneously to accomplish a specific task.

A sensor array is deployed in a certain geometric pattern or exposed to the same stimulus to measure different content or element or molecules or chemical/physical properties of that stimulus. In this paper array of force sensors is arranged in a geometric pattern based on the pressure points to be analysed on the surface of the foot bottom of human beings. Each sensors in the array measures the force executed by the foot at a particular point on the surface of the foot bottom (i.e. force per particular area of the foot)[1-3]

Following are the various criteria to choose a sensor

- Accuracy
- Precision
- Repeatability
- Reproducibility
- Stability
- Error
- Noise
- Drift
- Resolution
- Minimum Detectable Signal
- Calibration curve
- Sensitivity
- Linearity
- Selectivity
- Hysteresis
- Measurement range
- Response and recovery time
- Environmental compatibility.

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Each sensor in the array is given a code or numbered and it represents the measurement at a particular region of the foot. Figure1 shows a sensor array interfaced to the Microcontroller or Microprocessor.

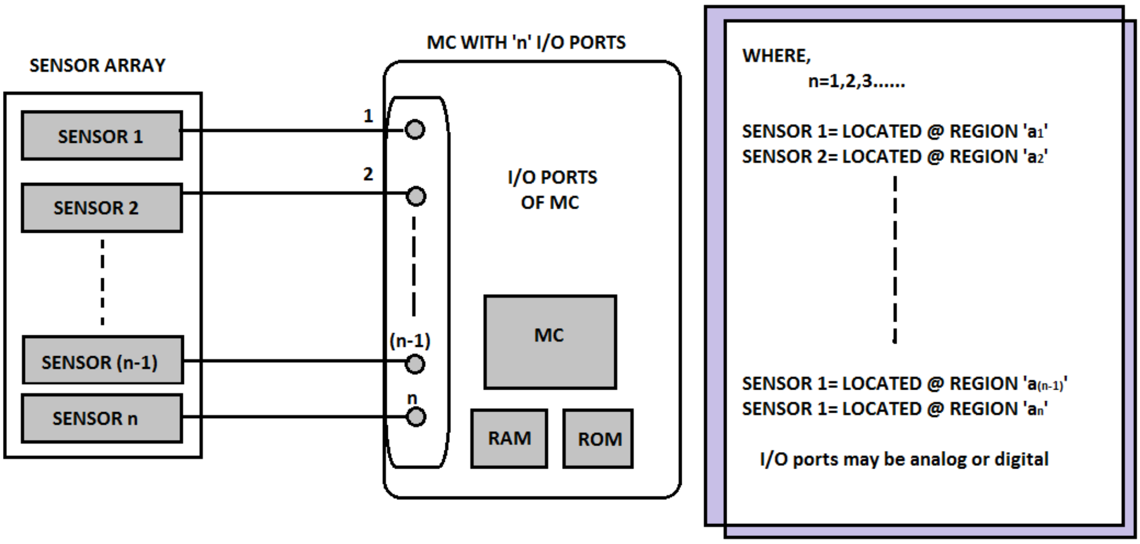

Figure1 shows a sensor array interfaced to the Microcontroller or Microprocessor.

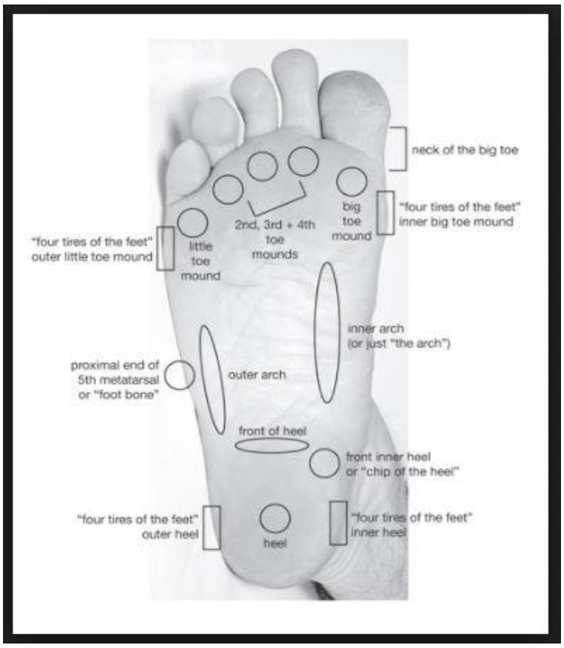

Figure 2 shows the important areas / regions of the human foot bottom.

II. PROBLEM STATEMENT

Sensing Area of the Sensor in which size and placement of the sensor are also critical. As a large sensor may underestimate the peak pressure. Slower loading response on the lateral aspect of the foot during gait. And sometimes patients problems are not identified if the feet is not properly align to the shoe Because of several weight and feet features. Therefore the potential of false positive detecting an effect that is not there. Another important aspect is IMU calibration for estimating distance. The use of the IMU is also associated with other errors including those of stability repeatability and drift etc. Such errors are considered unavoidable especially when using miniature micro-electro-mechanical (MEMS) sensors. Other possible areas of error are from friction with clothes and shoes. [3] To reduce these possible errors we have we validated our system with a gold standard motion capture system.

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III. STRUCTURE OF BOTTOM FOOT

A Human foot has a complex design and is unique for each individual. Following are the important areas / regions of the human foot as shown in figure 2

- Toe region (5 toes)
- Neck of these toe regions
- Toe mounds
- Inner arch
- Outer arch
- Proximal end of the fifth metatarsal or "foot bone"
- Front of heel
- Chip of heel
- Heel
- "Four tiers of the feet"-Inner and outer heel.

Each region experiences different Force/unit area or pressure based on the posture- standing, squatting, heels up, toes up etc... and based on the motion of the body. [5-7]

IV. BLOCK DIAGRAM AND METHODOLOGY

We follow the embedded system life cycle in developing the system, consisting of array of sensors (similar sensors),n I/O pin Microcontroller with a specific RAM and ROM, Bluetooth module for wireless communication and smartphone as the display unit, interpret and recording device. Figure 3 shows the block diagram of our device. In this project we have used three different sized force sensors. Each sensor used has a different area. The three sensors used are [7-8][9-11]

- Force sensor with circular active area and active sensing area of 0.2" [5.0mm] diameter.
- Force sensors with circular active area and active sensing area of 0.5" [12.7mm] diameter.
- Square active sensing area of 1.5" [38.1mm]*1.5"[38.1mm].

Figure 4 and Figure 5 shows the force sensors with circular active area and square active area respectively.

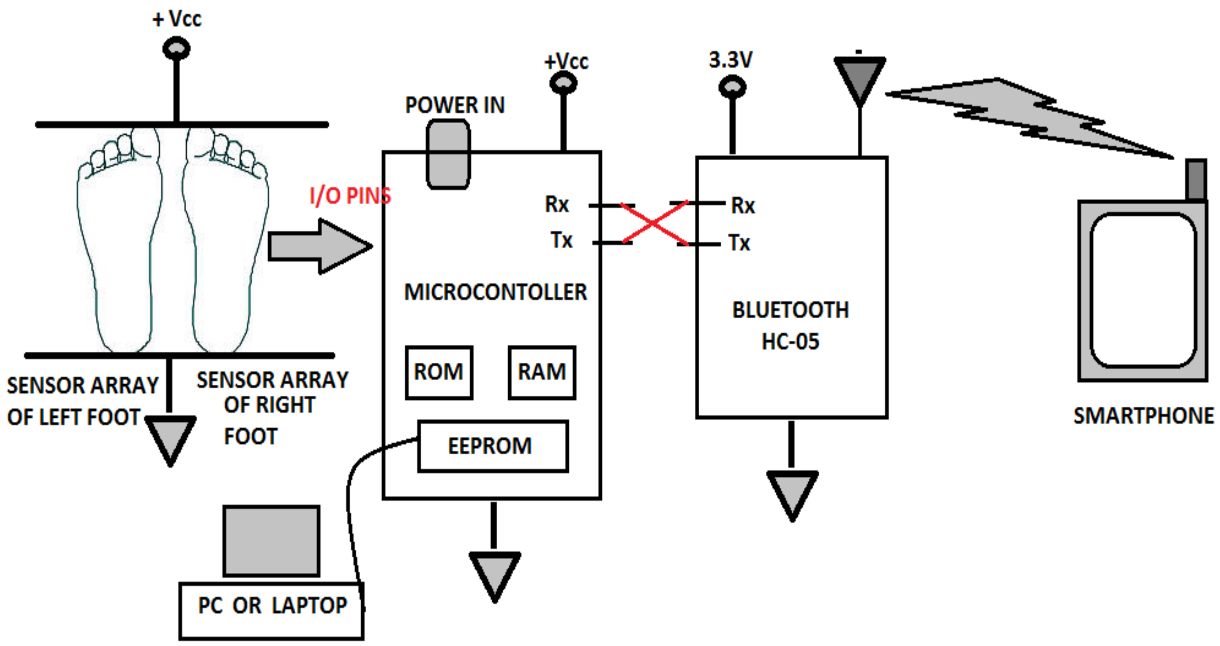

Figure 3 shows the Block diagram

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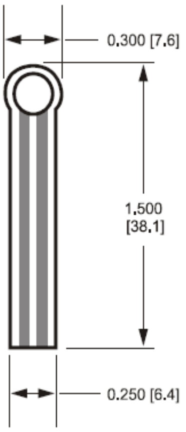
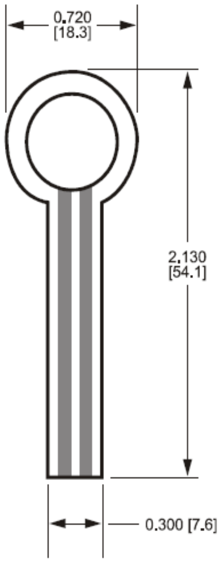


Active Area: 0.2" [5.0] diameter

Nominal Thickness: 0.012" [0.30 mm]

Material Build:

Semiconductive layer
0.004" [0.10] PES
Spacer adhesive
0.002" [0.05] Acrylic
Conductive layer
0.004" [0.10] PES
Rear adhesive
0.002" [0.05] Acrylic
Connector options
a. No connector
b. Solder Tabs (not shown)
c. AMP Female connector



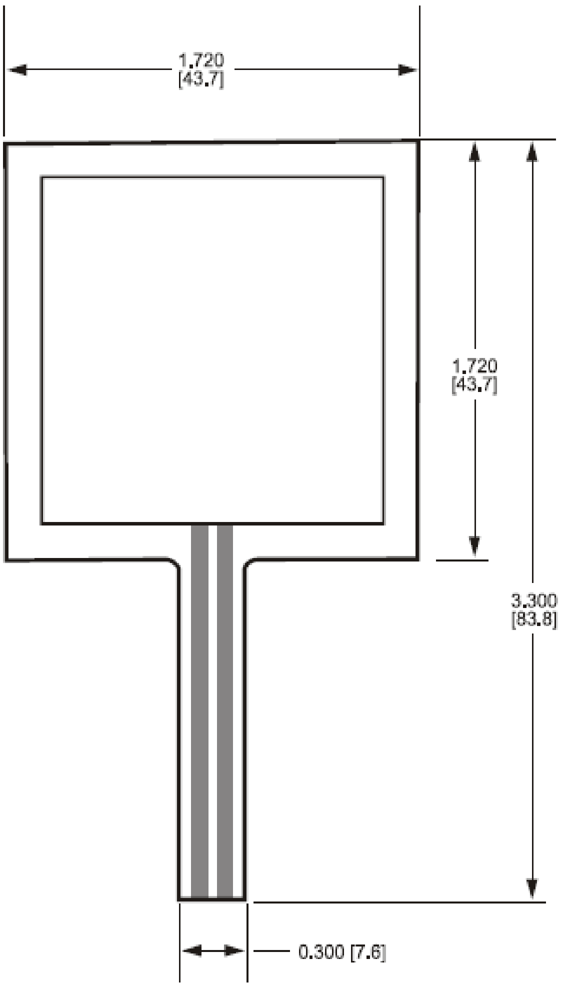
Active Area: 0.5" [12.7] diameter

Nominal thickness: 0.018" [0.46 mm]

Material Build:

Semiconductive Layer
0.005" [0.13] Ultem
Spacer Adhesive
0.006" [0.15] Acrylic
Conductive Layer
0.005" [0.13] Ultem
Rear Adhesive
0.002" [0.05] Acrylic
Connector
a. No connector
b. Solder Tabs (not shown)
c. AMP Female connector

Figure 4 shows the force sensors with circular active area.



Active Area: 1.5" [38.1] x 1.5" [38.1]

Nominal thickness: 0.018" [0.46 mm]

Material Build:

Semiconductive Layer
0.005" [0.13] Ultem
Spacer Adhesive
0.006" [0.15] Acrylic
Conductive Layer
0.005" [0.13] Ultem
Rear Adhesive
0.002" [0.05] Acrylic
Connectors
a. No connector
b. Solder Tabs (not shown)
c. AMP Female connector

Figure 5shows the force sensor with rectangular/square active area.

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V. RESULTS AND FINDINGS

Figure 6, 7, 8 and 9 shows the readings of foot bottom in N/m^2. A graph of N/m^2 v/s time is plotted for different pressure points of the foot bottom. Figure 10 shows our model/ prototype.

Figure 6 shows the pressure at the 'heel'.

Figure 7 shows the pressure at the 'mounds'.

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Figure 8 shows the pressure at the 'outer arch'.

Figure 9 shows the pressure at the 'big toe'.

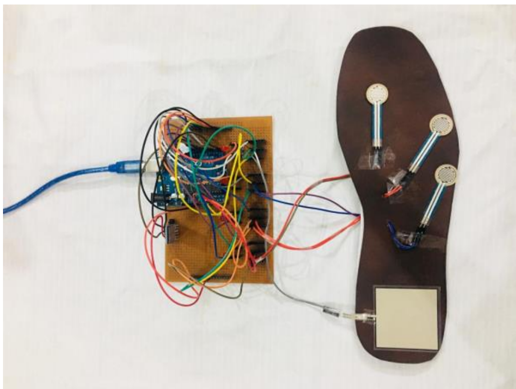

Figure 10 shows our model/ prototype.

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VI. ADVANTAGES

i. Easy to use
ii. Temperature sensitive
iii. Low power consumption
iv. Improves muscle weakness
v. Prevent Gait instability
vi. Balance impaired individuals

VII. APPLICATIONS

i. Diagnosing lower limb and foot problems
ii. Footwear design
iii. Medical tool development
iv. Sports performance analysis
v. Biomedical applications
vi. Risk management and general wellbeing
vii. Sport biomechanics

VIII. CONCLUSIONS

In this system, the insole shoe gives the pressure variation for the patient affected by foot abnormalities, fractures etc. This plantar pressure measurement identifies whether a person is having foot abnormalities or not that will prevent the patient from getting disease. In the system design prevention is taken by the proposed system. The result shows that such a device is reliable and measures the foot pressure distribution to detect abnormalities. Also the size of sensor is very small which is easily mounted on the in-sole.

The system is having limited cabling and it is safe to use for the patient. In this paper Real-time readings from the sensor array was obtained and displayed on the smartphone using the Android Application developed by us. Force/unit area of the foot was measured at various regions- toe, heel, inner and outer arch and foot mound regions. A graph of N/m^2 v/s time was plotted and recorded to the phone SD card. Each pressure point on the foot shows different values because of variations in the force applied per unit area of the foot.

This analysis of differential pressure across the surface of the foot is helpful in the analysis of foot pressure in shoe manufacturing industry, performance analysis of athletes, fitness test of athletes and foot pressure analysis of diabetics to prevent ulcers.

IX. FUTURE SCOPE

Our embedded system prototype can be given AI ability by training the Machine using ML algorithms. By doing so similar diseases of other subjects or patients can be predicted using the ML model designed along with the historical database.

The model in future can be made more robust and less complex by adapting miniaturization techniques. Power consumption can be reduced by about 20% by using insole attached sensors instead of array of sensors.

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