An Optical Method for Determination of Weight Distribution in the Foot

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ABSTRACT

The major technical challenge is to design the individual weight measuring point without using load cell or pressure sensor, since it will increase cost of the equipment. So our system incorporates low cost optical based weight measurement. In addition to this, we measure the severity of loss of sensation in the foot by introducing Vibro-tactile threshold sensation technique. By using this technique, the degree of loss of sensation can be determined for a diabetes patient. Our project has two foot plates in which one is designed with eight LED – LDR set up (sensor unit) and the other a dummy. Depending on the weight of the person, the intensity of light falling on the LDR from the LED varies. The detected signal is given to the ADC. The digital signal is processed by a microcontroller and the output is displayed in computer monitor via serial communication.

Keywords

Optical weight measurement, arch foot, Vibro-tactile setup.

1. INTRODUCTION

Fewer than 2% of people are born with congenital foot abnormalities such as clubfoot, flat feet, pigeon toes (pes adductus), or toe deformities. The number of foot abnormalities that develop during childhood, however, is steadily increasing, and nearly 60% of all adults have some degree of foot problems. Common consequences of foot deformities include pressure sores and unusual calluses on the soles and arches of the feet as well as the toes. Stress-related pain results in limping, which over time can lead to knee and hip problems as well as back pain. The overall objective of this mechanized set-up is to develop the best possible technical results in an automated method. Hence the main aim of this project is to help the podiatrists to diagnose foot abnormalities such as body weight distribution in the foot, nature of the foot and also the possibility for Diabetes Mellitus[1]. The degree of sensation in the foot of diabetic patients can also be examined in user friendly way.

2. EXISTING METHOD

One way to find out the nature of foot is completely subjective. The person has to stand perfectly normal and relaxed and have someone take a look at the arch that forms at the middle part of the foot. Another way to determine the foot type is the wet test. In which the person has to dip the foot in water, shake off the excess water and step on anything that will leave a print of the foot. It can be a sheet of paper, the floor or a piece of colored cardboard. The disadvantages of the existing methods are: completely manual, the foot print will be ruined, if the pressure applied is improper, needs repetitions for accurate results, 100% accuracy cannot be assured and results vary with perception of examiners.

3. PROPOSED METHOD

The person has to stand on the foot plates for examination which comprise of specially designed detector circuit (LED-LDR setup), which detects the changes in intensity of light due to weight applied on it. Thus the weight distributed in the foot, nature of the foot and possibility for Diabetes Mellitus is displayed in the computer. The degree of sensation in the foot of suspected diabetic patients is also determined by Vibro-tactile threshold sensation set-up. The advantages of the proposed method are that it is highly automatic and mechanized from existing manual method, less time consuming and economical, gives quick results with printed patient details, user friendly and doesn't require skilled labor and it is accurate and reliable.

4. DETERMINATION OF WEIGHT DISTRIBUTION

The knowledge about total weight distribution in the human foot opens a new path in the field of podiatry to determine the shape of the foot and other deformities such as pressure sores and unusual calluses on the soles and arches of the feet as well as the toes [2, 3]. The procedures are very easy and uncomplicated to record the static weight distribution underneath the foot. Static weight distribution under the human feet in the erect standing posture is utmost importance to the understanding of foot function in normal and orthopedically handicapped persons. Designing of foot wears exclusively for diabetic patients is based on the weight distribution in various points of the foot.

The entire setup (see Figure 1) for measurement of weight distribution in the foot comprises of three units - sensor unit, processing unit and display unit. Lab VIEW is used for display purpose.

4.1 Sensor Unit

The foot plate comprises of 8 sets of sensing units. The working of sensor is optical based, in which each unit has a detector circuit. Each detector circuit consists of one LED-LDR set-up[4]. According to the weight applied by the person on the foot plate, the amount of light falling on the LDR from the LED varies, as a result resistance of the LDR changes. The change in resistance can converted to voltage signal and then it is given to an ADC.

4.2 Sensor Design

The LED and LDR are placed opposite to each other. Resistance of the LDR increases as the intensity of light

falling on it decreases and vice versa. The LDR circuit has a constant resistor connected in series with a variable resistor which is nothing but LDR. The output is taken across the LDR and is given to the pin-4 of ADC0809. We use 8 sets of LED-LDR combinations. So the resistance of 8 LDRs changes according to the weight applied by the patient over the platform. This change in resistances is converted to a proportional analog voltage. The 8 analog voltage inputs are given to the 8 channel analog to digital converter (ADC0809).In order to make the setup cost effective one of the output channels from the ADC0809 is connected to the change over switch. Depending upon the closing and opening of the switch either the weight measurement setup or Vibro-tactile threshold sensitivity measurement setup will get enabled. When the weight measurement module is enabled by the switch the weight distributed in the 8 regions [7] of the left foot will be displayed on the computer monitor. If the Vibro-tactile setup is enabled the voltage value at which the patient can able to sense will be displayed in the LCD.

4.3 Processing and Display Unit

The 8 digital signals from the ADC is fed to the microcontroller (ATMEL 89S51) for processing and it is sent to the computer via serial communication. The 8 individual weight values, weight distribution in each foot and nature of foot (flat, normal, and high- arched foot) are displayed in the computer using Lab VIEW along with patient's details. If the patient is suffering from Diabetes Mellitus the pressure distribution in the foot will be abnormal especially in the metatarsal regions. In such patients Vibro-tactile threshold sensitivity measurements are conducted.

4.4 Vibro-Tactile Set-Up

This set up gives details about the degree of sensation in the foot of the patients. This is useful for the confirmation of diabetes mellitus if the patient is showing increased weight distribution in the fore foot. An astable multivibrator with a 555 Timer is used for getting continuous signals of varying frequency reference voltage of 9V is supplied to the timer and by varying RC value (time constant) the frequency of the output signals are adjusted. The output of the 555 Timer is a square wave (pin-3) and is given to the 6V relay via NPN transistor 6V AC supply is also given to the relay. A magnetic field is produced inside the relay. As a result the needle attached to it starts to vibrate. Here the electrical energy is converted into mechanical energy (vibrations). The circuit is designed in such a way to get 2 vibrations in one second [5, 6]. The circuit diagram of Vibro- tactile set-up is shown in Figure 2.

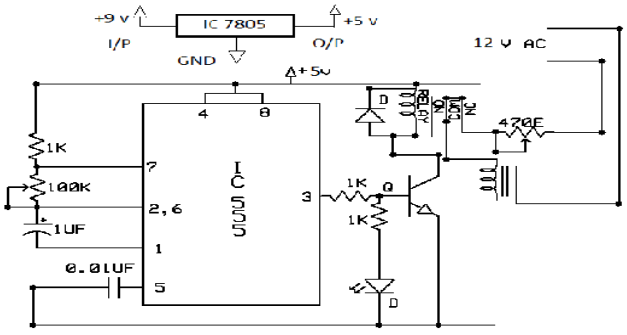

Fig 2: Circuit diagram of Vibrotactile

5. STEPS FOR MEASUREMENT

The patient details are entered into the computer.

The total body weight of the person is taken using a flat type weighing machine and entered in to the computer.

The patient is instructed to stand straight on the foot plates.

The results are monitored.

The LED corresponding to the chance for diabetes mellitus in the display is cross checked.

If the LED is ON, the patient is asked to undergo sensation measurement.

By varying the potentiometer, the ability to sense the vibration of the needle in the foot of the patient is checked.

If the LED is OFF, the patient can get down from the foot plates.

The printed results can be obtained.

6. HIGHLIGHTS

The nature of foot (flat foot or arch foot) can be determined.

Unbalanced weight of the body and abnormal weight distribution in 8 points of the foot can be obtained individually.

It can provide clear ideas to the foot wear designers.

Contribution to patient oriented treatment plan that includes orthotics and other orthopedic appliances. Degree of loss of sensitivity in the foot of diabetes patients can be observed.

7. RESULTS

The result of the examination of the foot is displayed in the computer using Lab VIEW. The foot plate comprises of 8 LED-LDR set-ups. According to the weight applied on the foot pate the amount of light intensity received by the LDR varies and the results are displayed in the computer monitor. The weight distribution in the 8 points of the foot is displayed as digits. The weight applied by the left foot is displayed as the sum of the above mentioned 8 weight values. The weight applied by the right foot is also displayed by subtracting the left foot value from the total weight of the person. The color coding is done to indicate any abnormalities in the weight distribution. If the weight distribution in the foot is normal green color is displayed in the fore foot, mid foot and the hind foot region. Red color is indicated if there is any abnormal increase in weight distribution is shown in any region of the foot. Yellow color is indicated if there is a corresponding decrease in weight values. The indicator corresponding to the flat foot goes high, whenever the mid foot region is red in color. The high-arched foot indicator goes high, whenever the fore foot and the hind foot regions are displayed in red color. If the above mentioned conditions are not satisfied then the indicator corresponding to the normal foot goes high. Even if the foot is indicated as normal there is a chance for displaying only the fore foot as red in color. In such conditions the indicator corresponding to the chance for diabetes goes high. For such patients sensitivity testing is done for the confirmation of Diabetes Mellitus [8]. Results of case studies are shown below from Figure 3 to Figure 7.

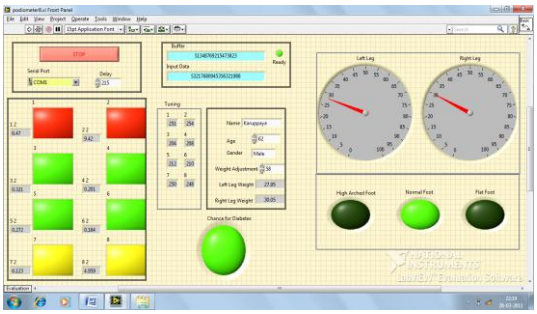

Fig 3: Front panel display in Lab VIEW

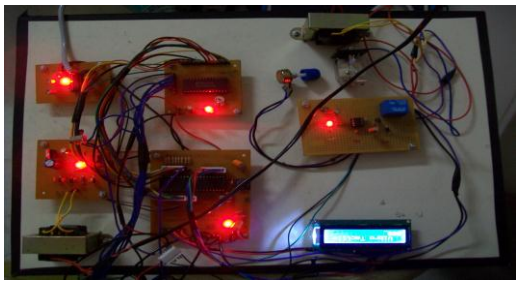

Fig 4: Hardware setup

Fig 5: Patient standing on the Foot Plate

Fig 6: Sensitivity testing in metatarsal region using Vibro-tactile setup

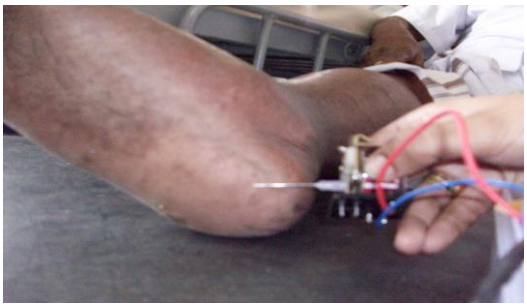

Fig 7: Sensitivity testing in tarsal region using Vibro-tactile Setup

8. DISCUSSION

In all the 7 subjects it was found that the weight distribution is more in the right foot. Chance for diabetes was high for 4 diabetic patients Out of 5, and it was found from the medical records that 5 are suffering from severe peripheral neuropathy. Degree of sensation was checked for all the 4 diabetic patients, the 3rd neuropathic patient lack their sensation ability almost completely in their metatarsal region. The 4th diabetic patient, who was not suffering from neuropathy, was able to sense the vibration at the minimum level itself in the metatarsal region. Out of 7 subjects, it was found that two of them have flat foot and the rest have normal foot. The severe peripheral neuropathic patients have a loss of sensation in their metatarsal region and the heel region. In those patients, sores and ulcers were found. Details are shown in **Table 1.**

9. CONCLUSION

Determination of weight distribution in the foot plays a vital role in the field of podiatry. But in today's world where new technology and equipments are developed overnight, the current system will become obsolete unless these new developments are incorporated into it. The currently available method is completely manual. Our method offers a completely mechanized and a reliable system of determination of weight distribution in the foot. It aims at the determination of results in very short duration in very cost effective manner.

Hopefully, the idea in this work will serve as a useful foundation for the development and the encouragement of future research. Our module is designed to bear a weight of 80 Kg. only. It can be developed to bear more weight (greater than 100 kg). We can increase the number of pressure points to measure the pressure values developed in various parts of the foot. Pressure values in both the foot can be measured. Module can be developed for all foot sizes. Degree of sensation in leprosy patients can also be measured. This project uses electrical power supply which should be connected to the sensors throughout the analysis in order to power the sensors. This can be made wireless by using a battery system. Image processing can be implemented for better visualization of results. Hence the enhancement mentioned above can be implemented in the future, making the system more compact and user friendly.

Table 1. Results of case studies

NAME	AGE	TOTAL WEIGHT (kg)	LEFT FOOT WEIGHT (kg)	LEFT FOOT WEIGHT DISTRIBUTION (kg)								RIGHT FOOT WEIGHT (kg)	TYPE OF FOOT	DIABETES
				1	2	3	4	5	6	7	8			
SUBJECT1	65	55	21.4	4.9	6.3	0.18	0.16	0.18	0.21	4.93	4.52	23.6	Normal	Yes
SUBJECT 2	75	73	34.3	7.3	11.1	0.82	0.64	0.73	1.11	6.12	6.46	38.7	Flat	Yes
SUBJECT 3	63	68	32.7	7.23	9.48	0.56	0.53	0.48	0.62	7.46	6.33	35.3	Flat	Yes
SUBJECT 4	71	61	29.7	5.55	5.73	0.23	0.21	0.24	0.20	6.10	6.36	31.3	Normal	No
SUBJECT 5	65	58	27.9	6.47	9.42	0.32	0.20	0.27	0.18	6.12	4.95	30.1	Normal	Yes
SUBJECT 6	22	70	34.6	5.47	8.36	0.29	0.32	0.37	0.38	10.6	8.63	35.4	Normal	No
SUBJECT 7	21	60	28.7	4.36	6.25	0.26	0.28	0.33	0.26	5.68	7.43	31.3	Normal	No

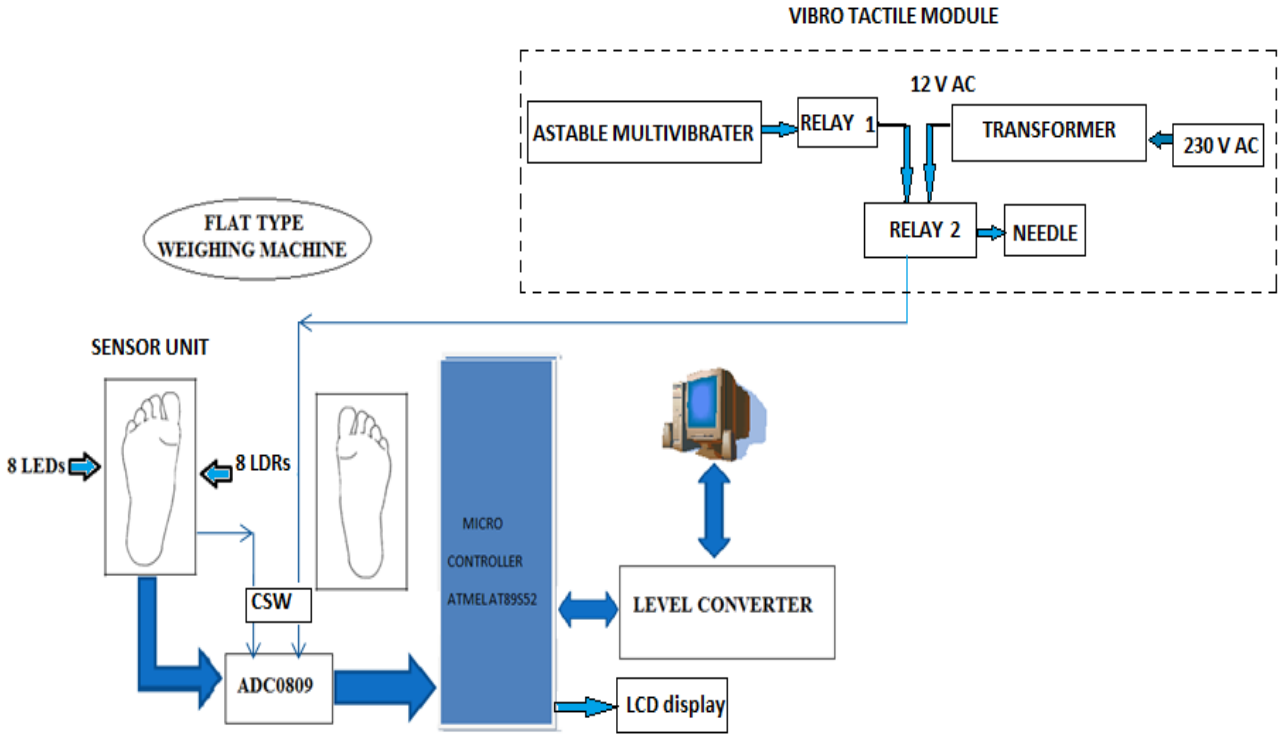

Fig 1: Proposed method of weight distribution measurement

10. REFERENCES

[1] Pecoraro.R.E, Reiber.G.E, Burgess.E.M, "Pathways to Diabetic Limb Amputation, Basis for Prevention, Diabetes Care", 1990; 135(5); 13-21

[2] Kenneth S. Saladin, "Anatomy and Physiology", Georgia College and State University, Mc Graw Hill Publications, 2006

[3] B.D. Chaurasia, ".Human Anatomy, Volume 2, Lower Limb and Abdomen", 3rd edition, CBS Publications, 1998

[4] Tokhein, "Digital Electronics Principles and Applications", 6th edition, Tata Mc GrawHill Publishers, 2000

[5] Hoyd.R.Fortney, "Principles of Electronics Analog and Digital", Duke University, 2006

[6] A. Anand Kumar, "Fundamentals of Digital Circuits", 2003

[7] E. J. Luger, M. Nissan, A. Karpf, E. L. Steinberg, S. Dekel, "Patterns of weight distribution under the metatarsal heads", Journal of Bone and Joint Surgery (Br), Vol, 81-B, No.2, 1999.

[8] Robert Van Deursen, "Mechanical Loading and Off-Loading of the Plantar Surface of the Diabetic Foot", Journal of Clinical Infectious Diseases, Vol.39, Iss.2, pp S87-S91,2004.