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Wearable Body Weight Estimation using FSR

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Abstract – *Introduction* *Body weight estimation is an objective of this paper. It is basic requirement for obese person, diabetic person, pregnant woman, automatic dietary monitoring (ADM) system and health-conscious persons to maintain weight, BMI and much more problems related to weight management. Persons measure body weight by using conventional electronic scale but what if a person can measure body weight anywhere just wearing smart shoes or smart insole for shoe.* ***Methods*** *Hardware system uses Arduino Nano 3.0, HC-05 bluetooth module, IMU sensor MPU-6050, FSR sensors. Block diagram for hardware system design of both shoes. Hardware installed in heel of both shoes.* ***Results*** *Experimentation done on 10 subjects with average of 2.5 kg. error in actual and estimated weight. This system count foot step taken by subjects and calculate calories burned for each step or during walk.*

***Key Words*:** Body weight estimation, Smart insole, IMU sensor MPU-6050, FSR, ADM.

1. INTRODUCTION

Motivation: In day today life we all measure body weight using electronic weighing machine and in the India health awareness is very low compare to other developing and developed countries this is one of the reason Indians don't measure their weight regular basis. Figure-1 shows 'Fit India Survey' conducted by fitness brand Reebok in which with over 1500, out of men (54%) and women (46%) surveyed across top 8 cities, all were between 20-35 years of age and engaged in at least one fitness activity per week [1].

Rank	City	Fit Score
1	Pune	7.65
2	Chandigarh	7.35
3	Kolkata	6.71
4	Delhi NCR	6.70
5	Mumbai	6.68
6	Hyderabad	6.60
7	Bangalore	6.34
8	Chennai	6.20

Source: IndianExpress

Fig -1: Fit India Survey.

A person with a BMI of 30 or more is generally considered obese. A person with a BMI equal to or more than 25 is considered overweight. In 2016, 39% of women and 39% of men aged 18 and over were overweight. (WHO http://new.who.int/news-room/fact-sheets/detail/obesity-and-overweight)

Pregnant women [2], some programs related to Automatic Dietary Monitoring Using Wearables [3] and to treat obesity, weight management, individuals who undergone bariatrics surgery in these cases body weight changes weekly and they can't rely on electronic weighing machine [4, 5, 6]. It is also useful to researchers in biomedical field and podiatrist to treat their patient well.

A lot of information can be obtained from footwear by using wearable technology. To capture this information by integrating electronic sensing system in the footwear began in the 1990, both for academic research purposes and in commercial products [6].

2. METHODS

2.1 Hardware Design:

Hardware design is compact and installed inside of shoe hill. It uses 5 Force Sensitive Resistors (FSR). These are sensors that allow to detect physical pressure, squeezing and weight. They are simple to use and low cost made by Interlink 402 model. The 1/2" diameter round part is the sensitive bit [7]. These 5 FSR are installed on insole of a shoe as shown in figure-2. For foot step count used sensor MPU-6050 break-out board [8, 9]. For processing, sampling and controlling data flow, it uses Arduino Nano 3.0 which has perfect size to design compact hardware [10]. This arduino nano powered by 9 volt PP3 rechargeable battery of capacity around 400 mAh. For wireless transmission to android smartphone used HC-05 Bluetooth module and data is obtained from bluetooth terminal app and processed further using Libre Office Calc. Total hardware system requires 140 mAh power means in one recharge of battery it gives around 3 hours of backup. This hardware system is installed inside of both shoes heel and 5 FSR are installed on insole of each shoe. Figure-3 shows the block diagram of a system.

Fig -2: FSR position at Hallux (1), Medial forefoot (2), Central forefoot (3), Lateral forefoot (4), and Heel (5).

Fig -3: Hardware installed in heel of the shoes.

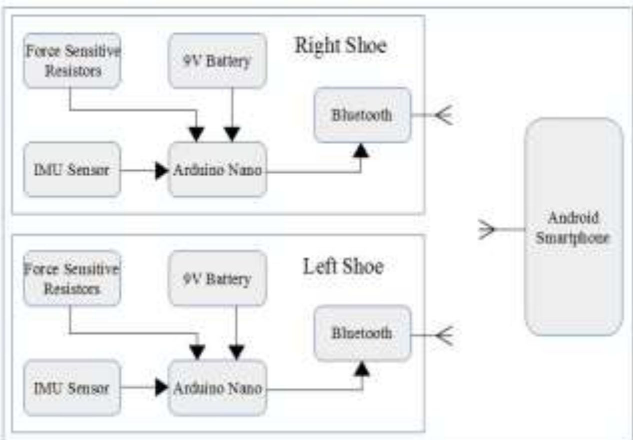


Fig -4: Block Diagram of Total System.

2.2 Experimentation:

For body weight experimentation total 10 subjects are studied, 3 of them are females and 7 are males. All subjects are with Indian shoe size 10 and all samples for each subject are collected in real time while they are standing stable and not when subject is walking. Also foot step count is collected for each subject and calories burned per step is calculated.

Table -1: Experimentation data of each subject.

Subjects	Actual Weight (kg.)	Estimated Weight (kg.)	Error in Weight (kg.)	Step Count	Calories Burned	Temperature
1	65	67.47	+2.47	27	13.5	33.21
2	73	70.26	-2.74	12	6	31.16
3	68	67.11	-0.89	21	10.5	28.54
4	59	65.05	+6.05	16	8	30.19
5	70	73.84	+3.84	15	7.5	31.74
6	81	83.09	+2.09	20	10	33.46
7	63	65.52	+2.52	33	16.5	29.18
8	76	79.81	+3.81	28	14	31.22
9	57	60.71	+3.71	45	22.5	29.65
10	74	75.54	+1.54	36	18	30.47

2.3 Statistics:

To calculate body weight FSR is used which gives change in resistance according to force applied. Resistance decreases when force is maximum and resistance is infinite when force is zero.

Pull down 10 kohm resistor and the sensor is read on Analog pin of arduino. It is pretty advanced and will measure the approximate Newton force measured by the FSR. This can be pretty useful for calibrating what forces you think the FSR will experience. The voltage is calculated by using analog reading at analog pin of arduino board. This calculated voltage is used to calculate resistance of FSR by using this formula $FSR = ((Vcc - V) * R) / V$, where Vcc is 5V, V is voltage calculated using analog reading, R is pull down 10 kohm resistor. From FSR resistance we can calculate conductance and finally force on that FSR sensor [7].

For foot step count threshold method is used means if value of addition of accelerator sensor Ax, Ay, Az crosses threshold value it will count as one step, chart (1) shows graph of accelerator sensor values during walking of a subject. According to article by Rough Parrish, one normal person burn 1 calorie per 20 steps means 0.5 cal for one step [11, 12].

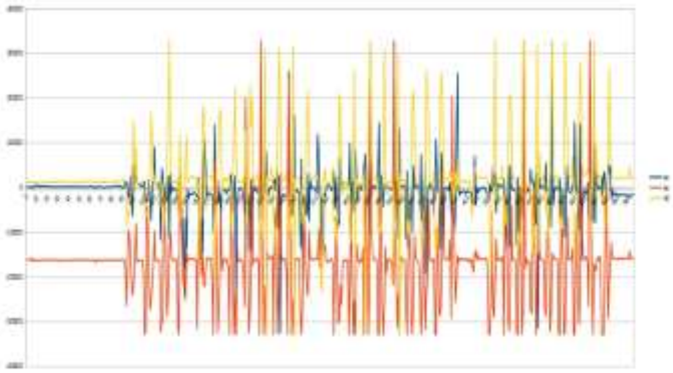
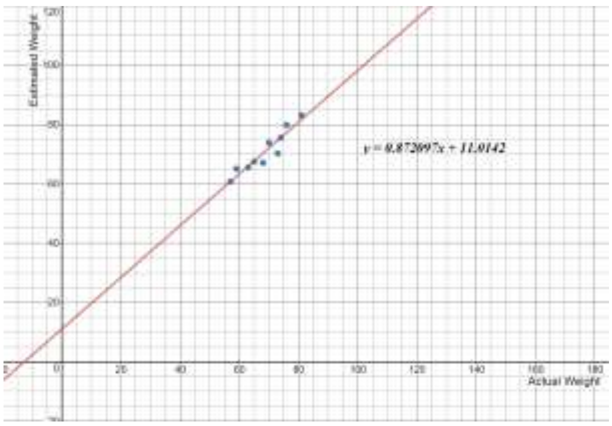


Chart -1: IMU sensor values for Ax, Ay, Az.

3. RESULTS

Figure (6) shows slope line *y=0.872097x+11.0142* which has *m=0.872097* very close to ideal value for that is



m=1.

Chart -2: Statistical graph for actual weight and estimated weight.

It shows that Average error in estimation of weight is 2.5 kg. When subject is standing and battery used is sufficient to use for 3 hours.

4. CONCLUSION AND FUTURE WORK

In this paper we studied feasibility of FSR sensor is to estimate body weight and IMU sensor can be used in combination of FSR sensor to get better values of body weight while standing, another one future scope for this system is that to develop android app to connect both bluetooth at same time that is by implementing piconet in app so that we will get both shoes data on one channel and precision in calories burned by using height and estimated weight. It has turned out that this system definitely will have a bright prospect under today's market economy for its good practicality and acceptable development expense.

Podiatrist and researchers in footwear based technology can use this product or system as a gait analysis of their clients who can paralyzed person, diabetic person, and various person who are disable or have some problem related to foot and gait. In future this product should be developed for more compactness, waterproof and power efficient for long use in one charge.

With the slowdown in world economic growth, the Smart Shoes industry has also suffered a certain impact, but still maintained a relatively optimistic growth, the past four years, Smart Shoes market size to maintain the average annual growth rate of 18.23% from 38650 million $ in 2013 to 63880 million $ in 2016,believe that in the next few years, Smart Shoes market size will be further expanded, we expect that by 2021, The market size of the Smart Shoes will reach 155790 million $ [12].

We can develop one footwear based wearable technological solution for gait monitoring, plantar pressure measurement, posture and activity classification, body weight and energy expenditure estimation, biofeedback, fall risk applications, navigation, along with footwear-based energy harvesting solutions [13] and can be implement over IOT to collect large data from number of subjects which will be further helpful to increase accuracy in smart shoe based wearable system.

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