Evaluating the Performance of a Pedometer using Bluetooth

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Abstract— **Pedometer available in the market is a pocket held device. This is very common that the pocket held pedometer will get a massive uncontrolled movement while running and wrong movement of the accelerometer can manipulate the pedometer reading. So we are concentrating on this fact and how to overcome this problem. The Pedometer is based on android platform so that it is available for most of the person. Our device has two parts. One is the accelerometer with a microprocessor which will be tied to ankle or shin, the other part, the display module i.e. the Smartphone. Data will be transmitted via Bluetooth. This Pedometer uses an ADXL 335 accelerometer which measures the acceleration with a minimum full scale range of ± 3g reading for three axis and an Arduino Uno Board with DIP ATmega328P microprocessor for programming. Forward acceleration of the body changes as we take a step. It increases while we take the front step and decreases again as soon as the step is completed. From the plotted graph it was like a noisy sinusoidal one but not with equal magnitude at every peak. Noises were filtered out using a low pass IIR filter. Then from that axis graph, observing variation in acceleration and using threshold detection method the device takes decision whether a step has been made or not. Some other parameters like distance, speed and total calories burnt during walking are also measured.**

Keywords— Pedometer, Accelerometer, Arduino Uno Board, IIR Filter, PROCESSING, MIT app inventor 2

I. INTRODUCTION

The positive health benefits of physical activity among children and adolescents are well established [1]. Recent concerns over rising levels of obesity and the link with increasingly sedentary lifestyles, has highlighted the need for schools and other relevant organizations to provide opportunities for children and young people to increase their activity levels [2]. Levels of physical activity decrease during early adolescent years, particularly among the girls. Opportunities which enable young people to be active in a non threatening, fun and social environment may provide a useful alternative. Walking interventions are one such opportunity. They allow participants to increase their physical activity levels without the need for specific skills, equipment or facilities. In this context there has been increased interest in using pedometers as a motivational tool to promote physical activity [1].

Physical activity is an important method of treatment for type-2 Diabetes (T2DM). In Bangladesh, which had a population of 149.8 million in 2011,[3] a recent meta-analysis showed that the prevalence of diabetes among adults had increased substantially, from 4% in 1995 to 2000 and 5% in 2001 to 2005 to 9% in 2006 to 2010.[4] According to the International Diabetes Federation, the prevalence will be 13% by 2030.Walking is a safe form of physical activity which improves glucose utilization in inactive people diagnosed with T2DM.

Pedometers have been successfully used to motivate and track progress in many types of walking programmes. A systematic literature review was performed using MEDLINE, CINAHL, SPORTDiscus, ERIC and Academic Search Premier to determine the effectiveness of pedometer-based walking interventions at increasing physical activity in free living adults with T2DM. Ten studies from 2004 to 2011 were included. All studies were randomized controlled trials except for one quasi-experimental design. Interventions lasted from 6 weeks to 6 months and 2 studies showed significant improvements in blood glucose control following the intervention. Nine of the ten interventions were able to produce an increase physical activity using a pedometer and/or other methods. Pedometers are effective for increasing physical activity among T2DM patients in the short term. [5]

So we aim to implement a pedometer with universal design and flexibility. The user-friendly prototype and low

cost design makes it available for the mass people of Bangladesh.

The remainder of this paper is organized as follows. Section II contains the walking characteristics of a person. Then in section III we have described the algorithm to follow. Section IV contains the execution of that algorithm. Section V concludes the paper.

II. WALKING CHARACTERISTICS ANALYSIS

To implement Pedometer, analyse of individual person's running or walking characteristics is needed. Acceleration is the primary parameter here. Single axis observation has been choosen for simplification. In this case our forward axis is the z axis. As the person walk through, his vertical acceleration increases (The white leg in Fig. 1) and decreases subsequently. And also his forward acceleration decreases and increases (the shadowed leg in Fig. 1) if we think the knee as the centre of a simple pendulum and the foot as the pendulum ball then forward acceleration is minimum when the angular displacement is zero degree and as the angular displacement increases the acceleration also increases. The following figure describes this characteristics.
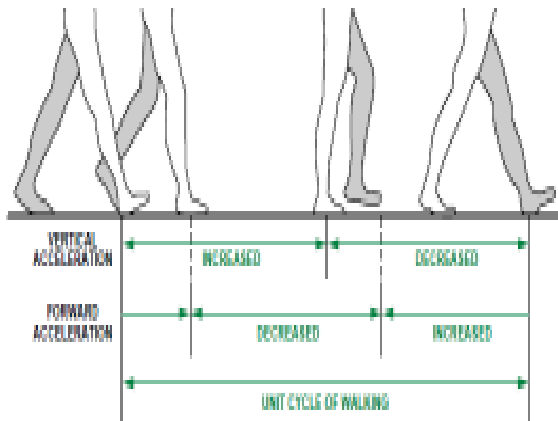

Fig. 1 Walking stages and acceleration pattern [6]

III. METHODOLOGY

The microcontroller needs to be programmed according to the graph of acceleration change during walking, so that it can count whether a step has been made or not.

A. Graph analysis

If the variation of acceleration is plotted it should be like a sinusoidal one with no noise or very low noise in the ideal case. The graph should be like the Fig. 2. This graph has
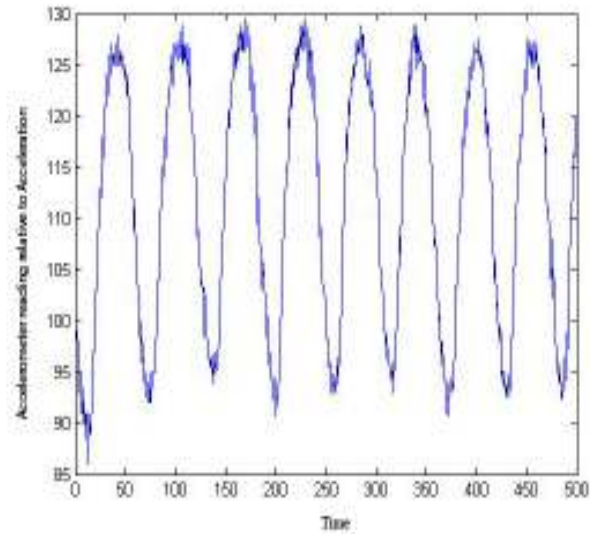
been plotted using MATLAB.

Fig. 2 Change of acceleration while walking

B. Filtering

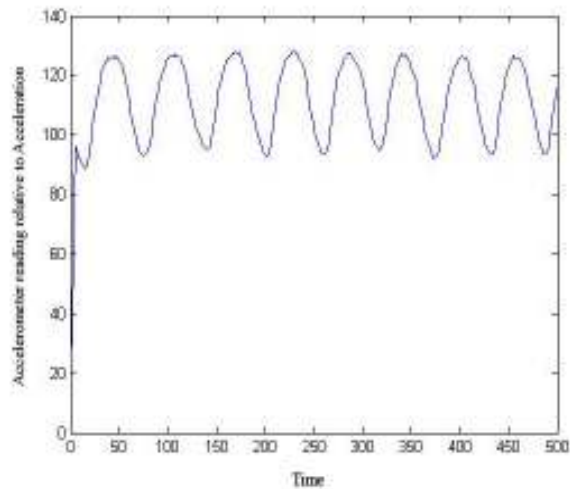Filtering is needed to remove the added noise so that unwanted step detection does not happen.

Fig. 3 Variation in acceleration after filtering

C. Defining the Threshold Level

A step is said to be made after one cycle of walking i.e. as soon as the increasing and decreasing part of a cycle is completed. So the count should be made at a point in the downward slope of the graph where the average between previous minimum and maximum point exists. This has been
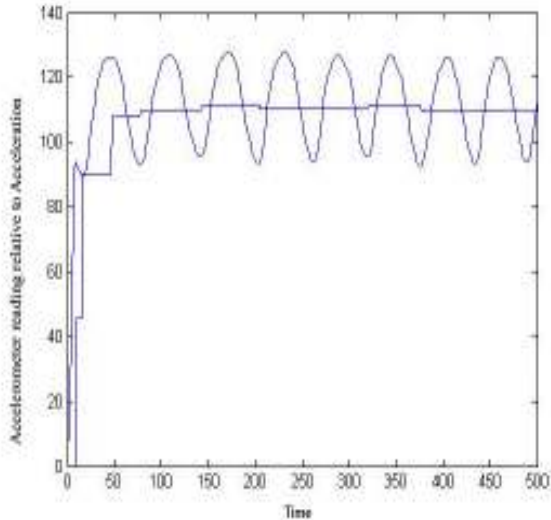
shown in Fig. 4.

Updating data in every 2 cycles it keeps record of the steps taken , distance , speed and calories burnt much more accurately. If a person can make maximum 5 steps in every seconds and minimum 1 step in every 2 seconds then a time window of 0.2 sec to 2 sec can be used. All the other step values out of time window will be discarded.

Fig. 4 Defining the threshold level

IV. EXECUTION OF METHODOLOGY

Various software for the execution of the above methodology. The graph has been observed using Arduino Uno serial monitor and PROCESSING 2. The programming has been done by using DIP ATmega328P microcontroller integrated with Arduino Uno Board for simplicity. The android application was developed using MIT App Inventor 2. Accelerometer takes record of acceleration change and the programming determines the parameters . All the parameters are sent to Smartphone via Bluetooth. This Smartphone application is used as the user interface. Whole connection diagram has been provided in Fig. 5.
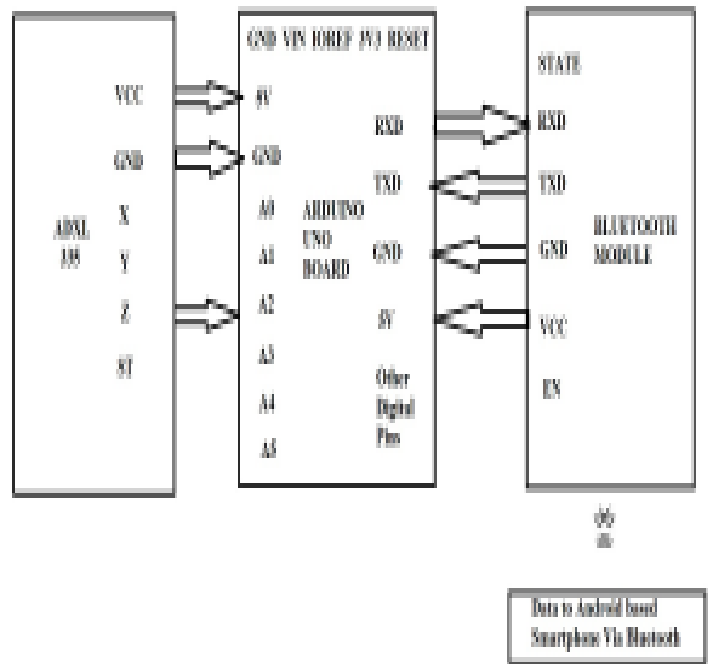
D. Others

This Pedometers will also calculate distance, speed and calorie burnt during walking. The following equations and tables have been used to determine these parameters.

Distance = Number of steps x Distance per step [6]

Distance per step depends on the height of the user.

TABLE I
STRIDE AS A FUNCTION OF SPEED (STEPS PER 2 SEC) AND HEIGHT [6]

Steps per 2 sec	Stride(m/s)
0-2	Height/5
2-3	Height/4
3-4	Height/3
4-5	Height/2
5-6	Height/1.2
6-8	Height
>= 8	1.2 x Height

Speed= (Step per 2 sec) x (Stride per 2 sec) [6]
Calories (C/2 s) = 4.5 × speed × weight/1800 [6]
Calories (C/2 s) = 1 × weight/1800 (while at rest) [6]

Fig. 5 Connection Diagram for the Pedometer

A. Graph

The first graph of accelerometer data versus samples is a very noisy one which was filtered using a low pass IIR filter . The equation for the filter is

$$y(n) = \frac{1}{A_o a_0}\left[A_i b_0 x(n) + b_1 x(n-1) + b_2 x(n-2) - a_1 y(n-1) - a_2 y(n-2)\right]$$

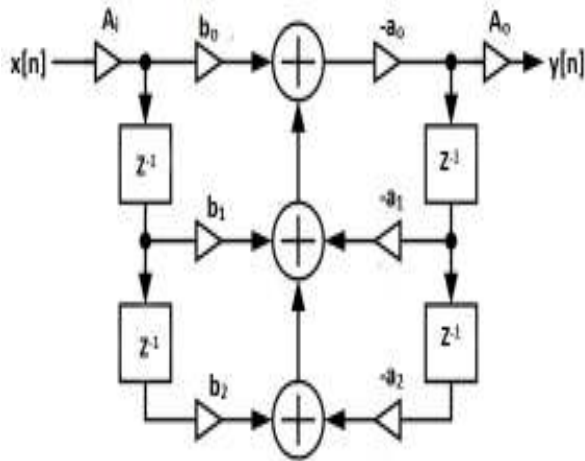Where A_o is output gain and A_i is input gain.

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Fig. 6 Block diagram of a biquad IIR filter

Here, A_i =0.0169, A_o = 1, a_0=1, a_1= -1.6002 , a_2=0.6677,b_0=1,b_1=2,b_2=1;

The filtered graph is a more smoother one as shown in fig. 7. The blue curve is the graph of accelerometer data and the green curve is the threshold level curve. By Programming in Arduino Uno and PROCESSING using the algorithm described at section III C and III D the pedometer can detect steps which are marked as Red Dots in fig. 7. Step detection is the main part of this pedometer system as other datas are dependent on this reading. As soon as the step detection is computed the microcontroller computes all the other parameters using the equations given at III D.
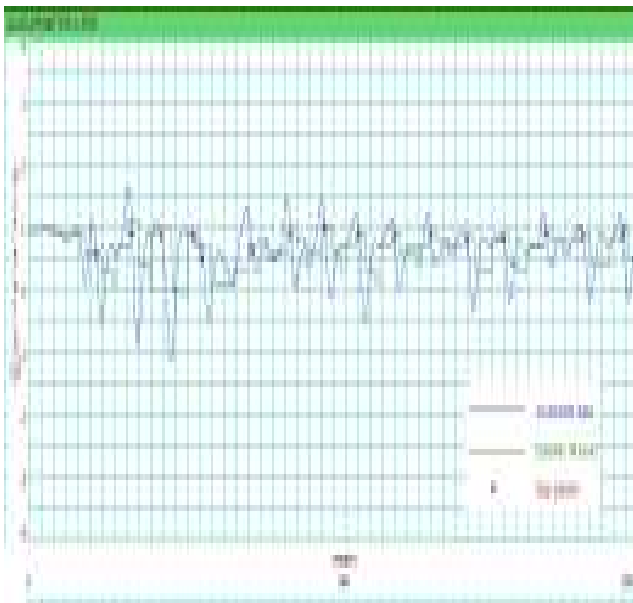

Fig. 7 Filtered Forward Acceleration graph while walking with point shown where the step change has been counted

B. User Interface: Application for Android Based Smartphones

Now a days cheap Smartphones are available throughout the country. To display the parameters, android based Smartphones are much more flexible platform, no separate device as user interface is needed. To build the android application we used MIT app inventor 2.

App Inventor for Android is an open-source web application originally provided by Google, and now maintained by the Massachusetts Institute of Technology (MIT). It allows newcomers to computer programming to create software applications for the Android operating system (OS). It uses a graphical interface, very similar to Scratch and the StarLogo TNG user interface, which allows users to drag-and-drop visual objects to create an application that can run on Android devices. In creating App Inventor, Google drew upon significant prior research in educational computing, as well as work done within Google on online development environments. [7]

Using the app is very easy. The user just has to enter his or her personal information including height , weight and age and then saving the information he/she is ready to go with the pedometer. Before using the pedometer the person needs to turn on his/her Smartphone's Bluetooth so that it can find the Bluetooth module attached to Arduino uno board. The Arduino Uno, processing all the data using it's microcontroller, send the informations to the mobile and user can see this in his/ her mobile app interface. We have created two extra buttons named temperature and humidity so that they can be used in future (installing temperature and humidity sensor) along with the pedometer to let the user know about the surroundings . This will help him/her to know whether he/ she can do walking exercise now or will have to do it later.

Fig. 8 User has to input his/her personal information

Fig. 9 The application showing various parameter values

C. Result and Analysis

Various user feedback had been collected to have a look at the Pedometer performance. The Data table has been provided below.

TABLE II
USER FEEDBACK

	Height (cm)	Age	Step reading in Pedometer	Original steps taken	Error (%)
1	172	23	9	9	0
2	172	23	25	26	3.84
3	178	22	52	50	4
4	178	22	16	15	6.66
5	172	55	54	52	3.84

The table shows the error rate is within 3-4% in most of the case which is acceptable. But it has been seen that low battery system provides much more wrong data . So user needs to be aware about changing the battery when it runs low. Also using the type 2 transmitter as bluetooth module which radiates 1mW peak power, the health safety from radiation is ensured.

V. CONCLUSION

We first proposed a simple method for step detection and then implemented the system. This Pedometer provides a low cost design which took us approximately 15 US Dollars and it is very flexible and easy to use as it can be used along with Smartphones via Bluetooth. Also it responds 96% accurately which is quite good. Research has suggested a daily 10,000 step goal for maintaining a desirable level of physical activity for health which is not normally achievable through routine daily activities. [8] So physical activity like walking exercises are needed. This Pedometer will help and motivate people to achieve this goal in a easy way by tracking record while walking. There are a lots of areas to improve the pedometers in future. There is a scope to work with three axis and to add temperature and humidity sensors . Also a memory can be added to keep a history of the users monthly experience. Overall this is a simple, flexible and cost efficient Pedometer that would be very much appropriate for the people of Bangladesh.

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