The Seventeenth International Symposium on Artificial Life and Robotics 2012 (AROB 17th '12),
B-Con Plaza, Beppu, Oita, Japan, January 19-21, 2012

The implementation of accelerometer and embedded system-based multi-functional pedometer

Yi-Yu Lu[1,2], Kuo-Sheng Cheng[1,3], Wen-Bin Lin[4,5] and Ji-Jer Huang[6]

[1] Department of Biomedical Engineering, National Cheng Kung University, Tainan 70101, Taiwan
[2] Department of Electrical Engineering, Far East University, Tainan 74448, Taiwan
[3] Medical Device Innovation Center, National Cheng Kung University, Tainan 70101, Taiwan
[4] Department of Optoelectronic Engineering, Far East University, Tainan 74448, Taiwan
[5] Graduate School of Engineering Sci. & Tech., National Yunlin University of Science & Technology, Yunlin 64002, Taiwan
[6] Department of Electrical Engineering, Southern Taiwan University of Technology, Tainan 71005, Taiwan
(Tel: 886-6-5979566 ext: 5408, Fax: 886-6-5977570)

[1,2]yiyu@cc.feu.edu.tw

Abstract: Pedometers are known to have steps estimation issues. This is mainly attributed to their innate acceleration based measuring sensory. In this work, purposes a novel implementation of microcontroller and accelerometer sensor- based for multi-function pedometer in calorie consumption calculation. To verify the output voltage stability of accelerometer sensor, the methods of statistics analysis is introduced to extract the useful features. Three kinds of different steps are employed to obtain the analytic data. The proposed pedometer dimension of a proto-type is 68 mm(L) X 42 mm(W) X 15 mm(H).

Keywords: Pedometers, Three-axis accelerometer, Calorie consumption, Microcontroller.

1 INTRODUCTION

Walking is one of the principle gaits of locomotion among legged animals. Walking motion is defined by an 'inverted pendulum' movement in which the body vaults over the stiff limb or limbs with each step. This applies regardless of the number of limbs – even to arthropods with six, eight, or more limbs [1]. In humans and other bipeds, walking is characterized by only one foot leaving the ground at any given time, resulting in a period of double-support. In contrast, running involves both feet leaving the ground with each step. This distinction assumes the status of a formal requirement in competitive walking events [1].

Sustained walking for a minimum of thirty to sixty min. a day, five days a week, with correct walking posture, [2-3] provides a variety of benefits in reducing health risks [4]. These benefits include a reduced chance of developing cancer, type 2 diabetes, heart disease, anxiety, and depression [1,5]. Walking can increase life expectancy, particularly among individuals suffering from obesity or high blood pressure. Walking enhances bone health, especially the hip bone, reduces harmful low-density lipoprotein (LDL), and increases useful high-density lipoprotein (HDL) cholesterol[6]. Studies have determined that walking can even prevent dementia and Alzheimer's.

Pedometers are often worn on the belt to record how many steps the wearer has taken, and thus determine the distance walked each day (distance = number of steps × step length) [5].

Some pedometers will also erroneously record movements other than walking, such as bending to tie one's shoes, or road bumps incurred while riding a vehicle, though the most advanced devices record fewer of these 'false steps'. Step counters provide encouragement by enabling the user to compete with oneself in getting fit and losing weight. A total of 10,000 steps per day, equivalent to 5 miles (8.0 km), are commonly recommended as a benchmark for an active lifestyle, although this remains an issue of debate among experts [5]. Step counters are increasingly being integrated into portable electronic devices such as music players and mobile phones.

Many pedometers erroneously record road bumps incurred while riding in vehicles or movements other than walking (such as bending over), although more advanced devices record fewer of these 'false steps'. Pedometers generally detect steps from vertical acceleration at the human trunk [7]. The technology for a pedometer includes a mechanical sensor and software to count steps. Today advanced step counters rely on MEMS inertial sensors and sophisticated software to detect steps. These MEMS sensors have either 1-, 2- or 3-axis detection of acceleration [5]. The use of MEMS inertial sensors permits more accurate detection of steps and fewer false positives. The software technology used to interpret the output of the inertial sensor and "make sense of accurate steps" varies widely [7-8].

This study develops the design and fabrication for an accelerometer and embedded system-based multi-functional pedometer in calorie consumption calculation.

2 MATHEMATICS MODEL & SYSTEM STRUCTURE

The system schematic diagram is shown in Fig. 1. The system is using PIC16F877A microcontroller [9] as the pedometer core, uses its embedded 10 bits A/D converter. The variation voltage value of exercise angles detected by MMA7260Q accelerometer [10] sends to the microcontroller for handling. When the angle is bigger the setting threshold value, it will start step-counting program for recording. Finically, the LCD displays the calorie consumption and the step counting during exercise by means of the calorie calculation formula. By means of the element of MAX232, this system also has an interface that links to the UART of personal computer for program initial debugging and development.

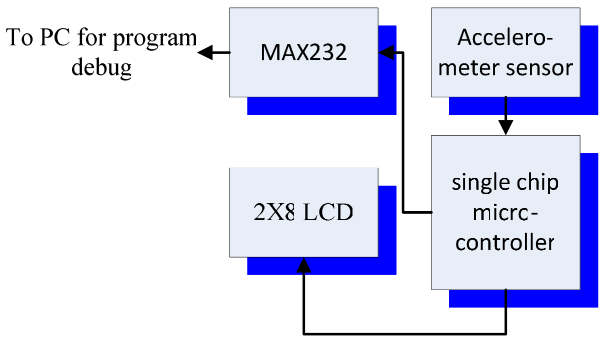

Fig. 1. Schematic diagram of proposed pedometer

The detected g value is hardly make mathematic analysis with the corresponding x axis voltage (V) in static acceleration mode of MMA7260Q. So these two values relationship is obtained from the measurement of the experimental data in table1. And the linear fit equation is expressed by

$$g = 1.25 \cdot V - 2.0625 \quad (1)$$

where

$g \equiv$ The acceleration value after converting

$V \equiv$ The output voltage of x axis at three-axis accelerometer

Table 1. The experimental data in static acceleration mode

g value	+1	0	-1
x axis voltage (V)	2.45	1.65	+0.85

The correlation coefficient of curve fitting is 0.9999. From the food information websites in Department of Health at Taiwan [11], the relationship between speed and calorific capacity that can be a main reference issue about the calculation of exercise calorie is shown in Fig. 2.

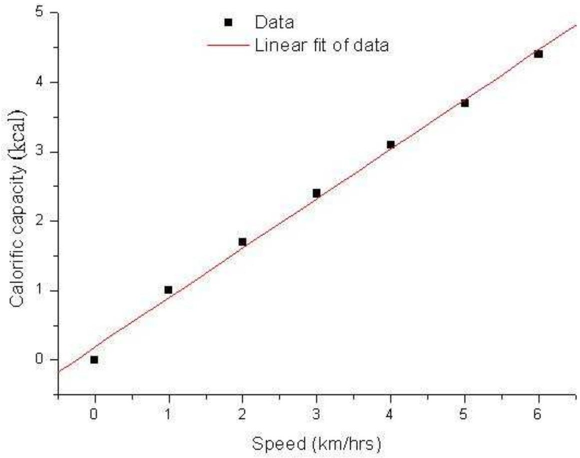

Fig. 2. The relationship between speed and calorific capacity [11]

We can get the Linear Fit equation is expressed as Equation (2). Where, $V(t)$ is the walking speed, and K is the Calorie consumption after converting. The correlation coefficient of curve fitting is 0.99761. Human weight is one of exercise calorie consumption factors, but we simplify the development of proto-type system. We make the human weight that is equals to 60kg as the basis, and leave the weight fitting as furthermore research in the future. Finally, the calorific capacity after converting displays in LCD module.

$$K = 0.71429 \cdot V(t) + 0.18571 \quad (2)$$

3 WALKING STEP SIZE CONDITIONS

The system also can set three modes that include big step, middle step, and small step. Apart of the human weight factor, walking calorie consumption has the relationship of a linear equation with walking speed. In theory, the big step mode will take more calorie than others. But it has slower speed in big step mode and it results in the calorie consumption is smaller than others in per step.

After the practical pedometer calculation, the calorie consumption is shown in Table 2. Theoretically, on condition of uniform velocity, the paces are the greater to walk, the more its calorific consumed is. However, the speed would be slowdown in actual measurement when it walks in great paces. Thus, the calorie consumption of average in single paces consume will be reduced instead.

For calibration purpose between g value and voltage of x axis accelerometer, we take the voltage measurements at small step, middle step, and big step. Among these three modes, we take 10 points data and make statistical analysis respectively, for classifying these data sets. In the small and big step modes, there mean value

(Mean), variance (Var.) and coefficient of variance (CoefVar.) are nearly equal to each others. In Table 3, the mean value of small step is only smaller 0.003 than big step. Although the standard deviation (Std.) of small step is bigger than big step, but there is only 0.0125 difference between small step and big step. Find in the test, the average calorie consumption of steps in these two modes are nearly equal to each others. Besides, three parameters that described above have the same trend as shown in Fig. 3.

Table 2. The comparison of 3 modes for different step sizes

Steps mode	No. (steps)	Calorie (cal.)	Average cal./step
Small (40cm)	16	11	0.7
Middle (50cm)	10	14	1.4
Big (70cm)	20	16	0.8

Table 3. The statistics analysis for 3 steps modes

Steps	Mean	Std.	Var.	CoefVar.
Small (40cm)	1.754	0.27645	0.07643	0.15761
Middle (50cm)	1.858	0.23925	0.05724	0.12877
Big (70cm)	1.757	0.26395	0.06967	0.15023

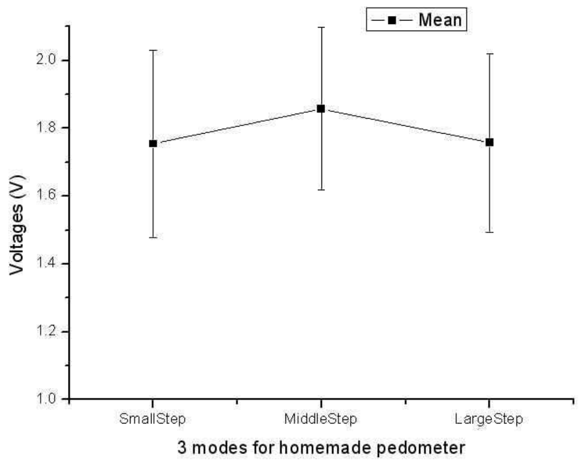

Fig. 3. The statistics data calculated at x axis in the pedo meter for 3 modes.

4 SYSTEM PROGRAMMING

Firstly, put the proposed pedometer on the shank. Then, turn on the power, it will display the words of Calorie (Calorie), st (step number), and se (setting) on LCD screen. Secondly, using push-button to select suitable step range by yourself. The region 1 is small step, and sensing range is from 0.25g to 0.05g. The region 2 is middle step, and sensing range is from 0.53g to 0.28g. The region 3 is big step, and sensing range is from 0.8g to 0.55g. If the user sets region 2 for walking step counting, then the setting location will display 2 on the screen of pedometer. After above procedures, the user pushes the "start" push-button for time counting, and then, it waiting the input signal.

By user walking, this action induces a signal to the x axis of accelerometer. This procedure contains the actions of step-counting plus one and time-counting during setting regions. By means of converting g value and formula (V=g • t) within software program setting, the program calculates the calorie consumption and displays the value on LCD screen. If the step span doesn't belong within setting sensing region, and then the program doesn't have step-counting action.

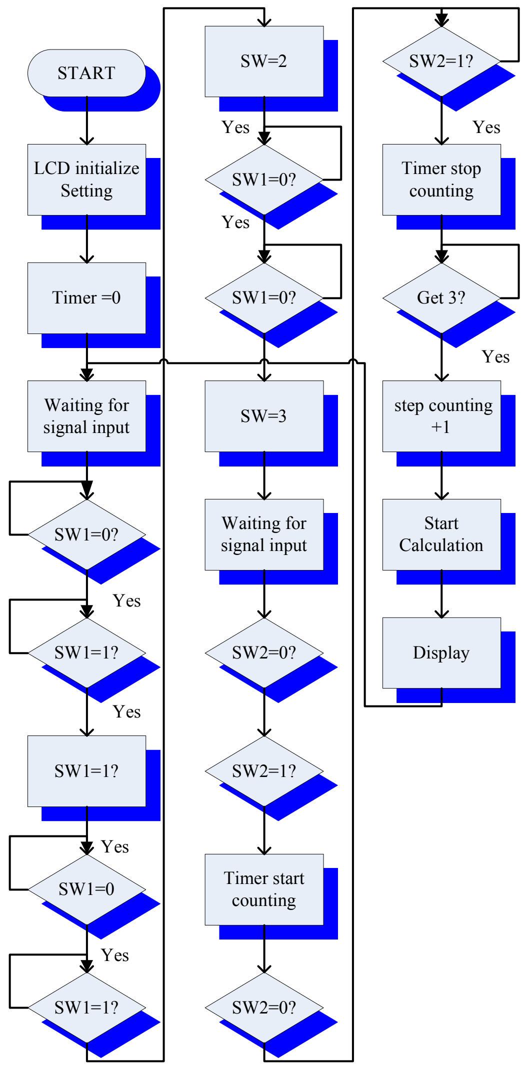

Fig. 4. The program flow chart of proposed pedometer [11]

After above procedures, the program will return last process. The setting procedures of region 1 and region 3 are the same as region 2. The user walk one step within setting sensing range, the program will plus one in step-counting procedure. After stop walking for one minute, it displays the data. And then, time counting, calculation, and display, the proposed pedometer will repeat the same actions again. The program flow chart of proposed pedometer is shown in Fig. 4.

5 CONCLUSION

The hardware pictures of this proposed pedometer are shown in Fig. 5 and Fig. 6. This study purposes a novel implementation of microcontroller and accelerometer sensor- based for multi-function pedometer with LCD display. It has the advantages with low power consumption, more robust and small dimension. Pedometer software is tested and showed 90% of step count accuracy. After verify the accuracy of the hardware design due to complete various function tests, the proposed hardware is realized that based on above concepts. The output voltage of accelerometer in three kind of different steps is employed to obtain the analytic data. The four parameters are calculated by statistics method. Finally, the three modes of hypothesis testing are verified for application. The 'mean' parameter is shown to be good to index the calorie consumption.

Fig. 5. The using picture of proposed pedometer

Fig. 6. The step-counting and Calorie consumption display of proposed pedometer

ACKNOWLEDGMENT

This work is supported by the National Science Council in Taiwan, Republic of China, through grant NSC 97-2622-E-269-013-CC3

REFERENCES

[1] http://en.wikipedia.org/wiki/Walking

[2] Frank L.D., Andresen M.A. and Schmid T.L. (2004), Obesity relationships with community design, physical activity and time spent in cars, American Journal of Preventive Medicine, 27(2), pp.87–96

[3] Michaud D.S., Giovannucci E., Willett W.C., Colditz G.A., Stampfer M.J. and Fuchs C.S. (2001), Physical activity, obesity, height, and the risk of pancreatic cancer, Journal of the American Medical Association, 286(8), pp.921–929

[4] Hatano Y. (1997), Prevalence and use of pedometer, Research Journal of Walking, 1(1), pp.45–54

[5] http://en.wikipedia.org/wiki/Pedometer

[6] Tudor-Locke C. and Bassett D.R. (2004), How many steps/day are enough?: Preliminary pedometer indices for public health, Sport Medicine, 34(1), pp.1–8

[7] Lim Y. P., Ian T., Joshua C.T. (2008),An accurate and robust gyroscope-gased pedometer, Proceeding of 30th Annual International IEEE EMBS Conference, Aug 20 - 24, 2008, Vancouver, Canada, pp.4587-4590

[8] Chae K.S., Park H.J. (2007), Evaluation of a 3D Motion Sensor including Accelerometer and Geomagnetic sensor, Proceeding of 16th IEEE International Symposium on Robot and Human interactive Communication, Aug 26-29, 2007. Jeju Island, Korea, pp.900 - 904

[9]http://ww1.microchip.com/downloads/en/DeviceDoc/39582b.pdf

[10]http://www.sparkfun.com/datasheets/accelerometers/MMA7260Q-Rev1.pdf

[11] http://www.mmh.org.tw/nutrition/ibw_doc.htm