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Assessing Physical Performance in Free-Living Older Adults with a Wearable Computer

Qi Zhao[1], **Jingjing Wang**[1], **Wenquan Feng**[1], **Wenyan Jia**[3], **Lora E. Burke**[4], **Janice C. Zgibor**[5], and **Mingui Sun**[2,3]

[1]School of Electronic and Information Engineering, Beihang University, Beijing, China

[2]Department of Electrical & Computer Engineering, University of Pittsburgh, Pittsburgh, PA 15213, USA

[3]Department of Neurosurgery, University of Pittsburgh, Pittsburgh, PA 15213, USA

[4]Department of Health and Community Systems, University of Pittsburgh, Pittsburgh, PA 15213, USA

[5]Department of Epidemiology, University of Pittsburgh, Pittsburgh, PA 15213, USA

Abstract

This study investigates the use of a chest-worn wearable computer, the eButton, to assess physical performance of older adults. The Short Physical Performance Battery (SPPB), a standard cliniucal test, is first conducted on older human subjects. Then, a triaxial accelerometer and a triaxial gyroscope within the eButton are utilized to record acceleration and angular velocity of body motion on the same subjects for one week. The sensor data corresponding to walking episodes are segmented and features in the time and frequency domains are extracted. Comparison between these features and the total SPPB scores shows that the sensor data acquired in free-living conditions can be used as indicators of the subjects physical performance.

Introduction

The Short Physical Performance Battery (SPPB) test is designed to assess physical and functional health in older adults with three objective subtests: a 4-meter walk, repeated chair stands, and standing balance. SPPB is scored from 0 to 4 for each subtest, and the total SPPB score is on a scale of 0-12, with 12 corresponding to highest performance. The SPPB test has been used widely and demonstrated to have a predictive value of fall-related mortality risk [1]. It requires 5 to 10 minutes to complete, but has to be performed by an assessor in a designated location, such as a laboratory or a community center. It cannot be conducted frequently because of the cost and inconvenience for both the assessor and the subject. The aim of this study is to investigate whether it is possible to assess physical performance of older adults in free-living older adults with eButton, a wearable computer. eButton is a chest-worn electronic device containing a microprocessor, a miniature camera, and a motion sensor (i.e., a triaxial accelerometer and a triaxial gyroscope) [4]. After analyzing the eButton data recorded in a relatively long period (e.g., one week), the relationship between the extracted features from motion sensor data and the wearers total SPPB score are investigated.

II. Data Processing Method

A. eButton Data

The real-world data acquired during a one-week study period are stored on the microSD card within the eButton and then uploaded to a computer. During data processing, the data are first segmented into episodes based on changes in motion sensor waveforms. A representative image for each episode is displayed for verification [4]. Then, the episodes corresponding to walking are manually selected and saved for further analysis by observing the representative images. A segment of eButton data is shown in Fig.1.

B. Extracted Features from Motion Sensor Data

The accelerometer and gyroscope in the motion sensor (MPU-6150TM, InvenSense, CA, USA) records the acceleration and angular velocity of body movement. When the eButton is worn on the chest, each of them outputs three traces, measuring the movement in three directions (x-axis: up/down, y-axis: left/right, and z-axis: forward/backward). For the walking episodes, eight time-domain features and two frequency-domain features are calculated. In the time domain, the average total energy of accelerometer and gyroscope, the standard deviation of three accelerometer traces, and the standard deviation of three gyroscope traces are computed. In the frequency domain, the step frequency calculated from the acceleration data and the peak power at this frequency are calculated [3]. Fig.2 shows the power spectral density of the z-axis (forward/backward) signal of the accelerometer in a walking segment. The power spectrum is computed using the Welch periodogram technique [5] for a reliable estimation. A significant peak representing the step frequency can be observed.

III. Experiment and Results

Before the eButton study, each participant conducted a SPPB test in a laboratory environment. Then, subjects wore the eButton for one week during daytimes. The camera within the eButton took pictures automatically within five-second intervals while the motion sensor data were sampled at 50Hz. The recorded eButton data from ten participants were analyzed in this study. Their age range was from 55 to 80 and their SPPB scores varied from 5 to 12.

Using the self-developed software, walking episodes were segmented [2]. The average number of walking episodes for the ten participants was nineteen and each segment was considered as a sample from the participant, see Table I.

Through the comparison between the calculated features and the total SPPB scores, we selected two parameters, the step frequency and standard deviation of the y-axis (left/right) in the accelerometer data, and conducted statistical analysis. Table I shows the mean value of these two features together with SPPB scores. The extracted features from the participant with the lowest SPPB score have the lowest values when compared with features from other participants. Fig.3 (a) and (b) present, respectively, the box plot of the step frequency and a scatter gram with the two features plotted along two axes for all the samples. It can be seen that all samples corresponding to the participant with the lowest SPPB score form a cluster in the left bottom corner of the plot.

IV. Conclusion

A physical assessment study has been conducted for older adults using wearable computer eButton. The data consisting of automatically acquired pictures and waveforms from a triaxial accelerometer and a triaxial gyroscope have been analyzed by segmenting and extracting features. Comparing with the SPPB test score, we have found that the step frequency and the standard deviation of the y-axis signal in the accelerometer data can be used as data features correlating with the SPPB test score. This preliminary study has shown that it is feasible to assess physical performance in older adults using a wearable computer. We will further improve our data processing methods and find more distinguishable features that correlate more closely with the SPPB test scores.

Acknowledgments

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References

1. Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, Scherr PA, Wallace RB. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. Journal of gerontology. 1994; 49(2):M85–M94. [PubMed: 8126356]
2. Li, Z.; Wei, Z.; Jia, W.; Sun, M. Engineering in Medicine and Biology Society (EMBC), 2013 35th Annual International Conference of the IEEE. IEEE; 2013. Daily life event segmentation for lifestyle evaluation based on multi-sensor data recorded by a wearable device; p. 2858-2861.
3. Renaudin V, Susi M, Lachapelle G. Step length estimation using handheld inertial sensors. Sensors. 2012; 12(7):8507–8525. [PubMed: 23012503]
4. Sun, M.; Burke, LE.; Mao, ZH.; Chen, Y.; Chen, HC.; Bai, Y.; Li, Y.; Li, C.; Jia, W. Proceedings of the The 51st Annual Design Automation Conference on Design Automation Conference. ACM; 2014. ebutton: a wearable computer for health monitoring and personal assistance; p. 1-6.
5. Welch P. The use of fast fourier transform for the estimation of power spectra: a method based on time averaging over short, modified periodograms. IEEE Transactions on audio and electroacoustics. 1967:70–73.

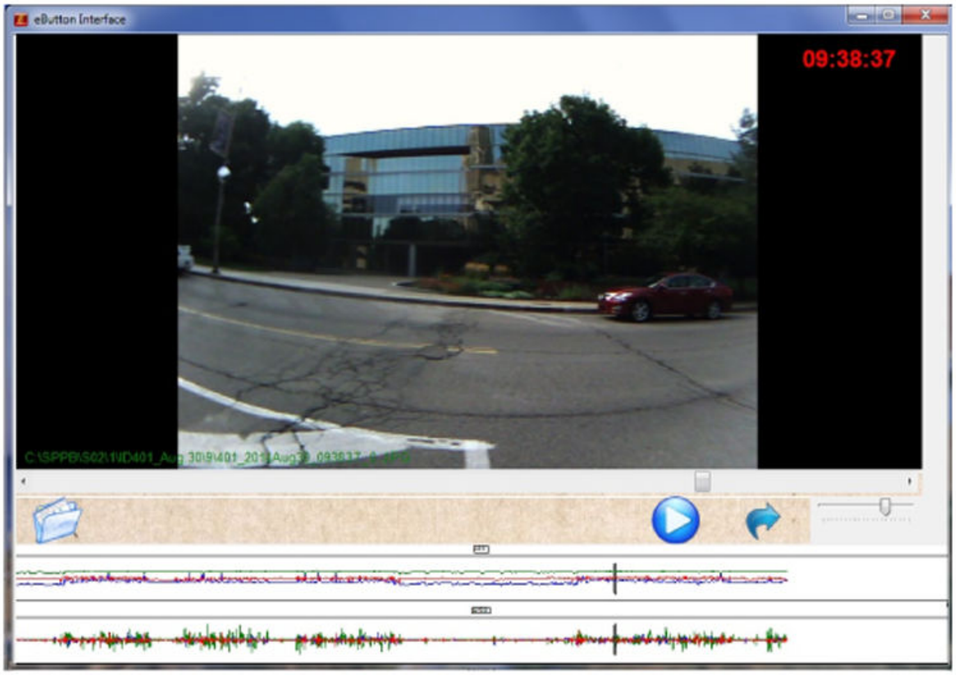


Fig. 1.
Recorded eButton data. The multiple traces in the bottom panel show the three accelerometer traces and three gyroscope traces.

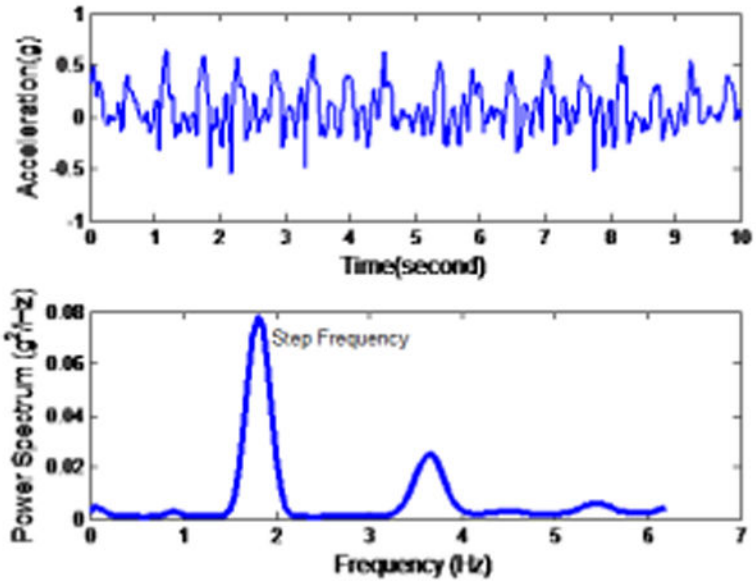
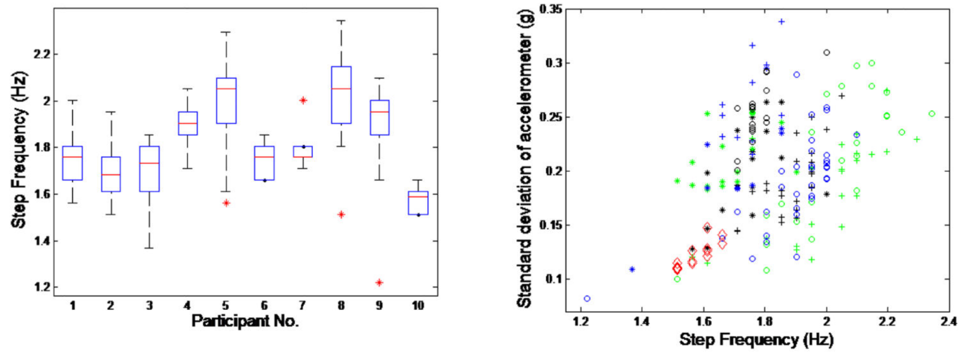


Fig. 2.
The trace (top panel) and power spectrum density (bottom panel) of a segment of z-axis accelerometer data.



(a) (b)

Fig. 3.

(a) Box plot of the step frequency for all the participants. On each box, the central line represents the median frequency and the top/bottom edges of the box are the first and third quartiles. The outliers are plotted individually as asterisks. (b) Scattergram with step frequency and standard deviation of accelerometer plotted along two axes for all the samples. Each red diamond symbol represents one sample from the participant with SPPB score of 5 and other symbols represent all the samples from other participants.

Table I
Total SPPB Scores and Computer Extracted Features

Participant No	Total SPPB Score	No. of walking episodes	Mean step frequency(Hz) Mean ± s.t.d.	standard deviation of y-axis mean±s.t.d.
1	11	18	1.74±0.11	0.20±0.04
2	12	20	1.70±0.12	0.22±0.03
3	12	10	1.70±0.15	0.21±0.05
4	11	23	1.89±0.09	0.19±0.03
5	12	21	2.00±0.19	0.18±0.05
6	12	10	1.75±0.08	0.27±0.04
7	11	19	1.78±0.06	0.25±0.03
8	12	23	2.02±0.19	0.21±0.06
9	12	35	1.90±0.15	0.19±0.04
10	5	14	1.58±0.05	0.12±0.01