Development of the Algorithm for Detecting Falls during Daily Activity using 2 Tri-Axial Accelerometers

Ahyoung Jeon, Geunchul Park, Jung-Hoon Ro, and Gye-rok Geon

***Abstract*—**Falls are the primary cause of accidents in people over the age of 65, and frequently lead to serious injuries. Since the early detection of falls is an important step to alert and protect the aging population, a variety of research on detecting falls was carried out including the use of accelerators, gyroscopes and tilt sensors. In exiting studies, falls were detected using an accelerometer with errors. In this study, the proposed method for detecting falls was to use two accelerometers to reject wrong falls detection. As falls are accompanied by the acceleration of gravity and rotational motion, the falls in this study were detected by using the z-axial acceleration differences between two sites. The falls were detected by calculating the difference between the analyses of accelerometers placed on two different positions on the chest of the subject. The parameters of the maximum difference of accelerations (diff_Z) and the integration of accelerations in a defined region (Sum_diff_Z) were used to form the fall detection algorithm. The falls and the activities of daily living (ADL) could be distinguished by using the proposed parameters without errors in spite of the impact and the change in the positions of the accelerometers. By comparing each of the axial accelerations, the directions of falls and the condition of the subject afterwards could be determined.In this study, by using two accelerometers without errors attached to two sites to detect falls, the usefulness of the proposed fall detection algorithm parameters, diff_Z and Sum_diff_Z, were confirmed.

***Keywords*—**Tri-axial accelerometer, fall detection.

I. Introduction

ACCORDING to the Ministry of Health and Welfare, the population of senior citizens aged 65 and over is expected o surge from the current 9.1 percent to 24.1 percent in 2030 and 37.3 percent in 2050, the highest level in the world. As the elderly population has been booming, the health management for the elderly is getting important. So, we are currently faced with a wide range of problems which are related to the ageing society. Especially, falls are a common public health problem among the elderly in many communities as such events often lead to more serious illness or even death.

A. Y. Jeon is now with Department of Biomedical-Engineering, School of Medicine, Pusan National University. Beom-eo, Mul-gum, Yangsan, South Korea. (e-mail: valonica@nate.com).

J. S. Nah is now with Department of Biomedical-Engineering, Pusan National University, Beomeo, Mulgum, Yangsan, South Korea (phone: +81-51-510-8119; fax: +81-51-510-8120; e-mail: kpelix@ nate.com).

G. C. Park is now with Department of Biomedical-Engineering, School of Medicine, Pusan National University. Beom-eo, Mul-gum, Yangsan, South Korea. (e-mail: parkgc10@nate.com).

J. H. Ro is now with Department of Biomedical-Engineering, School of Medicine, Pusan National University. Beom-eo, Mul-gum, Yangsan, South Korea. (e-mail: jhro@pusan.ac.kr).

G. R. Jeon is now with Department of Biomedical-Engineering, School of Medicine, Pusan National University. Beom-eo, Mul-gum, Yangsan, South Korea. (e-mail: grjeon@pusan.ac.kr).

So, the monitoring and classifying the human movement is important. In the past, the ambulatory measurement of the physical activity was based on various motion sensors such as pedometers and actometers. Recently the accelerometer has been employed to facilitate such long-term monitoring of human motion by using the wearable sensor unit [1], [2]. And, many of systems utilized the multiple accelerometer units which are placed at various sites of the body to assist their detection of activities such as walking, ascending and descending stairs, and cycling [3], [4]. And, in another research, a kinetic sensor, which is composed of one miniature piezoelectric gyroscope and two miniature accelerometers, was used to analyze the human motion [5]. Furthermore, new systems were developed to identify the static and dynamic activity using 3-axis accelerometer [6], [7].

In this study, the parameters were suggested and applied to algorithm for detecting falls during daily activity using the difference of two tri-axial accelerometers.

II. Methods

In this study, the attachable module was developed using two tri-axial accelerometers, which were attached on the chest and abdomen to investigate the change of z-axis. The flow chart of the fall detection system was shown in Fig. 1. The acquired 3-axial accelerometers signals using a signal sampling rate of 128Hz and 10 bit resolution were transferred to PC by Bluetooth. The transferred data was displayed and saved by Labview. The saved data was processed and the value of parameters was evaluated, which could be applied to the fall detection algorithm.

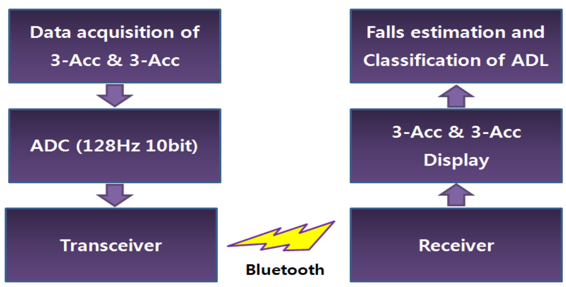

Fig. 1 The flowchart of implemented falls detection system

A. The fall detection algorithm

Strong impacts are generated with fall by crashing the obstacles or floors. The falls can be detected by the amount of impact (SVM) which is study by Mathie [28].

B. SVM function

As shown above, vector sum is effective parameter to detect the impact like falls. 4g was set as the threshold of falls by repetitive experiments.

$$SVM = \sqrt{x_i^2 + y_i^2 + z_i^2} \tag{1}$$

C. Fall detection using defference between two 3-axial accelerometers

The one accelerometer signal would be changed according to the attached site of accelerometer. When falls occur, a rotary motion and the z-axial acceleration signal by gravity acceleration was generated. As a result, two tri-axial accelerometers were attached on the chest and abdomen. The large amount of acceleration could be generated in case of bends and falls while the difference between two accelerometer signals would be 0g during translations like jumps. In other words, the signals of accelerometers, which are attached on the other sites, will be different as the body rotates when falls occur. The differences were generated by the acceleration signal according to the angular velocity during falls, the impacts occurred running into on gounds or obstables.

In the study, the acceleration difference between the accelerometers on the chest and abdomen was suggested as the important parameters for fall detection.The maximum of z-axial acceleration signal was designated as Diff_Z, and the integration of 0.25 second before and after the Diff_Z was designated as Sum_diff_Z. As a result of the repetitive experiment, the thresholds of Diff_Z and Sum_diff_Z were set 1.25g and 15 respectively.

D. Fall detection algorithm

In the study, falls were detected using the acceleration difference between the accelerometers on the chest and abdomen. Diff_Z was the maximum of z-axial acceleration signal, and Sum_diff_Z was the integration of 0.25 second before and after the Diff_Z. The fall detection algorithm was suggested by SVM1, SVM2(measured from each accelerometer) and the suggested parameters, Diff_Z and Sum_diff_Z, the flowchart of which was presented in Fig. 2.

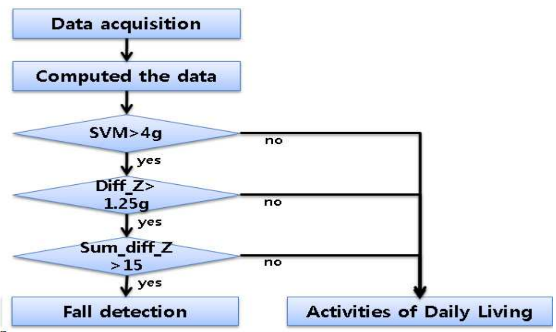

Fig. 2 Falls detection algorithm

TABLE I
THE PROTOCOL OF FALLS

Protocols	Action Sequence
falls	Stand(5s) – front falls
	Stand(5s) – back falls
	Stand(5s) – left falls
	Stand(5s) – right falls
	Walking(5s) – front falls
	Walking(5s) – back falls
	Walking(5s) – left falls
	Walking(5s) – right falls
ADL	Stand(5s) – sit(10s) – stand(5s)
	Stand(5s) – lying(10s) – stand(5s)
	Stand(5s) – lying on bed(10s) – stand(5s)
	Stand(5s) – sit on chair(10s) – stand(5s)
	Stand(5s) – slow walking(10s) – stand(5s)
	Stand(5s) – normal walking(10s) – stand(5s)
	Satnd(5s) – walking with cane(10s) – stand(5s)
	Stand(5s) – jogging(10s) – stand(5s)
	Stand(5s) – jump – stand(5s)
	Stand(5s) – jump down – stand(5s)
	Stand(5s) – up stairs(10s) – down stairs(10s) – stand(5s)

III. RESULTS

In the study, the developed acceleration modules were attached on the chest and abdomen respectively, and the experiment was performed according to the protocol (Table I). The measured acceleration data was processed to acquire SVM1, SVM2, Diff_Z, and Sum_diff_Z. The other parameter was also suggested using SVM1, SVM2, Diff_Z, and Sum_diff_Z to distinguish fall from daily activity more accurately. The thresholds of these parameters were set on the middle of the minimum of fall and maximum of daily activity. The threshold of SVM1 was 4g, the threshold of SVM2 was 4g, the threshold of diff_Z was 1.25g, and the threshold of Sum_diff_Z was 15. The result of experiments according to the protocol was shown in the Fig. 3 to 10 to distinguish falls from daily activity, and the average and standard deviation was presented in Table II.

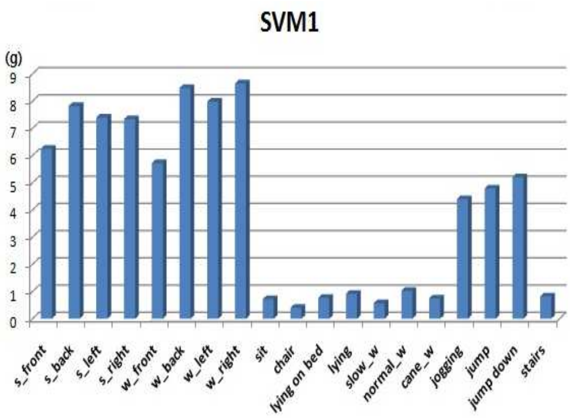

Fig. 3 The mean values of SVM1 according to the proposed experimental protocols

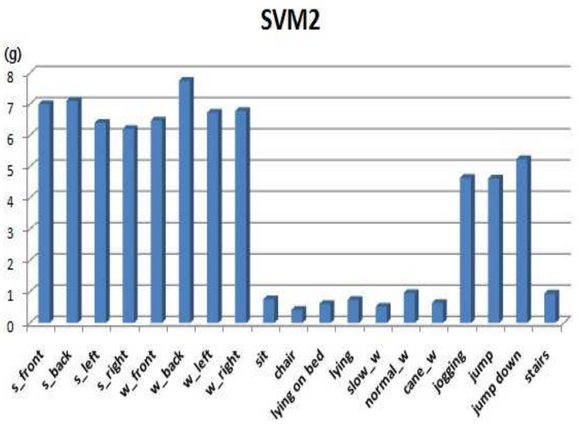

Fig. 4 The mean value of SVM2 according to the proposed experimental protocols

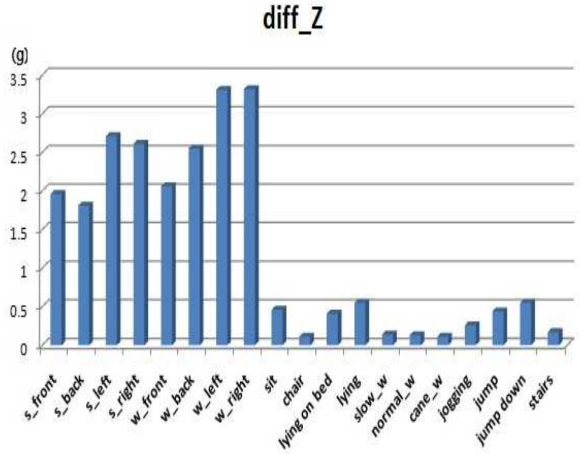

Fig. 5 The mean values of diff_Z accordinig to the proposed experimental protocols

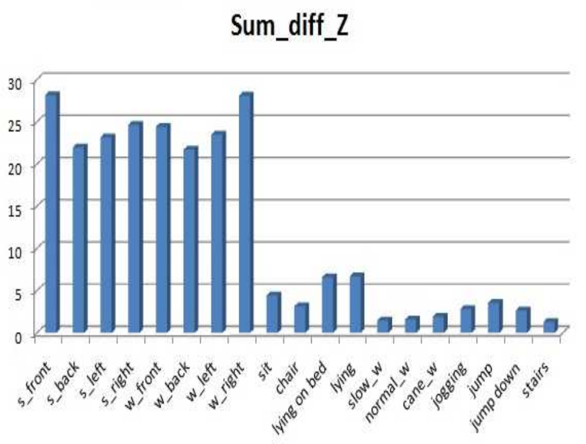

Fig. 6 The mean values of Sum_diff_Z according to the proposed experimental protocols

TABLE II
THE MEASURED MEANS AND STANDARD DEVIATIONS OF EACH PARAMETERS ACCORDING TO THE ESTABLISHED EXPERIMENTAL PROTOCOLS

		SVM1		SVM2		diff_Z		Sum_diff_Z	
		M	SD	M	SD	M	SD	M	SD
stand to falls	front	6.25	0.58	7.00	0.91	1.96	0.54	28.17	4.98
	back	7.82	1.41	7.11	0.78	1.81	0.51	21.98	3.91
	left	7.40	1.29	6.40	1.08	2.71	0.40	23.18	3.23
	right	7.34	1.00	6.21	1.09	2.61	0.78	24.63	3.70
W to falls	front	5.72	0.80	6.48	0.70	2.06	0.56	24.41	4.26
	back	8.49	1.07	7.75	0.76	2.55	0.29	21.70	4.23
	left	7.98	0.73	6.73	0.98	3.31	0.46	23.48	3.45
	right	8.65	0.72	6.78	0.71	3.32	0.53	28.10	2.50
ADL	sit	0.72	0.11	0.76	0.10	0.46	0.17	4.45	1.05
	chair	0.40	0.08	0.42	0.07	0.11	0.05	3.15	0.64
	lying	0.77	0.09	0.61	0.09	0.41	0.20	6.59	0.68
	bed lying	0.92	0.14	0.74	0.08	0.55	0.25	6.69	0.68
	slow_W	0.57	0.09	0.52	0.09	0.14	0.09	1.48	0.51
	normal_W	1.03	0.09	0.96	0.11	0.13	0.05	1.58	0.24
	cane W	0.75	0.10	0.64	0.07	0.11	0.08	1.92	0.28
	jogging	4.40	0.77	4.64	0.93	0.26	0.26	2.84	0.70
	jump	4.79	0.56	4.62	0.40	0.44	0.44	3.56	1.02
	jump down	5.20	0.62	5.24	0.67	0.55	0.55	2.67	0.56
	stairs	0.82	0.14	0.94	0.14	0.17	0.17	1.30	0.18

M = mean, W = walking

The fall detection rate was analyzed by threshold of SVM1, SVM2, diff_Z and Sum_diff_Z. The results of experiments were shown in figure 7-10. The result of fall detection algorithm was shown in table III.

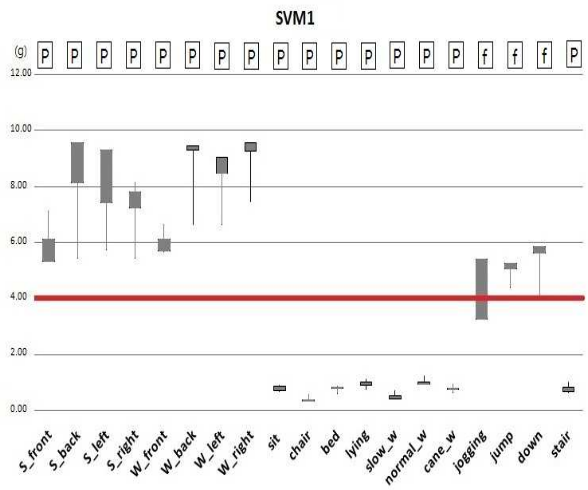

Fig. 7 The result of falls detection using SVM of accelerometer attached on the chest region

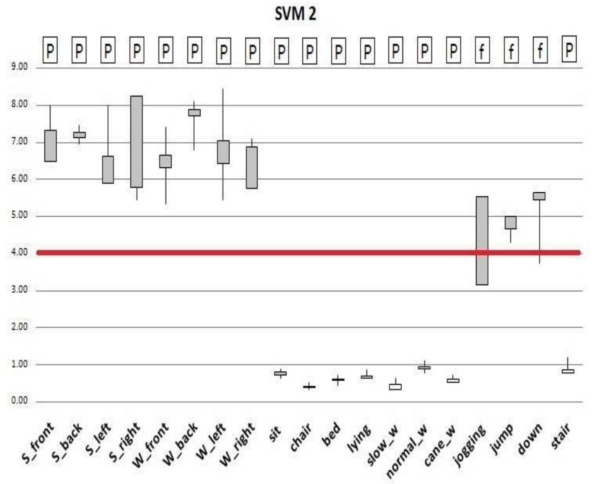

Fig. 8 The result of falls detection using SVM of accelerometer attached on the abdomen region

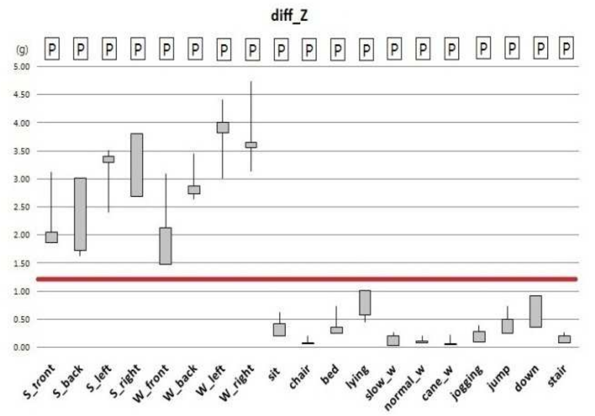

Fig. 9 The result of falls detection using diff Z

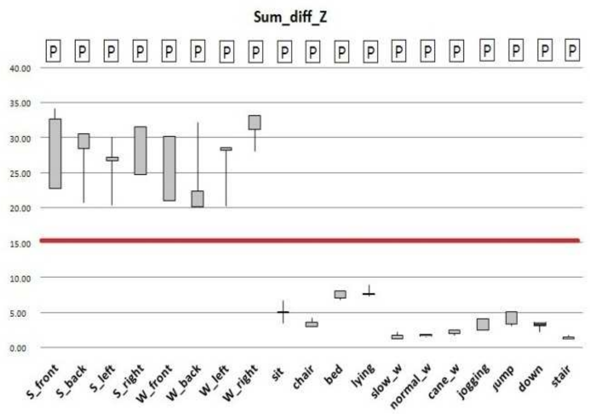

Fig. 10 The result of falls detection using Sum_diff_Z value

TABLE III
THE RESULT ON SUCCESS OR FAILURE OF FALLS DETECTION APPLIED TO FALLS DETECTION ALGORITHM USING ESTABLISHED EXPERIMENTAL PROTOCOL

		SVM1	SVM2	diff_Z	Sum_diff_Z
stand to falls	front	P	P	P	P
	back	P	P	P	P
	left	P	P	P	P
	right	P	P	F	P
walking to falls	front	P	P	P	P
	back	P	P	P	P
	left	P	P	P	P
	right	P	P	P	P
ADL	sit	P	P	P	P
	chair	P	P	P	P
	lying	P	P	P	P
	lying on bed	P	P	P	P
	slow walking	P	P	P	P
	normal walking	P	P	P	P
	walking with cane	P	P	P	P
	jogging	F	F	P	P
	jump	F	F	P	P
	jump down	F	F	P	P
	stairs	P	P	P	P

IV. CONCLUSION

In the study, the fall detection algorithm was suggested during daily activity. Fall detection parameters were suggested using the difference between the two-accelerometers attached on the chest and abdomen, and the fall detection algorithm was developed using these parameters.

SVM1 and SVM2 of each accelerometer was selected as parameters which reflect the amount of the impact when falls occur. Diff_Z was selected as a parameter, which means the maximum of two accelerometer difference. Sum_diff_Z was the integration of 0.25 second before and after the Diff_Z, which was used for fall detection algorithm. The thresholds were evaluated after the experiments were performed according to the protocol.

The algorithm for fall detection during daily was developed using these parameters. The experiments were performed according to the suggeted protocol to evaluate the reliability of this algorithm. Falls of 76% were detected during daily activity by using SVM1 and SVM2, but falls of 100% was detected by using algorithm using Diff_z and Sum_diff_Z. The developed algorithm could distinguish falls from jogging, and jump.

As a result, the algorithm of suggested parameters could detect falls 100% apart from a variety of daily activity.

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Ahyoung Jeon was born in Busan, South Korea on 10th of May, 1983. She received the B. D. in the Department of Biomedical-engineering from Inje University in 2006. She received the Master degree in the Department of Biomedical Engineering, from Pusan National University in 2008. .She is currently in the Doctor’s course in the Department of Biomedical Engineering, Pusan National University and is interested in Biomedical Signal Processing.

Geunchul Park was born in Jeongju, South Korea on 26th of September, 1976. He received the B. D. in the Department of Computer Engineering from Pukyoung National University in 2002. He received the B. D. in the Department of Electronic & Information Engineering from Korea University in 2004. He is currently in the doctor’s course in the Department of Biomedical Engineering, Pusan National University and interested in Biomedical and computer engineering.

Jung-hoon Ro was born in Pusan, Korea on August 2, 1961. He received the M.S. degree in the Department of Physics from Pusan National University in 1984. He received the Ph. D. degree in the Department of Physics from Pusan National University in 2001. His research interests include Biophysics, Mathematical biology and Medical engineering. He is currently a professor of Department of Biomedical Engineering, School of Medicine, Pusan National University and director of Department of Biomedical Engineering in Pusan National University Hospital.

Gye-rok Geon was born in Pusan, Korea on January 1, 1953. He received the M.S. degree in the of Electronic Engineering from Pusan National University in 1981. He received the Ph.D. degree in the Department of Electronic Engineering in 1992 from Dong-a University. He was responsible for the Korea Health 21 R&D Project both experimental and theoretical aspects of the project. He is currently a Professor of Department of Biomedical Engineering, School of Medicine, Pusan National University.