Fall Detection of the Elderly in the Activities of Daily Living

Taekyeong Lee, Youngho Lee, Jaemin Kim, Soonmoon Jung, Dongwook Yang, Beomgeun Jo, Jeongwoo Lee and Junghwa Hong*
Dept. of Control and Instrumentation Engineering
Korea University
Sejong, South Korea
E-mail: kenya9802, astrots, jaemini, moonol3, tellmeting, bumga91, jeong8523, *hongjh32@korea.ac.kr

***Abstract*—Falling of the elderly has become an important issue in today's aging society. As a result, active protecting devices are being developed to protect the fallers' body from severe injuries. The key task of the protecting devices is the exact detection of a falling event in Activities of Daily Living (ADL). In this study, a methodology for detecting the fall event is proposed using the accelerometer and the gyro-sensor of an active protecting device. The results of fall detection using the methodology proposed in this study were detected before impact and are accurate more than 99.9 % for ADL.**

Keywords-fall detection; double threshold algorithm; ADL; fall injury; Savitzky-Golay filter.

I. INTRODUCTION

More than 30% of the elderly over the age of 65 years have experienced at least one fall per year [1]-[2], which significantly deteriorates quality of life. Furthermore, approximately 15,800 adults over 65 years of age died from injuries related to unintentional falls in the USA. Also, about 1.8 million people over 65 years of age who had non-fatal injuries visited the emergency departments and spent $19 billion in the year 2000 in the USA [3]. Falls of the elderly while doing different activities occur in the bath room (26%), in the living room or bed room (26%), on the stairs (10%), in the hall way (8%), and outside of the house (20%) [4]. Based on movements, the elderly fall during level walking (43 %), going in-and-out of a bathroom (30%), sitting down and standing up from a seating position (13%), and in ascending and descending stairs (15%) [4]. The postural imbalance in activities and movements is caused by tripping or slipping (27.4%); surrounding hazards, for example, wet or uneven floor (21.8%); misjudging, overbalancing, or over-reaching (17.8%); and fainting, dizziness, illness, or legs giving way (17.7%) [5], which are part of the Activities of Daily Living (ADL). Many of these falls may be avoided if fall risk assessment and prevention tools where available as an integral part of ADL. However, the fall risk assessment is still not completed at this moment. Currently, active protecting devices for people falling are being developed to protect the person's body from severe injuries as an alternative or for a practical purpose. For these developments, the exact detection of the fall is important for active control of the protecting devices. Since the falls involve very complex body movements, a precise detection of the fall events is a very challenging task, particularly for industrial applications. In this study, a methodology for detecting the fall events is proposed using an accelerometer and a gyro-sensor for an active protecting device from the fall injuries.

The rest of the paper is structured as follows. In Section 2, the fall experimental method in ADL to obtain data and the fall detection algorithm are explained. In Section 3, the results of fall detection using proposed algorithm are explained and a conclusion is given.

II. MATERIALS AND METHODS

A. *The fall experiments in ADL*

21 male subjects participated in the experiment to obtain fall data. The 3D accelerometer (LIS3DSH, ± 16 g, 0.73 mg/digit), gyro-sensor (L3G4200D, ± 2000 Deg/sec, 70 mdps/digit), and compass (HMC5883L, ± 8 Gauss, 5 milli-gauss) were put on the sacrum of the subjects for the fall experiments during level walking, sitting down, ascending and descending stairs. In addition, the 3D kinematics of the lower limbs and upper body during the locomotion or movements were measured using a stereo photogrammetric system, which consisted of seven infrared emitting Charge Coupled Device (CCD) cameras (Motion Analysis System, USA). The data from the sensors was transmitted in a wireless manner using Radio Frequency (RF) (nRF2401+, 2.4GHz). Fig. 1 shows the experimental setups and an example of the fall experiments. A slider was used to induce a fall perturbation.

B. *The fall detection algorithm*

In order to be applied to active protecting devices, fall detection must be precisely performed just after the start of the fall event, which is, when the falling person cannot return to the balanced posture. For fall detection, the accelerations, angular velocities, and angle at the sacrum, thus pelvis, were used. Based on the resulting acceleration (see Figure 2) a fall event could be classified as Fall 1- the period from the start of the fall to the lowest peak, and Fall 2- the period from the lowest peak to the impact. For perfect protection of the falling persons' body, the detection should be accomplished within Fall 1. At the same time, the detection must be capable of discerning real fall from movements in ADL. In

 ISBN: 978-1-61208-549-4

this study, the experimental data collected from ADL, such as the level, slope, and stair gait, as well as the sit down and up motions, were statistically analyzed to obtain the fall criteria. The fall criteria were determined based on the superior-inferior and resultant accelerations, pelvic tilt and obliquity angles, and resultant angular velocity. The signals from the sensors were processed for the reduction of moving artifacts and random noises using the Savitzky-Golay filter [6]. Then, the onset of the fall using the criteria was detected after applying the double threshold algorithm [7].

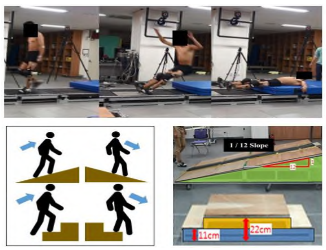

Figure 1. The fall test and experimental equipment

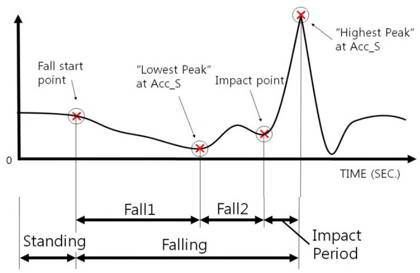

Figure 2. The fall event based on the resultant acceleration

III. RESULTS AND CONCLUSION

After analyzing the data collected from movements in ADL, the summation of acceleration at the sacrum could detect almost all movements of the fall, such as for level walking, stairs, slope, sit up and down, except the falls happening during running. The pelvic tilt, superior-inferior acceleration, and resultant angular velocity could discern real falls from all movements in ADL, except in sit up and down, and lay down cases.

Fig. 3 shows the flow for detecting a fall. In the case of level walking, the fall onset time after applying the perturbation by the slider was faster than the lowest peak point by as much as 0.105 sec. In addition, the fall onset time by the bump trap was earlier than the lowest peak point by as much as 0.329 sec. In general, the fall onsets by applying all perturbations were detected before the lowest peak points for all movements in ADL situations. Table 1 shows threshold ranges and detecting capabilities of the fall criteria. STS means motions in the sit down and up. The detections were accurate more than 99.9 % for 5 categories in ADL, as indicated in Table 1, based on the field experiments, which were performed for the elderly in a retirement home. Further research is required for the detecting capabilities in case of non-ADL situations.

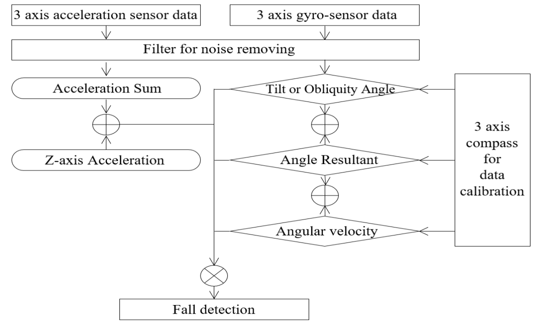

Figure 3. The fall detection algorithm flow chart

TABLE 1. THRESHOLD RANGE ANALYSIS RESULTS IN ADL

	ADL (Activities of daily living)							Threshold range
	Walking	Running	Slope	Stair	Stumble	STS	Lie down	
Acc_Z	○	X	○	○	○	X	X	0.23~0.35 g
Acc_Sum	○	X	○	○	○	○	○	0.36~0.4 g
AngV_R	○	○	○	○	○	X	X	105~135 Deg/sec
Tilt	○	○	○	○	○	X	X	26~58 Deg
Obliquity	○	○	○	○	○	○	○	21~43 Deg
Angle_R	○	○	○	○	○	X	X	30~46 Deg

○: Distinct motion from fall by IMU sensor
X: Not distinct motion from fall by IMU sensor

ACKNOWLEDGMENT

This work was supported by the Industrial Strategic Technology Development Program (No.10048732) funded by the Korean Ministry of Trade, industry & Energy, and the Korea Health Technology R&D Project (HI15C1025) funded by the Korean Ministry of Health & Welfare.

REFERENCES

[1] S. D. Berry and R. R. Miller, "Falls: epidemiology, pathophysiology, and relationship to fracture," Current osteoporosis reports, 2008, vol. 6, pp. 149-154.

[2] S. W. Muir, K. Berg, B. Chesworth, N. Klar, and M. Speechley, "Balance impairment as a risk factor for falls in community-dwelling older adults who are high functioning: a prospective study," Physical therapy, 2010, vol. 90, pp. 338-347.

[3] A. J. Sai, J. C. Gallagher, L. M. Smith, and S. Logsdon, "Fall predictors in the community dwelling elderly: a cross sectional and prospective cohort study," J Musculoskelet Neuronal Interact, 2010, vol. 10, pp. 142-150.

[4] W. L. Watson and R. Mitchell, "Conflicting trends in fall-related injury hospitalisations among older people: variations by injury type," Osteoporosis Int, 2011, vol. 22, pp. 2623-2631.

[5] A. J. Milat et al, "Prevalence, circumstances and consequences of falls among community-dwelling older people: results of the 2009 NSW falls prevention baseline survey," New South Wales public health bulletin, vol. 22, pp. 43-48, 2011.

[6] J. Luo, K. Ying, and J. Bai, "Savitzky-Golay smoothing and differentiation filter for even number data," Signal Processing, 2005, vol. 85, pp. 1429-1434.

[7] J. Vartiainen, J. J. Lehtomaki, and H. Saarnisaari, "Double-threshold based narrowband signal extraction," In Vehicular Technology Conference 2005. VTC 2005-Spring. 2005 IEEE 61st, IEEE, Jan. 2005, Vol.2, pp. 1288-1292.