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자이로센서를 이용한 낙상 방향 탐지 시스템 구현

(Implementation of Fall Direction Detector using a Single Gyroscope)

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요 약 낙상은 응급상황이 발생한 노인에게는 적절한 시간이 응급처치가 요구되는 주요한 상태이다. 응급상황의 경우, 낙상의 발생과 낙상 방향은 초기 상태의 응급처치를 위한 중요한 정보로 사용될 수 있다. 본 논문에서는 낙상의 발생과 방향을 정확히 판단하는 시스템을 구현하였다. 낙상과 방향을 감지하기 위하여 하나의 3축 자이로도센서(MPU-6050)를 사용하였다. 제안된 낙상 방향 알고리듬은 X와 Y축 가속도값을 사용하여 낙상여부와 앞, 뒤 좌 ,우 및 중간방향을 포함한 8개 낙상방향을 감지하였다. 제안된 시스템은 선택적인 가속도 임계값을 사용하여 97% 이상의 낙상과 낙상방향을 성공적으로 감지함을 보였다.

핵심주제어 : 낙상방향감지알고리듬, 자이로센서

Abstract Falling situations are extremely critical events for the elderly person who requires timely and adequate emergency service. For the case of emergency, the information of falling and its direction can be used as an important information for the first aid treatment of the injured person. In this paper, a falling detection system which can pinpoint the falling event with the falling direction is implemented. In order to detect the fall situation, a single gyroscope (MPU-6050) is used in the developed system. The fall detection algorithm that can classify 8 different fall directions such as front, back, left, right and in between falls is proposed. The direction of the fall is decided by examining the acceleration values of X and Y directions of the sensor. It is shown that the proposed algorithm successfully detects the falling event and the falling direction with probability of 97% for a selected value of acceleration threshold.

Key Words : Fall direction detection algorithm, Gyroscope

1. Introduction

Recently, numerous researches have been done to identify the fall event. In order to detect the fall event, inertial units such as accelerometer, gyroscope and magnetometer are used to pinpoint the fall event or to identify daily activities such as walking, falling and other movements. The algorithm proposed in [1] uses tri-axial accelerometer and tri-axial gyroscope data measured from the waist to distinguish between fall, possible fall, and

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activity of daily living. The decision between fall and possible fall is done by the posture information from the waist and ankle worn devices. values to distinguish fall directions. In [2], a barometric pressure sensor is used to measure altitude to differentiate a fall with a normal daily life activities. A practical real time fall detection system running on a smartwatch (F2D) is presented in [3]. A 3-axis accelerometer sensor embedded in the android smartphone is used to detect the fall. The development of an automatic fall detection/alert system is described in [4]. The system acquires information relating fall of an elderly via a body sensor unit and transmit it to an android mobile phone. A system utilizing the Wireless Intelligent Personal Communication Node (W-iPCN) for analyzing heart activities and detecting sudden fall situations of a remote patient is presented in [5]. Electrocardiography (ECG), accelerometer and gyroscope data analysis to show the feasibility and capability of the W-iPCN. An approach to fall detection with accelerometers that exploits posture recognition to identify postures that may be the result of a fall is presented in [6]. Nine placements of up to four sensors were considered: on the waist, chest, thigh and ankle. An automatic fall detection system consisting of a triaxial accelerometer and a smart phone is evaluated in [7].

In this paper, a single gyroscope is used to detect a fall with the direction of a fall. The direction of a fall is divided into 8 directions such as Front, back, Left , Right and in between directions. The rest of the paper is organized as follows. Section 2 explains the fall detection system hardware and the fall detection algorithm. In Section 3, the fall detection measurements are summarized with various threshold values. Finally, a concluding remark is given in Section 4.

2. Fall Detection System

2.1 Hardware Description

A fall detection system which composed of a gyroscope (MPU-6050), a microcontroller (UST-MPB-Atmega128_v5, US-Technology) with 10 bit analog-to-digital converter (ADC), a bluetooth module (FB155BC, Firmtech) was implemented as shown in Fig. 2. A switch is included to set a new fall test interrupt. An LED is used to alarm when a fall occurs.

The MPU-6050 features three 16-bit analog-to-digital converters (ADCs) for digitizing the gyroscope outputs and three 16-bit ADCs for digitizing the accelerometer outputs. For precision tracking of both fast and slow motions, the parts feature a user-programmable gyroscope full-scale range of ±250, ±500, ±1000, and ±2000°/sec (dps) and a user-programmable accelerometer full-scale range of ±2g, ±4g, ±8g, and ±16g. In this paper, the acceleration range of ±16g is used.

The axis orientation of the MPU-6050 is shown in Fig. 1. When a fall occurs, there is a sudden change in acceleration in either X or Y directions. Also, there is a sudden change in pitch and yaw angle. The developed system will monitor the sudden acceleration changes in X and Y directions. And, the system monitors the change of the anlge of the pitch and yaw when an actual falling occurs. The developed system not only detect a fall event and but also the angle of the falling direction. In this paper, the system will decide the falling direction as one of the 8 direction such as Front, Back, Left, Right, Front_Left, Front_Right, Back_Left and Back_Right as shown in Fig. 3.

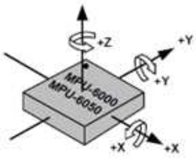

Fig. 1 MPU-6050 Axis Orientation

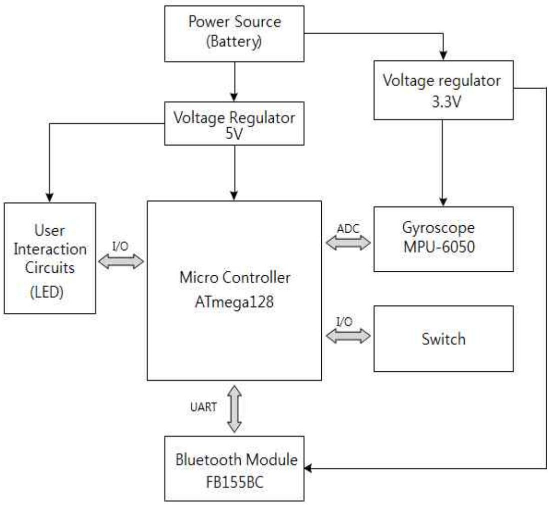

Fig. 2 Block diagram of a Fall Detection System

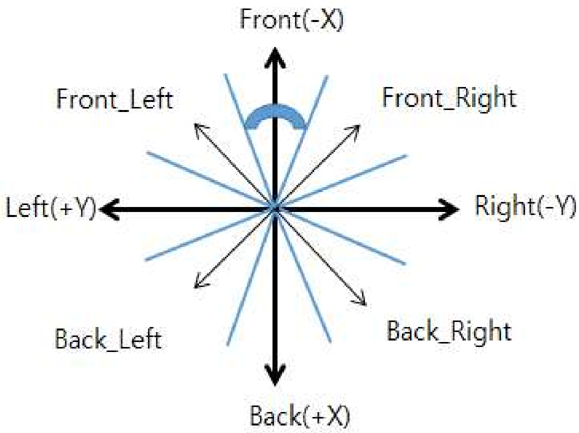

Fig. 3 Fall Direction Orientation

2.2 Fall Detection Algorithm

The fall detection algorithm works as follows. First of all, in order to detect a falling event, the algorithm is looking for the acceleration threshold values in X and Y direction, A_X and A_Y. At the same time, the value of the roll, θ_R, and the value of pitch, θ_P, are also monitored. When either one of the accelerations values A_X, A_Y are greater than the threshold value of a_{th}. It is assumed that an actual fall is assumed. At the same time, one of the roll or pitch values is greater than the threshold value, θ_{th}, a fall is assumed. To detect a fall is the one of the following condition should be satisfied.

$$|A_X| \geq a_{th} \text{ or } |A_Y| \geq a_{th} \text{ or } \theta_P \geq \theta_{th} \text{ or } \theta_R \geq \theta_{th}$$

In order to detect the falling direction, the angle of the fall is calculated by the following equation.

$$\theta_{Fall} = \tan^{-1}\left(\frac{\theta_P}{\theta_R}\right)$$

From the obtained falling angle, the fall direction is determined by the decision regions as shown in Fig. 3. The specific angles of the

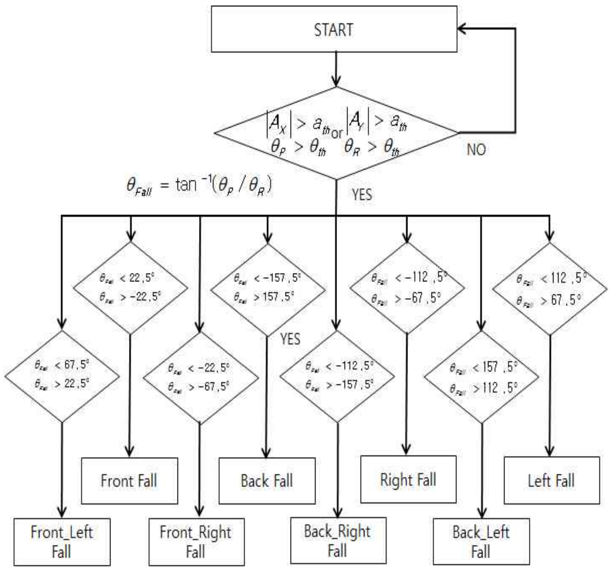

Fig. 4 Fall Detection Algorithm

eight decision regions such as Front, Back, Right, Left, Front_Left, Front_Right, Back_Right, and Back_Left are shown in Fig. 4.

3. Measurements Results

For the typical falling of 8 directions, the accelerations of X and Y direction and the angles are shown from Fig. 6 to Fig. 13. As shown in Fig 6, the acceleration in X direction has a large negative peak whereas small acceleration variation in Y direction is observed for the front fall. The falling angle is determined at the time instance when the either acceleration values or the falling angles exceed the designated threshold values of a_{th} and θ_{th}. The falling angle at the time of the fall detection is about -5^o which is equivalent to the Front fall. For the case of the Right fall as shown in Fig. 9, the acceleration in Y direction has a large negative peak whereas small acceleration variation in X direction is observed for the Right fall. The falling angle is determined at the time instance when the either acceleration values or the falling angles exceed the designated threshold values of a_{th} and θ_{th}. The falling angle at the time of the fall detection is about -90^o which is equivalent to the Right fall. Similar results for the rest 6 different fall directions are shown in Fig. 7 to Fig. 13.

In order to measure the detection rate of the falling event and the direction of the fall, the test unit shown in Fig. 5 is fallen from 50cm above the surface of the table toward the intended fall direction. As shown in Table 1, 3 different threshold values of 2g to 4g with angle threshold of $\theta_{Th}=40^o$ are used to measure the performance of the algorithm. Similarly, the fall detection performance of

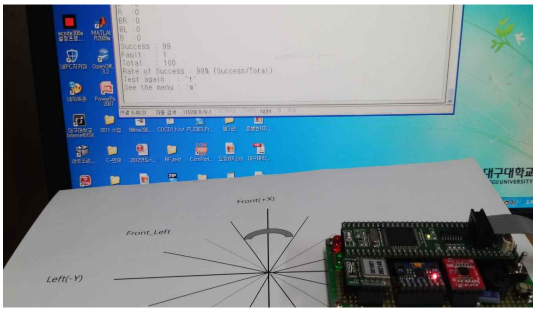

Fig. 5 Fall detection sysyem

different cases of $\theta_{th}=50^o$ is summarized in Table 2. For a given fall direction and a threshold, 50 fall trials are performed to measure the performance of the system. As shown in Table 1, for the case of $\theta_{th}=40^o$, the proposed algorithm can detect a fall event and the direction with at least 87% regardless of the threshold, V_{Th}, for the 8 directions of the fall. For the case of the large threshold such as $A_{Th}>4$, the algorithm can miss an actual fall with high probability. For the case of a small threshold such as $A_{Th}<2$, the algorithm can detect casual activities as a fall. For the threshold values of 2g and 3g, the detection rate of 97% and 93% is achieved, respectively.

Table 1 Fall detection rate for 8 Fall directions with $\theta_{th}=40^o$

Fall Direction	Threshold(a_{th})		
	2.0g	3.0g	4.0g
Front	50/50	46/50	43/50
Front_Left	48/50	46/50	42/50
Front_Right	48/50	45/50	43/50
Back	50/50	47/50	44/50
Back_Left	48/50	45/50	43/50
Back_Right	48/50	48/50	42/50
Left	50/50	47/50	43/50
Right	49/50	46/50	44/50
Detection Rate	98%	94%	89%

Table 2 Fall detection rate for 8 Fall directions with $\theta_{th} = 50^o$

Fall Direction	Threshold(a_{th})		
	2.0g	3.0g	4.0g
Front	49/50	48/50	44/50
Front_Left	48/50	45/50	42/50
Front_Right	47/50	45/50	41/50
Back	50/50	48/50	42/50
Back_Left	47/50	46/50	40/50
Back_Right	48/50	45/50	41/50
Left	50/50	46/50	43/50
Right	49/50	45/50	44/50
Detection Rate	97%	93%	87%

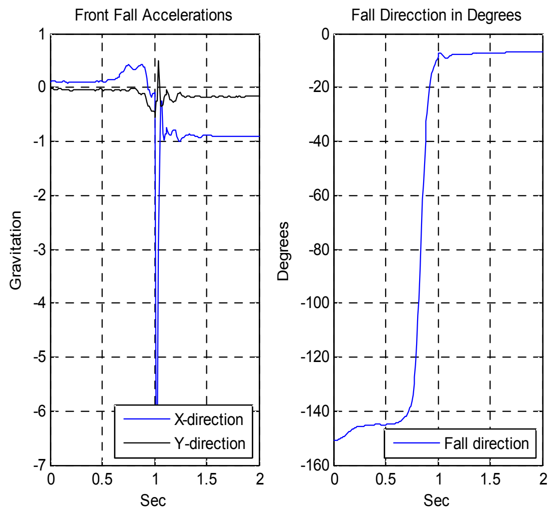

Fig. 6 Typical Front Fall Measurement

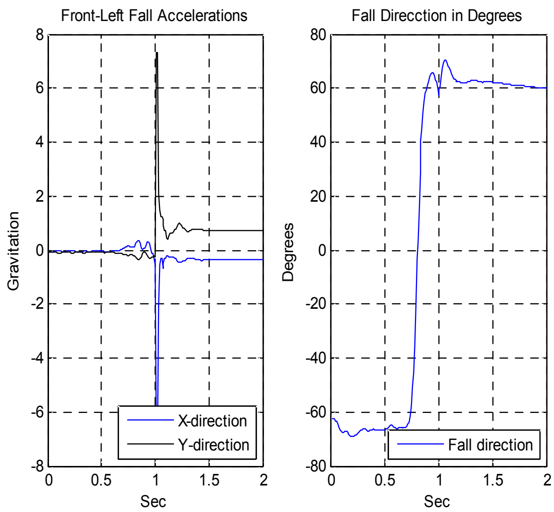

Fig. 7 Typical Front_Left Fall Measurement

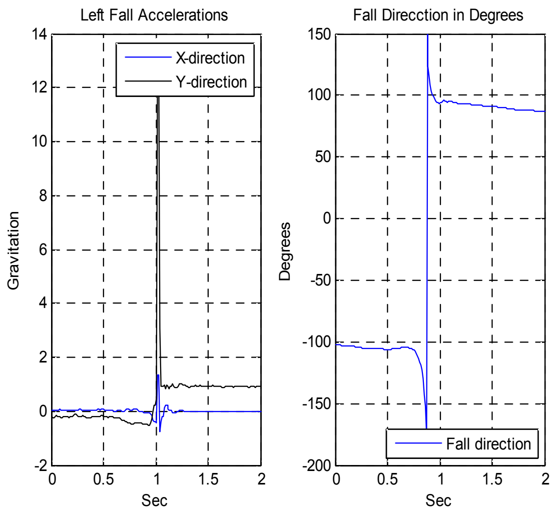

Fig. 8 Typical Left Fall Measurement

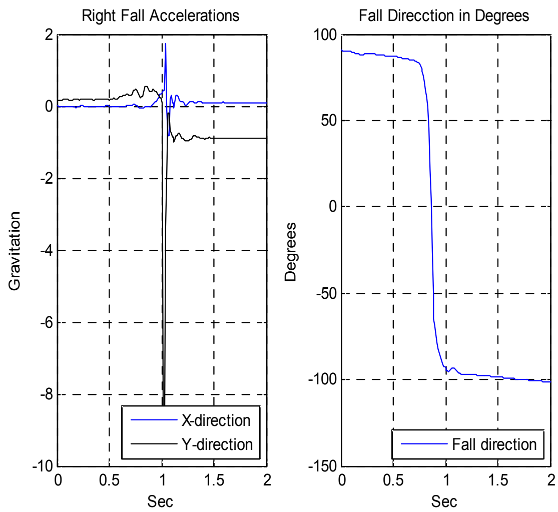

Fig. 9 Typical Right Fall Measurement

4. Conclusion

In this paper, a fall detection algorithm using a single gyroscope is proposed to detect a fall with 8 types of fall directions. In order to detect a fall, a sudden change in X and Y direction accelerations are observed. At the same time, a sudden change in pitch and yaw angle is monitored. A fall is detected when either acceleration values in X or Y direction

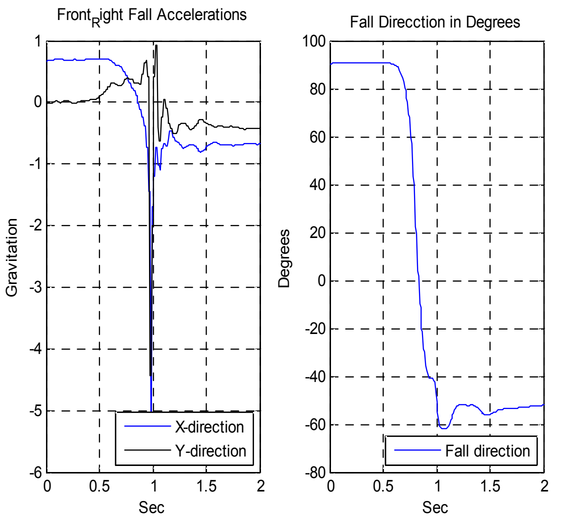

Fig. 10 Typical Front-Right Fall Measurement

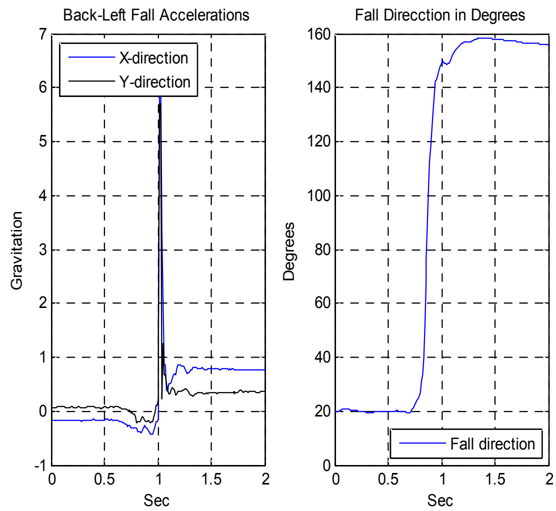

Fig. 12 Typical Back-Left Fall Measurement

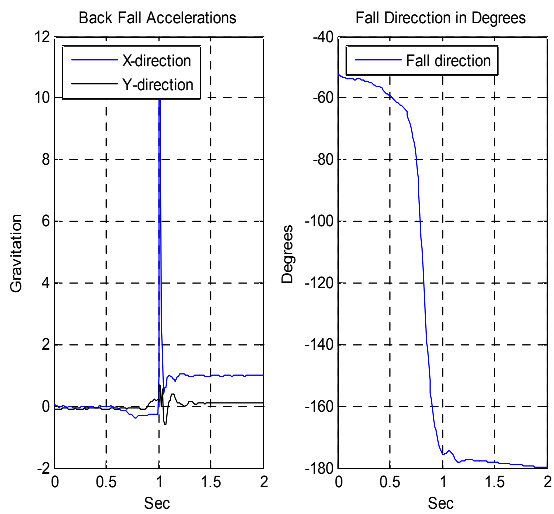

Fig. 11 Typical Back Fall Measurement

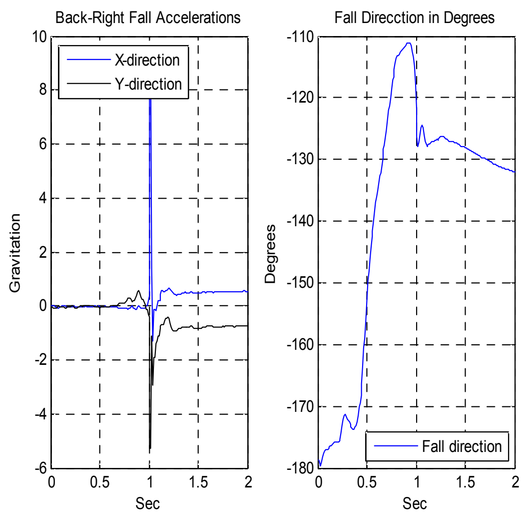

Fig. 13 Typical Back-Right Fall Measurement

or pitch or yaw angle exceeds specified thresholds. For a given fall direction and threshold, 50 falls are performed to measure performance of the algorithm. The proposed algorithm showed that at least 97% of fall detection rate for the given scenario of the fall environment with a acceleration threshold of 2g.

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