A study to demonstrate the use of an air bag device to prevent fall-related injuries

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Abstract— **We sought to develop a fall-related injury prevention system using a telemetry acceleration and angular velocity monitor, and an air bag. In this study, we have developed a fall detection system using both acceleration and angular velocity signals and triggering the inflation of an air bag. Sixteen subjects mimicked falls and their acceleration waveforms were monitored. Then, we developed a fall detection algorithm that could detect signals 300 ms before the fall. This signal was used as a trigger to inflate the air bag to a capacity of 2.4 L. While the proposed system can aid in preventing fall-related injuries, further development is needed to miniaturize the inflation system**

I. Introduction

Falls are a serious problem for the elderly and others prone to falls. One-third to one-half of the population aged 65 and over have experienced falls. Half of the elderly people who fall do so repeatedly. Falls are complex phenomena, suggesting present disease and predicting future disability. They are caused by interactions between the environment and dynamic balance, which is determined by the quality of sensory input, central processing, and motor responses. Falls are the leading cause of injury in older adults and the leading cause of accidental death in those over age 85. Even fall that do not result in injury can have serious consequences. Psychological trauma and fear of falling can produce a downward spiral of self-imposed reduced activity, leading to loss of strength, flexibility, and mobility, thereby increasing the risk of future falls and injuries.

To prevent the fall, the hip protector is usually used and we found the effectiveness of usage. However the attachment of hip protector is rather trouble. The simple fall detection system has been developed by several researchers. Mainly the accelerometer and angle velocity sensor are used to detect the fall [1-3] These researches were conducted only the detetion of falls. The main goal is the prevention of falls, We sought to develop a means to reduce or prevent injuries associated with falls. We have been proposed the measurement of acceleration before and during falls, and then inflating an air bag system [4]. The results indicated all falls were detected but also activated the air bag with daily activities. Thus in this report, we developed a new fall detection algorithm with both acceleration and angular velocity Then we tested a prototype air bag system.

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II. Objects and Method

A. Apparatus

The system consists of the telemetry acceleration and angular velocity monitoring and air bag-inflating parts.

For the acceleration and angular velocity monitoring parts, we designed a system with low power consumption and then evaluated its battery life. The system must be small, light, and able to be worn without discomfort.

To evaluate the movement of the subject, the telemetry system uses to accelerometer and gyro sensor which measures an angular velocity. The monitor consists of an accelerometer, a gyro-sensor, CPU, and transmitter that sends the acceleration waveform to a receiver. The monitor is 7×4×1.5 cm in size and 50 g in weight. The system was designed to operate without any complex setting. The triaxial acceleration sensor and tri-axial gyro-sensor (Gyrocube 3A Oni-23503, O-NAVI , USA) used to measure the movement of the subject. The acceleration and angular velocity waveforms were converted to digital data with 16-bit resolution. The received data were transferred to the CPU and then analyzed with the fall detection algorithm.

The air bag-inflating system consists of inflatable air bags at the neck and hip, a battery, a gas cartridge, sensors to determine acceleration and angular velocity, a triggering mechanism to release the gas, and a relief valve. When the user falls, the sensor detects this and causes the triggering signal to automatically release gas from the cartridge to inflate the air bag assembly and protect the user. The gunpowder was used to release gas. When the triggering signal was generated, 3 V signal transmitted to an ignition. Then the gunpowder exploded to make a small hole at gas cartridge. The invention is superior to presently available

devices because of its automatic deployment, compact size, light weight, ease of use, and reusability.
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B. Fall Detection Algorithm

The main assumption in the algorithm is that of free fall[4]. The acceleration signal toward the fall is like that of the free fall condition Thus, the acceleration value will be zero in free fall. We determined the zero acceleration condition as a sign of a fall. Additionally, the triggering signal operated with angler velocity over 30 degrees/s .

C. Experimental Set-up

1) Verification of the Algorithm

The prototype system was tested by 16 young, healthy subjects (22.1 ±5.4 years old, weight 55.5±6.0 kg, height 166.8± 5.6 cm) who mimicked falls to front, back and lateral direction while wearing the device. Further we investigated to evaluate the algorithm during daily life. This trial was approved by the ethics committee of Chiba University, School of Engineering. Written informed consent was obtained from each subject.

2) Experiment with developed prototype device

We connected monitoring system and airbag and simple back fall was performed to a subject to whether the air bag was inflated or not.

III. RESULTS

A. Verification of the Algorithm

Figure 1 shows typical examples of acceleration and angular velocity signals during falls. Figures 1(a) and (b) show acceleration and angular velocity during forward falling, respectively. In Fig. 1(a), the vertical acceleration of subject at standing was 9.8 m/s^2 (i.e., gravity). After 1.8 s, the large amplitude was the impact acceleration, corresponding to a fall. At 1 s after the start, the acceleration was decreased and was about zero. The arrow in this figure shows the determination of fall in our criterion (±3 m/s^2). In figure 1(b) the angular velocity of forward falling shows that the pitch direction of angular velocity is increased because of swing. Compared with acceleration signal, the pitch signal starts to change at 0.5 s before. Then the pitch angular velocity is a maximum value of 80 degree/s at the fall detection time of 1 s.

We have determined that accelerations between ±3 m/s^2 were free fall conditions and angular velocity was more than 30 degree/s. From this, free fall conditions were found at an average of 203±51 ms before large impact acceleration.

B. Experiment with developed prototype device

Figure 2 shows the inflation of the air bag. When the acceleration changed to zero, the pressure in the air bag was gradually increased before the large impact acceleration occurred.

IV. DISCUSSION

We determined the fall detection time with triaxial accelerations between ±3 m/s^2 and angular velocity more than 20 degree/s . From this, the shortest and longest times were 111 ms and 378 ms, respectively, before large impact acceleration occurred. Thus, the air bag was inflated above this time interval. We have used electromagnetic value in previous study and simulation study was success (in Fig.2 at ref [1]) but in real filed the response of electromagnetic value is not enough to operate. In this period, we used small amount of gunpowder which has been used airbag of automobile. Further study is need to improve the response of electromagnetic valve.

High reliability of such a fall detection system will be needed. This will require discriminating a real fall from similar acceleration signals resulting from events in everyday life. We analyzed the activity signal between ±3 m/s^2, and jumping and running were determined to be “falls.” Although elderly people do not often jump and run, we will need to further refine the algorithm to differentiate jumping and running from genuine falls..

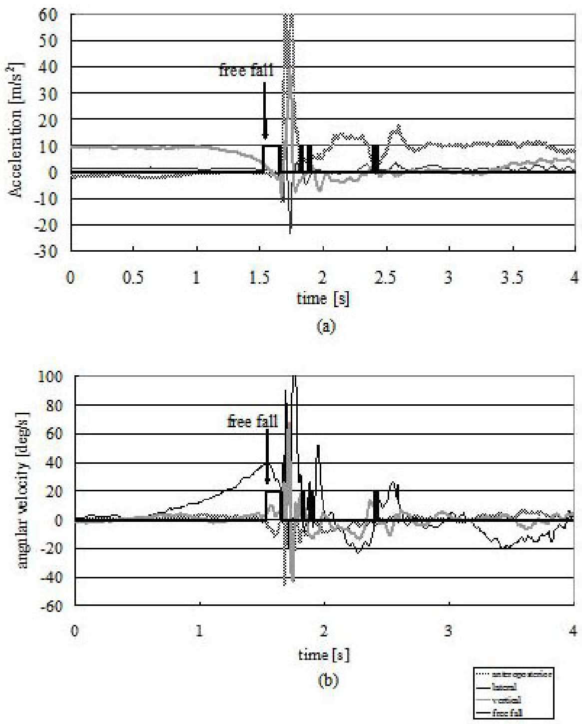

Figure 1. A typical example of acceleration signals(a) and angular velocity signal

Figure 2. Relationship between acceleration signal and air bag inflation

V. CONCLUSION

We developed a neck and hip protecting jacket to absorb the shock of a fall and reduce the impact on the human body by automatically inflating an air bag when a person falls. The heart of this life jacket is a sensor that detects falling. The key characteristics of this fall sensor are its application of a newly developed fall-sensing algorithm, using a triaxial, single-unit accelerometer and angular velocity sensor, and its compact design and battery powered operation that make it readily portable. The use of this fall sensor and an air bag-equipped life jacket may also save lives and reduce injuries from falls at construction sites and other locations

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