Overview of Smart Airbag to Protect the Elderly when Falling

Phan Thanh Thao[1], Vu Xuan Hien[2], Le Thi Mai Anh[1] *
[1] School of Materials Science and Engineering, Hanoi University of Science and Technology, Ha Noi, Vietnam
[2] Falculty of Engineering Physics, Hanoi University of Science and Technology, Ha Noi, Vietnam
**Corresponding author email: anh.lethimai@hust.edu.vn*

Abstract

Population aging is considered one of the prominent trends of the 21st century, manifested by the rapidly increasing proportion of elderly people, which profoundly impacts all aspects of a country, territory, and even globally. As the human body ages and its functions decline, falls become a significant risk to both physical and mental health, causing severe injuries to the elderly and creating a financial burden for their families. Therefore, proactive protective devices are highly valued for development to protect the elderly's bodies from serious injuries in the event of a fall. Airbags, which are known as safety components in automobiles, are designed to deploy during a collision to protect the occupants by reducing the force applied to the body by the dashboard, steering wheel, or any part of an automobile. Smart airbags are also designed to protect the elderly in a fall. The airbag will be inflated rapidly before falling to hug the body area that needs protection as a cushion to reduce the impact force between the body and the ground, thereby reducing injury to the body when falling. This paper provides an overview of research on smart airbags for protecting elderly people when falling, the sensors used in smart airbags, and the parameters that determine the moment of a fall.

Keywords: Elderly people, inertial sensor, smart airbag.

1. Introduction

Population aging is considered one of the prominent trends of the 21st century, manifested in the rapid increase in the proportion of elderly people, deeply and widely affecting all aspects of a country, territory as well as globally. In 1950, the world had only about 200 million people over 60 years old, by 2020, there were 727 million people over 65 and according to forecasts, this number could double by 2050 (about 1.5 billion people); in less developed regions, the median age will increase from 26 years old in 2010 to 35 years old in 2050 [1].

Falls are an accident that occurs when a person's balance is lost and the balance cannot be maintained again. This falls occur in all age groups, but especially in elder people [2].

Falls pose many risks such as broken bones, broken vertebrae, brain injuries, and are even more dangerous for the elderly due to the weakening of the immune system and health of age. This leads to many dangerous complications, directly affecting the health, life, and quality of life of the elderly [3].

Falling is a very common unexpected accident in the elderly. According to statistics from the National Council on Aging (NCOA), within a year, 1 in 4 people over 65 years old falls. Another statistic shows that the rate of falls in the elderly each year is about 28% - 35% for those aged 65 and over and 32% - 42% for those over 75 years old. Of these, more than 15% of the elderly fall more than twice a year. In Vietnam, it is estimated that about 1.5 - 1.9 million elderly people fall each year, 5% of whom are hospitalized due to injuries [3].

Therefore, it is necessary to develop active protection devices to protect the human body, especially the elderly, from serious injuries caused by falls. One of the effective measures is to use smart airbags to protect the elderly when falling. In this article, research on smart airbags to protect the elderly when they fall, sensors used for smart airbags, and parameters to determine the time of falling are summarized.

2. Smart Airbag to Protect the Elderly when Falling

2.1. Airbags

An airbag is an automatic safety restraint system for the occupants. It is an occupant restraint system consisting of a flexible fabric envelope or cushion designed to inflate rapidly during an automobile collision. The airbag module is designed to react rapidly to inflate during a sudden impact and deflate very quickly after the incident to offer the passengers delicate cushioning and thus avoid fatal injuries. Usually, the airbags are mounted on the steering wheel or a car's instrument panel and inflate within 30 ms of collusion. The key objective of an airbag is to lessen injuries by reducing the force applied to the body by

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the dashboard, steering wheel, or any part of an automobile [4, 5].

In addition to the common use of airbag to protect people in automobiles, there are many other useful applications, especially protecting the elderly from serious injuries when falling.

2.2. Materials for Airbag

Metwaly, *et al*. [6] reported that airbags are typically woven from high tenacity multifilament Nylon 6.6 in yarn quality fineness from 210, 420 to 840 deniers, which have considerable success due to their high strength, favorable elongation, adequate thermal properties, and relatively low cost of production. Polyester, which has good dimensional stability even at humid environmental conditions and good compaction, is beginning to be used in airbags. Nylon 6 is also used in a small percentage and is said to minimize skin abrasion because it is softer.

The main requirements in airbag fiber materials are high strength, heat stability, good aging characteristics, energy absorption, coating adhesion, and functionality at extreme hot and cold conditions. Other properties required are high tear strength, high anti-seam slippage, controlled air permeability and be capable of being folded into confined places for over ten years without deterioration, and in the case of coated fabric, without blocking or sticking together [6].

After weaving, the driver side airbag fabric is coated with black neoprene rubber or silicone rubber but most airbags now are made of siliconized Nylon fabric as it showed outstanding resistance to aging, as this thin silicon layer ensures that airbag can inflate within shortest time without sticking together even after being stored folded up in a very small space for many years. Other requirements for coating are good adhesion, anti-blocking, long term flexibility, long term stability, low air permeability, and low cost. Silicone rubber is not only used for fabric coating. The seams, too, are sealed with silicone rubber [6].

M.S. Parvez, *et al*. [4] researched the current advances in fabric-based airbag material selection. At present, most airbags are made of Nylon 6.6. Though other Nylon variants are also available, e.g., Nylon 6 is softer than Nylon 6.6 and can be used to lessen skin abrasion. Nylon 6.6, on the other hand, has properties superior to others, including a high strength-to-weight ratio, thermal and chemical stability, elastic properties, moisture contents, and density. The most commonly used Nylon 6.6 yarns range from 210 to 840 deniers. Apart from Nylon, Polyester exhibits good dimensional stability even in humid environments and gains favor. However, conventional component arrangements have significant drawbacks that have forced manufacturers to explore alternative options for improving airbag safety.

The preferred sheer weight of the airbag fabric is 150–200 g/m^2, and the thickness should be less than 0.35 mm. To tackle the fabric air permeability, the woven fabric compactness is maintained by adjusting the yarn count and fabric construction, calendaring, or coating. The coating process adds an additional weight of 70–80 g/m^2 to the fabric [4].

Nylon-made airbags are strong, resilient, and flexible, have a high specific capacity of heat, and have good bending properties. The current airbag manufacturing predominantly depends on Nylon 6.6 (PA 66) polymer. However, Nylon is costly, and Polyester is typically around half the cost of it. However, the thermal stability, tear resistance of Polyester made airbag is not up to mark as that of Nylon. Precisely, the melting temperature is approximately 40% less than Nylon. To cope with the growing demand, in recent years, manufacturers have used a hybrid configuration of Nylon and Polyester, which is relatively light in weight and exhibits better dimensional stability under humid circumstances [4].

The group of authors Hiren Mankodi, *et al*. [7] conducted a research about airjet textured yarn fabrics for airbag. The airbag is manufactured from Nylon 6.6 and Polyester woven fabrics. The airbag cushion should have properties like bursting strength, air permeability, and seam strength which are important during its performance. Hence during manufacturing proper selection of material and parameter is necessary to get good tensile, tear, bursting strength, and low air permeability.

The attempt has been made to produce airbag fabric from different airjet textured yarn made from Polyester and Nylon 6.6 combination to improve certain properties for better performance of airbag fabric and can be economical to produce when compared to commercial airbag fabrics. The main aim of this project is to produce the airbag using different combination of Polyester and Nylon 6.6 airjet textured yarns to reduce the volume and cost of the airbag fabric and check the performance [7].

The airjet textured yarn prepared using Polyester, Nylon 6.6 and its combinations gives stable structure and good feel due to loop structure and helps in reducing volume of fabric. The airbag fabric prepared using textured yarn in warp and weft gives good quality of the fabric with better cover. The airjet fabric structure gives little less strength and high permeability due to loop structure in grey fabric. In airjet textured fabric due to loop structure and air trapped within structure gives high air permeability hence coating is required. The coating was done in order to reduce the air permeability, whose result came out as expected and reduced air permeability drastically to 3.3 litre/min [7].

Tasnim N. Shaikh, *et al*. [5] conducted research on airbags in automobile safety systems. Mostly used raw material for the airbag fabric is Nylon 6.6 yarns in the deniers ranging from 420 to 840. Commonly, the airbag made were coated by neoprene, but recently silicon coated and uncoated varieties have become popular.

Air bag fabric has to keep a balance between two extreme conditions. It has to be sufficiently flexible to fold into relatively small volumes. At the same time, it should be sufficiently strong to withstand the deployment at high speed, e.g. under the influence of an explosive charge, and the impact of passengers or other influences when inflated. To play this role successfully airbag fabric should possess following quality parameters [5]:

1. Small fabric thickness;
2. Low specific fabric weight;
3. High tenacity in warp and weft direction as well as toughness;
4. High tenacity for furthers tearing;
5. High elongation;
6. Good resistance to aging;
7. Heat resistance up to 190 ^{0}C;
8. Good resistance to UV light;
9. Low and very even air permeability;
10. Reduced cost;
11. Precisely controlled gas permeability;
12. Excellent seam integrity;
13. Reduced value or burn through resistance;
14. Improved pliability and pack height.

Gülşah Pamuk [8] has pointed out the role of textile materials for airbag products. The role of textile materials that make up airbags is very important. The fabrics from which the bag is made must be able to withstand the force of the hot propellant chemicals and more importantly they must not penetrate through the fabric to burn the skin of the car occupant. Polyester is not used for airbags because its thermal properties are not suitable. Compared to Nylon 6.6, Polyester requires about 40% less heat to melt and the fabric could allow the penetration of hot gasses. Traditionally, Nylon 6.6 has been the material of choice for safety airbags.

Thus, most researches indicate that coated Nylon 6.6 fabrics are suitable for making airbags because they meet the requirements of airbags.

2.3. Smart Airbag with Integrated Sensor

Smart airbag to protect the human body from serious injuries caused by falls need to be integrated with sensors to determine the movement parameters of the human body to determine the time of fall and deploy the airbag in time to cushion before the body hits the ground. Smart airbags are proposed in researches to protect important body parts that are difficult to recover from injuries such as the hips, back, head, or all three of these body parts.

Guangyi Shi, *et al*. [9] developed a human airbag system designed to reduce impact force when falling (Fig. 1) [9]. A Micro Inertial Measurement Unit (µIMU), based on MEMS accelerometers and gyro sensors is developed as the motion sensing part of the system. A recognition algorithm is used for real-time fall determination. With the algorithm, a microcontroller integrated with the µIMU can discriminate falling-down motion from normal human motions and trigger an airbag system when a fall occurs. Our airbag system is designed to have fast response with moderate input pressure, i.e., the experimental response time is less than 0.3 second under 0.4 MPa. The overall size of the unit is designed to be less than 26 mmx20 mmx20 mm. Experimental response time is less than 0.3 second under 0.4 MPa.

In addition, they present our progress on using Support Vector Machine (SVM) training together with the µIMU to better distinguish falling and normal motions. Experimental results show that selected eigenvector sets generated from 200 experimental data sets can be accurately separated into falling and other motions.

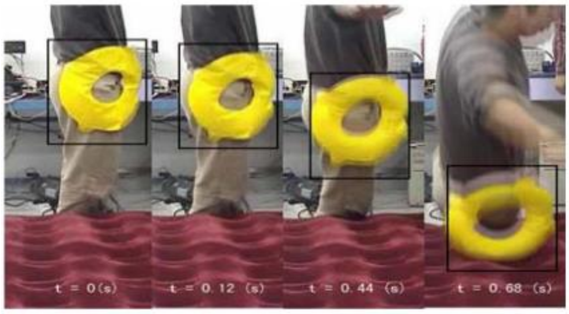

Fig. 1. A demonstration of real time recognition of falling-down motion with inflation of airbag.

Cheung Shing Chan, *et al*. [10] described the development of a human airbag system which is designed to reduce the impact force from slippage falling-down. The author group developed a novel protector with smaller dimensions and greater comfort according to the body figures of the elderly instead of hard plastic or soft foam. Basically, a MEMS motion sensing unit will be used to detect imbalance of the elderly and trigger the inflation of compact airbags worn by the elderly. One is a comfortable compress airbag that can be inflated instantly. Another is a small triggering device embedded with a rapid and accurate algorithm for recognition falling-down motion. For the fast inflated airbag, the authors first utilize an electromagnetic valve as a switch to open a compressed air source. When the valve is triggered, an airbag can be inflated in less than 0.3 second under 0.4 MPa, which is enough to effectively reduce the impact force on the hip due to a fall. Now, an independent airbag is under development based on compressed CO_2 cartridges. Initially, the airbags are folded in a belt. When an elderly loses balance, the MEMS micro sensors in the belt will detect his/her disorientation and triggers the inflation of the airbag on the side in a few hundred milliseconds before falling to the ground. The basic concept of an intelligent human airbag system is illustrated in Fig. 2 [10].

Guangyi Shi, *et al*. [11] continued to research the mobile human airbag system designed for fall protection using MEMS sensors and embedded SVM classifier (SVM-support vector machine). A Micro Inertial Measurement Unit (IMU) of 56 mm x 23 mm x 15 mm in size is built. This unit consists of three dimensional MEMS accelerometers, gyroscopes, a Bluetooth module and a Micro Controller Unit (MCU). It records human motion information, and, through the analysis of falls using a high-speed camera, a lateral fall can be determined by gyro threshold. The sampling rate of the microcontroller is 200 Hz, which ensures rapid reaction to human motion. A human motion database that includes falls and other normal motions (walking, running, etc.) is set up. Using a SVM training process, we can classify falls and other normal motions successfully with a SVM filter. Based on the SVM filter, an embedded digital signal processing (DSP) system is developed for real-time fall detection. In addition, a smart mechanical airbag deployment system is finalized. The response time for the mechanical trigger is 0.133 s, which allows enough time for compressed air to be released before a person falls to the ground.

Toshiyo Tamura, *et al*. [12] developed a wearable airbag that incorporates a fall-detection system that uses both acceleration and angular velocity signals to trigger inflation of the airbag (Fig. 3 [12]). The fall detection algorithm was devised using a thresholding technique with an accelerometer and gyro sensor. Sixteen subjects mimicked falls, and their acceleration waveforms were monitored. Then, the authors developed a fall-detection algorithm that could detect signals 300 ms before the fall. To evaluate the movement of the subject, the wearable system includes an accelerometer, a gyro sensor that measures the angular velocity of movement, and a central processing unit (CPU). The monitor measures 50 mm×56 mm×18 mm and weighs 50 g. They determined that a fall occurred when the triaxial acceleration was below ±3 m/s^2 and the angular velocity exceeded 0.52 rad/s. Airbags protect both the head and the hips. Before inflation, one bag is folded on the back, this bag covers the head and neck after inflating. This airbag measures 470 mm × 330 mm and has a volume of about 10 L.

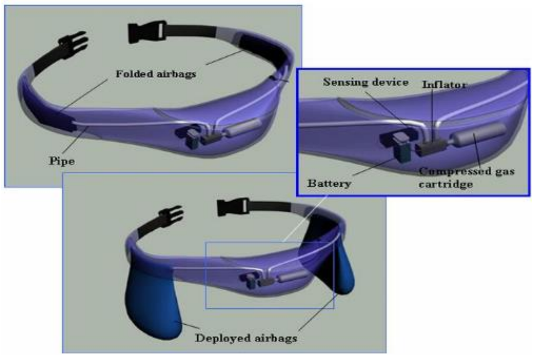

Fig. 2. Conceptual illustration of the "intelligent" human airbag system.

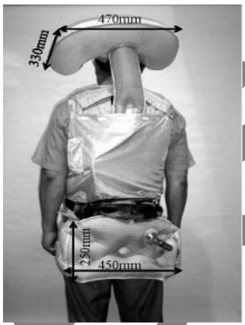

Fig. 3. Airbag system

Fig. 4. Photograph of the airbag system

The airbag protecting the hips is folded inside a pouch, this bag covers the hips and thighs when inflated. It measures 250 mm × 450 mm and has a volume of about 10 L. Each airbag has an independent inflator and cartridge. The two airbags weigh 1.1 kg and are worn like a jacket. Although the proposed system can help to prevent fall-related injuries, further development is needed to miniaturize the inflation system.

Toshiyo Tamura, *et al*. [13] continued research on airbags to protect the human body when falling. Five young healthy subjects mimicked falls, and their signals of acceleration and angular velocity were monitored. The thresholds of acceleration less than ±3 m/s^2 and the integral of angular velocity exceed 0.52 rad/s were used. In this study they have improved fall detection algorithm to operate correctly in daily life and improved the design of the airbag to cover a larger protected area than previous studies (Fig. 4 [13]).

Qi Zhang, *et al*. [14] presented a study on wearable hip-airbag system for fall protection. This paper presented an airbag system for hip protection, which included air source, sensors, micro-controller, gas circuit and, airbags. The authors adopted the wearable sensing technique in this system. The sensors were consisted of 6-axis inertial sensor module MPU6000 and obliquity sensor SCA60C.

Recognition algorithm which was based on thresholds was adopted in this system. Those thresholds contained acceleration, angular velocity, and angle of inclination. We could calculate the value by mathematical methods. The calculation equations were shown as follows [14]:

$$Acc = \sqrt{Acc_x{}^2 + Acc_y{}^2 + Acc_z{}^2} \quad (1)$$

$$Gyr = \sqrt{Gyr_x{}^2 + Gyr_y{}^2 + Gyr_z{}^2} \quad (2)$$

In (1), Acc presents resultant value of acceleration, Acc_x presents X-Axis acceleration, Acc_y presents Y-Axis acceleration, Acc_z presents Z-Axis acceleration.

In (2), Gyr presents resultant value of angular rate, Gyr_x presents X-Axis angular rate, Gyr_y presents Y-Axis angular rate, Gyr_z presents Z-Axis angular rate.

When sensors were worn on the human body, coordinate axis may have a deviation from ideal state, however, employing resultant value of acceleration and angular rate to recognize falls, we could ignore the deviation of accelerometers and gyroscopes. However, angle of inclination sensor could not be neglected. To solve the problem, we employed following equation to calculate turning angle of human body during the falls. The calculation equation was defined as follows [14]:

$$\Delta\theta = |\theta_1 - \theta_0| \quad (3)$$

In (3), θ_0 and θ_1 were the angle between human body and the horizontal plane, and the horizontal plane was an ideal plane that was perpendicular with gravity vertical. The θ_0 was defined as the initial angle, it could read and record from the angle sensor when CPU had detected that a resultant value of acceleration was larger than the threshold (ACC_{t1}). The value of ACC_{t1} was determined as experiments,when resultant value of acceleration was larger than the threshold ACC_{t1}, the system confirmed that the human body was walking, and a angle value was recorded as the initial angle θ_0 .After that, the MCU constantly read the real-time value of angle sensor and it was defined as θ_1 ,and then calculated the $\Delta\theta$ .It was clear that the $\Delta\theta$ was the turn angle of human body in falls. Fig. 5 [14] shows angular variation in falls [14].

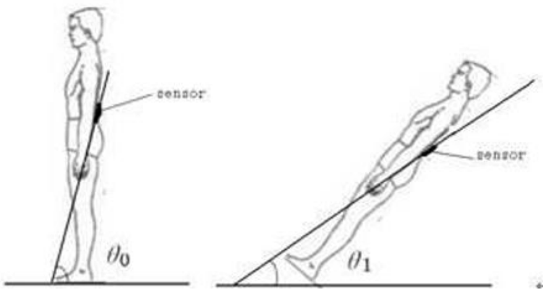

Fig. 5. Angular variation in falls.

They chose the acceleration (ACC_{t1}) value of 11-13 m/s^2 as a threshold for moving level, and chose the acceleration (ACC_{t2}) value of 5-7 m/s^2, angular velocity (GYR_t) value of 3-5 deg/s and angular variation (θ_t) value of 18° as the thresholds for fall level [14].

Mian Yao, *et al*. [15] implemented a fall protection and early warning system including an early fall alarm, protection airbags, a remote monitoring platform, and a guardian's cellphone app. The early fall alarm and airbags are integrated in a belt, convenient for wearing and hip-protection. The inner of early fall alarm has a MEMS sensor (MPU9150), which collects 3-axis accelerated velocity and 3-axis angular velocity. A fall detection algorithm is applied to recognize falls from activities of daily living (ADL). The minimum acceleration of forward, backward, leftward, and rightward falls respectively ranged from 0.0763 g to 0.15 g, from 0.08 g to 2.6 g, from 0.09 to 1.7 g, from 0.78 g to 0.14 g, and the maximum acceleration ranged from 5.4 g to 7.8 g. When acceleration was minimum, the corresponding pitch angles were: 38.67 degrees, 43.45 degrees, 47.17 degrees, and 56.4 degrees. Tests of deflating indicate that 380 ms after air bleeding module triggered, the airbag has been filled in more than 80% gas, creating a buffer layer. The size of buffer layer is 30 cm x 26 cm x 8 cm, which basically can achieve the goal of protection. When there is a dangerous movement approaching fall, the early fall alarm will warn the aged to stop the movement. When the fall happens, the early fall alarm will trigger the airbag system, then the airbags in the belt will inflate as soon as possible to reduce the damage to the aged. In addition, the early fall alarm will ring and send message to the guardian's cellphone for help.

Beomgeun Jo, *et al*. [2] also presented a study on the design of a wearable airbag to reduce hip injuries when falling. In this study, simulation test method of falls situation is established and the wearable airbag system for protecting from falls is designed through simulation. The shape of the wearable airbag is designed to cover all parts except the face part by considering the average body size of the elderly over 65 years old, and parts of the hips are designed as a skirt type to wrap around the side and back direction.

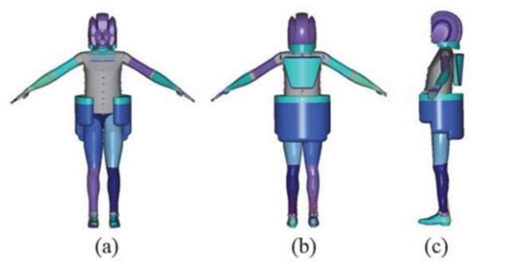

Fig. 6. Human model wearing airbag (front (a) back (b) side (c)).

The human model in Fig. 6 [2] wear the ergonomically designed airbag. The wearable airbag system uses acceleration sensor, gyro sensor, and compass sensor to input each sensor data to the CPU. Then, CPU uses the input sensor data to convert them to values such as angles, angular velocity, and acceleration. The converted values are substituted into the threshold value determination algorithm to determine whether the wearer's state is falling or not. When it is judged that the falls has not occurred, the continuous voltage is transmitted to the sensor unit so that the current state of the wearer can get feedback. In case of a fall, the CPU sends a signal to the inflator so that the airbag can be deployed. The airbag is deployed in the order of the hips, thorax, and head, which are the order of contact between the human body and the ground at the time of falling. When the airbag touches the ground, the vent hole is actuated at the moment and discharge the gas inside the airbag into the outside [2].

Youngho Lee, *et al*. [16] experimentally verified fall simulation using a hip protective airbag. In this study, the wearable protect airbag is designed and is confirmed through simulation of fall injury situation, and also, compare with the fall experiments by using an accelerometer and a gyro-sensor for an active protecting device from the falling injuries. The shape of the wearable airbag is designed to cover body and to protect pelvic area by considering the average body size of the elderly over 65 years old. 21 male subjects participated in the experiment for falling data. The 3D accelerometer (L3G4200D, ± 2000 Deg/sec, 70 mdps/digit), and compass (HMC5883L, ± 8 Gauss, 5 milli-gauss) put on the sacrum, thoracic, and neck of the subjects for the falling experiments. The falling postures were determined based on the resultant pelvic acceleration and angular velocity, pelvic tilt and obliquity angles. 60 kg-dummy is also used in the experiment for falling data. Wearable protect airbag is manufactured in the form of a belt and can accommodate the airbag. The graph of Fig. 7 [16] shows the impact force applied to the hips of the human model at the time of the falls in case 1 (before wearing airbag) and case 2 (after wearing airbag) in simulation. In case 1, maximum impact force is 4694 N, and in case 2, maximum impact force is 2240 N, respectively. The force in case 1 (4694 N) exceeds the reference hip fracture point of the elderly people (3100 N), whereas the force in case 2 (2240 N) does not.

Based on simulation and experiment results, the effectiveness of the airbag is proved by showing the injury value in the simulation and prototype. This airbag is expected to prevent fractures and reduce cost of treatment. In addition, through this study, it is possible to develop wearable airbags in other parts to prevent injuries caused by falls [16].

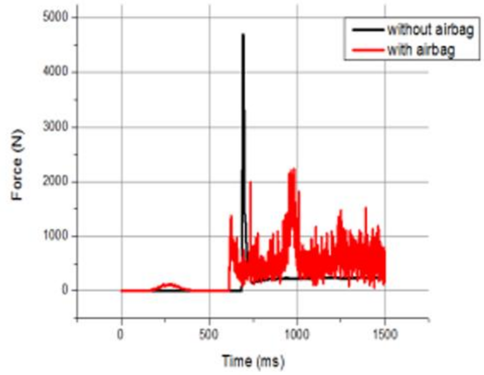

Fig. 7. Impact force of before and after wearing pelvic airbag.

T. Padma, *et al*. [17] present research on smart fall detection and protection for the elderly. The elderly people require attention because of their health conditions and in many cases falls lead to many critical consequences. When an elderly person falls results in physical injury and is not possible for them to request for help at that condition. The main intention of this project is to prepare a fall detection and protection system for the elderly people at an affordable cost. In that process a wearable airbag is developed which inflates when the fall occurs. MEMS accelerometer is used for the fall detection. The processing of data is done by the microcontroller based on the input given by accelerometer sensor. When the fall is detected microcontroller triggers the air pump which inflates the airbag. The microcontroller (NODE MCU) consists of a built in Wi-Fi module by which the entire data were presented to cloud platform.

Haneul Jung, *et al*. [18] researched enhanced algorithms for pre-fall impact detection for wearable airbags. In this study, 6 types of simulated falls and 14 activities of daily life, including some highly dynamic motions, were selected to simulate real-life situations. Thirty healthy young men (age: 23.4 ± 1.2 years, height: 173.7 ± 4.75 cm, and weight: 74.8 ± 8.41 kg) were recruited to perform ADLs and simulated falls. None of the participants had any neuromusculoskeletal abnormalities. Fig. 8a [17] depicts the airbag system prior to inflation, while Fig. 8b [17] presents it after inflation.


Fig. 8a. Complete Kit before inflation


Fig. 8b. Airbag after inflation

The MPU-9250 (InvenSense, San Jose, USA) sensor, measuring 3-axis acceleration (±16 g), 3-axis angular velocity (±2000 °/s), and 3-axis magnetism (4800 μT), has been generally used for motion capturing and gesture recognition. In general, highly dynamic motions have large acceleration and angular velocity. However, vertical angles in ADLs are relatively different from those in fall motions. In the present algorithm, two vertical angles (roll and pitch) were used. Roll and pitch angles were defined as the vertical angles of the body in the frontal and sagittal plane, respectively. Because the roll angle does not change significantly in ADLs, its threshold was set to 280. The threshold of pitch angle was set to 450, since the upper body moved back and forth in some ADLs. In lying motions, the vertical angle changed to about 900 as in fall motions, but acceleration sum vector magnitude (SVM) did not. Using the grid search method to maximize the specificity with 100% sensitivity, the threshold of acceleration SVM was set to 0.82 g. The threshold of angular velocity SVM was set to 47.3 °/s. The average lead time was 280.25 ± 10.29 ms. The inflation time of the wearable airbag was approximately 200 ms, since a spring-triggered type inflator instead of a gunpowder type one was used. Therefore, the airbag could be inflated sufficiently before impact using the developed algorithm [18].

Yunkung Ning, *et al*. [19] developed hip protection airbags that can effectively protect the hip joint when the elderly fall. This has been studied all over the world, but similar products need to use special gas cylinders and replacement of new gas cylinders needs to return to the factory. This research group previously designed a mechanical puncture protection system based on standard gas cylinders and standard threaded interfaces, but the airbag still has shortcomings such as the small protective area caused by a single gas cylinder. To solve the above problems, a set of wearable hip automatic protection systems based on micromechanical double gas cylinder rapid puncture (MDGCRP) was designed. Compared with the single gas cylinder approach, the airbag provides greater protection to the hip while the filling time and module weight remain essentially unchanged.

Through a large number of experiments, it was found that the response time of MDGCRP was 92 ms and the execution time was 177.5 ms. A strip-shaped structure made of Nylon and Thermoplastic Polyurethane (TPU) composite cloth is used. The airbag is about 1,097 mm long and 415 mm wide. It is about 36 mm thick, and the airbag is rapidly inflated at the same time through the two ends of the airbag [19].

Sakthivel Sankaran, *et al*. [20] researched, designed and developed a smart airbag system for the elderly with protection and notification system. The existing method has a hip protection airbag suit which prevents to get an injury in the trochanteric region and prevent to get fractures. The drawback of this methodology is that it protects only the hip region of patients, without protecting important parts like the head, thoracic cavity. Their proposed methodology is to make an airbag suit for the elderly by using MPU 6050 accelerometer sensor to detect the fall. This device is to sense the motion of the elder patient's while they are moving on faint or slippery floor, and to find different parameters like acceleration, gyroscope, and angular velocity. The digital MPU 6050 sensor measures in the range between -3 g and +3 g across six coordinate axes. An Arduino Mega 2560 Microcontroller is the heart of the project; it decides whether the airbag has to blow or not. Through the Arduino program, the threshold value of 25 MHz is tuned. When MPU 6050 reaches more than the normal threshold value the airbag will get deployed to protect the elder patients. Typically, the airbag itself is Nylon. To inflate an airbag, either nitrogen or argon gas can be used. Both are non-toxic gasses. "smoke-like" residues will be present in the air immediately after deployment. The injury to the elderly caused by impact with the floor can be reduced. The newly design and developed smart airbag suit provides better results and reduces the injury with notification system. The most important advantage is that it sends a notification to the caretaker to help avoid major problems.

Mariam Ibrahim, *et al*. [21] researched airbag protection and alerting system for the elderly. The system can be installed on a waist belt as an airbag. It is connected wirelessly to the elderly person's mobile, where an Android mobile application is created to receive alert notifications from the system. The system will detect the fall using a gravity sensor that is connected to an Arduino board. If a fall is detected by the gravity sensor, then the system will activate an air valve and inflate the airbag from the air tank. The flow rate through the air valve to inflate the airbag is 623.04 L/min. The system will also send a warning notification to the elderly person's mobile application via Bluetooth. Then, the elderly person's global positioning system (GPS) location will be determined from their mobile phone and an SMS will be transmitted to a mobile phone belonging to his/her emergency contact of choice.

Sena Sukmananda Suprapto, *et al*. [22] designed and built an airbag system to protect the elderly when falling using MPU 6050 sensor. In this research, there will be 11 movements that will be examined, namely walking, jogging, bowing, sitting, walking up the stairs, walking down the stairs, and prostrating, which will be referred to as regular movements. Additionally, falling backward, forward, to the left, and to the right, will be referred to as falling movements. To differentiate these 11 movements, the study utilized a threshold method based on acceleration, angle, and angular acceleration.

The results of this research show that the MPU 6050 sensor can be used to identify falling motion by detecting and meeting the threshold value. The threshold value obtained to detect falling motion is an acceleration relative (AR) value of less than or equal to 0.38 g, an angled slope of more than or equal to 40°, and an angular velocity of more than or equal to 30 °/s. In the design of the airbag, a discharge of 0.04876 m/s^2 with a duration of 0.05 s was obtained. The overall system analysis of the tool showed a specificity of 100%, sensitivity of 85%, and accuracy of 94% [22].

The airbag system depicted in Fig. 9 [22] takes the form of a belt and incorporates a fall-detection module. During a fall, the acceleration graph shows an initial decrease followed by a sharp increase after impact once the person has fallen. The threshold graph is shown in Fig. 10 [22].

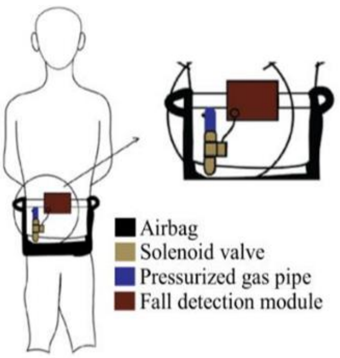

Fig. 9. The airbag system design

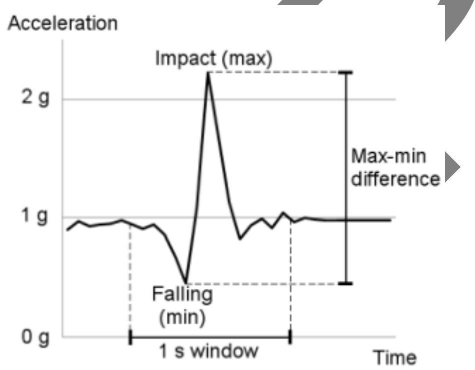

Fig. 10. Acceleration graph when falling

3. Conclusion

This paper provides an overview of smart airbags for protecting elderly people from injuries caused when falling. A summary of the research on the materials used to manufacture airbags, primarily Nylon 6.6, and the research on smart airbags that use sensors to detect falls as well as the parameters and algorithms to determine the moment of fall and trigger the deployment of airbags are presented in the paper. This overview paper can be used as a reference for research on the development of effective smart airbags that can reduce fall-related injuries in the elderly, or protect to people working at heights, in slippery environments, and when participating in traffic.

However, these studies were conducted abroad, such as measuring the human body's movement parameters during daily activities and when falling. Each study on protecting a different part of the human body such as the head, hips, back, etc., gave a different threshold, filter, and way of deploying airbags due to the different locations of the sensors measuring movement parameters.

Vietnam is still a developing country and the elderly in Vietnam have to bear the burden of health care. How to minimize the harm caused by falls in the elderly, to maximize life expectancy, and save medical costs for families and society is a matter of great concern. According to the research of the group of authors, in Vietnam there has been no research on smart airbags to protect the human body when falling, especially the body of the elderly, and importantly, it is suitable for the body shape and anthropometry of Vietnamese people. The group of authors hopes that in the next research of the group, they can develop a set of smart airbags to protect the elderly in Vietnam when falling, suitable for the anthropometry and body characteristics of Vietnamese people.

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