Smart Unit Care for Pre Fall Detection and Prevention

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Abstract— **Generally falls may occur from moving or resting postures. This may include slipping from bed and fall from a sitting, or from running or walking. The pre-fall is a non-equilibrium state of human position that may lead to serious injuries, and may negatively impact the quality life condition, particularly for elders. Physical disabilities resulting from the fall incidences may lead to high costs involved with the healing process.**

In this work, an embedded sensor system using Arduino micro-controller was utilized to coordinate the data received from accelerometer and gyroscope. For a given threshold voltage and fall pattern, the fall decision is made by the microcontroller, citing an incoming fall. The study addresses the number of sensors to be coordinated for enhancing probability of receiving a real fall. Sensors are suggested to be placed on the human body within a belt, and safety devices at human body as well as incorporated in a smart room will be coordinated with the processor commands. Near 150 ms time frame was detected from the simulation results, suggesting a safety device to be triggered and activated for protection within this time frame.

This paper discusses the research parameters such as response time for the device activation and interfacing the microcontroller to airbag switch, and means of activating the safety devices within the sharp edges in the smart unit care to minimize the impact of the fall injuries.

Keywords— **Accelerometer, fall detection, Smart Unit Care, Smartphone, Sensors, Embedded systems, Machine Learning Method - MLM (key words)**

I. Introduction (*Heading 1*)

In general, fall occurs mostly in the elders who may often lose their balance. This has become a frequent issue everywhere leading to serious complexities like death in some cases, physical disabilities, loss of self-confidence, insecurities and high cost involved in the treatment process etc. Statistical data indicates that near $30billion are being spent annually for the fall treatment in the United States alone [1]. The idea of pre-fall detection is unique, utilizing the high speed of sensor and microcontroller processing to detect the fall information before it occurs. Much of the research efforts for detecting the fall occurs after the fact that the fall has occurred, and a few work has been done to detect the fall earlier and secure the patients.

There are different ways to pre detect the falls using machine learning [2] [3], surface electromyography [4], vision based approach [5], and divide and conquer approach [6]. Recently, smart phones have been proposed to detect the fall before it occurs [7] [8]. Most of these methods use sensors and accelerometers. Tyson et al. [9] has estimated the pre-fall by looking into two different posture positions of a patient. Later a new system [10] was designed using three positions considering the orientation and the step mechanics during the fall. This system was tested for various types of falls at different speeds [10]. Lopes et al. [11] has optimized the system further by sending the fall information to their care takers. Recently some systems were designed with complex algorithms [12] with acceptable efficiency, using MLM's, featuring acceleration signals.

Researchers have used low complexity algorithms for the fall detections based on the threshold impacts of the accelerometer. Multiple sensors and branching algorithms have been accommodated in order to enhance the efficiency and smartness of the system. Restrictions with force, range of operation has set the upper limits of their use. Sometimes, individuals disregard the fall detection gadgets, as they introduce extra loads to wear them. This has motivated the use of smart phones since mobile phones are of highly carrying gadgets in the present days, and according to Pew Internet Project's research, near 64% of Americans has currently smartphones [13]. Therefore, utilization of smartphone in age groups higher than 65+ will expect to increase in the future.

II. Smart Unit Care Environment

Figure 1 shows the proposed smart care unit with associated safety devices. An estimated time of 150ms resulted from simulation, suggests that the mini air bags surrounding the sharp edges of the care unit should be partially inflated in order to optimize the time of air compression within them. Edges of windows, beds, chairs, doors, and tables are associated with these safety devices.

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Figures 2 & 3 give the detection approach and the multiple sensor system respectively.

Figure 1: Smart Assistive Care Unit

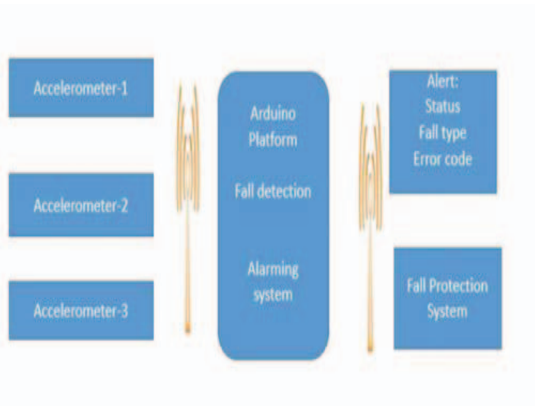


Figure 2: The Block diagram of Pre-fall detection system

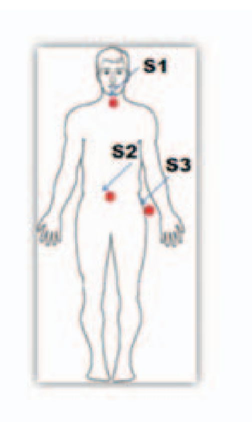


Figure 3: proposed sensor positions.

III. Embedded Sensor System

The integrated Arduino microcontroller with the sensor system was developed and tested for the fall detection of different positions. Figures 4 & 5 provide the hardware sensor system and the algorithm used for the development.

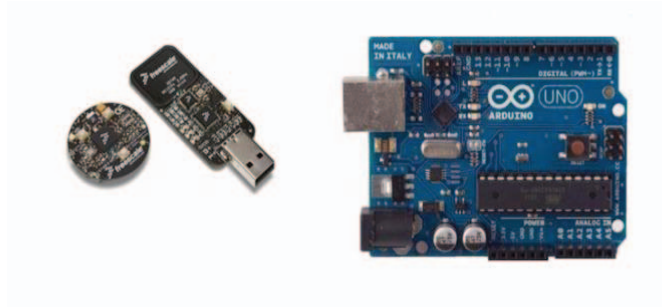


Figure 4: The Hardware for the pre-fall detection system

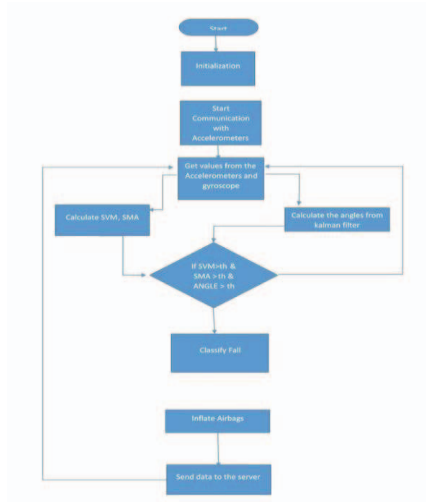


Figure 5: The algorithm of the system development

IV. Airbag Safety Devices

After detecting a fall there should be a safety device to protect the human from injuries. This device should simultaneously trigger a mini air bag before the fall occurs so that it alleviates the fall impact. Figure 6 provides the hardware used for interfacing the microcontroller to an airbag switch. In order to illustrate the impact of the airbag size on the safety device response, let us consider a general life vest shown in figure 7.

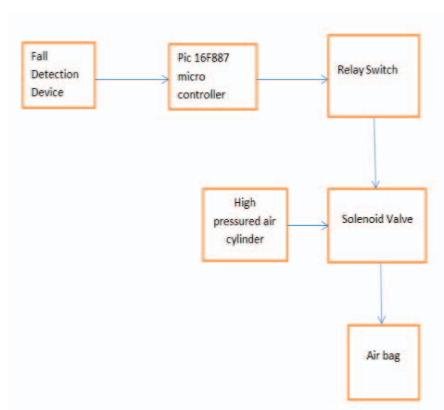
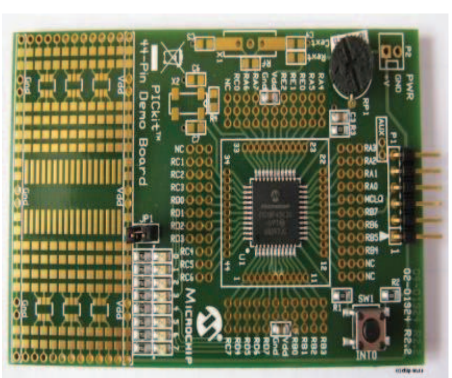


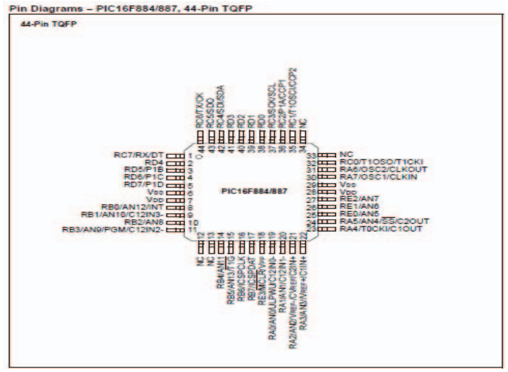
Figure 6: Design to trigger the Air bag.

Figure 7: General Life Vest

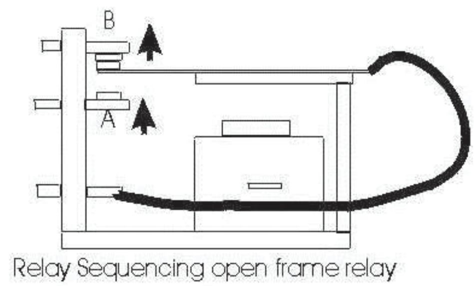
A general life jacket consists of a pressurized air cylinder and a triggering device to trigger the air bag. In the above air bag the yellow plastic lever is the triggering device. Pulling the lever pierces the air cylinder and air rushes into the airbag. This size of safety device may be difficult to achieve within a fraction of a second. To use the same concept as in the general life vest, a stepper motor must be arranged to pull the triggering device. The exact torque measure to pull the trigger should be calculated. The trigger should be instantaneously and the air bag inflation should be instantly. In order to fully inflate the airbag, a mechanical device such as the solenoid valve may be utilized. The solenoid [14] converts electrical energy into mechanical energy which, in turn, opens or closes the valve mechanically. A direct acting valve has only a small flow circuit, shown within section E of this diagram (this section is mentioned below as a pilot valve). In this example, a diaphragm piloted valve multiplies this small pilot flow, by using it to control the flow through a much larger. Power and speed issues raise some concern on using large size air bags. Therefore, it is suggested that a scalable air bag that may require low power that can be activated at higher speed will be advantageous. Small size airbags are suggested to be partially inflated before the pre-fall signal is activated, in order to optimize the time of inflation to the acceptable level. Figure 8 gives the hardware used for the switch triggering from the pre-fall signal activated by the microcontroller. Figure 9 shows the hardware setup for the activation of the airbag switch.



A. PICkit Evaluation Board



B. PIC16F887 Micro controller



C. Relay switch

Figure 8: Hardware used to trigger the airbag.

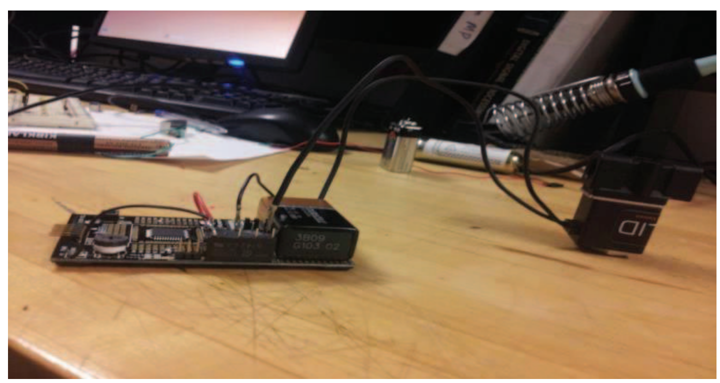


Figure 9: Hardware setup

Process to trigger the airbag (Hardware Programming):

The fall detection system is preprogrammed to give the threshold values. Whenever there is a fall a reference number is generated in the fall detection system. The Arduino in the detection system is programmed to take the number in and generate a 5v output. This output is fed into the PICkit, which acts as the input to the microcontroller. PIC16F887 takes the input and turns on the relay. Relay acts as a switch and shorts the connection to 9v dc supply. The solenoid valve now gets triggered and lets the air into the airbag instantaneously.

V. RESULTS AND DISCUSSIONS

Figure 10 shows the accelerometer signals and the pre-fall detection before the impact occurs. As it can be seen from various testing, near 150ms was determined from the simulation. Figure 11 shows the data from the start of the signal until the fall. The signal vector magnitude (SVM) changes from 1.37 to 0.8 corresponding to time change between 270ms to 413 ms, indicating near 150ms time frame for the pre-fall period of time. The impact occurs shortly after detecting the minimum magnitude. The efficiency was estimated based on the threshold SVM value given to the controller. A larger SVM may lead to a better efficiency, while shorter time for the impact to occur. A smaller threshold may lead to bigger time frame, while may give more of false fall detections.

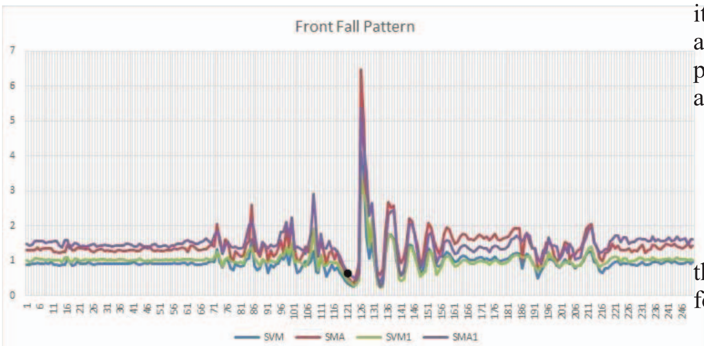


Figure 10: Accelerometer data indicating the pre-fall signal and impact timing

SVM1	Milliseconds
1.3742	270
1.2817	284
1.2425	289
1.1527	293
1.1183	297
1.1193	301
1.1287	304
1.0608	307
0.9946	311
1.0796	315
1.0026	319
1.0127	322
1.0271	325
1.0146	329
0.9959	333
0.9983	337
0.9538	341
0.9691	344
0.9833	348
0.9133	352
0.9396	356
0.9109	359
0.8947	363
0.9018	367
0.8734	371
0.874	376
0.8687	379
0.8504	383
0.8072	386
0.8603	389
0.8433	393
0.7803	397
0.8143	401
0.7524	405
0.8101	409
0.8	413

Figure 11: Screenshot of data acquisition

VI. CONCLUSION AND FUTURE WORK

The findings presented here indicate the high efficiency system on detecting the falls before they occur. Near 150ms is too short for triggering a sizable air bag. The interface of the microcontroller to the air bag switch provides basis of smart care units where mini air bags may be incorporated at the critical positions for elder protection. The suggestion of partially inflated air bags may satisfy the time frame of 150ms required for the security device to activate. This project addresses how to develop a device that can protect a person from fall injuries. Initial phase with a life vest and suggested high speed devices were discussed to optimize system latency. This hardware was implemented and verified its validity for proper interface between the microcontroller and the triggering switch. Future work should incorporate the pressure model that is suited for a patient weight. The design and testing of this work is reserved for future considerations.

VII. ACKNOWLEDGEMENTS

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REFERENCES

[1] Englander, Fred, Ralph A. Terregrossa, and Thomas J. Hodgson. "Economic dimensions of slip and fall injuries." *Journal of Forensic Science* 41.5 (1996): 733-746.

[2] S. Shan and T. Yuan, "A wearable pre-impact fall detector using feature selection and support vector machine," in Signal Processing (ICSP), 2010 IEEE 10th International Conference on, Oct 2010, pp. 1686–1689.

[3] [4] J. Liu and T. Lockhart, "Development and evaluation of a prior-to-impact fall event detection algorithm," Biomedical Engineering, IEEE Transactions on, vol. 61, no. 7, pp. 2135–2140, July 2014.

[4] J. Cheng, X. Chen, and M. Shen, "A framework for daily activity monitoring and fall detection based on surface electromyography and accelerometer signals," Biomedical and Health Informatics, IEEE Journal of, vol. 17, no. 1, pp. 38–45, Jan 2013.

[5] V. Bevilacqua, N. Nuzzolese, D. Barone, M. Pantaleo, M. Suma, D. D'Ambruoso, A. Volpe, C. Loconsole, and F. Stroppa, "Fall detection in indoor environment with kinect sensor," in Innovations in Intelligent Systems and Applications (IN- ISTA) Proceedings, 2014 IEEE International Symposium on, June 2014, pp. 319–324.

[6] Prado-Velasco, Manuel, Maria Gloria del Rio-Cidoncha, and Rafael Ortiz-Marin. "The inescapable smart impact detection system (ISIS): An ubiquitous and personalized fall detector based on a distributed "divide and conquer strategy"." *2008 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. IEEE, 2008.

[7] Suryadevara, V. and Rizkalla, M. (2015) Smartphone Based Fall Detection and Logic Testing Application Using Android SDK. *Journal of Biomedical Science and Engineering*, **8**, 616-624. doi: 10.4236/jbise.2015.89057.

[8] He, Yi, Ye Li, and Shu-Di Bao. "Fall Detection by built-in tri-accelerometer of smartphone." *Proceedings of 2012 IEEE-EMBS*

International Conference on Biomedical and Health Informatics. IEEE, 2012.

[9] Sposaro, Frank, and Gary Tyson. "iFall: an Android application for fall monitoring and response." *2009 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. IEEE, 2009.

[10] Dai, J., Bai, X., Yang, Z., Shen, Z. and Xuan, D. (2010) PerFallD: A Pervasive Fall Detection System using Mobile Phones. *Proceedings of the* 8*th IEEE International Conference on Pervasive Computing and Communications Work-shops* (*PERCOM Workshops*), Mannheim, 29 March-2 April 2010, 292-297.

[11] Lopes, Ivo C., Binod Vaidya, and Joel JPC Rodrigues. "Towards an autonomous fall detection and alerting system on a mobile and pervasive environment." *Telecommunication Systems* 52.4 (2013): 2299-2310.

[12] Albert, Mark V., et al. "Fall classification by machine learning using mobile phones." *PloS one* 7.5 (2012): e36556.

[13] http://www.pewinternet.org/2015/04/01/us-smartphone-use-in-2015/

[14] https://en.wikipedia.org/wiki/Solenoid_valve