ISSN 2047-3338

Fall Detection System with the Sensor Networks at the Elderly

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***Abstract*— The process of detecting falls in the elderly population in the modern implementation of wireless sensor networks is a very serious problem for which several types of research and scientific papers have been made. This paper presents a wireless sensor architecture based on the fall detection system, especially for the elderly. The fall detection system is implemented via a three-axis acceleration sensor to measure and collect data related to acceleration activities in the elderly and the collected data is transmitted remotely via the ZigBee-3G network.**

***Keywords*—Sensor Networks, Detection Systems, Data and ZigBee**

I. INTRODUCTION

FALLS are a common occurrence in many older people. According to one estimate, the fall occurs in 1/3 of people over the age of 65, and each year increases with increasing age. Falling is the biggest cause of various injuries and other bodily injuries in the elderly.

If a fall is not detected in time, in other words, if the rescue process for a certain person who had an accident, i.e. a fall is not detected in time, the probability of endangering the life of a certain person is affected by this type of accident increases.

The development of systems for detection and monitoring of falls in the elderly that will timely detect a certain event and generate a signal, i.e., alarm to a specific location responsible for this type of intervention, is a very important step in saving many lives of the elderly and improving the quality of life of the elderly population while promoting a stable and safer life in our society. Nowadays, we can classify fall detection technology in three ways depending on how different signals are sampled:

- Crash detection technology - based on video technology, which has a lower detection range and may have an impact on people's privacy,

-Fall-detection technology based on low-precision sound technology that is closely related to different terrain and floor. -Fall detection technology - based on technology with wear sensors such as special micro sensors in the form of glasses, clothes, shoes, hats, etc.

It can be real-time monitoring of human activities. For example, in the case when we have a change in the moving parameters of the body there is a possibility to detect a case when an old person fell and it is concluded that his body moving parameters have changed abruptly.

The fall detector is most suitable for systems based on wearable sensors, as they are not subject to restrictions in terms of location detection.

II. GENERAL STRUCTURE OF THE PROPOSED MODULE

The general structure of the ZigBee Elderly Crash Detection System based on wireless technology is shown in Fig. 1 where the following three components can be seen:

-mobile module containing ZigBee nodes for crash detection,

- ZigBee-3G network and

- Platform for medical monitoring system at a distance [2]

The system structure of the system is as follows the accelerator data collection unit from the mobile crash detection module collects raw data, the microprocessor unit processes the signal, and then the suspicious data obtained during the processing phase is transmitted over a wireless sensor network from the medical monitoring device, the system, the concentrator [3] integrates the ZigBee-3G network and forwards the data to the distance detection system, then that data is analyzed accordingly. If the crash action is confirmed, then the system will trigger an automatic alarm. The interaction unit mainly consists of function keys, an LED indicator, and a siren. Function keys allow the user to activate an alarm or otherwise cancel a false alarm. LED indicators are mainly used to display the connection status of network communication. The siren may receive an alarm signal when the system detects a fall.

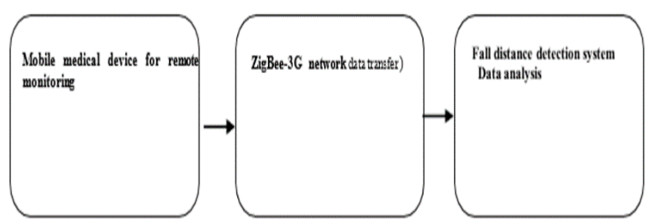


Fig 1. The whole structure

A. Axis acceleration sensor

For this paper, the ADXL345 accelerometer manufactured by ADI Company was used, which can be used as a device for detecting falls in the elderly. The ADXL345 is a 3-axis acceleration sensor with a digital output based on MEMS (Micro-Electro-Mechanical Systems) technology.

Its main properties are the following: multiple measuring ranges including +/- 2, +/- 4, +/- 8 and +/- 16g; high resolution: 13bit; fixed sensitivity: 4mg / LSB; very low consumption: 40-145uA; standard I2C or SPI digital interface; Level-32 FIFO etc. All of the above features greatly simplify the fall detection algorithm for the elderly. The following Fig. 2 shows the pin diagram of the acceleration sensor. The sensor is a polysilicon surface with a micromachine structure built on top of a silicon plate. Polysilicon suspends the structure above the tile surface and provides resistance to acceleration forces.

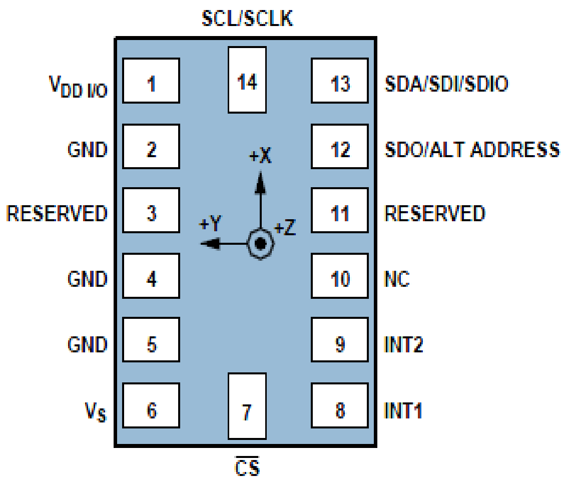


Fig.. 2. Pin diagram of ADXL345

III. FALL DETECTION ALGORITHM

When the human body is in the process of falling, the acceleration, velocity, and movement of a given object in all its directions will change. This means that in fact, it is very difficult to comprehensively identify the action of falling only with changes in the acceleration process of a certain person.

Speed can be obtained by applying one period of acceleration in the time domain while displacement is obtained by applying twice the displacement integral. All of the above procedures are undertaken to improve the accuracy of the entire system in the decision-making process.

The acceleration data obtained from an installed sensor always has two parts: acceleration caused by gravity and acceleration caused by human movement. The following Fig. 3 shows a model based on acceleration caused by human movement in three orthogonal directions from an acceleration sensor that performs the measurements.

If the device (sensor) connects correctly to the users and when the object is at rest or in constant motion, then the acceleration in the Y direction should be the acceleration of gravity (g) and the acceleration in the horizontal direction should be 0. When the object falls, only if given the change in acceleration between the initial and final state, the change in vertical direction should be from 1g to 0g, while the change in the horizontal direction (x or z) should be from 0g to 1g.

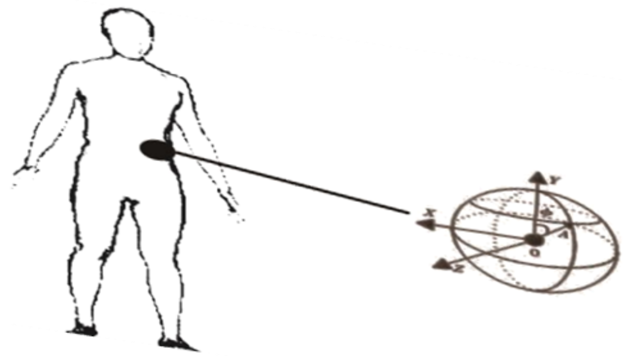


Fig. 3. The carrying position of the fall detection device and the coordinate system

Based on the coordinates of Fig. 3, the vector $\vec{A}$ can be expressed as $\vec{A} = (a_x, a_y, a_z) = |A|\vec{u}$ where | A | is the modulus of the vector $\vec{A}$, $\vec{u}$ is a unit of vector in the same direction. The angle of inclination of the human body ϕ (angle with the direction of gravitational acceleration) is $\phi = \arccos(a/g)$, where a is the static output on each axis while g is the gravitational acceleration

A. Designing the algorithm

The following figure 4 shows the entire flow diagram of the algorithm where the process from start to "data transfer" is accomplished at the user terminal. The entire pre-processing signal takes a sample in a given window as the base unit. If suspicious data is detected during sampling in a given window then the data from this unit will be transferred to the background for further confirmation, otherwise, this segment data will be discarded and the system will continue with the next signal. Meanwhile, to improve detection accuracy, information from ν (velocity), s (displacement), and Φ (angle of inclination) of the human body in a specific time domain is also included in the so-called support data [4].

In the process of detecting a fall, which is a complex and very difficult process when making a prediction, all the circumstances that arise when moving should be taken into account. This is the case when we have the moment of sitting where the sensor can detect the event as a fall and trigger the so-called "false" signal [5].

Therefore, the proposed algorithm provides very strictly and precisely to analyses the balance of the human body, the calculation of the speed at which the body moves, the angle of inclination, and suspicious displacements.

B. Analysis of the obtained results

In the process of the fall experiment, several young students were selected who simulated falling in a place previously provided with special material so that possible injuries to the participants in the simulation would not occur. The ways of falling in the experiment are chosen so that the sum of activities is as reliable as possible and the obtained values reflect the actual state of the falling process, as follows:

- falling forward / backward without lying down,

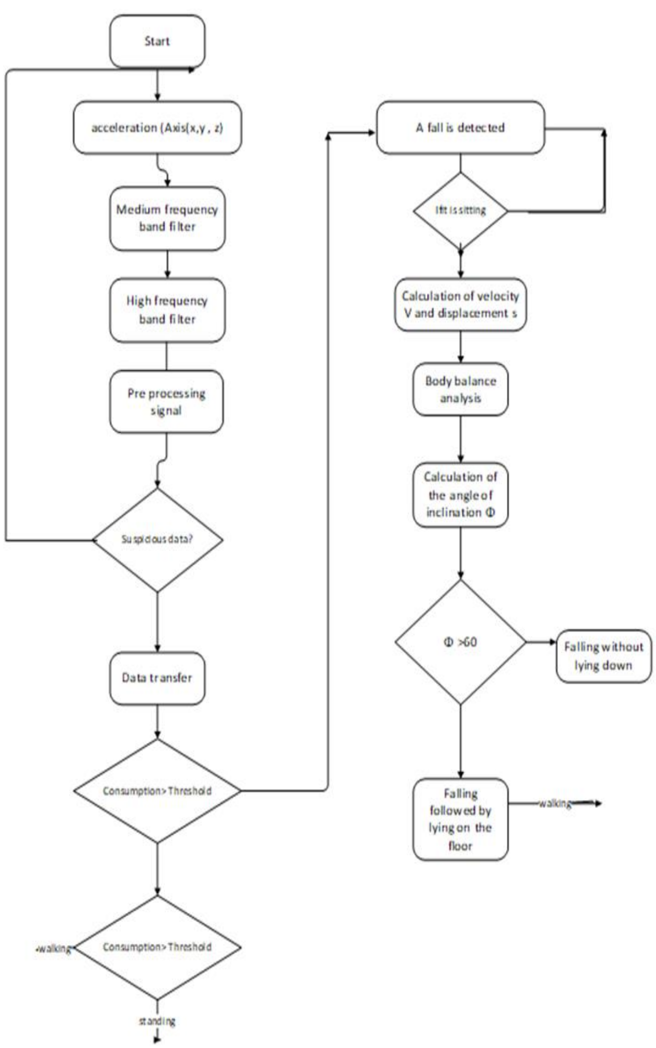
- falling forward / backward by lying down on a secured floor and
- falling left and right.

Taking into account these proposed ways, the set of activities is designed in the table below. In each experiment, participants were asked to select several activities from the table randomly and in combination with the actual fall to form a complete set of experimental activities.

The system first collects a data sample at a frequency of 45 Hz and then processes the data using the proposed algorithm [7]. Each participant had to perform 5 actions from the experiment and in each experiment, they would choose a random combination of the proposed actions. In total, about 50 sets of the given experiment were completed.

The table below shows the experimental results showing that the crash detection algorithm has achieved relatively satisfactory decision accuracy.

It should be emphasized that in almost all cases the fall of a certain person is identified or detected, except in the moments when the fall is without lying on the lower surface and the sliding activities where sometimes unsatisfactory results appears [8].



Type of activity by the participant	Should the alarm be activated?	Number of experiments	Number of alarms	Number without alarms	Accuracy%
1. Standing	NO	50	0	50	100
2. Stable	NO	50	0	50	100
3.Walking	NO	25	1	24	96
4. Loss of balance with rapid recovery to a stable state	YES	30	30	0	100
5.Going forward by lying down	NO	15	0	15	100
6. Climb the stairs	NO	30	1	29	96.7
7. Sliding backwards with fast recovery in steady state	YES	30	30	0	100
8. Falling back by lying down	YES	15	0	15	100
9. Descending stairs	NO	30	27	3	90
10. Going forward without lying down	YES	40	38	2	95
11. Falling back by lying down	YES	25	25	0	100
12. Going to the right	YES	25	23	2	92
13. Going to the left	YES	10	0	10	100

The graphs below show the results obtained in a graphic way

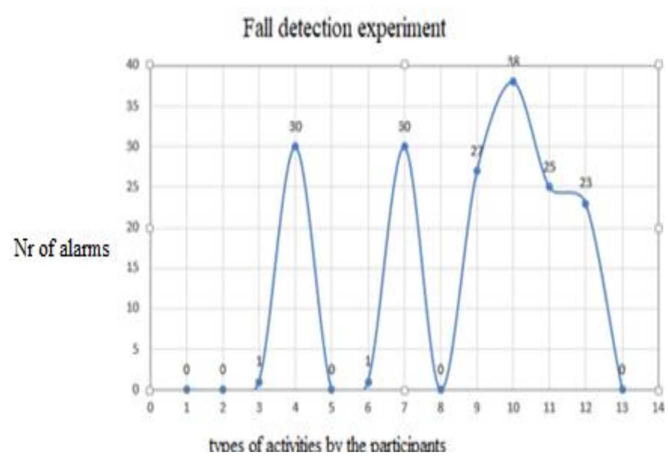


Fig. 5. The graphic view according to the number of experiments

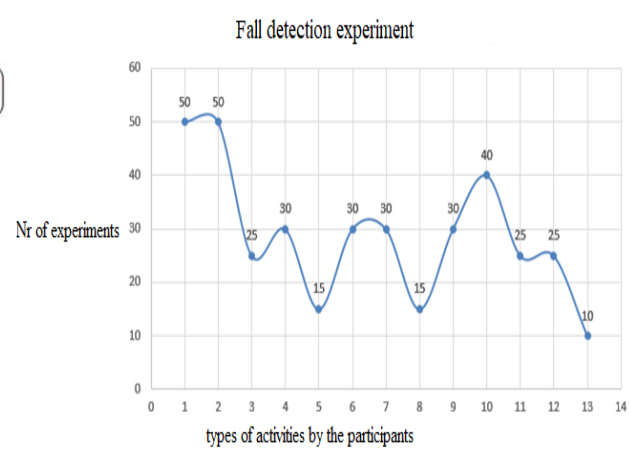


Fig. 6. The graphic view according to the number of displayed alarms

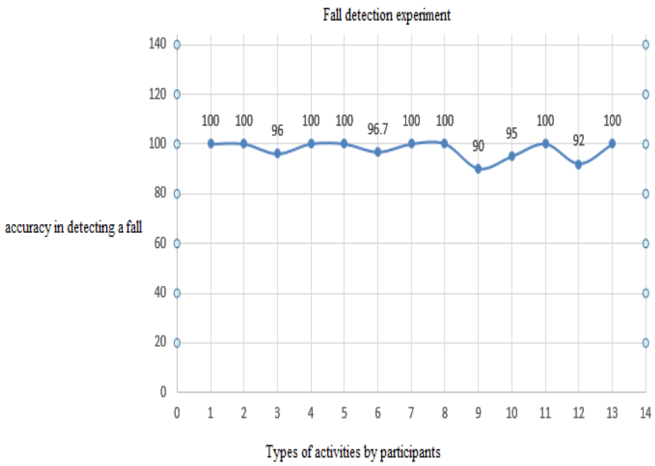


Fig. 7. Graphic view without displayed alarms

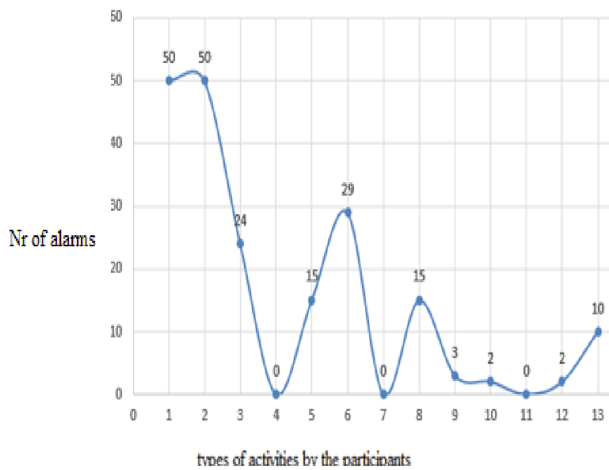


Fig. 8. The graphic view according to the accuracy of the detected falls

IV. CONCLUSION

This chapter provides a system for detecting falls in the elderly using a microprocessor acceleration sensor and technology based on a wireless sensor network. Also, a creative method is proposed which is based on the difference in energy consumption in different actions of the users when making the final decision to determine the fall in the elderly. Additionally, to improve the system's accuracy as a whole, the analysis of the balance of the human body (analysis of speed, displacement, and angle of inclination of the body) is included. In further research, we will focus on creating a commercial complete system for fall detection in the elderly which will be specifically implemented in appropriate institutions where there is a need for such systems (nursing homes, medical facilities, etc.). It remains in the future to work on improving the proposed fall detection system in the part where various types of movements that occur by all people are not detected as falling. Although an algorithm provides such considerations, there are still cases in the testing process when the system detects a fall although the body makes normal movements.

REFERENCES

[1] Dhillon, S. S., and Chakrabarty K.: `Sensor Placement for Effective Coverage and Surveillance in Distributed Sensor Networks' Proceedings of the IEEE Wireless Communications and Networking Conference (WCNC03), Mar. 2003.

[2] Y. Hui, Z. Xiaoyue, Z. Lixin and C. Yuzhen, "Elderly fall monitoring and remote assistance system", Computer Engineering and Applications, vol. 47, no. 35, (2011), pp. 245-248.

[3] X. Yuan and G. Xiangyang, "A Design for Fall Detection Monitoring System Based on Information Fusion of Multi-sensor", Journal of Wuhan University of Technology(Information & Management Engineering), vol. 33, no. 5, (2011), pp. 712-716.

[4] V. Chan, P. Ray, and N. Parameswaran, "Mobile e-Health monitoring: an agent-based approach", IET Commun, vol. 2, no. 2, (2008), pp. 223-230.

[5] M. Huo, M. Wu, and H. Hou, "Research on Fall Detection and Daily Activity Monitoring Technologies for Older People", International Journal of Digital Content Technology and its Applications, vol. 6, no. 16, (2012), pp. 548-557.

[6] S.-W. Lee and S.-H. Song, "A Monitoring System for Assessing Life Pattern of the Elderly Living Alone", Advances in Information Sciences and Service Sciences, vol. 3, no. 7, (2011), pp. 311-323.

[7] C.-C. Lin, W.-P. Chen, S.-C. Hsieh and S.-S. Chen, "Design and Implementation of Zigbee Wireless Controller Module", Advances in Information Sciences and Service Sciences, vol. 4, no. 18, (2012), pp. 106- 115.

[8] Adhikari K., Bouchachia H., and Nait-Charif H. (2017). "Activity recognition for indoor fall detection using convolutional neural network," in 2017 Fifteenth IAPR International Conference on Machine Vision Applications (MVA) (Nagoya: IEEE), 81–84.

[9] Boulard L., Baccaglini E., and Scopigno R. (2014). "Insights into the role of feedbacks in the tracking loop of a modular fall-detection algorithm," in 2014 IEEE Visual Communications and Image Processing Conference (Valletta: IEEE),

[10] Daher M., Diab A., El Najjar M. E. B., Khalil M. A., and Charpillet F. (2017). Elder tracking and fall detection system using smart tiles. IEEE Sens

[11] .de Araújo Í. L., Dourado L., Fernandes L., Andrade R. M. C., and Aguilar P. A. C. (2018). "An algorithm for fall detection using data from a smartwatch," in 2018 13th Annual Conference on System of Systems Engineering (SoSE) (Paris: IEEE)

[12] El-Bendary N., Tan Q., Pivot F. C., and Lam A. (2013). Fall detection and prevention for the elderly: a review of trends and challenges. Int. J. Smart Sens. Intell.