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Automatic fall detection of elderly living alone at home environment

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Abstract – Recently the problems connected with the ageing population all over the world have become more and more severe. Many projects have been developed to enable the people to live longer in home environment, thus keeping their independence together with reducing the expenses of the public health care. The results in this area have a quick public impact. Different sensor systems have been proposed for monitoring the functional abilities in elderly and for detecting their functional decline. The sensors are located in the bathroom, bedroom, closet, front door, kitchen, living room and shower. The statistic shows that 30% of the old people fall at least once a year and 75% of these events are responsible for accidental death. The feeling of fall increases the anxiety and the depression in the elderly. Therefore, the monitoring system must enable the caregiver to track remotely the user's walk around the rooms and to perceive immediately the falls without the need of confirmation request. We started to develop and implement a low-cost system directed to monitor the user walk, to detect the falls and to check the cardiac activity by analysing the photo-pletismographic signals. An interface for communication between the patient and health care expert is also provided. This paper is aimed to report the results obtained in reliable fall detection of solitary living elderly.

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AUTOMATIC FALL DETECTION OF ELDERLY LIVING ALONE AT HOME ENVIRONMENT

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Abstract - Recently the problems connected with the ageing population all over the world have become more and more severe. Many projects have been developed to enable the people to live longer in home environment, thus keeping their independence together with reducing the expenses of the public health care. The results in this area have a quick public impact. Different sensor systems have been proposed for monitoring the functional abilities in elderly and for detecting their functional decline. The sensors are located in the bathroom, bedroom, closet, front door, kitchen, living room and shower. The statistic shows that 30% of the old people fall at least once a year and 75% of these events are responsible for accidental death. The feeling of fall increases the anxiety and the depression in the elderly. Therefore, the monitoring system must enable the caregiver to track remotely the user's walk around the rooms and to perceive immediately the falls without the need of confirmation request. We started to develop and implement a low-cost system directed to monitor the user walk, to detect the falls and to check the cardiac activity by analysing the photo-pletismographic signals. An interface for communication between the patient and health care expert is also provided. This paper is aimed to report the results obtained in reliable fall detection of solitary living elderly.

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I. Introduction

Recently the problems connected with the ageing population all over the world have become more and more severe. In 2035 a third of the Europeans will be over 65 years old (Ambient Assisted Living Joint Programme, 2008; Communication from the Commission to the European Parliament 2010; COOP-005935-HEBE, 2006). People over age 65 in the United States are expected to hit 70 million by 2030. It has been reported (Qixin Wang et al., 2006) that the number of elderly people living alone in Korea has increased by 100% during the last ten years. According to data published by the Bulgarian National Institute of Statistics (2011), the relative part of the population older than 65 years has reached 23.5%. Nowadays, the average life expectancy is extended up to 80 years. At the same time the percentage of people with disabilities is dramatically growing (Giles et al, 2003). The need for health care and social assistance will lead to expense's growth by 4-8% of the Gross Domestic Product (De Ipiña et al, 2008). As a result, objectives about cost reduction in the public health services will arise simultaneously (COOP-005935-HEBE, 2006).

Ambient Assisted Living (AAL) is an initiative from the European Union (International newsletter on micro-nano integration, 2007), which is aimed to improve the life quality of adults by implementing new Information and Communication Technologies (ICT). The goal is to enable the people to live longer in home environment, thus keeping their independence together with reducing the expenses of the public health care. The results in this area have a quick public impact.

Aviles-Lopez et al (2010) tested in laboratory a platform intended to be implemented in nursing home. The concept of the AAL system is based on the appearance of new types of mobile and embedded computing devices. Data about blood pressure, sugar levels etc. should be acquired, derived and communicated in fast and reliable way. Other intelligent components of the care monitoring are the closed circuit camera system and the sensors with embedded accelerometer. The patients may also communicate the caregiver by depressing a button on their wearable tag or say another command. No details about the hardware and software implementation are given. The reported platform is planed to meet the needs of solitary living elderly by a sophisticated approach. However, the expected price of the instrumentation may be onerous for several users and nursing homes.

Alexander et al (2008) reported results of an expert review on sensor system used for monitoring the functional abilities in elderly and for detecting their functional decline. The sensors are located in the bathroom, bedroom, closet, front door, kitchen, living room and shower.

Healey and Logan (2005) presented a prototype wearable monitoring system capable of recording, transmitting and analyzing continuous ECG and accelerometer data. The system also provides an application for recording activities, events and potentially important medical symptoms. The authors conducted experiments using the system for activity monitoring, exercise monitoring and medical screening tests and reported good preliminary results. Sitting and walking activities were recorded in office environment by means of accelerometer. The RMS values of the signals or their variance were used for discriminating the

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epochs with lower and higher amplitudes, corresponding to sitting and walking movements.

Holtzinger et al (2010) evaluated the user acceptance of a wrist device, designed to monitor vital signs and to detect situations, such as falls, unconsciousness, etc., and aimed a further study to show the acceptance level of the elderly to the personal monitoring.

The statistic shows that 30% of the old people fall at least once a year and 75% of these events are responsible for accidental death (COOP-005935-HEBE, 2006). The feeling of fall increases the anxiety and the depression in the elderly. Therefore, the monitoring system must enable the caregiver to track remotely the user's walk around the rooms and to perceive immediately the falls without the need of confirmation request. Many technologies have been investigated for automatic fall detection: bed and chair pressure detection; vibration analysis; video monitoring; sensor devices like accelerometers, tilt sensors, gyroscopes; 'watch-type' and belt-worn' design. No descriptions of algorithms for fall detection are available.

We started to develop and implement a low-cost system directed to monitor the user walk, to detect the falls and to check the cardiac activity by analysing the photo-pletismographic signals. An interface for communication between the patient and health care expert is also provided. Some preliminary considerations were recently reported at the XX International Scientific Conference on Electronics'11, September 2011 in Sozopol, Bulgaria (Dimitrov et al; Sapundjiev et al). This paper is aimed to report the results obtained in reliable fall detection of solitary living elderly.

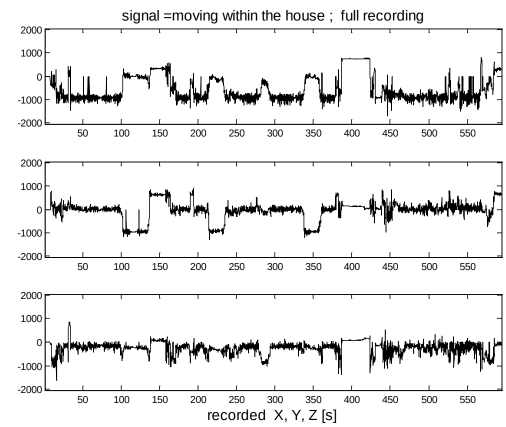
II. Materials

The selected and used sensor of motion activity is the 3D accelerometer LIS302DL, produced by Semiconductor Technology. Its parameters are: 3x5x0.9 mm size; power supply in the range of 2.16 V through 3.6 V; consuming power lower than 1 mW; 12C/SPI interfaces. The accelerometer signals are emitted according to the SimplisiTI protocol, using CC1110 and CC1111 (Texas Instruments) low-power sub-1 GHz system-on-chip (SoC) designed for low power wireless applications. The inherent sampling rate SR is near to 9 Hz; the digital code uses 8 bits but with irregular resolution.

Signals during different activities of a volunteer are stored in commonly used Laptop by an appropriately written program on Visual Basic. The recorded signals represent several epochs and episodes of movements within the house; falling on the floor; falling on the bed; sleeping; feeding; reading; and watching TV.

The acquired signals were further processed in MATLAB environment. They were studied in the time and the frequency domain to find the useful signal manipulation leading to reliable discrimination between fall detection and natural movements accompagnying other activities of the monitored subject.

Some of these signals are presented in Fig. 1 to Fig. 4, which show relatively long epochs of user's activities. The ordinate units are relative; the abscissas are scaled in *s*.



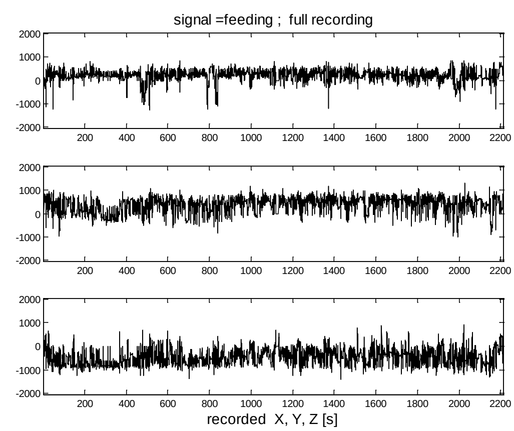
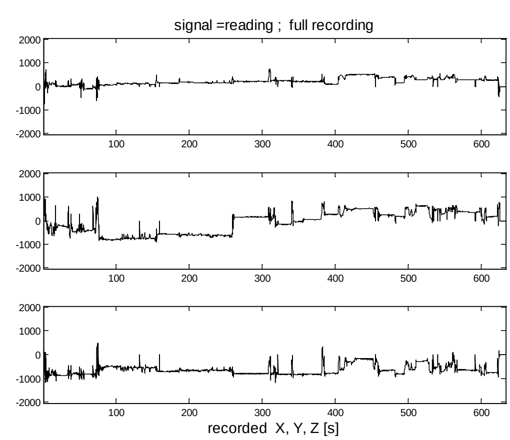


Fig. 1 : Moving within the house.
Fig. 2 : Feeding.



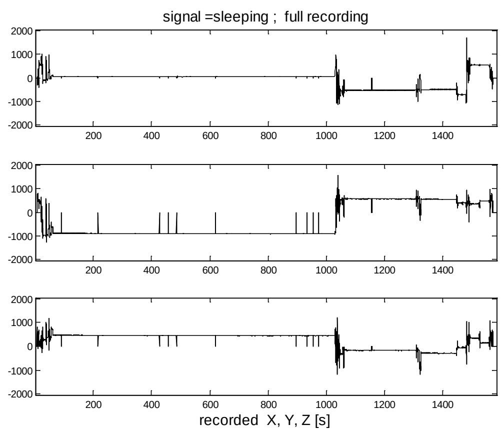


Fig. 3 : Reading.

Fig. 4 : Sleeping.

III. Algorithm

The signals generated by the accelerometer in the three space directions *X*, *Y* and *Z* are currently summed and a first derivative of the sum is calculated using its first differences. This derivative is then raised to second power but the result is divided by a coefficient of 32 to reduce the excessive amplification of the result. The value of 32, which is not crucial, is chosen because of the simple division. An appropriate threshold is finally introduced to detect user's falls among other normal movements.

Version of the algorithm, which calculates the first differences separately for each of the three signals before summing them, was tested without obtaining any advantages. Therefore, this version was abandoned since the computation time is slightly prolonged.

The first differences were taken first as signed and then as unsigned addends. No influence on the fall detection accuracy was observed. We speculate that on the one hand, the signed addends may give priority to the vertical signal component, which is practically unidirectional, while the other components collect bidirectional fluctuations. On the other hand, the unsigned non-vertical components may contribute to better discrimination between crucial fall on the floor and abrupt movement of elderly, which is going down to bed or armchair.

IV. Results and Discussion

The following Figures present selected episodes of different activities. The three signals *X*, *Y* and *Z*, shown in the first three subplots, are subjected to processing and analysis. The forth subplot depicts the differentiated sum of the signals, $V_1=\Delta V=\Delta (X+Y+Z)$; the fifth demonstrates the amplification of the high frequency components after raising to second power, $V_2= V_1^2/32$; and the last subplot may contain rectangular pulses that mark recognized falls in case they are simulated by the volunteer in the corresponding recording. The ordinate units are relative; the abscissas are scaled in *s*.

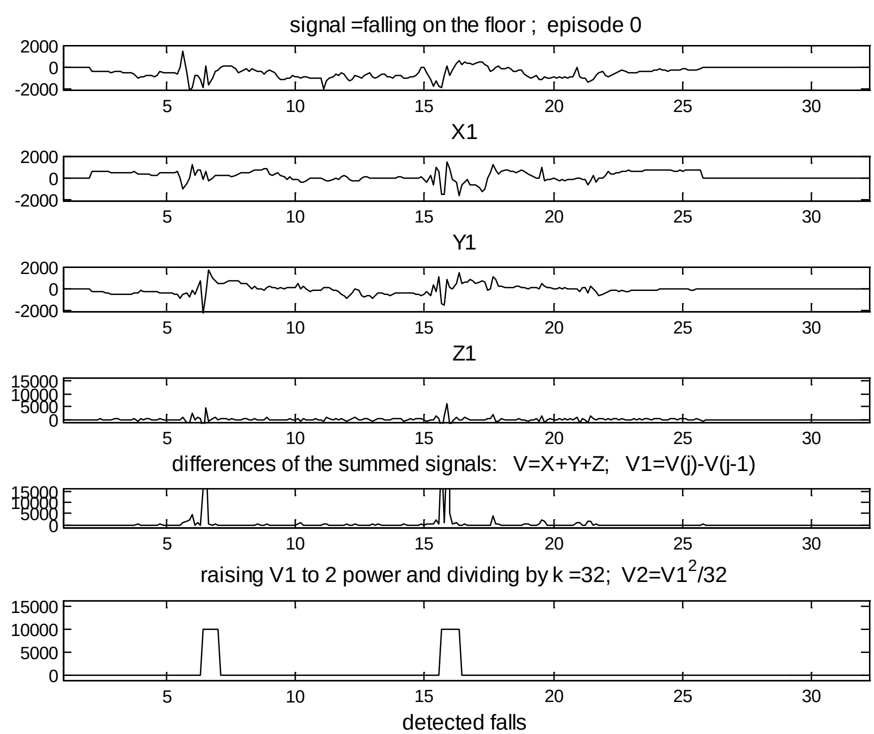


Fig. 5 : Correct fall detections on the floor.

Fig. 5 shows two recorded falls, which are recognized. The parts of the signal corresponding to them are extremely emphasized compared to the movements before and after the falls. The fall patterns are going far beyond the vertical scale, which is reduced to be approximately near to the amplitude scaling of the other episodes thus allowing a correct assessment of the movement differentiation and detection.

Fig. 6 demonstrates the reliable suppression of user's normal movement, although the volunteer received instruction to try to introduce maximum amplitude of the extremities during the walk. No fall detections can be observed in the last subplot. This is normal since the processed signal (subplot 5) remains below 1000 relative units that are far from the 10000 units chosen as fall detection threshold.

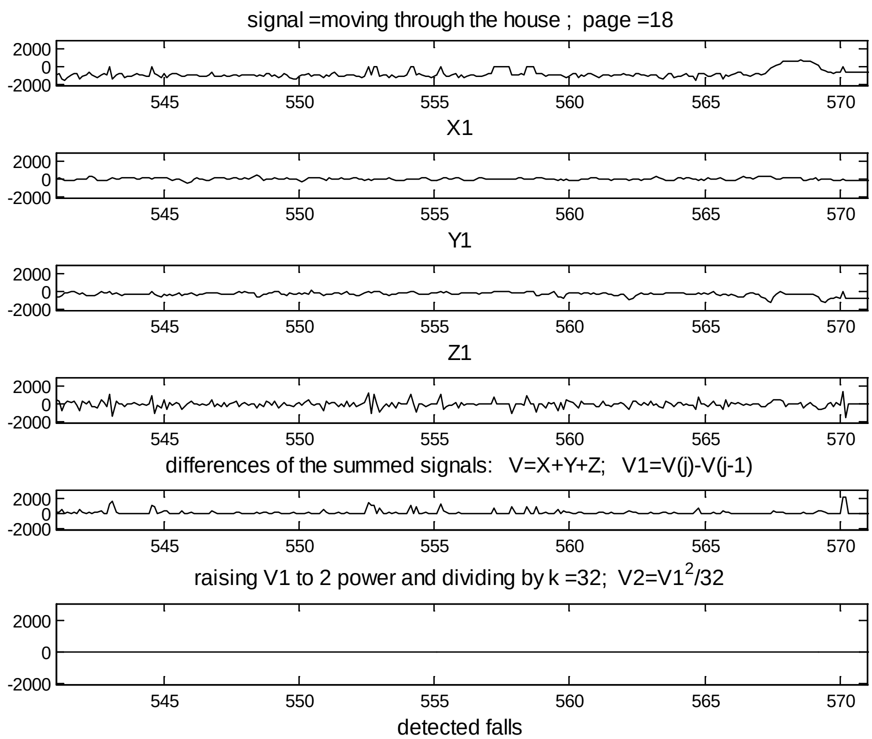


Fig. 6 : Neglected movements through the house.

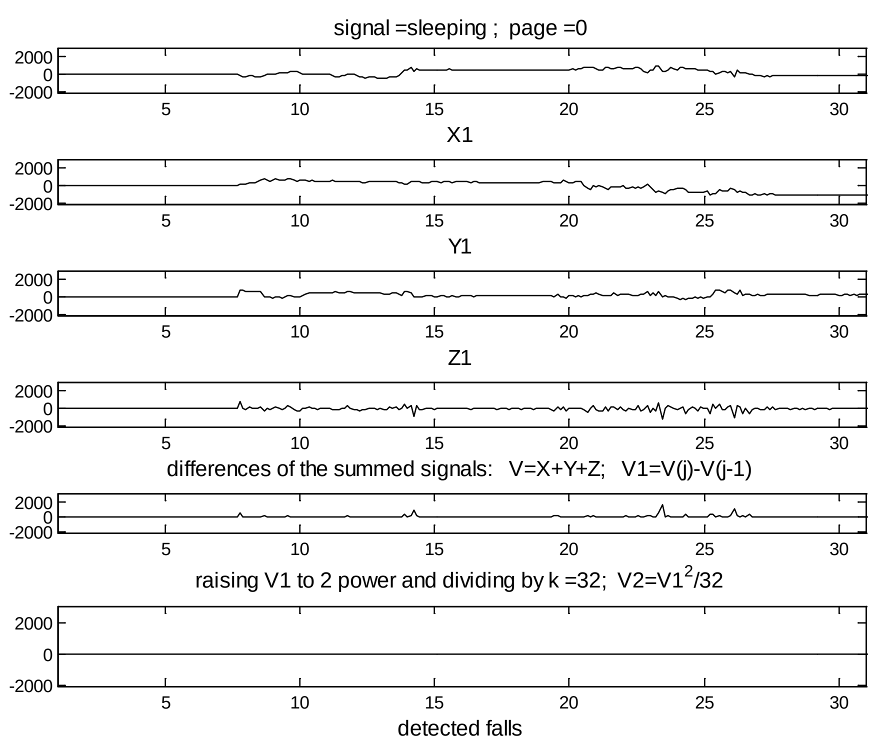


Fig. 7 : Neglected movements during sleeping.

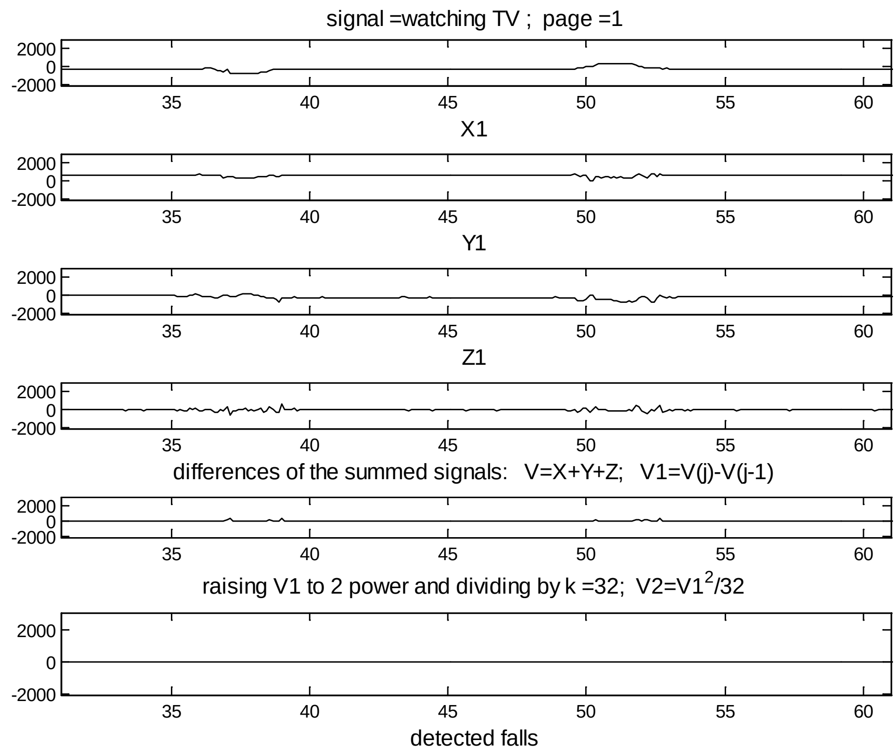


Fig. 8 : Neglected movements during TV watching.

The next Fig. 7 and Fig. 8 illustrate the accelerometer signals during sleeping and watching TV. The other not presented in the paper processed recordings do not differ from the shown episodes. Even the recommended to the volunteer jerky movements during several falls on the bed did not provoke false detections

V. Conclusion

The results obtained by processing numerous recordings of normal and abnormal movement of solitary living elderly prove that the developed algorithm for fall detection is extremely reliable. Besides, it is very simple and fast real time going.

Acknowledgement

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