RESEARCH ARTICLE OPEN ACCESS

Elderly Fall Monitoring System

Ver I.*, Ver A.*, Ianosi-Andreeva-Dimitrova A. *, Mandru S.D.*
** Department of Mechatronics and Machine Dynamics, Technical University of Cluj-Napoca, Romania*

ABSTRACT
The quality of life of the elderly people represents a major challenge for the researchers working on developing systems that contribute to increasing their independence, mobility and safety. There is a major risk of falling for aging people that may lead to severe disabilities and generate high social costs. The smart system presented in this paper is able to detect falls, being useful for the supervision of the elderly living alone at home or in elderly care institutions, where there is no permanent surveillance. It provides permanent assistance and immediate alert in the event of a fall. The system can be installed in any type of space, including bathroom and kitchen. The structure of the proposed low-cost system is presented, its operation is highlighted and some typical positions of the fallen subject are analyzed.

Keywords – elderly care, fall detection, smart floor

Date of Submission: 13-05-2020 Date of Acceptance: 26-05-2020

I. INTRODUCTION

Internet of things (IoT) is a new paradigm in which network-enabled devices have the capability of initiating data transfers without the need of human intervention; these paradigm is implemented in various fields, a relevant application being for elderly fall detection.

On the one hand, due to the drastic increase of the elderly population in the past decades, which will reach 2.1 billion in 2050 [1] and on the other hand, due to numerous age-related health issues that may limit the physical functions [2], there are many concerns and research for the development of systems that make their lives more secure and independent, leading to an increase in their quality of life.

Falling is a major risk factor in the elderly population; after a first fall, the risk of its repetition is very high. Fall-related injuries lead to physical and psychological complications, thus a fast detection of a fall event enables a quick help intervention for decreasing these potential complications caused by trauma, (limb fractures or brain damage) [3].

In the las years different fall detection and fall monitoring systems were discussed. Nooruddin et al. [4] proposed a centralized system continuously connected to various devices from which accelerometer data is received. Data processing and classification is done on a multithreaded server which enables monitoring of concurrent clients; if a fall is detected, the server retrieves the geographical coordinates which are send via SMS service to a predefined emergency contact. The cited article reports high values of accuracy, sensitivity and specificity across various devices ranging from Arduino based clients to Smartphones ones. An extensive survey for IoT fall detection technologies is [5] by Mozaffari et al. who asserts that wearable computers alone are not suitable for robust fall detection, as different activities beside simple walking are hard to discriminate from falls, therefore, an IoT architecture that comprises Edge, Fog and Cloud layers is needed for developing an fall diagnosis system that is able to predict, prevent and, in the worst case scenario, detect a fall.

Artificial intelligence, despite the prolonged periods of underfunding, is nowadays a hot topic of research; one of its many applications is real-time fall detection. Torti et al. [6] implemented a recurrent neural network (a type of neural network that capture temporal correlations in the data) on a microcontroller capable of real-time fall detection for the person wearing the device. The neural network is initially trained on a workstation with accelerometer data in order to obtain the proper weights for the model implemented on the microcontroller. The cited source claims comparable results for the microcontroller with the ones obtained on a fully fledged workstation. Another approach is to the usage of a vision-based system monitored by convolutional neural network (a type of neural network that capture spatial correlations in the data) proposed by Espinosa et al. [7]. The method consists of analyzing fixed time windows images and extracting its features; by comparing consecutive

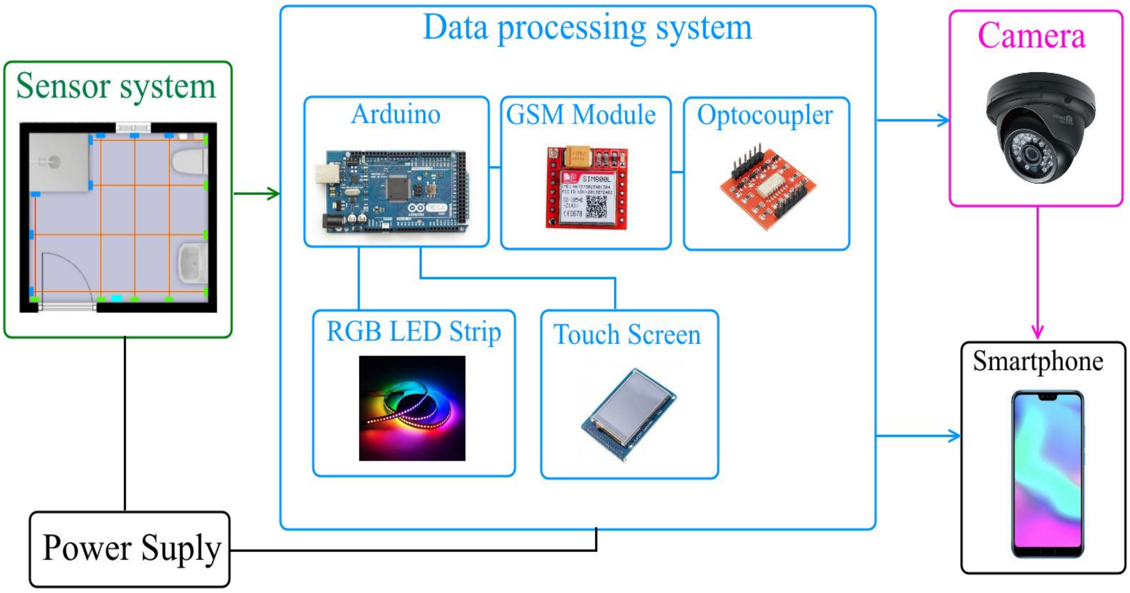

Fig. 1 The block diagram of the proposed fall monitoring system

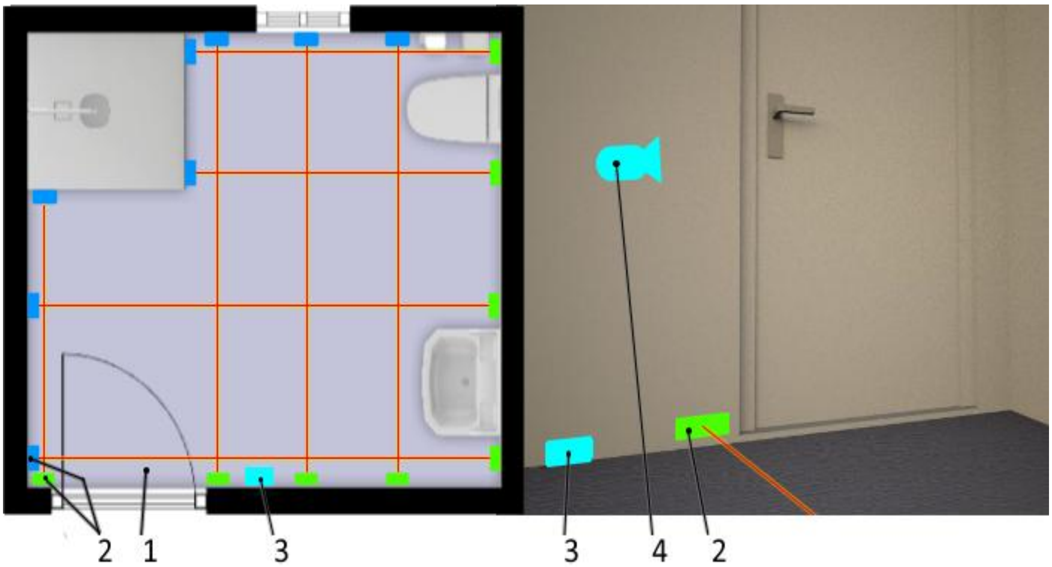

Fig. 2 Example of implementation of the fall monitoring system in a bathroom

data sets information regarding relative motion is obtained. Compared to conventional machine-learning models, their approach outperforms them with over 95% for accuracy, precision and specificity by using just two cameras. A video based system is useful for general-purpose rooms, but are tricky to implement in sensitive areas (bathrooms, bedrooms), even if an artificial intelligence is the only one who "watches" the video feed.

A comprehensive perspective on this field is presented in [8] and [9]. The existing fall detection systems are categorized in into two groups: wearable and ambient devices. The advantages and drawbacks of a large number of existing systems are discussed and the key research challenges are emphasized.

This paper refers to an intelligent system with laser sensors, which is useful for monitoring possible fall-related incidents, which could endanger the health or even the life of the elderly, living alone people or hospitalized persons. The system offers to the caregiver or the medical personnel an effective tool to come to their aid or to make the fastest and most correct decisions for their rescue.

II. THE STRUCTURE AND OPERATION OF THE PROPOSED SYSTEM

The block diagram of the fall monitoring system, which highlights the main modules in its structure, is presented in Fig. 1, while an example of implementation of this system in a bathroom is shown in Fig. 2.

We have used M12 NPN NO Laser Sensor / Photoelectric Switch Correlation, with the specifications: 0-20 m detection range, 4 mm +/- 10% detection distance, 1ms response time, spot diameter within 1.5mm. Based on the information given by the sensorial sub-system which detects a fall, after a predetermined time from the occurrence of the incident, the system sends a SMS to the mobile phone of the supervisory person / nurse / medical staff, for example: "*Attention an incident occurred*!". The system resets automatically, if the patient got up, but it can be resettled manually too. If after sending the warning SMS, the system resets, the caller receives a new SMS with the message "*There is no more alarm!*". If the patient does not get up, after another predetermined time, the system sends the following alert also through an SMS: "*The video camera has been turned on, please see if there are problems!*", so the supervisory person has the possibility to interact audio-video with the patient.

The data processing sub-system is composed of an Arduino module (Mega, or other development boards can be used), a GSM module, an opto-coupler relay module, which has the role of activating / deactivating the surveillance camera, a touch screen for setting the number of sensors to be activated in the event of a fall, the time intervals for transmitting the alerts, as well as the phone number on which the SMS will be sent, a reset button. An RGB-type warning LED that changes color depending on the system status: green, when everything is fine, blue, at the transmission of the first SMS, red, at the transmission of the second one. The reset button can also be located outside the data processing system, so that a general reset of the entire system is performed.

The surveillance camera can be placed as needed or desired, the camera can memorize alerts that can then be viewed by the caregiver, even if the patient has switched off the system and does not remember what happened or does not want to report what happened.

According to Fig. 2, the arrangement of the sensors (2) is made so that a network is created at the level of the lower limbs, at approximately 100 mm above the floor (1). When an event occurs, a signal interruption occurs between a number of sensor pairs, depending on the patient's anthropometric date and the distance between the sensors. The notations in Fig. 2 are: 3 - the data processing system, 4 - the surveillance camera.

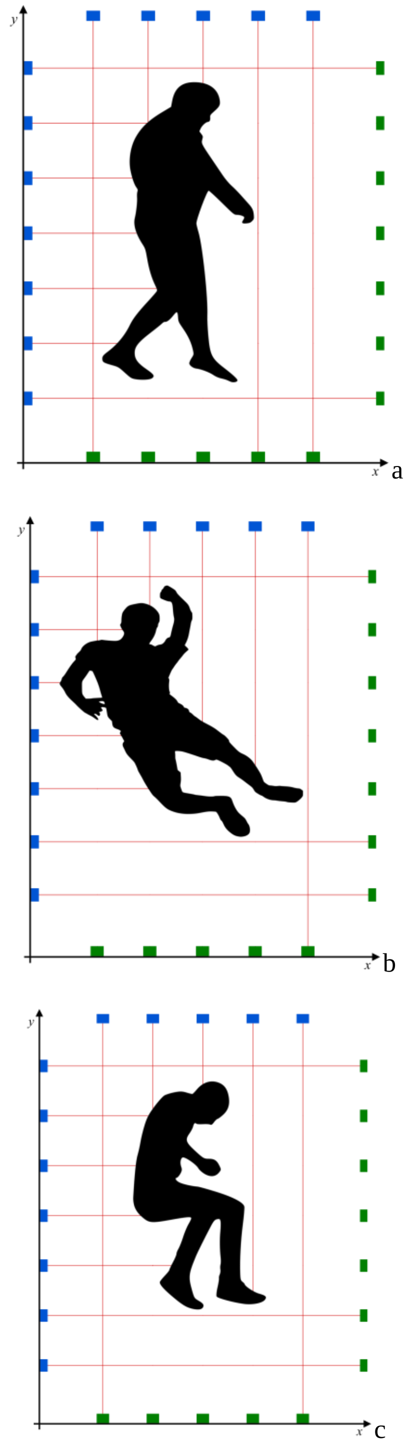

Fig. 3 Different falling positions

Considering a subject with the height of 175 cm, using the anthropometric dimensions of the body calculated according to [10] the minimum number of sensor pairs to activate in certain fall positions, to avoid false alarms, was determined. The anthropometric data taken into account are: the height of the subject 175 cm, shoulder width 45.32 cm, length of the upper limb 77 cm, arm length 32.55 cm, the length of the forearm 25.55 cm, hand length 18.9 cm, the width of the pool 33.42 cm, the length of the lower limb 92.7 cm, leg length 49.87 cm, thigh length 42.88 cm and sole length 26.60 cm.

In figure 3, a network of sensors arranged in squares with the side of 28 cm was considered in order to avoid the possibility of recording false alarms even in orthostatic posture. Three different fall positions were studied in terms of minimum number of sensors that are activated for each type of fall. If the subject falls straight, in the dorsal or lateral decubitus, with the hands near the body, a minimum number of seven pairs of sensors are activated (Fig. 3a), if the subject falls diagonally activates at least 8 pairs of sensors (Fig. 3b), while the subject is with knees in flexion, with the hands near the body, or in the crouching position, activates a minimum 7 sensors (Fig. 3c).

III. CONCLUSION

The fall monitoring systems are useful because they avoid the worst consequences of falls, like injures, dehydration, hypothermia even death.

The advantages of the system proposed in present work, are the followings: it can be mounted in rooms with any type of floor (plastic floor, concrete floor, a.s.o.), such as bathroom, kitchen where the most frequent accidents are; it does not require under-floor mounting, as in the case of different smart floor systems, it offers the possibility to mount in / on the baseboard, furniture, walls; its operation ensures a low number of false alarms and the costs of components and implementation are very low.

Our future work is focused on the integration of the proposed fall monitoring system with other monitoring and assistive equipment in a smart home for the elderly.

ACKNOWLEDGEMENTS

The paper was partially supported through project ID 37_215, MySMIS code 103415 “Innovative approaches regarding the rehabilitation and assistive robotics for healthy ageing” co-financed by the European Regional Development Fund through the Competitiveness Operational Programme 2014-2020, Priority Axis 1, Action 1.1.4, through the financing contract 20/01.09.2016, between the Technical University of Cluj-Napoca and ANCSI as Intermediary Organism in the name and for the Ministry of European Funds.

REFERENCES

[1]. United Nations, Department of Economic and Social Affairs, Population Division 2019 *World Population Ageing 2019: Highlights*, United Nations, New York, 2019.

[2]. Q. Ni, A. Hernando and I. Cruz, The Elderly’s Independent Living in Smart Homes: A characterization of Activities and Sensing Infrastructure Survey to Facilitate Services Development, *Sensors, 15*, 2015, 11312-11362.

[3]. S. Gasparini, E. Cippitelli, S. Spinsante and E. Gambi, A Depth-Based Fall Detection System Using a Kinect Sensor, *Sensors, 14*, 2014, 2756-2775.

[4]. A. Nooruddin, M. Islam, and F.A. Sharma, An IoT based device-type invariant fall detection system, *Internet of Things, Vol. 9*, DOI: 10.1016/j.iot.2019.100130, 2019.

[5]. N. Mozaffari, J. Razazadeh, R. Farahbakhsh, S. Yazdani and K. Sandresagaran, Practical fall detection based on IoT technologies: A survey *Internet of Things*, *Vol. 8*, DOI: 0.1016/j.iot.2019.100124, 2019.

[6]. E. Torti, et al, Embedding Recurrent Neural Networks in Wearable Systems for Real-Time Fall Detection, *Microprocessors and Microsystems, Vol. 71*, DOI: 10.1016/j.micpro.2019.102895, 2019.

[7]. R. Espinosa, et al, A vision-based approach for fall detection using multiple cameras and convolutional neural networks: A case study using the UP-Fall detection dataset *Computers in Biology and Medicine, Vol. 115*, DOI: 10.1016/j.compbiomed.2019.103520, 2019.

[8]. N. Pannurat, S. Thiemjarus and E. Nantajeewarawat, Automatic Fall Monitoring: A Review, *Sensors 14*, 12900-12936, 2014.

[9]. G.K. Moghaddam, C.L. Lowel, *Health and Wellness Measurement Approaches for Mobile Healthcare*, (Springer 2019) 28-29.

[10]. P. Assantachai, Anthropometric Aspects and Common Health Problems in Older Adults, in V.R. Preedy (Ed.), *Handbook of Anthropometry*, (New York: Springer-Verlag, 2012) 1415-1435.