International Journal of Research in Advent Technology, Special Issue, ICATESM 2019
E-ISSN: 2321-9637
Available online at www.ijrat.org

Review Of Fall Detection Techniques For Elderly

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Abstract- Rapid aging of global population is the topic of concern, which makes the issue of elderly care increasingly important. Falls of old people is the biggest reason for deaths among elderly. Fall detection is a leading challenge in public health problems particularly among elder people. These kinds of falls may become fatal if remain overlooked in time. Thus to avoid such accidents and provide medical help in case of such emergency, fall detection system is built. To minimize the fall and its related injuries continuous examination of patients and those who are prone to fall is needed. The given paper presents reviewed history of fall detection system using wearable, ambient sensors, also technologies and algorithms used for the following situations and prevention systems to aid the elderly people and their caregivers. Moreover the paper has discussed about the foremost challenges while dealing with elderly falls, besides proposals for potential research directions.

Keywords- Fall detection system, Wearable Devices, Vision based approach, Accelerometer

1. INTRODUCTION

Falls is primary public health issues in the world. An estimation of fatal falls is about 646,000 over the world each year [1], making falls the second foremost cause of unwitting injury death. The risk of serious injuries is increased if the person remains unconscious or unbalanced after the fall because of their inability to call for someone for help. As elderly are unable to control their daily actions as they grow older this could result in one of the threats in public health. According to report from World Health Organization (WHO) adults, with age greater than 65 years, experience the utmost total of fatal falls, also the deaths caused by falls are maximum among adults over the age of 60 year[1].Females have been found at greater risk in this issue[2]. Not only physical, but these falls could also result in severe psychological effects in elderly. History of falls can result in a higher probability of fall in future. This could cause increase in dependence from elderly. The maximum number of unnoticed falls occurs when patient goes to the toilet.

Fall detection is noteworthy research direction in the study of falls. The time required to provide patient proper treatment after the fall determines the severity of a fall. If the patients are attended at time, the consequences of fall can be minimized. To distinguish a fall from other actions based on this definition requires lots of efforts, since there are many similar actions. For example, falling has the most resemblance to lying [3]. Furthermore it is quite difficult to obtain the real statistics in the daily life, since it is a kind of random and accidental. Therefore, it is a intimidating task for researchers to build datasets with real fall data to study and analyze.

Furthermore, the fall detection problem lacks a universal solution because various kinds of sensors are being used. We need to conduct a comprehensive study in order to get an overall view of world. Lots of work has been done in the field till 2019. The rapid advancement in the area of smart sensors and the Internet of Things has brought various opportunities in fall detection research and created series of research results.

2. OVERVIEW OF ELDERLY FALLS

A. Causes of falls

The reasons of falls are due to interaction among various factors. Nearly 400 such factors have been observed [5]. Accordingly, identifying these aspects may lessen the possibility of falling. We can categorize them as factors related to the behavior, factors related to person, factors related to environment.

B. Identifying the possibility of falling

Various risk factors are needed to be computed using adequate evaluation tools and methods to reduce the possibility of falls.

For all the previously mentioned factors, the need for assist arises. This research work can be carried out into two tracks. These are

1] Fall detection: in order to minimize the rescue time to reach the patient

2] Fall prediction: to prevent the falls .The system can be programmed such that it will send help as soon as emergency situation is predicted. Collection the signals from the sensors are included in data acquisition. The sensors may be wearable, ambient sensors or camera. The data collected is compared with reference data in order to predict the fall.

C. Different types of approaches

From the review of technologies for elderly monitoring and alarm systems can be categorized into three categories.

1. By using wearable sensors:

The system senses acceleration of the subject using the input data. Development in the technology has brought in those devices that can determine activity making use of accelerometers. The sensors are positioned on different places, such as waist, thigh, wrist, shoes etc. We can use accelerometer in smart phone to determine the fall.

2. By using ambient sensors:

The ambient sensors are those that are placed in the periphery of subject. Ambient based techniques combine audiovisual signals besides other records including floor vibrational data or even microphone signals taken through environmental sensors. Microphones, pressure sensors on floor mat, microwave motion detector, infrared sensors are used as floor sensor to determine fall. In order to categorize daily activity and falls, neural network classifiers are used.

3. By image processing technique:

In this method body postures are recorded with the help of camera. Vision dependent recognition systems uses camera to monitor as well as characterize a person's movement and trial the incidence associated with falls. Because of this, various approaches with regard to image examining have been proposed including spatiotemporal features various image processing techniques such as matching of templates, recognition of posture, extraction of skeleton, elimination of background, optical flow processing etc… are used to detect falls. The fig.2 shows general flow of image processing steps for fall detection

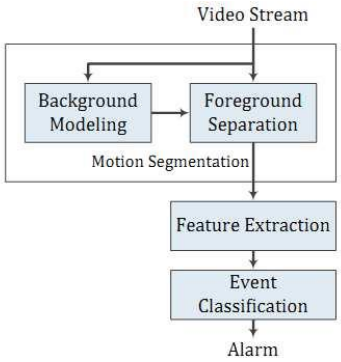

Fig. 1 General Flow of visual fall detection

3. SURVEY ON FALL DETECTION TECHNIQUES

In the last decennium, several papers have been published that discuss various aspects of the fall detection problem involving number of classification techniques, different sensor and feature extraction techniques.

Qiang Li et al. [6] developed a system which combines gyroscope (IDG-300, ADXRS300) and accelerometer (MMA7261QT). The system measures both angular velocity and acceleration in order to detect falls. For the trial sensors are attached at chest (node A) and thigh (node B). It records the rotational rate and linear acceleration readings from A node to B node for typical walking, standing, running and sitting as given in Fig. 2. The fall detection solutions were classified by author into three steps: posture analysis, activity intensity analysis, and transition analysis. To determine the fall preceding recording of 5 seconds is considered. Then the data acquired is measured with the reference value. The algorithm is helpful to determine false negatives (e.g. falling on stairs) and false positive(e.g. sitting down fast) . A number of experiments were executed to attain accuracy of 92%

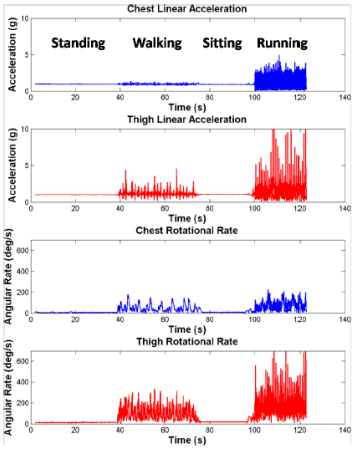

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Fig. 2 The linear acceleration and rotational rate of the trunk and thigh for standing, walking, sitting, and running

Khalil Niazmand et al. [7] applied the sensors on clothes instead. The sensors are located on washable clothes for avoiding the discomfort by patient. The system has eight accelerometer sensors. It is used to sense movements of the torso and the upper body. This data is examined and that's how the fall is analyzed. After the detection of fall, emergency messages are sent to the respective person. Removable and rechargeable battery is provided in system which proves energy. The sensors are positioned inside washable material. The sensors under arms provides the true-positive-rate maximum (TP-rate) and the false-positive-rate minimum (FP-rate). Threshold values are determined by taking consideration of several experiments. The given system is not feasible to differentiate among falls and normal daily activities like bending, lying. Subsequently system gives false alarm.

Ziyu Lv [8] developed a system known as iCare which is a health monitoring system equip by mobile for the elderly. The system dynamically monitors the elderly on a regular basis and automatically alarm to the emergency centre in the emergency situation. It also plays a role of living assistant which provides auxiliary functions such as scheduler or quick alarm. The system also acts as personal health data system in order for doctors to view present as well as past condition of the elderly, sensors are set for threshold to suggest patents about their daily activity in order of their tele-monitoring. Additionally, medical guidance system is constructed and the on the based on that information data base is formed on server, which is unique compared with other monitoring systems.

SHOU-HSIUNG CHENG [9] proposes a system of fall detection using triaxial accelerometer incorporated by active RFID. The accelerometer is used to determine three axis acceleration values. This system is able to distinguish walking and falls as well as postural orientation of the respective wearer. There are

six falling postures included in this study as shown in Fig. 3. The data is collected then preprocessed. To recognize the falling postures machine learning technique is employed which uses neural network classifier. 300 records, 50 of each falling postures were taken. These were divided into experimental and training data. Around 98% to 99% accuracy is acquired.

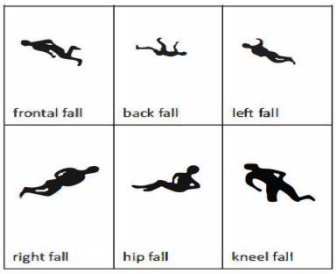

Fig.3 Six falling postures

Basavaraj G M [16] proposed a real- time detection of human fall detection system in real time using static digital camera which is fixed in the indoor of respective elderly. The proposed work is based on two techniques, an Ellipse approximation (EA) and Motion History Image (MHI).The shadows are removed for best detection of human in an indoor environment. The fall detection is done by considering ellipse approximation, Motion history image and combining both the techniques. The flow of methodology is as follows: Image acquisition, Image preprocessing (to enhance the quality of video), Foreground Segmentation (to separate person from background), Feature Extraction (to determine fall), display message. Feature extraction is done by either EA or MHA.

Motion of image is recorded by MHA. As given by,

$$\text{Vmotion} = \frac{number\ of\ gray\ pixel}{white\ pixel + gray\ pixel}$$

The combine result gives accuracy of around 90%.

S.Y.Sim et al. [10] sited accelerometer sensor in shoe. The change in accleration is determined by comparing it with the threshold value. Several trials were taken to determine the exact location for placing sensor. Inconsistent accuracy is yielded by different locations. Sensor at tongue of the shoe got maximum accuracy providing sensing was fastening. Algorithm was unable to determine activities like jogging, jumping etc… The achieved sensitivity was 81.5%.

Febus Reidj G. Cruz [11] developed a Wearable Fall Detection System using two accelerometers, XBee module, and a microcontroller. The system determines the fall threshold by analyzing accelerometer g values for different Activities of Daily Living (ADL) and for falling activities. They created a System Network based on ZigBee Technology (IEEE 802.15.4 Standard) and IEEE 802.11 Standard, in order to send the emergency message. Based on the results of the data, the fall detection system is fully operational, has 100% fall detection accuracy, and has high data transmission reliability, but the testing shows that there is an average delay of 20 seconds before the android mobile application receives an update.

Alan K et al. [12] combined camera and tri-axial accelerometer for data acquisition. Vertical velocity profile is tracked using chest worn accelerometer, whereas the special markers placed on the area of human body help the camera to analyze human activity. To detect fall, an algorithm which thresholds the vertical velocity and body posture tracking from camera is employed. Data analysis was done, in order to determine RMS error during four different falls and six ADL types and the peak velocities that were recorded, by using MATLAB. The algorithm separated daily activity from six types of falls with an accuracy of 100%

Jer-Vui Lee [13] presents an Android-based smart phone for fall detection of the subject, with 3-axial accelerometer, to use it as the tele-health device. In order to attach smart phone to the monitoring system via Wi-Fi the TCP/IP networking method is used. To exhibit the information collected from the system a graphical user interface (GUI) is developed as the monitoring system. The remote panic button concept is also tested and applied in respective project, using the similar android based smart phone.

Kabalan Chaccour, et al. [14] presented an overall classification among different fall detection technologies. They have categorized fall detection methods into wearable dependent system, non-wearable dependent system and hybrid or fusion based system. He proposed the categorization scheme based on the deployment of sensors to either detect or prevent falls. The paper discusses about different data processing techniques for fall detection which depends on the extracted parameters from the sensors.

These techniques are [1] Analytical and [2] Machine learning methods.

Analytical methods are the customary techniques that use statistical models for gaining interpretation on data for prediction. One of the method is thresholding techniques (TH) where peaks or valley points and other shape features are used to detect falls. These methods are usually used in wearable sensors. this differentiate posture from basic motion patterns. Camera based systems employ image processing techniques for obtaining spatiotemporal features (e.g. weight, silhouette height ratio, width, orientation axis of main body, color of skin) for recognizing lying or standing posture. To detect abrupt motion image processing applies vector analysis.

Machine learning methods rely on complex algorithm to get close insight on data to predict output decisions. These fall detection techniques can get assistance from techniques such as Regrouping Particle Swarm Optimization, Support Vector Machine (SVM), Decision Trees , Multilayer Perceptron, Naive Bayes, Gaussian Distribution of Clustered Knowledge, ZeroR, and OneR to gain insights in to the data to

detect and even predict future falls in order to observation and classification of falls.

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4. COMPARISON

TABLE I.COMPARISON OF VARIOUS FALL DETECTION TECHNIQUES

Reference Paper number	**Year**	**Sensor And Its Placement**	**Measure Of Performance**	**Remark**
[6]	2009	Accelerometer, gyroscope Chest and upper thigh	Sensitivity: 91% Specificity: 92%	Can't detect vertical fall
[7]	2010	Accelerometer, Washable jacket	Sensitivity: 97.5% Specificity:96.92 %	Activities like picking an object quickly, standing suddenly are detected as fall.
[15]	2018	Accelerometer, on clothes	Accuracy 92%	Use smart clothes, BLE component and indoor positioning algorithm
[8]	-	Wireless body sensor and smart phone	-	Smart phones will be used to gives alerts in case of emergency
[9]	2014	Triaxial accelerometer integrated by active RFID , on clothes	Accuracy 98% to !00% for different falling postures	Machine learning is used to detect various falling postures
[16]	2017	Camera, ambient	Accuracy 86.66%	Vision based surveillance system is proposed for detection of human fall
[10]	2011	Accelerometer, shoes	Sensitivity: 81.5%	Jogging, walking on stairs, jumping activities are classified as fall
[11]	2017	Accelerometer, stomach	Accuracy 100%	Two accelerometer were used to increase te accuracy
[12]	2008	Accelerometer, camera, chest worn	Accuracy 100%	combined tri-axial accelerometer and camera for data acquisition
[13]	2013	Accelerometer of Smart Phone, Waist worn	The application enables the user to set sensitivity according to the requirement	The challenge is to classify acceleration values when the device is worn different parts of body. Facilitated with GPS and SMS alert
[17]	2012	Accelerometer, Anywhere on the torso	Sensitivity: 99% Specificity:100%	Failed to detect falling to right and left side with bent knees
[18]	2011	Accelerometer and barometric pressure sensor Waist	Accuracy : 94.12% Sensitivity: 87.77% Specificity: 85.24%	The height of subject affects the performance of barometric pressure sensor
[19]	2009	Thermistor: palm of non-dominant hand Skin resistance sensor: the second phalanx of the index finger and the third finger of the non-dominant hand. ECG electrodes	Sensibility: 70.37%, specificity: 80% positive Predictor: 73.8%.	Physiological parameters are measured instead of body posture and acceleration. The study of autonomic nervous system during fall conditions

4. CONCLUSION

The fall detection system with the causes of falls is studied in this paper. Along with this, three categories of fall detection system (wearable, non- wearable, and fused), various sensors used (accelerometer, camera, and gyroscope) and analytical and machine leaning methods used for computation are also given. The paper reviews various fall detection techniques and hence compares performance of various techniques based on parameter such as accuracy and features used for the fall detection. We can conclude hereby that fall can be recognized even before its occurrence if thorough knowledge of daily activities of the subject is provided.

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