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Review of Fall Detection and Alert Systems for Elderly People

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***Abstract*—Nowadays since people are busy due to their schedule, it's not always possible to keep someone at home to take care of elder person. Most of the people who have fallen cannot get up without assistance. Tissue injuries, joint dislocations, bone fractures ,and head trauma are some of the damages caused by falling. The absence of movement of a person after a fall may cause severe complications regarding health and may even lead to death if immediate assistance is not provided. Fall detection system using sensors are available in the market. But they need to be attached to the body to detect fall. The elderly may forget to wear them and they can cause discomfort too. In order to overcome these challenges, automatic fall detection and alert system can be used at the home for quicker assistance. The solutions in these papers are implemented using Machine Learning, Deep Learning and Computer Vision technology. In this paper, we discuss different methodologies to detect human falls. This paper is aimed towards analyzing the effectiveness of those methods for the detection of human falls.**

***Index Terms*—Fall detection, Machine Learning, Deep Learn- ing, Computer Vision, Detection, Sensors**

I. INTRODUCTION

The number of people above the age of 60 is growing rapidly especially in India, the second most populated country in the world. The increase in life expectancy has resulted in an increase in the number of elders. Falls are one of the serious problems faced by elder people. Tissue injuries, joint dislocations, bone fractures , and head trauma are some of the damages caused by falling. Nowadays people are busy due to their schedule, so they are not getting enough time to take care of the elders at home. An alternative is to appoint caretakers.

But we can't completely trust them at all times. Most of the elders who have fallen cannot get up without assistance. This makes the situation more worse for elders living alone in their homes. And if they keep lying on the floor for more time or if they don't get proper assistance at the exact time, it can cause more damage to the injuries and even death.

In this survey, we provide an overview of fall detection systems using AI. These systems aim to notify others when a fall is detected such that immediate care can be given to the fallen person without any delay. Most of the existing systems are electronic sensor-based devices whereby older people need to wear them all the time in order to detect the falls. But this can cause discomfort to the elders and most of them don't like to attach anything to their body. And a major disadvantage of the wearable sensor-based system is that the elders may forget to wear these devices and in which case the fall won't be detected. Another commonly used technology is the vision based detection systems. These systems eliminate the need to wear devices on the body all the time. But they can't be used in private places and these systems won't detect falls not in the vicinity of the camera. All these technologies have been discussed in detail in section II of this paper. Lastly, Section III concludes the paper.

II. DISCUSSION

In the recent years, several existing fall detection systems have been developed; for example, [1] developed a system using computer vision and Internet of Things. This approach is able to detect fall event by detecting features from scene captured by single camera. IoT (Internet of Things) is also used to notify the caretaker about accident through email with attached screenshot of scene and video recorded after fall. The caretaker/relative can also view the live streaming of the room by entering IP address of raspberry pi on browser. Camera interfacing and internet connection is done through raspberry pi3 model B. Camera captures scene, foreground which is moving object in this case is detected and different features are extracted from that object. Extracted features are used to detect fall event. System involves 4 steps as: 1) detecting movement features 2) finding threshold for these features to detect fall

3) sending email along with saved screenshot and video after fall has been detected. Here, we have used python2.7 software and OPEN CV 3.1. Mostly used approach for

identifying the moving object is background subtraction, in which each frame is compared with background model. Pixels in current frame deviating from background are considered as moving object. This foreground region is used to extract features from it to detect fall. Features can be of many types like aspect ratio, distance of centroid of human body to the floor, fall angle, shape, center of mass, etc.

This method involves detecting movement and then extract- ing that movable object (In this case Patient), detecting four movement features from foreground object as aspect ratio, orientation angle, centroid and Hu moment invariants, taking decision whether fall has happened or not based on threshold found out during experimental analysis, and finally sending a notification through email along with attached screenshot and video after fall has been detected. The methodology in- volved are foreground extraction, movement feature extraction, sending mail using SMTP, video surveillance availability , and hardware setup. This approach resulted in 92.98% specificity and 91.89% accuracy.

In [2], Convolutional Neural Networks (CNN) are used for fall detection in video surveillance environment. To each frame in the video, CNN is directly applied to learn human shape deformation features if a fall occurs. The UR Fall Detection Dataset which contains 40 activities of daily living (ADL) and 30 fall video sequences is used for training. Modified AlexNet is used as the CNN architecture and network architecture consists of five successive convolutional layers Conv-1...Conv- 5 and three fully connected layers FC6, FC7, FC8. The FC7 layer has 1024 neurons and the FC8 layer has 2 neurons corresponding to 2 classes namely ADL and fall. Minibatch stochastic gradient descent is used to train the network, with a batch size of 85. The early stopping algorithm, a regularization technique, is used to stop the training before the network begins to overfit the training set. The average sensitivity, specificity, geometric mean and accuracy are 100%, 99.98%, 99.99%, 99.98%, respectively. This means this approach gen- erates fewer false alarms. But changing the backgrounds of the video such as shadows, moving objects may decrease the performance of this approach.

Here [3], a novel machine learning-based wearable belt for fall detection is used to detect falls. It is a wearable belt that detects a fall of a person.In this system to detect a fall leveraging machine learning and signal processing algorithm deployed over a simple 32 bit microcontroller to achieve high accuracy custom dataset of various types of falls as well as other daily activities are noted. This device informs the family/bystander via the gsm module when a fall is detected. The main purpose of the system is to detect a fall, trigger an alert, and take immediate action to minimize the impact of the fall. The system is able to detect falls in .25 sec with high accuracy. It helps to minimize the injury. The real-time data from the sensor is classified into fall or no fall and according to that the family/bystander is notified through the alert message the design of the belt was made using lightweight material the component is fixed at a particular position so that they detect all movement of the person. The algorithm can detect the fall before a complete fall occurs. The product is low cost as the algorithm can be implemented on a simple microcontroller.

In this approach [4], a fall detection system based on combining multiple shape features and motion analysis is used in order to increase the accuracy of the fall detection. The entire process of detection consists of several stages like background subtraction method to extract the silhouettes of the moving person and its post processing methods to initiate an efficient fall detection. Several algorithm has been used to detect and classify the processed images as fall and not fall. The main method of this paper is the development of a new method of computing the vertical velocity of the head without the need for a tracking filter which represents a great constraint in time and resources, especially for real-time applications. This method also resolves the dependency to the skin or hair color to estimate head coordinates, which often limits the capability of such systems. The results of classification show a global error rate of less than 1.5% for knn and 1.0% for bpnn-svm respectively.

In this method [5], a vision based fall detection system is presented to improve the safety of elders in indoor envi- ronments using machine learning. Since the input is a video sequence from a static camera, background subtraction is used to obtain human candidates. Foreground mask including human is extracted using the background subtraction method VIBE+. Then human object is extracted using Connected Component Analysis and a bounding box. An augmented feature vector HLC combining the Histograms of Oriented Gradients (HOG), Local Binary Pattern (LBP), and feature extracted by the Deep Learning Framework Caffe is used to represent the silhouette area of the person. Two linear SVM models are trained: Single frame classification model and fall detection model. In the first training stage, the images are classied into three categories: Walking, Falling, and Lying and then a single frame classication model is obtained by training these images. In the second training stage, the predictions of every 30 continuous frames in a video sequence given by the first model is taken as input. Then the fall detection model predicts whether the state of humans is ”Fall” or ”Not Fall”. Multiple Cameras Fall Dataset is used to train and test the fall detection models. This approach achieved an average fall detection result of 93.7% sensitivity and 92.0% specificity as well.

Here [6], a fall detection system is proposed based on ma- chine learning. The system detects falls by classifying different activities into fall and non-fall actions and alert the relative or caretakers of the elderly person in case of emergency. Machine learning algorithms SVM and decision tree are used to detect the falls on the basis of calculated features. The system uses open source available dataset SisFall which has recorded Gait data by using a Tri-axial accelerometer. Fall can be detected using two techniques after collection of data from sensors and feature calculation. One is threshold based, if reading of the sensor is above particular threshold, it can be categorized as fall. In the current work, accelerometer data from a wearable sensor is used, which is already measured for different activities in small dataset. Most relevant features are calculated. Machine learning models of SVM and decision tree are trained and tested. The SisFall dataset is considered which consists of data collected with the help of ADXL345 accelerometer from the waist band. Tri- axial accelerometer ADXL345 is used to get the acceleration values along three axes x, y and z. The methodology involved are 1) Data Acquisition 2) Data Processing 3) Feature Extraction 4) Fall Detection 5) Alert. The system acquires accuracy up to 96% by using decision tree algorithm.

This paper [7] presents a fall detection system that monitors in real-time an older adult. The system defines two major components: a wearable device and a cell phone. Once, the wearable device detects a fall, it sends an alert to the cell phone; then the cell phone alerts to the emergency contacts defined by the user. The main objective is to avoid the need of carrying the cell phone every time. In addition, the system has a panic button that can be used in order to alert the emergency contacts in the event that the user feels that a fall may happen. The system defines two main components. The first component is a wearable device acting as a pendant, and the other one is a mobile application running on a cell phone. These two items will communicate with each another via a Bluetooth. The pendant has a motion sensor attached to it for fall detection. When a person falls, the pendant sends an alert to the mobile. Then, the cell phone calls and messages a person of interest informing the location of the event. The experiments included several fall types: backwards, right side, left side, diagonal towards left, diagonal towards right. The higher accuracy, 92%, is achieved backwards, and left sided fall. Other situations achieve over a 83%.

Another wearable-based fall detection system is presented in [8] using accelerometer and gyroscope based on smartphone. Accelerometer and gyroscope sensors are embedded in smart- phone to get the result of fall detection more precisely. Here the algorithm for fall detection is divided into four parts. First the difference of the maximum and minimum values in the sample are compared with a specific threshold. Secondly, the angle value (in degrees) is used to measure the posture. It can be use to determine whether the user actually fell or stood up quickly. Thirdly, test its threshold value if the value of those points are met. This threshold value determines whether the user experienced sudden acceleration. Fourthly, observe the specific direction of the user when they fell if all the above points are fulfilled. The smartphone is placed in the left shirt pocket. This is used to find a well positioned condition to capture the data which is then processed based on the above algorithm. This system obtained an accuracy of 93.33% of the 120 trials fall, and an average accuracy of 98% of the ADL 210 times the total experiment. The moment a person fell, the system will detect and activate an alarm system.

Sl. No	Name	Wearable Sensor-based system	Vision-based system	Alert System	Algorithm Used	Performance
1	Fall Detection for Elderly People Using Machine Learning	Yes	No	Yes	Decision Tree	95.7% Accuracy
2	Automatic Fall Detection of Human in Video Using Combination Features	No	Yes	No	SVM	93.7% Sensitivity 92% Specificity
3	Elderly Fall Detection System based on Multiple Shape Features and Motion Analysis	No	Yes	No	BPNN	99.61% Accuracy
4	A Novel Machine Learning based Wearable Belt for Fall Detection	Yes	No	Yes	Logistic Regression	100% Accuracy
5	Fall Detection for Elderly Person Care Using Convolutional Neural Networks	No	Yes	No	CNN	99.98% Accuracy
6	A Fall Detection and Alert System for an Elderly Using Computer Vision and Internet of Things	Yes	Yes	Yes	Hu Moment Invariants	91.89% Accuracy
7	Fall Detection System Using Accelerometer And Gyroscope Based on Smartphone	Yes	No	Yes	N/A	96.67% Accuracy
8	Fall Detection System for the Elderly	Yes	No	Yes	N/A	92% Accuracy

Fig. 1. Comparison Table

III. CONCLUSION

This paper provides a literature review of different approaches used for the development of an automatic human fall detection system. The different techniques used are i)Vision- based ii) Machine Learning iii) Deep Learning iv) Wearable- based. The highest accuracy obtained is 100% and lowest accuracy obtained is 93.7%. Further research can be conducted in this field to overcome the drawbacks by combining the other methods.

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