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Machine detection of Human Fall – a survey

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Abstract— Fall detection using sensors is becoming an active area of research, especially related to caring of elderly people. Several devices such as video camera, wearable and other forms of sensors are widely in use. Numerous fall detection algorithms, based on machine learning concepts are reported. For research purpose, several standard data sets are available. In this paper, a survey of different fall detection approaches and the algorithms are presented. The approaches are summarized highlighting advantages and limitations. A discussion based on the review, suggesting possible research directions is also given.

Index Terms— Accelerometer, Computer Vision, Human Fall detection, Kinect sensor, Machine learning, Upfall detection, Wearable sensors.

1 Introduction

In a report from World Health Organization it was found that people with age 65 years and above suffers falls and consequent death rates are higher [1]. Hence fall detection has become an important and significant area in artificial intelligence research domain. The severity of the fall depends on the time duration the elderly people remain on the floor after falling [2]. It can lead to various health issues like dehydration, pneumonia and hyperthermia. Studies shows that there are cases where fall can lead to death within 6 months of the fall. A timely fall detection helps in providing immediate medical attention and reduces the negative consequences of fall [3].

Lots of research work has been done to design new equipment, better algorithms and efficient frame works for the detection of falls. Computer Vision based systems are one category, capable of monitoring and detecting falls. Advancement in the design of smart sensors, especially those integrated with mobile phones, opened up new avenue for the design of fall detection systems. IoT concepts based on vision as well as sensors provides for the design of integrated fall detection and management systems. One of the major limitations of studies on fall detection is the non- availability of real-life data sets. Most of the reported work are based on artificially created data sets. A typical example is “upfall detection” dataset.

There are different ways in which falls can be identified. These are: “falls from standing, walking, ladders, sleeping or lying in bed”. The current fall detection approaches are categorized into three different aspects [4]. These are namely Wearable based, ambience sensor based and Camera or Vision based[5]. The general classification block diagram is given [6].

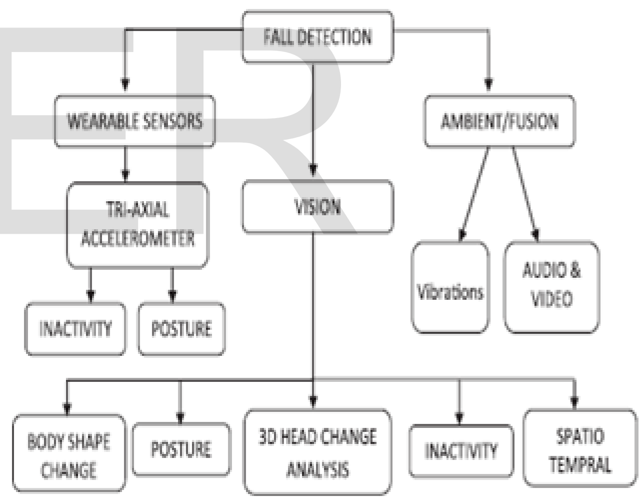

Fig 1. Classification of fall detection [6].

This work presents a comparative study of fall detection based on Wearable sensors. Recently striking innovations have been reported in wearable sensors. These sensors are capable of collecting various types of data from the environment. Sensors such as “Accelerometer”, “Kinect sensor”, “Doppler Radar” and “video sensor” are now widely used for variety of applications such as “medical diagnosis”, “health monitoring” and “biometrics”. A preliminary study on fall detection revealed that “Accelerometer” and “Kinect sensor” are the most common sensors employed in fall detection. Hence the paper focuses more onto the works based on them. In the following section a review of selected prominent works in fall detection is given

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2 Literature Review

Stone and Skubic (2015) demonstrated two stages of fall detection in homes of elder people [7]. They used Microsoft Kinect. The dataset has a total of 454 falls among it 445 falls were performed by some trained stunt actors and remaining 9 are natural falls. The first stage studies about the person's vertical characteristics in image frames. For the second stage, Decision Trees are used to compute the fall on ground. The proposal takes into account portrayal of framework execution under certain conditions to a degree that has not been appeared in other research studies. The authors claimed better results in comparison to existing approaches. Finally this method is compared with other fall detection algorithms and better results were achieved. There are some limitations to this method. The limitations include reduced resolution of the faller which leads to difficulty in segmentation of the foreground. The study also pointed the need of using multiple Kinect sensors.

Yacchirema et. al. (2018) proposed an IoT-based framework for detecting falls of older people in indoor conditions, which takes focal points of low-control remote sensor systems, keen gadgets, enormous information and distributed computing [8]. A 3D-axis "accelerometer" inserted into a 6LowPAN gadget wearable is utilized, which continuously collect data from the individuals under study. The data obtained is suitably processed and analyzed using a "Decision tree based" model executed on a Smart IoT Gateway. When a fall is detected, an alarm is enacted and the framework responds by sending warning messages to the concerned persons like relatives / family doctor. The system also provide certain cloud based services. The authors claim high accuracy for fall detection. On the negative side, the model was tested on a controlled environment with very few samples.

Li et.al. (2013) used "Neyman-Pearson" detection framework for fixing the threshold which detect falls. [9]. The authors claim that the proposed detection threshold maximizes detection accuracy. They employed "TelosW mote" with "accelerometer" which was connected to the waist of the elderly person to obtain the movement attributes. The authors considered three activities (sitting, squatting and falling), 200 trials per activity performed by five participants. Respective acceleration peak values are recorded. The results are analyzed based on detection accuracy, false alarm and relation between detection accuracy and threshold. Maximum accuracy reported is 92%. The data set used is non-standard. Further the work is not compared with competing models

Mastorakis and Makris (2014) suggested a new method for fall detection which uses the Kinect sensor for data collection [10]. They used velocity and inactivity measures for the detection of fall. Major contribution is highlighted as the way the velocity is calculated using contraction and expansion of 3D bounding box. Another advantage projected is the non-requirement of prior knowledge of the scene. The data used for the experiment includes 180 video samples of different activities performed by eight subjects. The data collection as well as the experiments are well explained. The authors claim that their proposal is less complex than other reported approaches, as it relies mostly on the bounding box concept,. But no convincing comparative analysis is carried out.

A low-cost solution for reliable fall detection with minimal false positive ratio was proposed by Kwolek and Kepski (2014) [11]. A tri-axial accelerometer was used to collect data. A threshold value for acceleration is used to identify possible fall and is confirmed by considering more features and an SVM classifier, which minimizes false alarm. The authors claim unobtrusive fall detection as well privacy preservation. The work used UR fall detection data set which consists of 612 images having different activities. They reported 98.3% accuracy and is compared with model which uses only SVM and Depth maps, and a work which uses only threshold on tri-accelerometer data.

Lee Y. et al (2018). proposed a real-time location mapping using "Google's 3D Mapping service " for effective tracking of falls and thereby to deal with critical situations [12]. For this they used "acceleration sensor" of smartphones for fall detection and the communication facilities available in phones for appropriate notification. The googles 3D mapping service provide precise information regarding the surroundings where the person is in. Acceleration sensor readings are analyzed and categorized based on age and gender leading to classification of different activities. The work focuses more on to location identification and the fall detection performance is not established. Though the model of fall detection and reporting is presented and demonstrated, there is no substantial contribution to fall detection problem.

Ajerla D. et al. (2019), discussed a fall detection model, claimed to relatively inexpensive and adaptable[13]. The frame work uses edge computing in place of cloud computing and a cheap wearable sensor from MbientLab and MetaMotionR. Long Short Term memory (LSTM) network model was used for classification. The data was collected from 64 falls by persons from different age group. The falls were enacted. Experiments were conducted by attaching the sensor at different parts of the body and they concluded that wrist position is the most accurate. Further the authors experimented with MobiAct dataset. The work is an extension of a previous work of the same authors, where LSTM model could give a recognition accuracy of 99%.

Dogan J. C. and Shafeat Hossain M. D. (2019) proposed a two stage fall detection using "smartphone sensors" [14]. They highlighted the advantages of smartphones over other wearable devices - can automatically send messages in the event of a fall and no extra devices required. The first step highlighted is a multi-class classification to identify the correct type of falls. This is followed by a binary decision making. Data comprises of five activities performed by ten people. The used five common smartphone sensors – "accelerometer, gyroscope, magnetometer, gravity and linear acceleration". For learning and classification tasks five machine learning tools were used – "Naïve Base, Random Forest, Support Vector Machine, KNN classifier and Decision Tree". SVM together with Gyroscope reported maximum detection accuracy.

Gasparrini, S. et al. (2014) [15] proposed a fall detection approach which employs "Microsoft Kinect depth sensor". The proposed method ensures privacy and also focuses on indoor activities only. Raw depth data provided by the sensor is used by an ad-hoc segmentation algorithm for the detection of ele-

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ments. Blobs are classified and used for the identification of persons. Once a person is recognized, the algorithm track the person and based on the relative position of the blob associated with him, a fall is detected. Though the work is well demonstrated with examples, extensive experimentation is missing.

3 DISCUSSION

In the previous section, nine chosen papers are reviewed. Based on the review as well the analsysis of related literature the following points are derived, which would give directions for future research.

- The topic of fall detection in elderly people and patients poses several research challenges.
- Most of the data set used are not real-life data. How far the projected performance would hold in real-life situation is a serious concern.
- Several papers are focusing on the processing architecture rather than on the detection process. Detection challenges include designing scalable algorithms to suite light weight systems like embedded systems. Edge computing over cloud computing for the processing is to more explored.
- It is required to have standard data sets exclusively for detection of falls in elderly people, with annotated results from various studies.
- The feasibility of capturing real-life data is to be explored to build large repositories with ground truths.
- There is a need for designing Artificial Intelligence based fall detection algorithms which can be used for the development of mobile applications.
- More coordinated nd extensive study on video based fall detection, especially employing deep architectures.
- Extensive study is required for the selection of most efficient wearable sensors. Further possibility of augmentation of sensors for better results. can be explored in hardware design

4 CONCLUSION

In this paper, a survey and review of selected papers on human fall detection is presented. Based on the study, several research directions are identified and presented. The study is not an exhaustive one as the topic of discussion is now so vast and need to be split into domains such as video based, wearable sensor based, constrained to in- house, IOT based, mobile phone based and embedded system based.

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