Fall Detection through Video Surveillance using CNN

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Abstract

There has been an exponential increase in the number of elderly people living alone. This is mainly due to the increasing number of nuclear families that have been abandoning their parents. This has forced them to take care of themselves, which is a herculean task when a person is very old. Added to this epidemic, old people are highly susceptible to balance issues due to weak musculature. It is a very deadly combination that can lead to some seriously fatal falls. The elderly people are also more prone to get severely affected by these falls and some can also be fatal. Therefore, an innovative system is proposed, that utilizes image processing for the purpose of detection of falls and provides a constant vigilance on the subject. This novel approach is made possible due to the integration of Convolutional Neural Networks and the region of interest to evaluate each frame efficiently to ascertain the fall. As soon as the fall is detected, the neighbors, relatives and the emergency services that can provide much-needed lifesavingassistance.

Keywords: *Convolutional Neural Network, Image Normalization, Fall Detection.*

I. INTRODUCTION

Fall detection has been constantly on the rise since the past decade. There has been increasingly gathering the interest of the various researchers all over the world. Many authors have researched and published their findings on the concept of fall detection extensively. This is due to the fact that this field of computer science needs a lot of innovation and it is one of the most crucial and critical applications of technology in the area of Health care. It is highly essential to allow for better techniques for fall detection.

There has been a lot of interest in this fall detection category due to the fact that various statistics describe that elderly people are very prone to falling and can sustain severe injuries. Due to the fact that elderly people are weak and cannot be inflicted the stresses and impacts of a fall that could damage them badly. In addition to elderly people, another set of people that are vulnerable to falling are the people suffering from vestibular dysfunction and also patients suffering from Equilibrium Disorders.

These types of patients are very prone to falling and can gravely injure themselves when they fall. It is very crucial to monitor the patients and their movements even while in the hospital to reduce the impacts of such violent and damaging falls. Hospitals need to maintain constant watch over their patients to ensure none of them experiences a fall. Which is highly time-consuming and cannot be physically possible after a stipulated amount of time. Most of the hospitals are already packed to the brim with staff performing round the clock shifts.

This kind of atmosphere at the hospital would leave patients like these also and vulnerable to attack. And the hospital cannot assign every patient one staff to monitor if they are falling or no as there is never that much-qualified staff in the hospital, moreover,it would be highly time-consuming and not at all economical to attempt something like that. Therefore, it is imperative to implement an automatic efficient and accurate technique for the identification of a fall and also provide assistance to the victim.

Due to large scale advancements in the area of medical science, there has been an exponential increase in the life expectancy of individuals. This attributed to the fact that a lot of life-threatening diseases and ailments have been cured and

many epidemic diseases have been entirely eliminated from the earth. This has led to an increase in the number of elderly individuals. Also, it has been reported that there has been an increase in the number of old people living alone.

Therefore, implementation of a technique that can automatically and remotely detect a Fall, is the need of the hour. It is imperative that a system that can achieve efficient and accurate detection methods for this purpose are utilized to increase the quality of life for those people.

Convolutional Neural Networks are a category of Computational networks that are primarily used for the purpose of machine learning applications. Convolutional Neural Networks are a sub-category of computational networks referred to as Artificial Neural Networks or ANN's. The ANN's are a set of networks that have been designed after taking inspiration from the workings of the human brain. therefore, the smallest unit of computation in both the brain and ANN's is the neuron.

The neuron is responsible for the computational prowess of the neural networks and also forms the basis of Convolutional Neural Networks. There is one defining feature that separates CNN from the ANNs and that is the former's implementation of convolutional layers that are individual filters that can analyze and filter the data. Therefore, CNN's are quite powerful are predominantly used in applications involving generative and descriptive problems, such as pattern recognition.

This research paper dedicates section 2 for analysis of past work as literature survey, section 3 deeply elaborates the proposed technique and whereas section 4 evaluates the performance of the system and finally section 5 concludes the paper with traces of future enhancement.

II. LITERATURE SURVEY

This section of the literature survey eventually reveals some facts based on thoughtful analysis of many authors work as follows.

J. Lee [1] addresses near fall scenarios in addition to typical falls and the activities which occur in day to day life. There are two different types of falls detection method first one is a novel approach which can detect it by using a sensor and the second is by using the acceleration-based method. There are two types fall one is the actual fall and the second one resembles the usualactivities of daily living. In the proposed methodology, they have worked with both falls. The results of former fall the technique is of very high accuracy rate as compared to the latter one. This result demonstrates the superiority of the vertical velocity over the peak acceleration as a fall detection parameter.

K. Chaccou states that the fall is one of the major problems arising in the community of old peoples from last two decade there has been a vast increase in cases of the falls. Medical institutions are trying to generatea solution to this problem and minimizing these kinds of incidents. This problem of fall is not only concerning health professional but also the scientific community that is taking look in it and trying to find the solution for it.[2]This paper uses a data processing technique for fall prevention and fall detection.

N. Otanasap elaborates on the epidemic of falling accidents like slipping, tripping which is the primary reason for the injury in youngsters and in elders or old people and some of the severe ones can cause death. Therefore, the authors developed a method called as pre-impact fall detection which detects the fall early. Pre-fall will be very useful in initiating airbag inflation. There are various detection methods that depend on the threshold values it maximizes, which are True positive prediction values but the lead time, which is defined as the time before thesubjects' impact on the floor; will likely increase the chance of false alarm.[3] The proposed method confirms the results that an automatically adjustable threshold-based motion detector is suitable for using in pre-impact fall detection system than fixed threshold-based method.

T. Tan introduces a statistic that every year in the world 30% of people whose age is above 60 experience a fall. If these people experience the fall they may suffer from the injuries and it will be so dangerous that they can suffer from death if treatment is not provided in time. [4] There are many methods to detect the fall detection there are various sensors which sense and detect the fall. In the present paper on the basis of acceleration, signals are brought to the microcontroller to monitor and provide the alert message. If people fall the message will be sent to the relative or family friends.

S. Agrawal presents human fall detection by using video surveillance.The authors used four steps for detecting the falls, which are as follows, in the first step using the GMM improved the performance to subtract the background to find the foreground image. [5] In the second step utilizes a template matching protocol to see whether the object is human or non-human. The third step is used to see if there are any sudden changes in the height-width ratio of human. The fourth step is used to calculate the threshold value of the human by the top and mid center of the rectangle, if the threshold value is less than the

human fall detection is confirmed. If the human stays inactive for a certain frame then it will generate an alarm to provide treatment in time.

K. R. Bhavya addresses a statistic that there is an increase in the number of people living alone, Automatic fall detection has also become an important topic in the surveillance system and the smart home system is used to send the alert if any fall activity occurs, to prevent further injuries or to provide treatment in time [6] This paper presents novel fall event detection method based on motion vector and accumulated image map. Four steps that are used to detect the fall,the first step utilizes the subtraction method to extract a human object from the background, the second step is generating the energy map by accumulating the detected human object region consecutively,the Third step is the motion vector of the human object obtained by optical flow method.In the last step, they have used KNN classification with an estimated motion vector and energy map to detect the fall.

C. Nadee elaborates on the risk of falling for a human can be reduced by using the CCTV footageand systematically using ultrasonic sensors for detection. The receiver, ultrasonic sensors, and a transmitter are connected to the microcontroller to pass the signal using Wi-Fi.[7] The threshold signal is used to find the action of standing and sleeping and they are added to the comparison. The accuracy of this paper is to indicate the fall is 92 percent.

Basavaraj GMaims to provide an accurate fall detection by using the real-time method by using a novel system for real-time detection which utilizes footage from the digital cameras which are fixed indoors to provide the best environment and to improve the quality of life of elderly people and the small children. [8] The proposed work is based on the two techniques an Ellipse approximation and Motion History Image (MHI). Results of this technique are compared with the other technique.This combined technique givesvery high accuracy and efficiency of human fall detection.

W.Qu states that there is an increase in the number of elderly people suffering from the various fall events, therefore, to avoid these fall events there is an increased relianceon the wearable devices.[9] In the recent studies, they have focused on different false fall activity to check the accuracy rate of the fall activities such as, running followed by a sudden stop reaches 32% while running upstairs or downstairs and standing quickly from the sofa is less confusing with the false positive rates of 20 %. Thus, this false positive rate decided on the basis of threshold and the intensity of motions has decreased the incidence of false positives and increased the accuracy of the technique.

E. Stone expresses that there is a method for detecting the fall in the homes of senior citizens and adults by using Microsoft Kinectwhich forms a two-stage fall detection system. The vertical state is the first stage to detect the fall in individual depth image frames, the second stage uses a unit of decision tree to compute the ground event.[10] The authors have also included standing, sitting, and lying down positions, near (within 4 m) by using the cross-validation. The method is compared against five state-of-the-art fall detection algorithms and this technique performs significantly better than the traditional techniques.

A. Vecchio addresses a major problem that is fallingand aging in society.The main aim of the fall detection system is to send the alarm as soon as the fall occurred. In the market, there are some systems that can detect the fall but most of the time they identify a false fall and generate the false alarm on the bases of accelerometric sensors.[11]Thus the proposed results show that the approach is reliable in detecting falls and simplepostures when compared to the traditional techniques, it also has significantly lower chances of detecting a false fall.

H.Wang[12] investigates human fall detection by using ultra-wideband radar and the demonstration utilizes a stepped-frequency continuous wave radar. In the proposed methodology the authors utilize the radar system to measure the Doppler signature of the humans. Many methods have been developed for fall detection in recent years but this technique is very unique and efficient. According to how fall is detected there are mainly two different approaches: wearable devices and non-wearable devices.The effectiveness of the proposed method is validated using measured results.

P.D. Rosero-Montalvo expresses that a person is considered elderlywhen he/she is at the last life stage due to the natural deterioration ofthe body's capacities, that exceeds 60 years.If in that condition he falls it may cause severe injuries or it also may cause death.[13] The proposed paper provides an alternative approach to address for the fall detection by giving a warning message to the user by utilizing theaccelerometer. In the future,the researchers aim to study real-time applications by applying various techniques and optimizations of array storage to improve performance.

III PROPOSED METHODOLOGY

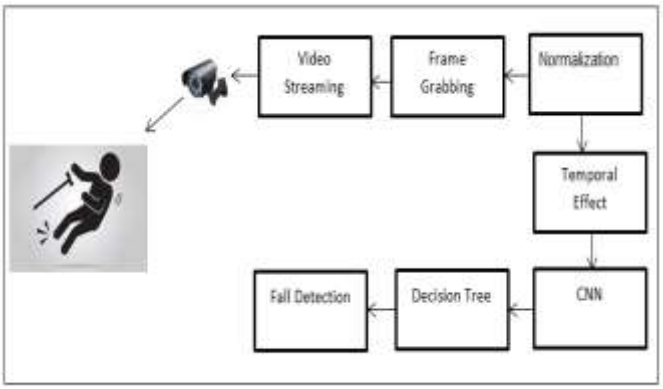

Figure 1: Proposed Methodology System

The above figure (see Figure 1) details the specific steps involved in the proposed methodology for the detection of falls in elderly people. The various steps outlined are elaborated on in detail below.

Step 1: Setup and Frame Grabbing – The Fall Detection system is achieved on a laptop running Windows Operating System, with a Core i5 Central Processing unit and 4 GB of physical memory. The image capturing has been achieved with the help of the inbuilt web camera in the laptop which has a depth of 1.4 Mega Pixel. The methodology has been implemented by utilizingthe Java Media File API to access and capture images from the laptop web camera. The frames are grabbed with the help of the frame grabbing controller mechanism of the JMF platform. The frames are captured with a 1-second interval and stored sequentially and their names are added to a queue subsequently.

Step 2: Frame Normalization – The path of the frames that are extracted in the previous step, is obtained through the queue that has stored all the path names of the 1-second interval frame. As the first frame that is captured is regarded as the model frame, this frame is then subsequently used to normalize all the rest of the frames captured. This is done to ensure that there has to be some kind of uniformity in the frames to detect the fall efficiently and easily.

The normalization technique normalizes the amount of light in most of the pictures. This is done through the process of utilizing the mean difference of the first frame and the other images contained in the queue. The process has been detailed in algorithm 1 given below.

The equation below has been utilized for the estimation of the RGB values of the images in the queue. This is done to obtain the best-normalized image with respect to the model image. The image will be enhanced, providing efficient results; from the model image. The equation 1 for the normalization is given below.

$$\int_{i=0}^{n} RGBi + (\mu m - \mu f) \qquad (1)$$

Where

μ_m - Mean of the RGB of the model image.
μ_f - Mean of the RGB of queue image.
RGB_i - RGB of instance pixel.
n - Number of pixels in the image.

Step 4: Temporal Effect – There are few temporal changes that keep occurring from one frame to another. These changes are then identified and maintained in this step. Every iteration that the system performs on the images stored in the queue, this done with the help of mapping the changes in the pixels from the past frames and current frames. This is done by assigning the values from the past values of the frame and regaining the current values. These values are then compared with the help of Convolutional Neural Networks.

Step 5: Convolutional Neural Network (CNN) – First Layer – The Convolutional Neural Network is the most critical component of this methodology. Every image from every iteration of the queue is firstly converted into an average grayscale image. The grayscale image is obtained by averaging the RGB channels of all the pixels in an image and them amalgamated into one. Then a binary image is created from the greyscale image based on a threshold of 125. This is elaborated on in algorithm 1.

ALGORITHM 1: Average Grayscale Conversion and Binary Conversion

// Input: Normalized Image N_{IMG}
// Output: Binary
acvGrayScale_BinaryConversion (N_{IMG})
1: Start
2: BIN_{IMG}= Ø
3: **for** i = 0 to size of Width of N_{IMG}
4: **for** j=0 to size of Height of N_{IMG}
5: P_{SIGN} =$N_{IMG\ (ij)}$ RGB
6: R= P_{SIGN} >> 16 & H_D
7: G= P_{SIGN} >> 8 & H_D
8: B= P_{SIGN} >> 0 & H_D
9: AVG=(R+G+B)/3
10: IF(AVG>125)
11: SET $BIN_{IMG(i,j)}$ RGB → (255,255,255)
12: ELSE
13: SET $BIN_{IMG(i,j)}$ RGB → (0,0,0)
14: END IF
15: **End for**
16: **End for**
17: **return** BIN_{IMG}

The detection of a human entering and leaving the area under surveillance is done by estimation of the pixel numbers in the converted image threshold.

Deep Layer and Decision Tree–This step has the responsibility for normalization of all the frames and then conversion of this set of normalized images into binary images. The is done to ensure that the black pixel count is approximated correctly in the binary image. After the calculation of the number of black pixels in the current frame, it is compared with the black pixel count of the previous frame. If there is a sudden drop in the number of black pixels, there is a fall that has happened.

Three alarms are integrated to set off on an event of a fall, these three alarms ask the person to confirm if there isn't a fall, this is done to ensure that no false positives are detected. After successfully registering the fall and the inability of the person to stand up to remove a false positive, the system starts the alert. The alert is sent through a text message to the relatives, the neighbors, and the hospital to provide immediate assistance to the elderly patient.

IV RESULT AND DISCUSSIONS

The technique for the detection of a fall in the elderly patient is implemented on a Laptop operating on a Windows Operating system. This technique has been implemented in real-time on a laptop with a web camera having a depth of 1.3 Megapixel; for the purpose of capturing the frames. The system has been coded in the Java programming language on a NetBeans Integrated Development Environment, with database capabilities handles by the MySQL Database server. The efficiency of the system has been calculated by extensive experimentations.

The Root Mean Square Error is one of the most insightful tools to measure the effectiveness of the proposed methodology. In this technique, the change in two correlated variables and the difference between them. The two entities in this context are the actual fall and the accurate detection of the fall by the technique. The Root Mean Square Error can be calculated with the equation given below.

$$\mathbf{RMSE}_{fo} = [\sum_{i=1}^{N} (z_{f_i} - z_{o_i})^2 / N]^{1/2}$$

Where,
$\sum$ - Summation
$(Zfi - Z_{oi})^2$ - Differences Squared for Actual no of falls and detected number of falls
N - Number of samples or Trails

The system is experimented on with 5 experiments with each of the experiments consisting of 10 trials to ensure accuracy. The observations have been documented in Table 1 below with the values plotted in figure 2.

Experiment Number	Number of Trials	Actual Number of Falls	Number of Detected Falls	Mean Square Error
1	10	5	4	1
2	10	6	6	0
3	10	3	3	0
4	10	6	4	4
5	10	6	5	1
			Average MSE	1.2

Table 1: Mean Square Error

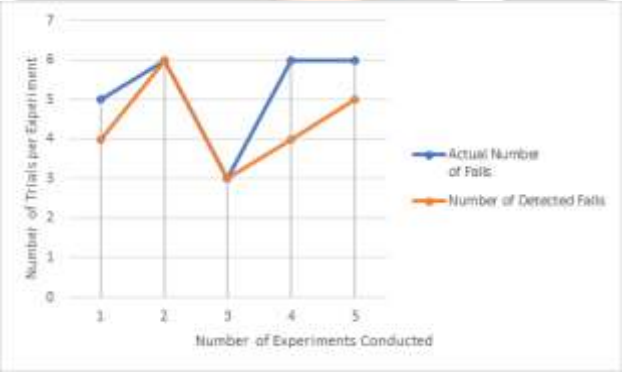

Figure 2: The Graph plotted for the change in Mean Square Error depicting the System accuracy.

As evident from the table and graph above, the average Mean Square Error of the system is calculated to be around 1.2, which translated to a Root Mean Square Error of 1.1.This is a significantly low margin of error which is expected from a critical system of this level of competence. Therefore, the proposed fall detection methodology has proven to be efficient and effective in a Constrained Environment.

V CONCLUSION AND FUTURESCOPE

The presented technique for the detection of a Fall of an elderly patient living alone, with the help of video surveillance is implemented in a constrained environment that consists of a Laptop web camera for capturing the frames with a configuration of 1.3 Megapixels. The system has been implemented to reduce the instance of falls occurring in Elderly individuals who live alone. As a fall in old age is very common and can lead to a serious injury and has a large potential to be fatal. This system can provide surveillance to the person by the application of various techniques such as normalization of the frames recorded every second and subjecting it to a CNN based temporal effect evaluation to detect the Fall. As soon as a fall is detected successfully, the system intimates the neighbors, the relatives, and the hospital to provide immediate medical assistance which has the potential to save lives.

The Future scope of this research is to be implemented into a CCTV network to achieve better and ubiquitous coverage of fall detection.

REFERENCES

[1]Jung Keun Lee1, Stephen N. Robinovitch, and Edward J. Park, "Inertial Sensing-Based Pre-Impact Detection of Falls Involving Near-Fall Scenarios",IEEE Transactions on Neural Systems and Rehabilitation Engineering, 2015.

[2]Kabalan Chaccour, Amir Hajjam El Hassan, and Rony Daraziy, "From fall detection to fall prevention: A genericclassification of fall-related systems"IEEE Transactions on Sensors, June 2016.

[3]Nuth Otanasap, "Pre-Impact Fall Detection Based on Wearable Device Using Dynamic Threshold Model"17th International Conference on Parallel and Distributed Computing, Applications and Technologies, 2016.

[4] T. Tran Dunc, "Reliable Fall Detection System Using a 3-DOF Accelerometer and Cascade Posture Recognitions", IEEE International Conference on. IEEE, 2009.

[5]Subhash Chand Agrawal, Rajesh Kumar Tripathi, and Anand Singh Jalal, "Human-fall Detection from an Indoor Video Surveillance Subhash", 8th ICCCNT 2017 July 3-5, 2017.

[6]Bhavya K R, Jinho Park, Hasil Park, Heegwang Kim, and Joonki Paik, "Fall Detection Using Motion Estimation and Accumulated Image Map",IEEE Int. Con. Intelligent Transportation Systems, PP. 318- 323, Oct. 2011.

[7]Chokemongkol Nadee andKosin Chamnongthai, "Ultrasonic Array Sensors for Monitoring ofHuman Fall Detection",2017 2nd IEEE International Conference on Recent Trends in Electronics Information & Communication Technology (RTEICT), May 19-20, 2017.

[8]Basavaraj GM, andAshok Kusagur, "Vision-Based Surveillance System for Detection",2017 2nd IEEE International Conference on Recent Trends in Electronics Information & Communication Technology (RTEICT), May 19-20, 2017.

[9]Weihao Qu, Feng Lin, Aosen Wang, and Wenyao Xu, "Algorithm on Wearable Sensor towards Falls and Fall-alike Activities"IEEE Transactions on, vol. 50, no. 6, pp. 711– 723, 2003.

[10]Erik E. Stone, and Marjorie Skubic, "Fall Detection in Homes of Older Adults Using the Microsoft Kinect",IEEE Journal of Biomedical and Health Informatics, 2015.

[11]Alessio Vecchio and Guglielmo Cola, "Fall Detection Using Ultra-Wideband Positioning",IEEE Sensors, 2016.

[13]P.D. Rosero-Montalvo, D.H. Peluffo-Ord´o˜nez1, Pamela Godoy, K. Ponce, E.A. Roser, and C.A. V´asquez, "Elderly Fall Detection Using Data Classification on a Portable Embedded System", IEEE Second Ecuador Technical Chapters Meeting (ETCM), 2017.

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