Human-fall Detection from an Indoor Video Surveillance

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***Abstract*— In this paper, we present a human fall detection method from visual surveillance. In first step, background subtraction is performed using Improved GMM to find the foreground objects. In second step, contour based human template matching is applied to categorize the human or non-human object. It helps to detect fall incident by providing sudden change in generated score after matching. Height-width ratio is computed in third step to decide whether the human shape is changed or not. In fourth step, distance between top and mid centre of rectangle covering human is computed, if it is less than a certain threshold, then human fall is confirmed. Finally, if inactive pose of human is continued till 100 consecutive frames, then an alarm is generated to alert the people at home to provide treatment on time. Experiments have been performed on 21 video sequences having different usual and unusual fall incidents. Experimental results show that proposed system works well efficiently and effectively in real-time for recognizing human fall.**

Keywords— Human Fall, foreground object, height-width ratio, contour.

I. INTRODUCTION AND RELATED WORK

Human Fall Detection from Visual Surveillance is an active research area of the image processing and computer vision. It plays a significant role to protect the elder people having age more than 70 years or children from the injury caused by fall incident; also avoids the death of human beings due to the head injury just happened due to an accidental fall at home. In recent days, there are lots of sensor based devices such as accelerometer, manual help button available to wear on hand. But, sometimes elder people forget to wear such devices or fail to press the help button becoming unconscious after a sudden fall. The recent advancements in the field of computer vision have brought an innovative solution to overcome such drawbacks. Now, visual surveillance provides the more information related to the human activity such as fall incidents.

There are several semi-automated video surveillance is being used to monitor the elder people or children at home to recognize the fall incidents so that a proper treatment can be provided on time but continuous watch on video captured by semi-automated video surveillance is a complex task. Therefore, an intelligent video surveillance for human fall detection is required that can recognize the fall incidents immediately and alert it to the member present at home through the message or alarm to take care of elder people or children.

Several researchers have developed human shape analysis [1],[2],[3],[4],[5] human posture analysis [6],[7],[8],[9],[10],[11],[12],[13] and human motion analysis [14],[15] based techniques to recognize fall incidents. Chua et al. [1] presented a method based on line drawing between three centroids of upper body, middle body and lower body of human being and analyze the orientation and distances in between the two lines for shape analysis to decide the fall incident. This approach achieved accuracy 90.5% with false alarm rate of 6.7%. Liu et al. [2] utilized bounding box method for human shape analysis based on the features such as human aspect ratio, effective area ratio and center variation rate. This approach worked for indoor video in which human is far 5 to 10 meters from the camera. In [3], Auvinet et al. proposed vertical volume distribution ratio to find the 3-D volume of the person for human shape analysis from multiple camera views with low frame rate. In [4]-[5], ellipse around the human has been drawn to analyze the temporal change of head position [4] and shape deformation features [5].

Many researchers have tried to draw an ellipse around silhouette for the posture analysis to recognize the fall incident [6]-[8]. Thome et al. [6] used lengthened and standing postures with layered HMM to find the fall incidents. This approach detects 82% falls correctly with 18% false negative rate. Khan et al. [9] proposed an approach for posture analysis to recognize fall based on binary silhouette in which Kernel Discriminant Analysis on R-transform features, k-means clustering algorithm and HMM have been utilized. Bounding box method has been utilized for the posture estimation analysis in [10]-[13]. Nasution et al. [10] proposed a novel method to detect falls in which adaptive background subtraction approach has been used. In this, adaptive characteristics are removed to prevent the inclusion of static human as background. Vertical and horizontal histograms of foreground objects and angle between last standing postures with current foreground bounding box are used as feature set. Extracted features are passed to the k-NN classifier and falling speed infer the real falling incidents. K-NN classifier with multiple posture templates yields recognition rate about 90%. Liu et al. [11] proposed a falling detection system in which statistical scheme and vertical projection histograms of the silhouette image are used to reduce the effect of upper limb activities of human body. The k-NN has been used to classify the postures using the difference and height-width ratio of silhouette's bounding box. This approach yields the fall detection and lying down event detection rate 84.44%.

Few researchers have worked based on posture of moving human [14] and human pose [15] for motion analysis to recognize the fall incident.

In this paper, we have introduced a robust approach to detect the fall incident of human at home through video surveillance in real-time which can distinguish in between human or other pet animals. We generate an edge based template of human to match with human contour in frame of video, if score is matched up to a certain threshold then, that object is human otherwise non-human.

The paper is structured as follows: Section 2 deals with proposed method, Section 3 discusses the human fall analysis, experimental results are discussed in Section 4, and Section 5 concludes the paper.

II. Proposed Method

Proposed method deployed the framework for recognizing the human fall. There are various steps have been followed to recognize the human fall incident on real-time. First step is the background subtraction through which foreground objects are extracted. In this step, we have applied background subtraction technique proposed by Zivkovic [16]. This method has less processing time and improved segmentation. Secondly, edge based detection technique has been applied to make distinction between human and non-human object. In third step, height-width ratio and distance between top and mid-center of rectangle is computed to analyze the human fall, height-width ratio and distance is found less than a *threshold* then, a fall incident can be found. If human is inactive for 100 frames continuously, then human fall is confirmed and an alarm is raised as an alert to provide help on time.

A. Foreground Object Extraction

Background subtraction is a very common technique for the segmentation of foreground objects in video sequences captured by static camera, which basically detects the movable objects from the difference between the current frame and a background model [17]. We have applied improved Gaussian Mixture Model that has been proposed by Zivkovic [16]; which is an interesting extension of Stauffer-Grimson algorithm. This technique shows how to automatically adapt the number of Gaussians being used to model a given pixel. This improved method reduces the memory requirements of algorithms, increases its computational efficiency, and can improve performance in case of highly multi-modal background [16].

B. Noise removal

Background subtraction methods are not capable to remove noises from the images of video. These noises create problems in identification of objects. We have applied erosion and dilation to remove the noise from the foreground images.

C. Human and non-human object detection and human shape change detection by applying human edge based template matching

To detect the fall incident of human at home through video -surveillance in real-time, there must be an approach that can distinguish in between human or other pet animals. We generate an edge based template of human to match with human contour in frame of video, if score is matched up to a certain threshold then, that object is human otherwise non-human. In this approach, we follow the following steps:

1) Contour Template Creation and intensity gradient Computation

Step1: Contour object from foreground frame of video sequence is cropped.

Step2: Applied Sobel operator to compute the gradients of X and Y direction G_x and G_y.

Step3: We compute magnitude and direction after finding gradient as per the formula specified below:

$$Magnitude = \sqrt{G_x^2 + G_y^2} \tag{1}$$

$$Direction = inv\tan\left(\frac{G_y}{G_x}\right) \tag{2}$$

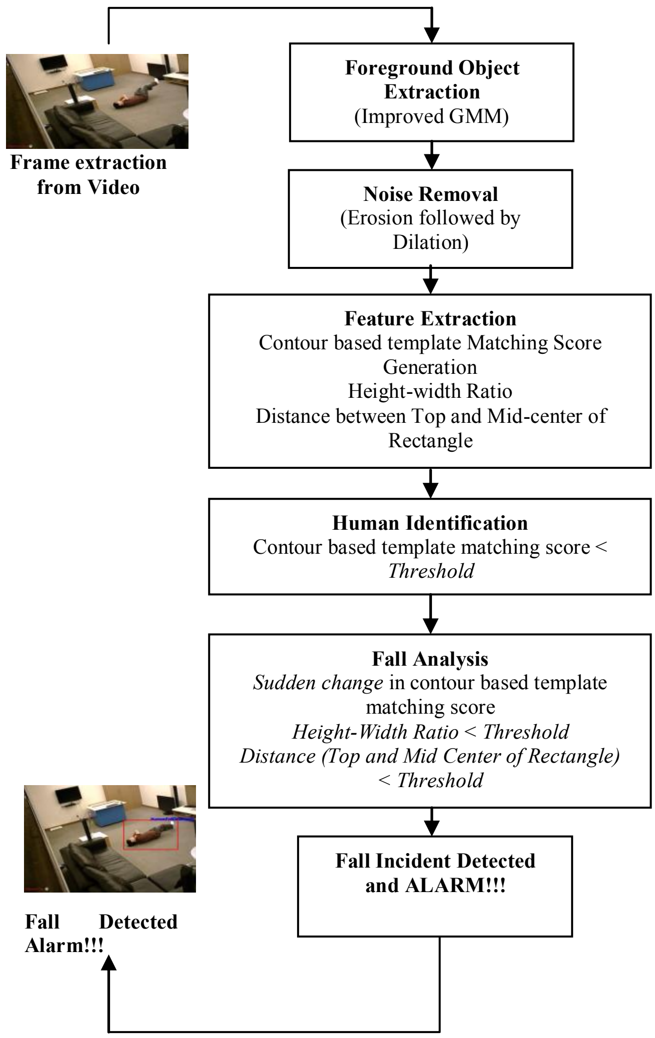


Fig. 1. Proposed framework for Human Fall Detection

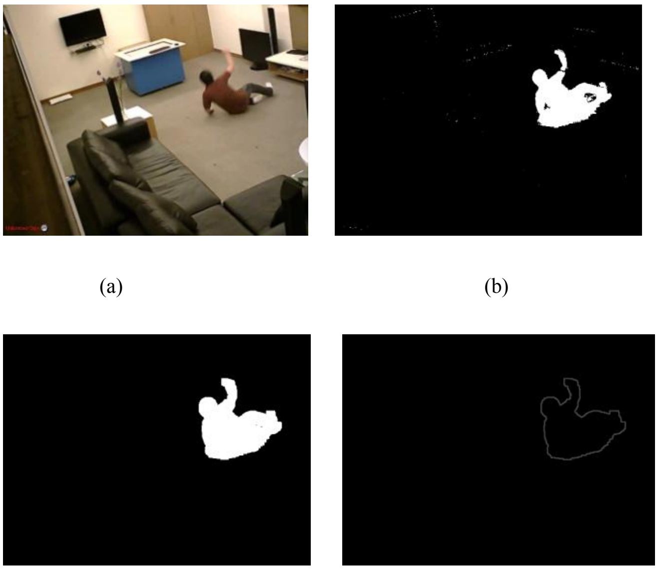


Fig. 2. (a) Original image of video (b) Image after background subtraction with noises (c) Image after noise removal by applying erosion and dilation (d) Human contour extracted from image.

Step4: After computation of edge direction, we have four possible directions i.e.0, 45, 90, 135 degrees, to describe the surrounding pixels.

Step5: We performed non-maximum suppression to make thin edge, in which right and left pixels are traced in the edge direction and suppresses the current pixel magnitude if it is less than the right and left magnitudes of pixel.

Step6: We save G_x and G_y which are X and Y derivatives respectively of selected edges template.

2) Contour based Template Matching and Score Generation

To detect the fall incident of human, it is very important that human should be detected among objects of video. In the continuation process of template matching, A score is generated after matching predefined human template image with the newly created contour template of foreground object of frame of a video. In this process, Gx_i^T and Gy_i^T are gradients of X and Y direction of an object of video frame where $P_i^T = (X_i^T, Y_i^T)$ is a set of n points. After this, $G_{x_i}^H$ and $G_{y_i}^H$ are the generated gradients of X and Y direction of a contour based human template. After computation of gradients of both the templates, matching process is done to find the similarity in between both the templates. Similarity can be determined by finding sum of the normalized dot product of all gradient vectors of the template images.

We set a minimum score $S^{\min}$ to compute the similarity matching score for the visible portion of an object. This score S_m at any point m can be calculated by using the following formula:

$$Sm = \frac{1}{m}\sum_{i=1}^{m} \frac{(Gx_i^T \cdot Gx_i^H) + (Gy_i^T \cdot Gy_i^H)}{\sqrt{(Gx_i^T)^2 + (Gy_i^T)^2} \cdot \sqrt{(Gx_i^H)^2 + (Gy_i^H)^2}} \tag{3}$$

The score evaluation process is discontinued when the condition is satisfied as per the given formula:

$$\mathrm{Sm} = \mathrm{MIN}\left(\left(S^{\min} - 1 + \frac{1 - g.S^{\min}}{1 - g} \cdot \frac{m}{n}\right), \left(S^{\min} \cdot \frac{m}{n}\right)\right) \tag{4}$$

In the above formula, g is a greediness value, which is applied for the checking all points in template image, if g=1, all points in template image are matched. Generated score which lies between 0 and 1 is analyzed to make distinction between the human and nonhuman objects.

This matching score is also helpful in identification of sudden change in human body pose. Matching Score has less deviation in frames of video sequence until a sudden change occurs in human body. When a person falls, matching score will decrease suddenly and this change will be continued until human body comes to static pose after fall.

D. Height-Width Ratio and Distance between Mid-center and Top-center position of Rectangle surrounding contour of human

When matching score is suddenly changed, at the same time the height-width ratio and distance between top-center and middle center of rectangle is considered to decide the human fall. As we know that height of human is 3 to 4 times larger than width of the human. In case of straight sitting or crouching down position, sometimes, there is very less difference in height and width of human. To handle this situation, we have computed distance between mid-center and top-center of rectangle and decided a threshold to recognize the fall incident.

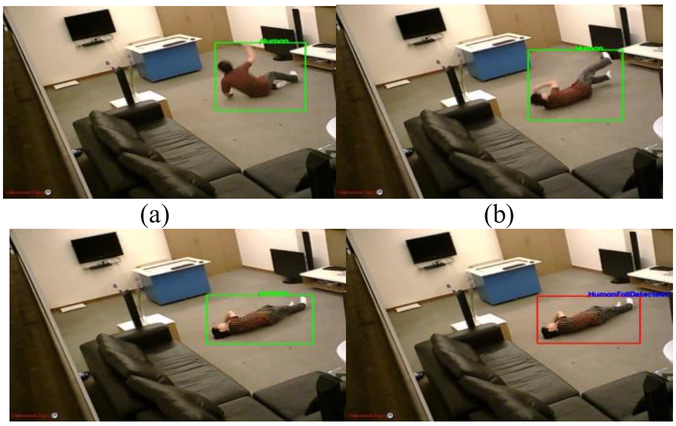
III. Human Activity Analysis to Detect Human Fall

Sudden change in the pose of human changes all the three important parameters i.e. matching score, height-width ratio of human body and distance between top and mid center of rectangle covering human. After sudden change in score, height-width ratio and distance between top and mid center point is computed and if it is found less than the threshold, then human body posture is analyzed, if human body remains inactive up to 100 consecutive frames then human fall is confirmed and alarm is raised as an alert.

IV. Experiment Results and Analysis

We have implemented our proposed system using OpenCV Library and evaluated its performance on 21 videos dataset available at (http://foe.mmu.edu.my/digitalhome / Fall Video.zip). The video sequences of this dataset consists of 30 daily usual human activities such as sitting down, walking, squatting down, and crouching down, and 21 unusual human activities such as forward falls, backward falls, sideway falls, and falls due to loss of balance. We have shown falling activity by red rectangle over the falling human image and normal activity by green rectangle.

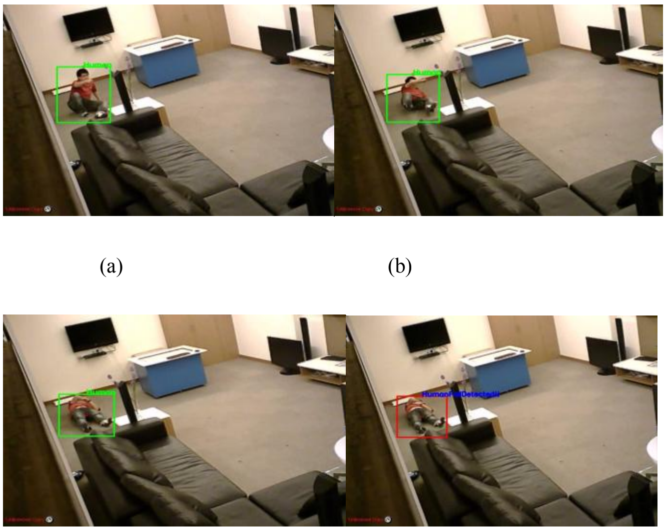
In first video sequence of dataset, a human enters in the room and performs falling activity, three frames of figure 3 (a-c) shows the falling activity, which is covered by green colored rectangle and after few seconds of falling incident happens, human fall incident is detected which is shown in figure3(d).



(a) (b) (c) (d)

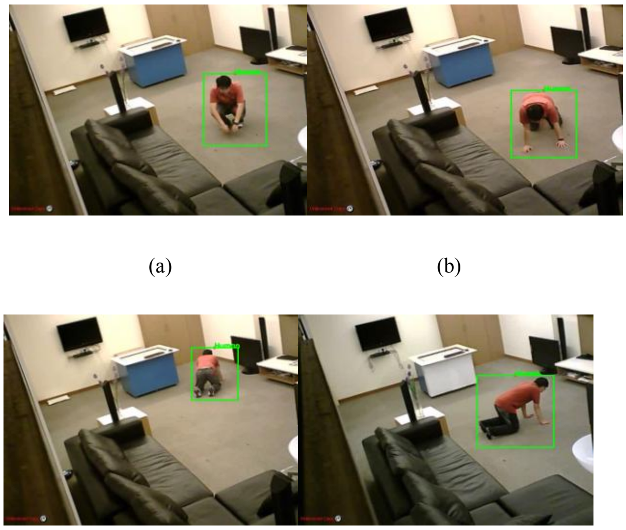
Fig. 3. Fall detection in Video Sequence 1 (a) Fall incident occurred (b) Fall incident is continuing (c) Fall incident finished (d) Fall detected after few seconds

In video sequence 4, human entered in the room, and in corner of the door, human performed falling incident which is also parallel to camera, still falling incident has been detected due to the distance between top and mid center point of rectangle which is less than the threshold. Figure 4 (a-d) shows falling incident happening to falling incident detection.



(a) (b) (c) (d)

Fig. 4. Fall detection in Video Sequence 4 (a) Fall incident occurred (b) Fall incident is continuing (c) Fall incident finished (d) Fall detected after few seconds



(a) (b) (c) (d)

Fig. 5. (a) Sitting is not detected as a Fall incident in Video Sequence 10 (b)-(c) Crouching down position is not detected as a Fall incident in video sequence 11 (d) Crouching down position is not detected as a Fall incident in video sequence 12.

Proposed method fails to detect a human fall in one video sequence 7 in which human falls very close to camera and also parallel to camera.

TABLE I. RECOGNITION ACCURACY OF HUMAN FALL DETECTION.

Incidents	Human Fall Detected (in videos)	Human Fall not detected	Detection Accuracy
Human Fall	20	1	95.20%
Human Usual Activities	1	29	3.33%

TABLE II. COMPARATIVE STUDY OF OUR PROPOSED SYSTEM WITH CHUA ET AL. [1]

Method	Human Fall Detection Rate (%)	False Alarm Rate (%)
Proposed Method	95.20	3.33
Chua et al. [1]	90.5	6.7

Table 1 shows the accuracy of human fall detection which is 95.20% with 3.33% false detection. Table 1 (in first row) show that proposed system detected human fall incident in 20 videos out of 21 videos and proposed system failed in fall detection in one video sequence. Table 1 (second row) show that proposed system failed in one video of the dataset and falsely detected one daily routine as fall incident and in 29 videos, usual activities has been detected as usual activities. Table 2 presents comparison of proposed method with Chua et al. [1] where accuracy of proposed method is higher than the [1].

V. CONCLUSION

The proposed method utilized background subtraction method to extract foreground objects and contour based template matching method for detecting sudden change, height-width ratio and distance between top and mid-center point of rectangle to decide the human fall. The proposed method worked well and provided the 95.2% detection accuracy. This method can be improved for outdoor videos also. Multi-view camera can resolve the problem of human fall detection close to camera and parallel to camera.

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