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Human fall classification system for ceiling-mounted kinect depth images

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Abstract: The number of elderly people living alone has been considerably increased over the past few years. Hence the research regarding Ambient Assisted Living (AAL) systems has been given significant importance to improve the quality of life for them. Falls have become one of the major health concern among elders. Many fall detection and classifications methods are being developed to provide a reliable solution. The proposed system presents a vision based human fall classification method to discriminate falls from non-fall events. The depth images from a ceiling mounted Kinect camera are considered in the proposed system to preserve privacy, reduce the influence of occlusion and complex cluttered background. Human silhouettes are obtained after background subtraction and shape based features are extracted. A binary Support Vector Machine(SVM) classifier fed with these features is used to classify the fall events from non-fall events. The proposed method was tested on a publicly available dataset and classifies falls from other actions with an accuracy of 93.04%.

Keywords: Fall classification, Ceiling-mounted, Depth images, Kinect camera, Shape based features.

1. INTRODUCTION

As the number of senior citizens living alone has been increasing, many health concerns are also on rise constantly. Falls are one of the major cause of fatal injury among the elderly hindering their independent life and increasing the dependence on care takers. A study of 351 individuals aged 65 years or older in Korea found that 42 percent reported at least one episode of falling in the previous 12 months, 38 percent of whom required either the attention of a physician or hospitalization [1]. Statistics [2] show that falls are the primary reason for injury related death for seniors aged 79 or more. Also, many post-traumatic stress disorders in elderly people after a fall are observed [3]. Hence a fall detected in time can alert the care takers reducing the medical costs and possible risk of a fatal injury, or death.

The fall detection and classification systems can be broadly classified into three categories [4]. First one is wearable sensor based methods. The main disadvantage of this method is they are intrusive, the elderly has to wear them always causing discomfort and might forget to wear them. Floor vibration detectors [5] are sensitive to other vibrations and might cause false alarms and need a complex setup. Second is the vision based systems including CCD camera, multiple cameras, specialized omni-directional ones and stereo pair cameras. These systems offer multiple advantages over the sensor based systems. They are less intrusive and provide information regarding fall and related injury but they have their set of disadvantages including occlusion problem, privacy invasion of elderly and poor lighting conditions. The Kinect camera[6] sensor consists of RGB, depth and infrared sensor providing good information even in poor lighting conditions. The depth images preserve the privacy of elders providing just the shape information of the human silhouette. Also, Kinect camera in ceiling mounted configuration reduce the effect of occlusion to an extent. The third category is the ambient or fusion based systems employing both sensor based and vision based methods into one system, but these are computationally expensive.

In the proposed system, depth images of ceiling mounted Kinect camera from UR fall dataset [7] are considered. After background subtraction, the human silhouettes are obtained and the shape based feature vectors are extracted. These features are fed to a binary (SVM) classifier to classify the fall events from non-fall events.

2. RELATED WORKS

In [8] a k-NN based classifier system is used to separate lying pose from other daily life activities in a ceiling mounted 3D depth camera. However the processing of depth images is initiated only after the indication for a potential fall is observed by an extra accelerometer system.

Shape based features like height and width aspect ratio of a 2D bounding box are used in [9]. The system detects a fall event when the aspect ratios are less than some selected thresholding value. They used an FPGA system integrated within their system.

The system in [10] contains two modules. RGB-D camera and the fall detector module based on available libraries for camera management and computer vision procedures. Firstly, the human silhouette is recognized by Kinect and the bounding rectangle is constructed around it by the algorithm [7]. Kalman filter is used to reduce the spikes in the variation of rectangle to reduce classification errors. The features are extracted by evaluating the expansion and contraction of the width, height, depth of the 3D bounding box.

The proposed system uses the shape based features like bounding box, area, orientation, centroid and extent of the silhouette for human fall classification. A binary SVM classifier performs the fall action classification from non-fall using the shape based features.

3. PROPOSED METHOD

The proposed system overview is shown in the Fig 1. A fixed background is considered for all the scenerios. At any given current frame the human foreground is obtained by simple frame differencing method.The current frame is subtracted from the fixed background to obtain the human foreground. Then the human silhouette is obtained by extracting the largest connected component. Minimum Bounding box, centroid, area, orientation and extent features of the silhouette are extracted.

The features considered can distinguish a fall event from non-fall . In the top view configuration, the minimum bounding box for a fall event is larger than for a non-fall events like standing, walking. The area gives number of pixels in the region, and the variations in area can be used to discriminate a fall from non fall.The centroid and orientation of the silhouette also varies greatly for a fall and other actions. The extent gives ratio of pixels in the silhouette to total bounding box.These feature vectors are fed to a binary SVM classifier to classify fall events from non fall events.

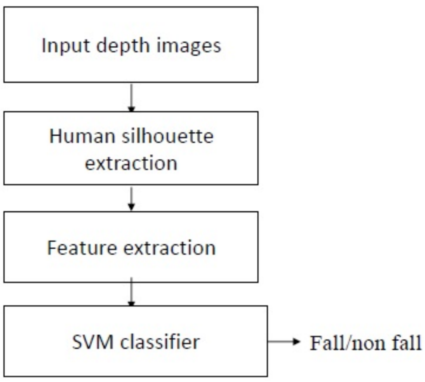

Fig. 1 Proposed system flow.

4. EXPERIMENTS

4.1 Dataset

The proposed method is tested on one of the few publicly available standard datasets called UR fall detection dataset. This dataset contains 70 (30 falls + 40 anon fall) RGB and depth video sequences. Fall events are recorded with 2 Microsoft Kinect cameras and corresponding accelerometer data is also provided. In the experiments,10 videos over 1000 depth frames containing falls and other actions like standing, walking and sudden falls are considered. A total of 782 non fall sequences and 422 fall and a fixed background sequence are used in the simulation. Two classes of fall and non-fall frames categories are labeled manually and half of the sequences are used for training and other half for testing.

4.2 Performance criteria

The performance of proposed system was measured by a confusion matrix and evaluated in terms of classification accuracy, sensitivity and specificity criteria as in following equations. The average sensitivity and specificity over the 10 videos are calculated.

$$Classificationaccuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (1)$$

$$Sensitivity = \frac{TP}{TP+FN} \quad (2)$$

$$Specificity = \frac{TN}{TN+FP} \quad (3)$$

5. RESULTS

Fig.2 represents the fixed background considered. Fig 3, 4 shows the sample input sequences. The experimental results of bounding box features for some sample test fall and non-fall events are shown in Figs5, 6.

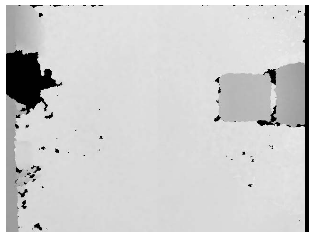

Fig. 2 Fixed reference background.

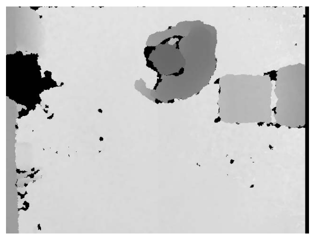

Fig. 3 Sample non-fall frame.

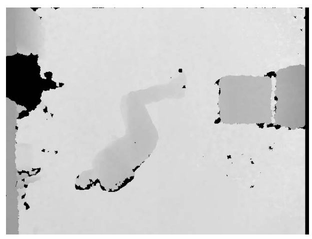

Fig. 4 Sample fall frame.

Also, sudden falls are classified accurately using the proposed method as shown in Figs.7∼10. A sudden fall in the video is the falling of human during the entry itself without prior walking or standing for sometime. However the videos with fall from chair are not considered.

Fig. 5 Bounding box for Sample non-fall frame.

Fig. 9 Bounding box for sudden non-fall.

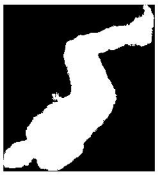

Fig. 6 Bounding box for Sample fall frame.

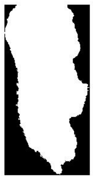

Fig. 10 Bounding box for sudden fall.

Proposed system has shown a training accuracy of 100% and a testing accuracy of 93.04%. The table 1 gives the comparison of the current method to the method stated in literature[10] over different thresholding values,both using same performance criteria.The proposed system classifies fall from non fall events with higher accuracy and sensitivity.

6. CONCLUSION

The paper proposes a human fall classification system for ceiling mounted Kinect camera depth sensor. The shape based features are extracted over the input depth frames and fed to a binary SVM classifier. The system efficiently classifies fall activity from non fall with a high sensitivity of 100% and an accuracy of 93.04%. Also, the system was able to distinguish backward, forward, side ward and sudden fall events from non fall actions like standing, walking. In future works, falls from bed or chair can be considered and multi- class classification can be performed.

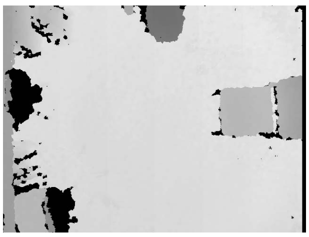

Fig. 7 Sudden non-fall frame.

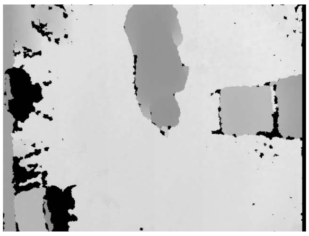

Fig. 8 Sudden fall frame.

Table 1 Comparision of test results.

	Testing accuracy	sensitivity	specificity
Proposed method	93.0476%	100%	88.33%
bevilacqua2014fall	76-87%	68-83%	89-95%

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