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Multiple Anomalous Activity Detection in Videos

Sarita Chaudhary[a], Mohd Aamir Khan[a], Charul Bhatnagar[a,*]

[a]*GLA University, Mathura, 281406, India*

Abstract

Due to exponential increase in crime rate, surveillance systems are being put up in malls, stations, schools, airports etc. With the videos being captured 24x7 from these cameras, it is difficult to manually monitor them to detect suspicious activities. So, there is a great demand for intelligent surveillance system. The proposed work automatically detects multiple anomalous activities in videos. The proposed framework includes three main steps: moving object detection, object tracking and behavior understanding for activity recognition. By using feature extraction process key features (speed, direction, centroid and dimensions) are identified. These features helps to track object in video frames. Problem domain knowledge rules helps to distinguish activities and dominant behavior of activities shows whether particular activity belongs to normal activity class or anomalous class. It has been experimentally proven that the proposed framework is capable of detecting multiple anomalous activities successfully with detection accuracy upto 90%.

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Keywords: anomalous activity; gaussian mixture model; rule-based classification;

1. INTRODUCTION

Over a last decade it has been seen the rapid growth and an extraordinary improvement in real-time video analysis. Main goal of video analytics is to identify the potential threaten events with less or no human intervention. Video surveillance is a prominent area of research which includes recognition of human activities and categorization of them into usual (normal), unusual (abnormal) or suspicious activities.

Main task is to locating unusual events in videos by using some surveillance system which can be manual, semi-automatic or fully automatic. Manual surveillance system is fully dependent on human. It required manual labor to analyze behavior or to make difference between abnormal and normal behavior. Semi-automatic system required less human intervention while fully automatic are intelligent and smart video surveillance system which doesn't required human intervention to make decision.

* Corresponding author.
E-mail address: sarita.gla_mtcs14@gla.ac.in

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According to current market research[5] corporations, government, public and private sector are investing huge amount of money for protection of offices, building, malls, houses, infrastructure etc. and this trend is going to accelerate more in coming years of automatic security industry. As today terrorist activities are increasing exponentially so it is an important task to detect suspicious or anomalous activities that can affect normal human activities.

Anomalous Events are the irregularities or deviation of the object behavior from the normal behavior includes object in unusual location, unusual motion pattern such as movement in wrong direction, object entry or access in restricted-area, illegal turns in traffic, violence or fighting among the human, left bag, different moves of object in army training like all members are walking but some are crawling or walking in different direction, sudden movements, dropped object or any type of unusual event. Any event is normal in one scenario and anomalous in another scenario.

Applications [5] of anomalous event detection system are: Traffic monitoring, Medical science, highly surveillance areas like military area, airport etc., crowd analysis[9], criminal activity recognition, automatic forensic video retrieval.

Despite its potential applications[15] it is widely used in making transportation system more intelligent, security alarms for surveillance in schools or care houses, training institutes etc. It is also encountering or facing lot of challenges, which are as follows:

- Representation of normal regions in video stream is quite difficult.
- Exact notion of abnormal behaviour is either subjective or changes over different applications.
- Possibility of ambiguous boundary between normal or anomalous behaviour.
- Presence of noise and tricky to label the behaviour.

A great variety of approaches have been proposed to solve above mentioned challenges. Two main assumptions are considered to generate method for making anomalous event detection system:

- Frequency of occurrence of anomalous events is less than normal event in video stream.
- Normal events are having less similarity to anomalous event.

All anomalous behaviour recognition methods can be classified as single layered approach and hierarchical approach. Hierarchical approach is further sub-classified as description- based approach, syntactical approach and statistical approach. Single layered approach considers how human activities are modeled.

Anomalous event detection can be carried out in two ways: First way is by training the system with normal and abnormal event and then distinguish the future events by using prior information. Second way is following dominant set property according to which dominant behaviour (frequently occurring and less attention seeking behaviour) of object is considered as normal behaviour and less dominant behaviour is considered as abnormal or anomalous behaviour.

Anomaly can be detected by capturing and analyzing motion cues and appearance cues of the object in video. Motion anomaly detection method includes speed, direction, location, trajectory or route of the moving object. Appearance anomaly detection method includes posture of object, identity, or color of object etc.

Ying et.al[15] used both appearance and motion patterns to detect anomaly, and considered histogram bins and support vector data description. Object behaviour understanding is an important and highly challenging task. Object behaviour can't be predicted directly from an input video. For that video analysis is required. But behaviour understanding is an easy task for human, to make this task automatic involves lots of issues to be handled before this. Some of them are disclosed below:

- Presence of cavities while acquiring foreground.
- Modeling of human (as incorrect modeling can lead to faulty pose prediction).
- Occlusion handling (when one or multiple object crosses each other).
- Human identification (same person recognition correctly).

- Scene modeling (accurate modeling between 2D captured images to 3D model for better visualization).

In this paper we design a system to handle the anomalous behaviour in video. We are using Rule-Based approach to classify events as normal and anomalous. Motion pattern are analyzed and used as features. Unlike previous work, we followed concept of dominant set[1] in which dominant behaviour is treated as normal and less dominant behaviour is considered as anomalous. Finite number of previous work considered multiple activities in single video for detection, but the proposed system is able to detect multiple event altogether. This is ensured by testing framework on different videos. Unlike in SVM, if new activities doesn't match with trained pattern then system treated that as anomalous and for recognition of that activities system is trained again from initial step while in case of Rule-Based System new event can be recognized easily only by changing some rules.

2. RELATED WORK

In this section, the recent work in the field of automatic suspicious or anomalous activity recognition is discussed. There are variety of framework available which can be used for detection of anomalous behaviour in surveillance videos without human intervention. [7] Different researchers have used different methodologies according to application or event.

Every recognition system is mainly having following steps: pre-processing, feature extraction, object tracking and behaviour understanding. In pre-processing step, noise removal and foreground is extracted. In feature extraction, several features of the object is extracted from the frames of video. After feature extraction object trajectory is established on the basis of extracted feature. Behaviour understanding is a crucial and important step on recognition system as in this step behaviour of object is detected and on the basis of that behaviour classification of events are done. Last step give result as some events belongs to normal and other belongs to abnormal in anomalous event detection in videos but unfortunately, not so much work is done in multiple anomalous event detection. The proposed framework detect and recognize multiple events and give event label to them as normal or abnormal.

In earlier research on anomalous event detection.[6] Mehrsan et.al proposed a novel approach to detect anomalous behaviour and dominant behaviour. Dominant set theory has been given by Alvar et.al.[1] to detect abnormal behaviour of object in videos. [12] Wang et.al proposed a theory in which covariance matrix is used as feature descriptor and further online non-linear one-class SVM classification is used for classification of normal and anomalous events.

Yong et.al [3] has given a review paper that describe method to solve problem of anomalous event videos representation. Concept of Conditional Restricted Boltzmann Machine, Independent Component analysis for better feature extraction as conventional method is not easy to learn complete feature representations and deeply-learned slow feature analysis concept are discussed. In activity recognition task most important and critical task is of behaviour understanding for that Toa Xiang et.al presented a survey paper[13], in that author described profiling of behaviour in videos for anomaly detection in detailed. Different body parts are used for gesture and emotion recognition of human. [2] Cheng et.al introduced an approach of joint temporal filtering in which head and body parts pose are used features for human behaviour analysis.

Research was facing problem of utilizing related exemplars in multiple feature scenario, then[14] Zhongwen Xu et.al proposed a concept of labelling the features with multi-level relevance in videos for event detection.

Anomalous event recognition includes three major steps: object detection and segmentation, feature extraction, object tracking and classification. Object segmentation is the process of extracting interesting pixels that are representing the localized object in the video and segment the object from the background before event recognition. Numerous amount of research is done in object tracking, multiple object tracking in videos. Multi-feature based approach is given by Hong Lu et.al for different object detection and tracking by using affine motion model and non-parametric distribution. [4] Stefan Duffner and Christophe Garcia proposed an approach in which pixel based descriptors are used that are able to detect extremely

small object in the image. Jifeng Ning et.al[10] proposed joint registration and active contour segmentation approach for object tracking. Fan Yang et.al handles heavy occlusion in object tracking by discriminative appearance model.[15] Fast visual tracking concept is introduced by David Zhang et.al. Spatial-temporal model is used for tracking occlusion suffering object videos. Many methods have been proposed for anomalous behaviour detection. Depending on whether or not samples of videos are required for initialization or training before detection of any type of anomaly.[15] They are divided into three classes as supervised, semi-supervised, un-supervised approach.

In supervised approach of anomaly detection input samples are labelled as both normal and anomalous samples. This method is designed for the behaviour whose properties are pre-defined and appearance, velocity, motion or trajectory act as cues to classify them as normal and anomalous cues.

Second approach is Semi-supervised that only require normal data for training the system. This method is further divided into sub-categories as rule-based category and model based category.

In Rule-based method rules are established, and that rules helps to categories the samples as normal or anomalous. Samples that matches the rules are treated as normal and those nor are matches the rules treated as abnormal or anomalous samples. Sparse Coding[3][8],Online dictionary updating are the techniques mainly used in rule based method.

Third approach is Unsupervised, in which neither normal nor anomalous samples are required as antecedent examples for training. In this, classification is done based on assumptions that anomalies are less frequency of occurrence as compared to normal behaviour occurrence.

3. Proposed work

Anomalous activity recognition systems are developed to make surveillance system more smart and intelligent. Main aim is to detect suspicious or abnormal activities in videos to avoid future mishappening or to give alert whenever any type of mishappening occur. These anomalous activity recognition system classify normal and abnormal activities of objects.

Most of previous research in anomalous or suspicious activity recognition has focused on behaviour understanding by training the system manually. Some of work shows unsupervised learning methodologies for activity detection.

The main aim of this proposed work is to design an framework that can detect anomalous activity in surveillance real-time videos. Our proposed work is capable of recognition multiple activities in single video and also perform behaviour understanding. If any anomalous activity occurs it give alert to the system which signifies the presence of such activity by labeling it. Gaussian Mixture Model (GMM) is used for object detection and some problem domain rules are used distinguish different types of behaviour.

We considered running, walking and crawling as main activities of our approach. In which behaviour pattern and direction of object help to identify anomalous event. Our proposed framework consists of following components:

1. Determining object direction –whether all objects are moving, running or crawling in same direction or not.
2. Analysing motion pattern- whether all objects are performing same activity or some are doing same activity and other are doing other activity.

Hence, in this section brief discussion of the proposed architecture for anomalous activity detection in video is given.

3.1. Proposed Framework

The framework of the proposed work is depicted in Figure 1 The main components of this framework are: preprocessing phase, feature extraction phase and recognition phase. In first phase, i.e. the preprocessing, moving object is detected and noise removal is done. In feature extraction phase different features

like centroid, movement, speed, direction and dimensions are calculated. Finally, in last phase Rule-based classification method is used to classify the activities of the input video and alarm is generated for every suspicious activity.

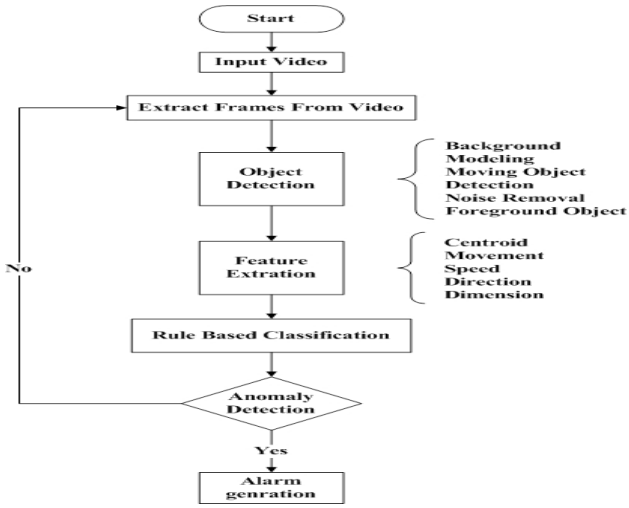

Figure 1: Framework of the proposed model

3.1.1. Preprocessing

:

The preprocessing phase consists of input video segmentation, background modelling, moving object detection, and noise removal.

1. Video Segmentation: The input video V is segmented into N continuous segments i.e. V= $\{v_1, v_2, \ldots\ldots v_n\}$ such that each video segment contains different behaviour pattern. Initially input video is converted into frames.
2. Background Modelling: In Video processing background and foreground extraction is an important step. For analysis, background and foreground is detected by using Gaussian Mixture Model (GMM).
3. Gaussian Mixture Model: GMM[11]is most sophisticated approach used for background subtraction. GMM is a parametric representation of probability density function. In this every pixel of frame is modelled into Gaussian distribution. Division of pixels is done by using its intensity values. Then probability is calculated to decide whether particular pixel is foreground or background pixel.
   By using equation (1)

$$P(Y_t) = \sum_{n=1}^{k} w_{i,t}.\eta(Y_t, \mu_{i,t}, \Sigma_{i,t}) \tag{1}$$

Where
Y_t : Current pixel in frame t
k: number of k_{th} distributions in mixture
$w_{i,t}$: the weight of k_{th} distribution in frame t
$\mu_{i,t}$: the mean of k_{th} distribution in frame t
$\Sigma_{i,t}$: standard deviation of k_{th} distribution in frame t

And , $\eta(Y_t, \mu_{i,t}, \Sigma_{i,t})$ is probability density function (pdf) which is formulated as equation

$$\eta(Y_t, \mu_{i,t}, \sum_{i,t}) = \frac{1}{(2\prod)^{n/2}|\Sigma|^{1/2}} \exp^{-1/2(Y_t-\mu)\sum^{-1}(Y_t-\mu)}$$

In Stauffer and Grimson method, every RGB is uncorrelated with each other, so difference in intensity can be assumed to possess uniform standard deviation.
Covariance matrix can be calculated as equation (2)-

$$\Sigma_{i,t} = \sigma_{i,t}^2 I \tag{2}$$

Threshold is set to decide whether particular Gaussian is classified as background or foreground. If Gaussian is larger than given threshold T it is classified as background and other those distribution not belong to previous category classified as foreground.

$$B = \arg min_{\ b}\left(\left(\sum_{i=1}^{b} w_{i,t}\right) > T\right) \tag{3}$$

If a pixel matches with any one of Gaussian then the value of w, μ and σ updated as given in equation (4),(5),(6) &(8)

$$w_{\ i,t} = (1-\alpha)\, w_{i,t} + \alpha \tag{4}$$

$$\mu_{i,t} = (1-\rho)\, \mu_{i,t} + \rho\ Y_{t+1} \tag{5}$$

$$\sigma_{i,t+1}^2 = (1-\rho)\, \sigma_{t+1}^2 + \rho\left(Y_{t+1} - \mu_{i,t+1}\right)\left(Y_{t+1} - \mu_{i,t+1}\right)^T \tag{6}$$

Where,

$$\rho = \alpha.\eta(Y_t, \mu_{i,t}, \Sigma_{i,t}) \tag{7}$$

Otherwise if all k of Gaussian do not match then only value of w is updated.

$$w_{j,t+1} = (1 - \alpha).w_{j,t} \tag{8}$$

After getting all values of parameters foreground detection is performed.

4. Noise Removal: Noise removal is an important and necessary step before further processing for better results. Video segments are prone to different types of noises which are result of error in capturing video. For removal of such noise we are using median filter and region filling method.

3.1.2. Feature extraction:

Feature extraction is a most crucial step in any recognition step for precise recognition of different activities. After video pre-processing features of consecutive frames are extracted. For anomalous and normal activity recognition we consider parameter like measurement, speed, direction, movement of object and centroid as main features for classification of activities.

1. Measurements- It is measure of the height of blob to its width for every object. Calculation height-width ratio which is essential for blob analysis.
   By using formula

$$Height - width - ratio(hwr) = \frac{height\ of\ blob(h)}{width\ of\ blob(w)} \tag{9}$$

2. *Speed*- It is measure of distance covered by object in consecutive frame to time taken by that object to cover that distance. To analyse and distinguish whether object is running or walking speed of object is calculated. It is computed as:

$$Speed\ of\ object = \frac{distance\ covered\ by\ object}{time\ taken\ to\ cover\ that\ distance} \tag{10}$$

3. Direction- Direction of motion of an object is determined to detect whether all objects are moving in same direction or in opposite direction. Direction is also an important feature we have taken to detect anomalous activity.
4. Movement-Motion pattern of object is analysed as we are dealing with moving objects and analysing their behaviours.
5. Centroid- Centroid is a measure of centre of mass of object. Centroid of blob of an object is formulated as

$$Centroid\ of\ blob\ in\ x - direction = \frac{width\ of\ blob}{2} \tag{11}$$

$$Centroid\ of\ blob\ in\ y - direction = \frac{height\ of\ blob}{2} \tag{12}$$

3.1.3. Recognition:

In the proposed work, Rule-based classification has been used to classify activities as normal or abnormal. In this phase classification of activities is done on the basis of problem domain knowledge i.e. rules. This method doesn't require any type of labeled or unlabeled training samples. They require some external knowledge or rules of the domain to create model. Accuracy of this approach is heavily depending on rules. In this method set of rules, pre-defined threshold is defined initially. It include if-then rules for making decision and these rules decide whether the recognised activity belong to normal activity class or anomalous activity class. When proposed system recognize any anomalous activity it generate alarm to show the presence of anomalous activity by making its bounding box colour as red which is different from normal activity bounding box.

4. Results and Discussion

This section includes the experiments performed on the proposed approach, the dataset used, the environmental conditions, setup, constraints imposed. Furthermore, the results of different experiments are calculated and are also compared with previous works in anomalous activity detection.

4.1. Dataset

Standard dataset of multiple anomalous activities in single video is unavailable. Therefore, due to unavailability of standard dataset we had created a new dataset. Our synthesized dataset consists of 45 videos of three activities. These activities are walking, running and crawling of multiple human. Some videos are containing normal activities and other are of both normal and anomalous activities in single video. We also consider the direction as a parameter to find anomaly so scenario of human performing activities in different direction also taken in account. Our proposed work is scenario dependent as any activity can be normal in one scenario but anomalous in another scenario.

4.2. Experimental setup

To perform our experiment we created our dataset video for anomalous activity detection by using canon 16 megapixel kept at 5 meter of height from ground. The object made to move in a manner to avoid much overlapping. The code is implemented in Matlab 2014 on system configuration with corei7 processor and 8 GB RAM. Proposed framework is trained by using predefined set of rules and tested on various videos some of the test videos snapshots are shown in the Figure 2, 3, 4, 5, 6. In below figure shows anomalous activity(less dominant)that is bounded with red box and normal activity(more dominant) with yellow color box.

Figure 2: Sequence showing walking in different direction

4.3. Results and Discussion

The results are shown in Figure 7 The performance of our anomalous activity detection system is evaluated in terms of accuracy. The accuracy of our proposed architecture is given as follows:

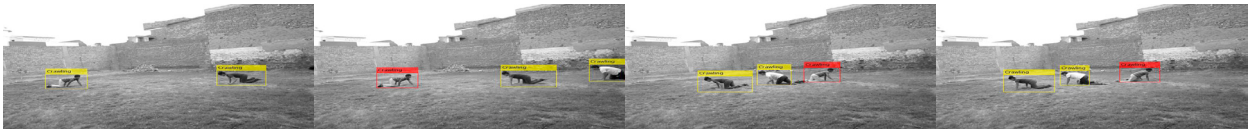

Figure 3: Sequence showing crawling of object in different direction

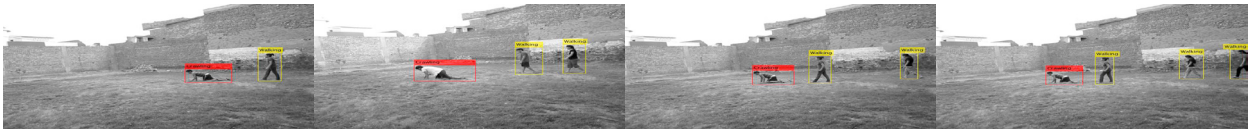

Figure 4: Sequence showing crawling and walking activity

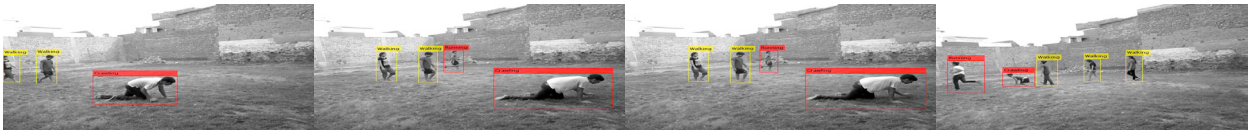

Figure 5: Sequence showing crawling,walking and running activity

Figure 6: Sequence showing walking and running as main activity

$$Accuracy = \frac{correctly\ classified\ activity}{total\ occurrence\ of\ activity} \tag{13}$$

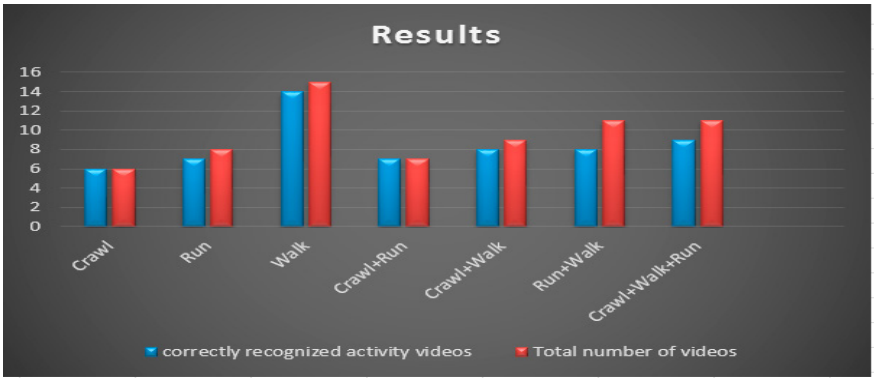

Figure 7: Results describes accuracy of Proposed Work

This framework is able to detect various types of anomalous activities in different scenarios. The framework is also tested on different videos containing multiple activities. The results shows in 7 is the accuracy calculated on our proposed work in different scenarios. Scenarios are crawling(C), running(R), walking(W), crawling-running(C+R), crawling-walking(C+W), running-walking(R+W) and crawling-running-walking(C+R+W).

5. Conclusion

In this paper, we mainly focuses on the problem of anomalous activity detection automatically without much human intervention. Our proposed work includes object segmentation, multiple feature extraction and dominant behaviour analysis.

Foreground extraction is done by using GMM. Multiple features like speed, direction, dimensions and centroid are extracted for analysis. Anomalous activity is detected by using some problem domain rules which helps to find dominant and less dominant behaviour also direction of object is considered in recognition process. In our work we considered dominant activities (having higher frequency of occurrence) as normal behaviour and less dominant (having less frequency of occurrence) behaviour as anomalous event. Result shows that Rule-Based approach proved good in case of handling multiple activities in single video. In future we will try to implement some more features and they are listed below:

(a) We will focus on some more suspicious activities.

(b)Multiple object overlapping will be taken in consideration.

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