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A Comparative Study of Statistical and Machine Learning Techniques of Background Subtraction in Visual Surveillance

ABSTRACT

Video is basically collection of images. Through a single image we can take a screenshot of a scene, which helps in detecting motion with sequence. Now a days, video has popular usage in many applications like identification of exceptional behavior in parking, monitoring of traffic, finding the cause of road accidents, detection of pedestrians, ATMs etc. This is done with the help of many applications that include object tracking, motion segmentation using one of its part background subtractions with the help of various algorithms such as particle filter, mean shift method, kalman filter etc. This paper presents a survey on various algorithms that helps in improving the motion of the object. Research is made on motion detection and tracking in videos along with comparative analysis on various algorithms.

Keywords : Meanshift, Kalman Filter, Particle Filter, Motion Segmentation, Background Subtraction.

I. INTRODUCTION

In todays world with increasing technology and population it becomes very challenging for a human eye to analyze and detect each and everything be it in marketing, bussiness, traffic regulation, health, education and so on.Thus, video analytics comes as a life saver in this situation.a video is basically a collection of images.Video anlysis is the process of automatic analysis of videos in order to detect temporal and spatial activities of an object.There are three important aspects to analyze real world objects through videos :Object detection, Object tracking and analysis.Detection in moving object is the way of recognizing the movement of an object in a given region or area.Tracking is defined as evaluating the path of an object in image plane as it moves around in a scene.In this paper ,a detailed anlysis of various algorithms and techniques of motion detection and object tracking has been made with advantages and drawbacks of each [1].

Image processing is the process of manipulating digital images through digital computer. It particularly focusses on developing such type of computer system that is capable of performing processing on an image. Taking digital image as input for the system than system processes that image using algorithms and provides image as output. An image is basically a two dimensional signal which is defined mathematically as f(x,y) such that x and y are two cordinates horizontally and vertically .The value of f(x,y) at any point denotes pixel value at that point of an image. A signal is a function that provides some information, so a higher dimension can be considered as signal. It can be one dimensional ,two or higher dimensional. One such exampe of two dimension is a digital image. Signal are divided into two types:- analog and digital signal. Analog signals are the one that are defined with respect to time. Also it is a continuous signal and defined over continuous independent variables. Such signal is difficult to examine as they carry huge values and are very much exact due to large part of values. Such

signalsare represented by sin waves whereas digital signals are easy to analyse and are not continuous signal. Digital means discrete values and uses proper values to provide any information. As compared to analog signal thay are less accurate because they are distinct samples of analog signal that are taken with respect to time. They are not subjected to noise and denoted by square waves. Digital image is formed by taking an image from camera , sunlight is also used as being a source of energy. Some signal is used for producing the image. When sunlight falls upon the object, the amount of light reflected back by the object is sensed by sensor and a continuous voltage signal is produced by the amount of data which is sensed. Then we replace such data into digital form in order to create digital image[2]. Sampling and quantization techniques are involed which providesa digital image. Frame is basically bit by bit transmission of data.

II. LITERATURE SURVEY

VISUAL SURVEILLANCE :- From vision of computer,visual survelliance is one of the research topic that is used to detect, identify and monitor objects by getting the set of images that helps in understanding and describing the behaviour of object simply by converting the old method of monitoring camers by human operators. Depending upon the human involvement, visual survilliance is defined as manual, semi-automatic and fully automatic. In manual visual survillance, only the human is responsible for detecting and performs all the job while viewing the visual information obtaining from several camers. In semi-automatic visual surveillance both human and system , responsible as object tracking is under computer vision algorithm and human operator is responsible for personal identification, job of classification and recognising activity. Low level of video processing is used in it, and most of the task is performed by human . Whereas in fully automatic, no human involvement and the whole job is performed by the system. On comparing all the three , fully automatic system is more intelligent to track, classify and identify object. Also it helps in reporting and detecting the doubtful behaviour and recognizing the activity of object[3],[4],[5].

Various stages of Visual surveillance

visual surveillance has the following stages such as: background modeling, motion segmentation, classification of foreground moving objects, human recognition , monitoring and examining the behavior of object .

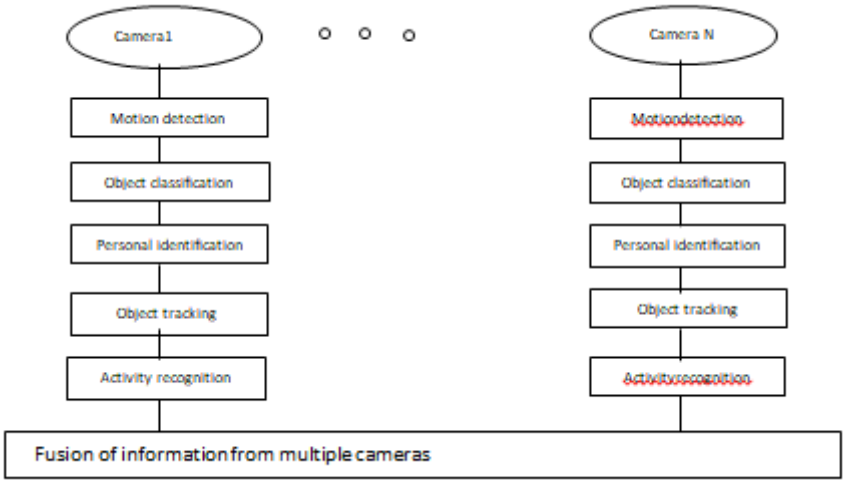

Figure 1. stages of visual surviellance

III. MOTION DETECTION

The first step in visual surveillance system is detecting the motion of an object . Motion detection is the process of segmenting object moving foreground from the remainig image. Motion segmentation is basically done with many techniques such as background subtraction , temporal differencing andso on. Background subtraction is the most popular method among them that helps in detecting the moving regions in an image by taking the exact difference between current image and the background image which is referred and very common technique for detecting the moving object. Very much easy and inexpensive for real time systems, but also sensitive to extraneous events etc. The goal of such technique is to extract current image from reference background image, that is taken during period of time. Otherwise no change occurs and the pixel belongs to the object. The subtracting operations that are applied helps in finding the absolute difference for each pixel, by detecting object that differs from background. If difference is below the threshold then no change in the scene and pixel is observed as it belongs to background. So that is why it is very much dependent on good background maintenance model. There are several algorithms that come under background subtraction[6],[7].

BACKGROUND SUBTRACTION:

Below figure shows the flow chart of background subtraction techniques (BGS).

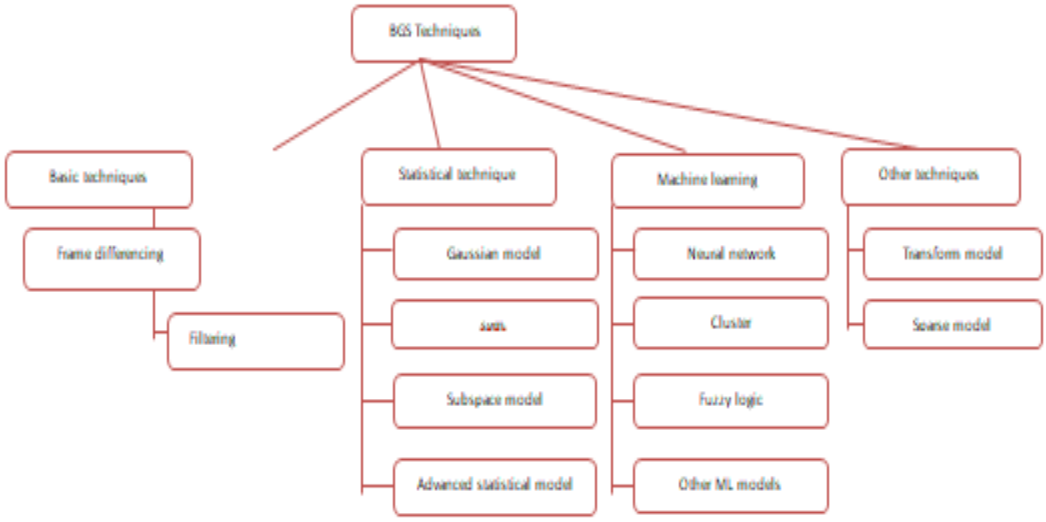

Figure 2. BGS techniques

Statistical techniques

This technique is used to identify the requirements of a process through the method of collection of data from the process and then analyzing them in order to establish control and validate the process capability. It is one such type of background subtraction technique which is more robust towards camera jitter and dynamic background. This technique is further divided into Gaussian model (GM), support vector model (SVM), subspace and advanced statistical model [8]. The figure below shows the flowchart of its various techniques [9], [10], [11].

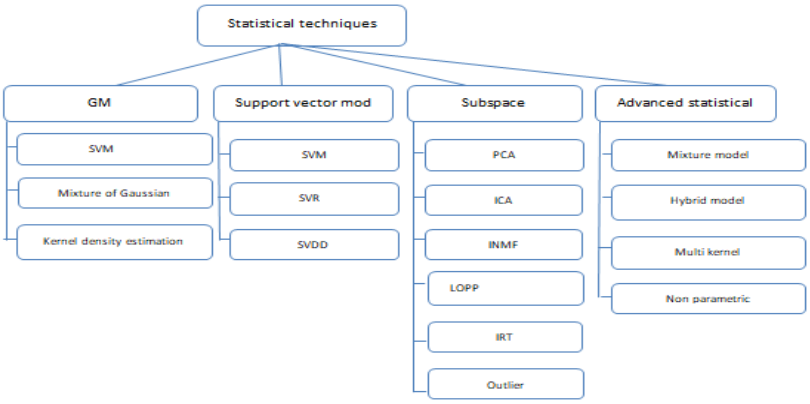

Figure 3

Table 1

Name	Type/category	Precision	Computation time	Performance in bad weather	Performance in low frame rate	Advantages and disadvantages
Single Gaussian method	Gaussian model	0.4036	Less(1.32)	Performs very well	Less robust	Works well for static background only .Not suitable for shadows &camera jitter
Mixture of Gaussian	Gaussian model	0.6336	More(4.91)	Performs well	Most robust	Static background only. Cannot detect shadows or any changes to background
Support vector machine	Support vector model	High precision	Low	Performs well	Less robust	Suitable for applications with camera jitter and dynamic background
ViBe	Non-parametric model	0.7793	More(4.8)	Performs very well	Most robust	Fails to detect shadows, works well for camera jitter and illumination
KDE	Gaussian model	0.3700	Very high(13.80)	Works very well	Less robust	Works well for dynamic background, camera jitter and illumination changes
PCA	Subspace model		Very high	Perform good	robust	Can't be used with dynamic scenes
SVR	Support vector model	High precision	More	Performs well	More robust	Does not work well with more dynamic backgrounds

Median filter	filtering	Good precision	Switching median filter used to improve the speed	Well perform	Less robust	
PBAS	Non-parametric	0.6670	low	Performs good	Most robust	Works well for camera jitter and dynamic background

1. Single Gaussian method:

Ideal conditions like a complete noise-free background cannot be satisfied in real life scenario. Thus, for noise every pixel is used with a Gaussian distribution .The background and foreground represented as

$$|(It - \mu t)|\ \sigma t > k \longrightarrow \text{Foreground}$$

2. Mixture of Gaussian

Single Gaussian method works well for static background only, however, mixture of Gaussian method is a more robust method in this regard [12],[13]. It performs well in bad weather. It supports static background but cannot detect shadows or any changes to background and takes more computation time.

3. Kernel density estimation

It is a non-parametric method for estimating the probability density function of random variables. It is an unstructured approach. It has low robust and works well for dynamic background, camera jitter and illumination changes.

4.Support vector model

It is a more sophisticated model for background subtraction as it uses support vector machine(SVMs) and also uses support vector regression(SVR). In this method the frame is basically partitioned into 4x4 size block and then it is found whether the block is a part of background or not by making use of probabilistic support vector machine(PSVM). SVR also uses the same features as that of SVM for classification with only a few minor differences.

5.Principal component analysis(PCA)

This method makes use of transformation that is orthogonal ,use to convert a series of observations which are possibly correlated into linearly uncorrelated variable which are known as principal components.

6.Visual background extractor(ViBe)

In this method, a series of values taken previously is calculated for each pixel in the same location or in neighborhood. Then a compression is made of these values with the current pixel value in order to determine whether the pixel leads to the background or not. It is a non-parametric statistical approach.

7.Pixel-based adaptive segmenter(PBAS)

In this method , a segmentation decision is taken based on the fact that how close is the value of the pixel to the corresponding pixel model which is created by an array of recently observed background values. If the value of pixel closer than a certain threshold value, then it is said to belong to the background.

Comparative analysis of different statistical techniques :-

Machine learning

Machine learning is one of the types of artificial intelligence which helps a machine to perform activities without explicitly being programmed which at times human can perform better. The basic idea behind machine learning is to build algorithms that can receive output data and use statistical analysis to find out the output of the process. Following are some of the machine learning

techniques which can be used for BGS. Now the flowchart below shows different techniques under machine learning.

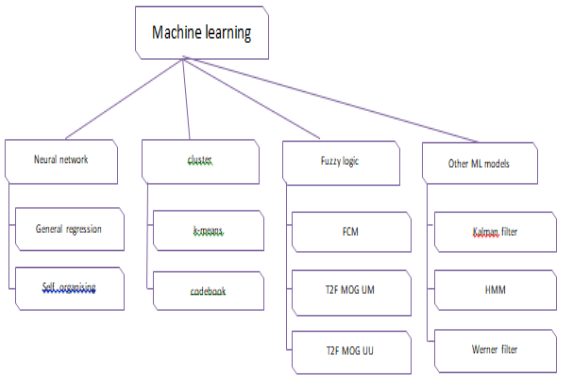

Figure 4

1. Artificial Neural network.

ANN can be used in BGS in a very efficient manner. The background information is stored at each neuron and a neural network which is three layered is used that comprises of aninput layer, hidden layer and output layer. Various variants of neural network have been implemented over years.

2. Codebook

It is an efficient technique to deal with multi model background. A sequence of key values called code words is assigned to each background pixel based on the training sequence which determines the pixel a color which is most likely to take over a certain period.

3. K-means clustering.

Clustering is the process of dividing a set of data points to a small number of clusters. It is is a method in which we find the locations of clusters that reduces the distance of cluster from data points.

4. Kalman filter

This technique uses its recursive nature. It is basically a recursive method in which weighted average of previous estimates and the new information is used and the weights are optimized to reduce the squared error.

5. Hidden Markov model

A method where there is sequence of outputs but the sequence of states the model went through to generate the output is not known. In image processing the conventional block based classification ignored the context information. Therefore in order to improve classification by context hidden markov model was proposed[14],[15].

Comparative analysis of different machine learning techniques :-

Table 2

Name	Approach	Computational time	accuracy	Memory requirement
Artificial neural network.	Non parametric	training is time consuming	Less accurate	Less memory required
Decision tree	Non parametric	Less time consuming	Less accurate	Less memory required
SVM	Non parametric with binary classifier	Training is time consuming	Less accurate	Scalability improves by reducing memory use
Fuzzy logic	Stochastic approach	Less time consuming	Less accurate	Less memory requirement
k-nearest neighbor	Parametric	Less time consuming	Less accurate when large data set is there	More memory needed
Kalman filter	Non parametric	Less time consuming	exact	Limited memory
Hidden markov	Stochastic approach	Time consuming	Less accurate	Less memory

IV. CONCLUSION

This paper presents a comparative study of various background modeling techniques. This paper categorizes the available background modeling approaches into four general types, basic, statistical, machine learning and other approaches. The main two categories i.e statistical and machine learning techniques of background subtraction are focused upon in this paper. Comparison of such methods depends on their cpu or memory requirements as well as their capability of correctly detecting motion in different kind of videos. As far as statistical methods are concerned , methods such as MOG and KDE has proved very good model accuracy. KDE has a high memory requirement. Gaussian methods perform very well but work for static background only while SVM techniques work well with dynamic background and camera jitter and their computation time is also very efficient. In case of machine learning methods , the new approaches like fuzzy logic are less time consuming. Also the kalman filter and k-nearest neighbor approaches are good in this regard. As far as accuracy is concerned kalman filter gives a very accurate result also requires less memory than k-nearest neighbor approach. Thus, overall each method has its own advantages and disadvantages. All we can do is try to incorporate the good features of some techniques into other so that it can result intogood technique.

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