EFFICIENT MULTIPLE OBJECTS DETECTION AND TRACKING USING PARTICLE FILTER

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\textbf{ABSTRACT}

Efficient multiple objects detection and tracking using particle filter presents a new approach for detection and tracking of multiple objects in video surveillance systems using particle filtering technique and considering environment factors as additional information. Till now all previous methods like kalman filter, mean shift used only object characteristics (orientation, location and scale) for tracking, ignoring environment factors which results in high computational overhead and low tracking accuracy. We take relationship between object and environment factors and model it as environment state using distance transform technique, and integrate it into particle filtering for better tracking accuracy. And also tracking error is minimized greatly by large number of effective particles.

\textbf{KEYWORDS}

Object Tracking, Particle Filter, Environment Factors, Distance Transform Technique.

1. \textbf{INTRODUCTION}

Object tracking [8] is a method of following an object into number of frames of a video and find its relative motion with respective to other objects in the scene. It is very important task in the field of computer vision and has increasingly focused on objects recognition and the main goal of vision system is to monitor the highways, buildings etc over the extended periods of time and the main purpose is to track both vehicles and humans in order to detect abnormal behaviours. It is very important tool for police for finding stolen vehicles.

Highway monitoring, traffic monitoring are main applications of object tracking. Highway traffic is continuously monitored using cameras if any vehicle breaks traffic rules or if any vehicle violated speed or if any vehicle causing accidents can be tracked down easily [10].

Object detection is a method of detecting moving objects in the scene. It is required by the every tracking method for knowing the objects in the scene. Video surveillance systems are increasingly used in security systems, possible dangers are detected early. It is valuable and economical means of providing security to people, buildings and highways.
Extensive research has been done during the last decade on multiple objects tracking.

In [12] particularly selected object is tracked in multiple moving objects. Difference image region based tracking is used for multiple moving objects detection and background update for ensuring there is an accurate detection. Particle filter is used for tracking particular interested or selected object in multiple objects.

In [13] same colors shared by objects are tracked without detection methods using hybrid sequential state estimation.

In [14] without loss of any information about objects state to be identified, discrete wavelet transform is used. Simple kernel mask or bounding box is applied for tracking if no occlusions such as object to object to interactions and if in case of occlusions profile appearance based tracker is used.

In [15] background subtraction model is used for detecting multiple objects and feature based tracking is used for tracking detected objects.

In [17] comparing with adaptive backstepping control algorithm, adaptive backstepping sliding mode control is proved as efficient algorithm for estimating unknown parameters and tracking trajectories with stable system accurately.

In [18] for taking right decision for paths to the flight, imperialist competitive is used where congested area is mapped into graph and it is colored using this method for detecting or reducing traffic.

In [19] unmanned flying robots or vehicles and four rotor aerial vehicles are dynamically unstable, to make them stable, classic PID controller and linear matrix inequality are used where linear matrix inequality proved as efficient algorithm and given better performance than PID controller.

Mean shift [7] and kalman filter are previous techniques for object tracking, which takes only object characteristics for tracking violated (traffic rules, speed violation and causing accidents type vehicles for example). Mean shift tracking is very deterministic method. It is region based object tracker based on color. For attaining quick, mean shift tracking method is applied. But limitation of mean shift is, it may get stuck sometimes, and if there is any sudden change in the motion of objects being tracked mean shift cannot handle it.

Kalman filter [3] method combines noisy or missing measurements and predictions of state of object being tracked to achieve an estimate of its true current state. Limitation of kalman filter is if initial state is wrongly modeled then tracker will be degraded and gives poor estimation of object state or variables. It is sequential algorithm and it depends only on current measurements. Complicated object tracking problems are not possible to analyze analytically.

Mean shift take more number of iterations for finding object state and take more search area for tracking object. For decreasing number of iterations kalman filter is used. Comparing to the Kalman filter, the particle filter has a more robust performance in the case of nonlinear and non-Gaussian problems. Particle filter take less search area for object tracking [11]. These tracking algorithms are limited and not able to handle decently some complex situations like rapid motion, full or partial or self occlusion, multiple object tracking. Tracking multiple objects is a very challenging task. If there abrupt object motion, changing appearance of object and scene, object to object occlusions and object to scene occlusions are main difficulties arise during tracking.
Particle filter [6] tracked the single object efficiently without loss of any information. It is an efficient algorithm for multiple objects tracking which overcomes all the limitations of mean shift and Kalman filter tracking methods. It can track many objects as there are particles (may be the object state it could be). Main thing in particle filter is it removes noise present in the scene.

System is mainly divided into three parts (shown in Figure 1): 1. Object detection 2. Environment states modelling using distance transform technique and 3. Object tracking using particle filter. In our system we are taking frame difference method detecting moving objects in the scene, because as we taking video from stationary camera, the background doesn’t change over the period of time.

An video is taken and convert it into frames then we apply distance transform technique for finding distance between one edge of road to vehicle edge for modelling environment state, before applying distance transform we have to detect multiple moving objects in scene for that we apply frame difference [1] method and we apply thresholding technique for removing noise if present after frame difference method and apply particle filter for tracking detected objects.

The paper is organized as follows: Section 2 presents the moving object detection using frame difference method and removal of noise using thresholding technique. Section 3 presents environment modelling using distance transform technique. Section 4 presents the object tracking using particle filter. Section 5 presents experimental results. Section 6 presents conclusion and future work.

2. OBJECT DETECTION

Here we are using frame differencing method [9] for object detection and thresholding technique is used to remove any noise present in the scene. Object detection method is used for detecting moving objects in a scene. Detection method is required by every tracking method to know the moving objects and stationary things in the scene. Object detection method is used for reducing the number of false detections of an object.

A. Frame Difference

Detecting moving objects in a video sequence is very challenging and fundamental system. Frame difference is the simplest method for moving object detection. It finds the difference between two frames (current frame and previous frame). It is basically an image subtraction operator which takes two images as input and produces a third image as a output And instead of using previous frame, a single frame, which does not include any moving objects, can also be used as reference image. This method is fast and has adaptation ability to changes in the scene.
FD(x,y)=I1(x,y)-I2(x,y) \quad (1)

FD(x,y)=0 \quad \text{if} \quad I1(x,y)=I2(x,y) \quad (2)

FD(x,y)=I2(x,y) \quad \text{if} \quad I1(x,y) \neq I2(x,y) \quad (3)

I1(x,y) \text{ and } I2(x,y) \text{ are previous frame and present frame.}

**B. Thresholding**

Thresholding technique [20] is a simplest and widely used method of image segmentation. It is very useful in discriminating foreground from the background. This method is based on clip level or threshold value which turns gray scale image into a binary image. The advantage of obtaining binary image is to reduce the complexity of the data and to simplify the process of detection and recognition. Most advantage of this method is unnecessary details of an image can be removed and we can concentrate on more useful details, and also hidden objects in the image can be found. We can measure sizes of objects and also count them by choosing appropriate threshold value. The threshold image is given as

\[
DO(x,y) = \begin{cases} 
1 & \text{if } \quad FD(x,y) \geq T \\
0 & \text{if } \quad FD(x,y)<T 
\end{cases}
\]

Thus the pixel labeled 1 is object and all other are removed using threshold value T.

**3. ENVIRONMENT MODELING**

Till now methods used only object characteristics for object tracking instead of that if we take environment factors we can track the violated objects at initial stage only, if we find the distance of object at every time the violated object can be detected and we can track it. Before that we have to know the geometrical (means number of boundaries and where they are located) relationship between objects and the surroundings and these are very useful observations. And as we considering the environment factors, current dynamics state (object characteristics) is dependent upon both previous dynamics states and previous environment states. On the other hand, the current environment state depends upon previous environment states.

**A. Distance Transform**

Distances transform technique transforms a 2D image into a distance map, in which the value at each point corresponds to its distance to the nearest feature point. It was first developed by Rosenfeld and Pfaltz [4],[5] in 1960’s. It is generally refers to labeling of each pixel of object by distance to the closet point in the background. This technique is used to find the minimum distance between one edge of road to vehicle edge. This is widely applied to many image analysis applications like shape description, morphological operations and skeletonazation etc, and also compute direct measurements like local width and differential estimations. It is also used to find the tracking error [16].

\[
d(p) = \min \text{dist}(p,q) \quad (6)
\]

dist (p, q) is the distance function which measures the distance between two points p and q. The distance map is a matrix with the same dimension as the transformed image and stores the distance field values d(p) at the corresponding location for each point p.Among various distance
transform techniques, Euclidean distance transform (EDT) is an better and common choice. It uses Euclidean metric for measuring distance between two pixels that having the coordinates \((x1,y1)\) and \((x2,y2)\) then the Euclidean distance is given by

\[
\text{Euclidean Distance} = \sqrt{(x2-x1)^2+(y2-y1)^2}
\]  

(7)

Environment state \(e\) by distance field value \(d_t\) is

\[
e = [d_t, d_t - d_{t-1}]^T
\]  

(8)

4. OBJECT TRACKING USING PARTICLE FILTER

After applying distance transform transform technique we employ it into particle filter for tracking. Here in our multiple objects tracking system is characterized by set of features like pixel location, speed and colour. Object tracking is a very difficult problem. Single object detection and tracking is good and efficient but situations where multi target is difficult to detect and track. Particle filter [2] object tracking is proven as very efficient tracking algorithm. This filter maintains probability distribution over the dynamics state of object (location, state) being tracked and environment state, and represents this distribution as a set of set of weighted samples or particles (represents one possible location of object being tracked). We find the trajectory of the tracked object by taking highest weight. Particle filter can deal with non linearity and it is very easy to implement.

Particle filter basically can be done in four steps.

\[
\{x^{(i)}_t\}_{i=1}^n \text{ is an object at n frames and its corresponding weight } \{w^{(i)}_t\}_{i=1}^n \text{ calculated from likelihood } p(y_t|x_t)
\]

Weight = weight*likelihood

Firstly it specifies the object of interest by extracting features of objects by their location and also finds the new objects entering the scene.

Each sample or particle (object being tracked) is predicted.

The object state at current frame \(\hat{x}_t\) is predicted where it depends on previous frame \(\hat{x}_{t-1}\) and noise \(\tilde{u}_{t-1}\). the current object state is given by without the knowledge of \(\tilde{y}_t\)

\[
\hat{x}_t = f_t(\hat{x}_{t-1}, \tilde{u}_{t-1})
\]  

(9)

Predicted state of object is given as

\[
p(\hat{x}_t | \tilde{y}_{1:t-1}) = \int p(\hat{x}_t | \hat{x}_{t-1}) p(\hat{x}_{t-1} | \tilde{y}_{1:t-1}) d\hat{x}
\]  

(10)
Calculates the weight of each sample or particle combining the predicted state \( p(\tilde{x}_t \mid \tilde{y}_{t-1}) \) with likelihood of current measurement \( p(\tilde{y}_t \mid \tilde{x}_t) \). Now here the measurement of \( \tilde{y}_t \) depends on noise measurement \( \tilde{u}_t \) and current predicted state \( \tilde{x}_t \).

\[
\tilde{y}_t = \tilde{h}_t(\tilde{x}_t \mid \tilde{u}_t)
\]

Weights are based on likelihood \( p(\tilde{y}_t \mid \tilde{x}_t) \)

\[
p(\tilde{x}_t \mid \tilde{y}_t) = \frac{p(\tilde{y}_t \mid \tilde{x}_t, \tilde{y}_{t-1}) \cdot p(\tilde{x}_t \mid \tilde{y}_{t-1})}{p(\tilde{y}_t \mid \tilde{y}_{t-1})}
\]

Finally collects all data according to their weights, and discards lowest weights.

Tracking error is greatly reduced by number of number of effective particles. Effective particles is given by

\[
N_{\text{eff}} = \frac{1}{\Sigma w}
\]

The rate of effective particles is given by

\[
\lambda_{\text{eff}} = \frac{1}{N_{\text{eff}}}
\]

For tracking objects before we have to model the object using rectangular bonding box also known as kernel mask defined by the dynamics state \( y_t = [a_t, b_t, c_t, d_t, e_t, \dot{a}_t, \dot{b}_t, \dot{c}_t, \dot{d}_t, \dot{e}_t]^T \), where \( a, b, c, d, \) and \( e \) correspond to the \( x/y \) image coordinates, width, height and orientation. Actually by using bounding box reduces the area of object being tracked which overcomes limitation of mean shift tracker.

5. EXPERIMENT RESULTS

We have taken an video and converted video into frames then applied frame differencing and thresholding technique for detecting objects in the video frames. Distance transform technique is used to distance between one edge of road to one edge of vehicle (environment state) and finally applied particle filter for multiple objects tracking. Our system automatically refreshed and tracks the new coming objects in the scene.

A. Video to frame conversion

Fig.2 : video to frame conversion.
B. Moving object detection

Fig. 3: detected objects using frame difference and thresholding.

Objects are detected using frame difference method and by choosing appropriate thresholding value if any noise present in the video frames is removed.

C. Distance calculation using Distance transform

Fig. 4: Calculation of distance using Distance Transform technique.

After objects detections using Frame difference and thresholding technique we apply distance transform technique which finds the closet distance between vehicle edge to frame boundary.

D. Means of tracking error

Fig. 5: Means of tracking error.

Tracking error is given by the difference of calculated distance between current frame and previous frame. If difference at each frame is same means the object moving in the same lane or there is an tracking error.
E. Object tracking using particle filter

After distance transform technique we integrate it into particle filter which tracks multiple objects one by one (If new vehicle enters the scene then it is also tracked). Before tracking we model object using bounding box (which reduces the size of search area).

F. Number of effective particles

As more and more particles (object being tracked) the tracking error is greatly reduced. This figure shows the number of particles at each frame.

6. CONCLUSION

An efficient multiple objects detection and tracking using particle filter presented a new approach for detecting and tracking of multiple objects in video surveillance systems. Unlike previous methods like mean shift and kalman filter techniques it tracked multiple objects efficiently taking relationship between environment state and object characteristics as additional information which is ignored. We modelled environment state using distance transform technique. Before that by using frame difference method we detected objects efficiently which is very important for tracking objects. Tracking error is greatly minimized because of large number of particles. Our tracker automatically refreshed and tracks new coming objects in the scene. This system can be applied to track multiple objects in complex and dynamically changing environments and to track multiple objects using non stationary cameras.
7. REFERENCES


[6] Lyudmila Mihaylova, Paul Brasnett, Nishan CANAGARAJAH and David BULL “Object Tracking by Particle Filtering Techniques in Video Sequences”.


[12] Hyung-Bok Kim and Kwee-Bo Sim “A Particular Object Tracking in an Environment of Multiple Moving Objects” International Conference on Control, Automation and Systems 2010


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