A Review on Multiple Objects Tracking in a Video Scene with Particle Filtering Techniques

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Abstract - *Multiple objects tracking in a video scene is one of the most challenging tasks in the field of computer vision as well as it is highly demand in many computer applications, such as surveillance, tracking of animals, pedestrians, vehicles, human behavior analysis, and so on. A complex scene is characterized by several moving objects such as people, animals, vehicles, etc. In order to perform higher level tasks, such as to fight against terrorism, crime, public safety for efficient management of traffic, etc. which are demanded by typical surveillance or monitoring applications, to detect, identify and track various objects of interest. There are many approaches have been proposed to solve this problem, it still remains challenging due to factors like abrupt appearance changes and severe object occlusions. The objectives of multiple object tracking are to place moving objects in sequential video frames. In this paper, we contribute the first comprehensive and most recent review on this problem using Particle filters. We provide a discussion about issues of multiple objects tracking via Particle filters research, as well as some interesting directions which could possibly become potential research effort in the future.*

Keywords — *Object tracking, Computer vision, Particle filter, Video scene.*

I. INTRODUCTION

Multiple Object Tracking system plays an important role in computer vision and as well as image processing. When a video contains multiple moving objects that we wish to track, we refer to this as multiple object tracking. In some sense, the task is an extension of object detection, since in addition to detecting objects; we need to connect detections between frames to get a consistent tracking. Object detection is still an unsolved problem, and the most powerful methods are limited by their speed. The task of object tracking is largely partitioned to locating multiple objects, maintaining their identities, and yielding their individual trajectories given an input video scene. Objects to track can be, for example, pedestrians on the street [1], [2], vehicles in the road [3], [4], sport players on the court [5], [6], [7], or groups of animals (birds [8], bats [9], ants [10], [11], [12], cells [13], [14], etc.). Multiple "objects" could also be viewed as different parts of a single object [15].

As a mid-level task in computer vision, multiple object tracking grounds high-level tasks such as pose estimation [16], action recognition [17] and behavior analysis [18]. It has numerous practical applications such as visual surveillance [19], human computer interaction [20] and virtual reality [21]. These practical requirements have sparked enormous interest in this topic. Compared with Single Object Tracking, which primarily focuses on designing sophisticated appearance models and/or motion models to deal with challenging factors such as scale changes, out of-plane rotations and illumination variations, multiple object tracking additionally requires two tasks to be solved: determining the number of objects, which typically varies over time, and maintaining their identities. Apart from the common challenges, further key issues that complicate multiple object tracking include among others: 1) frequent occlusions, 2) initialization and termination of tracks, 3) similar appearance, and 4) interactions among multiple objects.

The fundamental in object tracking is object detection, object classification and then finally object tracking. Moving object detection is the first and important step for many video analysis tasks. Moving object detection aims at extracting moving objects that are important in video sequences. The next step is object tracking. It is an important task within the field of computer vision. It is used not only for video surveillance but also for traffic control, medical imaging, gesture recognition etc. The approaches for object tracking are as follows.

A. Object Detection

Object detection is a computer technology related to computer vision and image processing that deals with detecting instances of semantic objects of a certain class (such as humans, buildings, or cars) in digital images and videos. Well-researched domains of object detection include face detection, face recognition, object tracking and pedestrian detection. Object detection has applications in many areas of computer vision, including image retrieval and video surveillance.

B. Object Classification

Moving regions detected in the video may matches to different objects in real world such as humans, vehicles etc. The approaches to classify the objects are Shape-based classification, Motion-based classification and Color based classification.

C. Object Tracking

The object tracking problem is deceptively simple to formulate: given a video sequence containing one or more moving objects, the desired result is the set of the of the trajectories of these objects [36]. The goal of a moving object tracking is to create the path for an object above time by detecting its position in every single frame of the video.

Following are the challenges that should be taken care in object tracking.

• Noise in images.
• Complex objects shapes / motion.
• Partial and full object occlusions.
• Scene illumination changes.

Few object tracking methods are as below:

Kalman Filter

Kalman filter are based on Optimal Recursive Data Processing Algorithm [22]. Here Gaussian state distribution is assumed. Kalman filtering is composed of two stages, prediction and correction. Prediction of the next state using the current set of observations and update the current set of predicted measurements. The second step is gradually update the predicted values and gives a much better approximation of the next state. Kalman Tracking is capable of dealing with:

- Kalman filters always give optimal solutions.
- Another potential approach is to handling noise
- Tracking is applicable only for single and multiple objects.

Particle Filter

Particle Filter algorithm can solve object tracking under non-Gaussian or non-linear conditions, its core conception is Monte Carlo integration. In most cases, it can obtain a better tracking result compared to mean-shift [23]. In the method of staring with population of particle, each will assign value to no variables and weight of 1.

Multiple Hypothesis Tracking (MHT)

The MHT algorithm is based on motion correspondence of several frames together. Better results are obtained if correspondence is established observing several frames rather than using only two frames. The MHT algorithm upholds several suggestions for each object at each time. The final track of object is the most likely set of correspondences over time period of its observation [22]. MHT is an iterative algorithm. Emphasis starts with a set of existing track speculations. Every theories is a group of detach tracks. For every speculation, a prediction of object's movement in the succeeding casing is made. The predictions are then analyzed by computing a separation measure.

Simple Template Matching

Template matching is a brute force technique for analyzing the Region of Interest in the feature. In template matching, a reference image is checked with the frame that is differentiated from the feature. Following could be possible for single question in the feature and covering of item is carried out incompletely. Layout Matching is a procedure for transforming computerized images to discover little parts of an image that matches, or identical model with an image (format) in each one frame. The matching strategy contains the image format for all conceivable positions in the source image and ascertains a numerical file that points out how well the model fits the picture that position. It capable of dealing with:

• Tracking single image.
• Partial occlusion of object.
• Necessity of a physical initialization.

Mean Shift Method

Mean-shift tracking [24] tries to find the area of a video frame that is locally most similar to a previously initialized model. The image region to be tracked is represented by a histogram. A gradient ascent procedure is used to move the tracker to the location that maximizes a similarity score between the model and the current image region. In object tracking algorithms target representation is mainly rectangular or elliptical region. It contain target model and target candidate. To characterize the target color histogram is chosen. Target model is generally represented by its probability density function (pdf). Target model is regularized by spatial masking with an asymmetric kernel.

Contour Tracking

Contour tracking techniques create a unique contour in the foregoing frame to its new position in the present edge, covering of object between the current and next casing. Contour tracking is in the form of state space models [22].

Shape Matching
This approach checks for object model in the existing frame [22]. Shape matching performance is similar to template based tracking in kernel approach. Another approach to Shape matching is to find matching silhouettes in two successive frames. Detection based on Silhouette is carried out by background subtraction. Models object are in the form of density functions, silhouette boundary, object edges [22]. Shape matching execution is like template based tracking in kernel approach. An alternate approach to Shape matching is to discover matching silhouettes in two successive frames. Detection based on Silhouette is carried out by background subtraction. Models object are in the form of density functions, silhouette boundary, object edges [22].

II. ORGANISATION OF THE OVERVIEW

Early stage of researches on object detection and tracking, the first fundamental problem encountered is the object segmentation which extracts the areas (or objects) of interest from the scene. We provide the comprehensive review on the object tracking problem for the computer vision community, which we believe that these is helpful to understand this problem, its main challenges, pitfalls and the state of the art. The main contributions of this review are summarized as follows:

Jaward, M. et al. [25], in the proposed scheme, track initialization is embedded in the particle filter without relying on an external object detection scheme. The proposed scheme avoids the use of hybrid state estimation for the estimation of number of active objects and its associated state vectors as proposed in (Czyz et al., 2005). The number of active objects and track management are handled by means of probabilities of the number of active objects in a given frame. These probabilities are shown to be easily estimated by the Monte Carlo data association algorithm used in our algorithm. The proposed particle filter (PF) embeds a data association technique based on the joint probabilistic data association (JPDA) which handles the uncertainty of the measurement origin. The algorithm is able to cope with partial occlusions and to recover the tracks after temporary loss.

Li P. et al [26], Color-based particle filter for object tracking has been an active research topic in recent years. Despite great efforts of many researchers, there still remains to be solved the problem of contradiction between efficiency and robustness. The paper makes an attempt to partially solve this problem. Firstly, *the Integral Histogram Image* is introduced by which histogram of any rectangle region can be computed at negligible cost. However, straightforward application of the Integral Histogram Images causes the problem of "curse of dimensionality". In addition, traditional histogram is inefficient and inaccurate. Thus we propose to adaptively determine histogram bins based on K-Means clustering, which can represent color distribution of object more compactly and accurately with as a small number of bins. Thanks to the Integral Histogram Images and the clustering based color histogram, we finally achieve a fast and robust particle filter algorithm for object tracking. Experiments show that the performance of the algorithm is encouraging.

Beiji Zou et al. [27], This paper presents an object tracking method in diving video sequences by particle filter with multiple motion models. In this method, video paragraphing based on Hough transform technique and the knowledge of critical frame is proposed to divide a whole diving video sequences into several sub-sequences and construct a particle motion model for each sub-sequences. The particles are predicted by multiple motion models to adjust an athlete motions in diving video sequences. The experimental results have demonstrated the efficiency of the object tracking method.

Md. Zahidul Islam et al. [28] presented a paper on particle filter based algorithm, in this paper, an approach to improve the video based object tracking system with particle filter using shape similarity. It deals with single object tracking whose dynamics age highly non-linear. The shape similarity between a template and estimated regions in the video sequences can be measured by their normalized cross-correlation of distance transformation.

J. Kim. et al. [29], In this paper, an adaptive Rao-Blackwellized particle filtering method with Gaussian mixture models has been proposed to cope with significant variations of the target appearance during object tracking. By modeling target appearance as Gaussian mixture models, they introduce an efficient method for computing particle weights. To achieve robustness to outliers caused by tracking error or partial occlusion in updating the appearance models, divide the target area into sub-regions and estimate the appearance models independently for each of those sub-regions.

Particle filter based algorithm is a powerful tool in solving visual tracking problems but, the sample impoverishment problem which is brought by the procedure of re-sampling is a main obstacle of the particle filter. For solve this problem, M.-L. Gao et al. [30] proposed an improved particle filter based on firefly algorithm. In this paper, the particles in the particle filter are optimized using firefly algorithm before re-sampling. Thus, the number of meaningful particles can be increased, and the particles can approximate the true state of the target more accurately.

How to track an object using Particle filter based approach the true target state with computation cost as low as possible has always been an important issue. Z. Fan et al. [31] presented a paper with computation cost. In this paper a novel iterative PF (IPF) is proposed, which can converge to the true target state as close as possible by sampling the particles iteratively with the search scope contracted. The search scope is iteratively contracted around the centers determined by the previous converging results.

Sanjay S. Sakharkar et al. [32], represent object detection and tracking using Particle filtering. In this method, the frame differencing and particle filter mechanism is used to track the object in a color video. Particle filter uses a color particle that is displayed on the object. To track the object using particle filter we concentrated on the color particles in the detected foreground object.

Hamd Ait Abdelali et al. [33] In this paper, we present a new method for object tracking. We use an efficient local search scheme based on the probability product kernel using particle filter (PPKPF) to find the image region with a histogram most similar to the histogram of the tracked target.

W. Li. At el. [34], presents a paper. This paper presents a top–down visual attention computational model based on frequency analysis and integrates it into particle filter to solve many challenging problems such as abrupt motion and longtime occlusion. In this method, an image sequence given as input and target-related salient regions are detected. Then the target is tracked by the proposed local and global search processes in which the salient regions are incorporated into particle filter.

The computation cost is always the big problem for particle filter because the number of samples and iterations until convergence. Pirayawaraporn, A. et al. [35] present a paper on Object Tracking. In this paper, back projection-based sampling method applied the concept of corresponding between 3D world space and 2D image plane. Size of search space is reduced by sampling the particles in 2D image plane then will be back projected to 3D world space. This paper applied object detection algorithm as saliency segmentation using RGB-D information. It is used to obtain the object saliency before sampling the particles. The required number of samples is more decreased because the samples are not generated into the background boundary.

III. CONCLUSION

There are some difficulties arise of tracking multiple objects from a video scene, which is captured by multiple moving cameras such as out of field-of-view, different appearance among cameras, how to fuse information from cameras. When tracking multiple objects from a video scene in outdoor scene within 3D space, it is challenging task due to occlusion between objects. In order to deal with all these issues, a wide range of solutions have been proposed in the past decades. These solutions concentrate on different aspects of multiple object tracking systems, making it difficult for multiple object tracking researchers, especially newcomers, to gain a comprehensive understanding of this problem. Therefore, in this paper we provide the board literature survey on different moving object tracking methods has been introduced and this review highlights the features of algorithm for researchers in the area of moving object tracking.

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