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Multiple Objects Tracking in Video Sequences - Survey

Adinarayana Ekkurthi[1], Dr.G.Sudhavani[2]
Associate professor, Dept .of ECE, SMCE, Guntur, A.P[1].
Professor, Dept .of ECE, R.V.R &JC College of Engineering, Guntur, A.P[2].
adinarayanamtech@gmail.com[1], gsudhavani@gmail.com[2]

Abstract- Multiple object tracking is important in research area and in computer vision task. There are many virtual applications like video surveillance, traffic monitoring, robot navigation, security and object recognition. Multiple object tracking can be achieved by detecting objects in individual video frames and then linking across frames. There are several methods proposed for the multiple object tracking. In this paper, we discuss various multiple object tracking methods.

Keywords - Multiple object tracking, Observation model, Dynamic model.

1. INTRODUCTION

Videos are represented as scene, shot and frame. A video shot can be defined as the video frames that consist of continuous action. The frames in video shots are captured by a camera in single operation. The complete video sequence is formed by joining two or more video frames which is input to the video tracking. The main goal of multiple object tracking is the process of segmenting the features of an object from video frames and tracks its motion and shape. Object tracking requires location and shape of the objects in video frames. So, object detection and representation (classification) are the preceding steps of object tracking in computer vision applications [1]. The basic black diagram of object detection and tracking is shown in below figure 1.

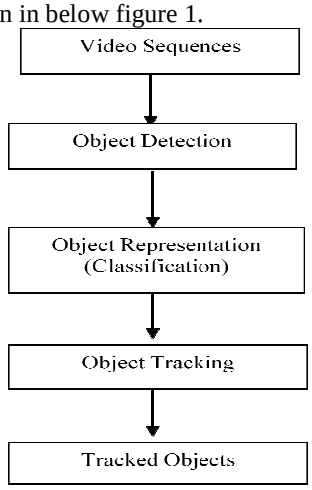

Fig: 1 Basic Block Diagram of Object Detection and Tracking.

The basic steps for tracking an object [2] are described below:

a) Object Detection: Object Detection is a process to identify objects of interest in the video sequence. Object detection can be done by various techniques such as temporal differencing, frame differencing, Optical flow and Background subtraction [3]**.**

b) Object Representation: Object Representation involves various methods such as Shape-based representation, Motion-based representation, colour-based representation and texture-based representation [4] where object can be represented as vehicles, birds and other moving objects.

c) Object Tracking: Tracking is the process of locating moving objects over a time in video sequences. Object tracking can be done by different methods such as [5] Point based tracking, Kernel tracking and Silhouette based tracking.

2. MULTIPLE OBJECT TRACKING

In general, Multiple Object Tracking (MOT) classification is difficult. Existing Visual tracking system has provided a MOT classification based on several factors. MOT mainly classified based on factors like initialization, way of data processing (or learning), mathematical methods and based on state estimation model [6] will be discussed in later sections.

2.1 *Based on initialization method*

Based on this method MOT classified into two sets those are Detection Based Tracking (DBT) and Detection Free Tracking (DFT).

Detection Based Tracking (DBT): In this, first of all, objects are localized in each frame. A specific type of object detection (background subtraction) [7] is applied to each frame to obtain object hypotheses. DBT made on a pre- trained object detector which produces object hypotheses and object hypotheses treated as observations. Hence object tracking is used to link detection hypotheses into trajectories. DBT is more popular than DFT [8] why because new objects are discovered and disappearing objects are terminated.
Detection Free Tracking (DFT): It processes observations sequentially. It does not require pre-trained object detector to provide object hypotheses. DFT require manual initialization of fixed number of objects. Those fixed objects localized sequentially [9] (i.e. in subsequent frames).

2.2 *Based on data processing*

Based on processing the data, MOT can be grouped into online tracking and offline tracking.
Online tracking: It uses observations up to the current time instant for estimation process. It is a sequential process that why it is also called as sequential tracking. It gives appropriate results when video stream is obtained sequentially. So, this approach is used in practise.
Offline tracking: It contains both past and future observations for estimation. Observations of all frames are required in advance to estimate the final output. It cannot handle the all frames at a time due its complexity [10]. So, it cannot be used in practise.

2.3 *Based on state estimation model*

Generally, MOT can be formulated as a multi-variable estimation problem. Dynamic and Observation models are used to estimate the states of objects.

2.3.1 *Dynamic model*

This model specifies the states transition across frames. This model again classified into probabilistic optimization and [11] deterministic optimization. This model is also called as mathematical model.

2.3.1.1 *Probabilistic approach*

This approach represents object states such as position, velocity (motion) and size with probabilistic distribution. The main aim of probabilistic approach is to estimate the probability distribution of objects status by using existing observations. Then objects states estimated with this probabilistic distribution. Different types of probabilistic distribution methods are used in MOT [12], such as Kalman filter, particle filter and multiple hypothesis filters.

Kalman filter: It is a set of mathematical equations that provides an efficient recursive state estimation process [12]. It calculates estimations of past, present and also future States. It has feedback control to update the states. Kalman filter algorithm involves two steps, prediction and correction (update step).

The first step uses previous state to predict the current state. The second step uses the current measurements like location of objects to update the state. Kalman filter provides optimal solutions when assumptions of state variable are normally distributed (Gaussian).

Particle filter: Particle filter generates all the models like initial state, noise covariance, number of particles etc for one variable before moving to the next variable. This algorithm uses contours, color features and texture mapping [13]. The drawback of Kalman filter is overwhelmed by using particle filtering.

Multiple hypothesis filters: It is widely used method for solving data association problem in MOT. It is an iterative algorithm. Several frames have been observed for better tracking. Iterations begin with a set of existing track hypothesis. For each hypothesis, a prediction of object's position in the succeeding frame is made. The predictions are compared by calculating a distance measure [14]. It gives optimal solutions in MOT and handles occlusions.

2.3.1.2 *Deterministic approach*

In this approach, first observations from each frame in the image sequence are obtained. Final estimation of tracking results is obtained by defining the similarities among observations. Various kinds of deterministic optimization have been applied to MOT such as [15] Bipartite graph matching, Dynamic programming, Min- cost Max-flow Network flow, Conditional random field and Maximum weight independent set.

2.3.2 *Observation model*

It measures similarities between object States and observations. It includes appearance model, motion model, interaction model, exclusion model and occlusion models [16].

3 COMPARATIVE STUDY OF MULTIPLE OBJECT TRACKING METHODS

According to survey [7] Table 1 describes comparative study between DBT and DFT.

S.No	Parameter	DBT	DFT
1	Initialization	Automatic and Imperfect	Manual and perfect
2	Number of objects	Variable	Number of objects must be fixed here.
3	Applications	In most of the cases, it is used for a particular type of objects only	It used for any type objects
4	Advantages	It has the ability to handle the varying number of objects.	No need of object detectors
5	Disadvantages	Performance of this approach depends on object detection methods	It requires manual initialization

Table 2 describes comparative study between Online and Offline Tracking.

S.No	Parameter	Online tracking	Offline tracking
1	Number of inputs required	Up to time observations	All observations
2	Procedures (methodology)	Existing trajectories and current observations	It link observations into trajectories
3	Advantages	It is used in online tasks	It provides theoretical optimal solution
4	Disadvantages	It suffer from shortage of observation	Delay exists in producing final outputs.

Table 3 [16, 17, 18] describes Comparative study of various kinds of Probabilistic Approach.

Probabilistic Tracking	Time Complexity	Accuracy	Advantages	Disadvantages
Kalman Filter	medium	moderate	It provides optimal solution. it is used to track points in noisy images	it gives poor performance when objects assumptions not normally distributed (Gaussian)
Particle Filter	high	high	in complex background and occlusion, it gives good results	due to its complexity, it is not used in real time applications
Multiple Hypothesis Filter	low	low	it has the capability to deal with new object entries and exit existing object	in both time and memory, it is computationally exponential

4 CONCLUSION

This paper presents a review of multiple object tracking. The proposed multiple object tracking methods have been explained and compared. Among all those methods, probabilistic approaches are generally used for multiple object tracking. Especially Kalman filter is widely used due to its

accuracy and optimal solutions of objects tracking. Advantages and disadvantages of each technique also described in this paper.

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