Multiple Camera Based Multiple Object Tracking Under Occlusion: A Survey

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Abstract— **In recent years, vision based technologies have gained immense attention across academia-industries to enable optimal surveillance solution for event monitoring, analysis and control. However, the complexities of real time environment and expected functional characteristics often put question over existing approaches and their efficacy. In this paper, a number of the existing approaches for vision based object detection and tracking have been discussed. One of the important issues which come across in the object tracking is Occlusion. However, a very few efforts have been done to alleviate occlusion issues so as to enable optimal moving object detection and tracking. This review paper reveals that to enable efficient multiple object detection and tracking under occlusion conditions, the combination of different features such as depth data, geometry, textural, color feature metrics, speed, etc can be taken into consideration. With multiple synchronized cameras set up, 3D techniques including depth estimation, azimuth, texture, color, geometric information and speed etc, in conjunction with optimal trajectory estimation model can be vital for multiple objects tracking under occlusions. In addition, efficient region of interest (ROI) feature extraction, trajectory estimation and feature fusion across synchronized cameras can be explored to track multiple objects under occlusions. Synchronizing multiple cameras with best feature training, association, continuous object skeletal tracking using stochastic trajectory prediction and classification; can be an effective solution, especially for traffic surveillance or outdoor surveillance applications.**

Keywords— Video Surveillance; Multiple Objects detection; multiple camera; Occlusion.

I. INTRODUCTION

Among high pace rising technologies and associated application arena, visual surveillance has emerged as one of the most sought and interesting research area to serve a major socio-industrial and defense requirements. The demand of computer based vision technologies has been increasing exponentially due to its efficiency, robustness and significance in numerous applications such as public surveillance, security, military purposes, and intelligent transport system etc. Most of the surveillance systems are installed to perform continuous monitoring at the specific locations including public places, border areas, banks, traffic, railway stations, airport, naval cost, highways etc. The huge data quantity involved in this process makes overall system complicate and infeasible to certain extent to ensure optimal vigilant monitoring by traditional approaches like human operators. To enable an optimal solution for assisting human operators for identifying certain significant event or tracking certain entity an "intelligent" visual surveillance mechanism is inevitable. In practice, intelligent surveillance approaches needs swift and robust mechanism to detect moving objects and to continuously track them. The system demands even more robust method for detecting and tracking multiple moving objects. Enabling an approach to deal with various intricacies present in single object detection and tracking, like varying appearances, dynamic background and illumination, non-rigid motion, occlusion scenarios, etc can be vital to achieve aforementioned demands. Considering the significance of vision technologies and visual surveillance, in recent years a number of researches have been done. Efforts have been made to enhance background subtraction, tracking moving objects, dealing with occlusion issues and predictive measure based moving object trajectory characterization etc. However, considering further enhancement feasibility, this manuscript intends to examine major significant efforts done so far and future scope to develop certain more effective and robust solution for multiple moving object tracking under occlusion scenario.

A. Challenges in object tracking

In fact, the predominant intricacy in moving object tracking is the dynamicity in target shapes because of the varying lighting condition different camera view and its position etc. Some other intricacies in object tracking are occlusion and blurred motion. A few efforts have been made to deal with the key issues of rapid appearance dynamism, transient and temporary exclusion from the view and drifting, etc. The effectiveness of the tracking systems might be severely influenced because of occlusion scenarios that usually take place when an object becomes invisible from the camera viewpoints to continue tracking. Some of the key reasons of occlusion are the inter-object occlusion among multiple objects and it is introduced by the background features. In some cases, occlusion takes place when a section of the moving object gets occluded due to other. This occlusion scenario is stated as self-occlusion. In general, self-occlusion is the most frequent condition that comes into existence while tracking certain articulated objects. On the other hand, inter-object occlusion takes place when two moving objects occlude each other. On the contrary, occlusion due to background dynamicity comes into existence when certain structure in the background temporarily occludes the object under tracking.

Before discussing major occlusion alleviating strategies proposed so far, discussing occlusion issues and its severity is of paramount significance. The following section briefs occlusion severity in object tracking.

B. Severity of Occlusion

There have been varied types of occlusion conditions, especially in the condition of object tracking in certain Adhoc paradigm. An effective approach to classify occlusion is to categorize it on the basis of the severity of the occlusion. Usually, this is classified into four broad categories. These are: Non-occlusion, Partial occlusion, Full occlusion, and long term full occlusion. In case of multiple-camera system, the time-gap in between leaving the camera-view region and moving to the other camera or even switch to the preceding camera is also stated as occlusion. In case of non-occlusion, here, the tracked object looks like a single blob having entire significant tracking information revealed to the sensor to perform tracking. Similarly, partial occlusion takes place in those situations when certain associated significant features of the tracked object get hidden or out of camera- vision when performing tracking. It might take place when a section of the tracked object gets blocked by other or analogous background feature or during self-occlusion condition. In practice, it is highly intricate task to detect partially occluded object by certain foreground structure. This is because, differentiating those objects having dynamicity in shape and occlusion phases turns out to be highly intricate. Traditionally, occlusion scenarios are dealt with template matching, however this approach doesn't consider object's evolution over a time period, and therefore fails. Generally, full occlusion takes place when certain tracked object gets invisible completely while being in knowledge that the object is still in the vision area of the camera. In case of full occlusion, the approach depending on only the object appearance can't perform continuous tracking. This is because there can be insufficient appearance-clue available during occlusion. In order to alleviate the full occlusion scenarios, a number of tracking approaches have been proposed using object spatial motion model. However, a dynamic model can have a better provision to re-initialize the tracker once observing partial or full occlusions. In addition, it can significantly reduce the search space of the dynamic states. This paper intends to explore and assess various techniques developed so far in multiple object detection using multiple cameras under occlusion conditions along with its limitations and strengths.

II. LITERATURE SURVEY

Some key literatures discussing multiple object tracking using multiple cameras set up are assessed as follows:
To enable robust object recognition and tracking under occlusion scenario, Yang et al. [1] proposed distributed object identification model using multiple camera. Considering confined resource (bandwidth) between the observer computer and cameras, authors extracted SIFT features from individual cameras viewpoints and then compressed it. Authors [1] stated that the high-dimensional SIFT histograms share a joint sparse pattern, which is similar to a set of common features in three dimensional structures. The joint sparse pattern can be used to encode the distributed signal through arbitrary projection method. Similarly, at the observer computer they applied decoding to extract the multiple-view object features. To perform this, they [1] used the distributed compressive sensing theory. To enable low cost solution for reliable object tracking under dynamic appearance conditions, Exner et al. [2] employed accumulated multiple histograms to form a sophisticated object appearance model and unremitting object movement monitoring to deal with partial or full occlusion. Cai et al. [3] applied multi-camera interaction mechanism to perform multi-object tracking; where unlike generic image matching key image features were used to track moving body from one camera to other. Jiang et al. [4] proposed a two-phase based object tracking and detection scheme using multiple cameras. To deal with adversaries like occlusion, missing detection etc; authors formulated data association into a maximum a posteriori (MAP) problem and exhibited that MAP problem is similar to that for retrieving min-

cost trajectory in a two-phase directed acyclic graph. The first graph emphasizes on extracting a set of tracklets by means of the two dimensional appearance feature and three dimensional spatial distances. Further, the extracted tracklets are joined into combined tracks in the second graph employing spatial as well as temporal distances. Tseng et al. [5] applied multiple depth cameras to perform indoor surveillance to track human. At first they introduced image stitching based on the spatial relation of the multiple cameras, then performed background subtraction of the stitched top-view image so as to retrieve the foreground objects. They applied a cascaded approach including graph-based segmentation, head hemi ellipsoid model, and geodesic distance map to detect humans in the indoor cluttered environment. In addition, they designed a diffusion distance based shape feature to validate the tracking hypotheses within particle filter. Particle filtering approach was used in vandewiele et al. [6] for multiple pedestrian tracking using multiple cameras network. To enable consistent tracking under occlusion authors applied the best view selection and its merging. To estimate the severity of occlusion, they they introduced a matrix called visibility index. They derived a model with multiple autonomous instances of the particle filter for multiple objects tracking, where each filter tracks single targeted pedestrian movement while dealing with occlusion.

Kaenchan et al. [7] developed multiple skeletal tracking scheme using multiple Kinect cameras, where they obtained information about varied angles and positions that helps in tracking whole body. However, their approach needs multiple supporting functions to convert multiple camera views into single skeleton view. To alleviate the sensory errors and mismatch, they applied a transformation scheme; however positioning couldn't ensure optimal skeleton tracking. To deal with adversaries such as dynamic illumination, occlusions and dynamic scenes in industrial environment, Padeleris et al. [8] proposed multiple cameras based human tracking system, where they applied volumetric representation and colour features of the human body to extract tracking failures. In their work, they collected and updated the color appearance representation of the targets. Unlike traditional approaches, Zhang et al. [9] introduced the depth of interest (depth information) to identify targets for detection. To distinguish human from other objects, they applied cascaded detector model, where they employed intermediary features reuse concept for consecutive detection. Limprasert et al. [10] emphasized on ensuring continuous object tracking under overlapping and non-overlapping fields of view. At first, they labeled targets (i.e., moving human) using a parametric ellipsoid having a state vector, which encodes the human position, movement metrics (i.e., velocity) and geometric (i.e., height) features. Additionally, they encoded illumination condition and persistence to deal with short -period occlusion problem. To enhance overall computation, they incorporated a learning scheme that learns human subject movement features (using features such as blind spots, color, and texture surface of each ellipsoid) during scene.

An occlusion segmentation based approach was suggested by Ding et al. [11], where they estimated the probabilistic histogram of the individual object's motion vector or the optical flow analysis, which in conjunction with color and appearance information generated an updated pixel distance presentation. To perform occlusion segmentation, authors applied K-Means clustering algorithm. The continuous object tracking was performed using a particle filtering and a probabilistic appearance model that estimated the best particle for tracking. Babaei et al. [12] applied trajectory analysis using SVM clustering so as to enable anomaly detection in intelligent transport system. To deal with occlusion, they applied multiple camera viewpoints to form a uniform tracking configuration which they used to perform behavioral extraction. In addition they applied a hybrid approach using SIFT for vehicle detection and tracking in multi view environment.

Madrigal et al. [13] developed a multi-object tracking system that targets object in both video streams as well as in the reference ground frame. Authors suggested their approach to alleviate ambiguities introduced due to occlusions. To enable multiple objects tracking they developed a collaborative approach using data association based on the principal axis and a partially interfaced probabilistic approach with Monte Carlo sampling. This approach ensured that the tracked targets remain distinct and distinguishable even during multiple targets simultaneous appearance. To identify and track players in sports, Yamamoto et al. [14] suggested tracklets based tracking to enable individual player identification and tracking. To deal with iterative occlusion, level set method was used to detect human region, and then the detected region was checked where it is occluded o not. A similar approach was suggested by Byeon et al. [15] where authors focused on finding the matches of head detections from multiple cameras. Authors suggested that matching of the detected region in multiple cameras and providing the same label to the detection results can play vital role for tracking an individual even under severe occlusion conditions. In their work [15], they introduced two similarity estimation approaches for target (here, head) matching on the basis of homography and epipolar similarity, which are the key geometric features. Mehta et al. [16] used depth camera based multi-object detection and tracking system. Considering the fact that typical depth maps are usually noisy and obscure, they formulated a region-based approach to suppress higher noise component which can't be filtered using certain spatial filters. In addition, they incorporated temporal learning based ROI detection which was then followed by weighted graph based tracking. Authors stated that the proposed system can be effective to deal with occlusion scenario. Stillman et al. [17] used the static and the Pan-Tilt-Zoom (PTZ) cameras to perform multiple object tracking. At first, they used the static cameras to localize human in the scene, while the other camera (PTZ cameras) performs "lock-on" to the distinct one. It enables consistent human tracking between PTZ cameras that operates reliably even during occlusion. However, this approach depends on multiple constraints such as color segmentation, effectiveness of the movement tracking and geometrical information to locate targets. They used color indexing approach so as to register identified targets with the PTZ cameras. Sekii [18] used multiple calibrated cameras based multiple moving objects tracking system. To track the objects with similar appearances, unlike appearance features they applied 3D geometric information. They used the mixture models along with the semi parametric component distributions representing the 3D target shapes to enable precise object tracking. To alleviate any possible confusion, they applied closed-world assumption to perform automatic detection and tracking. Xiang et al. [19] developed a multiple object detection scheme and occlusion reasoning between the targets. To deal with occlusion, they introduced "3D aspectlets" concept on the basis of a piecewise planar object representation. Here, a 3D aspectlet signifies a section of the object that facilitates substantiation for fractional surveillance of the moving object. In addition, they proposed a probabilistic approach to join the bottom-up evidence from 3D aspectlets and the top-down occlusion reasoning that played vital role in object detection. Yao et al. [20] performed 3D objects tracking in a multi-camera networked environment under partial occlusion condition. They incorporated a joint multi-object state space formulation where the individual object was represented in the 3D world. Features such as multi-object dynamics, color and foreground estimation estimations etc were used to perform tracking. Authors [20] used the Reversible-Jump Markov Chain Monte Carlo (RJ-MCMC) model to enable optimal object tracking.

Han et al. [21] developed a weighted Kanade-Lucas-Tomasi (KLT) based global feature tracking scheme to perform object tracking under occlusion. In practical condition, where some of the key features could get vanished after multiple frames, it becomes highly intricate to track the features to deal with such issues. To perform tracking they used a consistency weighted function. At the last of their implementation model, authors identified the object's trajectory. Applying the optimal weight function, they identified moving object's trajectories with higher accuracy that plays vital role in dealing with partial occlusions. Shantaiya et al. [22] made effort towards simultaneous multiple objects tracking using Kalman filter and improved optical flow analysis that plays vital role in alleviating occlusion problems. A similar effort was made by Jeong et al. [23] who developed multiple objects tracking algorithm using Kalman filter. However, their approach requires individual Kalman filters for each moving object. Ali et al. [24] used salient feature points to perform multiple objects tracking under partial occlusion conditions. Authors at first extracted the significant ROI feature points, which were then processed using a particle filter-based scheme to track the target features (also called feature-points). To perform tracking they used various factors such as object location, movement pattern, velocity and other key feature descriptors. Authors then perform target detection over updated feature points that have been tracked erroneously. Here, the prime hypothesis was that even if some features are not tracked effectively because of occlusion, the other precisely tracked features could perform the corrections itself. Ultimately, authors performed objects tracking by means of the acceptably tracked feature points using a Hough-type method. Chu et al. [25] derived an appearance model based object tracking scheme using multiple cameras, where they incorporated Kalman filter and multiple kernels based object tracking. To enable effective multiple object tracking using multiple cameras, authors [25] developed a Brightness Transfer Functions (BTFs) to balance the color difference between camera field of views. They constructed BTF from the overlapping region by using robust principal component analysis (RPCA) scheme. Authors [25] suggested that the differences due to multiple camera viewpoints can be balanced by means of the tangent transfer functions (TTFs) that can be easily retrieved by the homography between two distinct cameras. Feris et al. [26] developed focused on object detection and tracking using multiple video surveillance cameras. At first, they retrieved samples from the general-domain detector (GDD) which was at first trained using the images collected from multiple cameras. Unlike other labeling based approach, it [26] doesn't require manual labels from the object (say, target) domain. It collects training data by performing target tracking over a short duration from the high-confidence samples selected by GDD. To achieve this, authors proposed a novel confidence measure to assist target detection on the basis of a cascade of classifiers.

Yang et al. [27] proposed multiple objects tracking system for real time (dynamic) environment. One of the prime novelties of their approach was the ability to adapt with long duration and full-occlusion condition without demanding earlier knowledge about the target's trajectory.

III. DISCUSSION AND FUTURE SCOPES

This is the matter of fact that the development of any technology often intends to make human life comfortable, secure and efficient in either direct or indirect ways. Considering vision technology based surveillance systems, object detection and tracking has always been a dominating research area. Researchers have been making efforts to enable optimal tracking approach; however real time constraints such as multiple objects, resembling objects, geometrical dynamism, background or the environmental condition changes etc, often motivates towards developing more effective solution. This survey intended to study and analyze various existing approaches for vision based object detection and tracking. In this manuscript, a number of literatures presenting different approaches to perform object detection and tracking under dynamic real time environment have been discussed. Considering literatures and their respective contributions it can be easily found that single object detection is relatively a simple task than multiple object detection and tracking. The constraints such as colour, texture, geometrical similarity make the detection and tracking tedious task. And the occlusion condition makes the tracking process too difficult and intricate. Further, labeing based approaches for multiple objects tracking also introduces computational overhead at one end while pilling up ambiguity due to similarity features. In major existing approaches, identifying different objects and maintaining their labels throughout the scene is highly intricate task. In practice it becomes even more complicate during intersection of the objects having similar or near-similar features. To deal with this some researchers have suggested for individual tracker for each object. In generic view, this approach seems good alternative; however, there exists numerous conditions where maintaining individual tracker for each object is complicate and even infeasible. Kernel functions and particle filter based detection and tracking schemes have been applied in major works; however the effective ones have applied individual kernel and individual particle filter for each object to alleviate occlusions. Some predictive approaches, particularly based on Bayesian state estimation and Hidden Markov Model (HMM) have been suggested to predict object movement trajectory. Trajectory prediction can be no doubt an effective measure for reliable tracking, however requires optimal computations to alleviate ambiguities that usually might occur in traffic scenario, pedestrian behavior, crowd etc. In these cases, maintaining distinguishing features, similarity features analysis based distinct object identification and optimal trajectory estimation can be vital. Dividing detected object region (say, region of interest (ROI)) into patches and then matching it at different scene has also been suggested by authors, however its computational overhead, time consumption and efficiency yet to be validated. Homography approach has also been applauded by numerous researchers for multiple object localization and tracking, especially during intersection.

In comparison to the single camera based approach, multiple camera based tracking schemes can be more effective. However, synchronizing all networked cameras and feature combination is must. The development of three dimensional (3D) projection of an object using multiple cameras is no doubt a better approach; however computational overheads incurred can’t be ignored. To deal with this parallel computing can be explored further. Depth data, including geometrical, textural, and color feature metrics can be vital. In case of missing data, Kalman filter has been suggested by major researchers, however its implementation with other features and classifier can make better solution. Object detection being the foundation for tracking requires optimal detection solution. In 3D approaches, precise depth estimation, azimuth calibration, texture, color, geometric information and speed as combined feature can lead precise detection and hence tracking using certain feature mixture model and classification technique. In future, effective ROI feature extraction, trajectory estimation and effective feature fusion (to form a single object skeletal for tracking) across synchronized cameras network can be explored to enable optimal multiple object tracking under occlusion conditions. Stochastic trajectory prediction and feature based classification can be the better alternative to enable optimal object tracking under occlusion conditions. Synchronizing multiple cameras with best feature association and maintaining continuous object skeletal tracking using effective trajectory estimation can be of paramount significance, especially for traffic surveillance or outdoor surveillance applications, where multiple cameras is needed to retrieve multiple views.

IV. CONCLUSION

In this manuscript different approach dealing with double camera based object detection and tracking have been studied and examined for respective strengths as well as weaknesses. In addition, literatures presenting single object tracking and multiple object tracking are discussed in this manuscript. Observing overall literatures and their respective inferences, it has been found that single camera based set up are inefficient to deal with multiple moving object tracking under occlusions. Multiple objects tracking under long term occlusion or even full occlusion condition is highly tedious task and gives ambiguous outcome. Existing approaches to deal with this scenario, either focuses on detection measures or the tracking. However, multiple camera based multiple object tracking can be of paramount significance. To deal with occlusion conditions, various features including depth data, geometry, textural, and color feature metrics can be used. To strengthen overall tracking solution, object detection approaches requires enhancement. With multiple camera set up, 3D approaches including depth estimation, azimuth calibration, texture, color, geometric information and speed as combined feature can lead precise detection and hence tracking. In future, effective ROI feature extraction, trajectory estimation and feature fusion across synchronized cameras can be explored to track multiple objects under occlusions. No doubt, feature training of the ROI, stochastic trajectory prediction and features based classification can be a better alternative. Synchronizing multiple cameras with best feature association and maintaining continuous object skeletal tracking using effective trajectory estimation model can be effective alternative, especially for traffic surveillance or outdoor surveillance applications, where multiple cameras can be used to retrieve multiple views.

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