Computers and Electrical Engineering 000 (2017) 1–12

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

Multi-technique object tracking approach- A reinforcement paradigm☆

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ARTICLE INFO

Article history:
Received 14 September 2016
Revised 31 January 2017
Accepted 1 February 2017
Available online xxx

Keywords:
Object tracking
Surveillance
CamShift
Unscented particle filter
Corrected background weighted histogram

ABSTRACT

In recent years, surveillance is fast becoming an essential part of everyday life in both commercial and residential environments due to the vital role it plays in the society. The existing tracking methods are limited by factors such as illumination variations, occlusions, camera movements, and background clutters among others. Hence, a robust multi-technique tracking method based on *continuous adaptive mean shift* (CamShift), *corrected background weighted histogram*, and *unscented particle filter* techniques is proposed. The mean square error statistic was used to evaluate the performance of the proposed method in terms of correctly estimating the path of a target object in video sequence acquired from three different scenarios. The obtained results showed that our proposed method has a significant improvement both quantitatively and qualitatively across all scenarios compared to the traditional CamShift and some existing methods. The proposed multi-technique approach might potentially improve the tracking capability of surveillance devices.

1. Introduction

Surveillance, a task that involves monitoring of behavior, activities, or other changing information, usually of people and objects for the purpose of managing, directing, or protecting them is fast becoming an essential part of daily life activities. In recent years, the adoption of surveillance cameras are widely applied in places such as the banks, supermarkets, prisons, airports, parking lots, petrol stations, and other imaginable business environments [1,2]. These applications are majorly targeted towards security of lives and properties, and also for rescue operations, traffic monitoring, patient monitoring, and medical imaging [1,3]. Due to the rapid spread of these cameras, intense research efforts have been made towards improving the performances of existing object detection and tracking algorithms which are the backbone of such surveillance devices [4]. Among the developed state-of-the-heart detection and tracking methodologies are: detect-and-track [5,6], track-before-detect [10], and probability hypothesis density filter based multiple target tracking techniques [7,8]. Despite these numerous advances, detection and tracking of objects in video sequences are still challenging task due to illumination variations, occlu-

☆ Reviews processed and recommended for publication to the Editor-in-Chief by Guest Editor Dr. S. A. Aljawarneh.

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http://dx.doi.org/10.1016/j.compeleceng.2017.02.002

sions [9], camera movements, structural deformation, background clutters, and real time restrictions among others. Although many approaches have been proposed to address some of these issues in a mutually exclusive manner, the joint problem is still far from being resolved [10]. Mean-shift tracking algorithm, a kernel-based method that is built on density- appearance models for tracking stationary or moving objects had been extensively applied to real time tracking of objects due to its simplicity and low computational cost [7]. This method basically track objects by finding the most similar distributed pattern in a sequence of frames by iterative searching [11]. However, its major setback is that it fails when the target object moves toward or away from the camera's focus [7,12]. To address this problem, the continues adaptive mean-shift (CamShift) which adaptively adjusts the tracking window's size and the distribution pattern of the target object during tracking was proposed [13]. Some key limitations of the CamShift tracking method are: firstly, it performs poorly when the target objects has other objects with similar color property at the background, and secondly, the CamShift algorithm equally performs poorly when the object to be tracked suddenly gets occluded by an obstacle. Based on these limitations, CamShift has undergone various levels of modifications by different researchers in an attempt to enhance its overall tracking performance [14]. Also, Benezeth et al. proposed a method that could detect human presence in an indoor environment by combining a background-subtraction algorithm that integrates both tracking and recognition techniques [15]. Such background-subtraction algorithm in their method could potentially address the issue of poor tracking encountered with the CamShift method when the target object has similar color property with its background [16].

For instance, in a combination of CamShift and Kalman filter, the possible positions of the target object were predicted by using Kalman filter while the CamShift was used to search and match the target object in the predicted areas [14]. In another study, Kalman filtering technique was adopted to track an object of interest whenever CamShift fails to correctly estimate the path of the targets object [16]. However, both variants could not provide good tracking results since they are limited by their Gaussian assumption nature. Particle filter, a path estimation technique that recursively predict the target object's posterior with discrete sample-weight pairs in a dynamic Bayesian framework, has been successfully applied to visual object tracking as a result of its non-Gaussian, non-linear assumption, and multiple hypothesis property [17]. Earlier study reported that a combination of particle filter and CamShift led to improved performance for on-line tracking however inefficient sampling and huge computational complexity were the key limitations observed [18]. This limitation could be attributed to the fact that particle filter uses transition prior as the proposal distribution and does not take into account current observation data thereby leading to the wasting of many particles in the low likelihood area [16]. To overcome this problem, unscented particle filter (UPF) technique has recently been proposed in the field of filtering theory [19]. Considering the individual unique strength of CamShift, UPF, and corrected background weighted histogram (CBWH) techniques in the tracking of a target object, the current study is motivated by the need to develop a robust and reliable object tracking methodology by exploiting the strength of the traditional CamShift, CBWH, and UPF techniques.

In this study, a robust object tracking system was built by integrating CBWH and UPF techniques into the CamShift algorithm. The CBWH method plays an important role when the object to be tracked has similar color property with its background or background objects while the UPF technique is employed to address the problem of occlusion when CamShift suddenly lost track of the target object during the tracking process. In addition, the integration of the following three techniques CamShift, CBWH, and UPF for detecting and tracking objects in video sequences has not been proposed to the best of our knowledge.

The rest of this paper is organized as follows; Section 2 presents the framework of the proposed multi-technique tracking system as well as the principle of operation of CamShift, CBWH, and UPF techniques. Section 3 presents the different experiments conducted and their respective results. In addition, Section 3 shows the performance of our proposed method when compared with the conventional CamShift algorithm and some existing methods. Meanwhile, Section 4 presents the conclusion of the study and possible future direction.

2. Materials and methods

The framework of the proposed multi-technique object detection and tracking system is presented in Fig. 1 as follows. Firstly, a sequence of video frames is passed into the *color conversion module* which decomposes the color of the target object in the frames. Next, if the target object has similar color property with its background or background object, the CBWH *module* which helps to recover the target object from its background disturbance is called otherwise, the CamShift module is called. In addition, in situations where the target object's path is occluded by an obstacle, the output of the CamShift module is passed on to *the* UPF *module* in order to correctly estimate the path of the target object.

2.1. The CamShift tracking algorithm

The Continuously adaptive mean shift (CamShift) is an object tracking algorithm which incorporate the Mean-Shift algorithm in a loop by varying the size of the window until convergence is attained [19]. The location and size of the search window is initialized to include the area that contains the target object in a video sequence, and then the hue value for each pixel within the search window is sampled to generate the probability density function which is stored as the histogram model of the target object [20]. In the next stage of the tracking, the probability distribution map is estimated by scanning through each pixel of the captured scene. Lastly, the probability of that pixel belonging to the target object is computed. These steps are expressed mathematically as follows: The initial position of the search window is stashed based on a (x, y)