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A novel algebraic method for kernel-based object tracking ☆

F. Khakpour *, G. Ardeshir

Faculty of Electrical & Computer Engineering, Babol Noushirvani University of Technology, Babol, Iran

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ABSTRACT

In the present paper, a new tracking method based on kernel tracking is proposed. The proposed method employs a novel algebraic algorithm to get the kernel movement. In contrast to the mean-shift method which uses a weighted kernel to reduce the effect of the background, the algebraic algorithm of the proposed method allows dividing the candidate area into two parts in order to identify the object and background regions. To detect the object and background regions, we propose measuring the similarity of weighted histogram for each part. The experiments show the superiority of the proposed method for the removal of the background. The effect of noise and background clutter is reduced by segmentation of the object which produces the narrow histogram. In conclusion, the ability of the proposed method for tracking in crowded and cluttered scenes is demonstrated.

1. Introduction

Due to the simplicity and efficiency of mean-shift tracking, it is a common method for kernel object tracking. In the original mean-shift tracking, a symmetric weighted histogram kernel and a geometric shape are used for modeling the target [1]. The motion of the kernel from one video frame to the next is computed by iteratively estimating the color centeriod for reach to the best similarity between the candidate and the target models. Including the spatial information, predictive component, radial basis function network and multiple reference histograms to the mean-shift tracking are proposed for better performance [2–6]. Many efforts are made to solve the original mean-shift drawbacks related to its scale and orientation changes, symmetric kernel and isotropic shape. Because of change in object size, the fixed scale model is not appropriate for tracking. Using three different kernel bandwidths (scales) for algorithm and selecting the one which maximizes the appearance similarity is proposed by Comaniciu [7]. This method, named as ±10% method, is computationally expensive due to the brute-force nature. Using difference of Gaussian mean-shift kernel in scale to include scale as additional dimension has been proposed in [8]. This method performs well; but, it needs convolving the image with a set of Gaussian filters at various scales which is a computationally complex task. Using asymmetric kernel and considering the scale and orientation as additional dimensions to the spatial image in which the tracking algorithm is solved simultaneously in all coordinates can be seen in recent works [9–12]. Paying attention to the moment features of the weight image of the target candidate region and the bhattachryya coefficients and also using the principal components of the variance matrix of the spatial-color distribution are proposed to solve the scale and orientation problems [13,14]. Another limitation is related to the geometric region and its asymmetric kernel. In cases where the object does not have an isotropic shape, the symmetric kernel which is isotropic in shape cannot describe the object properly, and it can be contain the considerable background information. Using

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* Corresponding author. Tel.: +98 9111253177.
E-mail addresses: f.khakpoor@stu.nit.ac.ir, f.khakpour@nioc.ir (F. Khakpour), g.ardeshir@nit.ac.ir (G. Ardeshir).

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a Shape-adapted asymmetric kernel constructed based on the mask of the detected object can improve the tracking result [15–17]. Despite various efforts to improve the mean-shift algorithm, there is an intrinsic problem in all mean-shift methods. The problem is related to the iterative process of mean-shift tracker for finding the best similarity between the candidate and the target model. In the first iteration, the candidate and model regions are considerably inconsistent. Thus, the influence of background information can be significant, especially in objects which are undergoing rapid motions or are spatially adjacent objects. Of course, this is the problem of every tracker which finds the target by searching for the best match such as contour [18–21] and template tracking [22,23].

In this paper, we propose a new method for tracking the target area in which the displacement of the kernel is obtained using the previous object region as a starting point in the current frame. In contrast with the mean-shift tracking which finds the kernel location using an iterative technique to achieve the best histogram matching, the proposed method offers algebraic equations for the kernel displacement. Expressing the displacement kernel using algebraic equations is much more effective than the mean-shift way to remove the background. In order to eliminate the effect of background, we have defined two types of disconnected and connected background. Defining disconnected background allows the algorithm to consider the object and background areas as individual objects. We acquire the corresponding target area for each of these objects using tracking equations. The object and the background can be identified with the weighted histogram, which is defined as a metric to measure the similarity. The background which is connected to the object can be eliminated using the segmentation of object and also modified histogram. The experiments results depict the validity of the proposed tracking equations and its advantages over the mean-shift method to remove the effect of the background.

The paper is organized as follows. In Section 2, the target model is presented. Section 3 describes the proposed method for calculating the displacement of kernel and removing the background effect. Experimental results and conclusion are given in Sections 4 and 5.

2. Target model

We define the target model based on the binary mask in the first frame and also histogram and window that are associated with the mask region. If (x_k, y_k) denotes the kth pixel position in R^2 (image) space, the binary mask object locations with n pixels (which obtained from previous object) can be defined as:

$$\mathrm{Bin\_mask} = \{x_i, y_i\}, \quad i = 1, 2, \ldots, n \tag{1}$$

The color histogram feature of the target model for binary mask with color u ($u = 1, \ldots, m$) is considered as:

$$q_u = \sum_{i=1}^{n_1} \delta[F(X_i) - u], \quad u = 1, 2, \ldots, m \tag{2}$$

where δ is the kroneker delta function and F is a function in which $F(X_i)$ denote the bin corresponding to the pixel at location X_i. In addition, the vertices of window of target model for binary mask object of Eq. (1) are:

$$\begin{cases} r_{\min} = \arg\min\{x_i\}, & r_{\max} = \arg\max\{x_i\} \\ c_{\min} = \arg\min\{y_i\}, & c_{\max} = \arg\max\{y_i\} \end{cases}, \quad i = 1, 2, \ldots, n \tag{3}$$

3. Proposed method

The proposed method uses a novel idea which relates the displacement of object to the previous object center and the center of the target region which lies in the previous object region. The relation is in the algebraic form which can be used to remove effectively the background information. We describe this process in detail in the following subsections, which is organized as follows. Section 3.1 describes how to obtain the object pixels of the current frame which are in the previous area. The tracking relations for the displacement of kernel in two consecutive frames are presented in Section 3.2. Removal of the background is described in Sections 3.3 and 3.4. The effect of changes in the scale and shape of the object is the subject of Section 3.5. The last part of the Section 3 presents tracking procedure for the proposed algorithm.

3.1. Extracting the target pixels of previous object region

The idea of the proposed tracking method is shown in Fig. 1. Fig. 1a shows the centers of the objects in the previous and current frames which are denoted by W1m and W2m, respectively. Fig. 1b demonstrates that the kernel location in the next frame can be achieved by moving the kernel center from W1m to W2m. As illustrated in Fig. 1a, we can get W2m if Po has been identified; Po is the distance vector between the centers of the objects in consecutive frames. To obtain Po, we propose a novel idea which is shown in Fig. 1c–e. Fig. 1c depicts that the proposed method uses the previous object region as the candidate model for the next frame. Then, as shown in Fig. 1d, the algorithm obtains the target pixels within this area. Since these pixels also belong to the previous region, we call this the common area. We state that the common area is a part of the previous object which has now been moved to the current frame. According to Fig. 1e, the displacement of the object can be achieved if the algorithm finds the center of a part of the previous frame which is corresponding to the common area.