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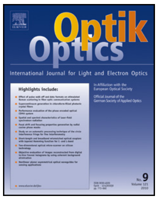

Mean shift tracker with Chaotic Artificial Bee Colony and Space Variant Resolution

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ABSTRACT

A novel mean shift algorithm is proposed for object tracking in this paper. The mean shift procedure with Chaotic Artificial Bee Colony (Chaotic ABC) and Space Variant Resolution (SVR) of human visual system is utilized for adaptation of the target acceleration and estimation of the target's scale and orientation changes. In order to test the effectiveness and robustness of our proposed method, two groups of experiments were carried out and the related results of the proposed mean shift tracker with Chaotic ABC and SVR (MS-Chaotic ABC&SVR) are compared with three other algorithms, which demonstrate that our proposed approach is most robust and effective in solving object tracking problems than the others.

1. Introduction

Object tracking is an important task within the field of computer vision, which can be defined as the process of estimating the trajectory of an object in sequential video frames [1]. To accurately track an object in video sequence, numerous tracking algorithms have been proposed by the researchers. Among them, mean shift (MS) is one of the most popular tracking algorithms as its simplicity and robustness, which was proposed by Fukunaga and Hostetler in 1975 [2] and gradually introduced into object tracking by Cheng [3], D. Comaniciu and P. Meer [4,5] and Collins [6].

In the MS procedure, the computation of the translation of the object patch in a small number of iterations without any parameter estimation, eliminate a brute force search. The assumption of this method is that the motion is small between two consecutive frames. Therefore, the MS tracker is often prone to local optimum when the object moves fast. In addition, MS cannot adaptively estimate the scale and orientation changes of the object in consecutive frames, which could lead to poor tracking performance.

In this paper, an algorithm for tracking fast motion objects, which combines mean shift, an improved hybrid optimizing algorithm called Chaotic Artificial Bee Colony (Chaotic ABC) and Space Variant Resolution (SVR) of human visual system is proposed to copy with those disadvantages. In the basic framework of MS, our improved algorithm is generalized in the following two ways. Firstly, so as to track fast motion objects, Chaotic ABC is first applied to adapt the target candidate with a better candidate in every frame. Secondly, SVR is introduced to predict the scale and rotation changes of the moving target in frames.

The remainder of this paper is organized as follows. Section 2 introduces the mean shift tracking method. Section 3 describes the principle of basic ABC algorithm, while Section 4 introduces SVR. Section 5 specifies our proposed MS tracker. Then, in Section 6, comparison experiments are conducted. Our conclusion is given in the final section.

2. Mean shift tracking method

The mean shift algorithm (MS), an iterative method, is a procedure for locating the maxima of a density function given discrete data sampled from that function [3]. The application of MS for object tracking takes the kernel color histogram's and Bhattacharyya coefficient as the tracking feature and the similarity function respectively. The kernel profile $k(x)$ with the bandwidth h is used in the kernel color histogram of the target model which was given by [7].

$$\hat{q}_u = C\sum_{i=1}^{n} k\left(\left\|\frac{x_0 - x_i^s}{h}\right\|^2\right)\delta[b(x_i^s) - u] \quad (u = 1, \ldots, m) \tag{1}$$

where $\{x_i^s\}_{i=1,2,\ldots,n}$ is the pixel locations of the target model, which centered at x_0 in the initial frame. $C = 1/\sum_{i=1}^{n} k(\left\|(x_0 - x_i^s)/h\right\|^2)$ is the normalization constant by imposing the condition $\sum_{i=1}^{m} \hat{q}_u = 1$,

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$\delta(x)$ is the Kronecker delta function with the index of the histogram bin u, and $b(x)$ is the histogram bin index function.

Similarly, the color histogram of the target candidate can be computed as

$$\hat{p}_u(y) = C_h \sum_{i=1}^{n_h} k\left(\left\|\frac{y-x_i}{h}\right\|^2\right)\delta[b(x_i)-u] \quad (u=1,\ldots,m) \tag{2}$$

where the pixel locations of the target candidate centered at y is denoted as $\{x_i\}_{i=1,2,\ldots,n}$, the normalization constant $C_h = 1/\sum_{i=1}^{n_h} k(\left\|(y-x_i)/h\right\|^2)$ is derived by imposing the condition $\sum_{i=1}^{m}\hat{p}_u(y) = 1$.

To measure the similarity between them, the similarity function based on Bhattacharyya coefficient is defined [8].

$$d(y) = \sqrt{1-\rho[\hat{p}(y),\hat{q}]} = \sqrt{1-\sum_{u=1}^{m}\sqrt{\hat{p}_u(y)\hat{q}_u}} \tag{3}$$

MS is used to find the peak of the distance value $d(y)$, which is referred to literature [4]. The smaller $d(y)$ is, the better performance the target candidate maintains.

3. The principle of the basic ABC

The ABC algorithm proposed by Karaboga [9] in 2005 is a bio-inspired optimization algorithm based on the intelligent foraging behavior of a honeybee swarm optimization. It has been successfully applied to many applications, such as path planning [10]. So as to lead to the emergence of collective intelligence of honey bee swarms, the minimal model of forage selection consists of three essential components (food sources, employed foragers and unemployed foragers), two leading modes of the behavior (recruitment to a nectar source and abandonment of a source), as well as three groups of bees (employed bees, onlookers and scouts for cooperation). In ABC algorithm for an optimization problem, the position of a food source represents a possible parameters solution to the problem and the nectar amount of the food source corresponds to the similarity value of the associated solution. The main steps of the ABC algorithm were described in Ref. [11].

In this paper, the ABC algorithm is first introduced into the mean shift tracker for looking for a better starting position to help MS jump from local optimum. The combination of a proposed ABC algorithm and the mean shift tracker will be described in detail in Section 5.

4. Space Variant Resolution

The human visual system is an excellent multi-scale image acquisition and processing system. The characteristic of human visual system called SVR was introduced by Schwartz [12] in the late 1980s. In the human visual system, the cortical mapping is performed by a space variant sampling strategy, which can be described as a transformation from the retinal plane (the retinal) to the cortical plane or the log-polar plane [13].

In the log-polar plane, taken the video object tracking as an example, the changes of the scale ($\Delta\xi$) and rotation ($\Delta\psi$) between the object area of the k-th frame and that of the $(k-1)$-th frame are denoted by $\Delta\xi^k$, $\Delta\psi^k$. They can also be transformed to the real scale and rotation changes of the object in the retinal plane by the log-polar coordinate inverse transform.

$$S_k = \frac{\rho_k}{\rho_{k-1}} = \frac{e^{\xi_k/M}}{e^{\xi_{k-1}/M}} = e^{\Delta\xi_k/M} \tag{4}$$

$$r_k = (\theta_k - \theta_{k-1}) = (\psi_k - \psi_{k-1}) = \Delta\psi_k \tag{5}$$

where S_k and r_k are the scale and rotation changes relative to the $(k-1)$-th frame; M is a positive real number and adjustable parameter on the basis of the dimensions (width, height) of the receptive field. (ρ_k, θ_k), $(\rho_{k-1}, \theta_{k-1})$ are any coordinates of the object area of the k-th frame and the $(k-1)$-th frame in the retinal plane, respectively. (ξ_k, ψ_k), (ξ_{k-1}, ψ_{k-1}) are their transformed coordinates of (ρ_k, θ_k), $(\rho_{k-1}, \theta_{k-1})$ in the log-polar plane, respectively.

5. Our proposed method for object tracking

MS has been widely applied to object tracking, due to its rapidity and robustness. By estimating the gradient from one frame to another, MS estimates the shift of the object between the adjacent frames under the assumption that the shift between two consecutive frames is small. However, if the object shift is relatively huge either because of fast moving object or low frame rate, the assumption may not hold. So MS is prone to fall into local optimum and easily fails to track the object. Another flaw is that the scale and orientation changes cannot be adaptively estimated by MS, especially when the object warps in frames. In order to overcome those disadvantages, firstly a proposed ABC algorithm which integrates ABC with chaos theory is introduced into the mean shift tracker for helping MS to adapt the target candidate with a better candidate. Secondly, SVR is introduced to estimate the scale and orientation changes to update the size and rotation of the tracking window. In this section, Chaotic ABC is firstly presented, and then the implementation procedure of our proposed mean shift tracker based on Chaotic ABC and SVR is described in details.

5.1. Chaotic ABC

Although ABC algorithm is a flexible, versatile and robust algorithm, there are some weak points in solving optimization problems, such as requiring a large number of iterations to reach the global optimal solution and the tendency to converge prematurely. Chaos theory, which was discovered by a meteorologist named Edward Lorenz [14] in 1960, can be introduced into the basic ABC to accelerate the process of looking for the optimal solution.

Chaos theory is sensitive to initial conditions. Small differences in initial conditions yield widely diverging outcomes for chaotic systems, rendering long-term prediction impossible in general. Besides it, chaotic systems have another two properties. One is that an infinite number of unstable periodic orbits embed in the underlying chaotic set. The other is that the dynamics in the chaos is ergodic which means that the system ergodically visits a small neighborhood of every point in each one of the unstable periodic orbits embedded in its temporal evolution. The basic idea of chaos theory can be understood by considering the following well-known one-dimensional logistic map, one of the best studied chaotic systems [15,16]:

$$x_{n+1} = 4x_n(1-x_n) \tag{6}$$

In this equation, n is the number of iteration of an algorithm; x_n is restricted to the unit interval [0,1] where 1 represents the maximum possible population and 0 represents extinction. When $x_n \neq 0.25, 0.5, 0.75$, it will eventually visit every neighborhood in a subinterval of [0,1] with the best periodicity.

In our Chaotic ABC algorithm, we conduct the chaotic search in the neighborhood of the current optimal parameters by listing a certain number of new generated parameters through chaotic process after each search round. In this way, we can make use of the ergodicity and irregularity of the chaotic variable to help the ABC algorithm jump from the local optimum for finding the optimal parameters, as well as to increase the speed of reaching the optimal solution.