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Fast and Optimal Visual Tracking based on Spectral Method

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Abstract

Visual object tracking is the process of continuously localizing visual object in a video sequence. We would like to investigate the problem of short-term model-free tracking which the main purpose is to track any object just based on an annotation box of object. Many factors affect the performance of the tracking algorithm. In the Visual Tracker Benchmark, there are eleven challenges in object tracking. There has not been a single tracker that successfully handles all of these scenarios. In addition, the tracker must be fast enough to be useful in real applications. We propose a new tracking algorithm within the Bayesian framework. The proposed algorithm is constructed by solving optimally particle filters (OPF) efficiently using spectral methods. Therefore, the constructed tracker is called as Spectral Tracker (ST). Although ST can efficiently compute object position, it cannot estimate the scale and rotation directly. To overcome this weakness, it is proposed to use multiple observation points simultaneously and to use information on the observation point movement to estimate scale and rotation. In the experiments, the performance of ST tracker was compared with 9 relevant trackers based on 100 data sets. The experimental results on on tracker performance show that increasing performance especially in tracker precision and success rate.

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Keywords: short-term model-free tracking, optimal particle filter, spectral method, bayesian framework

1. Introduction

Visual object tracking has many practical applications in automated surveillance system, robot vision system,

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intelligent traffic system and fault detection system. Visual tracking is the process of continuously localizing an object target in a video sequence. When the target is successfully tracked in each video frame gives more information about the identity and the activity of the object target. In general, tracking problem is easier than detection, tracking algorithms should be faster than running an object detector on every frame. Therefore, the key requirement for many tracking applications is ability to track an object target in video sequences in real-time.

Currently, many existing tracking algorithms have been introduced for certain tasks. However, many of them have weakness because of their main approaches that is (1) they make basic assumptions about object appearances [1] and the environment [2] (2) most visual tracking algorithms are computationally expensive [3]. In this paper, we would like to overcome these weakness by considering its fundamental approach. We focus to solve short-term model-free tracking problem [4]. The short-term tracking in here means the tracker does not perform re-detection after the object target is lost. Out of the target is considered as a failure. While model-free property means that the only example for supervised learning is provided by the bounding box in the first frame. In addition, the tracker output is indicated by a rotated bounding box.

First, we consider human visual perception in order to understand how visual information is represented and processed in the brain. It is clear that geometry of object and visual perception are closely related, but very little is known about their relation beyond the retinotopic association [5]. In visual perception studies, retinotopic refers to the visual process where object geometry are projected in the retina by similar process as appearance models in a digital image. However, a recent study on human vision shows that the representation in higher visual areas of the visual cortex occurs in a nonretinotopic way [5]. It means that visual perception creates dynamic layers for each moving object in the scene. This representation suggests that the object appearance and their position dynamics are marginal independent. Based on the inspiration from the above study, a tracking algorithm is proposed by imitating the nonretinotopic process in human visual processing. The suitable approach that can govern the relationships between the object appearance model and the object dynamic model is probabilistic Bayesian framework. The advantage of the Bayesian approach is able to maintain a history of probability estimation from the sequence of incoming visual perceptions. This means the Bayesian approach is able to integrate knowledge of the target object dynamics with visual observations of object appearance.

Second, we need to choose a numerical approach for implementing Bayesian framework. Particle filter is a practical tool to implement dynamic state estimation in Bayesian framework [6]. The basic idea is to approximate the posterior distribution of transition dynamics by using a finite set of weighted samples or particles, when given a sequence of observation measurements. Moreover, particle filter can overcome non-linear and non-Gaussian distribution in transition model and observation model. Particle filter is a sequential Monte-Carlo technique and can be proved to produce the correct posterior distribution from finite set of samples as the sample size toward infinity [7]. In practice, it is necessary first to design its important sampling. There is, of course, trade off between accuracy and computational load in the chosen design.

There are two main types of particle filters based on the design of its important sampling: bootstrap and optimal particle filter. The easiest particle filter to implement is a bootstrap particle filter (BPF). In BPF, the transition distribution is choosen as important density. BPF has the characteristic that the weights only depend on the likelihood observation distribution. For BPF, the sampling process is very easy by using the transition distribution to predict the new particle and then followed by the process of weight determination by using likelihood distribution. BPF has been used by many researchers in visual object tracking and often called as Condensation (Conditional Density Propagation) [8]. Note that in BPF algorithm, its important density does not take into account the latest measurements. So even if BPF is easy to implement, BPF has some weaknesses associated with robustness in the face of unexpected noise. This is mainly due to the fact that variance of the weights can not go down [9]. As a result, the degeneration phenomenon in BPF may appear. One way to overcome the degeneration phenomenon is by using resampling process.

However, to really overcome the degeneration phenomenon, the important density should be chosen more carefully. The optimal choice for important density is the distribution, which is able to minimize the variance of the weights and it is called as optimal particle filter (OPF). In short, OPF can be achieved by incorporating the new observations when generating the new particles. However, the OPF has two major difficulties [6] that is: (1) we should be able to generate