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Three-step-ahead prediction for object tracking

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Abstract

In this paper, a three-step-ahead prediction method is introduced using chaotic dynamics for state estimation in object tracking. The nonlinear movement of an object is embedded into a low-dimensional state space to utilize the short-term predictions of chaotic systems. The computational architecture of the method is structured as follows. A pseudo-orbit methodology is presented to embed the high dimensional observations of non-linear movement into the pseudo trajectory in the state space with chaotic characteristics. After the Grey theory is applied into the pseudo trajectory in order to reduce the dimension of trajectory, the fractal method is used for three state predictions of the object's movement. For state correction, ensemble members are used to select the best state based on the likelihood function of the color model of candidates. In order to evaluate the efficiency of the chaotic tracker, we compare the chaotic tracker against tracking by detection and stochastic methods. The numerical results demonstrate that the method predicts the target in full occlusions and abrupt motion with a high level of accuracy. Thus, the chaos-based method for making target prediction is vastly superior to existing trackers. The tracker can localize small targets in video sequences accurately. The proposed algorithm is about two times faster than the particle filter method while the error of the particle filter is more than the error of the proposed tracker. The limitations of the proposed method are also illustrated in clutter background and complex scene.

Keywords: Multi-step ahead prediction, fractal theory, Grey theory, pseudo-orbit, object tracking.

1. Introduction

Object tracking is an important topic in computer vision which is used in applications of the motion analysis and pattern recognition. The tracking methods are applicable in motion analysis, traffic monitoring, and video analysis. The tracking is a challenging task, because it is hard to estimate the target state with fast motion, low frame rate, and uncertain motion in image sequences. The tracking methods can be categorized into two groups; namely deterministic [1] and stochastic [2] methods. The mean shift algorithm is a kernel-based deterministic procedure which exploits a region to maximize a similarity measure of a template image and the current image [3]. The method is computationally efficient, but it is sensitive to background distraction and clutter [4]. The Kalman filter [5, 6] and particle filter [7, 8] estimate the next state based on Bayesian theory. The Kalman filter is developed for linear and a Gaussian observational noise [9] but it cannot be applied to nonlinear movement. The particle filter method can maintain the nonlinearity and uncertainty of the model evaluation and analysis step in visual tracking [10]. In the particle filter method, multimodal distribution may lead to a noisy estimation of the target position. The particle filter method is used for one step-ahead prediction. Many extended trackers have been proposed to improve the weaknesses of the particle filter. The main drawbacks of the particle filters are the limitations of dynamic model, the computational complexity, and one-step prediction. However, efficient and effective filtering based on deterministic dynamics of motion information can reduce the computations and prediction errors in multi-step-ahead prediction for tracking [11, 12]. Multi-step ahead prediction (MSP) method has been presented to handle the problems based on chaos theory [11]. The weaknesses of MSP are 2D object tracking (Ikeda map in chaotic system) for global search and ensemble members for local search. The chaotic particle filter (CPF) has been introduced to improve the local search of MSP based on the particle filter method [12].

The purpose of the paper is to introduce a chaos-based prediction method to generate a simple tracker which can predict and locate chaotic motions in video sequences. In this paper, we propose a multi-step-ahead prediction using chaotic dynamics to handle the main weaknesses of probabilistic and deterministic methods. The stochastic dynamics of object movement have high dimensional dynamics with noise in video sequences. In order to use chaotic dynamics for state estimation in object tracking, the high dimensional observations of non-linear movement can be embedded into a pseudo trajectory in the state space. For this purpose, Ikeda map is applied to create a