Information Sciences xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Information Sciences

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

Refined particle swarm intelligence method for abrupt motion tracking

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A R T I C L E I N F O

Article history:
Received 10 July 2013
Received in revised form 17 December 2013
Accepted 3 January 2014
Available online xxxx

Keywords:
Abrupt motion tracking
Visual tracking
Particle swarm optimisation
Computer vision

A B S T R A C T

Conventional tracking solutions are not able to deal with abrupt motion as these are based on a smooth motion assumption or an accurate motion model. Abrupt motion is not subject to motion continuity and smoothness. We address this problem by casting tracking as an optimisation problem and propose a novel abrupt motion tracker based on swarm intelligence – the SwATrack. Unlike existing swarm-based filtering methods, we first of all introduce an optimised swarm-based sampling strategy for a tradeoff between the exploration and exploitation of the state space in search for the optimal proposal distribution. Secondly, we propose Dynamic Acceleration Parameters (DAP) that allow on the fly tuning of the best mean and variance of the distribution for sampling. Combining the two strategies within the Particle Swarm Optimisation framework represents a novel method to address abrupt motion. To the best of our knowledge, this has never been done before. Thirdly, we introduce a new dataset – the Malaya Abrupt Motion *(MAMo)* dataset that consists of 12 videos with groundtruth. Finally, experimental on both quantitative and qualitative results have shown the effectiveness of the proposed method in terms of dataset unbiased, object size invariant and fast recovery in tracking the abrupt motions.

1. Introduction

Visual tracking is one of the most important and challenging research topics in computer vision. Its importance stems from the fact that it is pertinent to the tasks of motion based recognition, automated surveillance, video indexing, human–computer interaction and vehicle navigation [36,37]. In general, motion estimation in a typical visual tracking system can be formulated as a dynamic state estimation problem: $x_t = f(x_t - 1, v_t - 1)$ and $z_t = h(x_t, w_t)$, where x_t is the current state, f is the state evolution function, v_t is the evolution process noise, z_t is the current observation, h denotes the measurement function, and w_t is the measurement noise. The task of motion estimation is usually implemented by utilising predictors such as kalman filters [32,29,22], particle filters [11,2,18,3,4], or linear regression techniques [7]. These predictors are commonly enhanced by assuming that motion is always governed by a Gaussian distribution based on Brownian motion or constant velocity motion models [37,10].

While this assumption holds true to a certain degree for smooth motion, it tends to fail in the case of abrupt motion such as inconsistent speed (e.g. the movement of ball in sport events), camera switching (tracking of subject in a camera topology)

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http://dx.doi.org/10.1016/j.ins.2014.01.003
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and low frame-rate videos, as illustrated in Fig. 1. The main reason is that the state equation cannot cope with the unexpected dynamic movement, e.g. sudden or sharp changes of the camera/object motion in adjacent frames. These sampling-based solutions also suffer from the well-known local trap problem and particle degeneracy problem. In order to handle these problems, one of the earliest work [16] considered tracking in low frame rate videos. Their work considers tracking in low frame rate as abrupt motion, and proposed a cascade particle filters to solve this problem. This is then followed by a number of sampling strategies [12–14,40,41,34,30], which are incorporated into the standard Markov Chain Monte Carlo (MCMC) tracking framework. Their method alleviates the constant velocity motion constraint in MCMC by improvising the sampling efficiency.

The aforementioned works have shown satisfactory results in tracking abrupt motion. However, we observed that most of the work involved applying different sampling strategies to the Bayesian filtering framework. There is a clear trend towards increase complexity; as methods become more complicated to cope with more difficult tracking scenarios. Often these sophisticated methods compensate the increased in complexity by trading-off performance in some other area. For example, the increased number of subregions for sampling to cope with the variation of abrupt motion is compensated by using a smaller number of samples to reduce, if not maintaining, the computational cost incurred. *However, are these complex and sophisticated methods really necessary?*

Recently, Particle Swarm Optimisation (PSO) [6,28,39,26,21,25], a new population based stochastic optimisation technique, has received more and more attention because of its considerable success. Unlike the independent particles in the particle filter, the particles in PSO interact locally with one another and with their environment by using the analogy of the cooperative aspect of social behaviours of animal swarm. For example, the flocking and schooling patterns of birds and fish. However, the standard PSO is not able to track abrupt motion efficiently, due to swarm explosion and divergence problems when the motion is highly abrupt [15,38,17].

In this paper, we proposed the SwATrack – Swarm intelligence-based Tracking algorithm to handle the abrupt motion. Our contributions are firstly, in contrast to the conventional solutions that are based on the different sampling methods in Bayesian filtering which are computationally expensive, we cast the problem of tracking as an optimisation problem and adopted the particle swarm optimisation algorithm as the sole motion estimator. In particular, we replace the state equation, $x_t = f(x_t - 1, v_t - 1)$ with a novel velocity model which is estimated by the PSO. Secondly, we introduced Dynamic Acceleration Parameters (DAP) and Exploration Factor ($\mathcal{E}$) into the proposed PSO framework to avoid the swarm explosion and divergence problems when tracking highly abrupt motion. While the standard PSO algorithm is not new, the novelty is in combining the DAP and $\mathcal{E}$ in an ingenious way to handle the abrupt motion, which is worth noting. To the best of the authors knowledge, there has yet to be published work with similar idea. Thirdly, a new abrupt motion dataset namely as the Malaya Abrupt Motion *(MAMo)* dataset with ground truth is introduced. The dataset consists of 12 videos in real and synthetic environment. Finally, experimental results and comparison with the state-of-the-art algorithms have shown the effectiveness and robustness of the proposed method in terms of dataset unbiased, object size invariance and recovery from error.

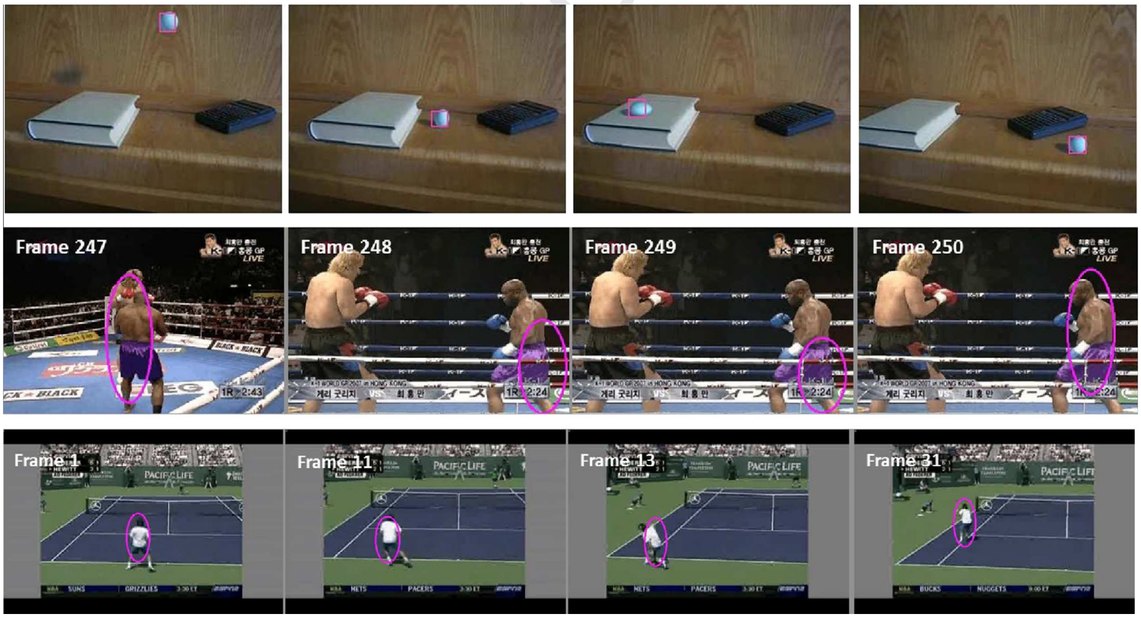

Fig. 1. Example of the abrupt motion in different scenarios. Top: Inconsistent speed. Middle: Camera switching. Bottom: Low frame-rate videos.

Q1 Please cite this article in press as: M.K. Lim et al., Refined particle swarm intelligence method for abrupt motion tracking, Inform. Sci. (2014), http://dx.doi.org/10.1016/j.ins.2014.01.003