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Intelligent video target tracking using an evolutionary particle filter based upon improved cuckoo search

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ABSTRACT

The aim of this paper is to propose an evolutionary particle filter based upon improved cuckoo search algorithm which will overcome the sample impoverishment problem of generic particle filter. In our proposed method, improved cuckoo search (ICS) algorithm is embedded into particle filter (PF) framework. Improved cuckoo search algorithm uses levy flight for generating new particles in the solution and introduced randomness in samples by abandoning a fraction of these particles. The second important contribution in this article is introduction of new way for tackling scaling and rotational error in object tracking. Performance of proposed improved cuckoo particle filter is investigated and evaluated on synthetic and standard video sequences and compared with the generic particle filter and particle swarm optimization based particle filter. We show that object tracking using improved cuckoo particle filter provides more reliable and efficient tracking results than generic particle filter and PSO-particle filter. The proposed technique works for real time video objects tracking.

1. Introduction

Visual tracking in video sequences is an emerging area of research in the field of computer vision. The visual tracking found its application to myriad areas such as security and surveillance, man–machine interaction, activity analysis, road traffic control, video indexing, video communication/compression and augmented reality etc. A number of innovations in the field of cluster computing, high quality video, object detection techniques and advancement multi sensors technology, open the new area of research in the field of video tracking. Visual tracking is complex due to: (1) loss information due to transformation of 3D world to 2D image; (2) occlusion of object subjected for tracking by multiple intermittent disturbances; (3) noise in images; (4) abrupt object motion change during tracking; (5) and real time restrictions. Under Bayesian framework, visual tracking is considered as state estimation of dynamic system where both measurement and observation model bring in uncertainty (Sherrah & Gong, 2001; Toyama & Horvitz, 2000). The representative work under Bayesian framework can be categories into: (a) state estimation for linear and Gaussian model using Kalman filter and its variants such as unscented Kalman filter and extended Kalman filter; (b) state estimation for non-linear and non-Gaussian problems using Sequential Monte Carlo methods (Doucet, Godsill, & Andrieu, 2000; Liu & Chen, 1998; Neal, 1993) also known as Condensation filter (Isard & Blake, 1998), Bootstrap filter (Gordon, Salmond, & Ewing, 1995), and particle filter (Gordon, Arulampalam, Maskell, & Clapp, 2002; Nummiaro, Koller-Meier, & Van Gool, 2002). The main advantages of Sequential Monte Carlo methods (Particle filter) are reduction of sampling patches during tracking and its ability to handle multi modal distribution generated by cluttered environment. Although, there are a number of applications for particle filter due to its superiority over other tracking algorithm, it has some inherent problems which need to be addressed in order to increase the tracking accuracy.

1.1. The problems in visual tracking using particle filter and proposed framework

In spite of number of advantage, the efficiency of visual tracking using particle filter is greatly affected by its inherent shortcoming i.e. particle impoverishment, and by choice of reliable measurement model and observation (object) model. Number of researcher has contributed towards development of efficient object model and measurement models. Although, a simple object model (Jepson, Fleet, & El-Maraghi, 2003; Odobez, Gatica

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Perez, & Ba, 2006; Perez, Hue, Vermaak, & Gangnet, 2002; Vermaak, Perez, Gangnet, & Blake, 2002) with 3–4 state parameter is considered to be efficient for real time application but amount of information provided is low which leads to pre and post processing of video data. For achieving additional information about object, more number of parameters gives more reliable information at the cost of high computational requirement (Wu & Huang, 2004). In case of measurement model of particle filter, a number of methods are reported which either use single cue (e.g. edge, color, motion, etc.) or multiple cues which are fused using different data fusion techniques (Perez, Vermaak, & Blake, 2004; Shen, van den Hengel, & Dick, 2003; Spengler & Schiele, 2001). A review on video tracking indicates that a lot of work has been carried out for development of object and measurement model and there is very little scope for further improvement.

The most perturbing and perpetual problem of particle filter is the curse of dimensionality and degeneracy phenomenon, and solution of it leads to sample impoverishment. Theoretically, any posterior PDF can be estimated by selecting infinite number of particles but, in practice it is impossible to process infinite number of particle for estimation of PDF. In case of particle filter, particle degeneracy occurs when there is only few particle represent the true state of object and remaining contribute either little or none towards estimation of state due to their negligible weight. Processing these particles whose contribution towards state estimation is insignificance adds to computation power with no gain. Researchers addressed the degeneracy by number of methods such as re-sampling and good choice of proposal distribution. During resampling processes, particle whose contribution towards state estimation is little are replaced by particles whose weights are signification. But, suboptimal sampling mechanism in important sampling resampling leads to another problem of sample impoverishment. This will allure the particle in wrong likelihood area due to lack of diversity of particles after few state estimation. In present research work, we have provided solution for sample impoverishment problem in order to improve tracking accuracy i.e. better estimation of posterior probability distribution. The highlight of this work are:

- *A method of object representation for object tracking.*
- *Proposed ICS-PF for overcoming sample impoverishment of PF.*
- *Better qualitative and quantitative performance over PSO-PF and PF.*
- *Real time application due to less computational requirement.*

The remaining of paper is organized as follows:

Section 2, recalls the Sequential Monte Carlo framework and Improved Cuckoo search via Levy flight optimization algorithm for video tracking. Proposed target representation model, along with used object model and measurement model are given Section 3. Section 4, introduced our novel improved cuckoo particle filter we named it as ICS-PF for tracking object in video sequences. The data set used for tracking experiment and performance of our proposed algorithm is presented in Section 5. Also, the results are compared with the best solution available in the literature. Finally, Section 6 sketches brief summary of our contributions and highlight future directions in this field. However, for better understanding of problem, it is absolutely necessary to have a quick review of related work carried out by different researchers.

1.2. Related work

The sample impoverishment problem is addressed by number of researchers. One group is dealing with improvement in resampling process so that sample impoverishment is reduced. A number of resampling variants such as systematic re-sampling (Isard & Blake, 1998), adaptive re-sampling (Wang, Liu, Liu, & Kong, 2011), and residual re-sampling (Cho et al., 2006) were reported in the literature. But, most of these methods solve the problem to limited extend due to failure to replace particle which are statistically independent after re-sampling process. Another group of researchers were solving impoverishment problem through approximation of PDF. The algorithm introduced under this category are extended Kalman particle filter (Liang-Qun, Hong-Bing, & Jun-Hui, 2005), unscented PF (Wan & Van Der Merwe, 2000), approximation moments of the PDF (Masreliez, 1975; West, Harrison, & Migon, 1985), or Gaussian sum filter (Alspach et al., 1972). However, most of these methods could not be applied automatically to any problem. Also, the solutions obtained through these methods are suboptimal due to approximation of PDF by a Gaussian and requirement of more computational power. Hence, solution for sample impoverishment problem which is both computational efficient and provide optimized solution is foremost requirement of video tracking.

In recent year, nature inspired optimization methods has been attempted by number of researchers. These methods aim at concentrating particles into high probable region of probability distribution function and at the same time introduce randomness in particles so as to improve sample impoverishment. Uosaki, Kimura, and Hatanaka (2003) solved particle degeneracy to some extend by exploring the similarity between sampling important resampling and evolutionary strategies. Evolutionary strategies propagate particles based upon selection which exploit the required fitness function. Also, more heuristic in these particles were introduced by mutation and recombination process. However, results were presented for one dimensional generic problem and applicability of approach for two dimensional models or video object tracking was not discussed. Zhong and Fung (2009) provided solution for sample impoverishment and degeneracy problem in particle filter by introducing Ant Colony optimization into particle filter framework. Results show that ACO rearrange the particle before update stage of particle filter for one dimensional generic economic problem. But performance for object tracking in video sequences was not reported. In Liang, Feng, Li, Lu, and Li (2008), artificial fish swarm optimization was used for moving particles into region of high likelihood. The problem of particle destitution was resolved to some extent and results were reported for maneuvering target tracking problem and robot localization. However, the qualitative analysis of results was not reported. Park, Hwang, Rou, and Kim (2007) introduced Genetic algorithm incorporated into particle filter for solving sample impoverishment problem. The proposed algorithm performs better during abrupt change in state because crossover and mutation operation of Genetic algorithm explore new area of proposal distribution and overcome interruption in measurement. Simulation of some complicated problem was presented in order to prove the proposed algorithm where abrupt changes were taken in the video sequences subjected for experiments. Han, Ding, Hao, and Liang (2011) embedded immune genetic algorithm in front of resampling step of particle filter in order to solve the sample impoverish problem of generic particle filter. The antibodies (Particles) were reproduced before resampling by mutation and crossover process of immune system. Further these antibodies were diversified for exploring new search area by regulatory mechanism of immune system such as promotion and suppression. The performance of proposed algorithm was presented on video object tracking and author claimed that proposed algorithm performs better in terms of efficiency and particle diversity than generic particle filter. However, qualitative performance measures were not presented also ability of algorithm for