Combating Tracking Drift: Developing Robust Object Tracking Methods

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Certificate of Original Authorship

I certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This thesis is the result of the research candidature conducted jointly with Beijing Institute of Technology as part of a collaborative doctoral degree.

Signature of Student: ____________

Date: 26/7/2017

I would like to dedicate this thesis to my loving parents and wife

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Abstract

Visual object tracking plays an important role in many computer vision applications, such as video surveillance, unmanned aerial vehicle image processing, human computer interaction and automatic control. This research aims to develop robust object tracking methods, which are capable of tracking general object without the prior knowledge of the target. Tracker drift is one of the most challenging issues in object tracking due to target deformations, illumination variations, abrupt motions, occlusions and background clutters. This thesis focuses on the tracking drift problem, and adopts three main solutions. These include: designing an efficient target shape feature extraction method, comparing target features with metric learning and using the ensemble tracking method to tackle the tracking drift during tracker online update. The main work and contributions are as follows:

1. We propose a Weber's Law Shape Descriptor (WLSD) for efficient object tracking under background clutters. Weber's Law indicates that the perceived change in stimuli is proportional to the initial stimuli, which means that the saliency variations is not only relative to the feature variations, but also the initial feature quantity. Motivated by Weber's Law, this thesis proposes a Weber's Law Shape Descriptor to describe the saliency variations of the shape contour. The proposed method first designs a Contour Angular Feature as the initial stimuli, and builds the WLSD according to Weber's Law. Then, WLSD is extended to multi-scale to enhance its shape discriminative strength. Finally, a feature selection scheme is used to extract the effective WLSD scales. The proposed WLSD is naturally invariant to the shape scale and rotation, and has low computation load as a whole shape descriptor. We further apply WLSD in thermal infrared object tracking, and propose a multi-feature integration method based on WLSD shape, target area and target trajectory. The experiments are first conducted on MPEG-7 and Tari shape dataset to test the shape discriminative capacity of WLSD, and then tested on the infrared tracking videos to validate the proposed multi-feature integration tracking framework.

2. We propose a Time Varying Metric Learning (TVML) object tracking method. Recently, tracking-by-detection (TBD) methods are very popular. Traditional TBD methods track the objects by training a binary classifier to discriminate the target and background, which

leads to two main issues: firstly, the classifier is unreliable when trained with insufficient data, secondly, comparing the object features with traditional Euclidean distance leans to tracker drift. To solve the above problems, we propose a time varying metric learning model and apply it to object tracking. The proposed TVML adopts Wishart Process to model the variation of the positive semi-definite (PSD) matrices, i.e. the metrics, and uses the Recursive Bayesian Estimation (RBE) framework to learn the metrics under the side information constraint. We introduce the side information constraint to omit the clustering of the negative samples, which is very suitable to the background cluster tracking scenarios. Furthermore, the RBE framework guarantees the proposed model is able to estimate the metrics with limited training data. The experimental results demonstrate the comparable performance of the TVML tracker compared to many state-of-the-art methods on OTB-50 dataset.

3. We propose a historical tracker snapshots based ensemble tracking method. There are frequent target appearance changes due to illumination variations, abrupt motions and target deformations, which needs the tracker to conduct online update to adapt to the target appearance variations. The online update of the tracker often leads to drift. This thesis proposes a historical tracker snapshots based ensemble tracking framework, and designs a Scale-adaptive Multi-Expert (SME) tracker according to the proposed method. The tracker ensemble is composed of the current tracker and its historical tracker snapshots. When the tracker drift is detected, the framework will select the suitable tracker snapshot to replace the current drift tracker according to their accumulated scores. Due to the fact that the tracker tends to be more confident to its own prediction, we propose to define the tracker score in a semi-supervised learning perspective to describe the consistency and the ambiguity of the tracker ensemble simultaneously. We use the regression correlation filter as the base tracker due to its high efficiency. Furthermore, we propose to establish the target scale pyramid to estimate the target scale accurately. The proposed SME tracker is tested on the OTB-50 and VOT2015 tracking dataset, which demonstrates the excellent performance of the proposed tracker with real time speed.

4. We propose a discrete graph based ensemble tracking method. The tracker ensemble is constituted by the current tracker and its historical snapshots as the multi-expert. This thesis proposes to introduce the discrete graph to model the tracker ensemble, where the graph node represents the expert hypothesis. After defining the unary and pair-wise score of the graph, the best expert is selected according to the graph path of the highest score. With the efficient solver of dynamic programming, the proposed method can implicitly analyze the reliability of the multi-expert trajectories by only computing their scores in the current frame, so as to correct the tracker drift. We integrate three base trackers into the proposed

tracking framework to validate its generality, including online support vector machine on a budget, hand-craft feature based correlation filter and convolutional neural network based correlation filter. The proposed three trackers are widely tested on the OTB-50, OTB-100 and VOT2015 dataset, which demonstrates the proposed trackers are superior to the compared state-of-the-art trackers in both the tracking accuracy and robustness measures.

Keywords — Object tracking, Weber's Law, time varying metric learning, ensemble tracking, correlation filter, discrete graph.

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