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DISSERTATION RESEARCH IMPACT

Of all the things which can be impacted by this dissertation, safety is the one which resonates most deeply as we as a society seek to prevent and to protect. When by dint of circumstance a large number of people move in a small area, safety becomes the biggest concern. Tragic incidents such as Boston marathon bombing, or the recent Hajj stampede exemplify why there is a need for video analysis, which is the topic of this dissertation. Moreover, understanding the dynamics of large groups of people is critical in the design and management of any type of public events. When dealing with high-density crowd scenarios such as religious rites participations, political rallies, concerts or marathons, modeling and analysis of crowd dynamics can become quite complex. This dissertation contributes to automatic video analysis of such scenarios.

SELECTED PUBLICATIONS (h-index: 7, total citation: 524)

1. **Target Identity-aware Network Flow for Online Multiple Target Tracking,** A. Dehghan, Y. Tian, P.. H. S. Torr and M. Shah , *in IEEE International Conference on Computer Vision and Pattern Recognition (**CVPR**),* 2015.
2. **GMMCP-Tracker: Globally Optimal Generalized Maximum Multi Clique Problem for Multiple Object Tracking ,** A. Dehghan, S. M. Assari and M. Shah, *in IEEE International Conference on Computer Vision and Pattern Recognition (**CVPR**),* 2015.
3. **Complex event recognition using constrained low-rank representation,** A. Dehghan, O.Oreifej and M. Shah , *in Image and Vision Computing (**IVC**),* 2015.
4. **Improving Semantic Concept Detection through the Dictionary of Visually-distinct Elements,** A. Dehghan, H. Idrees and M. Shah, *in IEEE International Conference on Computer Vision and Pattern Recognition (**CVPR**),* 2014.
5. **Who Do I Look Like? Determining Parent-offspring Resemblance via Gated Autoencoders ,** A. Dehghan, E. Ortiz, R.Vilegas and M. Shah , *IEEE Conference on Computer Vision and Pattern Recognition (**CVPR**),* 2014.
6. **Visual Tracking: an Experimental Survey ,** A. W. M. Smeulders, D. M. Chu, R. Cucchiara, S. Calderara, A. Dehghan and M. Shah , *IEEE Transaction on Pattern Analysis and Machine Intelligence (**PAMI**),* 2013.
7. **Improving an Object Detector and Extracting Regions using Superpixels,** G. Shu, A. Dehghan and M. Shah , *in IEEE International Conference on Computer Vision and Pattern Recognition (**CVPR**),* 2013.
8. **Visual Business Recognition-A Multimedia Approach,** A. Zamir, A. Dehghan and Mubarak Shah , *ACM international Conference in Multimedia,* 2013.
9. **Part-based Multiple Person Tracking with Partial Occlusion Handling** G. Shu, A. Dehghan, O. Oreifej, E. Hand and M. Shah , *in IEEE International Conference on Computer Vision and Pattern Recognition (**CVPR**),* 2012.
10. **GMCP-Tracker: Global Multi-object Tracking Using Generalized Minimum Clique Graphs,** A. R. Zamir, A. Dehghan and M. Shah , *in European Conference on Computer Vision (**ECCV**),* 2012 .

DISSERTATION

GLOBAL DATA ASSOCIATION FOR MULTIPLE PEDESTRAIN TRACKING

Multi-object tracking is one of the fundamental problems in computer vision. Almost all multi-object tracking approaches consist of two main components; detection and data association. In the detection step, object hypotheses are generated in each frame. Later, detections that belong to the same target are linked together to form tracks. The latter step is called data association. There are several challenges that render tracking difficult, such as occlusion, background clutter and pose changes, miss-detection, ID switches etc. This dissertation addresses the data association component of tracking and contributes three novel methods for solving data association.

Firstly, a new framework for multi-target tracking that uses a novel data association technique employing the Generalized Maximum Clique Problem (GMCP) formulation is presented. The majority of current methods, such as bipartite matching, incorporate a limited temporal locality of the sequence into the data association problem. On the other hand, our approach incorporates both motion and appearance in a global manner. The proposed method incorporates the whole temporal span and solves the data association problem for one object at a time. GMCP is used to solve the optimization problem of our data association. GMCP leads us to a more accurate approach to multi-object tracking; however, it has some limitations. Firstly, it finds target trajectories one-by-one, missing joint optimization. Secondly, for optimization we use a greedy solver, making GMCP prone to local minima. Finally GMCP tracker is slow.

In order to address these problems, we propose a new graph theoretic problem formulation called Generalized Maximum Multi Clique Problem (GMMCP). GMMCP has all the advantages of the GMCP tracker while addressing its limitations. Previous works assume simplified version of the ideal tracking scenario either in problem formulation or problem optimization. However, we propose a solution to GMMCP where no simplification is assumed in either steps. We show that, GMMCP can be solved efficiently through Binary-Integer Program while guaranteeing the optimal solution. We further propose a speed-up method which reduces the size of input graph without assuming any heuristic.

Thus far we have assumed that the number of people do not exceed a few dozen. However, this is not always the case. In many scenarios such as, marathons, political rallies or religious rites, the number of people in a frame may reach few hundreds or even few thousands. Human detection methods often fail to localize objects in extremely crowded scenes. This limits the use of data association based tracking methods, including GMCP and GMMCP. Finally, we formulate online crowd tracking as a Binary Quadratic Programing, where both detection and data association problems are solved together. Our tracker brings in both target's individual information and contextual cues into a single objective function. Due to large number of targets, state -of-the-art commercial quadratic programing solvers fail to efficiently find the solution to proposed optimization. In order to overcome the computational complexity of available solvers, we propose to use the most recent version of Modified Frank-Wolfe algorithm. The proposed tracker can track hundreds of targets efficiently and improve state-of-the-art results by significant margin.