



UNIVERSITY OF CENTRAL FLORIDA
CENTER FOR RESEARCH IN COMPUTER VISION

FINAL ORAL EXAMINATION

OF

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B.Sc., LAHORE UNIVERSITY OF MANAGEMENT SCIENCES, 2007

FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY
(COMPUTER SCIENCE)

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DISSERTATION COMMITTEE

Professor Mubarak Shah, *Chairman*
Professor Bahaa Saleh
Professor Kenneth O. Stanley
Professor Niels da Vitoria Lobo
Professor George Atia

OUTLINE OF GRADUATE STUDIES

Major: Computer Science

Computer Systems

3D Vision

Advanced Computer Vision

Computational Complexity

Machine Learning with Bioinformatics

Shah

Foroosh

Shah

Hughes

Hu

SELECTED PUBLICATIONS

- Afshin Dehghan, Haroon Idrees, and Mubarak Shah, **Improving Semantic Concept Detection through the Dictionary of Visually-distinct Elements**, *IEEE Conference on Computer Vision and Pattern Recognition (CVPR), Columbus, Ohio, 2014.*
- Mahdi M. Kalayeh, Haroon Idrees, and Mubarak Shah, **NMF-KNN: Image Annotation using Weighted Multi-View Non-Negative Matrix Factorization**, *Computer Vision and Pattern Recognition (CVPR), Columbus, Ohio, 2014.*
- Haroon Idrees, Nolan Warner, and Mubarak Shah, **Tracking in dense crowds using prominence and neighborhood motion concurrence**, *Image and Vision Computing (IVC), Volume 32, Issue 1, Pages 14-26, January 2014.*
- Haroon Idrees, Imran Saleemi, Cody Seibert, and Mubarak Shah, **Multi-Source Multi-Scale Counting in Extremely Dense Crowd Images**, *IEEE Conference on Computer Vision and Pattern Recognition (CVPR), Portland, Oregon, 2013.*
- Haroon Idrees, Imran Saleemi, and Mubarak Shah, **Statistical Inference of Motion in the Invisible**, *European Conference on Computer Vision (ECCV), Florence, 2012.*
- Subhabrata Bhattacharya, Haroon Idrees, Imran Saleemi, Saad Ali, and Mubarak Shah, **Moving Object Detection and Tracking in Forward Looking Infra-Red Aerial Imagery**, *Book chapter in Machine Vision Beyond Visible Spectrum, Springer, 2011.*
- Vladimir Reilly, Haroon Idrees, and Mubarak Shah, **Detection and Tracking of Large Number of Vehicles in Wide Area Surveillance**, *European Conference on Computer Vision (ECCV) Crete, Greece, 2010.*

PATENT

- Haroon Idrees, Imran Saleemi, and Mubarak Shah, **Multi-Source Multi-Scale Counting in Extremely Dense Crowd Images**, *University of Central Florida, 2014. (U.S. Patent Application filed)*

DISSERTATION

VISUAL ANALYSIS OF EXTREMELY DENSE CROWDED SCENES

Visual analysis of dense crowds is particularly challenging due to large number of individuals, occlusions, clutter, and fewer pixels per person which rarely occur in ordinary surveillance scenarios. This dissertation aims to address these challenges in images and videos of extremely dense crowds containing hundreds to thousands of humans. The goal is to tackle the fundamental problems of counting, detecting and tracking people in such images and videos using visual and contextual cues that are automatically derived from the crowded scenes.

For counting in an image of extremely dense crowd, we leverage multiple sources of information to estimate the number of individuals present in the image. Our approach relies on multiple sources such as low confidence head detections, repetition of texture elements, and frequency-domain analysis to estimate counts in an image region. Furthermore, we employ a global consistency constraint on counts using Markov Random Field which caters for disparity in counts in local neighborhoods and across scales. We validate this approach on a very difficult dataset of crowd images with the head counts ranging from 94 to 4,543. Besides counting, we also propose to localize humans by finding repetitive patterns in the crowd image. Starting with detections from an underlying head detector, we correlate them within the image after their selection through several criteria: in a pre-defined grid, locally, or at multiple scales by finding the patches that are most representative of recurring patterns in the crowd image. Finally, the set of generated hypotheses is selected using binary integer least squares with Special Ordered Set (SOS) Type 1 constraints.

Detection of complete humans in low to medium density crowds is another important problem in the analysis of crowded scenes as it is a pre-requisite for many other visual tasks, such as tracking, counting, recognizing actions or detecting anomalous behaviors exhibited by individuals. For that, we propose to explore context in dense crowds in the form of locally-consistent scale prior which captures the similarity in scale in local neighborhoods with smooth variation over the image. Using the scale and confidence of detections obtained from an underlying human detector, we infer scale and confidence priors using Markov Random Field. In an iterative mechanism, the confidences of detections are modified to reflect consistency with the inferred priors, and the priors are updated based on the new detections. The final set of detections obtained are then reasoned for occlusion using Binary Integer Programming where overlaps and relations between parts of individuals are encoded as linear constraints. In addition, we propose a mechanism to detect different combinations of body parts without requiring annotations for individual combinations.

Once human detection and localization is performed, we then use it for tracking people in dense crowds. The approach begins with the automatic identification of prominent individuals from the crowd that are easy to track. Then, we use Neighborhood Motion Concurrence to model the behavior of individuals in a dense crowd, this predicts the position of an individual based on the motion of its neighbors. These two aspects are then embedded in a framework which imposes hierarchy on the order in which positions of individuals are updated. The results are reported on eight sequences of medium to high density crowds and our approach performs on par with existing approaches without learning or modeling patterns of crowd flow.



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- 2015- Research Associate, Center for Research in Computer
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