

# Camera Networks

The Acquisition and Analysis of Videos over Wide Areas

# Synthesis Lectures on Computer Vision

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### Camera Networks: The Acquisition and Analysis of Videos over Wide Areas

Amit K. Roy-Chowdhury and Bi Song

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# Camera Networks

**The Acquisition and Analysis of Videos over Wide Areas**

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University of California, Riverside

*SYNTHESIS LECTURES ON COMPUTER VISION #4*

## ABSTRACT

As networks of video cameras are installed in many applications like security and surveillance, environmental monitoring, disaster response, and assisted living facilities, among others, image understanding in camera networks is becoming an important area of research and technology development. There are many challenges that need to be addressed in the process. Some of them are listed below.

- Traditional computer vision challenges in tracking and recognition, robustness to pose, illumination, occlusion, clutter, recognition of objects, and activities;
- Aggregating local information for wide area scene understanding, like obtaining stable, long-term tracks of objects;
- Positioning of the cameras and dynamic control of pan-tilt-zoom (PTZ) cameras for optimal sensing;
- Distributed processing and scene analysis algorithms;
- Resource constraints imposed by different applications like security and surveillance, environmental monitoring, disaster response, assisted living facilities, etc.

In this book, we focus on the basic research problems in camera networks, review the current state-of-the-art and present a detailed description of some of the recently developed methodologies. The major underlying theme in all the work presented is to take a network-centric view whereby the overall decisions are made at the network level. This is sometimes achieved by accumulating all the data at a central server, while at other times by exchanging decisions made by individual cameras based on their locally sensed data.

Chapter 1 starts with an overview of the problems in camera networks and the major research directions. Some of the currently available experimental testbeds are also discussed here. One of the fundamental tasks in the analysis of dynamic scenes is to track objects. Since camera networks cover a large area, the systems need to be able to track over such wide areas where there could be both overlapping and non-overlapping fields of view of the cameras, as addressed in Chapter 2. Distributed processing is another challenge in camera networks and recent methods have shown how to do tracking, pose estimation and calibration in a distributed environment. Consensus algorithms that enable these tasks are described in Chapter 3. Chapter 4 summarizes a few approaches on object and activity recognition in both distributed and centralized camera network environments. All these methods have focused primarily on the analysis side given that images are being obtained by the cameras. Efficient utilization of such networks often calls for active sensing, whereby the acquisition and analysis phases are closely linked. We discuss this issue in detail in Chapter 5 and show how collaborative and opportunistic sensing in a camera network can be achieved. Finally, Chapter 6 concludes the book by highlighting the major directions for future research.

## KEYWORDS

wide area tracking, distributed video analysis, Kalman consensus, distributed tracking, recognition, active sensing, opportunistic sensing

*Amit: To my parents for all they have done*

*Bi: To my parents*

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# Preface

Camera networks is a highly interdisciplinary area of research that has been very active over the last few years. In this book, we focus specifically on the topic of video understanding in camera networks and touch upon the other related areas (e.g., communication resources, machine learning, cooperative control of multi-agent systems) as they pertain to this main focus. Our goal is to provide an overview of the current state-of-the-art in one single document. Researchers interested in the broad area or a particular sub-topic can start out with this book and then move on to specific papers that provide more details.

We divide the area of video analysis in camera networks along the lines of traditional computer vision – tracking, recognition, geometric calibration, 3D estimation, active vision. In each of these, we specifically focus on issues that are relevant to camera networks. For example, in tracking this entails analysis of handoff between non-overlapping cameras, while in active sensing, cooperative control of the camera network is addressed. An issue that is specific to camera networks is distributed processing and we dedicate a chapter to this aspect.

In writing this book, we build upon our experience in working on various research projects related to camera networks. We would like to thank the different funding agencies that made this possible: National Science Foundation through grants ECS-0622176 and CNS-0551741, Office of Naval Research through N00014-09-1-0666 and N00014-09-C-0388, Army Research Office through W911NF-07-1-0485, and CISCO Inc. The first author would like to thank his students and collaborators in this area who have contributed immensely to his understanding of the subject – his former student and co-author Dr. B. Song, without whom this book would never have been possible, his current students Mr. C. Ding and Mr. A. T. Kamal, and his colleagues Prof. B. Bhanu and Prof. J. A. Farrell, with whom he has shared some of the research projects. He is indebted to his advisor Prof. R. Chellappa (Univ. of Maryland, College Park) for initiating him into the world of academic research and to Prof. B. S. Manjunath (Univ. of California, Santa Barbara) for all the help and support in the initial years of his academic career.

Both of us are immensely grateful for the continuous support from our families – the joy they bring makes the whole effort worthwhile. We thank our parents for all that they have done and dedicate this book to them.

Amit K. Roy-Chowdhury and Bi Song  
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