Chapter 1: Report on NSF/ARO/ONR Workshop on Distributed Camera Networks: Research Challenges and Future Directions

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Summary of Workshop

Large-scale video networks are becoming increasingly important for a wide range of critical applications. The development of automated techniques for aggregating and interpreting information from multiple video streams in large-scale networks in real-life scenarios is very challenging. Research in video sensor networks is highly interdisciplinary and requires expertise from a variety of fields. The goal of this effort was to organize a two-day nationally-recognized workshop in the domain of camera networks that brings together leading researchers from academia, industry and the government. The workshop was held at the University of California at Riverside on May 11-12, 2009. The workshop was attended by 75 participants. The workshop was sponsored by the US National Science Foundation, US Army Research Office and US Office of Naval Research. The workshop addressed critical interdisciplinary challenges at the intersection of large scale video camera networks and distributed sensing, processing, communication and control; distributed video understanding; embedded real-time systems; graphics and simulation; and education. The recommendations of the workshop are summarized in the following order of topics:

A. Video Processing and Video Understanding
B. Simulation, Graphics, Cognition and Video Networks
C. Wireless Video Sensor Networks, Communications and Control
D. Distributed Embedded Cameras and Real Time Video Analysis
E. Applications
F. Educational Opportunities and Curriculum Development

We include the workshop report in this book with the hope that it will catalyze a research agenda and interdisciplinary collaborations in large scale camera networks – an emerging field with significant and exciting scientific and technological challenges which will set the stage for potentially transformative breakthroughs.

The workshop website is http://videonetworks2009.cs.ucr.edu/

Introduction

This document summarizes the activities and recommendations of NSF/ARO/ONR sponsored Workshop on Distributed Video Sensor Network: Research Challenges and Future Directions.

A multitude of real-world problems can be addressed now using video networks. Some of the examples are:

- Monitoring civilian conditions such as disasters, evacuations, urban patterns, and transportation.
- Monitoring natural habitats, colony collapse disorder, bird habitats.
- Home care with personal robots in households.
- Object-ensemble tracking: annotations of scene by type, and by contents (object classes, motion patterns, events and anomalies).
- Webcams for science for active research in phenology, smart offices, classrooms and education outreach.

The workshop discussed critical interdisciplinary challenges at the intersection of large scale video camera networks and distributed sensing, processing, communication and control; distributed video understanding; embedded real-time systems; graphics and simulation; and curriculum development.

The agenda for the workshop, the composition of various research groups and the list of participants are given at the end of this report.

In the following we present the Workshop Report and topics for major research projects.

Workshop Recommendations

The recommendations of the workshop are summarized in the following order of topics:

A. Video Processing and Video Understanding (Group 1)
B. Simulation, Graphics, Cognition and Video Networks (Group 2)
C. Wireless Video Sensor Networks, Communications and Control (Group 3)
D. Distributed Embedded Cameras and Real-Time Video Analysis (Group 4)
E. Applications (Group 5)
F. Educational Opportunities and Curriculum Development (Group 6)

A. Video Processing and Video Understanding

This group was led by Profs. Rama Chellappa and Gerard Medioni. The group discussed the core issues associated with camera control, algorithms and architectures for distributed processing, and real-time/forensics scenarios and applications. The group also identified high risk and payoff areas and outreach efforts to other groups.

The following are identified as new research directions within this group:

- New algorithms for
    - Camera control (e.g., game theoretic approach):
    - Camera placement in dynamic environments, scheduling cameras for data acquisition to optimize tracking, and choosing the most informative cameras for a task.
    - Architecture for distributed processing, real-time vs. forensics; semantic models for group activities, theory of crowd behavior. Better understanding of physical phenomena, local context, and low-level image features.
    - Theory of visual information and representation to support the inference of scene properties (topological, geometric, photometric, dynamic) from images.
    - Central role of occlusion with respect to network topology and mobility, control authority vs. actionable information, and theory of active vision.
    - Scalable representations to handle increases in object complexity, count and dynamics; and sparse representations (e.g., compressive sensing).
    - Statistical learning and adaptation for data driven, scene specific models.

- Several core issues are related with the algorithms. They include
    - Calibration.
    - Localization using non-line of sight sensors.
    - Tag and track.
    - Integration of multiple trackers.
    - Integration of modeling and tracking from sample to ensemble (statistics of crowds, objects).
    - Dynamic compensation for imaging inconveniences (using multiple sources).
    - Trade-off between camera mobility/fixed cameras.
    - Distributed vision algorithms based on consensus approaches.
    - Power aware vision algorithm.
    - Inference (decision, analysis and classification) in high-dimensional (multiple properties, objects and dynamics) time series.
    - Efficient and robust integration of information through the network.
    - Parameter free grouping and clustering.

Additional items were building models of complex objects from parts, modeling relationships among objects and phenomena, automatic identification of informative features, modeling complex motions, and advanced sensing to reduce processing, integration of multiple cues and strategies for reducing the need for low-level coordination among cameras.

Risks associated with the algorithms for distributed video sensor networks include calibration, complexity of nuisance factors (illumination, deformations, etc.), non-linear (or even linear) increase in complexity with problem size, fragility of low-level vision algorithms, new potential issues due to integrating visual data through a network with communication constraints, and run-time issues such as the synchronization of multiple video streams.

Calibration Risk and Payoffs
The calibration problem has been studied for a long period of time but not solved for automated calibration of the network. Algorithms for self-calibration and opportunistic use of environmental data can address this need. If done right, calibration simplifies all data fusion problems and increases the accuracy of registration, recognition, tracking etc.

Nuisance Factors Risks and Payoffs
Complexity of nuisance factors is caused by environmental conditions, occlusion and scene clutter. New directions are to improve current representations and decrease the dependency on extensive training sets to learn known nuisances. On the other side, a larger amount of data, obtained intelligently, can overcome many of the nuisance factors. Developing representations that are designed to be insensitive/invariant to nuisance factors simplifies learning (no extensive datasets necessary to "learn away" spurious variability). Further, the development of a theory of representation would enable provable bounds, given specific sets of assumptions.

Intersection/Outreach of Video Processing and Video Understanding (Group 1) to other groups

(a) Simulation, Graphics, Cognition and Video Networks (Group 2)
Video understanding results do the following:
- Feed into graphics simulator.
- Populate the synthetic world as vision can generate descriptors of objects and their behaviors, information on gender, height, gait parameters, behavior patterns of humans, dimensions of vehicles, their traffic flows, etc.
- Immersive environments where real video and synthetic environments can be integrated.
- Synthetic environments can produce data for validating vision algorithms.

and, graphics provides the context for designing robust vision algorithms and interfaces; and builds more on computational photography.

(b) Wireless Video Sensor Networks, Communications and Control (Group 3)
Understanding the impact of compression on vision algorithms (quality loss, use of metadata); finding the impact of transmission error on vision system performance (track failures, maintaining identity); developing application-aware compression and transmission; and collaborative processing algorithms.

(c) Distributed Embedded Cameras and Real-Time Video Analysis (Group 4)
Understanding tradeoffs between local, collaborative and centralized processing (cost-benefit of implementing on embedded platforms, computation vs. bandwidth (information exchange); studying mobility issues; codesigning hardware and vision software (selecting algorithms for hardware, GPU, etc.); building robustness to camera and network failures; designing power aware vision algorithms; and designing novel sensors.

At the system level, issues include the following:
- Scalability (tradeoff accuracy to computational time).

- Architectural issues (distributed implementations, tradeoffs in bandwidth, cost, accuracy (depends on kinds of questions posed in server/edge device)).
- Architecture – link to Neuroscience/Psychology.
- Performance models of distributed sensing, intelligence and control.
- Human factors issues and new concepts when dealing with distributed sensing, intelligence and active control, novel visualizations; algorithmic issues (develop algorithms which do not need manual tuning).

B. Simulation, Graphics, Cognition and Video Networks

This group was led by Profs. Demetri Terzopoulos and Chuck Dyer. The group discussed the issues of analysis in camera networks using simulations. Since there are practical challenges in installing camera networks for research purposes and getting access to the real-life data, simulations through computer graphics methods can be very useful in understanding the performance of these methods. Moreover, simulation studies can be used to create virtual scenarios through active camera control. Such simulations require models of the areas, environmental models and dynamic models of people and vehicles.

The group discussed a number of advances in computer graphics that would enable this research direction. They included simulation in camera networks, realistic renderings of humans and their activities, tele-immersion systems, and ubiquitous displays. The issue of distributed processing and architectures was also discussed. Some researchers raised the issues of camera control, tracking and biometric recognition.

The following were identified as future research directions.

1. The use of biometrics in simulations has not been studied, but they are obviously important in scene analysis in camera networks. Information from the sensor network can be used to obtain higher quality simulations since this information can be obtained from different views and over time. Also, realistic biometric simulations can be used in the scene analysis algorithms for tracking and control.
2. The issue of view-invariant matching across camera networks, which are spread over wide areas, was considered to be a challenging problem.
3. The issue of building intelligent architectures that would be adaptive to different representations, categories and constraints was discussed. This would be especially important in efficiently organizing the infrastructure prior to deployment.
4. Distributed processing and camera control is another area of future work in this domain.
5. Simulations must be application specific since they have specific requirements. For example, tele-immersion systems have hard time constrains, while surveillance systems can have weaker restrictions.

C. Wireless Video Sensor Networks, Communications and Control

This group was led by Prof. Antonio Ortega and Prof. Venkatesh Saligrama. The group discussed issues related to infrastructure, synthesis, design and integration of low-level tools leading to a system-level understanding of the video network and its functionalities. The inputs to the system are the low-level data acquisition and processing methods, algorithms capable of analyzing the low-level data like image/signal processing algorithms, the design constraints and objectives, the quality metrics that need to be satisfied and evaluation datasets. The outcome of this system level understanding will be models (either deterministic or stochastic), protocols that describe the communication between the different sensor nodes, centralized and distributed algorithms for system level analysis, and overall performance analysis of the entire system. A number of key research problems need to be solved to achieve all these outcomes.

The group identified the following areas where interactions with the other groups were necessary. The system analysis is dependent on the application domain, specifically the video analysis methods. Simulated environments could be helpful for their analysis if the system level issues, e.g., networking constraints, could be built into the simulation methods. The proposed ideas need to be analyzed for possible real-time applications. Finally, how the proposed methods will be built into major products and standards was an issue that was discussed and it was felt that these applications can provide the ultimate metrics for quality of service and performance analysis. The group also brought up the issue of how video sensor networks can provide unique examples in teaching different core systems theory courses like signal processing, information theory, controls, networking, etc.

The general challenges in the system-level understanding are the following:

- Scalability, which includes the ability to deal with high data rates, latency and large number of nodes;
- Computation-communication tradeoff to decide on distributed vs. centralized processing;
- Spatial coordination and its potential benefits compared to the coordination overhead;
- Identification of generic tools that can be used across application domains;
- Quality metrics for Resources vs. Analysis quality;
- Robustness of the overall system to faults, losses and security threats;

Some desired characteristics of the solution methods were also identified.

- For the physical layer, the group felt that new MAC layer tools can be developed for video sensor networks.
- The networking protocols should be capable of handling distributed architectures, provide different levels of reliability for different data types, and lead to cooperative approaches for sensing, processing and communication.
- The ultimate goal of the system will be optimization of quality vs. available resources (power, bandwidth, time). A major question will be to decide what are the desirable metrics for measuring “distortion” in the system and the group felt that it was application specific. There is very limited work on “analysis-based” metrics.
- The system analysis can be lossy for the data, but lossless for the information.
- Application specific compression techniques need to be studied.
- Information driven adaptive sensing, followed by distributed fusion of the sensed data, will be a major focus area for this research.

- Collaboration between the different entities is necessary and leads to a number of sub-problems like opportunistic communication, parallel processing, distributed algorithms, distributed control and resource management, and the interaction between control and communication.

D. Distributed Embedded Cameras and Real Time Video Analysis

This group was led by Dr. Hamid Aghajan and Dr. Paul Brewer. Its focus was to analyze the issues related to developing smart cameras capable of performing the tasks necessary in a distributed video sensor network (DVSN). The group identified the issues in this regard with respect to the other groups.

- For Group 1 (Video Processing and Video Understanding), the challenges identified were related to developing efficient architectures for sensor processing so that the algorithms could run in real time. It was raised that most video understanding algorithms are computationally intensive and, therefore, it is necessary to focus on how to make them more efficient.
- Another issue in this regard was the methodology that would be followed in creating the metadata that could be exchanged among sensors.
- With respect to Group 2 (Simulation, Graphics, Cognition and Video Networks), the issues were related to architectures that would allow such simulations to run. It was, however, felt that this may not be a critical issue since simulations were being done offline and using powerful GPUs.
- It was felt that the real-time processing issues were closely related to the networking, control and communication aspects. The network protocols would directly affect the smart camera architectures. Communication resources would dictate the tradeoff between local and distributed processing, which would, in turn, affect the architecture. Control mechanisms have to work in real-time and, thus, need significant computational power.
- With the Applications group, the main issues would be deciding upon the platforms, operating system and architectures.

E. Applications

The applications group was led by Prof. Glenn Healy and Dr. Bogdan Matei. This group identified a number of application areas of video sensor networks. Some of the examples mentioned are given below.

- One interesting problem was recognizing activity patterns over large areas from a number of simple events. This requires advanced video analysis techniques in camera networks.
- The integration of biometrics with wide area surveillance was considered another interesting problem domain. This is especially important because it is hard to track individuals over large areas without identification information.
- Another application area was in the health care industry, especially assisted living facilities.
- In all of these, the integration of video with other sensory signals was considered critical.

- The group members expressed concerns about the real-time abilities of video analysis algorithms and felt that closer interaction was necessary between the low-level signal analysis, communication protocols and real-time implementation.

F. Educational Opportunities and Curriculum Development

This group was led by Prof. Sharad Mehrotra and Prof. Jenq-Neng Hwang. The related talks were also given by Prof. Tom Henderson and Prof. Narendra Ahuja. The group identified the challenges associated with distributed video sensor networks because of its interdisciplinary nature and offered potential solutions. Several ideas for interdisciplinary curriculum were discussed. The highlights of this group are:

- The field of Distributed Video Sensor Network (DVSN) is interdisciplinary. It includes many aspects of computer vision, pattern recognition, distributed algorithms, signal processing, graphics, simulation, verification and validation, sensors, robotics, operating systems and networking, hardware and embedded systems, data management, analysis of large datasets, cognitive systems, ethics, intellectual property rights, science and math and technical writing. Each of these technical areas have their core set of problems, techniques, approaches, biases, languages, research methodologies, acceptable validation mechanisms, etc. One idea is to look at the intersection of disciplines involved and expand disciplinary curriculum with concepts/ideas/abstractions from different fields. The associated challenges are: What are the core disciplinary concepts? How do we create common understanding of different areas, while being flexible enough to meet the needs of educators from different perspectives?
- One possible solution is to create testbeds highlighting different application areas such as the UCR VideoWeb camera network testbed and Responsphere at UCI. There could be a testbed for open access similar to ORBIT project sponsored by NSF Network Research Testbed for large scale wireless networks with remote data collection and remote algorithms porting. Building, usage, validation can all be incorporated as strategies to improve graduate education. Note that testbeds are not easy to share and require dedicated staff and researchers and economic models for sustainability and sharing of testbed are needed. Some solutions are NSF Site REU, NSF IGERT, DoD MURI, Summer school, Educational Programs. Currently the sustained funding for infrastructure and its maintenance is very limited. NSF may consider modifying CRI, MRI programs. The community can help the funding agencies by promoting the field through establishing the needs of DVSN.
- Another possible solution is to develop a systems approach to education. Experts design micro-modules in their areas of expertise. Modules consist of course slides, test data, etc. Modules can be combined to create courses offering with different perspectives. Modules are refined over time. This will allow the shared burden with huge payoffs at the community level.
- Another possible solution is the creation of "grand challenge" tasks similar to ones done in robotics, web search, etc. In this regards calibrated, time synchronized, and ground truth labeled benchmark videos (e.g., VideoWeb of UCR, Human ID of Southampton, IEEE PETS dataset) will be helpful.

- Another possible solution is to develop Network Simulator-2 like camera network simulators. The simulator will allow for camera placement and specification, event building and scheduling, protocol for information exchange and an integrated display.
- Other ideas for introducing DVSN relevant material into curriculum are:
    - Exploit electives to influence curriculum e.g., adding project oriented special course.
    - Create interdisciplinary classes with projects requiring students from different disciplines to work together and make courses interesting for students.
    - Revise existing classes with new relevant material.
    - Create opportunities to improve course quality and allow participation in “large” multi-university courses.

Teaching methodology must adapt to how students learn today. Include active learning techniques such as gaming, novel and interactive applications, virtual reality. Interested schools need to create summer schools/courses/seminars and set the pre-requisites to include right set of courses.

Suggested Major Research Topics

Topic 1: Robust Scalable Video Networks for Wide Area Analysis

Disciplines Involved: Image Processing, Computer Vision, Pattern Recognition, Graphics, Databases, Learning, Real-time systems, Applications

Research Concentration:

1) Detecting, tracking and recognizing objects of interest in changing environmental conditions.
2) Extraction and manipulation of real-time sensory data for wide area object and activity recognition.
3) Simulating real environments for increased robustness and scalability of vision algorithms and systems.
4) Integrating analysis-by-synthesis and synthesis-by-analysis in a learning framework for increased robustness.
5) Strategies for synthesizing and analyzing data for many sensors and their performance characterization.
6) Recognizing objects and evolving activities over time and their interaction with databases.

Topic 2: Active, Distributed and Communication Aware Video Sensor Networks

Disciplines Involved: Image Processing, Computer Vision, Pattern Recognition, Distributed Computing, Communications and Control, Real-time Systems

Research Concentration:

1) Develop distributed algorithms for image processing, computer vision and pattern recognition to detect, track and recognize objects and actions.
2) Develop strategies for real-time control of sensors for robust and efficient feature acquisition, recognition and targeting.

3) Model communication constraints for operation of camera networks in a theater of operations.
4) Perform information theoretic analysis for dynamic optimization of networks for practical applications such as tracking, recognition and targeting.
5) Perform system theoretic analysis that includes aspects of communication, control, image processing, computer vision and pattern recognition, and develop fundamental theories and practical algorithms to achieve them.

Topic 3: Large Scale Heterogeneous Sensor Networks for Wide Area Analysis

Disciplines Involved: Image Processing, Computer Vision, Pattern Recognition, Distributed Computing, Fusion Architecture, Statistics, Performance Characterization, Aerial and Ground Vehicles, Applications

Research Concentration:

1) Physics and statistics-based multisensory fusion algorithms that include control and communication among various ground and aerial sensors.
2) Coordination of ground and aerial platforms for wide area robust performance for detection, tracking and recognition.
3) Integration of global trajectory analysis with local processing algorithms for detection, tracking and recognition.
4) Real-time sensing, monitoring and control for recognition and targeting.
5) Distributed fusion architectures for real-time processing, communication and control at different abstraction levels.
6) Analysis of complex behavior over long-term.
7) Develop strategies for dynamic optimization of available resources and their effects on performance.

Appendix

A. List of attendees in alphabetical order

Note: All the abstracts by participants are available on the workshop website:
http://videonetworks2009.cs.ucr.edu/

JK Aggarwal, The University of Texas at Austin
Abstract: **Sensor Networks and Recognition of Human Activities**

Hamid Aghajan, Stanford University
Abstract: **Vision: ideas for enabling Ambient Intelligence and serving Social Networks**

Narendra Ahuja, UIUC
Abstract: **Image Representation for Image Understanding**

Ian Akyildiz, Georgia Tech
Abstract: **Research Challenges for Wireless Multimedia Sensor Networks**

Rick Allan, BBN

Kevin Almeroth, UC-Santa Barbara

Norman Badler, UPenn
Abstract: **Simulating a Functional Populace**

Ruzena Bajcsy, UCBerkeley
Abstract: **Active Perception: past, present, and future**

Azer Bestavros, Boston University
Abstract: **Virtualization and Programming Support for Video Sensor Networks**

Bir Bhanu, UCR
Abstract: **VideoWeb: Design of a Wireless Camera Network for Real-time Monitoring of Activities**

Paul Brewer, ObjectVideo
Abstract: **Maritime Persistent Surveillance**

Mark Campbell, Cornell University
Abstract: **Sensing, Cooperation and Control in Networked Systems**

Rama Chellappa, UMD
Abstract: **Exploiting Sparsity, Geometry and Statistics for Video Processing and**

Understanding Using a Camera Network

Jie Chen, University of California
Abstract: **Best Achievable Tracking Performance Under Limited and Constrained Information Feedback**

Hui Cheng, Sarnoff Corporation
Abstract: **Real-Time Entity Tracking Using Wide Area Surveillance Videos**

Bojan Cukic, West Virginia University
Abstract: **Fault Tolerant Sensor Networks for Border Activity Detection**

Liyi Dai, US Army Research Office

Raju Damarla, US Army Research Laboratory

Larry Davis, UMD
Abstract: **Event modeling and recognition in camera networks**

Jim Davis, Ohio State University
Abstract: **Control, Registration, and Exploitation of Video Sensor Networks**

Sudhir Dixit, Center for Internet Excellence
Abstract: **Challenges of Wireless Communication in Video Sensing**

Chuck Dyer, University of Wisconsin - Madison
Abstract: **Tracking in camera networks using joint projective invariants**

Jay Farrell, U of CA Riverside

John Fisher, MIT CSAIL
Abstract: **Information-driven inference under resource constraints**

Arun Hampapur, IBM
Abstract: **Media Analytics Research at IBM**

Mary Ann Harrison, WVHTC Foundation
Abstract: **Tactical Analysis of Video Imagery**

Parag Havaldar, SONY Pictures, Imageworks
Abstract: **Performance driven character animation on a real production set using multiple cameras**

Glenn Healey, UC Irvine
Abstract: **Processing Multispectral/Hyperspectral Video**

Tom Henderson, University of Utah
Abstract: **Cognitive Video Sensor networks**

Jenq-Neng Hwang, University of Washington, Seattle
Abstract: **Intelligent Surveillance and Event Understanding in Distributed Embedded Camera Networks of A Large Scale Community**

Ted Isaacson, ONR / MTCSC

Ioannis Kakadiaris, University of Houston
Abstract: **Face Recognition: Your Face is Your Password**

Behzad Kamgar-Parsi, ONR

Aggelos Katsaggelos, Northwestern University
Abstract: **Content-based scalable video streaming in video sensor networks**

Iouri Kompaniets, Physical Optics Corporation
Abstract: **Advanced Hyperspectral Zoom Optics Sensor**

Rick Kremer, Logostech

Martin Kruger, Office of Naval Research

Vinod Kulathumani, West Virginia university
Abstract: **Collaborative face recognition using network of smart cameras**

Mohan Kumar, The University of Texas at Arlington
Abstract: **Collaborative Virtual Observation (CoVO) in Dynamic Environments**

Aditi Majumder, UCI
Abstract: **Ubiquitous Displays via a Distributed Framework of Projector-Camera Systems**

BS Manjunath, UCSB

Bogdan Matei, Sarnoff Corporation
Abstract: **Multi-Camera Tracking and Data Association**

Shean T McMahon, Physical Optics Corporation
Abstract: **Advanced Hyperspectral Zoom Optics System**

Gerard Medioni, University of Southern California
Abstract: **Distributed Vision: algorithms, scalability, forensics**

Sharad Mehrotra, UCI
Abstract: **SATWARE: a semantic enhanced middleware and database system for sentient**

spaces

Scott Midkiff, National Science Foundation

Vassilios Morellas, UMN
Abstract: **Linking Video Information Across Cameras**

Thinh Nguyen, Oregon State University
Abstract: **Towards building a robust video sensor network**

Antonio Ortega, University of Southern California
Abstract: **Challenges in Practical Distributed Video Compression**

Robert Pless, Washington University in St. Louis
Abstract: **Passive Vision: Observing the world while sitting still**

T V Prabhakar, Indian Institute of Science
Abstract: **An Energy Efficient Distributed Algorithm For Image Slicing in WSNs**

Ranjit Pradhan, Physical Optics Corporation

R R Venkatesha Prasad, Delft University of Technology
Abstract: **An Energy Efficient Distributed Algorithm for Image Slicing in Wireless Sensor Networks**

Faisal Qureshi, UOIT
Abstract: **Proactive Camera Control for Collaborative Sensing**

V. Ramesh, Siemens
Abstract: **Robust Video Understanding Systems - Review and Challenges**

Raghuveer Rao, Army Research Laboratory

Chinya Ravishankar, UC Riverside

Ray Rimey, Lockheed Martin
Abstract: **Recognizing Activity Structures in Massive Numbers of Simple Events Over Large Areas**

Amit Roy Chowdhury, University of California, Riverside
Abstract: **Video Understanding in Distributed Active Camera Networks**

Maya Rubeiz, Office of Naval Research

Venkatesh Saligrama, Boston University
Abstract: **Video Analytics in Multicamera Networks**

Wes Snyder, NCSU
Abstract: **Shape recognition Based on Accumulators**

Stefano Soatto, UCLA
Abstract: **From Shannon to Gibson: Actionable Information in Video**

Bi Song, UCR
Abstract: **Scene Analysis, Control and Communication in Distributed Camera Networks**

Tanveer Syeda-Mahmood, IBM Almaden Research Center

Demetri Terzopoulos, University of California, Los Angeles

Satish Tripathi, University at Buffalo, SUNY

Mohan Trivedi, University of California at San Diego
Abstract: **Distributed Video Networks in Intelligent Vehicles and Transportation Systems**

Yanghai Tsin, Siemens Corporate Research

Peter Tu, GE
Abstract: **Video Analytics from Homeland Protection to Theft Prevention and Crowd Analysis**

Pramod Varshney, Syracuse University
Abstract: **Sensor Selection and Information Fusion in Sensor Networks**

Rene Vidal, Johns Hopkins University
Abstract: **Distributed Scene Understanding**

Wayne Wolf, Georgia Tech
Abstract: **Distributed Smart Cameras**

Ming-Hsuan Yang, University of California at Merced
Abstract: **Visual Tracking with Online Multiple Instance Learning**

Allen Y Yang, UCB
Abstract: **Multiple-View Object Recognition in Band-Limited Distributed Camera Networks**

Avideh Zakhor, U.C Berkeley
Abstract: **Indoor localization using cameras and laser scanners**

B. Groups and group leaders.

Group 1: Video Processing and Video Understanding
Group Co-Leaders: **Rama Chellappa** (UMD), **Gerard Medioni** (USC)

Participants:

JK Aggarwal also group 2
Narendra Ahuja also group 6
Robert Pless
Vinod Kulathumani
Amit Roy Chowdhury also group 3
Stefano Soatto also group 2
Rene Vidal
Ming-Hsuan Yang

Bir Bhanu
Jim Davis also group 2
Larry Davis also group 6
V Ramesh also group 4
Wes Snyder also group 4
Bi Song
Yanghai Tsin
Allen Y Yang also group 4

Group 2: Simulation, Graphics, Cognition and Video Networks
Group Co-Leaders: **Demetri Terzopoulos** (UCLA), **Chuck Dyer** (U. Wisconsin)

Participants:

Ruzena Bajcsy also group 6
Jim Davis also group 1
Ioannis Kakadiaris
Aditi Majumder
Faisal Qureshi
Avideh Zakhor also group 6

JK Aggarwal
Norman Badler
Parag Havaldar also group 5
Tom Henderson also group 6
Stefano Soatto also group 1

Group 3: Wireless Video Sensor Networks, Communications and Control
Group Co-Leaders: **Antonio Ortega** (USC), **Venkatesh Saligrama** (BU)

Participants:

Ian Akyildiz
Jie Chen
Mohan Kumar
Thinh Nguyen
Pramod Varshney also group 6

Mark Campbell
Raju Damarla
Jay Farrell
John Fisher also group 6
Aggelos Katsaggelos also group 6
Amit Roy Chowdhury also group 1
Satish Tripathi

Group 4: Distributed Embedded Cameras and Real Time Video Analysis
Group Co-Leaders: **Hamid Aghajan** (Stanford), **Paul Brewer** (Object Video)

Participants:

Jenq-Neng Hwang also group 6
Sharad Mehrotra also group 6
Ray Rimey also group 5
Wes Snyder also group 1
Mohan Trivedi also group 6
Wayne Wolf (phone/internet)
Allen Y Yang also group 1

Rick Allan
Azer Bestavros
Rick Kremer
V Ramesh also group 1
Raghuveer Rao

Group 5: Applications
Group Co-Leaders: **Glenn Healey** (UCI), **Bogdan Matei** (Sarnoff)

Participants:

Bojan Cukic
Mary Ann Harrison
Iouri Kompaniets

R Prasad/T Prabhakar

Parag Havaldar also group 2
Ted Isaacson
Shean T McMahon
Ranjit Pradhan
Ray Rimey also group 4
Peter Tu also group 6

Group 6: Educational Opportunities and Curriculum Development
Group Co-Leaders: **Sharad Mehrotra** (UCI), **Jenq-Neng Hwang** (UW)

Participants:

Narendra Ahuja also group 1
Ruzena Bajcsy also group 2
Larry Davis also group 1
John Fisher also group 3
Tom Henderson also group 2
Aggelos Katsaggelos also group 3
Mohan Trivedi also group 4
Peter Tu also groups 5
Pramod Varshney also group 3
Avideh Zakhor also group 2

C. Talks with titles and presenters.

Plenary Presentations

Past, Present and Future of Active Vision Ruzena Bajcsy (UCB)

Past, Present and Future of Motion Analysis JK Aggarwal (UT Austin)

Event Modeling and Recognition in Camera Networks Larry Davis (UMD)

Robust Video Understanding Systems - Review and Challenges V. Ramesh (Siemens)

Simulating a Functional Populace Norm Badler (UPenn)

Information-Driven Inference under Resource Constraints John Fisher (MIT)

Research Challenges for Wireless Multimedia Sensor Networks Ian Akyildiz (GTech)

Content-based Scalable Video Streaming in Video Sensor Networks Aggelos Katsaggelos (Northwestern)

Sensing, Cooperation and Control in Networked Systems Mark Campbell (Cornell)

snBench: Virtualization and Programming Support for Video Sensor Networks Azer Bestavros (BU)

Video Analytics from Homeland Protection to Theft Prevention and Crowd Analysis Peter Tu (GE)

VideoWeb: A Network of Wireless Video Cameras Bir Bhanu (UCR)

Education Opportunities: Computer Science Perspective Thomas Henderson (UU)

Education Opportunities: Electrical Engineering Perspective Narendra Ahuja (UIUC)

ONR Programs, Martin Kruger (ONR)

NSF Opportunities, Scott Midkiff (NSF)

ARO Opportunities, Raghuveer Rao (ARO)

Group Presentations to the Entire Workshop and Discussions

Group 1: Video Processing and Video Understanding
Group 2: Simulation, Graphics, Cognition and Video Networks
Group 3: Wireless Video Sensor Networks, Communications and Control
Group 4: Distributed Embedded Cameras and Real Time Video Analysis
Group 5: Applications
Group 6: Educational Opportunities and Curriculum Development

Recommendation by the Groups for Research Directions and Educational Opportunities/Curriculum Development

Group Presentations and Discussions

Group 1: Video Processing and Video Understanding

Exploiting Sparsity, Geometry and Statistics for Video Processing and Understanding Using a Camera Network Rama Chellappa (UMD)

Distributed Vision: algorithms, scalability, forensics Gerard Medioni (USC)

Presentations by other group participants (see abstracts on the website)

Group 2: Simulation, Graphics, Cognition and Video Networks

Virtual Vision: A Simulation Framework for Camera Sensor Networks Research Demetri Terzopoulos (UCLA)

Tracking in camera networks using joint projective invariants Chuck Dyer (U. Wisconsin)

Presentations by other group participants (see abstracts on the website)

Group 3: Wireless Video Sensor Networks, Communications and Control

Video Analytics in Multicamera Networks Venkatesh Saligrama (BU)

Challenges in Practical Distributed Video Compression Antonio Ortega(USC)

Presentations by other group participants (see abstracts on the website)

Group 4: Distributed Embedded Cameras and Real Time Video Analysis

Vision: ideas for enabling Ambient Intelligence and serving Social Networks Hamid Aghajan (Stanford)

Maritime Persistent Surveillance Paul Brewer (Object Video)

Presentations by other group participants (see abstracts on the website)

Group 5: Applications

Processing Multispectral/Hyperspectral Video Glenn Healey (UCI)

Multi-Camera Tracking and Data Association Bogdan Matei (Sarnoff)

Presentations by other group participants (see abstracts on the website)

Group 6: Educational Opportunities and Curriculum Development

Educational Opportunities and Curriculum Development Sharad Mehrotra (UCI), **Jenq-Neng Hwang** (UW)

Presentations by other group participants (see abstracts on the website)