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Editorial

Visual Sensor Networks

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Research into the design, development, and deployment of networked sensing devices for high-level inference and surveillance of the physical environment has grown tremendously in the last few years. This trend has been motivated, in part, by recent technological advances in electronics, communication networking, and signal processing.

Sensor networks are commonly comprised of lightweight distributed sensor nodes, such as low-cost video cameras. There is inherent redundancy in the number of nodes deployed and corresponding networking topology. Operation of the network requires autonomous peer-based collaboration amongst the nodes and intermediate data-centric processing amongst local sensors. The intermediate processing known as in-network processing is application-specific. Often, the sensors are untethered so that they must communicate wirelessly and be battery-powered. Initial focus was placed on the design of sensor networks in which scalar phenomena such as temperature, pressure, or humidity were measured.

It is envisioned that much societal use of sensor networks will also be based on employing content-rich vision-based sensors. The volume of data collected as well as the sophistication of the necessary in-network stream content processing provides a diverse set of challenges in comparison generic scalar sensor network research. Applications that will be facilitated through the development of visual sensor networking technology include automatic tracking, monitoring and signaling of intruders within a physical area, assisted living for the elderly or physically disabled, environmental monitoring, and command and control of unmanned vehicles.

Many current video-based surveillance systems have centralized architectures that collect all visual data at a central location for storage or real-time interpretation by a human operator. The use of distributed processing for automated event detection would significantly alleviate human operators from mundane or time-critical activities, and provides better network scalability. Thus, it is expected that video surveillance solutions of the future will successfully utilize visual sensor networking technologies.

Given that the field of visual sensor networking is still in its infancy, it is critical that researchers from the diverse disciplines including signal processing, communications, and electronics address the many challenges of this emerging field. This special issue aims to bring together a diverse set of research results that are essential for the development of robust and practical visual sensor networks.

In the first paper entitled "Determining vision graphs for distributed camera networks using feature digests" by Chen et al., the authors present a new framework to determine image relationships in a large network of visual sensors in which communication between sensor nodes is constrained. The work focuses, in part, on the problem of estimating the *vision graph* for an ad hoc visual sensor network, in which a node represents each camera and an edge appears between a node pair if the two cameras jointly image a sufficiently large part of the observation area. The approach is decentralized, requires no camera order, and works under limited communication. The authors demonstrate how camera calibration algorithms that exploit the vision graph can perform in a distributed manner.

In the next paper by Devarajan and Radke entitled "Calibrating distributed camera networks using belief propagation," a fully distributed 3D camera calibration approach that leverages belief propagation is presented. Here, each camera node communicates only with its neighbors that image a sufficient number of scene points. The authors demonstrate how the natural geometry of the system and the formulation of the estimation problem give rise to statistical dependencies that can be leveraged in a probabilistic framework. Simulations on simulated and real data demonstrate the potential of the technique.

Dependencies among cameras are also exploited in "A novel distributed privacy paradigm for visual sensor networks based on sharing dynamical systems" by Luh et al. The authors address the problem of distributed privacy protection for visual sensor networks with correlated readings. Here, a novel paradigm based on the control of dynamical systems is shown to have potential to protect visual data against both eavesdropping and tampering. A low-cost algorithm, named TANGRAM, is introduced that provides a robust form of obfuscation. Both theoretical results and practical simulations demonstrate the feasibility of this collaborative approach for wireless surveillance applications.

In "Collaborative image coding and transmission over wireless sensor networks," Wu and Chen propose a novel collaborative image coding and transmission scheme for visual sensor networks. Here, spatial shape matching is applied to effectively exploit correlations among cameras in order to provide greater efficiency in terms of visual encoding. Temporal redundancy, when background scene information is stationary, is also exploited to reduce transmission bandwidth. Target detection is performed against a static background and the associated details are transmitted. Energy reduction is evidenced from the use of this collaborative approach to distributed image compression.

In the next paper, entitled "efficient on-demand image transmission in visual sensor networks," Chow et al. investigate how to optimize the energy resources when transmitting visual data on-demand to a mobile node via judicious path selection for tracking applications. A distributed protocol requiring only local information is proposed and evaluated through simulations.

Next, Chen et al. propose a mobile agent-based directed diffusion (MADD) communication paradigm that is designed to be more suitable for visual sensor networking. Empirical arguments and simulations demonstrate the potential of the approach in improving performance metrics such as network lifetime in comparison to straightforward directed diffusion.

A multiagent framework for video sensor-based coordination in surveillance applications is proposed by Patricio et al. in "multiagent framework in visual sensor networks." Essentially, a software agent is embedded in each camera controlling the capture parameters. Coordination, in order to extend surveillance functionalities such as continuity of tracking, is based on the exchange of high-level messages among agents and via use of an internal symbolic model to interpret the inference results from the messages of other agents.

In "Autonomous robot navigation in human centered environments based on 3D data fusion," Steinhaus et al. study efficient navigation of mobile platforms in dynamic, human centered environments. They present data fusion algorithms that are implemented for 3D world modeling and real-time path planning for the MEPHISTO navigation system currently developed by the authors.

Awad et al. address the problem of action classification using real-time multiple video signals collected from homogeneous sites in "Incremental support vector machine framework for visual sensor networks." A new framework is proposed based on incremental support vector machines. Experimental results are provided for behavioral classification of motions involving humanoid limbs.

It is clear that visual sensor networking is a field of growing activity in which innovations in applied signal processing interact with emerging applications and technology. This special issue is intended to provide an overview of the area through an exposition of timely research in the field. We hope that this collection inspires continued research progress, greater debate, and increased interaction among the diverse parties involved in its evolution.

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Deepa Kundur was born and raised in Toronto, Canada. She received the B.A.Sc., M.A.Sc., and Ph.D. degrees all in electrical and computer engineering in 1993, 1995, and 1999, respectively, from the University of Toronto, Canada. In January 2003, she joined the Department of Electrical Engineering at Texas A&M University, College Station, where she is a member of the Wireless Communications Laboratory and holds the position of Assistant Professor. Before joining Texas A&M, she was an Assistant Professor at the Edward S. Rogers Sr. Department of Electrical and Computer Engineering at the University of Toronto. Her research interests include privacy and protection for scalar and broadband sensor networks, multimedia security, digital rights management, and steganalysis for computer forensics. She is an Associate Editor for the IEEE Transactions on Multimedia, IEEE Communication Letters, EURASIP Journal on Information Security, and Journal on Peer-to-Peer Networking and Applications. She currently serves as the Vice Chair of the Security Interest Group of the IEEE Multimedia Communications Technical Committee. She has won numerous teaching and research awards including the 2006 Association of Former Students Distinguish Achievement Award for College-Level Teaching and the 2005 Tenneco Meritorious Teaching Award.

Ching-Yung Lin received his Ph.D. degree from Columbia University in electrical engineering. Since October 2000, he has been a Research Staff Member in IBM T. J. Watson Research Center, where he is currently leading projects on the IBM large-scale video semantic filtering system and people mining system. He is also an Adjunct Associate Professor at Columbia University and an Affiliate Associate Professor at the University of Washington, Seattle. His research interest is mainly focused on multimodality signal processing and understanding, with applications on distributed computing, embedded vision system, social computing, and security. He is the Editor of the Interactive Magazines of the IEEE Communications Society, an Associate Editor of the IEEE Transactions on Multimedia, and an

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Chun-Shien Lu received the Ph.D. degree in electrical engineering from National Cheng-Kung University, Tainan, Taiwan, in 1998. From October 1998 to July 2002, he joined Institute of Information Science, Academia Sinica, Taiwan, as a Postdoctoral Fellow for his military service. From August 2002 to June 2006, he was an Assistant Research Fellow at the same institute. Since July 2006, he has been an Associate Research Fellow. His current research interests mainly focus on various topics (including security, networking, and signal processing) of multimedia and time-frequency analysis of signals. He organized a special session on multimedia security in the 2nd and 3rd IEEE Pacific-Rim Conference on Multimedia, respectively (2001–2002). He coorganized two special sessions (in the area of media identification and DRM) in the 5th IEEE International Conference on Multimedia and Expo (ICME), 2004. He was a Guest Coeditor of EURASIP Journal on Advances in Signal Processing, special issue on visual sensor network in 2005. He has owned two US patents, two ROC patents, and one Canadian patent in digital watermarking. He has received the Paper Awards many times from the Image Processing and Pattern Recognition Society of Taiwan for his work on data hiding. He was a corecipient of a National Invention and Creation Award in 2004. He is the editor of the book "*Multimedia Security: Steganography and Digital Watermarking Techniques for Protection of Intellectual Property*" (ISBN 1-59140-275-1). He is a Member of the IEEE and ACM.