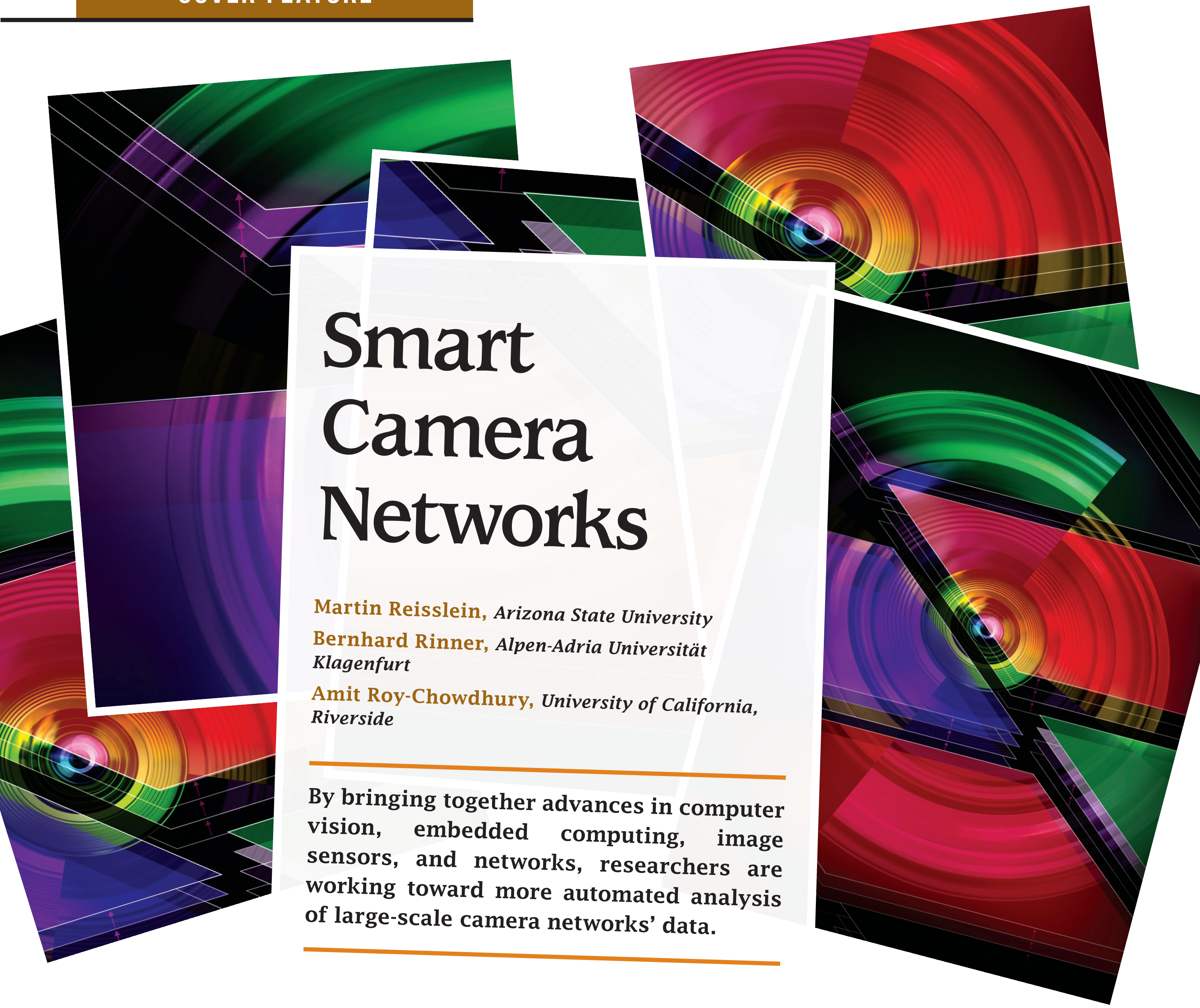

Smart Camera Networks

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By bringing together advances in computer vision, embedded computing, image sensors, and networks, researchers are working toward more automated analysis of large-scale camera networks' data.

Camera networks that capture data in both private and public environments are now ubiquitous and have applications in security, disaster response, environmental monitoring, and smart environments, among others. However, the captured data from camera networks is, for most applications, primarily stored or analyzed manually. Processing this data manually is an immensely tedious task, and some level of automation in the overall system would be highly desirable and beneficial. Thanks to the confluence of simultaneous recent advances in four key technologies—computer vision, image sensors, embedded computing, and sensor networks—*smart* camera networks have emerged.

AN EMERGING FIELD

Smart camera networks are real-time, distributed, embedded systems that perform computer vision tasks using multiple cameras; they are considered an emerging technology for various applications.[1–4] But these networks pose problems for a wide range of hardware-, software-, and system-level design issues. For instance, on the hardware side, camera networks require energy-efficient, small computing node design with the ability to capture and process visual information.[5] On the software side, these networks require scalable, robust, and computationally efficient video analysis methods.[6,7] On the system side, smart camera networks require adaptive control and coordination[8] to increase flexibility, ease deployment, protect security and privacy, and manage the middleware that links different sensor control modules[9,10] to higher-order data processing and management. Camera networks are a fascinating area for current research—although a general body of knowledge around many of these issues exists, the nature of cameras and the information-rich data they generate calls for more specialized attention in this area.

Camera networks are a fascinating area for current research—the nature of cameras and the information-rich data they generate calls for an increase in specialized attention to this area.

This special issue provides an introduction to this emerging field, reports recent results from active research, and envisions the challenges that future research will address. Although several conferences, journals, and books on this topic have appeared in the past decade, almost all focused on research from specialized areas, such as computer vision, networks, embedded systems, and so on. In contrast, we offer a more general computing and engineering overview and bring together a collection of advances in different fields to foster novel applications for future developments.

IN THIS ISSUE

The six feature articles presented in this issue address video analysis, system design, sensing, and sensor networks.

Robust video analysis in a camera network requires building models of the objects in the scene, such as people or vehicles. In "Camera Networks for Healthcare, Teleimmersion, and Surveillance," Ching-Hui Chenand his colleagues address this issue for both overlapping and nonoverlapping networks of cameras. In particular, they look at three application domains: surveillance for security and monitoring, teleimmersion for smart environments, and healthcare. The challenges addressed include markerless motion capture, which provides raw data from which the object models are built, and calibration of camera networks, which is required to map objects from the image planes of individual cameras to the 3D world. The article also provides a survey of the existing methods and systems in these application areas.

Camera networks for surveillance applications require a careful tradeoff between cost and performance. In "Wireless Smart Camera Networks for the Surveillance of Public Spaces," Kevin Abas, Caio Porto, and Katia Obraczka present a taxonomy for wireless smart camera network systems. Using their taxonomy, the authors classify cutting-edge wireless surveillance systems and then introduce the Solar Wi-Fi Energy-Efficient Tracking camera system (SWEETcam), which strives to maximize the cost–performance tradeoff for surveillance applications.

Although camera networks can be built from specialized camera node systems, such as SWEETcam, consumers increasingly carry mobile devices with built-in cameras, such as smartphones and tablets. In "Integrating Consumer Smart Cameras into Camera Networks: Opportunities and Obstacles," Andrea Prati and Faisal Qureshi examine how to integrate consumers' smart cameras into camera networks by reviewing innovations in mobile vision—such as computer vision and image-processing techniques for consumer devices with cameras—and then discuss the broad technical issues arising from the integration of consumer cameras into camera networks, including geometric calibration, time synchronization, and network topology.

Compressive sensing (CS) and sparse representations are promising approaches to dealing with "big data" in camera networks, which have some of the largest volumes of data in any sensing system. In "Toward Compressive Camera Networks," Kaushik Mitra and his colleagues, explore approaches for addressing this data deluge and scalability in large-scale camera networks using recent advances in CS. The authors highlight trends that transcend specific applications and speculate about the possibility of leveraging CS techniques to completely restructure camera networks, which gives an interesting vision for the future.

Emerging 3D video is very computationally demanding and can overwhelm camera sensor nodes or quickly deplete their energy resources. Offloading compute-intensive 3D video processing to the cloud can relieve the camera nodes. In "Cloud-Assisted Smart Camera Networks for Energy-Efficient 3D Video Streaming," Zhangyu Guan and Tommaso Melodia review state-of-the-art multimedia cloud computing techniques and present architectures for integrating mobile cloud computing services with camera networks, along with a range of video-processing steps—from cloud-assisted video encoding to cloud-assisted video streaming and decoding.

Smart camera networks require applications that facilitate adaption to unforeseen conditions, changing tasks, and limited resources. In "Self-Reconfigurable Smart Camera Networks," Juan C. SanMiguel and his colleagues identify the key components—cameras, network, environment, tasks, and performance—for dynamically changing a camera network configuration. They also discuss how these intertwined components achieve self-reconfiguration while addressing the major smart camera network challenges—namely, topology discovery and self-calibration, resource and task allocation, and active vision.

We hope this special issue inspires further exploration and research to address the many open challenges of smart camera networks. Advancing smart camera networks' functionality and enabling their integration into the emerging Internet of Things promises many benefits for humanity, as well as presents steep challenges.

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