Abstract

Thanks to the decreasing manufacturing cost, size, and energy consumption of CMOS image sensors, wireless cameras are becoming ubiquitous. Visual monitoring applications are numerous, ranging from security to environmental monitoring. Among these, we are particularly interested in natural hazards, where a visual feedback from the monitored area can be used to detect potentially critical situations, such as avalanches, rock slides or fires. One of the key aspects of a wireless camera system design is the reduction of its energy consumption to extend its lifetime without replacing or recharging the batteries of nodes. This is particularly challenging for visual monitoring, since cameras generate much higher data rate than traditional sensors. Another challenge of wireless visual monitoring is the vulnerability of the system. Because deployments are often located in remote and uncontrolled environments (e.g., mountain regions) where nodes are exposed to environmental hazards and extreme weather conditions, the reliability of a single camera system would be seriously compromised.

A multi-camera wireless monitoring system provides a solution to these two challenges. First, multiple cameras can collaboratively share the monitoring tasks and hence reduce energy consumption on each camera. Second, physically distributed cameras also share environmental risks. In case of camera failures, the remaining cameras can dynamically reconfigure and continue to monitor the scene of interest. In this thesis we address the question of how cameras can collaborate to efficiently monitor the environment and minimize the energy consumption.

More precisely, we study two fundamental problems, namely, sampling and coding. The first part of the thesis investigates a cooperative sampling scheme that equally distributes the sampling task among all the cameras. We prove that the optimal spreading of cameras’ sampling operations is a uniform configuration. To allow the cameras to adaptively establish the correct sampling configuration, we propose a distributed, self-organizing algorithm, that exploits the broadcast nature of wireless communications. We show the effectiveness of this algorithm in fully connected networks, partially connected networks, and under overhearing losses.

The second part of the thesis investigates the cooperative coding methods for static images, videos, and event detection applications. First, for static images captured by distributed cameras, we propose a distributed successive refinement coding scheme. The theoretical study of the Gaussian case proves that this scheme is successively refinable on the rate-distortion limit of distributed coding. Practical experimental results on multi-view images show that it operates within 3dB to the distributed coding bound. Secondly, for videos captured by distributed cameras, we propose and evaluate various cooperative coding schemes for achieving efficient video compression.
Experimental results on a two-camera system show that the per-camera consumption can be reduced by up to 50% with respect to a single-camera system. Finally, for event detection applications, we propose an energy-efficient coding algorithm that transmits only event-specific information and achieves much lower communication rates than conventional video compression schemes. Experiments on a real-world multi-view dataset show an optimal per-camera energy scaling that is inversely proportional to the number of cameras, without introducing distributed losses.

**Keywords:** wireless camera network, environmental monitoring, sampling theory, successive refinement, distributed source coding, multi-view images, video compression, energy harvesting, energy efficiency, distributed smart cameras.