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Distributed Estimation, Coding, and Scheduling in Wireless Visual Sensor Networks

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In this thesis, we consider estimation, coding, and sensor scheduling for energy efficient operation of wireless visual sensor networks (VSN) to prolong the lifetime of these wireless systems. Motivated by a telepresence setting in visual sensor networks, we first consider an abstract setting for investigating efficient estimation and coding where we model the captured data by a joint Gaussian distribution. The geographically dispersed sensors acquire indirect, noisy observations pertaining to a desired signal. A central processor (CP) communicates with these sensors via a rate-constrained channel and estimates the desired signal. In a simplified scenario where information from one sensor is to be sent to the CP that already has information regarding the desired signal, we establish a decomposed structure for the optimal encoding of the local observation: a first pre-processing step to extract relevant information from local observations, followed by a second step of side-informed encoding. In the general scenario consisting of multiple sensors, we present a sequential framework to recursively utilize the separation. Simulation results demonstrate that constructions obtained using the proposed decomposition closely match nonconstructive information theoretic bounds for the problem.

We next propose a novel code construction and design method for low-density parity check accumulate (LDPCA) codes used for rate-adaptive distributed source coding. We propose a code construction using non-uniform splitting, in contrast to the uniform splitting used in literature. We also develop methods to analyze the proposed LDPCA codes using density evolution, based on which code search strategies are developed to find good LDPCA codes. Simulation results show the proposed code design outperforms the conventional LDPCA code design, and provides state-of-the-art performance.

The final part of the thesis addresses the networking aspect of VSNs considering sensor scheduling and energy allocation in a telepresence application, where visual coverage over a monitored region is obtained by deploying image sensors (cameras) and a CP coordinates these cameras in order to gather required visual data. We model the network lifetime as a stochastic random variable that depends upon the coverage geometry for the cameras and the distribution of data requests over the monitored region, two key characteristics that distinguish our problem from other WSN applications. By suitably abstracting this model of network lifetime and utilizing asymptotic analysis, we propose lifetime-maximizing camera scheduling and energy allocation strategies. The effectiveness of the proposed strategies is validated through simulations.