Signal Processing for Novel Acquisition Technologies

Abstract: Signal processing plays a central role in exciting new information acquisition technologies. I advocate an integrated view of signal modeling, physical device modeling, and algorithms for inverse problems. The sampling of results provided in this talk will exemplify improved theoretical understanding of inverse problems, improved performance in established applications, and innovative system architectures for acquisition that are inspired by this holistic view.

The talk will concentrate on the following two main topics: Compressed sensing has brought the use of sparsity- and compressibility-based signal models to the forefront of data acquisition and inverse problems. Inspired by the conservatism of the well-known analyses of compressed sensing, we develop instead a Bayesian analysis framework. Under the common assumption of replica symmetry, we prove a convergence result that provides a simple scalar equivalent problem from which one can make various asymptotically-exact performance computations. The method applies to least squares estimation with any separable regularizer, including but not limited to the $l_1$ regularization that has been extensively studied of late. The accuracy of our analysis makes it a useful system design tool, and the analysis also inspires new algorithmic approaches.

LIDAR systems and time-of-flight cameras use time elapsed from transmitting a pulse and receiving a reflected response, along with scanning by the illumination source or a 2D sensor array, to acquire depth maps. We introduce a method for compressive acquisition of scene depth with high spatial and range resolution using a single, omnidirectional, time-resolved photodetector and no scanning components. In contrast to compressive photography, the information of interest -- scene depths -- is nonlinearly mixed in the measured data. To overcome this aspect of the inverse problem, the depth map reconstruction relies on parametric signal modeling of the optical impulse response of piecewise-planar scenes. Through the use of parametric deconvolution, we achieve much finer depth resolution than suggested by the illumination pulse width and detector bandwidth alone. This opens up possibilities for compact, low-power 3D sensing for applications such as gestural interfaces and augmented reality in mobile devices, which we discuss as well.