Many branches of science and engineering are concerned with the problem of recording signals from physical phenomena. However, an acquisition system does not always directly provide the high-quality signal representations that a given application may require. Signal processing and the study of inverse problems offer a set of powerful tools to recover a good signal quality from altered raw measurements.

After a preliminary overview of the field, this thesis presents three main contributions. They involve, in various degrees, the interconnected constituents of a regularized inverse problem: the forward model, the prior or regularization, the data fidelity, and the recovery method.

The first and most theoretical contribution focuses on recovering a key structural property of a sparse signal, its support. It discusses guarantees associated to a convex optimization method with atypical fidelity, e.g., using a non-Euclidean norm. The second part introduces a method for learning a convolutional dictionary, which is to be used as a multimodal imaging prior. This constitutes, indeed, a practical way of sharing information between several imaging modalities, such as depth and light intensity, thus enhancing the reconstruction quality associated to each inverse problem. The last contribution revolves around the design of two multispectral compressive imaging strategies using spectrally filtered sensors. The first scheme relies on a generalized inpainting formulation in the multispectral volume, while the second system leverages the principles of compressed sensing from coded optical convolutions. The chapter studies and compares these two sensing models and discusses implementation challenges and tradeoffs. Each part of the thesis involves a detailed analysis that is validated by numerical experiments. The dissertation concludes with a discussion about the perspectives and open questions.

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