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論 文 要 旨

THESIS SUMMARY

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要旨（英文800語程度）
Thesis Summary（approx.800 English Words ）

This dissertation proposes convex optimization techniques for remote sensing data analysis. Remote sensing is a measurement technique to reveal the properties of target materials without getting close to them. Observed remote sensing data often suffer from various severe degradations caused by the conditions of the measurement environments and processes. These severe degradations adversely affect a wide range of tasks that provide information contributing to various applications. In addition, measurement costs are often expensive, making it difficult to obtain large amounts of data. Therefore, it is essential to analyze low-quality and small amounts of data to provide helpful information.

A promising approach is to formulate analysis tasks as optimization problems and then solve the problems with optimization algorithms. For the further development of remote sensing data analysis, it is essential to flexibly combine multiple data regularizations and degradation characterizations for the designs of optimization problems and to automatically construct algorithms for the optimization problems, i.e., to establish a framework that can handle a wide range of all target data and tasks. The bottleneck in establishing such a framework is due to parameters included in optimization problems and algorithms. Since these parameters significantly affect the analysis performance and running time, they need to be set appropriately. In terms of parameter settings, remote sensing data analysis should be flexible and reliable to cope with the interdependence of parameters within optimization problems (referred to as regularization parameters) and the difficulty of determining parameters of optimization algorithms (referred to as stepsizes).

To this end, we establish novel convex optimization techniques for remote sensing data analysis with the following two approaches. First, to eliminate the interdependence of regularization parameters, we introduce constraint modeling of prior knowledge. The appropriate parameters associated with constraints are invariant with the change of data regularizations and degradation characterizations. In addition, the constraint parameters for noise characterization can be determined from the statistical information of noise. Second, we develop a method that employs the structure of an optimization problem to resolve the difficulty of determining stepsizes. This allows us to set the appropriate stepsizes for any optimization problems. Furthermore, the explicit reflection of the structure of an optimization problem improves the reliability of stepsize determination.

In Chapter 3, we design a general framework for handling various types of target images and novel characterization for stripe noise, which is often present in remote sensing. Removing stripe noise, i.e., destriping, from remote sensing images is an essential task in terms of visual quality and subsequent processing. To establish a novel destriping framework, we formulate destriping as a nonsmooth convex optimization problem involving a general form of image regularizations and the flatness constraint, which is a newly-introduced stripe noise characterization. The constraint mathematically models that the intensity of each stripe is constant along one direction, resulting in a strong characterization of stripe noise. To solve the optimization problem, we also develop an efficient algorithm based on the preconditioned primal-dual splitting algorithm (P-PDS). The effectiveness of our framework is demonstrated through destriping experiments, where we comprehensively compare combinations of a variety of image regularizations and stripe noise characterizations using HS images and IR videos.

In Chapter 4, we propose a method for designing stepsizes of P-PDS, an efficient algorithm that solves nonsmooth convex optimization problems, called an Operator norm-based design method of Variable-wise Diagonal Preconditioning (OVDP). First, OVDP constructs diagonal stepsizes using (upper bounds) of the operator norms of the linear operators included in optimization problems, thus explicitly reflecting their structures. Furthermore, since OVDP takes a variable-wise preconditioning approach, it keeps any proximity operator analytically computable. We also prove that our stepsizes satisfy the convergence condition of P-PDS. Finally, we demonstrate the effectiveness and usefulness of OVDP through applications for mixed noise removal of HS images, HS unmixing, and graph signal recovery.

In Chapter 5, we introduce the constraint modeling and the problem structure-based stepsize design to establish a novel noise robust method of HS unmixing, which is the process of decomposing an HS image into material-specific spectra (endmembers) and their spatial distributions (abundance maps). Our method employs, in addition to the two existing regularizations for abundance maps, regularizations for the HS image reconstructed by mixing the estimated abundance maps and endmembers. This strategy makes the unmixing process much more robust in highly noisy scenarios, under the assumption that the abundance maps used to reconstruct the HS image with desirable spatio-spectral structure are also expected to have desirable properties. Furthermore, with constraint modeling including our flatness constraint, our method is designed to accommodate a wider variety of noise including stripe noise, which facilitates regularization parameter settings. To solve the formulated optimization problem, we develop an efficient algorithm based on P-PDS with our stepsizes design method based on the problem structure. Experiments on synthetic and real HS images demonstrate the advantages of our method over existing methods.