Development of Fast Sparse Representation Super-resolution Methods for Multispectral Remote Sensing Applications

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Chapter 6

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6.1 Summary

In this thesis, we focus on to develop SISR algorithms based on sparse representations for remote sensing applications. As we know that performance of sparse representation techniques highly depends on the quality of trained dictionary, in the first work focus is given for the development of an improved overcomplete dictionary from MS images built on highly relevant textural features extracted from MCA-based image decomposition and analysis. In SR, the sparse overcomplete dictionaries are trained using images, which are of similar origin and having high spatial resolution. However, the spatial resolution of MS images in the training dataset of our first work are of low spatial resolution. In order to circumvent the above limitation, we next apply the concept of pansharpening for image fusion. In particular, we collect images from the QuickBird MS imagery, where an HR panchromatic or PAN band is provided along with the LR spectral bands. We train a LR-HR dictionary pair from the HR PAN image and reconstruct each LR band using sparse representation over these learned dictionaries. It is observed that by using the standard sparsity prior alone to regularize the SR problem can not provide sufficient enhancement of the visual quality as well as the quantitative evaluation metrics of the reconstructed images. We, therefore, further explore other sparse representation or sparsity patterns involving concepts, like self-learning, group-sparsity, joint-sparsity, etc., to develop novel MS image SR algorithms. It is found that considering prior information, like the non-local similarity in MS images promoting joint patch-groups sparsity significantly improves the performance of traditional patch-based sparse representation for image SR. Additionally, by incorporating both patch and group-patch into a common framework of ADMM, we propose a joint sparse representation based algorithm for MS image SR. It is able to perform reasonably better in comparison to the state-of-the-art SR methods including the trending convolutional neural network (CNN)-based deep learning works.

Sparse representation-based methods are generally computationally expensive as they need to solve several regularization problems in iterative fashion for every patch or patch-groups. Moreover, it takes time in extracting complex image features which is performed prior to the sparse representation step. Considering these computational limitations, we exploit the high performance computing environment of PARAMTEZ cluster for multicore parallel programming in the proposed work. For this, OpenMP parallel programming features are used to convert the sequential algorithms into parallel one and speed-up the overall algorithm by implementing it across several processor cores simultaneously. Also, a parallel processing embedded hardware implementation is done for sparse representation-based MS image SR using CUDA programming with GPGPU in the MATLAB environment. Focus is given to implement the proposed parallel algorithm on a workstation equipped with NVIDIA's Quadro P5000 GPU card and achieve acceleration in it's execution. Experiments are conducted using real multispectral satellite images collected from publicly available standard databases and real-time datasets provided by Indian Space Research Organization (ISRO). Different remote sensing image analysis techniques, e.g. end-members identification, land cover classification, etc., are performed on the reconstruct images to emphasize the importance of the proposed work for real-world applications.

6.2 Future research scopes

Sparse representation is dominantly used for solving the ill-posed problems in image processing. With recent developments in sparsity promoting regularization constraints/priors fueled by efficient ℓ_1-solvers and adaptive dictionary learning strategy, there is ample scope for future research in image SR dedicated to practical remote sensing applications. Here, we provide a few possible future works related to MS image SR. These are as follows:

A. Spatial and spectral super-resolution:

The proposed work basically performs single image SR from each LR band to obtain a HR MS image by merging the reconstructed bands. However, future works can be done to enhance both spatial and spectral resolutions by taking all the bands simultaneously in the sparse representation problem. It may lead to additional regularization term besides the sparsity prior to include the spectral aspects of the image.

B. New feature extraction scheme:

Feature extraction is an important part of image SR methods. It reflects the quality of the dictionary trained as well as performance of sparse representation. In this thesis, we have shown feature extraction techniques, like gradient features using HPFs, Sobel operators, point features using the Laplacian operator, texture features using MCA decomposition, etc. Future work can be continued to explore new feature extraction schemes that can provide other meaningful features in reproducing the HR image.

C. Evaluation parameter of MS image SR:

The usual image quality evaluation metrics, like PSNR, SSIM, RMSE, etc., do not have any spectral significance. Few metrics e.g. ERGAS, SAM, etc., are used in this work for comparing spectral reconstructions. However, these measures are mostly defined for hyper-spectral images which consists a high number of spectral bands. Researchers can explore new evaluation methods to come up with a new parameter that may simultaneously index both spatial and spectral quality of the super-resolved images.

D. Deep learning-based approach:

If we talk about performance, it is needless to mention that deep learning-based methods are now outperforming the traditional techniques in signal and image processing with the availability of highly structured training data and required computational platforms. However, if the test data is random i.e. it may be from any satellite, a DL-model trained on one dataset will not work for a test image from another dataset. So, we prefer to develop an adaptive super-resolution algorithm, which uses the single input image only for dictionary learning. Research works may be further carried out to find if existing DL-based models trained on another dataset can be utilized for SR of a new test image without training from scratch. This may give rise to novel SR methods that are fit for real-time remote sensing applications.