Some Approaches for Hyperspectral Image Compression

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by

Yaman Dua

यमन दुआ

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY
(BANARAS HINDU UNIVERSITY)
VARANASI - 221005

Roll No. 18071004

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Chapter 6

Conclusions and Future Work

This chapter summarizes the work contained in this thesis. Some suggestions for future research are also given.

6.1 Conclusion

The recent advancement in the field of electronics has led to development of sensors that capture the image of an area or object in spectral-domain along with spatial information. Due to continuity of spectral domain in HSIs, it is difficult to store, process, analyze or transmit the critical information contained in it. Reduction in the image size is the basis of the development of the compression algorithm since it gives many benefits to the HS analysis. A large dataset is required to validate the results of such algorithms. Most of the HSI datasets used by the researchers are available as open-source and others at a nominal charge. Chapter 1 presents the steps of HSI processing techniques, namely, segmentation, compression, and classification. It gives a survey of sequential and parallel algorithms for all the three techniques that paves the way of the problem identification and its solution over this thesis. This analysis gives an overview of categorization of image processing techniques that have been implemented in parallel. It helps to identify the considerable storage problem for large size of HSIs to improve its acceptance for usage in real-life scenarios. The execution time taken by these techniques is very high that has been reduced by the concept of high performance computing.

Chapter 2 presents a review on different hyperspectral image compression algorithms that have been classified into two broad categories based on eight internal and six external parameters. It also helps to gain theoretical knowledge about the data source. We have also categorized algorithms on the basis of parameters that could help to decide the scope, objective, implementation environment, scalability, and strategy of the compression. A detailed study of HSI compression techniques is also covered; research challenges and future directions are discussed to overcome the observed limitations. Algorithms of different techniques are categorized with their methodology, advantages and limitations compactly. This analysis leads us to the fact that techniques adopted for classification can be used to evaluate and categorize any algorithm of the field. Such classifications could help in the development of advanced compression algorithms and may boost many space programs.

In Chapter 3, we propose a lossless prediction-based compression technique for multitemporal images. The model reduces the size of time-lapse HSI significantly. The experiments have been performed on four time-lapse HS imagery dataset having 7, 8, 9, 9 scenes, respectively, available in the public domain. Experimental results demonstrate the optimal number of bands to be selected for prediction, the comparative strength of individual correlations, and effectiveness of the technique in terms of bit-rate. Our results prove that including temporal correlations reduces the bit rate by 24.07% and our model provides optimization of 18.15% in terms of bits per pixel compared to the state-of-the-art method.

Chapter 4 presents a mechanism to reduce the complex structure of prediction - based compression algorithms by using HPC architecture. The very first step is to remove the dependency within the program, which restricts the use of parallel programming. Then, a multi-processing model is used to reduce the run time of prediction algorithms. The program was executed on multi-node system by changing the number of processors in multiple iterations. The effect of increasing number of processing elements on execution time of proposed parallel algorithm is discussed in terms of speedup and work optimality. We identified the optimum number of prediction bands for spectral decorrelation and number of pixels for spatial decorrelation. The average execution time of the RLS-filter based compression algorithm is reduced significantly (by a factor of 29 using 2 nodes with 28 cores each, on PARAM SHIVAY supercomputer) with the proposed technique. It can be visualized from the results that the best speedup and efficiency are obtained when A-CRLS is executed using parallel programming paradigms. However, it is noticeably worse in execution time, due to the inherent characteristics of the sequential algorithm (consumes 382% more time than CRLS).

In Chapter 5, deep learning based compression has been used to reduce the size of HSI. We propose two lossy HSI compression algorithm based on the concept of deep neural network. First model used the concept of autoencoder to extract the features of an HSI and store it into a small-sized 3D tensor. The experiment results proved that the method outperforms the existing state of the art algorithms in terms of compression ratio and PSNR. The proposed model is generally applicable to the HSI of similar sensors, for other datasets the network should be trained again. The method provides an improvement of 28% in PSNR with 21 times increment in the compression ratio. The effect of compression on classification performance has also been evaluated by comparing the OA, KA, and AA obtained by classification of the original and reconstructed image using HybridSN algorithm. The proposed solution in second model combines a traditional transform-based decorrelation method with a convolution network model to improve reconstructed image quality. This method provides an immense improvement in compression ratio and image quality compared to the state-of-the-art algorithms. We evaluate the effect of proposed compression technique on classification performance as for the first model.

6.2 Future Research Work

Based on the efforts initiated in this work, the following areas are proposed as an additional step to further enhance the compression of HSIs.The algorithm proposed in Chapter 3 can be extended to develop a model to select the number of temporal prediction bands automatically for a random dataset as the case of spectral bands. Furthermore, the effect of the presence of extensive sequence (counting to 100s) of temporal HSIs on compression performance has to be evaluated. The method of parallelization proposed in Chapter 4 can be used in real-time prediction and compression of more complex data. The process can be more optimized by using the concept of hybrid programming, which includes shared memory and distributed memory parallelism together. As a part of the future study of Chapter 5, we plan to improve the compression performance of the proposed model for HSIs with less spatial correlation. The model can further be evaluated for other applications of HSI processing like anomaly detection, time series analysis, video processing.

Transfer learning based compression

In recent years, deep learning techniques have emerged with immense performance. Transfer learning is one of such concept that stores the information obtained from one solution to solve similar problem without retraining. The most complex and time consuming phase of deep network is training on a large set of data. Transfer learning can solve this issue for HSI compression algorithms and reduce the execution time by avoiding retraining for each data.

Implementation on mobile devices

The modern developments in mobile computing technology demands for necessary transition of all major algorithms to be computed on devices that are portable and connected over a network. These devices are incapable of carrying heavy processing elements and thus require decomposition of the algorithms to be processed on a remote server and on the device. On a similar note, HSI compression can be extended to implement on mobile devices. An example of such application is the creation of first HS mobile device in Finland by VTT Research Centre. It is obtained by incorporating an optical sensor to the existing camera of iPhone for low-cost daily use applications [190].

Multi-temporal Hyperspectral Video compression

The recent advancement in the field of electronics has led to development of sensors that can make the acquisition and availability of hyperspectral videos, an easier task, in recent years. Interuniversity Microelectronics Centre (IMEC), an international research & development organization, presented its prototype for the same [191]. The characteristics of HS videos are similar to multitemporal HSIs with a wide range of applications. Size of these videos depends upon number of HS frames per second. Its extensive use will require advanced compression techniques dedicated to videos. The algorithms proposed in Chapter 3 can be extended with some modifications for compression of these videos.

Extending the support to medical HSI domain

For medical applications, hyperspectral imaging is an emerging imaging modality, especially in disease diagnosis and image-guided surgery. Since the characteristics and applications of medical HSI are entirely different from space/air-borne imagery, it requires dedicated support to lossless compression with improved performance. In future, our proposed algorithm can be extended to medical domain with little modifications.

Application oriented compression (Standalone system)

In the future, we plan to develop an automated model for the entire procedure of acquisition, pre-processing, compression, decompression, and application specific analysis of HSIs. We will also develop a model to select the optimal number of prediction bands automatically for a random dataset as the case of spectral bands.