AIN SHAMS UNIVERSITY
Faculty of Computer &
Information Sciences
Computer Science Department

Distributed Resolution Enhancement Techniques for Remotely Sensed Image

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By

Marwa Sayed Moustafa
National Authority for Remote Sensing and Space Science

Under the supervision of

Prof. Dr. Mohamed F. Tolba
Professor at Scientific Computing Department
Faculty of Computer and Information Sciences, Ain Shams University

Prof. Dr. Taymoor M. Nazmy
Professor at Computer science Department
Faculty of Computer and Information Sciences, Ain Shams University

Ass. Prof. Dr. Ashraf K. Helmy
Associate Professor at Receive and Analysis Data Department
National Authority for Remote sensing and space science

Ass. Prof. Dr. Hala M. Ebeid
Associate Professor at Scientific Computing Department
Faculty of Computer and Information Sciences, Ain Shams University

Cairo-2106

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Abstract

Resolution is an important attribute for different modern military and civil applications. High-resolution images facilitate image analysis tasks performed by machines, such as scene recognition and classification. However, in practice, high-resolution images are not always readily available for different reasons, such as the deficiency of the Camera optics and lenses, Motion between the camera sensor and the scene or subject, and atmosphere.

The problem of super-resolution has already been extensively researched. Different super-resolution algorithms have been developed. In this thesis, a comprehensive investigation of super-resolution methods is conducted. There are different categories for super-resolution methods, learning-based method offers more accurate reconstruction results compared to other traditional methods. In this thesis, three different super-resolution methods are proposed.

In the first super-resolution method, support vector regression is used to learn the relation between the low-resolution -HR patches using a predefined training set. In the reconstructing, the model obtained from the training step is used to recover accurate HR patches. Specifically, the input image is first decomposed into patches. Then, for each input patch, the SVR optimal model is used to recover the high-frequency information from the low-resolution input patch. To overcome the extensive computation in the proposed method, a transition from serial implementation to an optimized parallel on GPU architecture had been proposed.

Different experiments were conducted on the syntactic and multispectral dataset. Compared to the conventional super-resolution method, the proposed method reconstructs high-resolution images with higher accuracy. The speedup achieves approximately about 10-55 times faster than their optimized serial counterparts according to the image size.

The second SR method is based on manifold learning. Acceleration for a learning based SR method using locally linear embedding (LLE) algorithm is presented. The histogram of the gradient (HoG) is adapted to generate a training set. Three main kernels were implemented to improve the speed up of the performance. The bottleneck of the LLE was the matrix manipulation. CUBLAS library was adopted for matrix inverse and the calculation of matrix-vector multiplication modules; the shared memory was utilized in the matrix-addition and subtraction kernels to enhance the performance. Different experiments are conducted using the syntactic and multi-spectral dataset to show the effectiveness of the proposed algorithm. Manifold learning SR method outperforms significantly and achieves up to 11× to 163× speedup compared with the state-of-art method (bicubic interpolation).

Both SVR and manifold learning are example-based methods that show superior results for upscaling factor 2, but the image quality is degraded dramatically for larger upscaling factor.

To overcome these problems, compressed sensing framework had been adopted in the third method. The K-SVD algorithm had been utilized to formulate a joint dictionary, by exploiting high-frequency information from the external image database, where the local and nonlocal. In the reconstruction, acceleration for the compressive sampling matching pursuit (CoSaMP) algorithm is proposed of HR image. This method generates a sharper high-resolution image with fewer artifacts compared with state of the art super-resolution approach. The consistency and stability of the proposed method were experimentally tested using hyperspectral dataset. Experimental results demonstrate the speedup of the proposed GPU implementation to approximately 70x times faster than the corresponding optimized CPU.

Finally, the compressed sensing paradigm was extended to exploit self-similarities existing between image patches within a single image. There is no external training set is required. Different experiments have been carried out on a multispectral dataset. Extensive experimental were conducted to validate the effectiveness of the proposed approach. The GPU implementation accelerates the speedups compared to the CPU sequential implementation from 20× for small images to more than 40× for large image size.

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Abbreviations

BP	Basis Pursuit
CCD	Charge-Coupled Device
CoSaMP	Compressive Sampling Matching Pursuit
CS	Compressive Sensing
CSNE	Clustering And Supervised Neighbor Embedding
CUDA	Compute Unified Device Architecture
DCT	Discrete Cosine Transform
DFT	Discrete Fourier Transform
DWT	Discrete Wavelet Transform
FPGAs	Field Programmable Gate Arrays
GA	Genetic Algorithm
GD	Geometric Duality
GPGPU	General Purpose Graphics Processing Unit
GPU	Graphics Processing Unit
HH	High-High
HHSP	Heavy Hitters On Steroids Pursuit
HL	High-Low
HoG	Histogram of Oriented Gradient
HPC	High Performance Computing
HR	High- Resolution
IaaS	Infrastructure as a Service
IBP	Iterative Back-Projection
ICA	Independent Component Analysis
ILP	Instruction-Level Parallelism
IP	Isometric Property
IT	Information Technology
KM	Kernel Matrix
KPCA	Kernel Principal Component Analysis
LH	Low-High
LH-relation	Low–High Relation
LLE	Locally Linear Embedding
LL-relation	Low–Low Relation
LPC	Locality Preserving Constraints
LR	Low Resolution
MAP	Maximum A Posteriori
MCA	Morphological Component Analysis
MIMD	Multiple Instructions, Multiple Data