Unsharp based Pansharpening of Göktürk-2 Satellite Imagery

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*Abstract*— *Pan sharpening is a pixel-level fusion technique for increasing the spatial resolution of low-resolution multi-spectral satellite imagery using high resolution panchromatic imagery. In this work, the performance of various pan sharpening algorithms in improving the 2.5 meter resolution of Göktürk-2 satellite imagery is compared. Eight different pan sharpening algorithms are tested on seven different Göktürk-2 images and evaluated using eight different metrics which measures spectral and spatial quality of pansharpened images. We developed a preprocessing method which is based on unsharp masking of pan band. Pan band carries highest resolution spatial information while it lacks color. Unsharp masking is applied pan band to improve spatial contribution from this band. Then other pansharpening methods are applied to the image. Unsharp based preprocessing of pan bands improves sharpness of the images without degraded image quality. Unsharpening increases sharpness of pansharpened images which performs poorly persevering spatial features. Pansharpening methods from ArcMap, ENVI, PCI Geomatica and ERDAS are also compared in tests. Our results show that the Optimized High Pass Filter (HPF) yields the sharpest pan sharpened image, while the hyper spherical Color Space (HCS) method preserves the truest colors while preserving sharpness to a certain degree.*

Keywords—GÖKTÜRK-2 ; Unsharpening; pan sharpening ; HPF ; HCS.

# Introduction

Göktürk-2 is the second mini satellite of Turkey, which was built by TÜBİTAK UZAY and Turkish Aerospace Industries Inc. consortium. The Göktürk-2 spacecraft was launched on 18th December 2012. Göktürk-2 has a 2.5 m resolution pan and 5 m resolution multispectral imager.Göktürk-2 sensor includes Red, Green, Blue and Near Infrared (NIR) bands. Göktürk-2 satellite is operated by Turkish Air Force (TUAF) it provides high resolution imagery for national civilian and military imaging needs [1].

Pan sharpening is a pixel-level fusion technique for increasing the spatial resolution of low-resolution multi-spectral satellite imagery using high resolution panchromatic imagery [2]. The goal of Pan Sharpening is assembling pan and multi-spectral imagery using Pan Sharpening algorithms. During the fusion, multi-spectral imagery is resampled via interpolation techniques (nearest, bilinear, bicubic, etc). In accordance with the results obtained, the most accurate consequence is obtained with bicubic technique. In this study, eight different pan sharpening algorithms are tested on seven different Göktürk-2 images and evaluated using different metrics. In our previous studies pan sharpening methods are compared for RASAT imagery [3] and accelerated by using GPU implementations [4]. In this study, Unsharpening is applied to pansharpening algorithms: visual results are improved while similar metrics are obtained in the tests.

Pansharpening methods from ArcMap, ENVI, PCI Geomatica and ERDAS are also compared in tests. Our implementations shows similar performance to commercial counterparts.

# Pan Sharpening Algorithms

Pansharpening is an established research area [5] with well-known algorithms yet it is still an active research area where researchers try to achieve optimal methods which preserves sharpness of panchromatic images and spectral information of multi-spectral bands. This section describes commonly used pansharpening algorithms and

## Brovey

In this method, each spectral band is multiplied with pan imagery. Result obtained is divided sum of all spectral bands. Brovey method gives sharpness prominence.

## Gramm-Schmitt

In this method, multi-spectral imagery is not resampled using interpolation techniques differently from other methods. As a first step, multi-spectral imagery is calculated weighted mean, thereby low-resolution pan imagery is obtained, then pan imagery is chosen as a first spectral band. Whole bands are equated vertically using Gramm-Schmitt orthogonalization algorithm.

## Hyperspherical Color Space(HCS)

Multi-spectral imagery is transformed into hyperspherical color space. Intensity image matching algorithm is applied to pan and multi-spectral imagery. After Pan Sharpening, Pan sharpened imagery is obtained via inverse transformation [6].

## High Pass Filter(HPF)

In this method, 5x5, 7x7, 9x9 filters are used in accordance with ratio of pan and multi-spectral imagery. Filter’s elements except central element must be minus one, central element must be selected according to total of entire elements must be zero. This filter is implemented upon Pan Imagery. High passed imagery which is obtained this process is fused with multi-spectral imagery. By this means resolution of pan sharpened imagery increases [6].

## Intensity Hue Saturation (IHS)

The principal idea is to first transform the multi-spectral image into intensity (I), hue (H) and saturation (S) components (IHS color space). The next step is to scale the Pan image so that it has the same mean and variance as the intensity component of the MS image. The intensity component is then replaced with the appropriately scaled Pan image and finally the inverse IHS transformation is taken to get the fused image. The IHS method produces images that typically have high spatial fidelity but suffer from spectral distortion.

## Hue-Saturation Value (HSV)

The logic of HSV is similar to intensity hue saturation method.

Diversely, in this method, HSV color space is used instead of HIS color space.

## Optimized HPF

This algorithm resembles high pass filter method in many aspects. Similar to HPF, filters are chosen according to ratio of pan and multi-spectral imagery. Sharpened image is added by using the ratio of standard deviations of the spectral bands and pan band [6].

## Principle Component Analysis: PCA

The PCA is applied to the multispectral image bands and the principal components are computed. The first principal component is replaced by the panchromatic image. The inverse PCA transform is computed to go back to the image domain. The PCA sharpening is sensitive to the area to be sharpened [7].

## Wavelet

The multi-resolution analysis approach to pan sharpening is widely used and there are numerous techniques today based on it. The basic idea is to take the discrete wavelet transform of both the MS and Pan images. The next step is to retain the approximation coefficients for the MS image but replace the detail coefficients with those from the Pan image.

## Smoothing filter-based intensity modulation (SFIM)

SFIM method aims to preserve spectral information as much as possible. Pan band is smoothed with an averaging filter of size (2x2 for Göktürk-2). Ratio of pan band and smoothed pan band is multiplied with each band to compute pan sharpened image [10].

## Nearest-neighbor diffusion (NN Diffuse)

NN Diffuse algorithm assumes each pixel in pan band is weighted linear mixture of spectral bands in its neighboring superpixels [11].

# unsharp method

The methods which are mentioned before are used to add details an image. Unsharp mask increase the sharpness in an image. First unsharp mask is applied to pan image, using this unsharpened pan image other mentioned methods are applied, so the sharpened images are acquired. This method has 3 parameters such as sigma, weight, and threshold. Sigma determines the size of distance from a given pixel at the center of the convolution matrix; determines the kernel size of the smoothing Gaussian function. Weight affects the strength of sharpness. Threshold prevents from noise in an image. Default parameters are Sigma: 3(Gaussian filter size 16x16), Weight: 0.5, Threshold: 10. Threshold maybe adapted according to dynamic range of the image.

# Quantitative Quality Metrics

For the evaluation of the quality of the pan sharpened image, many different metrics have been proposed [6]. Most methods computes similarity of spectral information and results are correlated.

## Root Mean Square Error (RMSE)

The RMSE is defined as;

Where X is the MS image, Y is the pan sharpened image, x is the pixel and is the band number. Finally, n is the number of rows, m is the number of column and d is the number of bands.

## SAM (Spectral Angle Mapper)

The Spectral Angle Mapper (SAM) is a metric that calculates the spectral similarity between two spectral vectors as a spectral angle,

Where N is the number of bands and x = (x1, x2, · · ·, xN) and y = (y1, y2, · · ·, yN) are two spectral vectors at some pixel location in the original MS image and the fused image, respectively. The value of SAM for the entire image is the average of all the values for every pixel.

## Relative average spectral error (RASE)

RASE computes the average performance in terms of the RMSE of the bands in the pan sharpened image.

## ERGAS

This metric calculates the amount of spectral distortion in the fused image and is given by,

Where N is the number of bands, RMSE is the root mean square error, h/l is the ratio of pixels in the Pan image to the MS image and μ (n) is the mean of then band.

## Spatial

The spatial metric used computing the correlation coefficient

Between the high-frequency data of each MS band and the high frequency data of the Pan image. To extract the high-frequency data of a band, it is convoluted with the following mask. To extract the high-frequency data of a band, it is convoluted with the following mask

# THE RESULTS OF OPTIMAL PAN SHARPENING

The results figure out that HPF method is the sharpest method among all algorithms. On the other hand, in HPF method, value of color cannot be conserved. HCS, Wavelet and Optimized HPF method bring to a successful conclusion in terms of both metric results and visual results.

In IHS method, the point of sharpness is crucible, but Pan sharpened image have spectral determination.

In this examination, also Commercial software methods are tested in visual and metric criterion. Erdas which is one of the commercial software methods lead to success in HCS method.

|  |  |  |
| --- | --- | --- |
| D:\Staj2014\Pansharp\YeniData\Ankara_serit_ROUTER1_img_0\Pansharp\US Test (s=3,w=0.5,t=10)\Kıyas\tret\GramSchmidt_8bit.pngrapor_.png | D:\Staj2014\Pansharp\YeniData\Ankara_serit_ROUTER1_img_0\Pansharp\US Test (s=3,w=0.5,t=10)\Kıyas\tret\IHS_8bit.pngrapor_.png | D:\Staj2014\Pansharp\YeniData\Ankara_serit_ROUTER1_img_0\Pansharp\US Test (s=3,w=0.5,t=10)\Kıyas\Brovey_8bit.png_.png |
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| GS | IHS | Brovey |

Figure 1 Effect of Unsharpening, details are improved (Original Method: Upper Row, Unsharp: Lower Row)

|  |  |
| --- | --- |
| HPF | Optimized HPF |
| HCS | Unsharp HCS |

Figure 2 Visual Comparison of Best Performing Methods

Table 1 Average metric results of all method

**Table 2 Metric results of commercial software and pan sharpening methods of Ankara image**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **HPF** | **PCA** | **Brovey** | **GS** | **Wavelet** | **IHS** | **Opt\_HPF** | **HCS** | **HCS-US** | **SFIM** |
| **RMSE|0** | **87,24** | **75,20** | **70,77** | **53,87** | **15,66** | **49,60** | **32,26** | **33,39** | **46,87** | **25,32** |
| **SAM|0** | **2,71** | **4,69** | **0,00** | **3,06** | **0,92** | **2,12** | **1,57** | **0,19** | **0,19** | **0,00** |
| **RASE|0** | **29,94** | **25,81** | **24,29** | **18,49** | **5,37** | **17,02** | **11,07** | **9,15** | **12,89** | **5,88** |
| **ERGAS|0** | **7,94** | **7,36** | **7,82** | **5,25** | **1,51** | **4,53** | **3,13** | **2,40** | **3,38** | **1,49** |
| **SPATIAL|1** | **0,98** | **0,95** | **0,95** | **0,96** | **0,85** | **0,97** | **0,97** | **0,70** | **0,71** | **0,37** |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **IHS** | **Arcmap**  **IHS** | **Opt\_HPF** | **Erdas**  **Opt\_HPF** | **GS** | **Envi**  **GS** | **HCS** | **Erdas**  **HCS** | **NN Diffuse** |
| **RMSE|0** | **34,03** | **60,63** | **22,97** | **25,87** | **34,46** | **16,95** | **47,14** | **37,69** | **32,02** |
| **SAM|0** | **0,73** | **0,05** | **0,26** | **0,48** | **0,69** | **0,43** | **0,17** | **0,03** | **0,43** |
| **RASE|0** | **6,48** | **13,22** | **4,37** | **4,90** | **6,56** | **3,21** | **10,53** | **7,14** | **8,64** |
| **ERGAS|0** | **1,77** | **3,72** | **1,10** | **1,22** | **1,72** | **0,88** | **2,60** | **1,77** | **2,05** |
| **SPATIAL|1** | **0,91** | **0,95** | **0,90** | **0,92** | **0,91** | **0,88** | **0,87** | **0,90** | **0,87** |

References:

|  |  |
| --- | --- |
| [1] | M. Teke, "Satellite Image Processing Workflow for RASAT And Göktürk-2," *submitted for publication.* |
| [2] | I. Amro, J. Mateos, M. Vega, R. Molina and A. K. Katsaggelos, "A survey of classical methods and new trends in pansharpening of multispectral images.," *EURASIP J. Adv. Sig. Proc.,* vol. 2011, p. 79, 2011. |
| [3] | M. Teke, S. Seyfioğlu, A. Ağçal and S. Gürbüz, "Optimal Pansharpening of RASAT Satellite Imagery," in *Signal Processing and Communications Applications Conference (SIU), 2014 22nd*, 2014. |
| [4] | S. Açıkgöz, M. Teke, U. Kutbay and F. Hardalaç, "Performance Evaluation of Pansharpening Methods on GPU for RASAT Images," in *submitted for publication*. |
| [5] | L. Alparone, L. Wald, J. Chanussot, C. Thomas, P. Gamba and L. M. Bruce, "Comparison of pansharpening algorithms: Outcome of the 2006 GRS-S data-fusion contest," *Geoscience and Remote Sensing, IEEE Transactions on,* vol. 45, no. 10, pp. 3012-3021, 2007. |
| [6] | C. Padwick, M. Deskevich, F. Pacifici and S. Smallwood, "Worldview-2 Pan-Sharpening," *American Society for Photogrammetry and Remote Sensing,* p. 13, 2010. |
| [7] | R. A. Schowengerdt, "Reconstruction of multispatial, multispectral image data using spatial frequency content," *Photogrammetric Engineering and Remote Sensing,* vol. 46, pp. 1325-1334, 1980. |
| [8] | U. G. Gangkofner, P. S. Pradhan and D. W. Holcomb, "Optimizing the high-pass filter addition technique for image fusion," *Photogrammetric Engineering \& Remote Sensing,* vol. 73, no. 9, pp. 1107-1118, 2007. |
| [9] | F. Palsson, J. Sveinsson, J. Benediktsson and H. Aanaes, "Classification of Pansharpened Urban Satellite Images," *Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Journal of,* vol. 5, no. 1, pp. 281-297, Feb 2012. |
| [10] | L. Wald, "Quality of high resolution synthesised images: Is there a simple criterion?," in *Proceedings*, 2000. |
| [11] | J. Liu, "Smoothing filter-based intensity modulation: a spectral preserve image fusion technique for improving spatial details," *International Journal of Remote Sensing,* vol. 21, no. 18, pp. 3461-3472, 2000. |
| [12] | W. Sun, B. Chen and D. W. Messinger, "Nearest-neighbor diffusion-based pan-sharpening algorithm for spectral images," *Optical Engineering,* vol. 53, no. 1, p. 013107, 2014. |