A Fourier Transform-based Method to Fusion IKONOS Data

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Abstract

The principal objective of image fusion in remote sensing is to obtain high-resolution multispectral images that can combine the spectral characteristic of the low-resolution multispectral bands with the spatial information of the high-resolution panchromatic band. A method based on Fourier transform is proposed in order to obtain good spatial and spectral resolutions using all bands of IKONOS satellite. Quantitative measurements were applied to compare the results of the proposed method with IHS, IHS enhanced by Fourier transform and wavelet-based methods.

1. Introduction

Modern satellites, like IKONOS, are capable to producing high spatial resolution panchromatic (PAN) band with one meter or less. Simultaneously, they produce good multispectral (MS) bands. Spectral information from MS bands is useful to differentiate land cover classes, like vegetation, bare soil, water, roads and buildings. On the other hand, the spatial information from PAN is necessary for an accurate description of image details, such as shape, contours and features [1]. Image fusion is used to combine both PAN and MS bands to obtain high-resolution multispectral images.

The traditional image fusion methods, such as IHS, can keep almost the same spatial resolution as PAN, but they distort the spectral characteristics of the original MS bands [2]. Image fusion methods using frequency domain processing, like those based on wavelet transform (WT) [3-5], preserve good spectral information, but their spatial visual results are not satisfactory.

IHS fusion methods enhanced by Fourier transform have been very suitable in preserving both spectral and spatial information [1, 6], but they are limited to red (R), green (G) and blue (B) bands, excluding the near-infrared (NIR) band.

2. Proposed FT-based Image Fusion

For IKONOS images, it is necessary to perform some pre-processing, as the pixel sizes from PAN and MS are different (1 meter resolution for PAN and 4 meters for MS). One pixel from MS must be resampled for sixteen pixels.

In a remote sensing image, the details, like objects' edges, are a result of a high contrast between features, for example a light rooftop and dark ground. High contrast in spatial domain is high frequencies in the frequency domain. High frequencies are richer in PAN than in MS. On the other hand, spectral information appears as low frequencies in the frequency domain, which are richer in MS than in PAN.

The proposed method consists in obtain the spectral information from MS band by applying a low pass circular filter in the frequency domain, and obtain the spatial information from PAN by applying a high pass circular filter. No IHS transform is used in order to employ all the four IKONOS MS bands. The steps to fusion resampled R and PAN bands are illustrated in figure 1. The same steps must be applied to G, B and NIR bands.

For the filters, the optimum cutoff frequency must be measured accordingly to the spatial resolution, which depends on the image sampling interval following the Nyquist sampling criterion [1]: the sampling interval is in inverse proportion to the sampling frequency. Therefore the maximum frequency of an image is in inverse proportion to its spatial resolution. If the ratio of pixel resolution between PAN and MS is 1:m, the MS maximum frequency is 1/m PAN maximum frequency, that is, the cutoff frequency is equal to the maximum frequency of MS. But the maximum frequency of an image is $0.5\,\Delta x^{-1}$ (where Δx is its pixel size in meters). IKONOS PAN has one meter spatial resolution, so the maximum frequency is 0.5 cycles per meter. The maximum frequency of MS is 1/4 of that of the corresponding PAN, so the cutoff frequency for an IKONOS image is 0.125 cycles per meters.

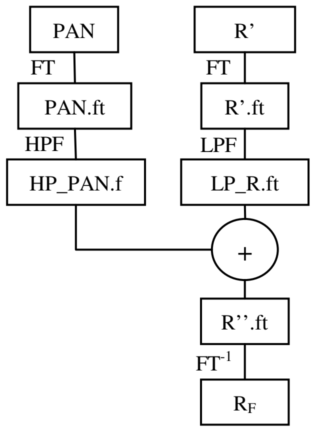
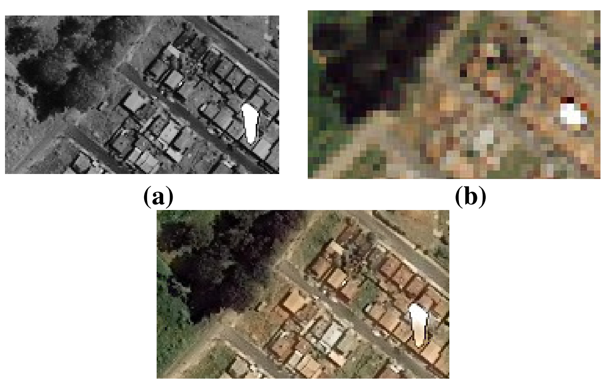


Figure 1 - Schematic diagram for FT-based fusion of PAN and R

The proposed method, using ideal circular filter, results in an image that presents artificial artifacts due to the abrupt combination of low and high frequencies. Some filters like Gaussian, Butterworth and Hanning were tested to smooth the results. The more suitable was Hanning. The high and low pass filter must be complementary to not lose or overlap any information.

Figure 2 shows the result of the proposed fusion method using Hanning filter. It could be noted that figure 2c has high spatial resolution (compare it to PAN in figure 2a), while maintaining the original colors (compare it to RGB composition in figure 2b).



(a) **(b)** **(c)**

Figure 2 – (a) original PAN, (b) original RGB composition, (c) result of the proposed method

After fusion, the MS bands are expected to be as similar to the original bands as possible. Correlation coefficient indicates how an image is “similar” to another. The proposed method has the higher correlation coefficient (see table 1) followed by IHS+FT method, indicating that these methods attain more spectral information than the others. When comparing correlation coefficient from IHS+FT and the proposed method, R band improves 7%; G band improves 8%; and B band remains almost the same.

Table 1 – Correlation index between the fused bands and their corresponding original bands for different fusion methods.

Method	R	G	B	NIR
IHS	0.34	0.24	0.27	----
WT	0.64	0.61	0.53	0.77
IHS+FT	0.77	0.70	0.75	----
FT (proposed)	0.84	0.78	0.74	0.86

3. Conclusions

A method based on filter in the frequency domain was proposed to the fusion of multiespectral satellite bands. It was compared to other reported methods and has the advantage of using any number of bands. In visual analysis, it can be observed that high information from PAN was added to MS information without distorting the original colors due to the smooth join of the PAN and MS. From a statistical analysis employing correlation coefficient, the proposed method attains more spectral information when compared with reported IHS, WT and IHS+FT methods. Further, differently IHS and IHS+FT, the proposed method can use the NIR band.

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4. References

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