Image Fusion

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Introduction

The purpose of our research is to determine the best method of fusing a high resolution gray-scale satellite image with a lower resolution multispectral satellite image to produce a multispectral image of high spatial resolution. Satellites provide panchromatic and multispectral images with different characteristics. It is more cost-effective and efficient to produce high spatial resolution gray-scale satellite images, but because multispectral satellite images are used by geographers, for instance, to study surface vegetation, the images have to be fused. Our research includes testing color transfer methods as well as discrete wavelet transformation (DWT) methods using Haar and Daubechies filters. We take three different satellite images and test each method on them.

Methods

We take the low resolution multispectral image and enlarge it to the size of the gray-scale image. The enlarged image is then separated into its three multispectral bands R,G, and B. From this step, we then proceeded to apply each method.

Y-Cb-Cr Transform

The three multispectral bands are transformed into the luminance and the chrominance channels. We then replace the luminance channel with the grey-scale image, combine the channels, and apply the inverse on the image.

$$Y = 219\left(\frac{.299}{255}r + \frac{.587}{255}g + \frac{.114}{255}b\right) + 16$$

$$Cb = \frac{224\left(\frac{b}{255} - Y\right)}{1.772} + 128 \qquad Cr = \frac{224\left(\frac{r}{255} - Y\right)}{1.402} + 128$$

I-H-S Transform

The three bands are transformed into the intensity, hue, and saturation color space using the following formula:

$$\begin{pmatrix} I \\ V_1 \\ V_2 \end{pmatrix} = \begin{pmatrix} 1/3 & 1/3 & 1/3 \\ 1/\sqrt{6} & 1/\sqrt{6} & -2/\sqrt{6} \\ 1/\sqrt{2} & -1/\sqrt{2} & 0 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

Transfer the gray-scale image into the intensity band, combine the bands, and apply the inverse.

Discrete Wavelet Transformations (DWT)

We apply a filter to the three bands along with the gray-scale image. We combine the approximation of the color bands with the detail of the filtered gray-scale image, apply the inverse on each band, and combine the channels. We performed this method with the following filters:

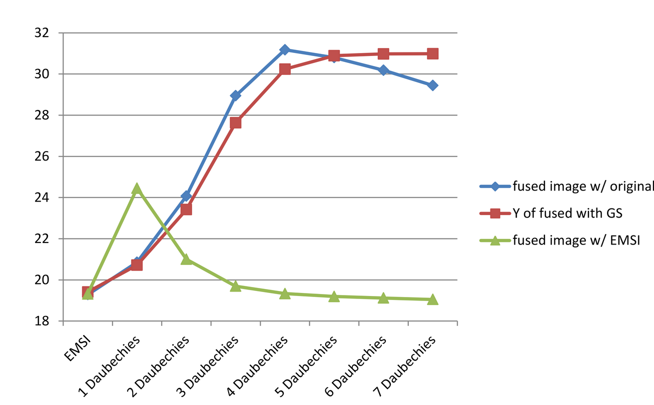
- Haar Wavelet
- Daubechies Wavelet (length 6)

Discrete Wavelet Frame Transformations

We apply a filter similar to the Haar Wavelet that isn't downsized so that when it is applied it yields a filtered image of the same size. We continue with the same process as the DWT method.

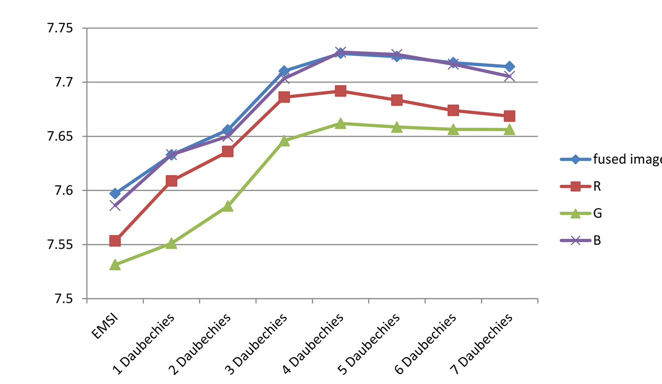
PSNR

Fusion Method	Fused image with Original	Y of fused image with GS	Fused image with EMSI
EMSI	19.285	19.4094	∞
Y-Cb-Cr	28.8008	∞	18.0862
I-H-S	29.4032	29.1733	19.1932
1 Haar	20.6524	19.7902	24.9657
4 Haar	30.8167	20.2101	19.3133
1 DWFT	22.4274	21.9449	26.2658
15 DWFT	30.4959	28.23	20.041

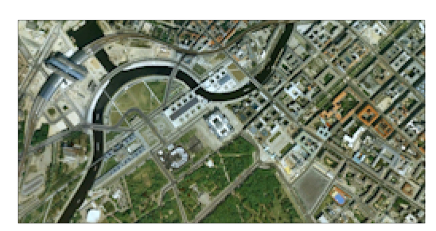


Entropy

Fusion Method	Fused Image	R	G	B
EMSI	7.59699	7.55335	7.53143	7.58607
Y-Cb-Cr	7.92296	7.90205	7.87135	7.911
I-H-S	7.70584	7.68816	7.65238	7.6868
1 Haar	7.69639	7.67309	7.62341	7.69606
2 Haar	7.78569	7.7681	7.72304	7.78102
1 DWFT	7.61336	7.58727	7.53405	7.61006
15 DWFT	7.69056	7.66304	7.62721	7.67964



EMSI

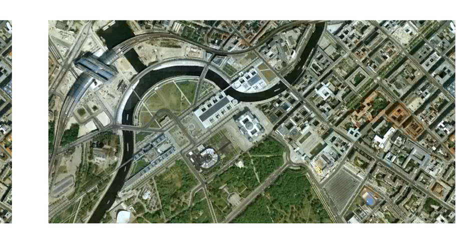


Original

Y-Cb-Cr

I-H-S

4 Haar



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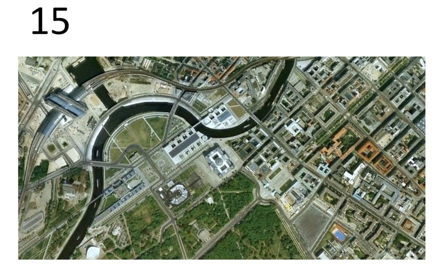
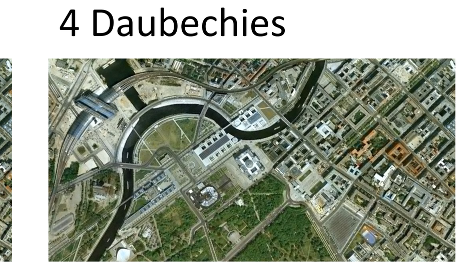


1 Daubechies

2 Daubechies

3 Daubechies

4 Daubechies



5 Daubechies

6 Daubechies

7 Daubechies

Original

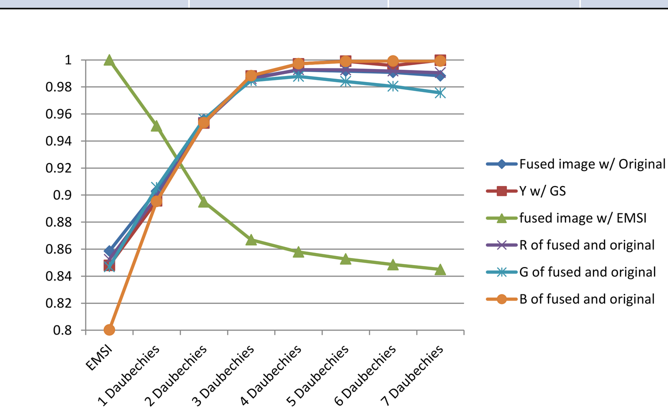
4 Daubechies

15 DWFT

Y-Cb-Cr

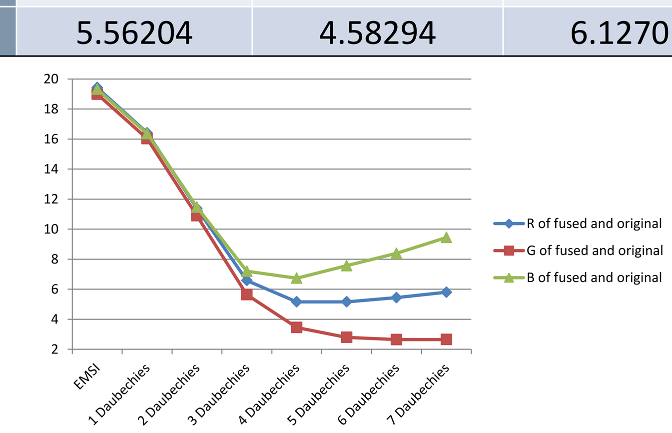
Correction Correlation

Fusion Method	Fused image with Original	Y of fused image with GS	Fused image with EMSI	R of both fused and original	G of both fused and original	B of both fused and original
EMSI	0.858556	0.848029	1	0.852378	0.846954	0.80029
Y-Cb-Cr	0.99695	1	0.856736	0.997413	0.999577	0.994867
I-H-S	0.995112	0.998203	0.853213	0.995077	0.996666	0.993771
1 Haar	0.899712	0.893261	0.959482	0.895279	0.892749	0.902104
4 Haar	0.991812	0.997284	0.858336	0.992178	0.99729	0.986126
1 DWFT	0.934237	0.929761	0.967717	0.931179	0.930084	0.935562
15 DWFT	0.991179	0.992485	0.875509	0.990629	0.992925	0.989514



Spectral Discrepancy

Fusion Method	R of both fused and original	G of both fused and original	B of both fused and original
EMSI	19.4245	18.9899	19.316
Y-Cb-Cr	7.2278	6.83007	7.93516
I-H-S	7.60197	5.89829	7.99989
1 Haar	16.4669	15.9896	16.4436
4 Haar	5.23586	3.43757	7.0641
1 DWFT	13.6349	13.2167	13.6062
15 DWFT	5.56204	4.58294	6.12701



**EMSI-enlarged multispectral satellite image, GS-gray-scale image, R, G ,B- red, green, blue color band

Fusion Quality Measurements

Improvement of Spatial Resolution

Peak Signal-to-Noise Ratio (PSNR)

- *The PSNR compares the error in the difference of the entries. A larger error provides a smaller PSNR.*

Entropy

- *Entropy is the average unpredictability in the information content, which measures the average length of the shortest possible representation to encode the information. More variety of numbers leads to a higher entropy.*

Preservation of Spectral Characteristics

Correlation Coefficient(CC)

- The correlation coefficient determines the degree to which two variables are associated. The more of a difference there is, the lower the CC..

Spectral Discrepancy(SD)

- *The Spectral Discrepancy measure the difference in the color channels. The larger the difference will lead to a higher SD.*

Conclusion

In concluding our results we were able to determine how the number of iterations we performed affected the resulting fused image. For both the Haar and Daubechies wavelet transforms, an increase led to an increase in spatial quality, but it also led to a loss of spectral characteristics. The number of iterations we could perform was also limited due to the wavelets being downsized which reduced the blur. These conclusions led us to apply the DWFT to the images since the wavelet was not downsized, so we would not be limited to a certain number of iterations. The results from the DWFT only improved for each measurement as we increased the number of iterations. Although we only reached 15 iterations due to the immense amount of information needed to calculate more iterations, we believe that as we increase the iterations we will only see an increase in quality which may provide better results than the color transfer methods. The color transfer methods did provide better results than the Haar and Daubechies, and we believe this to be associated with the fact that we manipulated the I-H-S and Y-Cb-Cr color spaces and not only the RGB channels. For further research, it will be beneficial to experiment with manipulating the Y-Cb-Cr color spaces and with applying more iterations with the DWFT, to see how each would improve the quality of the resulting fused image.

Acknowledgments

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