

JPEG2000: IMAGE QUALITY METRICS

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Abstract

High-resolution digital images that are used in geo-spatial and remote sensing technologies tend to be of large sizes, especially with newer satellite imageries that provide better than 5 m spatial resolution, and thereby consuming large storage space, large transmission bandwidth, and long transmission times. Therefore, method of compressing the archived images is required before storage and transmission. JPEG2000 is the latest image compression standard offering superior compression performance. JPEG2000 compresses and decompresses the images using discrete wavelet transformation and allowing image information to be retained without much distortion or loss. Compression in JPEG2000 can be performed in both lossy and lossless fashion. Lossy compression is preferred because of its higher compression ratio. When lossy compression is performed, some amount of data is lost during the compression. Such loss of data may lead to erroneous results when analysis is performed using computer based image applications. Thus, there is a need for image quality assessment of compressed and reconstructed images using JPEG2000 at various compression ratios. This paper focuses on such studies and, using image quality metrics, experiments are conducted to compute benchmarks of compression ratios for GIS systems that can be identified for the intended use of the image without significant degradation in the results.

INTRODUCTION

Satellite images that are used in GIS are generally very large in size (for example the size of the multi-resolution Quickbird GeoTIFF image used in this study is 380 MB), therefore compression of the images is a must before storing and transmitting to save storage space, bandwidth and to lower the transmission times. JPEG2000 is the latest image compression standard that compresses and decompresses the images using wavelet transformation opposed to its predecessor JPEG that uses Discrete Cosine Transformation. Wavelet transform-based image compression algorithms allow images to be retained without much distortion or loss when compared to JPEG, and hence are recognized as a superior method []. In JPEG2000, compression can be performed in either lossy or lossless fashion. Lossless compression is favored in life critical situations where any loss in image data and quality may lead to erroneous analysis. But in various other applications lossy compression is preferred because it provides high compression ratio that result in smaller image sizes. However, the trade off is that as the compression rate increases, the spatial and spectral features of the image are lost. This paper analyses the impact of JPEG2000 compression on image quality due to lossy compression.

Methodology

A toolkit was developed that compressed the images using the JAI and Luratech JPEG200 API. Using the toolkit, reversible compressions were performed at different rates on the test image and the JPEG2000 file was decompressed back to TIFF file format. The quality metrics were then calculated to compare the original and the reconstructed images. The test image is a 1024 x 1024 pixels subset of Quickbird multi-spectral image of Memphis, Tennessee area. The image was compressed at various compression rates and then decompressed using JPEG2000 codec and the quality metrics of the reconstructed image was computed by using the original image as a benchmark.

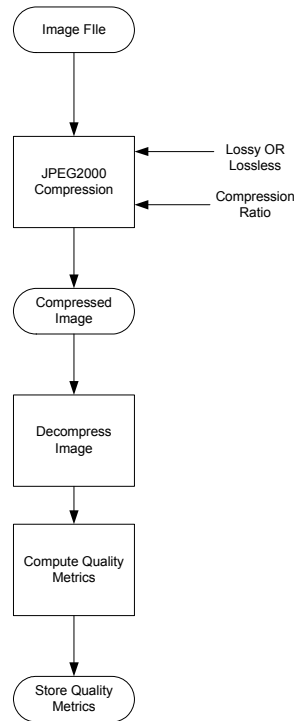


Figure 1 Process for computing quality metrics

Image Quality Metrics

Image quality metrics are figures of merit used for the evaluation of imaging systems or processes. The image quality metrics can be broadly classified into two categories, subjective and objective. Subjective image quality is a method of evaluation of images by the viewers and it emphatically examines fidelity and at the same time considers image intelligibility. In objective measures of image quality metrics, some statistical indices are calculated to indicate the reconstructed image quality. The image quality metrics provide some measure of closeness between two digital images by exploiting the differences in the statistical distribution of pixel values. The most commonly used error metrics used for comparing compression are Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) [].

1. Mean Square Error:

Mean Square Error measures the error with respect to the center of the image values, i.e. the mean of the pixel values of the image, and by averaging the sum of squares of the error between the two images.

$$MSE(u, v) = \frac{1}{MN} \sum_{m=1}^M \sum_{n=1}^N | u(m, n) - v(m, n) |^2$$

Where, $u(m, n)$ and $v(m, n)$ represent two images of size $m \times n$. In our case u is the original image and v is the reconstructed image. A lower value of MSE signifies lesser error in the reconstructed image [].

2. Root Mean Square Error:

The Root Mean Square Error (RMSE) is the square root of mean square error. It quantifies the average sum of distortion in each pixel of the reconstructed image.

$$RMSE = \sqrt{MSE}$$

The RMSE portrays the average change in a pixel caused by the image-processing algorithm [].

3. Correlation Coefficient:

Correlation coefficient quantifies the closeness between two images. The correlation coefficient is computed by using the following equation.

$$Corr(A/B) = \frac{\sum_{i=1}^M \sum_{j=1}^N (A_{i,j} - \bar{A})(B_{i,j} - \bar{B})}{\sqrt{\sum_{i=1}^M \sum_{j=1}^N (A_{i,j} - \bar{A})^2 \sum_{i=1}^M \sum_{j=1}^N (B_{i,j} - \bar{B})^2}}$$

The correlation coefficient value ranges from -1 to +1, where the value +1 indicates that the two images are highly correlated and are very close to each other. And the value -1 indicates that the images are exactly opposite to each other [].

4. Peak Signal to Noise Ratio:

Peak Signal to Noise Ratio (PSNR) measures the estimates of the quality of reconstructed image compared with an original image and is a standard way to measure image fidelity. Here 'signal' is the original image and 'noise' is the error in reconstructed image resulted due to compression and decompression. PSNR is a single number that reflects the quality of reconstructed image and is measured in decibels (db).

$$PSNR = 20 \log_{10} \left(\frac{S}{RMSE} \right)$$

Where S is the maximum pixel value and RMSE is the Root Mean Square Error of the image. The actual value of PSNR is not meaningful but the comparison between two values between different reconstructed images gives one measure of quality. As seen from inverse relation between MSE and PSNR, low value of MSE/RMSE translates to a higher value of PSNR, thereby signifying that a higher value of PSNR is better [].

Results and Analysis

The visual comparison of the images that are reconstructed with the original image shows that the reconstructed images losing fine details as the compression rate is increased. One cannot distinguish between the original and the reconstructed image that was compressed at the rate of 30 while doing a visual inspection. But the differences are more pronounced after each successive increase in compression rate. The images are zoomed such that the details are more visible in the next zoomed section of images. We can see the difference in various pixels as we increase the encoding rate.

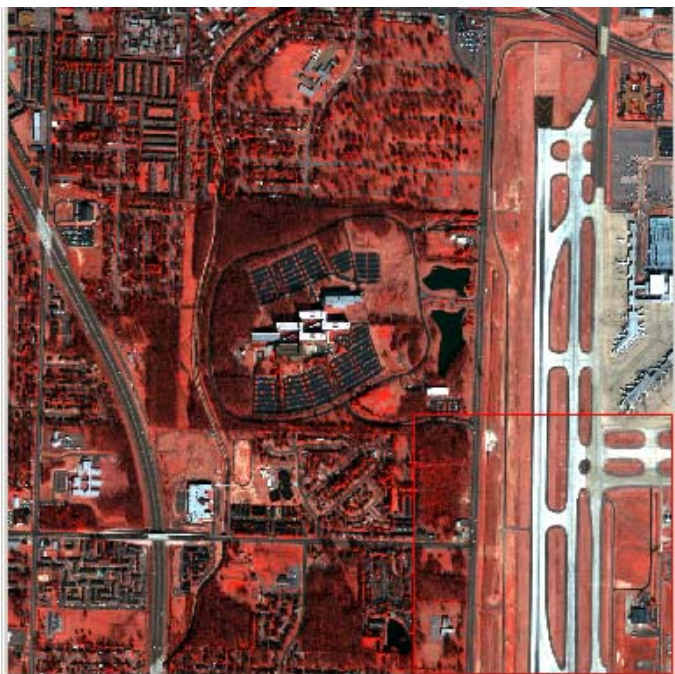


Figure 2. Original Image

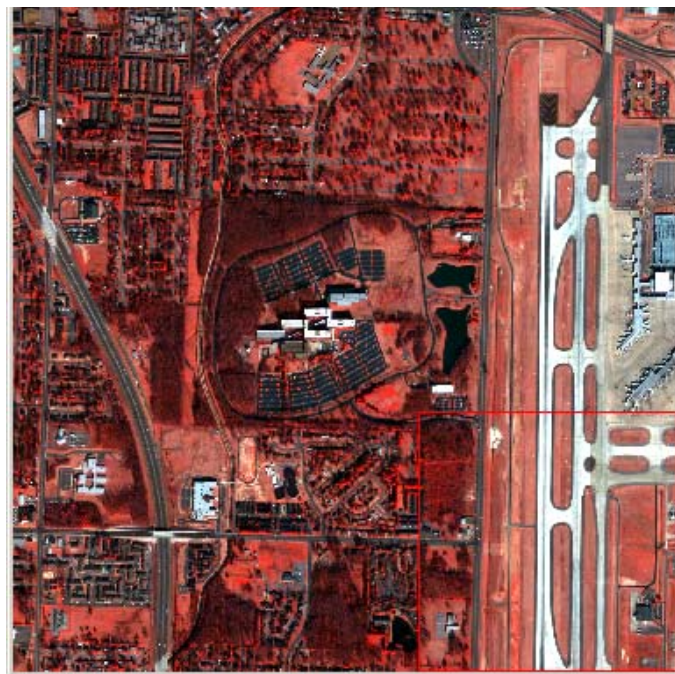


Figure 3. Image compressed at the ratio of 1:5

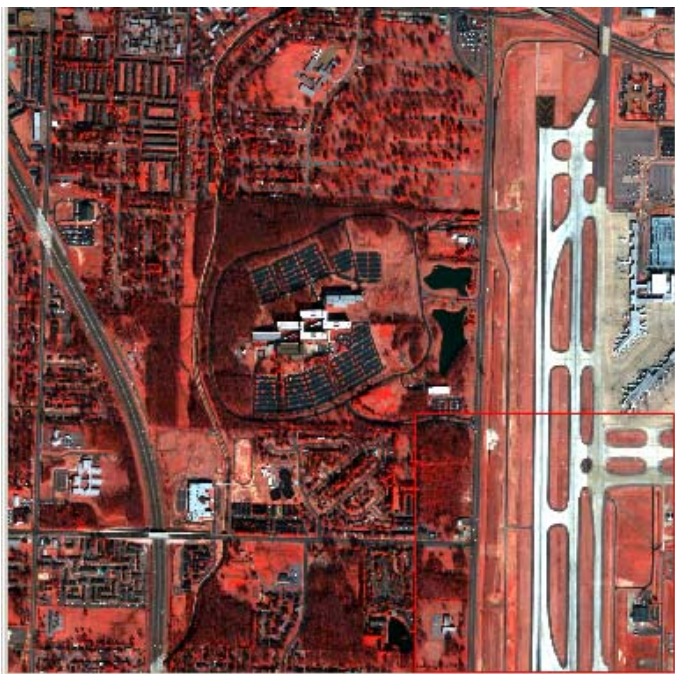


Figure 4. Image compressed at the ratio of 1:10

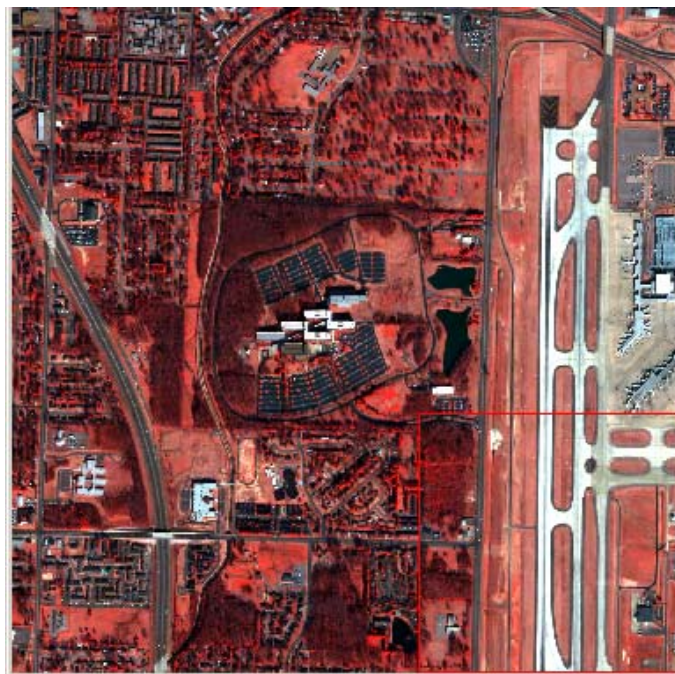


Figure 5. Image compressed at the ratio of 1:20



Figure 6. Image compressed at the ratio of 1:30
e) Image compressed at the ratio of 1:30



Figure 7. Image compressed at the ratio of 1:50

f) Image compressed at the ratio of 1:50



Figure 8. Image compressed at the ratio of 1:100
g) Image compressed at the ratio of 1:100



Figure 9. Image compressed at the ratio of 1:150
h) Image compressed at the ratio of 1:150



Figure 10. Image compressed at the ratio of 1:200

i) Image compressed at the ratio of 1:200

Even though the images seem similar visually the quality metrics show that the images are being distorted as can be seen from the MSE and RMSE of the images that are provided in the table 1 and the PSNR provided in the table 2. Similarly the correlation coefficient is provided in table 3.

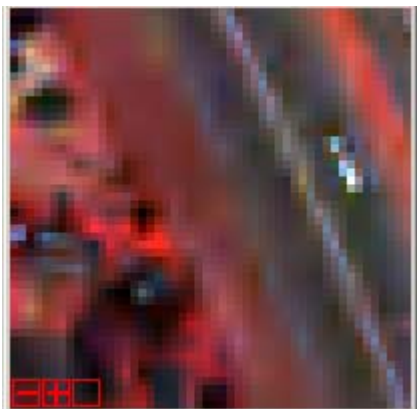
Detailed (Zoomed) Images:



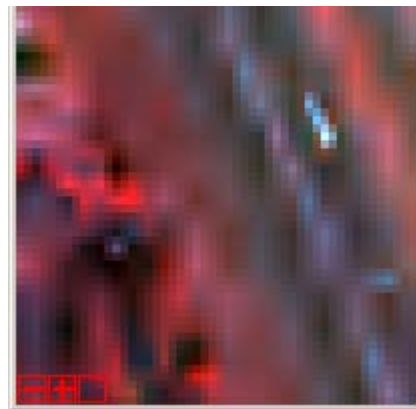
a) Original Image



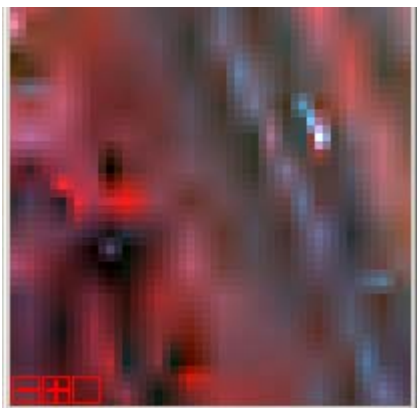
b) Image compressed at the ratio of 1:10



c) Image compressed at the ratio of 1:50



d) Image compressed at the ratio of 1:100



e) Image compressed at the ratio of 1:1500



f) Image compressed at the ratio of 1:200

As expected, the MSE and RMSE are equal to 0 and PSNR was infinity when lossless compression was performed. Lossless compression reduces the size of the image around a factor of 2; therefore lossy compression rate of 2 performs as well as lossless compression. As the encoding rate increases the MSE and RMSE values also increase accordingly implying that the distortion in the image increases as the compressed image get smaller in size, which go along with the theoretical expectations.

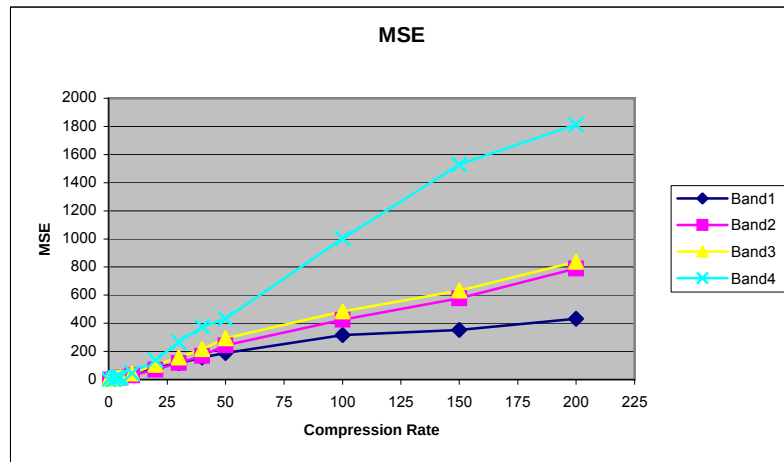


Fig. MSE values for images compressed at different rates

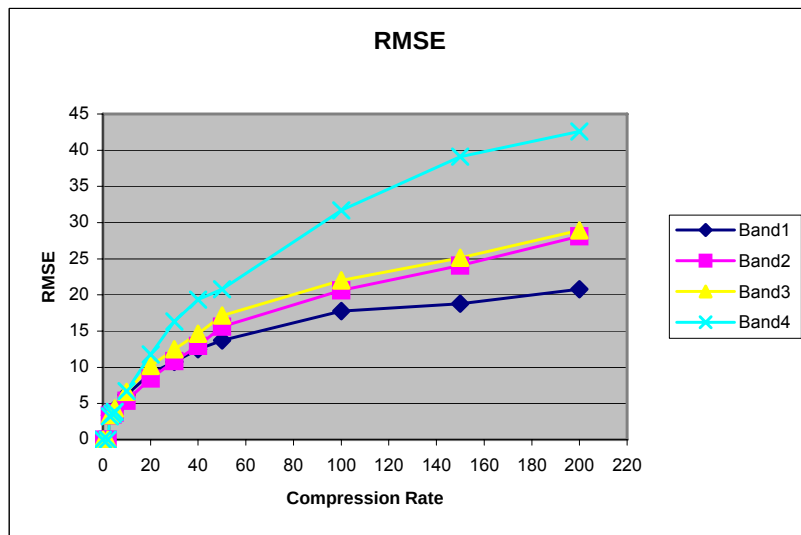


Fig. RMSE values for images compressed at different rates

Another interesting fact observed was that the fourth band (near Infrared) had the maximum values of MSE and RMSE, which is also understandable as that band contains larger pixel values and therefore is further distorted when compared to the other bands.

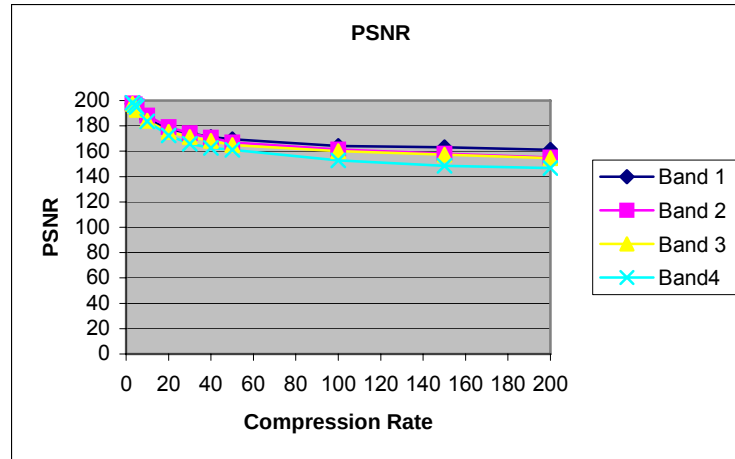


Figure 11 PSNR values for images compressed at different rates

Similarly PSNR values decrease as the compression rate increases. For comparable values of PSNR, from a compression ratio 0.33 to 0.005 its value ranges from 197.43 db to 161.1 db in band 1, which shows a range of 36.33. We can also see that PSNR value decreases most in the fourth band.

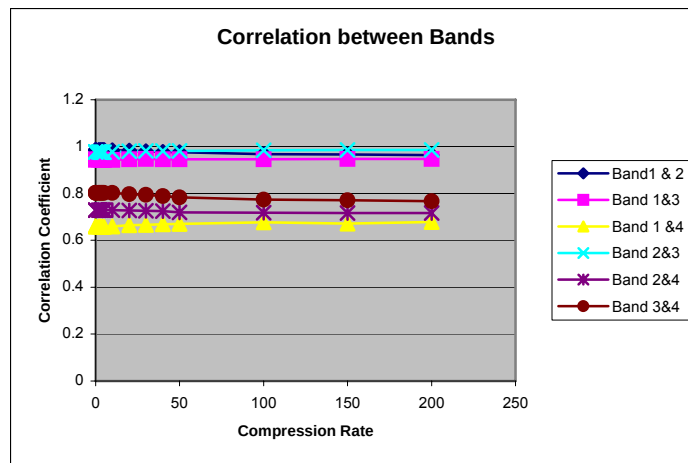


Fig. Correlation coefficient values for images compressed at different rates

However, an interesting fact observed was that the correlation between the different bands of images does not change by much even when the compression was performed at a ratio of 1:200. As can be seen from the fig, and the table the correlation between different bands are don't show much difference. This shows that the distortion is comparable among the bands.

Conclusion

This paper presents the use of image quality metrics to compute the quality of images compressed using JPEG2000 codec by Lura Tech Inc and JAI. The objective quality metrics used in the study are MSE, RMSE, PSNR and Correlation coefficient. Visual inspection could not determine much difference in images but the quality metrics show that the spectral fidelity of images decreases as the compression rate increases even for lower rates. It was also observed that the MSE and RMSE values increase most in the fourth band of the image and therefore we can say that the fourth band contains most noise when the image is subjected to higher compression rates. But since the correlation coefficients are comparable for all the different rates of compression, we can say that the changes are relative in each band.

Further extension of this work could be the comparison of JPEG2000 with other compression standards like MrSID® using additional specialized quality metrics as for example, edge quality metrics, spectral distance measures and context measures to get a better evaluation of the image quality

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