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STUDY & ANALYSIS ON USING JPEG2000 COMPRESSION STANDARD WITH HIGH RESOLUTION GEOSPATIAL IMAGERY PRODUCTS

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ABSTRACT

Many Surveying/Geomatics related organizations are in the process of constructing huge high-resolution imagery databases which contain digital color images covering different areas of their interest. The sizes of such image databases are very large A typical problem of such database projects is the huge size of the imagery for storage and/or distribution. With the development of remote sensing technology, large swath width along with multi-wavebands make data size to increase greatly. Therefore, image compression becomes one of the most essential tasks in dealing with such imagery. Several techniques exist on the market to compress such imagery. The compression market is now overwhelmed by Standard & non-standard compression tools and software. Each vendor pretends to have the most reliable compression techniques.

This paper is devoted to examine (subjectively and objectively) the effect of using the new *JPEG2000* standard compression algorithm -*Joint Photographic Experts Group*- in the market in dealing with high resolution spatial imagery & to recommend the optimum compression ratio to be used when using JPEG2000 standard in compressing high resolution imagery. The testing procedure considered the spectral as well as the spatial effect of the new market standard on the image pixels and to recommend the optimum compression ratio for such cases.

تهتم العديد من المنظمات و الهيئات المساحية بتطبيقاتها المختلفة ببناء قواعد بيانات لصور الاستشعار عن بعد ذات درجة الوضوح العالية حيث تحتوي هذه الصور علي المعلومات التي قد تغطي أو تفيد كمنبع إستخراج المعلومات للعديد من التطبيقات لهذه الهيئات و عملائها. العائق الأساسي لانشاء مثل هذه القواعد هو الحجم الهائل للصور الجوية أو صور الأقمار الاصطناعية. نظرا" لتطور التكنولوجيا السريع في هذا المجال زادت دقة و قوة تحليل الصور على حساب الحجم. لذايصبح استخدام تقنيات ضغط الصور ضرورة ملحة لمثل هذه المشاريع. توفرت فى الأسواق حديثا" العديد من التقنيات و البرامج المخصصة (المعتمدة و غير المعتمدة) في مجال ضغط الصور و التي تحمل معها العديد من التأثيرات على دقة و جودة الصورة الناتجة من عملية الضغط.

يختص هذا البحث بدراسة تأثير إستعمال تقنيات(JPEG 2000)المعتمدة و التي تعتبر أحدث تقنية معتمدة في هذا المجال – و المنشأه بواسطة مجموعة خبراء التصوير المتحدة – في السوق في التعامل مع الصور الجوية أو صور الأقمار الاصطناعية ذاتِ درجة الوضوح العاليةِ و تشمل هذة الدراسة التأثير الهندسي و المرئي الحادث على الصورة و كذلك التوصيات بدرجة الضغط المناسبة في هذه الحالات.

Keywords: High-Resolution, Compression, Spatial Quality, Spectral Quality, JPEG2000.

1. INTRODUCTION

Nowadays, high-resolution spatial imagery products are being well emerged and integrated in our daily surveying and/or Geomatics related projects and measurements. Direct qualitative high resolution (<1m resolution) satellite imagery and very high quality aerial photograph orthophoto collections are being now of a great concern in any surveying and Geomatics related firm's global budget. Such imagery helps us to visualize actual situation accurately, take precise measurements, produce high quality spatial data forms (DTM for example), and or perform accurate spectral classification for change monitoring applications (see for example USGS, SNB [11, 13]). It is believed that different users of such imagery would employ the products in any of three different ways, namely, as an "image backdrop" to vector topographic mapping, property mapping and resource inventory data stored and accessed using GIS, as a base for interpreting and "on-screen" digitizing vector information for the purposes of updating data stored in a GIS, and/or as a base upon which more advanced image analysis and processing operations be made for advanced resource inventory applications.

A very recent example of such organization is the process that is been undertaken at the Urban Planning

& Surveying Departments within the ROYAL COMMISSIOIN OF JUBAIL & YANBU (RC-Saudi Arabia). RC is in the process of producing high resolution imagery database of IKONOS imagery and aerial photography projects that will cover approximately 700 Km^2 of the very promising developing city of YANBU.

A typical problem of such database projects is the huge size of the imagery for storage and/or distribution. With the development of remote sensing technology, large swath width along with multi-wavebands make data size to increase greatly. Therefore, image compression becomes one of the most essential tasks in dealing with such imagery. Several techniques exist on the market to compress such imagery. The compression market is now overwhelmed by Standard & non-standard compression tools and software. Each vendor pretends to have the most reliable compression techniques.

This paper is devoted to examine (subjectively and objectively) the effect of using the new *JPEG2000* standard compression algorithm -*Joint Photographic Experts Group' or JPEG(5) standard that has been established by ISO (International Standards Organization) and IEC (International Electro-Technical Commission)*- in the market in dealing with high resolution spatial imagery. The testing procedure considered the spectral as well as the spatial effect of the new market standard on the image pixels and to recommend the optimum compression ratio for such cases.

2. IMAGE COMPRESSION: A QUICK LOOK

Image compression techniques are used to remove redundancy exist within neighboring pixels in a typical digital image and consequently, reduce the data content size of a digital image file. In other words, we can say that "image compression is concerned with minimizing the number of bits required to represent an image" [8, 10].

Image compression reduces the image file size by removing the redundancy from the image data, i.e. extracting essential information from the image, so that it can be reconstructed with a certain degree of accuracy. Still image compression techniques deals with two main types of redundancy, namely:

- ***Spatial Redundancy:*** or correlation between neighboring pixel values.
- ***Spectral Redundancy:*** or correlation between different color planes or spectral bands.

Image compression/decompression operations are essential for large images archival and/or transmission [1, 9, 10, and 17].

2.1 Lossless Vs. Lossy Image Compression

In lossless compression schemes, the reconstructed image is numerically identical to the original image.Lossless compression or error-free compression is a technique used when the image applications require the reconstructed image to be numerically identical to the original image. One of these applications is the archival of medical or business documents. In these documents we need every single character to be reconstructed again without any loss of information [1, 3].

Error-free compression will give a very low compression ratio in comparison with the lossy compression. Examples of lossless image compression/encoding techniques have been developed include Run-Length Encoding, Huffman Coding, lossless Predictive Coding, lossless Block Coding. An extensive review of these methods can be found in 1, 3, 10, and 12)

However lossless compression can only achieve a modest amount of compression. An image reconstructed following lossy compression contains degradation relative to the original.In other words, lossy schemes cannot be used to exactly and precisely reconstruct the original image. Examples of lossy encoding techniques include Truncation Coding, Lossy Block Coding, Transform Coding, Lossy Predictive Coding. An extensive review of these methods can be found in 1, 3, and 10)

2.2 Standard/Non-Standard Image Compression Schemes

Image compression standards and non-standards has been developed to support the industry needs such as JPEG "Joint Photographic Experts Group", CCITT Group3 / 4 and Joint Bi-level Image Experts Group (JBIG), and Wavelets. For detailed discussions, please refer to [3, 9, 10, and 12].

2.3 JPEG2000

JPEG 2000 is the very recent compression standard techniques developed to compromise for deficiencies exist within the original JPEG technique. After evaluating a number of coding schemes, the JPEG members selected a Discrete Cosine Transform (DCT) based method. JPEG became a Draft International Standard (DIS) in 1991 and an International Standard (IS) in 1992. Ten years later, JPEG2000 was considered to focus efforts into a new standard for coding still images. JPEG2000 is based on discrete wavelet transform (DWT) that provides a promising road in the compression market. For more details, see [5,16].

3. RESEARCH SCOPE & OBJECTIVES

The main purpose and scope of this research is to examine (subjectively and objectively) the effect of using the new *JPEG2000* standard compression algorithm -*Joint Photographic Experts Group' or JPEG[19,20] standard that has been established by ISO (International Standards Organization) and IEC (International Electro-Technical Commission)*- in the

market in dealing with high resolution spatial imagery from different aspect. In addition, this research considered all the aspects the image may be used for and recommend the optimum compression ratio to be used when using JPEG2000 standard in compressing high resolution imagery. Visual quality of the image was considered subjectively and objectively to help use the image as a backdrop or for visual interpretation. Geometric quality was considered for direct surveying and generally spatial measurements. Spectral quality was tested to evaluate the compression effect on the classified imagery. In other words, the testing procedure considered the spectral as well as the spatial effect of the new market standard on the image pixels and to recommend the optimum compression ratio for such cases.

4. TEST IMAGE

In order to simulate a valid situation, a real high-resolution product image with a reasonable size (a one that is similar to the expected product by RC project) was used rather than a sample image. An orthophoto was obtained from Service New Brunswick that satisfies the following conditions:

- Covers wide varieties of ground features (buildings – roads –green – forest – water, etc.)
- Contains different textures
- Constitutes Gradual color features
- Includes Topographic Sheets for control points coordinates
- Has a typical size of such image sheet (~130MB).

Figure (1) shows the image selected for the testing procedure within this research.

In this research, the author utilized Lurawave software package (one of the leading compression package in the market) for image compression and Erdas imaging extension within ArcGIS 9.1 for classification and measurements from the image.

5. TESTING, RESULTS & ANALYSIS

In this section, the author will discuss the main steps in testing the JPEG2000 compression standard and the major results produced.

5.1 Visual Quality

One of the most important aspects when judging image quality is to consider the user him/herself. The quality of the image affects the user's decision on the diverse use of such an image in different applications. In order to judge the quality of the image from a real user perspective (Subjectively), a questionnaire was made, as shown in Figure (2). This questionnaire was designed to cover the most important image visual quality, namely:

- Detectable Color Loss or Change.
- Detectable Feature Edge Change.
- Detectable Loss of Clean &Uniform Color Across Color Patch.
- Detectable Change in Edge of Each Color Patch.
- Detectable Change in Feature Geometry.
- Detection of Blocking Pattern.
- Detectable Change or Loss in Ability To Interpret Image Features.
- Detectable Loss of Features.

In order to test the visual quality subjectively, color plots along with image quality questionnaire were prepared. We had the best opportunity to test those images by inviting Geomatics users from RC Surveying &Urban planning departments to participate in the test, participants were asked to evaluate the images based on the factors presented in the questionnaire and based on their experience in dealing with imagery. Figure (3) shows a sample portion of the plotted image with the effect of different compression factors.

Fig. 1 Test Image Information

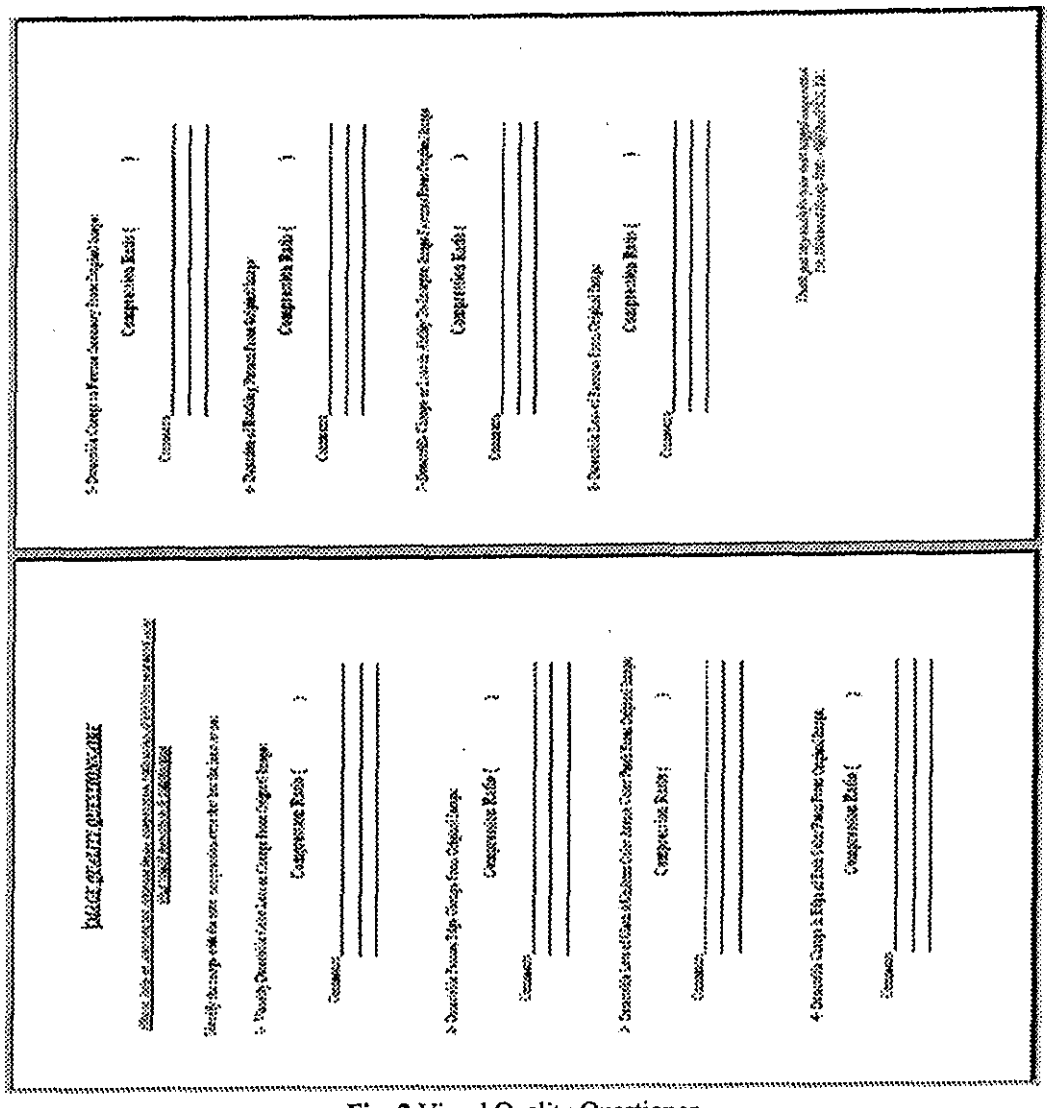

Fig. 2 Visual Quality Questioner

Based on the previously designed testing aspects, the following results were obtained:

- 100:1 compressed/decompressed imagery acquired crispy-like noise across the entire image patterns
- 80:1 and above compressed/decompressed images were well recognized by some evaluators to acquire serious artificial smoothness patterns across the image
- Starting from a compressionratio of 70:1, slight degradation was apparent, in a densely detailed features and edges.
- Although the reviewers could identify the original image, almost nobody could distinguish any difference between the 20:1 compressed image & its 50:1 counterpart.

Based upon the previously demonstrated subjective testing, it was concluded that the image compressed to 40/50:1 ratio using JPEG2000 would be satisfactory for most applications using the image as a backdrop or as the base for subjective photo interpretation usage.

5.2 Objective Quality Measure

Objective image quality measure is the process of calculation of some standard image parameters for the reconstructed image. In other words, try to compare the original and constructed image numerically. Assume that we have an image of MxN rows and lines. The original image can be expressed as a function of F(x,y) and the compressed image as a function of F'(x,y).

The following statistical measures can be used, as used within the statistical module of Lurawave image compression package:

Those parameters were calculated for all the compressed images (5 -10 – 15 – 20 – 25 – 30 – 35 – 40 – 45 – 50 – 55 – 60 – 65 – 70 – 75 – 80 – 85 – 90 – 95 – 100 – 125 – 150 : 1).

Figure (4) shows some the calculated parameters.

Fig. 3 Compressed Image Portion Examples

MAE	Maximum Absolute Error	$\max\left\|f(x,y)-\tilde{f}(x,y)\right\|$
MSE	Mean Squared Error	$\frac{1}{N\cdot M}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\left[f(x_i,y_j)-\tilde{f}(x_i,y_j)\right]^2$
RMS	Root Mean Squared Error	$\sqrt{MSE}$
SNR	Signal to Noise Ratio	$10\log\left(\frac{\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}f(x_i,y_j)^2}{\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\left[f(x_i,y_j)-\tilde{f}(x_i,y_j)\right]^2}\right)$
PSNR	Peak Signal to Noise Ratio	$20\log\left(\frac{255}{RMS}\right)$

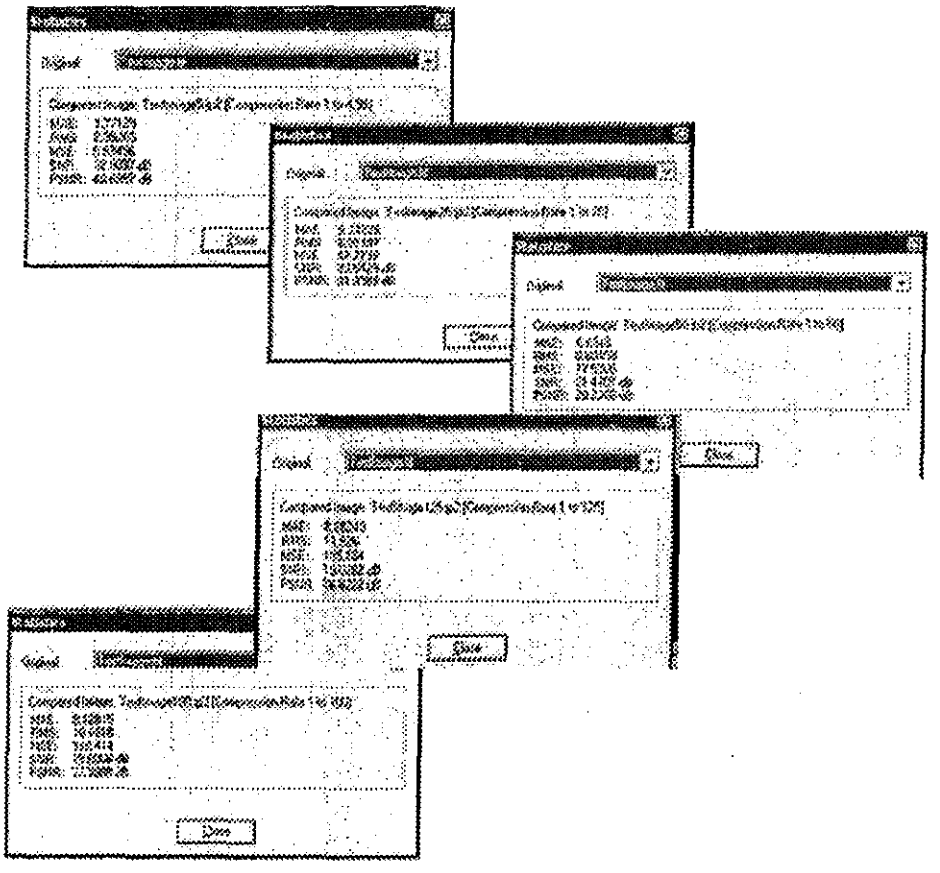

Fig. 4 Compressed Image Parameters

In this testing procedure, it was decided to use the most usable and widely accepted standard measures for image quality (see for example 14), namely:

- Signal To Noise Ratio
- Peak Signal To Noise Ratio
- Max. Absolute Error.

It was also important to set up a criteria or a threshold for judging the imagery using the previously mentioned parameters. An extensive research was conducted and the following was concluded:

- Based upon the ISO 12232 standard for determining image quality, Acceptable image quality should have a min. SNR of 22dB and recommend a value below 7 dB for MAE (4).
- Several researchers indicated that, a PSNR of 30 dB or greater is considered to be acceptable for subject recognition (see for example 15).

Table (1) and Figure (5) shows the complete results for all the compressed images.

Table (1) Objective Testing Results

Compression Ratio	SNR (dB)	PSNR (dB)	MAE
5	32.90	40.7	1.8
10	27.90	35.7	3.2
15	25.80	33.6	4.1
20	24.40	32.1	4.8
25	23.50	31.3	5.2
30	22.90	30.7	5.6
35	22.40	30.2	5.9
40	22.00	29.8	6.2
45	21.70	29.5	6.4
50	21.40	29.2	6.6
100	19.60	27.4	8.1
125	19.00	26.8	8.7

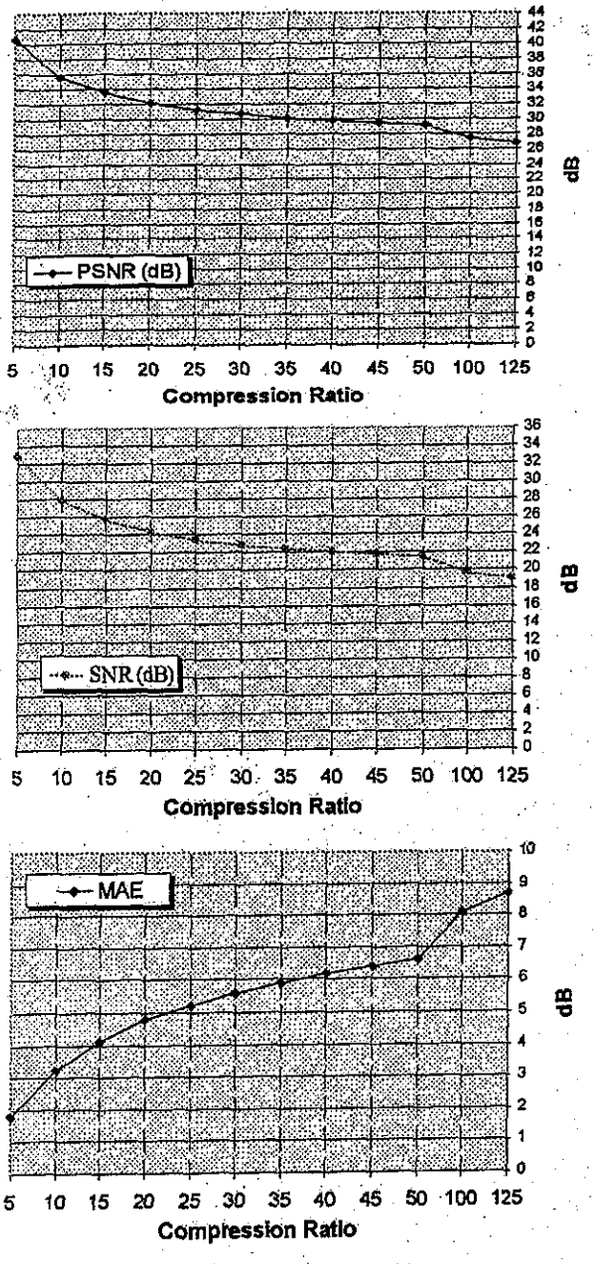

Fig. 5 Objective Testing Charts

When trying to interpret the previously produced results, we can find that:

- a compression ratio of 40 :1 and/or 45:1 and below will satisfy the condition of having an acceptable image quality based upon the PSNR parameter.
- a compression ratio of 45 :1 and/or 40:1 and below will satisfy the condition of having an acceptable image quality based upon the SNR parameter.
- a compression ratio of 60 :1 and/or 50:1 and below will satisfy the condition of having an acceptable image quality based upon the PSNR parameter.

Based upon the subjective and objective testing procedure conducted in this research, it was concluded that the image compressed to 40:1 ratio using JPEG2000 would be satisfactory for most applications using the image as a backdrop or as the base for subjective photo interpretation usage.

5.3 Spectral Quality

One of the most important aspect when deciding to use a certain compression technique is to be aware of the amount of change that may affect the spectral characteristics of such image, i.e. the pixel value. The change of the pixel value will affect any further spectral analysis of the image. In a change diction application, it is very important to preserve the spectral characteristics of the image to hold as a real representative for the situation at hand. A decision has been made to test the spectral effect of JPEG2000 compression standard at different compression level by:

- Classifying the original image using Max. Likelihood (ML) parametric classification
- Classify the compressed/decompressed images at different compression levels (5 – 10 – 15 – 20 – 30 – 40 – 50 – 60 – 70 – 80 – 90 – 100:1)
- Study the difference between the original image classified and the compressed/decompressed images using the same training areas
- It is important to realize that, we are not judging the classification accuracy, this is out of the scope of this research, but rather we are examining the difference between the original and the compressed images when performing the same spectral classifiers and with the same training conditions.

The test image contains 6 main categories of classification, namely, 2 Green area types, Forest areas, Water areas, Buildings, and Roads. Figure (6) shows the image with the training areas and the classification results for the test image.

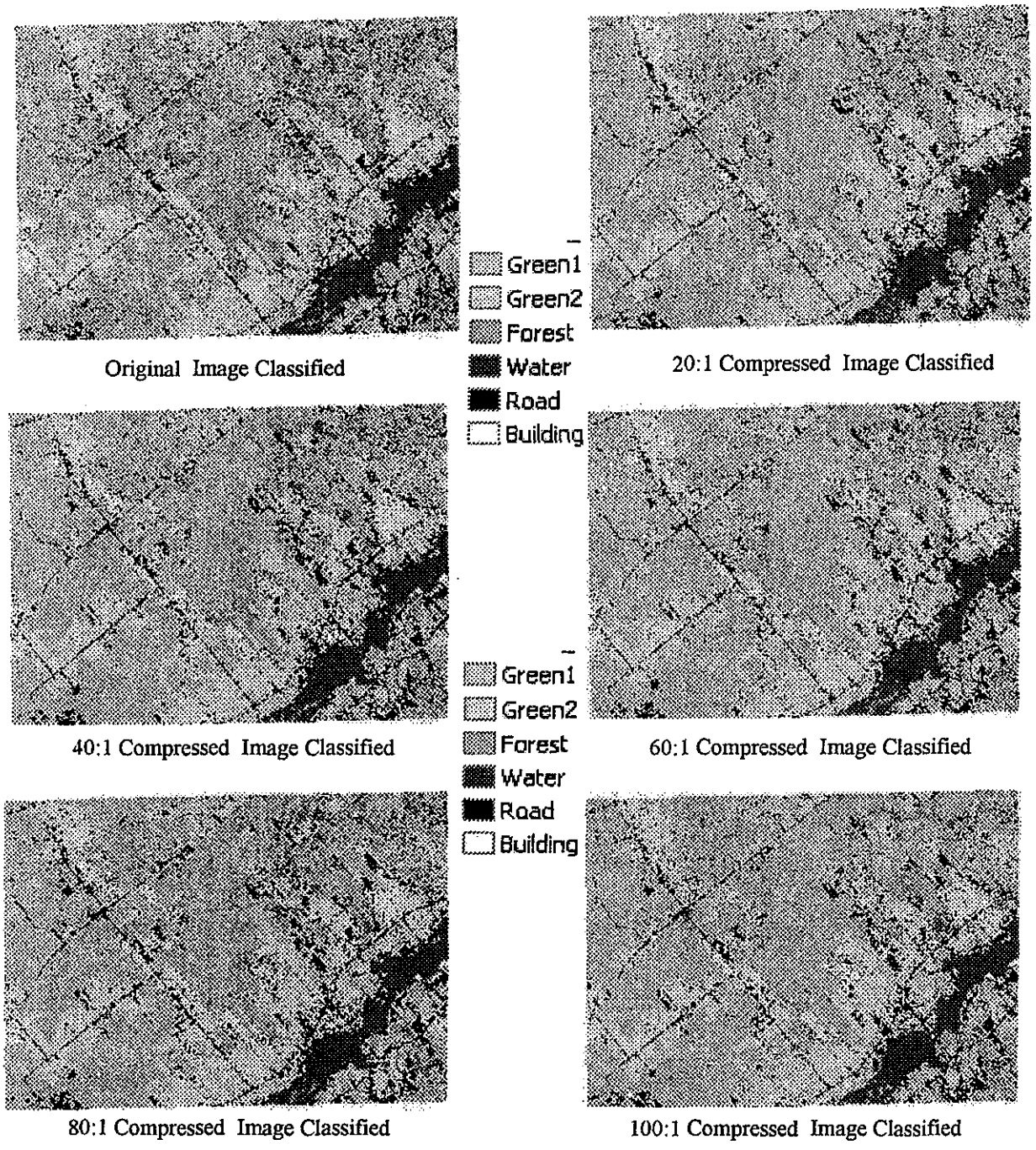

Fig. 6 Compressed Image: Classification Results

As can be seen in the following table, Table (2), the following process was followed to determine the effect of image compression on the classification results:

- we should identify and count the number of pixels for each information categories within the classification process and for different compression factors;
- calculate the difference between the compressed image and the original image results for all categories and for each compression factor
- based on the pixels count for each category, we create a weight for each category, for example the weight for G1 for the original image can be represented by the number of pixels of G1 divided by the total number of pixels;
- We can then calculate the weighted average of all categories for all compression factors.

The final results are shown in Table (2) and Figure (7).

Table (2) Compressed Image: Classification Results

Compression Ratio / Category	G1 (pixels)	G2 (pixels)	F (pixels)	W (pixels)	P (pixels)	B (pixels)
ORIGINAL	17287546	3124075	16484147	3651082	1617265	3294071
5	16756189	3037907	16422759	3511793	2093077	2836401
10	16243620	2990829	16993706	3348479	2140734	2940758
15	15867951	2925985	17441641	3192350	2207118	3018581
20	15578141	2890842	17794645	3057547	2235053	3093896
30	15256479	2860492	18135661	2926093	2254317	3215084
40	14862680	2815635	18570388	2859277	2298228	3231418
45	14727140	2814053	18702421	2848247	2297109	3269185
50	14665113	2809079	18765525	2835460	2295973	3288076
60	14499311	2793738	18931445	2832220	2308586	3292826
70	14328736	2785458	19144190	2829879	2350304	3210559
80	14231677	2765485	19208621	2802003	2376014	3273716
90	14089368	2730920	19331089	2790511	2412438	3303802
100	13998919	2730962	19415073	2783548	2433307	3433307

Compression Ratio	Weighted Average of Change %
0	0.0
5	3.7
10	6.6
15	9.3
20	11.3
30	13.5
40	15.8
45	16.5
50	16.8
60	17.6
70	18.4
80	19.1
90	19.9
100	20.5

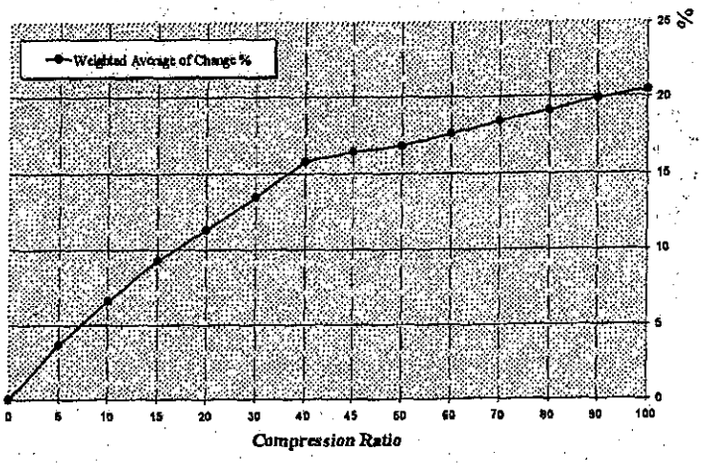

Fig. 7 Compressed Image: Classification Results Chart

Based upon the results produced form this part, the user should expect a classification result differences/errors of approximately up to a max. of +/- 15% if we would follow 40:1 ratio obtained from the visual quality testing stage when using JPEG2000.

5.4 Spatial Quality

The potential introduction of geometric distortions through the compression process is a very important issue in Surveying and/or Geomatics projects. Geometric distortions change the location of image points and as a result degrades the accuracy of any further operations or applications using the reconstructed images.

In order to quantitatively determine the geometric distortion caused by the compression/decompression operations, 10 control points (representing building corners and road intersections as shown in Figure (8)) have been chosen and their coordinates compared in the original and reconstructed images. Using The Max. Shift in X,Y we could identify the average range of error occurred in the position for both X and Y coordinates. The results of the geometric testing is shown in Table (3) & Figure (9).

Table (3) Compressed Image: Max. Shift Results

point #	Original Coordinates (X) m	Original Coordinates (Y) m
1	427041.4	795535.1
2	425701.1	794513.9
3	425343.7	7928?8
4	425499.0	792373.64
5	426492.5	791539.68
6	427449.9	790646.14
7	428751.8	702484.20
8	430334.7	793199.12
9	429753.1	793300.59
10	428407.2	793543.77

Compression Ratio	Max. Shift (X) m	Max. Shift (Y) m
5	0.73	0.82
10	0.81	0.86
15	0.92	0.95
20	0.89	0.96
25	1.04	1.1
30	1.15	1.21
35	1.23	1.28
40	1.41	1.25
45	1.45	1.31
50	1.64	1.52
100	1.53	1.58
125	1.72	1.81

Fig. 8 Control Points Location

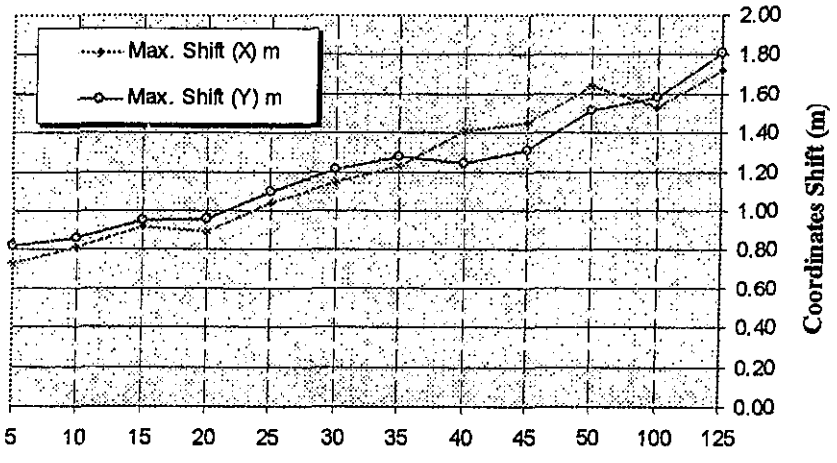

Fig. 9 Compressed Image: Max. Shift Chart

Based upon the results produced form this part, the user should expect a spatial shift of the image pixel/errors of approximately up to a max. of +/- 1.4m if we would follow 40:1 ratio obtained from the visual quality testing stage when using JPEG2000.

6. CONCLUSIONS & RECOMMENDATIONS

As shown in this piece of research, image compression is a very essential in handling high resolution spatial images. Although, there are some compression standard algorithms on the market, it is important to set up a criteria for max compression ratio that should compromise between the image size and the final compressed/decompressed image output. Based upon this research, using the most recent JPEG2000 compression standard on the market, the following can be concluded:

- Using JPEG2000 we can reach up to 40: 1 compression ratio with almost no or negligible degradation for image quality;
- This level of compression will produce a spectral degradation of about 15% on the image spectral characteristics, especially when used for image classification;
- A max. shift of 1.4 m should be expect when compressing the image using JPEG2000 40:1 compression ratio;
- The user should determine the extended use of his/her image and decide on the compression ratio suitable for the project at hand based on the results presented on this research.

It is also recommended that the same methodology developed in this research should be utilized in pure urban area imagery and for high resolution satellite imagery as well.

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