Satellite Imagery Quality Evaluation using Image Quality Metrics for Quantitative Cadastral Analysis

Babawuro Usman
Jigawa State Institute of Information Technology, Kazaure, Nigeria

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Satellite Imagery Quality Evaluation using Image Quality Metrics for Quantitative Cadastral Analysis

[1]Usman Babawuro, [2]Zou Beiji

School of Information Science and Engineering, Department of Computer Science, Central South University, Changsha, 410083, Hunan, PR China

[1]wuroabu@yahoo.com
[2]bejzou@vip.163.com

***Abstract*— Satellite imageries are provided in both panchromatic and multispectral images. The former have higher spatial resolutions while the latter have relatively lower spatial resolutions but are rich in spectral information. The two types of images have complementary features of spatial and spectral resolutions as such could be fused or merged to produce a better imagery that would be used in land use classification, cadastral feature analysis, change detection, maps updates, hazards monitoring and many other land related applications as well as for general quantitative image analysis. Image fusion quality evaluation approaches are divided into two main categories: qualitative and quantitative evaluation approaches. In qualitative approach, quantifying image quality is done through subjective means by human experts, whereas quantitative evaluation is based on objective performance assessments of the fusion processes. Registration of images that may be used as reference in image quality measure is a crucial step in Satellite image processing. Errors due to registration of reference images give rise to local errors in merging processes and these results in significant color and other distortions in the fused imagery. Before using the images in cadastral aspects of object extraction or recognition, the quality assessment of these image data is highly crucial and cannot be over emphasized. The paper attempts to measure the quality of high resolution multispectral images of a region that has a variety of artificial and natural patterns using some well known image quality assessment metrics or predefined quality indicators. Experimental comparisons, using Matlab as a tool, between sets of noised and referenced images of different high resolution images, demonstrated the effectiveness of the proposed method. Finally, the necessary metrically good satellite images for further quantitative cadastral analysis were practically obtained.**

***Keywords*— Satellite Imagery, Image Fusion, Quality metrics, Cadastral Analysis, Spatial resolution**

I. INTRODUCTION

With the successful launching of the new generation of satellite imaging systems, very high resolution Multispectral (MS) and Panchromatic (Pan) images are made available, to enhance the automation of vision tasks, and in some instances, act as replacements to the traditional aerial photographs [1]. The recent progress in Satellite imagery, in terms of higher spatial resolution and faster data processing, has opened up new possibilities regarding its use for quantitative and qualitative assessments. Using high resolution Satellite imagery, an assessment of cadastral features could be performed successfully. Based on the performance of GOES-8, future spacecraft in the GOES I–M series is providing many years of useful services to Image Analysists, Meteorologists, Oceanographers, and the general environmental community [2]. Satellite imageries are provided in both panchromatic and multispectral images. The former have higher spatial resolutions while the latter have lower spatial resolutions but are rich in spectral information. The two types of images have to be fused or merged experimentally to produce some complementary characteristics of spatial and spectral resolutions so as to be used in land use classification, cadastral feature analysis, change detection, maps updates, hazards monitoring [10], [11], and many other land related applications as well as for general quantitative analysis. Intensity–Hue–Saturation (IHS) based fusion methods, however, may introduce severe radiometric distortion, i.e., bias in local mean, in the sharpened MS bands, due to the low-pass component of the Pan image, which affects the fusion product [1]. All the above methods are simply used in the case of exactly three spectral bands. When a larger number of components is concerned, e.g., for IKONOS-2 and QuickBird having four spectral bands, comprising Blue (B), Green (G), Red (R), and Near Infrared (NIR), IHS methods are applied to three bands at a time, whose fused image are displayed in color, either true or false. However, spectral distortion can be measured, regardless of the number of components, as the absolute angle between a pixel vector in the true and in the fused MS data. It is desirable that such an angle is lower than or equal to that measured between the resampled original low-resolution MS data and the true high-resolution MS data, when available, as in fusion carried out on spatially degraded images. When the angles are equal means that the fusion algorithm has thoroughly preserved the available spectral information and also obtained the obvious benefits of spatial enhancement [1]. Measurement of image quality is a challenging problem in many fields of Image Processing [4]. It is of fundamental Importance to numerous image and video processing applications [13]. In the past years, a vast literature has appeared with many approaches attempting to provide solutions [12]. The goal of image quality assessment (IQA), is to design algorithms that can automatically assess the quality of images or videos in a perceptually consistent manner [13]. The most widely used full-reference image quality and distortion assessment algorithms are peak signal-to-noise ratio (PSNR) and mean squared error (MSE), which do not correlate well with perceived quality [4],[12]. MSE is also not good because the residual image is not uncorrelated additive noise and it contains components of the original image[12]. IQA of Pan-sharpened MS images is not an easy task [1]. Even when spatially degraded MS images are processed for Pan-sharpening, and therefore reference MS images are available for comparisons, assessment of quality, or more exactly of fidelity to reference, usually requires computation of a number of different score indices. Examples are Correlation Coefficient (CC) between each band of the fused and reference MS images, bias in the Mean, Root Mean Square Error (RMSE), and Spectral Angle Mapper (SAM), which measures the spectral distortions introduced by the fusion process [1]. IQA of different image fusion schemes are traditionally carried out by subjective evaluations. Image quality evaluation goal coincides with the subjective image quality assessment (SIQA) of an image, as the subjective mean opinion score of the image quality follows human visual perception [8] as such it is tedious, expensive and cannot be conducted in real time [12]. In addition to the stated demerits, SIQA is not only difficult to reproduce and verify, but it is also difficult to embed into the image fusion algorithms to optimize some parameters, hence the need for objective image fusion performance metrics that are consistent with human visual perception [3], [8], [12] so as to get the most metrically optimum images for certain quantitative image analysis. Objective image quality assessment (OIQA) research aims at designing quality measures that can automatically predict the perceived traditional image quality [6]. These quality measures play important roles in a broad range of applications such as image acquisition, compression, communication, restoration, enhancement, feature extration, analysis, display, printing and watermarking [6]. OIQA is generally classified into two approaches: Perceptual and Structural information based and the closer it is to the SIQA, the better the metrics [8], [6]. However, there is no current standard and objective definition of image quality as such the field is still open for rigorous reseach [7]. After spatial enhancement of satellite imagery, preservation of spectral information regarded as differences among spectral bands, or equivalently as color hues in the composite representation of three bands at a time should be guaranteed. So, the procedures developed have often been based on the transformation of spectral bands, resampled at the scale of Pan, into Intensity–Hue–Saturation (IHS) coordinates, replacement of the smooth Intensity component with the sharp Pan; and then getting the inverse transformation to yield the fusion product. Image fusion quality evaluation approaches are divided into two main categories: qualitative and quantitative [4] evaluation approaches. In qualitative approach, quantifying image quality is done through subjective means by human experts, whereas quantitative evaluation is based on objective performance assessment of the fusion processes. Registration of images that may be used as reference in image quality measure is a crucial step in Satellite image processing [9]. Specific examples of systems where image registration is a necessity include matching a target with a real-time image of a scene for target recognition, monitoring global land usage using satellite images, matching stereo images to recover shape for autonomous navigation, and aligning images from different devices for various analysis [9]. Errors due to registration of reference images give rise to local errors in merging processes and these results in significant color and other distortions in the fused imagery. Before using the images in cadastral aspects of object extraction or recognition, the quality assessment of these image data is highly crucial and cannot be over emphasized. Because of the inherent drawbacks associated with subjective measures of image quality, there has been a great deal of interest in developing quantitative measures, either in numerical or graphical forms, that could be consistently used as substitutes [5], [8]. The measure is not only to judge image quality but also for quality judgment across various algorithms. This latter part is definitely more challenging compared to the former. It is known that Mean Square Error (MSE), the most common objective criteria, or its variants do not correlate well with subjective quality measures [5]. In this paper, objective image quality metrics for MS images having three spectral bands are applied to the Pan-sharpened MS images produced using Erdas Imagine. We experimentally applied some algorithms for image quality assessments to two categories of multispetral satellite imageries.One category contained the original images while the other contained noised images of the first category so as to assess quantitatively their metric quality values using Matlab as a tool. In the end, we then assessed the capabilities of the image metrics with respect to the images used. Knowlegdge and performances of the metrics enabled us to understand the qualities of the images for future quantitative cadastral analysis. The images with the best or most optimum quality metrics are to be used for such analysis. The rest of the paper is organised as follows: Section 2, covers the related work. Section 3, gives highlight on the image fusion quality assessments. Section 4, handles the implementation. Section 5, is the results of the experiments, while Section 6, contains the conclusion.

II. RELATED WORK

Measurement of image quality is a challenging problem in many image processing fields from image compression to printing [4]. Earlier works by [5], described image quality vis-vis different compression techniques, and [4] used Singular Value Decomposition approach to measure locally and globaly the quality of a gray scale image. Reference [1] focuses on quality assessment of fusion of multispectral (MS) images with high-resolution panchromatic (Pan) observations. Using the theory of hypercomplex numbers, or quaternions, they defined new quality index suitable for MS imagery having four spectral bands. Reference [6], proposed a multi-scale structural similarity approach for image quality assessment, which provides more flexibility than single scale approach in incorporating the variations of image resolution and viewing conditions. One of the shortcomings of structural similarities measure index, (SSIM), index algorithm is that it is a single scale approach [6]. As contained in [6], the authors ended up by introducing a novel image synthesis-based approach to calibrate the parameters that weigh the relative importance between different scales in trying to determing the quality of an image. Reference [3], presented a novel objective quality metric for the evaluation of image fusion schemes where special interest of the metric lies in the fact that the redundant regions and the complementary/conflicting regions are treated respectively according to the structural similarity between the source images. Image quality measure based on Discrete wavelet transform (DWT) sub-band decomposition properties which are similar to human visual system characteristics facilitate the integration of DWT into image-quality evaluation as presented by [7]. Reference [8] approached the method from a different perspective. Since evaluating the quality of an image is equivalent to measuring the degree of deformation of the structure of the image, they proposed a new image quality metric based on the Harris response, which is computed from the gradient information matrix and its eigenvalues. Reference [12], presented detailed survey review of image and video quality assessment algorithms, for the metric quality assessment of such compressed images and videos.

III. IMAGE QUALITY MEASURE

In general, the qualititative evaluation approach for image fusion quality is a time consuming process and needs expert operators [3]. Therefore, there is a wide range of research in the direction of the quantitative evaluation which is based on objective performance assessment of fusion process. A quantitative approach should measure the ability of fusion process to transfer all perceptually important information of input images into the output image as accurately as possible. However, quantitative performance assessment is a difficult issue due to the variety of different requirements and the lack of a clearly defined ground-truth. A wide range of quantitative fusion assessment techniques are based on the initial concepts of image quality metrics such as Entropy, Universal Quality Index (UQI) and Correlation Coefficient (CC), which are already used to compare quality of two different images in image processing applications. Measures that require both the original (reference) image and the distorted image are called "full-reference" methods while those that do not require the original image are called "no-reference" methods. The quality measures included in our evaluation are all discrete and bivariate, e.g, they provide some measure of closenss between two digital images by exploiting the differences in the statistical distributions of pixel values. F(j,k) and f(j,k), could denote the samples of original and degraded image fields. One of the most commonly used quantitative measure metric is SSIM which uses the structural information for evaluating the image quality. Structural information used in SSIM consists of three components such as luminance, contrast, and structure comparison functions [8]. SSIM for the corresponding regions in a reference original signal x and the test image signal, y is as defined in equation (i) as contained in [3], [8].

SSIM(x,y|w) =

$$\frac{(2\overline{w}_x\overline{w}_y + C_1)(2\sigma_{w_x w_y} + C_2)}{(\overline{w}_x^2 + \overline{w}_y^2 + C_1)(\sigma_{w_x}^2 + \sigma_{w_y}^2 + C_2)} \qquad \text{(i)}$$

which is decomposed as shown in (ii),

SSIM(x,y|w) =

$$\frac{(2\overline{w}_x\overline{w}_y + C_1)(2\sigma_{w_x w_y} + C_2)(\sigma_{w_x w_y} + C_3)}{(\overline{w}_x^2 + \overline{w}_y^2 + C_1)(\sigma_{wx}^2\sigma_{wy}^2 + C_2)(\sigma_{wx}\sigma_{wy} + C_3)} \qquad \text{(ii)}$$

where C_1, C_2 and C_3 are small constants, with $C_3 = C_2/2$, wx denotes the sliding window or the region under consideration in x, $\overline{w}_x$ is the mean of w_x, $\sigma^2_{w_x}$ and $\sigma_{w_x w_y}$ are the variance of w_x $\sigma^2_{w_x}$ and covariance of w_x and w_y, respectively. The value SSIM(x, y| w) is a measure for the similarity between the regions w_x and w_y. If SSIM is close to one, the distorted image is similar to the reference image. Its dynamic range is [−1, 1] and the best value of 1 is achieved if and only if w_x and w_y are the same.

IV. Implementation

The proposed quality index is evaluated by using very high resolution multispectral Quick Bird Satellite Imagery data comprising of four bands with 2.4 m (7 ft 10 in) resolution acquired in 2005 over a relatively flat landscape at Changsha City, Hunan Province in the South Central region of PR China. From this, a set of true color imageries are fused and synthesied for the analysis. Then another set of noised images of the same format to tamper with their structural characteristics and size are as well obtained, as image degradation deforms the structure of an image [8]. In the experiments, classical image quality parameters were computed, analysed and visual comparisons of the images done and recorded. The purpose of taking the mentioned paramenters is to assess the reliability and the completeness of this method of image metric performance evaluation for images so as to metrically assess their qualities for further quantitative cadastral analysis. Thus, in our experiments, we employed sets of original 365x286 satellite images with different types of content and also used corresponding sets of distorted images for the metric analysis. In Fig 1 and Fig 2, we show sample of the results.

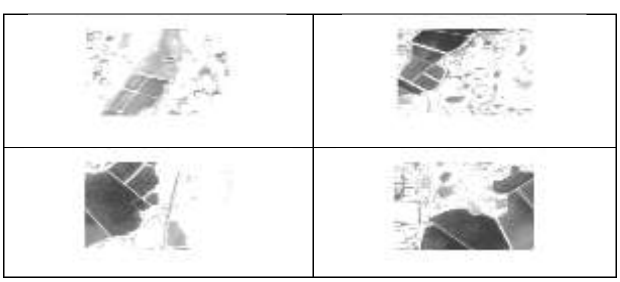

Fig.1 Fused and distorted Satellite Images

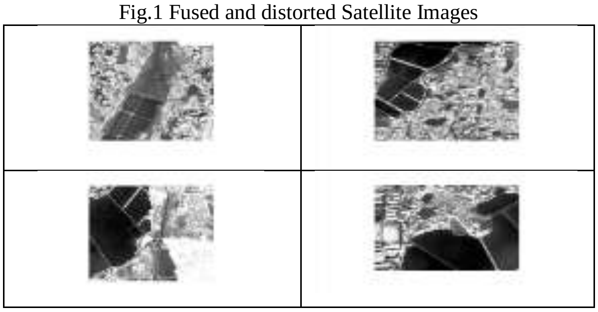

Fig.2 Original Satellite Images

V. Result

To carry out the image metric performance evaluation of the proposed approach, we have carried out sets of experiments comprising of the original and the corresponding distorted images. Hence, we tested a number of image quality assessment algorithms using the given images so as to assess their impact metrically and to know the best images metrically for quantitative analysis. In the experiment, each image was subjected to test metricallly using the twelve metics of the listed image quality metric indices shown in Table 1.

Table I Comparison between Different Quality Measures for the Images

Metrix	**Exp1 (Set of Image 1)**	**Exp2 (Set of Image 2)**	**Exp3 (Set of Image 3)**	**Exp4 (Set of Image 4)**
SSIM	0.7642	0.7578	0.7511	0.7597
PSNR	13.7039	14.6397	13.3603	13.1189
MSE	2.7713e +03	2.2341e+ 03	2.9994e+ 03	3.1709e+ 03
MSSIM	0.8213	0.7201	0.7514	0.6817
VSNR	10.2674	11.7424	10.6578	11.3086
VIF	0.2861	0.2294	0.2005	0.1879
VIFP	0.3097	0.2398	0.2382	0.2332
UQI	0.7650	0.7035	0.7568	0.7408
IFC	1.7546	1.2887	1.2148	1.2798
NQM	7.4247	6.0163	5.3648	2.4182
WSNR	12.6987	13.9335	12.5115	12.2932
SNR	12.2341	13.4979	12.0284	11.9274

Graphically the results are depicted as shown in Fig. 3, Fig. 4, and Fig. 5

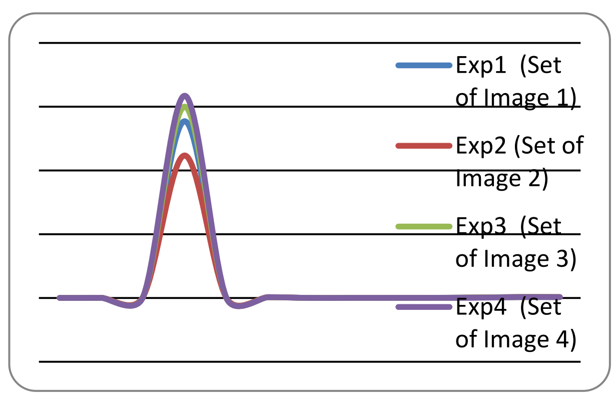

Fig 3 Shows the trends over image categories

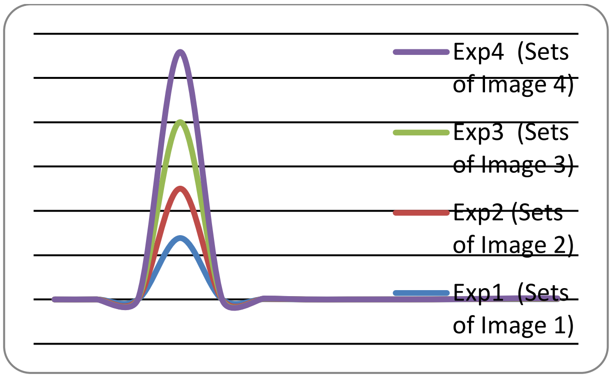

Fig 4 Shows the distribution of each value over the image categories

The summery of the trends and distribution of metric indices over the image categories are shown in Fig 3 and Fig 4.

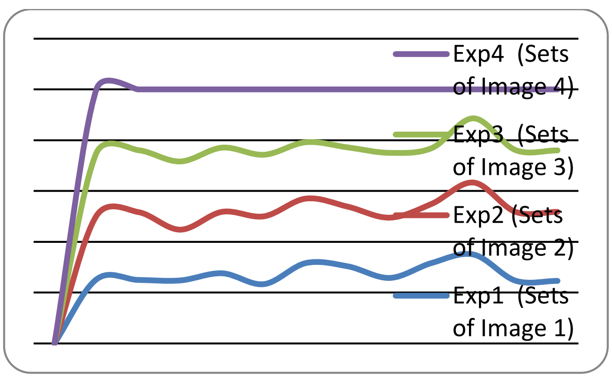

Fig 5 Shows trend of the percentage each value contributes over the image categories

Finally, for every one of the objective evaluation criteria, NQM model outperforms all the other models. From Fig.5, it could also be seen that the set of images for Exp4 responded in a very good manner compared to other sets of images as such it is assessed as the images with the strongest quality for further quantitative cadastral analysis.

V. CONCLUSIONS

In view of the importance of image fusion in high resolution satellite imagery, wide range of objective image fusion quality metrics have been discovered. The registration process is the main step in all of the image fusion techniques. Through this paper, we have been able to understand the sensitivity of image fusion quality metrics. Our experimental results show that, most of these metrics have acceptable capability and robustness for quantification of visual image fusion quality. On the other hand, some of them have serious problems in assessments of image fusion quality under registration errors. This is because of their inability to detect the local degradation.Through the experiment, we have been able to assess and identify the images with the most metrically good qualities so as to be used for further quantitative cadastral analysis of the features therein. It would be interesting, as part of future research, to study image quality based on the spectral and or spatial nature of the objects contained in the imagery, and also in order to improve the quality of our metric, other factors such as entropy or mutual information could be embedded in the experiment.

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