DOI: 10.24996/ ijs.2017.58.4A.19

ISSN: 0067-2904

The Effect of Using Inter-Frame Coding with Jpeg to Improve the Compression of Satellite Images

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Abstract

Many recent satellite image compression methods depends on removing the spectral and spatial redundancies within image only , such these methods known as intra-frame(image) coding such as predictive and transformed based techniques , but these contributions needs a hard work in order to improve the compression performance also most of them are applied on individual data. The other trend is to exploit the temporal redundancy between the successive satellite images captured for the same area from different views, different sensors, or at different times, which will be much correlated and removing this redundancy will improve the compression performance and this principle known as inter-frame(image) coding .In this paper, a latest powerful method for compressing sequences of satellite images using inter-frame coding concept with compression method (JPEG) has been presented to satisfy higher compression performance while keeping images quality as well as preservation of significant image details. The experimented results show that the proposed method outperformed many of lossy methods including JPEG.

Keywords: Satellite images, lossy Image Compression, Inter-Frame Coding, JPEG Compression.

تأثير استخدام الترميز الزماني بين الصور مع طريقة JPEG لتحسين ضغط الصور الفضائية

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الخلاصة:

تعتمد العديد من اساليب ضغط صور الاقمار الصناعية الاخيرة على توظيف التكرار الطيفي والمكاني داخل الصورة فقط ،هذه الطرق تعرف بالترميز داخل الاطار(الصورة) مثل التقنيات القائمة على التنبؤ والتحويل، ولكن هذه المساهمات تحتاج الى عمل شاق من اجل تحسبن كفاءة اداء الضغط ومعظمها يتم تطبيقها على البيانات الفردية. الاتجاه الآخر هو استغلال التكرار الزمني بين صور الأقمار الصناعية المتعاقبة التي تم التقاطها لنفس المنطقة من وجهات نظر مختلفة ،و أجهزة استشعار مختلفة، أو في أوقات مختلفة ، والتي سوف تكون مرتبطة الى حد كبير وازالة هذا التكرار سيساعد على تحسين كفاءة الضغط ، وهذا المبدأ يعرف باسم الترميز بين الاطر (الصور) .في هذا البحث تم تقديم أحدث طريقة قوية لضغط الصور الفضائية المتوالية باستخدام مفهوم الترميز بين الأطر مع طريقة الضغط (JPEG) لتلبية كفاءة ضغط اعلى مع الحفاظ

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على جودة الصور وكذلك الحفاظ على التفاصيل الهامة للصورة. اظهرت النتائج ان الطريقة المقترحة تفوقت على العديد من طرق الضغط من النوع (lossy) المعتمدة ومن ضمنها الطريقة القياسية (JPEG).

1- Introduction

The basic fundamental behind image compression is to remove unnecessary redundancies from data [1]. In the spectral domain the overlapping between different spectral bands and the similarity of pixels' responses for them will be reason to the spectral redundancy. In the spatial domain (intra-frame), the intensity value of the pixel could be estimated from adjacent symmetric features of its neighboring pixels within an image [2]. The transform based compression methods (i.e. JPEG2000, Wavelet transform) and prediction based methods (i.e. DPCM) depends on removing spectral and spatial redundancies within an image only and this is called (intra-frame /image coding) [3].

In temporal domain (Inter-frame) redundancy, the intensity of same pixel positions onto successive frames tends to be similar. Removing temporal redundancy are widely used in video compression such as HEVC technique, but recently it used side by side with other types of redundancy to enhance the compression performance for compress sequence of satellite images by taking advantage of the historical archive of satellite images captured for the same area at small temporal intervals under different conditions [4], and this is called (inter-frame /image coding).

This paper actually emphasis inter-intra image coding process, which consequently improves the compression performance. The two main stages are: - Inter-frame coding stage and the Intra-frame coding stage using standard lossy compression method (JPEG). Inter-frame coding stage includes implementing an automatic image registration procedure between two successive satellite images the base(historical satellite image) and sensed (new captured satellite image) to make the total differences between them as small as possible, these two satellite images taken for the same scene under different conditions (different sensors, different viewpoints, different times …etc). Then a subtraction operation has been applied between the base and new aligned satellite image to obtained almost sparse matrix which symbolize the residue image, this will substantially reduce the size of image to compress. Finally intra-frame coding stage is implemented using the lossy compression technique (JPEG) on the resulting residue image (only) that contains the new changes in sensed satellite image than the image itself.

The rest of this paper is organized as follows. Related work is discussed in section 2, Section 3 is the most important section and it describes the proposed satellite images compression scheme, image feature extraction and registration. In section 4 the used data set is described. Numerical simulation results are presented in Section 5, and the conclusion of this paper goes in Section 6.

2-Related Work

A number of recent attempts are proposed to applied several typical methods to satellite images compression. Here are some of these presented techniques:-

- Md. Al Mamun et al. [2] proposed a lossless compression method for satellite image based on using reversible integer wavelet transformation to improve the temporal correlation thus improves the compression performance. The introduced method results compared with JPEG2000.
- Aseel et al. [3] introduced a lossless satellite images compression using Inert-frame coding with the standard LZW compression method. And compare the obtained results with the compression of the entire satellite image using LZW (Lempel-Ziv-Welch), the introduced scheme attained CR (compression ratio) equal to 4.2.
- LIU XiJia et al. [4] Implemented a novel remote-sensing image compression, based on using priori-information collection of historical remote-sensing images and registration technique to remove temporal correlation between newly-captured remote-sensing images and historical ones. The results outperform JPEG2000 and JPEG by over 1.37 times for lossless compression.
- Rehna V.J and Jeya Kumar [5] introduced a survey on some of most current wavelet coding methods. The results proved that Geometric Wavelet (GW) coding, the Embedded Block Coding with Optimized Truncation (EBCOT) and the Adaptive Scanned Wavelet Difference Reduction (ASWDR) algorithms are doing better than Embedded Zerotree Wavelet (EZW) and the Wavelet Difference Reduction (WDR). Also, explained what the proper images for each above-mentioned method are.
- Shichao Zhou et al. [6] submitted a review of recently remote sensing image compression and dividing these methods into predictive coding and transform coding, also introduced the new solutions

for Remote sensing image compression which are: Region Of Interest (ROI)–based compression methods and task-driven coding methods.

- Sendamarai.P et al. [7] proposed satellite image compression using the Le Gall's 5/3 architecture with lifting based scheme. In this architecture all the operation is implemented using shift operations which reduce implementation overhead. The best PSNR is achieved is 29.81dB.
- Bogdan Rusyn et al. [8] introduced a comparison for some of lossless compression methods that suitable for remote sensing compression, the comparison are made in terms of implementation on FPGA (field-Programmable Gate Array) and the recommendations are given.
- Ahmed Hagag et al.[9] introduced a novel technique for satellite image compression based on rate control, the proposed technique divide the image bands into two groups and encode each at different bit rate, the used images taken from different sensors. The proposed technique was compared with traditional satellite image compression techniques and the results show lower impact than that of traditional techniques.

3-Proposed Method

The proposed compression technique for sequence of satellite image have two main stages are: - Inter-frame coding stage and the Intra-frame coding as show in Figure-1.But first of all to ensure correct detection for image features, a detail enhancement of image contrast should be implemented such that the output image contains a uniform distribution of intensities, this can be accomplished using histogram equalization method to stretches the dynamic range of image histogram [10].

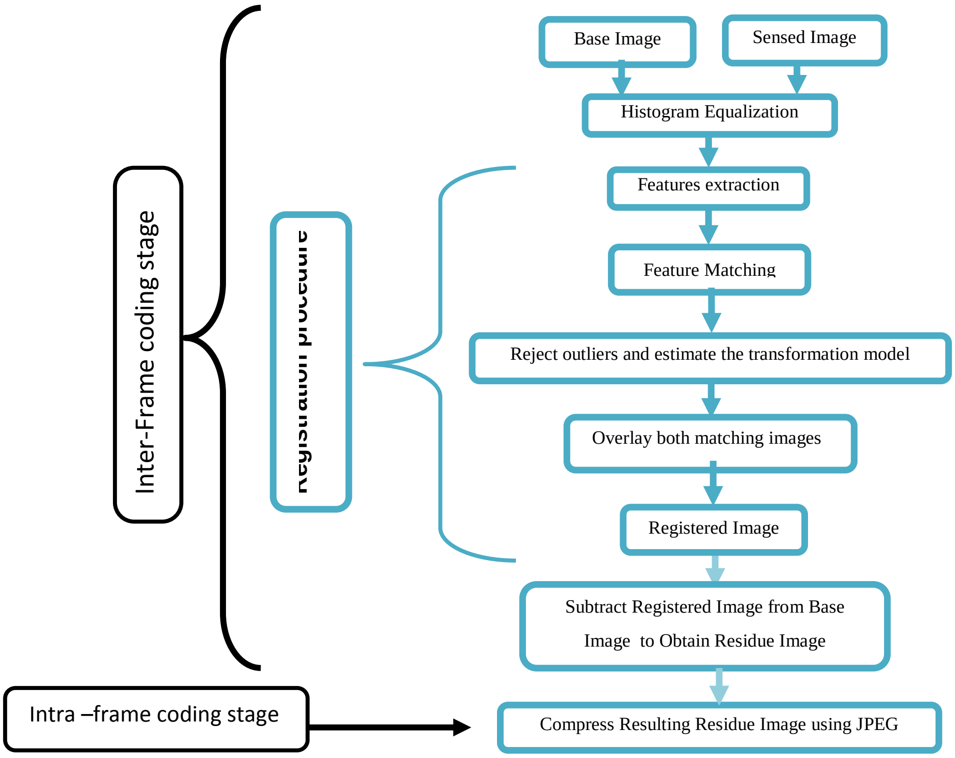

Figure1- Major Stages of the Proposed Satellite Image Compression.

3-1 Inter-frame coding stage

Inter-frame coding stage includes implementing an automatic image registration technique and subtraction operation in order to extract only the new added information in the sensed image to compress it.

3-1-1 Image Registration

To implement the geometrical transformation, which is needed to align two or more images taken under different conditions (different sensors, different viewpoints, and at different times), image registration is the key technology, Figure-1. Image registration techniques can be classified as: *Intensity based methods*, which are depending on compare intensity patterns in images, and *Features* *based methods*, these methods find point by point correspondence between images, where features represented points, lines or intersections [11].

The adopted registration method in this paper is the feature based method. Feature –based methods extract features (keypoints) automatically from each image then match these features to find the similarity between the two images and then estimate the geometric transformations [12]. The procedure for extracting and matching image features is summarized as follows:

➢ **1- Feature extraction**

This step including detection of features like points, edges, corners manually or automatically. Corners consider a good feature because it represents a point in which the gradient of the image in both directions has a large variation that can be used to detect it, Figure-2. The proposed algorithm uses Harris corner detector technique to extract features in the base and sensed images which will be registered. Harris detector based on Moravec's corner detector, in which sum of squared differences (SSD) must be computed between a patch around the point and patches shifted a small distance in any direction to determine if it a corner depending on if there is large changes or not [13].

Harris corner detector composed of:-

1. Compute the horizontal dx and vertical derivatives dy for both images.
2. Apply Gaussian filter to convolve each of those images, this smoothing filter is important to ensure that the derivative is not picking up any noisy bits and the derivatives will be more delicate.
3. Compute the three terms in the matrix *M*. (Equation 1).
4. Compute C (Equation 2) and determine if the detected good feature is a corner or not considering the given threshold.

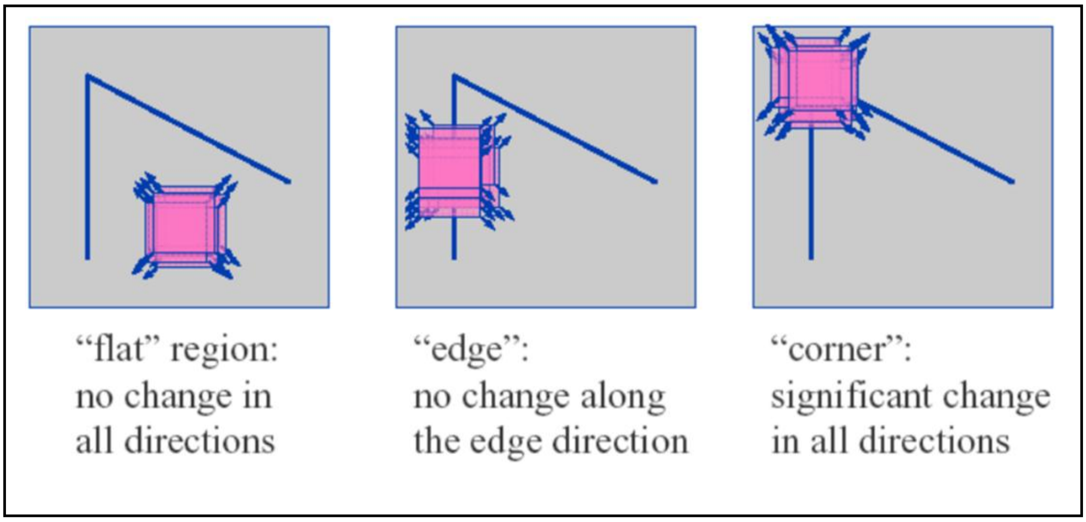

Figure2- Harris Corner Detector Basic Idea [13]

$$M = \sum_{x,y} w(x,y)\begin{pmatrix} I_xI_x & I_xI_y \\ I_xI_y & I_yI_y \end{pmatrix} \qquad (1)$$

$$C=|M| - k(trace\ M)^2 = \lambda1\lambda2 - \kappa\,(\lambda1 + \lambda2)2 \qquad (2)$$

Where:

$\begin{pmatrix} I_xI_x & I_xI_y \\ I_xI_y & I_yI_y \end{pmatrix}$: Harris matrix (denoted by *M*) represents products of the gradients (Ix, Iy).

w(x, y) :Gaussian blur weighting window is built around each candidate corner as a kind of smoothing the image prior to taking the derivative, so the derivative is not picking up kind of noisy bits of the imagery and the derivatives will be more accurate.

C : Harris point response if it large then it is a corner.

(λ1, λ2) : are the Eigen values of the matrix. If both values are greater than given threshold it will be consider a good chosen feature (corner).

K : is a tunable parameter.

- **2- Feature Matching**

It means matching the detected features from the newly acquired image with the base image. The limitations in these methods are: corresponding features may be hard to detect, and / or the features may be unstable with respect to time [14]. This operation can be performed using normalized cross correlation (NCC) rule to directly compare the intensities in small patches around each feature point. NCC can be defining as [15]:

$$NCC(A, B) = \frac{1}{N}\sum_{x,y}\frac{(A-\mu_A)(B-\mu_b)}{\sigma_A\sigma_B} \quad (3)$$

Where: N is the total number of pixels in image A and B;
(μA, μB) are the mean of images A & B, respectively, for simplicity let the mean =0.
(σA, σB) are the standard deviation of images A and B, respectively.

The matching operation will produce some of wrongly correlated matching point pairs because of the algorithm restriction, occlusion, sensor moves, or the symmetric structure of the scene itself, for this reason the robust estimator RANSAC algorithm was used to remove the outliers [16]; so the resulting contains only an enhanced list of correct matching points that demonstrates the actual matches list between the sensed and the base images.

- **3- Reject outliers and estimate the transformation model**

At the stage of feature points matching, the RANSAC algorithm (RANdom SAmple Consensus) has been used to get best effect and to solve and refine the transformation matrix between images.
RANSAC Algorithm has the following main Steps [16]:
1) Randomly selected a sample of 4 pairs of matched points as a sample RANSAC;
2) Calculate the transformation matrix H according to the 4 matching points.
3) Compute the transform matrix H and the error metric function According to the sample set, to satisfy the consistency of the current transform matrix, and return the number of uniform set elements.
4) Determine the set of data points that are within a distance threshold t of the model H to be inliers.
5) Check if the error probability (P) > the minimum allowable error probability, if so repeat (1) to (4) iteration, else stop.

- **4- Apply transformation function**

Pixel locations in the base image differ from pixel locations in the sensed one, because of the differences in geometrical translation and rotation between the two images [17], also called image rectification. Here, the 1st order affine geometrical transformation is applied; which performs linear mapping. It is a combination of linear transformation and translation. In 1st order affine transformations, the relation between two corresponding points (x, y) and (X, Y) can be defined as [3]:

$$x = m1+m2X+m3Y \quad (4)$$
$$y = n1+n2X+n3Y \quad (5)$$

Where: (m1, m2, m3) and (n1, n2, n3) are the transformation coefficients.

3-1-2 Obtaining the Resulting Residue Image

At this step the resulting residue image can be taken from the transformed image by subtracting the transformed sensed satellite image from the base one. (Adding 128 and clipping operations) can be used to remove negative values that appeared by subtraction operation.
The following main steps illustrate this procedure:
Step 1: diff←image2(x, y) - image1(x, y);
diff ← diff+128;
Step2: check IF (diff >255) Then (diff ← 255)
Else IF (diff < 0) Then (diff ← 0)
Step3: Obtaining residue image
Step 4: compress residue image using standard JPEG,
Step5: End.

3-2 Intra-frame coding stage

This stage involves compress the obtaining resulting residue image using standard JPEG to eliminate any remaining correlation among pixels within image, so the compression operation will be applied on the new added information only rather than the compression of the entire sensed image and this will satisfy a high compression ratio as shown below in the following sections.

4-Results

Using C# programming language, an application has been built to evaluate the proposed methodology. The image given in Figure- 3 was subset of tested images, Landsat7, gray scale images, each of which has 7 bands, with dimensions 8181x 7181 taken over Iraq/Baghdad.

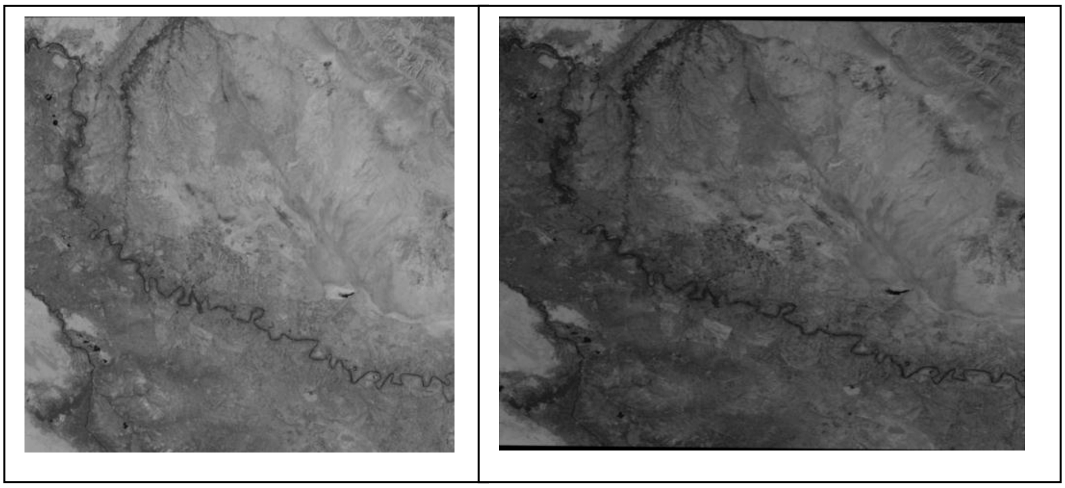

Figure3- Image pair, band7, Path: 168, Row: 037
Left side: reference Image, taken at 31/8/2000, size :(816X718) pixel
Right side: Sensed Image, taken at 2/10/2000, size: (818X718) pixel

To determine whether the transformation task has performed successfully or not, the similarity measurement (i.e., Mean Square Error (MSE) has been used as an error metric according to the following formula, [3] :

$$\mathrm{MSE} = \frac{1}{\mathrm{N}}\sum_{\mathrm{y}}\sum_{\mathrm{x}}\left(\mathrm{Img}_1(\mathrm{x},\mathrm{y}) - \mathrm{Img}_2(\mathrm{x},\mathrm{y})\right)^2 \quad (6)$$

Where, N is width x height.

This error metric was computed twice. Firstly between the base and sensed image (MSE1), and secondly between the base and transformed image (MSE2).

Table1- evaluation of transformation operation

Image Band	(MSE1) Between Base and Sensed Image	(MSE2) Between Base and Transformed Image
1	1883	728
2	1771	718
3	1693	641
4	2667	1298
5	1890	634
6	1685	592
7	1226	560

As shown in Table-1, the results indicate that the MSE2 always less than the computed MSE1,and this refers to that the registration operation minimize the dissimilarity between the base and transformed image .

Another measure was used to calculate the distribution of pixels values in transformed data image and in resulting residue data image, it is called Entropy measure .This statistical tool measures the randomness of values and can be defined as [3]:

$$E = -\sum P(i)\log P(i) \quad (7)$$

Where $P(i) = \frac{Histogram(i)}{no.of\ image\ pixels}$ (8)

The following table (Table- 2) given the computed entropy measurement for both transformed and resulting residue image, and the obtained results show that the Entropy values will always decrease for the resulting residue images, which is means that the resulting residue image is more convenient for any compression scheme.

Table2- Entropy Comparison

Image Band	Entropy for Transformed Image	Entropy for Residue Image
1	6.485	5.093
2	6.920	5.081
3	7.4255	5.001
4	6.646	5.063
5	7.284	5.014
6	7.363	4.933
7	6.926	5.237

For each Registered Sensing Image and residue image apply compression using standard JPEG for three chosen qualities for JPEG technique (80%,50%,25%) and calculate the (CR)for each case, then reconstructed it to calculate the (MSE) and (PSNR) between the compressed and the reconstructed one as clarified in Figure-3, the computed results shown in Table- 3.

Where the popular tool Peak signal to noise ratio (PSNR) is used for measuring the quality of the reconstructed image and its formula is [4].

$$\mathrm{PSNR} = 10\log_{10}\left[\frac{(\mathrm{MAX})^2}{\mathrm{MSE}}\right] \quad (9)$$

MAX: the maximum possible pixel value of the image.

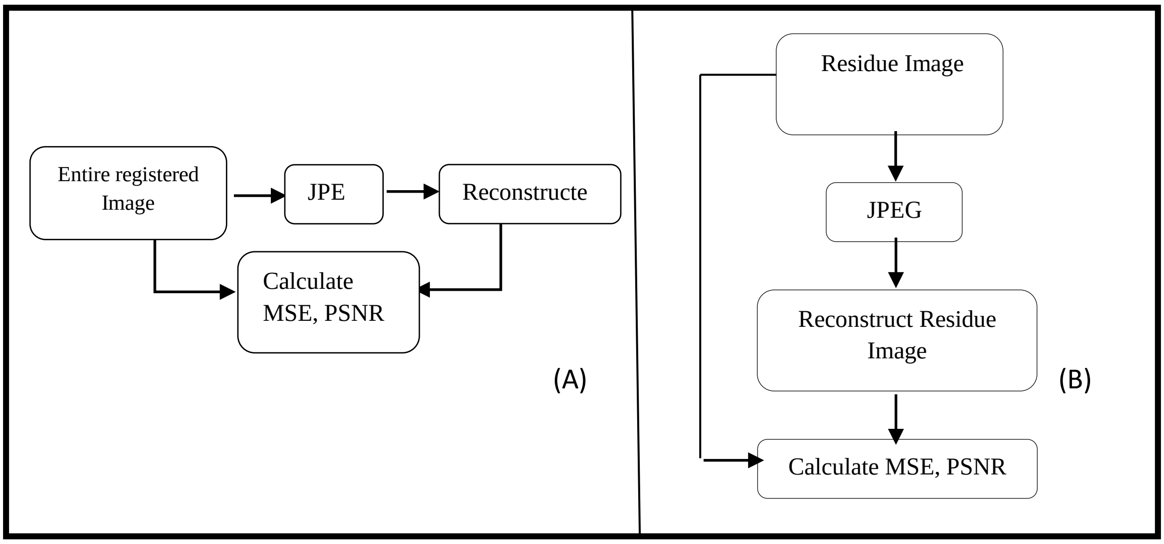

Figure3- Apply Compression for
(A): The Entire Registered Image **(B):** The Resulting Residue Data Image only

The following table (Table -3) shown the comparison results of the proposed scheme (compress the residue image only) and the compression of entire new sensed image using 3 different compression qualities for JPEG method (80%,50%,25%), the listed results shows that the proposed scheme outperformed the compression of the entire sensed image.

Table3- MSE, PSNR, CR comparisons

Image Band	JPEG quality	For Registered Image			For Residue Image		
		CR	MSE	PSNR	CR	MSE	PSNR
1	80%	15.242	25.70	33.981	27.543	12.22	37.338
2		15.392	25.311	34.151	27.543	12.41	37.338
3		15.392	24.734	34.151	28.807	11.32	37.716
4		13.193	34.122	32.816	21.896	19.44	35.343
5		14.857	11.312	33.716	28.312	26.733	37.817
6		15.242	25.411	34.151	28.597	11.142	37.716
7		15.242	26.353	33.981	27.068	12.41	37.338
Image Band	JPEG quality	For Registered Image			For Residue Image		
		CR	MSE	PSNR	CR	MSE	PSNR
1	50%	24.960	54.921	30.727	51.140	21.220	34.908
2		25.200	53.332	30.888	51.140	20.991	34.908
3		25.160	52.115	30.970	53.583	19.011	35.343
4		21.685	81.014	29.045	39.447	35.314	32.690
5		24.299	57.302	30.572	52.525	19.321	35.343
6		24.960	53.127	30.888	53.583	19.321	35.343
7		25.12	56.012	30.648	49.841	22.011	34.706
Image Band	JPEG quality	For Registered Image			For Residue Image		
		CR	MSE	PSNR	CR	MSE	PSNR
1	25%	37.559	88.833	28.636	90.751	31.936	33.079
2		37.831	85.320	28.836	90.751	31.239	33.217
3		38.014	84.212	28.888	96.913	28.449	33.659
4		32.776	131.001	26.958	66.808	51.720	30.970
5		36.619	91.214	28.540	93.975	29.440	33.506
6		37.559	83.788	28.888	96.319	28.434	33.659
7		38.060	90.980	28.540	91.388	32.632	32.945

The above results show that:

1- A highest gain in (PSNR, CR) when applying the proposed scheme for different JPEG compression qualities, where the best obtained CR is 96.913 for Image band3 with PSNR equal to 33.659.

2- Lowest (MSE) when applying the proposed scheme for different JPEG compression qualities, which means keeping image quality.

3- Whenever the JPEG quality value is decreased the (CR, PSNR) values will be increase.

5-Conclusion

In this paper, a lossy compression scheme for satellite images is proposed. Applying inter-frame coding as well as intra –frame coding techniques has been used to improve compression performance.

The numerical simulation results show that the proposed scheme for compression only the residue image outperforms standard image compression schemes such as standard JPEG, where the numerical simulation results show that the best obtained CR is 96.913.

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