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Satellite Image Enhancement using Optimized Wavelet Decomposition and Bicubic Interpolation

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Abstract: Satellite Images (SI) play a vital role in various civilian and military applications for weather forecasting, monitoring of resources of the earth, environmental studies, observing natural disasters and natural calamities, etc. When these SI are used in military applications and almost all other applications for efficient study, the big challenge is its resolution. In wavelet transforms based satellite image enhancement techniques, choosing a proper wavelet transform plays a key role and vary with the image to image. To improve the resolution, a novel robust optimized wavelet decomposition and a bicubic interpolation-based satellite image enhancement method is proposed. In this method, the Stochastic Diffusion Search (SDS) algorithm is used to get the optimized wavelet decomposition of the image into different subbands and bicubic interpolation is used to improve the resolution. Image is decomposed using the optimized wavelet filter bank based on the SDS algorithm, decomposed sub-bands are interpolated with bicubic interpolation and inverse wavelet transform is applied to compose the interpolated sub-bands into a high-resolution image. The proposed method is tested on satellite images and other images also. Compared to the proposed method with the existing methods and proved that the proposed method is superior to existing methods and applicable to any type of image.

Keywords:Bicubic interpolation, Discrete Wavelet Transform, Optimized Wavelet Transform, PSNR, UIQI.

I. INTRODUCTION

Image Enhancement (IE) is very essential pre-processing technique in many image processing applications like analysis of medical images to detect the various tumours [1], satellite images to analyse weather monitoring, geoscience, geographical conditions, etc. [2]. In almost all those applications images have to be enhanced to improve the quality analysis of the images. The main aspect of the IE process is how to get the efficient resolution enhancement without disturbing the edges and textures or how to get the best quantitative (maximum PSNR) and qualitative (best visual) results in IE process.

The image can be enhanced in terms of resolution [3][4] to get qualitative and quantitative enhancement [5]. Resolution Enhancement (RE) increases the number of pixels in an image.

Interpolation is a widely used up sampling method in RE, image zooming, image resizing, etc. Interpolation is a process to assign an intensity value to unknown pixels. Mainly there are three types of interpolation techniques are used in the IE process; those are the nearest neighbour, bilinear and bicubic interpolation. Nearest neighbour interpolation is the earliest method and intensity value of the unknown pixel is filled by the intensity value of the nearest neighbouring pixel. It produces distortion and many artifacts. So that it is rarely used in IE techniques. In bilinear interpolation, the unknown pixel value is assigned by the weighted average of the four surrounding pixels. This method gives better results than the nearest neighbour interpolation, but bicubic interpolation gives the best results among these three interpolation techniques. In Bicubic interpolation, the intensity value of the unknown pixel is assigned by the weighted average of the sixteen surrounding pixels [5].

RE can be done in the spatial domain and spectral domain methods. Generally in spatial domain RE, up sampling or interpolation is applied directly on the image plane itself. These types of RE process is very fast but produce undesired artifacts at the edges, then causes the blurring and ringing artifacts in an image. In spectral-domain RE process, first image is transformed into the spectral domain, apply the interpolation and then apply the inverse transform to get back the enhanced image into the spatial domain. When an image is converted from spatial domain to spectral domain, the image can be separated into detail coefficients and approximation coefficients. Then interpolation can be applied approximation coefficients to preserve the detail coefficients.

Wavelet Transforms (WT) [6] play an important role in many image processing applications to decompose an image into different frequency sub-bands. Recently, various types of wavelet transforms are using in IE, image compression [7] and other signal and image processing applications [8]. WT is used over Fourier Transform (FT) to get multi resolution analysis. FT can be used to transform the 1-D signal or 2-D image from the time domain to the frequency domain.

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But FT does not apply to non-stationary signals, while WT gives good time resolution and good frequency resolution for stationary and non-stationary signals and images.
Choosing the mother wavelet is the crucial part of the decomposition stage of images to decompose the image into frequency sub-bands and to reconstruct the image perfectly by combining the sub-bands. Recently IE using different WT have been proposed by the various researchers.
Hassan Demirel et. all proposed RE using Discrete Wavelet Transform (DWT) and bicubic interpolation [9]. In this method, image is decomposed using DWT into four different sub-bands namely LL, LH, HL, and HH. Whereas LL having very low-Frequency Components (FC), LH having low FC, HL having high FC and HH havingvery high FC. Here frequency means the variation of the intensity value of the pixel by nearby pixel intensity value. These four sub-bands are interpolated with the bi-cubic interpolation and then apply the inverse DWT to reconstruct the image. This method compared with the previously existing techniques along with the bicubic interpolation. This DWT based method gave better results than bicubic interpolation, due to edge preservation of images by theDWT image decomposition. Due to down-sampling of DWT caused many artifacts and blurring effect in DWT based IE methods. To overcome this drawback the same authors, Hassan Demirel et. all developed IE technique using Stationary Wavelet Transform (SWT) and DWT with bicubic interpolation. Due to shift-invariance of SWT improves the visual results and PSNR than previously existed methods [8]. The efficiency of image enhancement process depends on the image decomposition technique and interpolation. Hence choosing a mother wavelet to decompose the image is a big challenge and varies with the image to image.

To eliminate this drawback, we proposed a robust resolution enhancement method which can be applied to any type of image.

II. PROPOSEDMETHOD

Optimized wavelet transform based image decomposition with bicubic interpolation method is proposed to improve the visual results and quantitative results and is shown in figure1.

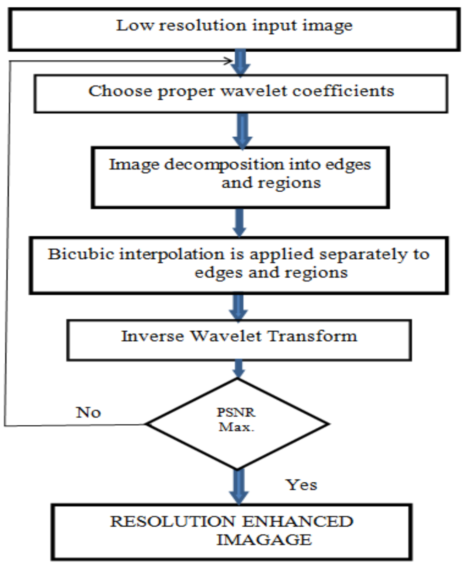

Fig1. Flow chart for the proposed Method.

A. Discrete Wavelet Transform

DWT is a wavelet transform that makes use of the wavelet coefficients. A DWT technique captures both the frequency and also the location information for an image. The resolution is a critical feature in case of satellite imaging. This has some frequency contents that are both high and low. So, this DWT technique is employed for a resolution for preserving the components of a high frequency in the satellite images [9].

The method further decomposes an input image into a total of four different sub-band images which are the Low–Low (LL), the Low–High (LH), the High–Low (HL), and the High–High (HH) where all of them are down-sampled images. The bi-cubic interpolation factor two is applied to the images to resize them. The LL sub-band image with a low-resolution input image will provide a difference image and this is combined with the rest of the sub-band images which are the LH, the HL and the HH for determining three other sub-band images. The bi-cubic interpolation along with a factor alpha/2 has been applied to all the estimated images along with the input images of a low-resolution. The Inverse Discrete Wavelet Transform (IDWT) is employed for generating a higher resolution of this input image. The components of a high frequency are not maintained owing to the DWT being used for down-sampling an image [10].

B. Bicubic Interpolation

In the processing of images, a bi-cubic interpolation is selected over a bilinear interpolation or even the nearest neighbor interpolation at the time speed is not an issue. Contrastingly, the bilinear interpolation takes only 4 pixels (2x2) into consideration. The images resembled the bi-cubic interpolation which is smoother and has a lower level of interpolation distortion [11].

In case of both function values and derivatives are known at all four corners, f, fx, fy, fxy and the (0, 0) (1, 0) (0, 1) (1, 1) of a unit square. An interpolated surface is written in (1).

$$p(x, y) = \sum_{i=0}^{3} \sum_{j=0}^{3} a_{ij} x^i y^j \qquad (1)$$

The problem interpolation contains the determination of a total of 16 coefficients aij. These will match with function values which are p (x, y) yielding about four equations (2),

1. $f(0,0) = P(0,0) = a_{00}$
2. $f(1,0) = P(1,0) = a_{00} + a_{10} + a_{20} + a_{30}$
3. $f(0,1) = P(0,1) = a_{00} + a_{01} + a_{20} + a_{30}$
4. $f(0,0) = P(1,1) = a_{00} = \sum_{i=0}^{3} \sum_{j=0}^{3} a_{ij}$

(2)

Advantages: The Bi-cubic interpolation is selected over that of the bilinear interpolation or the nearest neighbor in the image resembling at the time speed is not seen as an issue. This is because this provides a lower distortion of interpolation.

Disadvantages: This has a more complex calculation on being compared to two other methods that have been described. There is a need for more time for the generation of the output on being compared to either the nearest neighbour or bilinear methods.

C. Stochastic Diffusion Search(SDS)

There is another new approach that is introduced and this is called the SDS. This has a distributed computation mode which makes use of the correlation between all the simple agents since it is a global search based on multi-agent population and some techniques of optimization.

The root of the SDS is based on the Geoff Hinton's 3-D object classification and mapping. Compared to various other algorithms, the SDS has a mathematical model which is robust and this describes the behavior of a technique found in the researching of allotment of resources,

its global optimal convergence, a condition of minimum convergence, linear time complexity and its robustness. [12]. The work has suggested a wavelet filter bank method of optimization that has produced a better filter set which is problem-specific using the Stochastic Diffusion Searches (SDSs) that can discover the predetermined patterns and their location. The SDS can also be used for the pattern searches and also the matchings. The issues may also be considered to be in relation to the optimization through the objective function definitions F (x), for the hypotheses x with relation to the locations of the solutions as there are some similarities among target patterns and the regions at the x in the search spaces and discovering the x so that the F (x) is at its highest [19]. Normally, the SDS is employed easily to the issues in optimization in which the objective functions can be divided into several units that are evaluated independently (3):

$$F(x)=\sum_{i=1}^{n}F_i(x) \qquad (3)$$

In which the $F_i(x)$ is also given as an i^{th} partial evaluation of the F(x).

In order to locate the optimum of the specified objective functions, the SDS makes use of the population of the k agents that maintain this hypothesis. At the time of these operations, a model entails the iterations of the test and the diffusion stages until such time the convergence is performed. The SDS algorithm consists of the following steps:

1. *Initialiging agents()*
2. *While (terminating criterion is not fulfilled)*
3. *Testing hypothesis*
4. *Diffusion hypothesis()*
5. *Stop*

III. RESULTS AND DISCUSSIONS

Generally, a SDS is to discover the target in the search space or its best instantiation. Consider the search space size be N. Assume that the probability of locating the target in a uniformly random draw be p_m and let the probability of locating the suboptimal object be p_d. Let the probability of a false positive and false negative be p+ and p- respectively. Consider M agents. The state of the search in the nth step is measured by the number of active agents directing to the position of the target and active agents directing to the false positives. Only active agents are measured as useful data and efficiently they impact the search directions of all other agents. Also the strong halting condition uses only data from active agents. Thus there is finite number of discrete states in which each one is categorized by the pair of two natural numbers. SDS fluctuates its state in a random manner. The possible future evolution of the SDS is inclined by the past and so it can be demonstrated by a Markov Chain [13].
Construct the transition matrix and the state of the search in the nth step, stated as Xn, be quantified by a pair of integers (a, w), where "a" signifies a number of active agents directing to the target and w - number of active agents directing to the false positives. If in the nth step an agent is active and points to the target then it will become inactive with probability p-, else it will remain active. Likewise an active agent directing to the false positive remains in an active with probability p+, else it becomes inactive. After finding the filter coefficients which attain maximum PSNR values, images are decomposed into low pass (regions) and high pass (edges) components and apply the bicubic interpolation then apply the inverse wavelet transform to compose the interpolated sub-bands into high resolution image. The corresponding pictorial results and PSNR results are shown in figures 2 &3 respectively.

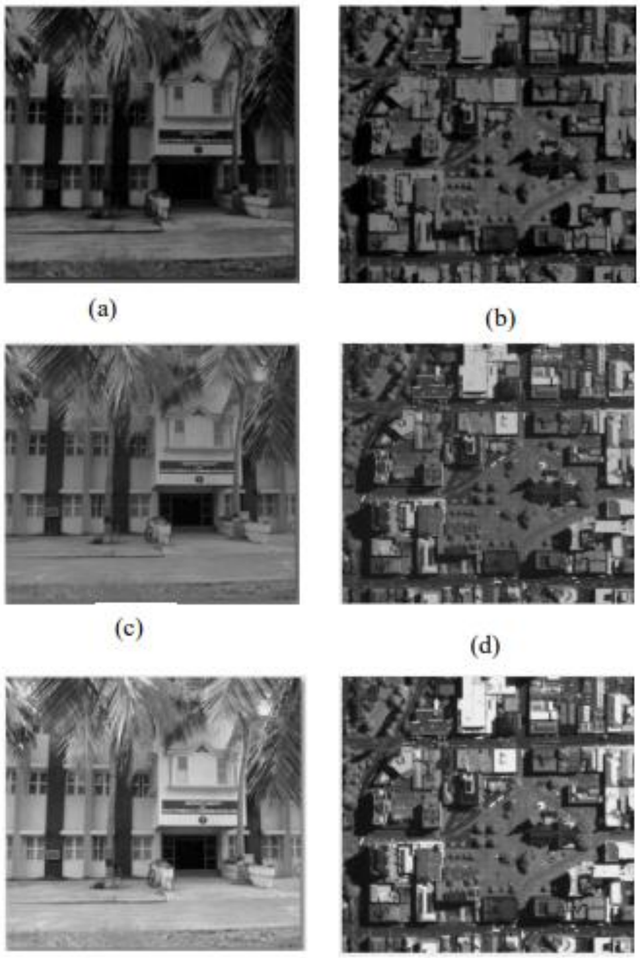
(a) (b) (c) (d) (e) (f)

Fig 2.(a) ,(b) Gray Scale Low Resolution input Images.(c),(d) DWT & Bicubic interpolation images , (e),(f) are Optimized wavelet decomposition and bicubic interpolation images.

In this section, DWT-SDS and bicubic interpolation method is compared with DWT and bicubic interpolation.

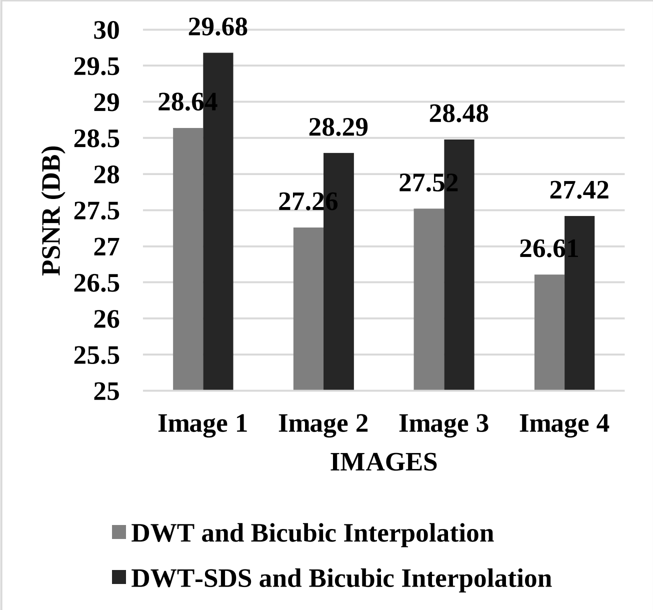

Figure 3 PSNR for DWT-Bicubic and DWT-SDS and Bicubic Interpolation

Table1. PSNR values for DWT-Bicubic and Proposed method

	PSNR in dB	
	DWT-Bicubic	DWT-SDS and Bicubic
Image1	28.64	29.68
Image2	27.26	28.29
Image 3	27.52	28.48
Image 4	26.61	27.42

From the figure 3 and table1, it can be observed that the DWT-SDS and bicubic interpolation has higher PSNR by 3.56% for image 1, by 3.7% for image 2, by 3.42% for image 3 and by 2.99% for image 4 when compared with DWT and bicubic interpolation.

IV. CONCLUSION

Optimized wavelet coefficients and bicubic interpolation basednovel robust Satellite image resolution enhancement method is proposed. Input image is separated into regions and edges to interpolate separately to the regions and edges to eliminate blurring effect in edges and reduce the artifacts by using optimized low pass and high pass filter coefficients. The accuracy of this division depends on the mother wavelet and varies with the image. Hence, a conventional image enhancement method does not give better results for all images. But this proposed method selects suitable filter coefficients for any image by the SDS algorithm. The proposed method is tested on several satellite images and also other normal camera captured images. Visual results and PSNR values prove the superiority of the proposed methodthan existing technique.

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