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Optimized Wavelet Decomposition and Gaussian interpolation based Satellite Image Enhancement

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Abstract: Satellite images (SI) play a vital role in various remote sensing applications like geoscience, geographical studies, observing the earth's atmosphere, monitoring natural disasters, etc. The SI are used in these applications require high-resolution. The performance of the wavelet transforms based resolution enhancement methods depends on the type of the mother wavelet used and it varies with image to image. The novel robust SI resolution enhancement technique including Optimized wavelet transform based image decomposition and Gaussian interpolation is proposed in this paper. Optimized wavelet decomposition is obtained using the Stochastic Diffusion Search algorithm and the Gaussian distribution function is used for interpolation. The proposed method is compared with the Discrete wavelet decomposition and Gaussian interpolation resolution enhancement method and proved that the proposed method gives the best results for any image.

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

I. INTRODUCTION

Satellite images play an important role in many research fields like weather forecasting, Geoscience and Geographical information systems etc. [1]. In all these applications, images need to be enhanced to improve the quality analysis of the images. [2][3]. 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.[4]

IE is a basic challenging task in image processing applications and it can be performed in spatial domain and spectral domain. Wavelet transforms can be transform the images from spatial domain to spectral domain efficiently but depends on the choosing mother wavelet and it varies from image to image [5]. By selecting a single mother wavelet may not be getting good results. This optimized wavelet transform can be applied to any image, optimally choose the proper mother wavelet to that particular image.

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Mainly this method consists of two main challenges. Those are separation of the image into edges and regions is the first challenge and how efficiently get the intensity value of the newly added pixels without disturbing the edges and regions is the second challenge.

From the few decades wavelets play a major role to decompose the image into low frequency components or regions and high frequency components or edges [6].

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.

Recently, various types of wavelet transforms are used 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. 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 having very 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 the DWT image decomposition [9].

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 [10]. 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. PROPOSED METHOD

The novel robust satellite image resolution enhancement is proposed and shown in figure1 below.

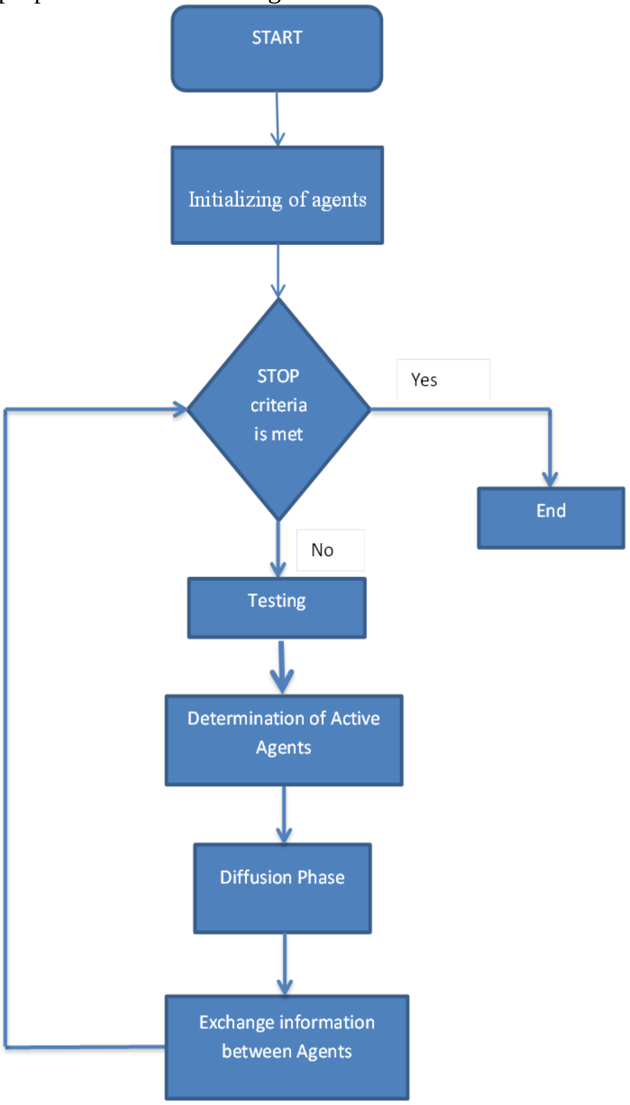

Figure1. Flow chart for wavelet filter bank optimization.

Generally, a SDS is to discover the target in the search space or its best instantiation. [11]. 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 are 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 [11].

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.

The evolution of the SDS is determined by the evolution of certain agents. There are many ways in which the SDS can transfer from one state to another, e.g. growth of the overall number of active agents by one outcome from one non-active agent passing the test or two active agents fetching inactive through the test and three inactive ones becoming active and so on. One step transition probabilities for the Markov Chain model of SDS are attained from summing up probabilities of all possible ways in which a given transition can be attained. For $p^- \neq 0$ and $p^+ \neq 0$ the probability of transition of the Stochastic Diffusion Search from the state (v,b) to (r,a) in one iteration is given by the equation (1):

$$P\{X_{n+1}=(r,a) \mid X_n=(v,b)\} = \sum_{k_2}^{\min(v,r)} \sum_{k_1}^{\min(b,a)} Bin(k_2,p^-)Bin(k_1,p^+)Mult(k_1,k_2,r,a,v,b) \quad (1)$$

Where

$$Bin(k_2,p^-) = \binom{v}{k_2}(1-p^-)^{k_2}(p^-)^{v-k_2}$$

$$Bin(k_2,p^+) = \binom{v}{k_1}(p^+)^{k_1}(1-p^-)^{b-k_1}$$

$$Mult(k_1,k_2,r,a,v,b) = \binom{M-v-b}{r-k_2} P_{ab}^{r-k_2} \binom{M-v-b-r+k_2}{a-k_1} p_{af}^{a-k_1}(1-p_{ab}-$$

and

$$p_{ab} = \frac{v}{M}p^+ + (1-\frac{v}{M}-\frac{b}{M})p_d p^+, \text{ g=M-r-a-v-b+k}_1 + \text{k}_2$$

and double summation in the is over such $k_1, k_2 \geq 0$ that $g \geq 0$.

Optimized wavelet filter coefficients achieved with the SDS algorithm. In each iteration, choose the coefficients randomly , to transform the image from the spatial coordinates into frequency coordinates

A GMM is quite flexible and also a powerful tool used for interpolation to get sharper edges and smoother details[12]. This distribution of the X samples (p (x)) has been modelled by the GMM as a linear combination of the components of the K Gaussian as per (3 and 4):

$$p(x) = \sum_{i=1}^{K} P_i f(x \mid c_i) \quad (2)$$

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In which,

$$f(x \mid c_i) = \frac{1}{\sqrt{2\pi\sigma_i^2}} \exp\left(-\frac{(x-\mu_i)^2}{2\sigma_i^2}\right)$$

$$0 < P_i < 1 \; and \; \sum_{i=1}^{K} P_i = 1 \qquad (3)$$

And the P_i, μ_i, σ_i^2 indicate the probability (or weight), the mean, and also the variance of that of the ith component. A set of parameters specifying this model was θ = $\{P_i, \mu_i, \sigma_i^2\}_{i=1}^{K}$. A model parameter (θ) has been estimated by the X samples $x_1, x_2, \ldots, x_{U\times V}$. By assuming samples of the X and independent identical distribution, the parameters of log-likelihood are (9):

$$L(\theta) = \log p(X \mid \theta) = \log \prod_{j=1}^{U\times V} p(x_j \mid \theta)$$

$$= \sum_{j=1}^{U\times V} \log \sum_{i=1}^{K} P_i f(x_j \mid c_i) \qquad (4)$$

The Maximum Likelihood (ML) based estimate of the θ is (10):

$$\hat{\theta}_{ML} = \arg\max_{\theta} L(\theta) \qquad (5)$$

It is a well-known fact that the $\hat{\theta}_{ML}$ is not easily found in an analytical manner. The normal algorithm for obtaining the $\hat{\theta}_{ML}$ has been the Expectation Maximization (EM). This EM has been an iterative process which identifies the local maxima of the L (θ). This EM begins from the initial guess for $\hat{\theta}_{ML}$, and the L (θ) which keeps increasing for every iteration until such time a convergence of EM takes place[13].

III. RESULTS AND DISCUSSIONS

In this section, DWT and GMM Interpolation, DWT-SDS and GMM interpolation methods are used. The PSNR values are shown in table 1 and visual results are shown in figure 2 and 3.

	DWT-GMM	SDS-DWT-GMM
Image 1	29.64	31.45
Image 2	28.26	29.05

Table1. Comparision of Proposed method with DWT-GMM method

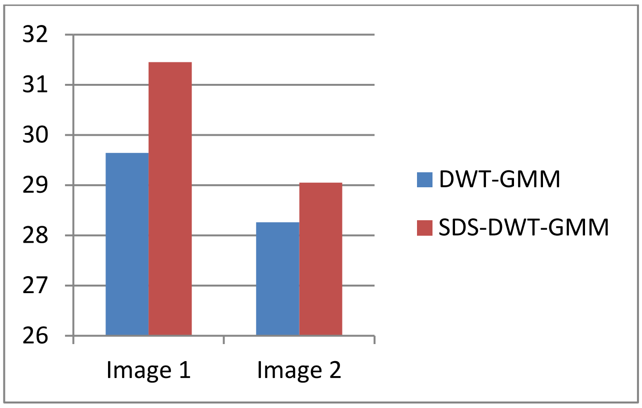

Figure2. Comparison graph of the proposed method with the DWT-GMM.

From the Table1 2, it can be observed that the DWT-SDS and GMM interpolation has higher PSNR by 6.1% for image 1, by 2.79% for image 2 when compared with DWT and GMM interpolation.

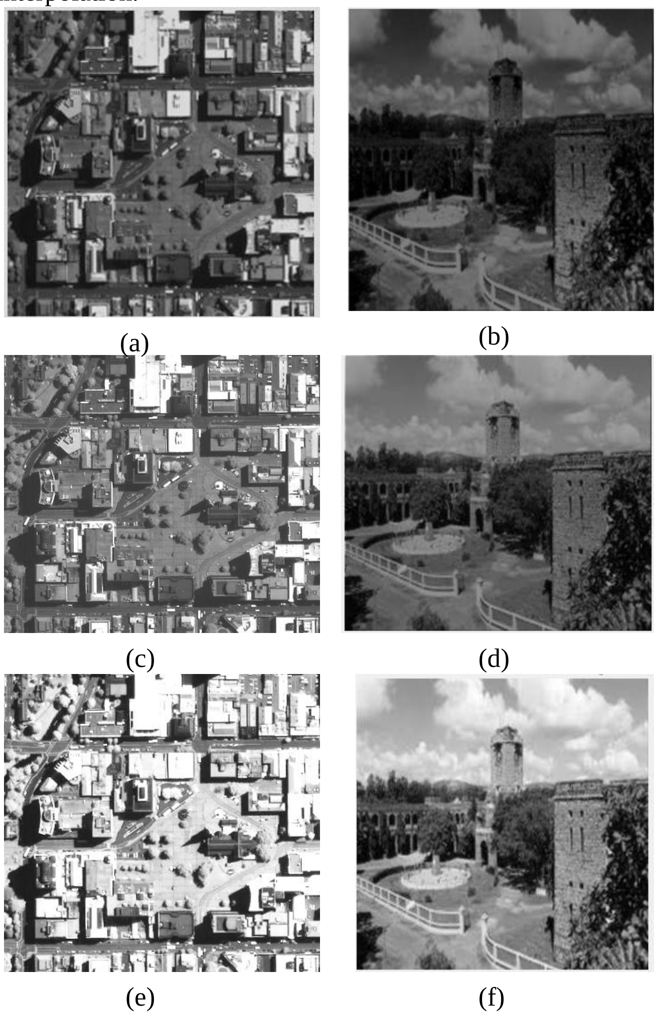

Fig 3. (a) ,(b) Gray Scale Low Resolution input Images. (c),(d) DWT & GMM interpolation images , (e),(f) are SDS Optimized wavelet decomposition and GMMinterpolation images.

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IV. CONCLUSION

A novel technique for the resolution enhancement of Satellite images with Optimized wavelet decomposition and Gaussian interpolation is proposed. Resolution enhancement is obtained by applying Optimum wavelet decomposition and Gaussian interpolation. The results show that the approach is reliable and robust for enhancing the quality of the image and further exhibit that even a change in wavelet coefficients effected the subjective (PSNR values) and objective pictorial results significantly which otherwise could not be found empirically or randomly. It can be observed that the DWT-SDS and GMM interpolation has higher PSNR by 6.1% for image 1, by 2.79% for image 2 when compared with DWT and GMM interpolation. This significant improvement in quantitative and visual results is obtained due to the precise selection of wavelet coefficients in the image decomposition and Gaussian model in interpolation for further enhancement of image resolution.

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