IMAGE RESOLUTION ENHANCEMENT OF SATELLITE IMAGES USING DYADIC INTEGER COEFFICIENT WAVELET FILTER FOR WAVELET TRANSFORM

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Abstract

In this paper, image resolution enhancements for satellite images are proposed using dyadic integer coefficients based wavelet filter (DICWF). We proposes a technique in which discrete wavelet transform and stationary wavelet transform using DICWF which is used to obtain a high resolution image and this image is derived from frequency subbands. The satellite images play a very vital role now days in the development of technical aspects which needs to be enhanced. These satellite images are superresolved with the help of dyadic integer coefficient-based wavelet filters, which reduces the hardware complexity and computational difficulties due to the rational and integer coefficients of these filter banks. The value of the peak signal-to-noise ratio (PSNR) of the proposed method and the resultant visual images of the proposed method show the effectiveness of this algorithm over other existing algorithms using discrete wavelet transform. Noise can be minimized by applying thresholding on different frequency subbands which obtained by the application of DICWF to the noisy, blurred input images.

Keywords: Image superresolution. Satellite image enhancement, wavelet transform, thresholding

1. Introduction

A satellite imaging system can be utilized for different applications significantly in daily routines, including: reports of daily weather monitoring as well as climate change, land surveillance system for both rural and urban, monitoring of vegetation, water, food materials, natural minerals etc., military reconnaissance. The list is enormous. Clearly, it has a number of applications in daily and important aspects of human life, it has to be analysed, synthesized, and processed properly. The majority of satellite images are processed using different digital image processing methods. In the satellite images, majorly two kinds of geometric errors are observed due to earth rotation effects, the scanning system induced variation in nominal ground resolution, cell size, and one-dimensional relief displacement along with the scanning system tangential scale distortion. This distortion can be rectified using the hardware of the satellite imaginary system, but its cost is more and is recurring. Even the hardware has its own limitations for the enhancement of resolution, hence most of the scientists and researchers have been developing different algorithms/techniques/methods for the correction of geometric errors of satellite images. Two processes have been adopted: image-to-map rectification and image-to-image

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registration for the enhancement of resolution by resampling. In these processes, translation and rotational alignment of satellite images are carried out. Furthermore, image enhancement is obtained by performing either at point or local operations such as contrast stretching, density slicing, spatial filtering, Fourier analysis, image reduction and magnification, etc. Normally, the size of the satellite images is larger than 3000×3000 pixels and has different bands of frequency. To view the image, either it has to be reduced or magnified along with enhancement. Different techniques have been adopted for image magnification reduction that comes under the resampling of the image which affects the resolution of the images.

Presently, satellite images are used in many applications to extract more information for daily use as compared to decades before. Thus, in this paper satellite images are chosen as the subject for processing using one of the proven techniques of image processing that is known as image superresolution, which is used for the enhancement of resolution and quality of images. It is the process to generate high resolution image from noisy, blurred, and undersampled low resolution images. Here in this paper, satellite images which are degraded due to under sampling, different motion blur, are improved with the help of superresolution algorithm based on dyadic integer coefficient wavelet filter. To achieve the same, it is needed to derive high resolution satellite image from different low resolution images. In various literature of image enhancement and improvement of resolution, using different techniques, methods, and algorithms have been suggested. Interpolation techniques such as pixel replication, bilinear, bicubic, linear interpolation which add the number of pixels without adding more information details, are used for single frame superresolution [1][2][3]. However, blur has been introduced in the edges of images when interpolation techniques are applied to any form of image. Hence, it is a convenient approach to follow the multi-frame superresolution techniques to obtain high resolved image. In the literature survey of superresolution techniques, it is observed that normally the superresolution techniques are come under the following one of the categories: Frequency domain reconstruction, Iterative, and Bayesian methods. The pioneers of superresolution, Tsai and Huang [4] have utilised frequency domain reconstruction for the generation of high resolution images from different noisy, blurred, and undersampled images. Gajjar and Joshi [5] proposed a superresolution method in which the discrete wavelet transform is used to derive the learning of high frequency subbands. In this method, orthogonal wavelet filter bank is used to generate high frequency information from the low resolution images. This filter creates boundary distortion of the image which causes degradation of the image itself. With the help of the standard biorthogonal wavelet filter bank (cdf-9/7), Ji and Fermullar [6] have obtained super resolution where more focus was concentrated on the problem of image restoration and frame alignment. In this paper, a problem of irrational coefficients of cdf-9/7 was defined and that problem causes the hardware complexity which increases the number of shifts and adders. Jiji et al. [7] obtained the super resolved images using wavelet coefficient from different frequency subbands which are obtained from wavelet transform. This method focuses on frequency analysis of local region than global using Fourier transform. Nguyen and Milanfar [8] presented the superresolution method using wavelet-based interpolation restoration. Anbarjafari and Demirel [9] invented a new superresolution method in which high frequency subbands are obtained from discrete wavelet transform (cdf-9/7). In this method, the superresolved image is obtained from interpolation of high frequency subbands and the input image. The same authors have used DWT

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and SWT to derive high frequency subbands and obtained the high resolved image [10]. Chappali and Bose [11] presented lifting-based wavelets for super resolution. Patil and Singhai [12] have used fast curvelet transform (FDCT) in super resolution algorithm.

In the above different filter banks, orthogonal (Daubechies family), bi-orthogonal (9/7), and Haar are used as a wavelet basis. However, there are many issues in image superresolution regarding the choice of filter bank. The performance of wavelet based system is determined by the choice of wavelets as well as the coefficients of wavelet which plays an essential role in image superresolution. If the coefficients are integer and rational of wavelet filters then the implementation of superresolution algorithm using the same wavelet filters will be remain best suitable for hardware. Hence, this paper proposes image resolution enhancement of satellite images using dyadic integer coefficient wavelet filter.

2. Review of the Related Filter Banks

Particularly in analysis, processing and representation of digital signals or digital images, multirate filter banks and wavelet filters are used. It is observed from many research articles and papers on superresolution that the filter banks with integer and rational coefficients are always the better choice for the implementation of superresolution algorithm because of its hardware friendliness and low power consumption. Factorization methods have been adopted to design the well-known biorthogonal filter banks (e.g. Cohen-Daubechies-Feauveau (CDF) 9/7 and spline family of wavelet FBs) [13]. Factorization of Lagrange half-band polynomial (LHBP) and general half-band filter is used to design two-channel biorthogonal wavelet filter bank(BWFB)[14]. Triplet half-band filter bank (THFB) has been presented by Rahulkar and Holambe [15], where the authors found out the coefficients are irrational numbers, which is difficult to implement on hardware. Further, Naik and Holambe [16] have designed low complexity wavelet filter banks.

Anbarjafari *et al.* [17] have obtained high resolution satellite image with the help of dual tree complex wavelet transform from noisy, blurred, and undersampled low resolution images. Further, Demiral *et al* [18] have reconstructed high resolution image from interpolated high frequency subbands and original input image with the help of stationary wavelet transform and discrete wavelet transform. Martin *et al.* [19] studied very well and put up in detail about the theory of multirate filter banks. Recently, Laghrib *et al.* [20] presented the best choice of regularization method amongst different methods using variational superresolution methods by Brgman distance. Wiener filter have been designed for the estimation of correlation of high resolution image by Hung *et al* [21]. This filter is evaluated using parameters like PSNR and SSIM. Xiao *et al.* [22] combined local self-similarity search and singular value decomposition of patches to enhance the details of the resultant image. Yoo *et al.* [23] generated high resolution image from low resolution images.

The above filter banks have irrational coefficients for its respective filter banks. These filter banks cause hardware complexity while the implementation of these filter banks on particular hardware platform. Furthermore, the computational complexity is also affected and its overall turnout increases. Hence, it is necessary to design the filters which give hardware-friendly dyadic coefficients. In this paper, dyadic-integer-coefficient wavelet filter which is designed by Chopade and Patil [24] has been utilised for the superresolution techniques for satellite images to reduce the computational complexity of satellite images. Furthermore, both results, qualitative and quantitative, are analysed properly and its superiority over the existing filter

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banks is evaluated.

3. Proposed DICWF based satellite image resolution enhancement

In satellite images, the quality of images plays a very vital role, which makes the resolution of images need to be enhanced. There are numerous applications of satellite images. It is observed that image enhancement algorithms for satellite images are implemented with the help of different filter banks which have complex coefficients. The main disadvantages with these coefficients are it needs more hardware complexity to implement. Thus, here we propose dyadic integer coefficient based wavelet filter to implement the image resolution enhancement algorithm for satellite images. To reduce the complexity of computational time and hardware, the coefficients of filters should be dyadic and integer. In this paper, DICWF has been employed on satellite images to achieve better computational time along with the quality of images. The DICWF has rational coefficients and has advantages over the other discrete wavelet transform and stationary wavelet transform (SWT). This DICWF decomposes the input images into different frequency subbands such as HH, HL, LH, and LL. In discrete wavelet transform using DICWF, loss of information occurs due to sampling by a factor of two. To overcome this loss, the detail subbands like LL, LH, and HL are obtained through stationary wavelet transform using DICWF in parallel. The proposed technique for enhancement of satellite images is shown in Fig.1.

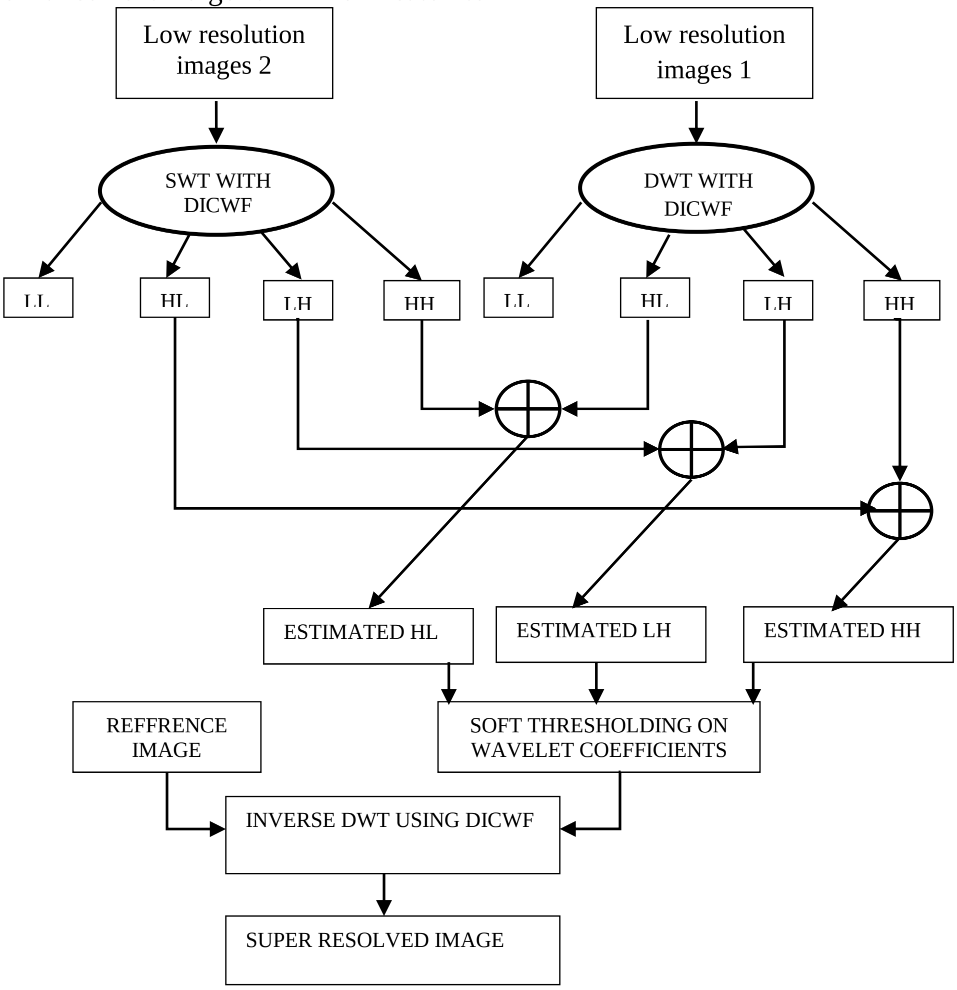

Fig.1: Block diagram of the proposed method using DICWFs.

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The frequency subbands LL, LH, and HL from the discrete wavelet transform (using DICWF) are interpolated to match the coefficients of the frequency subbands from the stationary wavelet transform (using DICWF). These subbands are combined to high resolved images. However, the stationary discrete transform using DICWF also plays a role to minimize the spatial domain noise which is generated due to the resampling of image by factor of two in DWT. Further, threshloding can be used to reduce noise. In this proposed method, the basic construction is used which is presented by Demirel[10]. Normally, superresolution is achieved with the help of different resampling techniques such as bilinear, bicubic, and quadratic interpolation which are the types of single frame superresolution where the information of the image may get loss. However, in the proposed technique, multi-frame (more than one image) of satellite images has been used to obtain the superresolved (resultant image) image in which the loss of information is a considerable minimum. The blocks for two input images and a superresolved image are shown in Fig. 1.

4. Results and discussions

The experimentation of the proposed algorithm has been carried out in MATLAB 2020(a) platform using different sets of images from a standard database of satellite images. For the validation of this experimentation, different subjective as well as objective quality parameters have been observed and it is compared with state-of-art algorithms/techniques. Particularly for the evaluation of any enhanced image, the eye is the prime evaluator which decides visual quality of image. Along with the subjective quality, the objective parameter such as PSNR (Peak Signal -to-Noise Ratio), which is majorly contributed for the evaluation of different image enhancement algorithms is measured.

Table 1: PSNR values for proposed DICWFs with well-known existing FBs

Methods/Images	PSNR in dB					
	1	2	3	4	5	6
Proposed DICWFs	28.72	31.72	25.82	27.62	25.33	29.85
CDF-9/7 wavelets	28.81	31.88	26.94	27.65	26.37	28.99
RH wavelets	28.87	31.68	27.05	28.04	25.15	29.67
Orhogonal wavelets(db-4)	27.77	29.73	26.02	28.01	27.02	28.37
Orhogonal wavelets(db-6)	28.07	29.99	25.93	27.53	27.23	28.39
Anbarjafari *et al* [17]	27.41	29.63	26.24	28.14	27.42	28.03
Demiral *et al* [18]	27.07	28.99	26.93	27.13	27.33	28.55
Martin *et al* [19]	28.10	27.19	27.92	27.11	27.34	27.12
Recently Laghrib *et al* [20]	27.21	28.22	26.65	27.22	26.99	27.12
Hung *et al* [21]	28.22	27.58	26.36	28.11	26.57	28.01
Chopade and Patil [24]	27.07	27.36	27.68	27.86	27.23	28.33

Table 1 shows the PSNR performance of the proposed algorithm along with existing algorithms, while the existing algorithm has similar construction with the implementation [10]. It shows that the values of PSNR for the proposed wavelets are slightly differing with other existing wavelet filters. However, other existing wavelet filters have fractional and irrational coefficients while the proposed wavelet has a dyadic and integer coefficient which is hardware friendly.

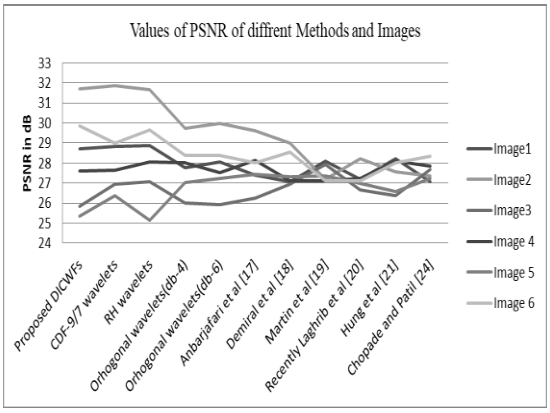
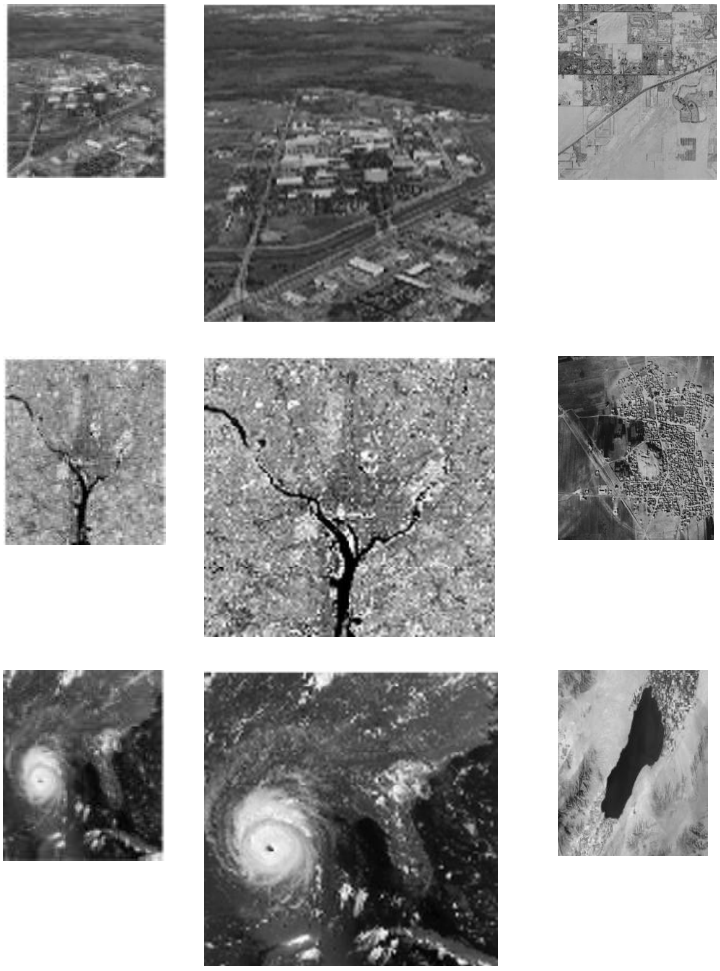


Fig 2: Graph of PSNR values of different wavelet filters for different satellite images

The comparison of values of PSNR of the proposed algorithm and existing techniques is shown in Fig. 2 graphically so that conclusion can be made based on graphical visuals and from this figure also it is concluded that PSNR values of the proposed algorithm is slightly vary with existing techniques on better side. To understand the subjective quality of the proposed algorithm, different satellite images of size 512×512 are applied to the proposed algorithm and its corresponding superresolved images are obtained faithfully, which are shown in Fig 3. It is observed that the resultant image is of size 1024×1024 with considerable quality, which can be seen by the naked eye neatly and easily.



(a) (b) (c)

Fig 3: (a) and (c) Original satellite images (b) and (d) Super resolved satellites images.

5. Conclusion

In this paper, a detail study of satellite images and its degradation is carried out. This paper proposed an image resolution enhancement algorithm for satellite images based on dyadic and integer coefficient wavelet transform. The proposed algorithm decomposes the input images into different frequency subbands. The high frequency subbands are interpolated to obtain high resolution image. The PSNR values of the proposed method are slightly differed with the existing wavelet filters. The advantage of the proposed filter is its coefficients

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which are dyadic and integer which easily implemented on any hardware platform. The subjective qualities of the resultant satellite images are determined by the naked eye easily and neatly. Furthermore, for the enhancement of resolution, resampling is used in this proposed algorithm multiframe used for image registration that leads to minimum loss of information compared to resampling techniques.

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