A Survey on Various Wavelet Domain Methods for Satellite Image Enhancement

Priyanka S. Kole¹, Prof. S. N. Patil²
Assistant professor¹, Associate Professor²
Department Of Electronics Engineering,
Walchand College Of Engineering, Sangli (Maharashtra), India¹
PVPIT Budhgaon, (Maharashtra), India²

Abstract:
Satellite images are being used in many fields of research. Satellite images are used in many applications such as geosciences studies, astronomy, and geographical information systems. One of the major issue of these types of images is their resolution. So image resolution is an important issue in satellite imaging. Because of the low frequency nature of these images, they appears as a blurred image. Thus the resolution of these satellite images is very low. In this paper we discuss the different types of transform techniques used for image enhancement. The edges of an image can be improved by using an effective transform technique and the resolution can be improved by using interpolation technique. The combination of transform techniques and interpolation methods helps to produce an overall enhanced image. Each method is analyzed quantitatively and visually. There are various wavelet domain based methods such as Wavelet Zero Padding, Dual Tree-Complex Wavelet Transform, Discrete Wavelet Transform, Cycle Spinning and Undecimated Wavelet Transform. On the basis of analysis, the most efficient method is proposed. The algorithms take the low resolution image as the input image and then wavelet transformation using daubechies (db3) is used to decompose the input image into different sub band images containing high and low frequency component. Then these sub-band images along with the input image are interpolated followed by combining all these images to generate a new resolution enhanced image by an inverse process.

Keywords: Cycle Spinning (CS), Discrete Wavelet Transform (DWT), Dual Tree-Complex Wavelet Transforms (DT-CWT), High Resolution (HR), Low Resolution (LR), Undecimated Wavelet Transform (UWT), Wavelet Zero Padding (WZP).

INTRODUCTION

In this paper we discuss the different types of transform techniques used for image enhancement. The edges of an image can be improved by using an effective transform technique and the resolution can be improved by using interpolation technique. The combination of transform techniques and interpolation methods helps to produce an overall enhanced image. There are many approaches that can be used to enhance the resolution of a satellite image. Wavelet domain based methods have proved themselves as most efficient technique serving for the required purpose. Interpolation in image processing is a well-known method to increase the resolution of a digital image. Many interpolation techniques have been developed to increase the image resolution. The three different types of interpolation techniques are nearest neighbor, bilinear and bicubic interpolation.

The paper is organized as follows: Section 2 describes various Interpolation methods for resolution enhancement of satellite image. Section 3 describes about the image enhancement using discrete wavelet transform. Section 4 describes image enhancement using stationary wavelet Transform. Section 5 describes about complex wavelet transform. Section 6 describes the other various Wavelet Domain methods for satellite image enhancement and finally section 7 describes proposed method using a combination of discrete wavelet transform (DWT) & singular Value Decomposition (SVD) method.

Section 2 : Image Enhancement Using Interpolation Methods:

One of the commonly used techniques for image resolution enhancement is Interpolation. Interpolation has been widely used in many image processing applications such as facial reconstruction, multiple description coding, and super resolution. There are three well known interpolation techniques are as follows:

- Nearest Neighbor Interpolation
- Bilinear Interpolation And
- Bicubic Interpolation.

NEAREST NEIGHBOR INTERPOLATION:

Nearest neighbor interpolation is the simplest interpolation scheme. It is the most basic interpolation technique. It requires less processing time among all the interpolation techniques. In this technique the interpolated pixel is replaced by the nearest pixel. Nearest neighbor...
interpolation is a simple method of linear interpolation. It gives good result when the image has high resolution pixels. In this some information at the edges is lost. The interpolation kernel for nearest neighbor interpolation is,

\[ u(x) = \begin{cases} 
0 & |x| > 0.4 \\
1 & |x| < 0.4 
\end{cases} \]

Where \( x = \) distance between interpolated point and grid point. Enlargement requires two steps: First is creation of new pixel locations and second is assignment of pixel values to those locations.

This can be done by treating image as a matrix and creating new rows and columns by padding it with matrix having double the size of original image matrix and having only zero value so that every alternate row(s) or columns of resultant matrix contains zero as its pixel value. Next step is to assign the pixel value of the near most neighbor to the newly generated pixel. That is why this method of grey level assignment is called Nearest Neighbor. Disadvantages Of Nearest Neighbor Interpolation are :

1) Blur in output image increases.
2) This technique may produce distortion in edges.

BILINEAR INTERPOLATION:

The bilinear interpolation has a large popularity due to its simplicity of implementation. Bilinear uses points to perform bilinear interpolation. This is done by interpolating between the four pixels nearest to the point that best represents that pixel. Bilinear interpolation considers the closest 2x2 neighborhood of known pixel values surrounding the unknown pixel's computed location. It then takes a weighted average of these 4 pixels to arrive at its final, interpolated value. Bilinear method gives greater resolution than the nearest neighbor method & removes the blur present in an image.

![Original Image, Nearest Neighbor, Bilinear Interpolation](image)

Fig. 1 Shows the original input image & the interpolated output images

BICUBIC INTERPOLATION:

In mathematics, bicubic interpolation is an extension of cubic interpolation. The interpolated surface is smoother than corresponding surfaces obtained by bilinear interpolation or nearest-neighbor interpolation.

In image processing, bicubic interpolation is often chosen over bilinear interpolation or nearest neighbor in image resampling, when speed is not an issue. Images resampled with bicubic interpolation are smoother and have fewer interpolation artifacts.

![Flow Chart for Bicubic Interpolation method](image)

Fig.2 Flow Chart for Bicubic Interpolation method.

Section 3: Image Enhancement By Using Discrete Wavelet Transform (DWT):

Though the interpolation is very simple & widely used technique, there is a drawback in using interpolation is the loss of high frequency components (Edges). This is due to the smoothing caused by interpolation. Preserving the edges is essential. To avoid this problem a new mathematical model called wavelet transform has been developed.

Image Resolution enhancement using DWT is a very popular technique. Image resolution is enhanced by using interpolation technique. The loss occurred due to smoothing caused by interpolation of high frequency components are avoided by using the discrete wavelet transform by which the edges are enhanced. Wavelet plays very important role in many image processing applications. The 2D wavelet decomposition of image results in four decomposed sub band images referred as low-low (LL), low-high (LH), high-low (HL) and High-high (HH).

![Block Diagram of DWT Filter bank](image)

Fig.3 Block Diagram of DWT Filter bank
Finally the high frequency sub-band images and the input low resolution images have been interpolated to generate a new resolution enhanced image.

**Section 4: Image Enhancement Using Stationary Wavelet Transform (SWT):**

The stationary wavelet transform is a wavelet transform algorithm designed to overcome the lack of translational invariance of discrete wavelet transform. It is similar to DWT but it does not use downsampling hence the subbands will have the same size as input image. Downsampling in each of the sub-bands of DWT cause information loss that’s the reason why SWT is employed. Image produced at the output will be of sharper high resolution image.

**Section 5: Image Enhancement Using Dual Tree Complex Wavelet Transform (CWT):**

Complex wavelet transform based approach of image enhancement is one of the recent approaches used in image processing and also an improvement technique of discrete wavelet transform. The lack of poor directionality of DWT is improved in CWT. Resolution enhancement is achieved by using directional selectivity provided by CWT.

Dual tree complex wavelet transform (DT-CWT) is used to decompose an image into different sub-bands. One level CWT of an image produces 2 complex valued low frequency images and 6 complex valued high frequency images. The high frequency sub-band images are the results of directional selective filters. They show peak magnitude responses in the presence of image features oriented at $+75^\circ$, $+45^\circ$, $+15^\circ$, $-15^\circ$, $-45^\circ$, $-75^\circ$. The loss in the edges of the image are improved by using CWT. The advantages of using DT-CWT are high directional selectivity when compared to DWT. It also has limited redundancy, shift invariant property.

**SECTION 6: Conventional Methodology**

**Pre-Processing:**

We take the sample test satellite image and it is passed through a low pass filter to obtain a low resolution image. On this low resolution image we proceed further to verify the proposed methods reliability.

**WZP:**

Wavelet zero padding is one of the simplest methods for image resolution enhancement. In this method, wavelet transform of a LR image is taken and zero matrices are embedded into the transformed image, by discarding high frequency sub-bands through the inverse wavelet transform and thus HR image is obtained.

**Cycle Spinning:**

In this method, we follow the following steps to get highly resolved image:

- First we obtain an intermediate HR image through WZP method.
- After that we obtain N number of images through spatial shifting, wavelet transforming and discarding the high frequency component.
• Again, the WZP process is applied to all LR images to obtain a number of HR images.
• These HR images are realigned and averaged to give a final HR image.

Un-Decimated Wavelet Transform (UWT):

Un-decimated wavelet transform is wavelet transform technique which does not use decimation after the decomposition of images into different frequency sub-bands. In this method, first WZP is applied to obtain an estimate of HR image. If the LR image is denoted with $Y$ of size $m \times n$ then the estimated HR image is given by:

$$\hat{x} = IDWT \begin{bmatrix} Y & B \\ B & B \end{bmatrix}$$

where, $b$ is the zero matrix of size $m \times n$ and IDWT is the inverse discrete wavelet transform.

In next step un-decimated wavelet transform is implemented on the estimated HR image, as a result of which image is decomposed into two bands called estimated details and approximation coefficients. The approximation coefficients are then replaced by initially estimated HR image and inverse UWT is taken to obtain.

Section 7: Combination Of Discrete Wavelet Transform (DWT) & Singular Value Decomposition (SVD):

This approach is based on interpolation of the high frequency sub-bands which are obtained by performing Discrete Wavelet Transform (DWT) on input image. DWT decomposes the input satellite image into different frequency sub-band images namely, low-low (LL), low-high (LH), high-low (HL) and high-high (HH). Interpolation can be applied to these four sub-band images. In the wavelet domain, the low-resolution image is obtained by low-pass filtering of the high-resolution image. The low-resolution image (LL sub-band) is used as input for the proposed resolution enhancement process. The LL sub-band is used for singular value decomposition (SVD) for brightness enhancement purpose. The high frequency sub-bands contain the high frequency components of image. Interpolation is carried out using bicubic interpolation algorithm and Inverse Discrete Wavelet Transform.

Fig.8 Shows the flowchart for the brightness & resolution enhancement of satellite image using DWT & SVD.
Results And Discussions:
Performance analysis of various resolution enhancement algorithms in wavelet domain is done and measured in terms of metrics such as PSNR, MSE and ENTROPY as tabulated above. Table 1 is calculated matrix value for different algorithms before histogram equalization for input image. As we can see from the table PSNR value for the different methods are around 30 db. These PSNR and MSE values are comparable to previous studies.

Quantitative analysis: To evaluate the performance of each algorithm different metrics such as Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), Root Mean Square Error (RMSE) has been calculated:

$$MSE = \frac{1}{MN} \left( \sum_{m,n} \left[ I_1(m,n) - I_2(m,n) \right]^2 \right)$$

$$PSNR = 10 \log_{10} \frac{R^2}{MSE}$$

Table 1: MSE, PSNR results for different Methods.

<table>
<thead>
<tr>
<th>Resolution Techniques</th>
<th>Advantage/Disadvantage</th>
<th>Mean Squared Error (MSE)</th>
<th>Peak Signal To Noise Ratio (PSNR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discrete Wavelet Transform (DWT)</td>
<td>Gives Sharper image / Loses high frequency contents.</td>
<td>0.0419</td>
<td>13.7804</td>
</tr>
<tr>
<td>Stationary Wavelet Transform (SWT)</td>
<td>Redundant / Distortion may occur to the image.</td>
<td>0.0464</td>
<td>13.3332</td>
</tr>
<tr>
<td>Singular Value Decomposition (SVD)</td>
<td>Improves the brightness of an image.</td>
<td>0.0402</td>
<td>13.9634</td>
</tr>
<tr>
<td>Discrete Transform-Continuous Wavelet Transform (DT-CWT)</td>
<td>Reduces Artifacts / Not much suitable for hyperspectral images</td>
<td>0.0243</td>
<td>16.1666</td>
</tr>
<tr>
<td>Combination of DWT &amp; SVD</td>
<td>Gives Sharper &amp; brighter image with increased resolution.</td>
<td>0.15</td>
<td>61.14</td>
</tr>
</tbody>
</table>

CONCLUSION
This paper gives a brief review of the image enhancement methods which uses a combination of transform techniques and interpolation. The proposed method enhances the image by reducing the noise, improving the edges and increasing the resolution. Even the brightness & resolution have increased to a great extent using the combination of DWT & SVD method. The performance of every technique can be measured by the values of PSNR and RMSE.

REFERENCES


12) Stationary Wavelet Transform -Wikipedia, the free encyclopedia


Authors Profile

Priyanka S. Kole is working as Assistant Professor in Dept of Industrial Electronics Engineering, Walchand College Of Engineering, Sangli, Maharashtra, India. She has received her Bachelor’s degree in ECE from Shivaji University, Kolhapur. She is perusing her master’s degree in Electronics Engineering from Shivaji University, Kolhapur. Her research interests are in the areas of Image Processing, CMOS VLSI DESIGN. She has published many papers in International Journals and presented papers in International and National conferences.

Prof. S. N. Patil, presently working as Associate Professor at Padmabhushan Vasantraodada Patil Institute of Technology, Budhgaon, Sangli, Maharashtra, India. He has 22 years of teaching experience & area of specialization is Digital signal processing and Instrumentation. He is Life time member of ISTE. He has published many papers in International Journals and presented papers in International and National conferences.