Hybrid Algorithms Based on Transforms for Denoising Satellite Images

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Abstract—The image acquired from a sensor is always degraded by some form of noise. The noise can be estimated and removed by the process of denoising. Recently, the use of Hybrid Algorithms for denoising have gained popularity. The most commonly used transformation are Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT). DCT has the property of more energy compaction and requires less resources for computational whereas DWT is a multiresolution transformation. The proposed Hybrid Algorithms take advantage of both of the algorithms and this reduces the false contouring and blocking artificats effectively. In this paper, the Hybrid Algorithms are evaluated for various images by comparing in terms of Mean Square Error, Peak Signal to Noise Ratio, Coefficient of Variance, Structural Similarity Index and Mean Structural Similarity Index.

Index Terms—CV, Denoising, MSE, PSNR, SSIM, MSSIM

1. INTRODUCTION

The noise free images are required for processing in satellite applications. MPEG-4[1]-[2] is the next generation visual coding standards that provides great flexibility for evaluating visual objects in multimedia based applications and improve the visual quality at very low bit rate. The arbitrarily shaped visual object must preserve its shape and texture. The existing methods include rectangle shape images and videos and coding like DCT coding and DWT coding. In conventional methods, the bounding box straighten the arbitrarily images, the values are padded in the pixel position outside the object and the pixels inside the object are coded and padded in the bounding box together, which might be inefficient [3]-[7].

The problem of removing the noise of visual objects without decomposing its attributes such as edges, textures, colors, contrast, etc., had been researched for the last two decades and many other types of denoising techniques have been developed.

The total variance based noise removing method developed by Rudin et al.[25] had much influence in image community and inspire a large quantity of formulations for removing the noise of an image. In [8] - [10] the Non-Local Means (NLM) algorithm manages to correctly remove most of the noises, they tend to not properly recover some of the image details. These methods also primarily deal with additive Gaussian noise, whereas for many images the noise model is unknown; in such cases, there is still ample room for improvement [10], [11],[12], [13].

This paper evaluates the Hybrid Algorithms as applied to denoise various satellite images. Section II deals about the Existing Transforms used for denoising the images. In Section III, Hybrid Algorithms designed for reducing artificats are described. Section IV reports the result of the various algorithms and comparisons with other coding techniques for different images. Section V will conclude the paper.

II. EXISTING TRANSFORMS FOR DENOISING

(a) Discrete Cosine Transform (DCT)

A DCT indicates the data points of input as a sum of cosine functions with various oscillating frequency and amplitude. The two main types of discrete cosine transform schemes are: one dimensional discrete cosine transform and two dimensional discrete cosine transform. Since an image is transformed as two 2-D matrix, two dimensional DCT is used. The two dimensional discrete cosine transform for a size of x input sequence can be described as [14] [15]:

\[ D_{dct}(i,j) = \frac{1}{\sqrt{2N}} \sum_{x=1}^{N} \sum_{y=1}^{N} M(x, y) \cos \left( \frac{2\pi x i}{2N} \right) \cos \left( \frac{2\pi y j}{2N} \right) \]

\[ B(u) = \begin{cases} 1 & \text{if } u = 0 \\ \frac{1}{2} & \text{if } u > 0 \end{cases} \]

\[ x \times y \text{ is the size of the input data } M(x, y). \]

In DCT, all the informations were accommodating in a small number at low frequency coefficients which are easily affected by noise. The low frequency coefficients are called as DC components and remaining coefficients are said to be AC components. Using \( 8 \times 8 \) quantization table, the DCT coefficients are quantized as in the JPEG standard. The equation for two dimensional inverse DCT transform is given below.

\[ D_{inv}(i,j) = \frac{1}{2N} \sum_{x=1}^{N} \sum_{y=1}^{N} B(x) B(y) M(x, y) \sin \left( \frac{\pi (2x + 1) i}{2N} \right) \sin \left( \frac{\pi (2y + 1) j}{2N} \right) \]

\[ D_{inv}(i,j) = \begin{cases} 1 & \text{if } u = 0 \\ \frac{1}{2} & \text{if } u > 0 \end{cases} \]
There exist certain limitations of DCT like blocking art crafts and False Counting. The distortion like blocking art crafts occurs due to high compression rate and looks abnormally as large pixel blocks. The false counting is due to smoothly graded area of visual objects was distorted and appears as a contour map for some image [17]-[22]. The heavy quantization of the transform coefficients is the main reason for false contouring effect.

\[(b)\text{ Discrete Wavelet Transform (DWT)}\]

The DWT indicate the visual information as the sum of wavelet function, also called as wavelet with various location and scale [8]. It represents the data as a set of high pass (detail) and low pass (approximate) coefficients. The input data is transferred through set of low pass and high pass filters. Filter kernel for this work is \([1,1,1] \ast [-1,-1,-1]\). The output of high pass and low pass filters are down sampled by 2. This process is one dimensional DWT and the schematic is given in figure 2.

\[\text{Figure.2: Schematic of 1D forward DWT}\]

In two dimensional DWT, the input data was sent through low pass filter and high pass filter in two different directions in both row and column. The outputs are then down sampled by 2 in each direction. The complete process is depicted in figure 3. The output is then obtained as four coefficients LL, HL, LH and HH. The first alphabet is the transformation in row and the second alphabet is the transformation in column. The alphabet L represent low pass signal and H indicates high pass signal. LH signal represents a low pass signal in row and HH represents a high pass in column. LH signal consist of horizontal elements, HL and HH consist of vertical and diagonal elements respectively.

\[\text{Figure.3: Schematic representation of 2D forward DWT}\]

As shown in Figure 4, during DWT reconstruction, input data can be obtained by decomposing LL coefficient for different levels in multiple resolutions [38]. The compressed data is up sampled by a factor of 2 in order to reconstruct the output data. Then the signal was sent through the same set of high pass and low pass filters in both row and column. The complete reconstruction process was given in figure 5.

\[\text{Figure.4: Multilevel Forward DWT}\]

\[\text{Figure.5: Schematic representation of 2D Inverse DWT}\]

\[\text{Figure.6: Schematic representation of DWT Decomposition}\]

The process goes on for one more level. The coefficients are split up by a constant scaling factor to obtain the desired compression ratio. At last for reconstructing the data, the data was rescaled, padded with zeros and directed to the wavelet filters. Figure 6 shows the complete procedure of 2-D DWT compression and reconstruction.

**III. PROPOSED HYBRID ALGORITHMS**

The Discrete Cosine Transform and Discrete Wavelet Transform are used for denoising of images. DCT had more energy compaction property with less resources for computational, while DWT is multi resolution transformation.
The proposed Hybrid Algorithms take advantage of both of the algorithms and thus reduce the false contouring and blocking artifacts effectively.

The algorithms are developed in such a way that the subsamples are processed in DCT while the main block is processed by DWT in Hybrid DWT-DCT as shown in figure 7.

**Algorithm for Hybrid DWT-DCT:**

The sub sampling strategies based on DCT and DWT algorithms, discussed above, the Hybrid algorithms for a satellite image can be described as follows.

1) Read the input raw satellite vision data
2) Estimate the noise in the image.
3) Apply the 2-D DWT with proper sub sampling strategy.
4) choose the wavelet coefficients that are to be processed to perform 2-D DWT and obtain the second level low pass wavelet coefficients.
5) Perform the 2-D DCT the obtained low pass coefficients.
6) Now perform 2-D Inverse DCT and subsequently two times 2-D Inverse DWT for reconstruction of denoised image.

Similarly, the subsamples are processed in DWT while the main block is processed by DCT in Hybrid DCT-DWT as shown in figure 9 and figure 10.

**IV. RESULTS AND DISCUSSION**

The Algorithms are coded and evaluated in MATLAB. The images considered for performance evaluation are shown in figures 11, 12, 13, 14 and 15. The Performance of hybrid algorithms is compared with existing algorithms based on MSE, PSNR, CV, SSIM and MSSIM parameters.
Hybrid Algorithms Based on Transforms for Denoising Satellite Images

The corresponding noise estimates are calculated for each channel as shown in figure 16, which shows that there exists noise in the images.

\[
\text{MSE} = \frac{1}{mn} \sum_{i=1}^{m} \sum_{j=1}^{n} \| f(i,j) - g(i,j) \|^2 
\]

The PSNR must be as high as possible. The mean square error must be as low as possible.

The coefficient of variance is a measure of relative variability between the images, given by

\[
\% \text{CV} = \frac{\sqrt{\frac{\text{MAX}}{\text{MSE}}}}{\text{X}} 
\]

\[
\% \text{CV} = \text{percent coefficient of variation} 
\]

\[
\sum = \text{sum of the assay values} 
\]

\[
N = \text{number of assay values} 
\]

\[
(\sum x)^2 = \text{sum of squares of all the values} 
\]

\[
\text{X} = \text{arithmetic average of all assay values} 
\]

The lower the value of the coefficient of variation the more the precise estimate

The method of estimating the similarity between two images was regarded as a Structural Similarity index. The SSIM index is also defined as a measure of quality of the visual object being compared by considering the quality of other visual data as perfect and is given by

\[
\text{SSIM}(i,j) = [i(x,y)]^\alpha \cdot [c(x,y)]^\beta \cdot [s(x,y)]^\gamma 
\]

\[
\text{SSIM}(x,y) = \frac{(2\mu_x \mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)} 
\]

Comparison of structure s(x,y) was performed on the normalized signals (x - \mu_x) / \sigma_x and (y - \mu_y) / \sigma_y, where the variables \alpha, \beta and \gamma are used to vary the relative importance of the three components.

The mean structural similarity for quantitative analysis of super-resolution image based on the size of the window which is given by

\[
\text{MSSIM}(X,Y) = \frac{1}{M} \sum_{j=1}^{M} \text{SSIM}(x_j,y_j) 
\]

The processed and reconstructed images for Hybrid DWT-DCT are shown in figure 17.

Table 1: Comparison of Denoising Algorithms based on various parameters

<table>
<thead>
<tr>
<th>Method/ Images</th>
<th>Test Image – 1</th>
<th>Test Image – 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCT</td>
<td>4.6175e+03</td>
<td>1.9393e+03</td>
</tr>
<tr>
<td>PSNR</td>
<td>11.4867</td>
<td>27.3432</td>
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<tr>
<td>CV</td>
<td>45.8474</td>
<td>45.6364</td>
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<tr>
<td>SSIM</td>
<td>0.4682</td>
<td>0.2397</td>
</tr>
<tr>
<td>MSSIM</td>
<td>-5.1406e-04</td>
<td>-0.0015</td>
</tr>
<tr>
<td>DWT</td>
<td>751.0471</td>
<td>506.3219</td>
</tr>
<tr>
<td>PSNR</td>
<td>28.2299</td>
<td>29.8954</td>
</tr>
<tr>
<td>CV</td>
<td>47.0400</td>
<td>45.3634</td>
</tr>
<tr>
<td>SSIM</td>
<td>0.9988</td>
<td>0.9988</td>
</tr>
<tr>
<td>MSSIM</td>
<td>0.1627</td>
<td>0.3229</td>
</tr>
<tr>
<td>DWT-DCT</td>
<td>506.3219</td>
<td>569.2167</td>
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<tr>
<td>PSNR</td>
<td>29.8954</td>
<td>29.6713</td>
</tr>
<tr>
<td>CV</td>
<td>45.3634</td>
<td>68.9416</td>
</tr>
<tr>
<td>SSIM</td>
<td>0.9988</td>
<td>0.9994</td>
</tr>
<tr>
<td>MSSIM</td>
<td>0.3229</td>
<td>0.3385</td>
</tr>
</tbody>
</table>

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for denoising the images captured by sensors. These algorithms use the DCT and DWT transforms for processing and take advantage of both transforms. These algorithms help in reducing false contouring and blocking artifacts effectively. Among these for a noisy satellite image, the Hybrid DWT-DCT algorithm proves to be a better choice as its PSNR has increased at least by 13.5%, MSE and Coefficient of Variance is minimum and SSIM and MSSIM are improved when compared to DCT, DWT and Hybrid DCT-DWT Algorithms. Also the denoised images prove to have less noise in the images.

REFERENCES


V. CONCLUSION

This paper presents description of Hybrid Algorithms