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A Novel Approach on Satellite Image Resolution Enhancement Using Object Tagging OLHE

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Abstract:
Illumination compensation and normalization play a crucial role in satellite image enhancement. The existing algorithms either compensated low-frequency illumination, or captured high frequency edges. Satellite image is affected by impulse noise during transmission. This impulse noise distorts the edge pixels in the satellite image, which degrades the segmentation process. Hence, this impulse noise should be removed before enhancing satellite images. Optimum Edge preserving impulse noise removing algorithm is proposed in this paper to remove the impulse noise present in the satellite image. OLHE technique which is similar to local histogram equalization is proposed to capture the orientation of edges in the image that enhances the resolution. However, the orientations of edges were not well exploited. In this paper, we propose the orientated local histogram equalization (OLHE) in brief, which compensates illumination while encoding rich information on the edge orientations. We claim that edge orientation is useful for satellite image enhancement. We evaluate the average performance of the proposed algorithm when the images lighted differently were observed, and the proposed algorithm yielded the promising results. Performance analysis is made by calculating PSNR and MSE value which reveals superiority of the proposed technique over the conventional and state-of-the-art RE techniques.

Key words*: Oriented Local Histogram Equalization(OLHE), Resolution Enhancement (RE),Hyper spectral Image(HSI)*

1. Introduction

Resolution of an image has been always an important issue in many image-and video-processing applications such as video resolution enhancement, feature extraction, and satellite image resolution enhancement. The performance of the proposed technique over performs all available state-of-art methods for image resolution enhancement. The visual and quantitative results are given in the results and discussion section. Interpolation in image processing is a method to increase the number of pixels in a digital image. Interpolation has been widely used in many applications, such as facial reconstruction, multiple description coding, and image resolution enhancement. The interpolation-based image resolution enhancement has been used for a long time and many interpolation techniques have been developed to increase the quality of this task. There are three well-known interpolation techniques, namely, nearest neighbour, bilinear, and bicubic. Bicubic interpolation is more sophisticated then the other two techniques and produces smoother edges. The essential thought behind the Histogram of Oriented Gradient descriptors is that the local object appearance and shape within an image can be described by the distribution of intensity gradients or edge directions. The implementation of these descriptors can be achieved by dividing the image into small connected regions, called cells, and for each cell compiling a histogram of gradient directions or edge orientations for the pixels within the cell. The combination of these histograms, then represents the descriptor. For improved accuracy, the local histograms can be contrast-normalized by calculating a measure of the intensity across a larger region of the image, called a block, and then using this value to normalize all cells within the block. This normalization results in better invariance to changes in illumination or shadowing.

2. Related Works

RESOLUTION (spatial, spectral, and temporal) is the limiting factor for the utilization of remote sensing data (satellite imaging, etc.). Spatial and spectral resolutions of satellite images (unprocessed) are related (a high spatial resolution is associated with a low spectral resolution and vice versa) with each other [1]. Therefore, spectral, as well as spatial, resolution enhancement (RE) is desirable. Interpolation has been widely used for RE [2], [3]. Commonly used interpolation techniques are based on nearest neighbours (include nearest neighbour, bilinear, bicubic, and Lanczos). The Lanczos interpolation (windowed form of a sinc filter) is superior than its counterparts (includingnearest neighbor, bilinear, and bicubic) due to increased ability to detect edges and linear features. It also offers the best compromise in terms of reduction of aliasing, sharpness, and ringing [4]. Methods based on vector-valued image regularization with partial differential equations (VVIR-PDE) [11] and inpainting and zooming using sparse representations [6] are now state of the art in the field (mostly applied for image inpainting but can be also seen as interpolation). RE schemes (which are not based on wavelets) suffer from the drawback of losing high-frequency contents (which results in blurring). RE in the wavelet domain is a new research area, and recently, many algorithms [discrete wavelet transform (DWT) [6], stationary wavelet transform (SWT) [8], and dual-tree complex wavelet transform (DT-CWT) [5] have been proposed [7] –[11]. A RE scheme was proposed in [9] using DT-CWT and bicubic interpolations, and results were compared (shown superior) with the conventional schemes (i.e., nearest neighbor, bilinear, and bicubic interpolations and wavelet zero padding). More recently, in [6], a scheme based on DWT and bicubic interpolation was proposed, and results were compared with the conventional schemes and the state-of-art schemes (wavelet zero padding and cyclic spinning [12] and DT-CWT [9]). Note that, DWT is shift variant, which causes artifacts in the RE image, and has a lack of directionality; however, DT-CWT is almost shift and rotation invariant [13]. DWT-based RE schemes generate artifacts (due to DWT shift-variant property). In[13] DT-CWT-based nonlocal-means-based RE (DT-CWT-NLM-RE) technique, using the DT-CWT, Lanczos interpolation, and NLM. Note that DT-CWT is nearly shift invariant and directional selective. Moreover, DT-CWT preserved the usual properties of perfect reconstruction with well-balanced frequency responses [13], [14]. Consequentially, DT-CWT gives promising results after the modification of the wavelet coefficients and provides less artifacts, as compared with traditional DWT. Since the Lanczos filter offer less aliasing, sharpness, and minimal ringing, therefore, it a good choice for RE. NLM filtering [13] is used to further enhance the performance of DT-CWT-NLM-RE by reducing the artifacts. This technique produces high latency.

3. Preliminaries

3.1. Hyperspectral Image

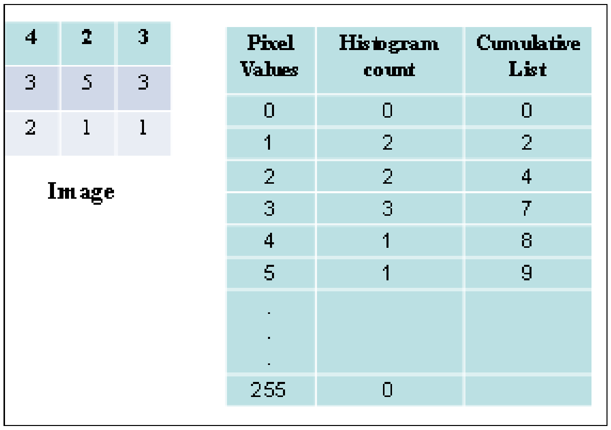
Many applications involve the detection of an object or activity such as a military vehicle or vehicle tracks. Hyper spectral imaging sensors provide image data containing both spatial and spectral information, and this information can be used to address such detection tasks. The basic idea for hyper spectral imaging stems from the fact that, for any given material, the amount of radiation that is reflected, absorbed, or emitted i.e., the radiance varies with wavelength. Hyper spectral imaging sensors measure the radiance of the materials within each pixel area at a very large number of contiguous spectral wavelength bands. A hyper spectral remote sensing system has four basic parts: the radiation (or illuminating) source, the atmospheric path, the imaged surface, and the sensor. Satellite images are hyperspectral images which can be used for resolution enhancement.

3.2. Histogram Equalization

An image histogram is a type of histogram that acts as a graphical representation of the tonal distribution in a digital image. It plots the number of pixels for each tonal value. By looking at the histogram for a specific image a viewer will be able to judge the entire tonal distribution at a glance. Image histograms are present on many modern digital cameras. Photographers can use them as an aid to show the distribution of tones captured, and whether image detail has been lost to blown-out highlights or blacked-out shadows. Histogram Equalization method usually increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values. The method is useful in images with backgrounds and foregrounds that are both bright or both dark. In particular, the method can lead to better views of bone structure in x-ray images, and to better detail in photographs that are over or under-exposed. A key advantage of the method is that it is a fairly straightforward technique and an invertible operator. So in theory, if the histogram equalization function is known, then the original histogram can be recovered. The calculation is not computationally intensive. A disadvantage of the method is that it is indiscriminate. It may increase the contrast of background noise, while decreasing the usable signal.

3.3. Local Histogram Equalization

Histogram equalization is used for enhancing the contrasts in an intensity image. This normally works quite well for smaller images or images where almost all of the different intensity levels are represented. For these situations, a different version of histogram equalization could be useful. If you could do equalization over a portion of the image, too many intensity levels in the image would less affect you. Of if you need to enhance the contrast more than a global histogram equalizer can offer. However, this is very computer intensive, as you would need to compute a histogram for each pixel in the image. The workload will increase proportional with n to the power of 2, where n is the number of pixels. In order to do local histogram equalization, the user has to pass over the image represented by a two dimensional array of short inputs. The user also has to choose a mask size, which describes the size of the portion of the image to equalize at a time. The mask size has to be an odd number, because only the centre pixel of the mask will be written to the new and equalized image. The equalization begins with the mask being cantered on the upper left pixel. A histogram will be calculated for all pixels covered by the mask. The pixel in the centre of the mask will then be written to the resulting image. The mask is then moved one pixel to the right and a new histogram be computed. This continues for each pixel of each row in the image. One of the tricks to lower the processing time is to reuse part of the previous histogram. In this implementation, we create a single dimension array with length equal to the number of possible intensity levels in the image. For an 8-bit grayscale image, the length would be 256.



4	2	3
3	5	3
2	1	1

Image

Pixel Values	Histogram count	Cumulative List
0	0	0
1	2	2
2	2	4
3	3	7
4	1	8
5	1	9
. . .		
255	0	

.

Replace 0,1…..255 by this cumulative histogram value. This is called Histogram equalization. It is applied on the entire image region. Histogram equalization is a technique used to improve contrast in face images. It differs from ordinary histogram equalization in the respect that the Local method computes several histograms, each corresponding to a distinct section of the image, and uses them to redistribute the lightness values of the image.Histogram Equalization is applied on the entire image. Local Histogram Equalization is applied on the 3*3 over lapped block on the whole image. For each pixel on an image, we perform the histogram equalization on the local w-by-h window centering on this pixel using:

$$f(x) = \mathrm{round}\left[\frac{cdf(x) - cdf_{min}}{w.h - cdf_{min}}\,(L-1)\right] \qquad (1)$$

where x is the pixel intensity value, cdf (x) is the cumulative distribution function of the histogram of the pixel intensities in the w-by-h window, cdfmin is the minimum intensity in this window, and L is the desired number of output gray levels=256.

Typically a square window is used, and we define k ≡ w = h. We call the center of the k-by-k window the anchor. For LHE, the anchor point is the pixel to be processed itself. For the whole image, each pixel repeats the above operation and uses f (x) to get its new intensity value.

4. Proposed Work

Proposed method is using a novel algorithm based on finding the optimal direction used as a measure to detect whether the tested pixel is noisy or noise-free pixel. More edge pixels can be detected if the accurate or optimal direction of the edge is determined. The noisy pixel that has small deviations with the pixels in the optimal direction is deemed an original pixel. Optimum Edge preserving impulse noise removing algorithm based land scale satellite image segmentation is proposed. OLHE (oriented local histogram equalization) is similar to local histogram equalization (LHE), but it captures the orientation of edges while LHE does not.

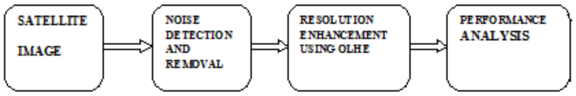


Figure 1 Block diagram of proposed system

Figure 1

5. Algorithm Description

In the Algorithm Description method, the filtering window is divided into four directions. Each direction has an equal number of pixels. These pixels may be located in a smooth area or on an edge. The key point is to find the optimal direction to be used as a reference, or a scale to find out whether the tested pixel is noisy or noise-free pixel.

The optimal direction is the direction that has the most similar pixels. Hence, for each pixel to be judged as an original, it should have small deviations with the pixels in the optimal direction. The proposed algorithm may be described as follows.

If the first pixel in a window of size K X K is denoted by $x_{i,j}$then the total pixels in the window, except the central pixel $x_{i+(k+1)/2,j+(k+1)/2}$ are divided into four directions as shown in figure 5.2 .

The Dd^{i,j}s,d=1:4 for a window of 9X9 size, and a first pixel $x_{0,0.}$ the pixels in each direction are listed in terms of their coordinates as follows:

$$
\begin{aligned}
D_1^{0,0} &= \{(0,0),(1,1),(2,2),(3,3),(5,5),(6,6),(7,7),(8,8)\}\\
D_2^{0,0} &= \{(0,8),(1,7),(2,6),(3,5),(5,3),(6,2),(7,1),(8,0)\}\\
D_3^{0,0} &= \{(0,4),(1,4),(2,4),(3,4),(5,4),(6,4),(7,4),(8,4)\}\\
D_4^{0,0} &= \{(4,0),(4,1),(4,2),(4,3),(4,5),(4,6),(4,7),(8,8)\}
\end{aligned} \qquad (2)
$$

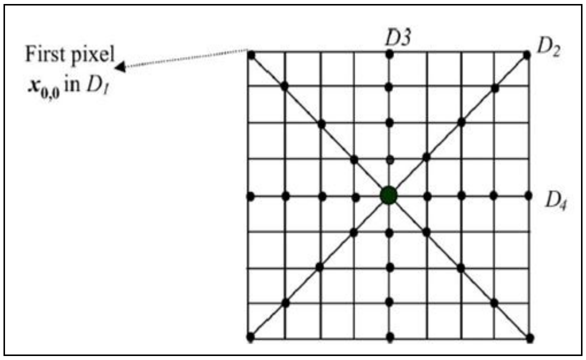


Figure 2: A 9X9 Window Divided Into 4 Directions

2) Then, the pixels in each direction $D_d^{i,j}$ are sorted in ascending manner, so that the outlier pixels can be specified. The new vector r_d^{ij} that attained from the corresponding sorted direction
D_d^{ij} is defined as

$$r_d^{ij} = \{x_{1,s}^d \mid x_{1,s}^d \in D_d^{ij}, s=1:k\text{-}1,\ d=1:4, x_{1,s+1} \geq x_{1,s}\} \qquad (3)$$

3) The smallest and the largest pixels in every direction are expected to be outliers, therefore they are removed. Hence, a new vector of $r_d^{\sim ij}$ lower elements is defined as

$$r_d^{\sim ij} = \{x_{1,s}^d \mid s = 2 : k-2, d = 1 : 4\} \qquad (4)$$

$\sigma_{\tilde{r}_d^{i,j}}$ is the standard deviation of the pixels in the vector $\tilde{r}_d^{ij}$. Equation (4) means that the optimum direction is the direction that has the most similar pixels.
4)The optimum direction D^{op} is attained by finding the vector r^{ij}_d that has the minimum standard deviation :

$$D^{op} = \operatorname{argmin}\{r_d^{\sigma\sim ij}\} \qquad (5)$$

σr^{ij}_d is the standard deviation of the pixels in the vector r^{ij}_d Equation (4) means that the optimum direction is the direction that has the most similar pixels.

5) For detecting the central pixel $x_{i+(k+1)/2,j+(k+1)/2}$ whether it is noisy or noise-free pixel, a similarity parameter S is calculated by measuring the normalized distance between the tested pixel, and the pixels in the optimal direction. By denoting the subscript $i + (k + 1)/2$ by $\tilde{i}$
and $j + (k + 1)/2$ by $\tilde{j}$, S is defined as

$$S = \sum_{s=2}^{k-2} \left| \frac{x_{1,s}^{op} - x_{\tilde{i}\tilde{j}}}{255} \right| \qquad (6)$$

Where $x_{1,s}^{op}$ is the pixel S in the optimal direction.

6) By using a proper threshold , we can decide if the tested pixel is a noisy x_{no} or an original pixel x_{or}. Also, it is clear from (5) that the range of is $[0, k-3]$ which is the bounds of . Thus,

$$x_{\tilde{i},\tilde{j}} = \begin{cases} x_{or} & if\ S \prec T, \{0 \leq T \leq k-3\} \\ x_{no} & else. \end{cases} \qquad (7)$$

The threshold T should have a value close to zero. The reason is that the tested pixel to be considered as an original should be similar to the pixels in the optimum direction, or lead to a small value of . The central pixel is flagged as 1 in a binary image , if it is detected as an original pixel, and flagged as 0, if it is detected as a noisy pixel. The detected noisy pixel is omitted immediately and is not involved in the detection process any more.

7) After detecting all pixels in the noisy image, the restoration process for getting the first restored image begins. Any pixel flagged as 0 is restored by replacing it by the median of its good neighboring pixels. Pixels among the neighboring ones that flagged as 0, and not restored yet, are excluded from the restoration process. Thus, the restored pixel $x_{i,j}^{rest}$ is given by

$$\mathbf{x}_{\tilde{i},\tilde{j}}(\mathbf{rest}) = \mathbf{median}\left(\mathbf{x}_{\tilde{i}+s,\tilde{j}+t} \middle| 0 \leq s,t \leq (k-1)\right) \quad (8)$$

8) The previous steps are implemented again on the first restored image, so that we can get a new restored image with better visual quality. Also, the closest four pixels are preferable to be used in the second restoration process for estimating the noisy pixel. The first detection process is used for removing the impulse noise that has sharp intensity values, while the second one is used for removing the impulse noise that has somewhat small differences with the pixels in the optimum direction. Thus, we use a threshold T1 of higher value in the first iteration, and a threshold T2 in the second iteration. The window size should be large enough, particularly at high noise rates to avoid finding an empty direction—a direction that is out of pixels (all its pixels are detected as noisy pixels). In the case of empty direction, it is difficult to determine the optimal direction.

6. Results and Discussion

To ascertain the effectiveness of the proposed Local histogram equalization RE algorithm over other wavelet-domain RE techniques, different LR optical images obtained from the Satellite Imaging Corporation webpage [1] were tested. The image of Washington DC ADS40 Orthorectified Digital Aerial Photography −0.15 m is chosen here for comparison with existing RE techniques.

Figure 3: Original Satellite Image

Figure 4: Impulse Noise Corrupted Image

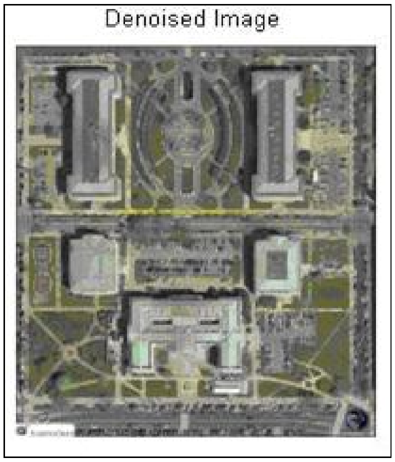


Figure 5: Impulse Noise Removed Image

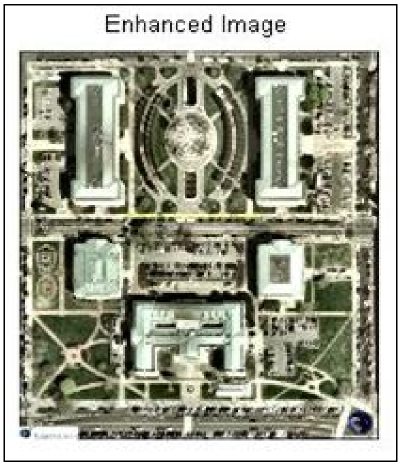


Figure 6: Resolution Enhanced Image

SI.NO	ALGORITHM	MSE	PSNR
1	SWT-RE	0.0464	13.3332
2	DWT-RE	0.0419	13.7802
3	SWT-DWT-RE	0.0335	14.7527
4	VVIR-PDE-RE	0.0269	15.697
5	LANCZOS-RE	0.0253	15.9770
6	DT-CWT-RE	0.0242	16.1576
7	DT-CWT-NLM-RE	0.0174	17.5895
8	PROPOSED LHE-RE	0.0121	66.61

Table 1: Comparision of the Existing and Proposed for the 'Washington DC'image

Table 1 shows that the proposed techniques provide improved results in terms of MSE and PSNR as compared with other techniques. It is clear that the proposed LHE-RE , schemes outperformDT-CWT-RE,DTCWT-NLM-RE, SWT, DWT, SWT-DWTRE,VVIR-PDE-RE, and DT-CWT-RE techniques qualitatively and quantitatively.

7. Conclusion

An RE technique based on local histogram equalization algorithm has been proposed. The technique decomposes the LR input image using optimum edge preserving impulse noise removal. Wavelet coefficients and the LR input image were interpolated using the Lanczos interpolator. The proposed technique has been tested on well-known benchmark images, where their PSNR and MSE and visual results show the superiority of the proposed technique over the conventional and state-of-art image resolution enhancement techniques. The PSNR improvement of the proposed technique is upto 66.61dB compared with the DT-CWT-NLM-RE. This work is mainly preferred for low resolution images though they give enhancement output to high resolution images as well. The precision and accuracy of enhancement will be more for low resolution images when compared with high resolution images. When this work is applied to high resolution images, we only get an accuracy of 70% but for low resolution images we obtain an accuracy of about 95% on the output image. Simulation results highlight the superior performance of proposed techniques**.**

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