Combination of image compression and contrast enhancement in aerospace application

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***Abstract*—Transmission data using satellite is expensive. How to get a better image with less storage is a challenge in exploring the space. We provide an effective way that combines image compression and contrast enhancement which can improve images' contrast as well as reduce the storage of the bit files of images. And the result is satisfactory compared with the original image.**

***Index Terms*—contrast enhancement, compression, JPEG, CLAHE, deblocking**

I. Introduction

At present, photographic equipment is more and more developed. However, in the aerospace industry, due to the weight and vulnerability of high-precision cameras, it is difficult to install very high-quality cameras on satellites and detectors, and because of insufficient illumination in space, space scientists have difficulty obtaining high resolution, and better quality pictures. So we need an effective image processing algorithm to process the low-contrast images captured by the detectors and satellites to get more information about the planets in the solar system. In this paper, we propose a method of combining contrast enhancement and image compression to increase the contrast of the image and reduce the time spent on satellite and terrestrial transmission while compressing the image with a higher compression ratio.

Several experiments were implemented and different methods were tested, like SVD-DWT [1] and CLAHE [2]. Finally, CLAHE [2] is selected in image enhancement part. Symbol reduction huffman coding [3] is used to replace the normal huffman coding method in JPEG compression. Then, improved signal adaptive filter for blocking effect reduction [4]is implemented after generating the JPEG file.

II. Literature survey

In contrast enhancement part, the most common method is histogram equalization which is put forward last century. [5] The disadvantage of simply spreading the dynamic range in the whole image is that it may increase the contrast of some background noise. In order to make up the disadvantage, AHE [6] was raised by S. M. Pizer. However, this method also has some limits. The large area of dark background would be too bright to be used. To better solve the problem, CLAHE [2] method was raised by Karel Zuidervel. Compared to AHE method, CLAHE has a limit on the maximum contrast to prevent making the background too bright and exaggerating the noise. Demirel showed that preserving the shape of the PDF of an image can be of vital importance. [1] [7] Therefore, DWT-SVD method, which can both preserve the shape of histogram and enhance contrast was raised by Hasan Demirel. [8] [9]

Modern technologies for data comprehension have been started since data theory development in 1940s. Claude Shanon and Robert Fano developed a way for code words with block probability in 1949. In the 1970s, Huffman created Huffman coding based on probability. In 1977, Abraham Lenore and Jacob proposed coding in terms of pointer. In 1980s, Teri Welch suggest the LZW algorithm, which became a popular compression techniques. [10] In the 1990s, lossy image compression has been used. [11] For compression, standard JPEG [12] is powerful and popular, which uses DCT and Huffman coding. We proposed a method combining the JPEG algorithm and symbol reduction Huffman Techniques for higher compression ratio. Also, we include a deblocking method to reduce the blocking effect in the end.

In blocking effect reduction part, many techniques have been implemented to reduce the blocking artifacts which is introduced when implementing block DCT. New approach is usually aimed to improve the image quality without any modification in the encoding stage. Reeve and Lim [13] applied a linear low pass filter to the block boundaries. However, low pass filtering results will blur around edges of the images. Ramamurthi and Gersho [14] used an edge-oriented classifier to determines the edge component using gradient threshold. Singh et al. [15] developed techniques which are based o n preserved the edge information and reducing blocking artifacts in smooth regions.

III. Methodology

A. Contrast enhancement

In this part, we use the two methods(CLAHE and DWT-SVD) mentioned above to process the image together.

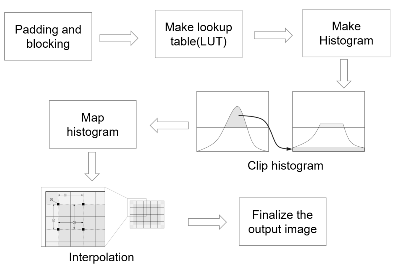


Fig. 1. Detailed steps of CLAHE

The CLAHE method can be briefly described as:

- Pad and block the image into small tiles.
- Make LUT to make the histogram for each tiles.
- Clip the histogram to limit the contrast.
- Map the histogram and do interpolation.

The key idea of CLAHE is the clip part. Since the slope of CDF shows contrast, CDF is the integration of the histogram. We only need to control the maximum of histogram to control the contrast. The clipped upper part is uniformly added to the bottom to keep the total area unchanged. The interpolation used in the last part can improve the processing speed and solve the blocking effect.

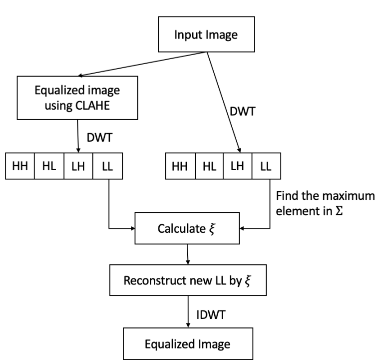


Fig. 2. Detailed steps of the DWT-SVD method

The DWT-SVD method can be briefly described as:

- Do CLAHE method to the original image.
- Do DWT method to both the two images.
- Do SVD method to the LL part of the two image.
- Find the maximum element of the two matrix and calculate the ratio $\zeta = \frac{\max(\Sigma_{LL_{\hat{A}}})}{\max(\Sigma_{LL_A})}$.
- Use the ratio ζ to reconstruct the LL part.
- Do IDWT to get the equalized image $\bar{A}$, $\bar{A} = \text{IDWT}\left(\overline{LL}_A, LH_A, HL_A, HH_A\right)$.

B. Symbol Reduction Huffman Coding

This part describe the improved compression method based on JPEG, using a sysmbol reduction Huffman coding method. Fig.3 shows the proposed method. If neglecting the shede blocks,this is a standard JPEG compression method. The image is divided into 8 by 8 blocks. For each block, we apply FDCT to generate DCT values. A table specification is applied to get a quantization table, and zigzag is used to generate symbol string for each block. Entropy coding is used to form compressed data for transition. And the reversal of the steps will recover the image.

The main difference is symbol reduction process. The number of sources symbols is a key factor in achieving compression ratio. We proposed a new technique to reduce the number of source symbols. For every adjacent two symbols, combing them together will form a new symbol. Because the string consists of 0 value in a large portion, this method will reduce the source symbols.

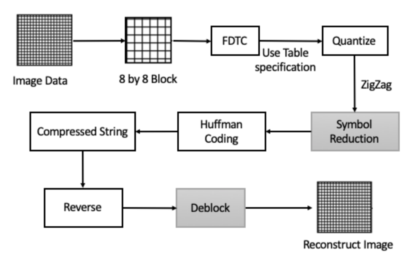


Fig. 3. proposed JPEG Encoder with symbol reduction and deblock

For example, after quantization we get a string below.

[26 18 -9 -3 -8 1 -3 1 -2 4 -2 4 0 3 -1 0 1 1 0 -1 -1 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]

Apply 128 to each coefficient to eliminate negative values.

[154 146 119 125 120 129 125 128 126 132 126 132 0 131 127 0 129 129 0 127 127 0 0 0 127 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]

Combing 2 adjacent together to form a new string, thus 64 symbols are reduced to 32 symbols.

[(154146) (119125) (120129) (125128) (126132) (126132) (0131) (1270) (12912) (90127) (127000) (127000) (00) (00) (00) (00) (00) (00) (00) (00) (00) (00) (00) (00) (00) (00) (00) (00) (00) (00)]

Therefore, the string is encoded with less symbols.

Algorithm1 Symbol Reduction

1. Divide the image into non-overlapping 8*8 blocks.
2. Shift the pixel value in range between [-128,127].
3. Apply DCT transformation in each block.
4. Quantize the coefficients using the quantization table.
5. Using zigzag ordering to get the coefficient string.
6. Add 128 to all non-zero values.
7. Combine 2 symbols together to reduce symbols.

C. Blocking Effect Reduction

In this part, a signal filter is implemented, the method is briefly described as:

- Input the JPEG image which has blocking effect between two 8*8 blocks
- Use two functions block boundary activity function and offset function to divide all edge into smooth region, non-smooth region and intermediate region.
- Different methods are implemented for different region to reduce the blocking effect.

This algorithm will be implemented both on vertical block boundary and horizontal block boundary.

First, find the edge of the different 8*8 blocks, then use block boundary activity function:

$$A(p)=\sum_{k=1}^{7} \emptyset\left(p_k-p_{k+1}\right) \tag{1}$$

where:

$$\emptyset(\Delta p)=\left\{\begin{array}{l} 0,|\Delta p| \leq S \\ 1, \text{ otherwise} \end{array}\right. \tag{2}$$

Four pixels on either side of the block boundary will be taken into account in this function. In our methods, T1 = 1, T2 = 4.

The offset is computed as the equation:

$$\text{Offset } =|(M+L)-(N+Q)| \tag{3}$$

In our method, Q was set to 2. The definition of M, L, N and Q is shown as the figure 4.

After getting the offset, if A(p) is less than T1 and offset is less than 2Q, this region is a smooth region. If A(p) is higher than T2 and the offset is less than Q, the region will be a non-smooth region. Otherwise, the region is an intermediate region.

Then different filters will be implemented in three regions.

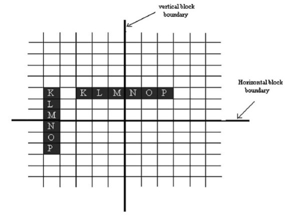


Fig. 4. Pixels symbol near the 8*8 block edge

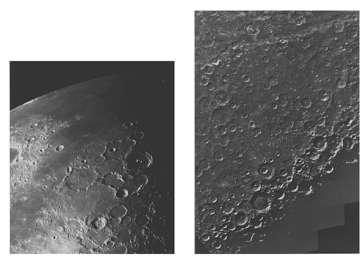
For smooth region:

k = K - (M + L - N - O)/8
l = L - (M + L - N - O)/6
m = M - (M + L - N - O)/4
n = N + (M + L - N - O)/4
o = O + (M + L - N - O)/6
p = P + (M + L - N - O)/8

For non-smooth region, only modify l, m, n and o. For intermediate region, perform 3*3 window low pass filter on M and N. In our method, mean filter was performed on M and N.

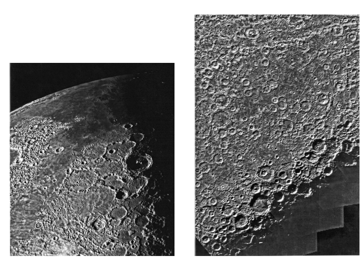
IV. Results

Some aerospace images are downloaded from NASA website. Those images will be used in our methods. Two image are selected to show the results. The original images and final results are shown as figures:



(a) Moon (b) Mercury

Fig. 5. Original image of the sample images



(a) Moon (b) Mercury

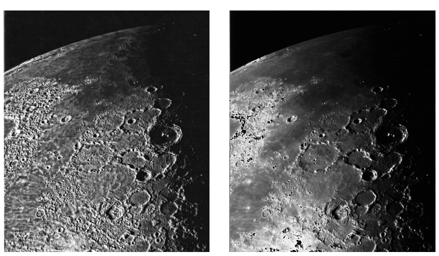
Fig. 6. Final result of the sample images

V. Thorough and Detailed Analysis

In the paper, we try to propose a method in order to enhance aerospace image and reduce its storage. CLAHE, symbol reduced huffman coding and signal filter for deblocking are combined to accomplish this task.

A. CLAHE result

At first, the method [1] was selected to do the contrast enhancement. However, the effect is not obvious, because after implementing DWT, the main information of edges are in the LH, HL and HH parts, but the DWT-SVD method only implement on LL part.This method is not that aggressive in enhancing contrast, but the advantange is that it better preserves the histogram of the original image, which may be useful in other further analysis. Since the aim of our method is to have better contrast, we choose the improved CLAHE method as the method of enhancement part. The following is the comparison of the two methods. Take the Moon image as example.



(a) CLAHE (b) DWT-SVD

Fig. 7. Example Moon image enhanced by these two methods

B. Compression result

To evaluate the compression result of the proposed method, measurement of compression ratio is adopted for the lossy compression.The equation 4 is used to evaluate compression ratio(CR).

CR = Original image size / Compressed Image Size

The results obtained from implementation of the proposed method is shown in the Table 1.The results shows that the compression ratio of proposed method is larger than the standard JPEG method. C is scalar that controls the quality of the compressed image. When C is larger, the size of image is smaller, but more information is lost. And the result shows that when C is bigger, the magnitude increase of compression ratio of the proposed method is larger than that of the standard JPEG, meaning if the quality of the image is not good, the proposed method works better. A better compression is achieved.

TABLE I
Compression Rate

Image	C	Proposed Method	Traditional JPEG
Mercury	1	6.265	4.827
Mercury	5	10.576	6.664
Moon	1	4.546	3.919
Moon	5	9.231	6.530

C. Blocking effect reduction result

After implementing blocking effect reduction algorithm, SSIM and PSNR are performed to evaluate the result:

image	SSIM	PSNR	SSIM(proposed method)	PSNR(proposed method)
Moon1	0.3378	15.6925	0.3418	15.6927
Moon2	0.0714	15.3509	0.0730	15.3521
Moon3	0.4423	14.3234	0.4232	14.2624
Mercury1	0.4300	16.4327	0.4252	16.41
Mercury2	0.5541	20.0032	0.5535	20.0247
Mercury3	0.4204	14.4336	0.4214	14.4418
Venus1	0.2824	18.1943	0.2739	18.1933
Venus2	0.4240	22.1411	0.4051	22.1701
Venus3	0.5591	16.9159	0.5537	16.9379

Fig. 8. Result comparison

As the result shows, deblocking algorithm won't affect SSIM and PSNR too much, and in some cases, the image quality even improved after deblocking.

Nowadays, many deep learning algorithm are implemented to reduce blocking effect on JPEG images, and some of then can get really good results. In the further improvement, the deep learning approach can be implemented in the blocking effect reduction part to get a better result.

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