A New Method Improving Image Matching Accuracy Based On Cumulative Histogram

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Abstract

The matching accuracy of remote sensing image-pair has a great relationship with the brightness value of the corresponding points. Generally the corresponding points of remote image-pair have great brightness difference, which may affect and reduce the matching precision. Therefore, in order to acquire high-precision stereo matching, a new method was proposed in this paper. This method can balance the brightness by combining the local information and middle axis cumulative histogram of image-pair and can adjust the brightness difference to be the same between image-pair. Both theoretical analysis and experimental results show that this new method can achieve better result in balancing brightness difference, keeping details and improving matching accuracy of remote sensing stereo image-pair effectively.

Key words: *stereo image-pair; contrast adjustment; middle axis cumulative histogram*

1. Introduction

Stereo image-pair matching based on gray level is widely used with the development of 3-D vision technology [1], because it has the advantage of simple and low complexity analysis in mathematical models, convergence speed, positioning accuracy and error estimates. While, almost all of the matching methods has a precondition that the corresponding point in the stereo image-pair has the same gray value, which is taken as a basic assumption. In fact, the gray value of the corresponding point in the left and right images has a great difference. The reason is that the acquisition processing of image-pair is interfered inevitably by difference light and brightness between the stereo cameras. If using the gray based method for image-pair matching, well accuracy can not be obtained. Therefore, uniform the brightness difference of stereo image-pair to be the same is necessary.

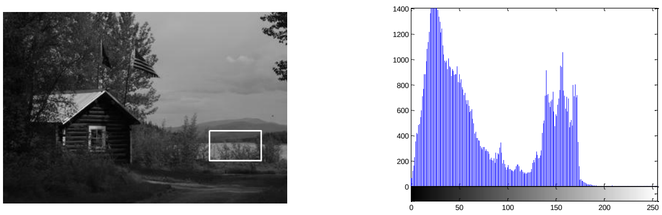
Histogram equalization is an approach that nonlinearly stretching the original grayscale of the image according to the mapping rule. Histogram equalization (HE) and related improvements are often used to uniform image brightness. This approach can make the number of pixels of each grayscale roughly the same and make the distribution of the image histogram changing into a "uniform" distribution. While, the operating gives the processed image an unnatural look, creates visual artifacts and reduces image grayscale etc. Some details after histogram equalization are almost not distinguishable. For that, many approaches about HE have been improved recently. Tarik Arici [2] gave a framework posed HE as an optimization problem that minimizes a cost function, furthermore the level of contrast enhancement can be adjusted; noise robustness, white/black stretching and mean-brightness preservation can easily be incorporated into the optimization. Wang [3] proposed a fast implementation of adaptive histogram equalization (AHE) and the local histogram is acquired by an iterative approach with a sliding window. M. Abdullah-Al-Wadud [4] tested a smart contrast enhancement technique algorithm and the dynamic histogram equalization (DHE) technique makes any loss of details. Otherwise, when selecting these approaches above to correct stereo image-pair brightness, there is no appropriate mapping rule considering both the change level of image gray dynamic range and the lost of original image details. Therefore, well accuracy can not be obtained.

Since, these approaches about HE are in view of cumulative histogram and there is some common futures about the two cumulative histograms of image-pair. This paper proposed a new image equalization method based on middle axis cumulative histogram (MACH). This new method can not only correct brightness differences to be balance, but also reduce the extent of the original image gray value changes and keep the image gray dynamic range unchanged. Experimental results show that, the proposed method can effectively correct brightness differences, keep the image gray dynamic range and can improve the matching accuracy with little image details lost. This paper is organized as follows: In the next section, theory of MACH is briefly summarized and our new implement is pressed in detail. Section 3 gives some experimental results and the discussion on image-pair and a conclusion follows in Section 4.

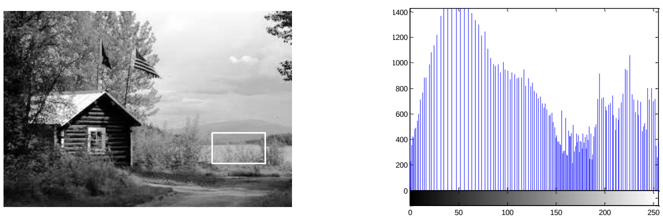
2. Theory of Middle Axis Cumulative Histogram

As previously mentioned above, in order to improving image matching accuracy and giving the image-pair with a same gray dynamic range, it is necessary to uniform the brightness difference of stereo image-pair to be the same.

When using HE, H which is selected to uniform the brightness is a specific cumulative histogram for all the image. The cumulative histogram is a straight line with a angle of 45°. Histogram equalization is the approach that nonlinearly stretching the original grayscale of the image according to the mapping rule. Therefore, the result is to make the number of pixels of each grayscale roughly the same and the distribution of the image histogram changing into a "uniform" distribution. But, this approach has many drawbacks, such as reducing of image grayscale, disappearance of image detail, through enhancement, artifact *etc.* [2]. See Figure 1, details after histogram equalization is almost not distinguishable from the vegetation, especially in the right part of the image (see in particular the part in the rectangular zone).



(a) Image and its histogram



(b) Image after HE and its histogram

Figure 1. Effect of histogram equalization

In this paper, a new image equalization method based on cumulative histogram is proposed. The purpose of our approach is to select an appropriate mapping rule based on cumulative histogram to adjust H_1 and H_2 with the same form. We consider image-pair as I_1 and I_2, whose cumulative histogram are taken as H_1 and H_2 . A prefect mapping rule H is the key part of the problem. Before we give the algorithm of how to find mapping rule in our methods, there are two propositions are given below.

If H is the identity function on [0,1], each image I_i becomes $H_i(I_i)$, i.e. the two histograms are equalized.

Proposition 1: if $I_i : \Omega \to [\mathbf{0,1}]^{\mathbf{1}}$ $(\Omega \subseteq \Re^2, i = \mathbf{1,2})$ is the image-pair, h_i is the image histogram of I_i, the cumulative histogram $H_i : [\mathbf{0,1}] \to [\mathbf{0,1}]$ of I_i is

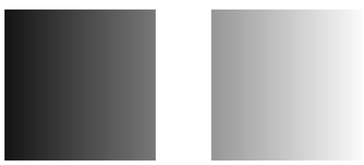
$$H_i(x) = \int_0^x h_i(t)dt \tag{2.1}$$

Proposition 2: if $F_i : [0,1] \to [0,1]$ is a continuous monotonically increasing function, then $F_i = H^{-1} \circ H_i$, and $F_i(I_i)$ is a new image, the cumulative histogram of the new image is

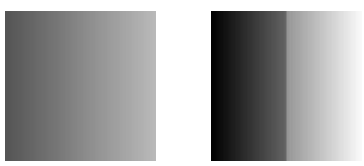
$$H_i = H \circ F_i^{-1} \tag{2.2}$$

To illustrate the theory of our method based on cumulative histogram, two artificial gray images with distinct gray dynamic range are shown in Figure 2. One image has higher gray value, while the other has lower gray value, See Figure 2(a). The cumulative histogram of the two original artificial gray images is H_1 and H_2 shown in Figure 2(c). There is another two cumulative histograms which are also placed in this unified coordinate. One is the straight line and the other is the fold line. The straight line is labeled as H, which is the average position of H_1 and H_2. The fold line is labeled as H_3 which is the numerical average of H_1 and H_2. From Figure 2(b), we can see the obviously deferent between the two images transformed by the cumulative histogram H or H_3. After transformed by H_3, new structure in transformed image is appeared. While transformed by H, the image is smooth. This result was already pointed out by Julie Delon [5], that the new structure will affect further image matching. So H_3 is not the best average result of H_1 and H_2, while H may be the better average which can be calculated from the formula (2.3), and we call H as the middle axis cumulative histogram.

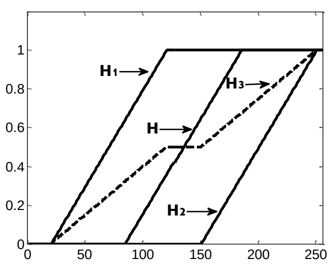
$$H = \left[\frac{H_1^{-1} + H_2^{-1}}{2} \right]^{-1} \tag{2.3}$$



(a) I_1 and I_2



(b) after H and after H_3



(c) Cumulative histogram H, H_1, H_2, H_3

Figure 2. Original images and transformed images after the corresponding cumulative histograms

Image transformed by middle axis cumulative histogram may appear a global result, it is not considering pixel space or neighbor details which is very important for image matching. In this paper, we introduce a local method based on middle axis cumulative histogram which is considering the brightness based on the neighborhood information of each pixel to maintain more image details during the brightness difference transform. The global middle axis cumulative histogram is note as MACH. The new approach combining the advantage of local adapt and MACH is named as block adaptive middle axis cumulative histogram (BAMACH). The BAMACH based approach can make every pixel adapt to its surroundings, better result can be obtained during brightness difference correction and more details can be maintained. Generally, the size of I_1 and I_2 is set to $M \times N$, real-time window size is W and step length is $W/2$, two zero matrix I_1' and I_2' with the same size as I_1 and I_2. The BAMACH can be expressed as in Algorithm 1.

Algorithm 1:

input : A couple of images I_1 and I_2; two zero matrix I_1' and I_2' with the same size as I_1 and I_2; partition of each image I_{1W} and I_{2W}; step length is $W/2$

output: A new image-pair I_1' and I_2'

foreach block with size of W. do

Compute the cumulative histogram of I_{1W} and I_{2W}, marked as H_{1W} and H_{2W};

Compute the middle axis as formula (1);

Compute the nonlinear mapping $F_1 = H^{-1} \circ H_{1W}$, $F_2 = H^{-1} \circ H_{2W}$;

Compute the image gray value of the block $I_{1W}' = F_1(I_{1W}), I_{2W}' = F_1(I_{2W})$;

Put I_{1W}' and I_{2W}' into I_1' and I_2' in the corresponding position;

end

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3. Experiments and Discussions

In this paper, test on three real remote sensing image-pairs was carried out and all methods were implemented in MATLAB. In order to illustrate our algorithm BAMACH effectiveness, we show all the result of the three experiments, and contrast the results with HE and MACH.

3.1 Effect on gray dynamic range

Figure 3~Figure 5 shows the first experiment of applying the proposed algorithm BAMACH and also the results of applying HE and MACH. See Figure 3, the first column is the original image-pair, although the angle variation between both original views is small, the light difference is exist. The second to the fourth column is the images transformed by HE, MACH and BAMACH. In Figure 4, after transformed by HE, MACH and BAMACH, we can see clearly that the number of pixels of each gray roughly the same. But after HE, the dynamic range of histogram is broad, which will bring the unnecessary gray value to image-pair; after MACH, the histogram has almost the same gray dynamic range but not smooth which means some gray value are dramatically deferent; after BAMACH, the distribution of the image cumulative histogram is nearly "uniform" and the histogram has the same smooth appearance especially. In short, histogram after BAMACH became more identical and satisfied with the assumption of stereo matching and gray dynamic range changes the same. If we scan some image details, we can see that the details in image after BAMACH are rich and visible.

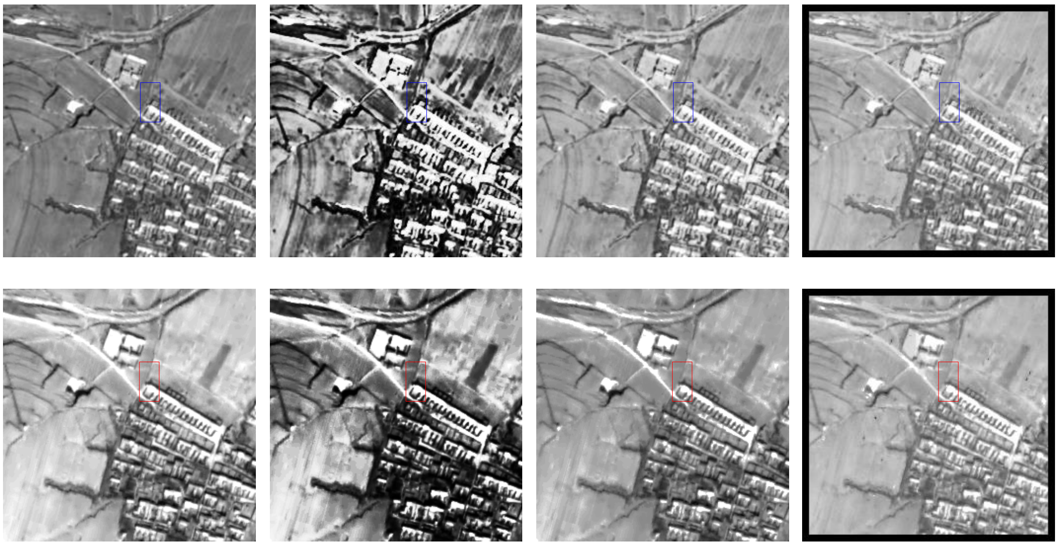

Figure 3. Column 1: Original image-pair, Column 2-4: the transformed view by HE, MACH and BAMACH

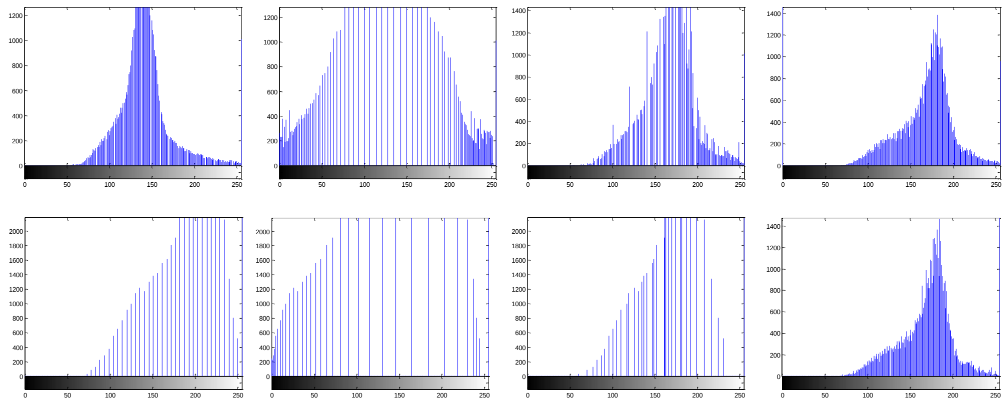

Figure 4. Column 1: The histogram of original image-pair, Column 2-4: The histogram of the processed view after HE, MACH and BAMACH

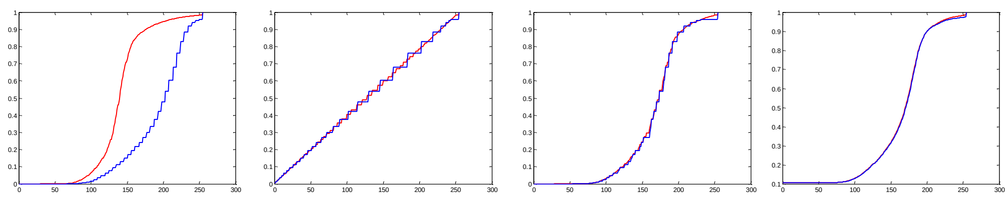

Figure 5. The cumulative histogram of original image-pair and after HE, MACH, BAMACH

3.2 Effect on image spectrum and details

Generally, image acquisition process doesn't satisfy with the property "to be well sampled according to Shannon-Whittaker sampling theorem". If we want a good matching precision, the image must be well sampled. In order to check the effects of the different transformations on the spectrum experimentally, we made the following example: we compute the modification of I_1 via HE, MACH and BAMACH. From Figure 6 and Table 1, we can see that the spectrums of I_1 via BAMACH remain more in the central square than that of others and the spectrums energy become balance between the image-pair. Most natural images have a spectrum really concentrated in the center of its support. It follows that after a transform like a histogram modification, the spectrum sprawls but doesn't go much out of its support. The ratios of energy presented illustrate that our algorithm is really useful in well sampled. If we scan some image details in Figure 6, we can see that the details in BAMACH are rich and visible. This algorithm is also an effective way in enhancing image detail.

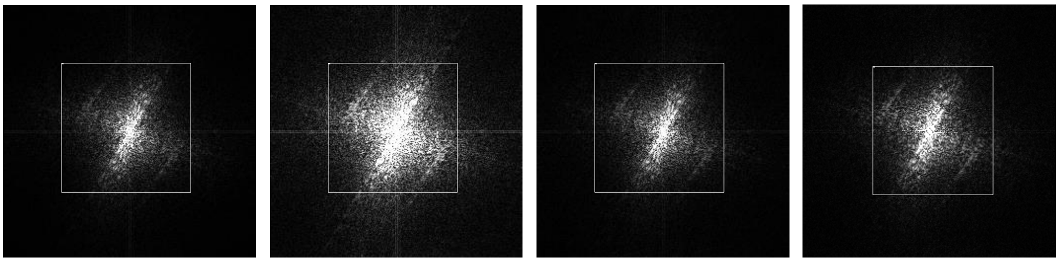

Figure6.The spectrums of the right view and after HE, MACH, BAMACH

Table 1. Spectrums Energy Remained in Central Square

	original	HE	MACH	BAMACH
Experiment 1 I1	0.2725	0.2804	0.2708	0.2944
Experiment 1 I2	0.2615	0.2496	0.2621	0.2945

3.3 Effect on image matching

Image transformed by BAMACH has the same gray dynamic range and maintain more image detail than HE and MACH without increasing or decreasing obviously. So image-pairs transformed by BAMACH may get a higher matching precision.

SSD [6] is a commonly used similarity measure method, named the sum of squared disparity. See Figure 3, the right image of remote sensing is the real-time image with the size of 256×256. Take a reference window from the left image at the random point （80,140） with the size of 41×21. The experimental results show that, the matching point from the image transformed by HE, MACH and BAMACH is (86,141),(110,139),(86,141). All the matching points is correct and same, while the matching accuracy is different, see Table 2, line one. And all the results show that image-pair transformed with the proposed approach can reach the higher matching accuracy. Figure 7~Figure 8 show the matching results of the second and the third experiment. The effectiveness are the same with the first one.

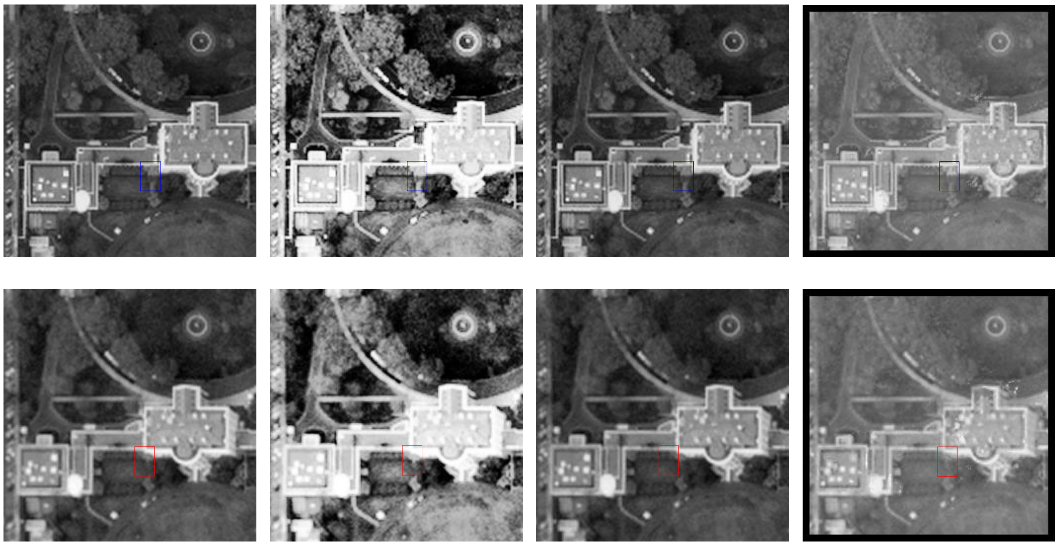

Figure 7. Column 1: Original image-pair, Column 2-4: the transformed view by HE, MACH and BAMACH

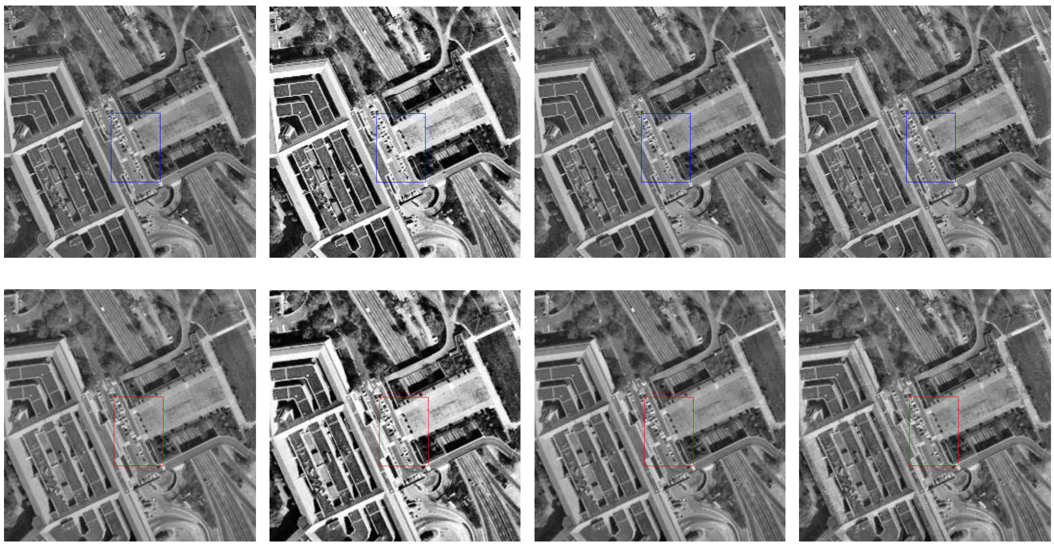

Figure 8. Column 1: Original image-pair, Column 2-4: the transformed view by HE, MACH and BAMACH

Table 2. Matching accuracy

	original	HE	MACH	BAMACH
Experiment 1	0.9805	0.8964	0.9867	0.9888
Experiment 2	0.9903	0.9754	0.9901	0.9920
Experiment 3	0.9936	0.9698	0.9933	0.9940

4. Conclusions

The main contribution of this paper is proposing a new approach noted as BAMACH which combining the advantage of local adaptive and MACH. BAMACH based approach makes every pixel adapt to its surroundings, better result can be obtained on brightness difference correction and therefore more details can be maintained. Both theoretical analysis and experimental results show that this approach can uniform brightness difference and improve matching accuracy of stereo image-pair effectively.

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