Multi-spectral image enhancement algorithm based on keeping original gray level

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Abstract: Characteristics of multi-spectral imaging system and the image enhancement algorithm are introduced. Because histogram equalization and some other image enhancement will change the original gray level, a new image enhancement algorithm is proposed to maintain the gray level. For this paper, we have chosen 6 narrow-bands multi-spectral images to compare, the experimental results show that the proposed method is better than those histogram equalization and other algorithm to multi-spectral images. It also insures that histogram information contained in original features is preserved and guarantees to make use of data class information. What's more, on the combination of subjective and objective sharpness evaluation, details of the images are enhanced and noise is weaken.

Keywords: multi-spectral imaging system; image enhancement; gray level; histogram information; sharpness evaluation

1. INTRODUCTION

Multi-spectral images is a group of multiple channel collected on the same target imaging system, with its development, the purpose of multi-spectral images is applied to extracting feature band, spectral reflectance reconstruction, observe the process of growing plants [1-3]. Because the refractive index vary with changing wavelength, in a fixed position on a certain band image focusing accurately, the rest bands will be continuous acquisition, but this part will be different from the focal depth.

At present, almost all image enhancement algorithms are proposed to improve sharpness on visual of human eyes, these methods ignore the grayscale to multi-spectral image. For example histogram equalization is a common airspace enhancement algorithm, it can get a larger dynamic range image with more rich grayscale [4, 5]. However, use this kind algorithms to improve the images' sharpness will cause much grayscale consumed. Lead to less grayscale after

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transformation, which lost many gray details of original input images. Do feature extraction of the output images will have nothing meaning which multi-spectral image should have.

After the analyzing the principle of histogram equalization, this paper presents a new algorithm to improve the sharpness of multi-spectral image. Algorithm's main goal is to build up an image enhancement filter[6]. According to the goal we proposed, the filter can be divided into three parts: the first part is used to keep the whole gray series which is a prerequisite for filter design; the second part is used to enhance the image details and texture information, which is the core of this algorithm, the last part is used to suppress image's noise due to high frequency amplifier, even the algorithm is not for reducing the noise of image, but this part can effectively improve the quality of the output image.

In order to better apply the "sharpness" to the field of multi-spectral image, we also studied the evaluation of multi-spectral image sharpness in the early of this paper. Beyond that, it also verified whether the grayscale is maintained by the histogram contrast of input and output images.

2. OBJECTIVE

In the experiment, we select outdoor planting "radish leaves" as the target, use multi-spectral LCTFs (Liquid Crystal Tunable Filter) gather a group of images of the target. The researching bands with central wavelength as 430nm, 460nm, 530nm, 560nm, 680nm, 710nm, each band image has different grayscale.

We can see the gray level from histogram distribution as shown in figure 2. The gray level is 0-255, the higher of peak the brighter of the image. And the sharpness values are shown in Table 1, compared Figure 1 and table 1, as the band increase, the sharpness is increase first and then decrease.

Figure 1. Original input images

$(a)\lambda = 430nm$ $(b)\lambda = 460nm$ $(c)\lambda = 530nm$ $(d)\lambda = 560nm$ $(e)\lambda = 680nm$ $(f)\lambda = 710nm$

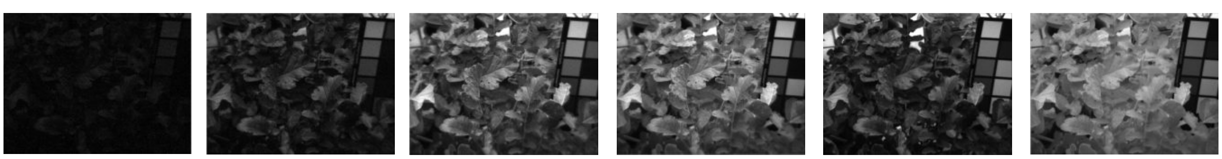
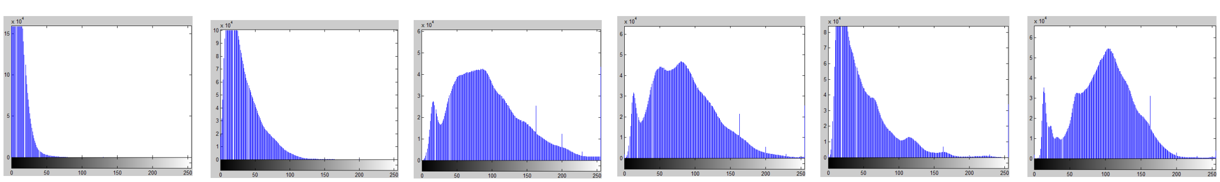


Figure 2. Histogram distribution of images

$(a)\lambda = 430nm$ $(b)\lambda = 460nm$ $(c)\lambda = 530nm$ $(d)\lambda = 560nm$ $(e)\lambda = 680nm$ $(f)\lambda = 710nm$



In Table 1, on the concept definition of sharpness is given a specific numerical measure, this value refers to the image’s gray level difference function value. Which is suitable for objective evaluation of multi-spectral image, we have discussed in my early paper [7].

Table 1. The sharpness of six band images

Band/nm	430	460	530	560	680	710
Sharpness	3. 91	9. 78	20. 47	18. 46	15. 66	16. 86

3. TRADITIONAL IMAGE ENHANCEMENT METHOD

At present, there are many algorithms for image enhancement, some because low illumination, some because low contrast, some because edge blur and other issues, almost all of them aims to enhance visual sense of human eyes. But these methods for multi-spectral image may not apply. Histogram equalization is a basic method of image enhancement technology, its purpose is transforming the original image histogram correction in the form of equilibrium distribution. To an multi-spectral image, the i^{th} gray level r_i term frequency is n_i, the corresponding pixel probability is calculate as:

$$p_r(r_i) = \frac{n_i}{n} \qquad i = 0,1,\ldots R-1 \tag{1}$$

n is sum of pixels, i is gray level, r_i satisfy the mormalization condition, the function of image transformation is:

$$S = T(r_i) = \sum_{i=0}^{k-1} p_r(r_i) = \sum_{i=0}^{k-1} \frac{n_i}{n} \tag{2}$$

Use histogram equalization process six multi-spectral images in figure 1, the results are shown in figure 3, histogram distribution is shown in figure 4 and the sharpness is shown table 2.

Figure 3. Images processed by histogram equalization

$(a)\lambda = 430nm$ $(b)\lambda = 460nm$ $(c)\lambda = 530nm$ $(d)\lambda = 560nm$ $(e)\lambda = 680nm$ $(f)\lambda = 710nm$

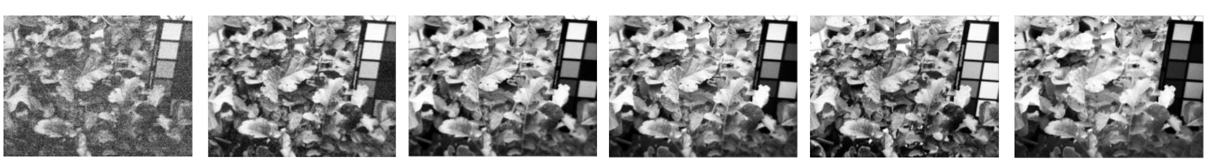


Figure 4. Histogram distribution processed by histogram equalization

$(a)\lambda = 430nm$ $(b)\lambda = 460nm$ $(c)\lambda = 530nm$ $(d)\lambda = 560nm$ $(e)\lambda = 680nm$ $(f)\lambda = 710nm$

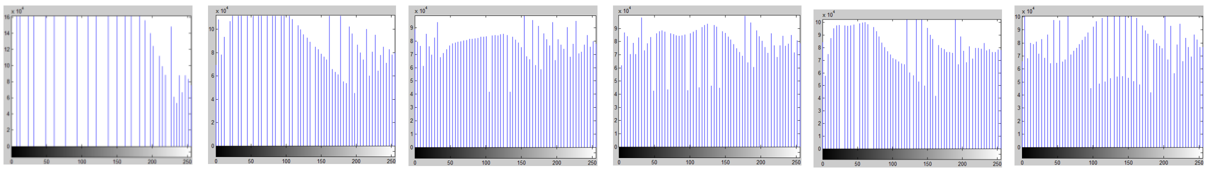


Table 2. The sharpness of histogram equalization images

Band/nm	430	460	530	560	680	710
Sharpness	29. 58	31. 25	32. 21	32. 86	36. 69	32. 24

From figure 3 and table 2, the sharpness of the images is enhanced, histogram equalization really improved visual clarity. Unfortunately, much gray information lost, analysis plants' spectral information will do nothing meaning.

Besides histogram equalization, some other traditional image enhancement algorithms are not suitable to process multi-spectral images. Just as histogram modification, nonlinear partial equation and so on, because all of them do gray value transformation, this kind of method may change the spectrum energy of original input image.

4. IMAGE ENHANCEMENT FILTER FOR MULTI-SPECTRAL

According to the above argument, the precondition to enhance the multi-spectral image is keeping spectrum energy no change. Because most energy of an image is in low frequency component, high frequency component determines the image details[8], so this experiment is from frequency domain to design filter.

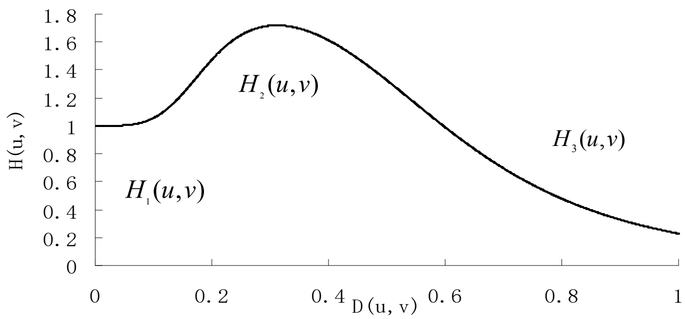
Keep energy distribution means without changing low frequency component as far as possible, strengthen the high frequency to improve original details, at the same time, we cannot ignore the influence of noise to image quality. If higher frequency strengthened, noise may be larger than original, so in this filter, we add the third component to decrease noise. Through iterative method find the image with minimum energy and largest sharpness.

Objective function as follow:

$$H(u,v) = \lambda_1 H_1(u,v) + \lambda_2 H_2(u,v) + \lambda_3 H_3(u,v) \tag{3}$$

In the formula, $H_1(u,v)$ is keeping energy, $H_2(u,v)$ is improving details, $H_3(u,v)$ is decreasing noise. and λ_1, λ_2, λ_3 are the shares in the function, schematic diagram of the function is shown in figure 5.

Figure 5. Schematic diagram of the function



The purpose of filter design is get an enhanced image more clearly than original, here choose Butterworth pass filter as transfer functions, the function as follow:

$$H = \frac{1}{1+(D_0/D)^{2N}} \tag{4}$$

In formula(4), D_0 is cut-off frequency, D is the distance to the centre of Fourier transform.

Now, we use this equation to design filter of two-dimension (u,v) image, according equation, three parts as follows:

$$H_1(u,v) = H_0(u,v) \tag{5}$$

$$H_2(u,v) = \frac{1}{1+[D_l/D(u,v)]^{2n}} \tag{6}$$

$$H_3(u,v) = \frac{1}{1+[D_h/D(u,v)]^{2m}} \tag{7}$$

In equations(5), (6), (7), $H_0(u,v)$ is original input; D_l is low strengthen frequency; D_h is high weaken frequency; n and m are order of cut-off filter.

Combine equations (5), (6), (7) to the function (3). There are seven parameters: λ_1, λ_2, λ_3, D_l, D_h, n, m. Among them $\lambda_1 = 1$, because only in premise of low frequency component no change can consider high frequency component. Other six parameters can be set through image transformation, with the help of histogram distribution and sharpness evaluation to modulate the parameters.

In order to set above parameters, we first choose clearest band 530nm do experiment as figure 6, comparing original input and processed output is convenient for observation change of details, texture and noise. Figure 7 is contrast histograms.

Figure 6. 530nm contrast images between before and after processing

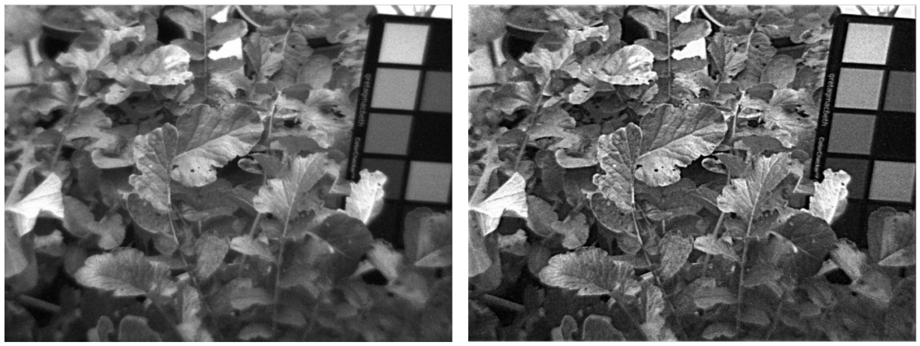
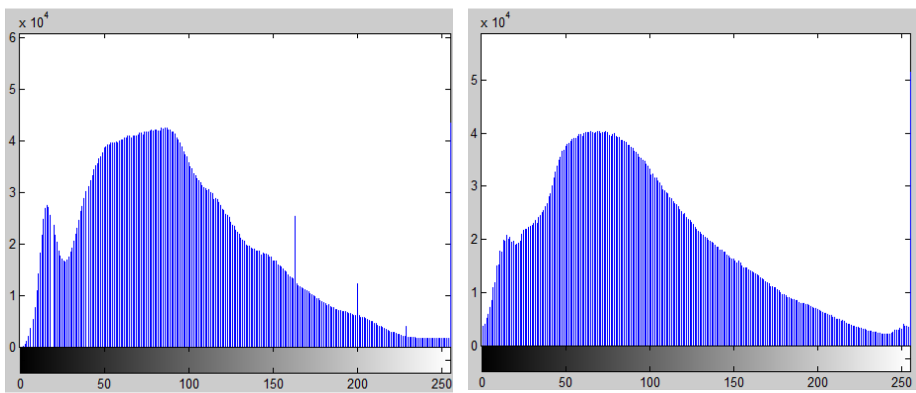


Figure 7. 530nm contrast histograms between before and after processing



From figure 6, the image output is more clearly than input, high frequency strengthened, noise has not be amplified. From figure 7, the shape of output histogram is very closed to input, and the peaks are both arrived at about 4×10^4, gray level in the range 50-100. According to the above steps, adjust the parameters of remaining five bands, output images are shown in figure 8 and histograms are shown in figure 9. Sharpness of six bands output images are on table 3.

Figure 8. Other five bands output images

$(a)\lambda = 430nm$ $(b)\lambda = 460nm$ $(d)\lambda = 560nm$ $(e)\lambda = 680nm$ $(f)\lambda = 710nm$

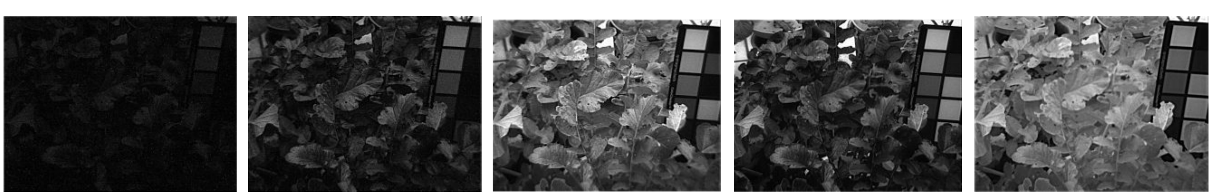


Figure 9. Other five bands output histograms

$(a)\lambda = 430nm$ $(b)\lambda = 460nm$ $(d)\lambda = 560nm$ $(e)\lambda = 680nm$ $(f)\lambda = 710nm$

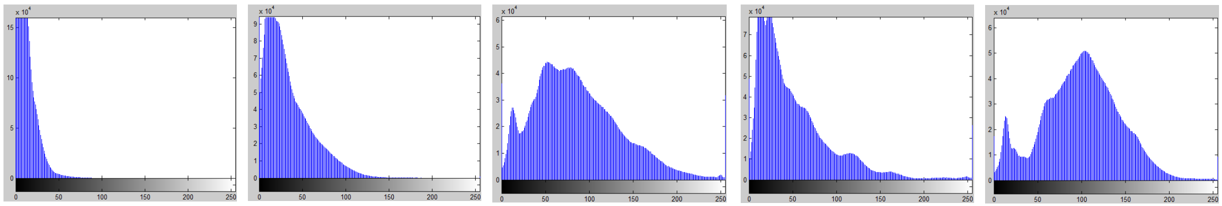


Table 3. Sharpness of six bands output images

Band/nm	430	460	530	560	680	710
Sharpness	4. 35	11. 74	24. 67	19. 81	16. 90	18. 27

Compared table 1 and table 3, from the number can be concluded that sharpness is improved by image enhancement filter, the noise has not been strengthened, most important of all, histograms of output are very closed to original input, which means the gray level has been kept well.

5. CONCLUSION

This paper introduced a new algorithm to enhance multi-spectral images, and this method is different from other methods. For example, the traditional histogram equalization also can strengthen sharpness, but it will change gray level and lost much gray information, we can see this from histogram distribution in figure 4, use this kind of method process multi-spectral images may cause original input lost much spectral energy, there's no meaning to output images. The advantage of algorithm we proposed is keeping gray level no change, which means enhance details and texture information in premise of guarantee the energy distribution. This algorithm choose Butterworth high pass filter as transform function, design low frequency keeping; intermediate frequency enhanced; high frequency decreasing filter. With above three parts combination, we can accomplished a filter with more details, little noise amplified and little energy lost.

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