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Optimization of Single Image Imaging At Night

Feiyu Liu

Nanjing Normal University Zhongbei College, Danyang City, Jiangsu Province, 212300, China

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Abstract: Usually, the influence of external factors will be greater when acquiring images. For example, capturing images in rain, fog and low light conditions will result in low definition, low signal-to-noise ratio and low illumination of image processing. This will affect our visual experience and the performance of computer algorithms. In this paper, some existing algorithms are studied and verified, and the experimental results are compared.Finally, It is concluded that LIME algorithm is simple and efficient, and image processing can achieve better effect.

1. Introduction

Infrared thermal imaging technology is used more and more widely, and has great application and demand in many fields,such as, the infrared temperature measuring door used for epidemic prevention and control.Due to the limitation of infrared searchlight and infrared detector, the existing infrared thermometer is susceptible to external influences.In particular, the lack of light at night, rain and fog, and other factors affect image clarity.In the night image, dark color occupies most of the content of the image, which makes the overall or local brightness insufficient, color contrast and saturation low, so that many key details can not be fully displayed.Image enhancement is mainly to display the content of the dark area, but if the brightness is too high, the details will be lost easily.

Many scholars have proposed different methods of image enhancement. The traditional image enhancement algorithm has gray-squares algorithm. its processing method is simple, but at the same time it will also increase the noise, thus affecting the final processing effect.Norbert Wiener proposed Wiener filtering with squared minimum as the best criterion to deal with the noise. The square of the difference between the actual output and the target output is the smallest. The linear filtering algorithm is simpler and faster, but it will cause details and edges blurring when processing the image.Marco Tulio Ribeiro proposes a local interpretability model algorithm -- LIME algorithm,which has strong versatility and good effect.In this paper, we mainly do some experimental research on the gray-scale straight square algorithm, Wiener filter and live algorithm, and compare their performance, so as to further explore a more suitable algorithm for night image processing.

2. Research on Common Algorithms

2.1 Gray-Scale Straight Square Enhancement Algorithm

The essence of gray-scale straight square algorithm is one-dimensional discrete function:

$$p(s_k) = \frac{n_k}{n};\ k = 0, 1, 2, \cdots, L-1 \quad (1)$$

In formula (1), s_k represents the k-th gray value of the image, n_k represents the number of pixels with s_k in the image, and n represents the total number of pixels.According to formula (1), $p(s_k)$ is an estimate of the gray value, and the histogram represents the dispersion of the gray value of the image.gray-scale straight square algorithm is essentially to enhance the image by changing the distribution of gray histogram.The main idea is: first calculate all s_k and n_k of the original image, and then draw the histogram of the original image, that is

$$t_k = \sum_{i=0}^{k} p_s(s_i),\ 0 \le s_k \le 1;\ k = 0, 1, 2, \cdots, L-1 \quad (2)$$

Then carry out the rounding calculation

$$t_k = \mathrm{int}\left[(N-1)t_k + \frac{k}{N}\right] \quad (3)$$

Mapping relations are defined:

$$s_k \to t_k \quad (4)$$

Finally, the number of pixels n_k in each gray scale of the new histogram is counted,and the new histogram is calculated.

$$p(t_k) = \frac{n_k}{n} \quad (5)$$

Fig.1 Original Image ,Grayed Image, Enhanced Image and Gray Histogram

Figure 1 is the result of gray-scale square algorithm processing. By analyzing Figure 1, it is not difficult to find that histograms are mainly distributed near the vertical axis of the coordinate system.Different night images have different distribution of histograms due to different brightness.From the experimental results, it is obvious that the clarity of the image after gray-scale gray-scale straight square processing is clearer than that of the original image, but the light source of the image background is magnified a lot, resulting in that the processed image still can not meet the visual experience, and reach the expected effect.

2.2 Wiener Filtering Algorithm

In order to find a suitable algorithm for night image processing, Wiener filtering algorithm is studied and experimented.Wiener filtering, also called least mean square filtering, is an image processing method that combines the degradation function and noise features,whose essence is to use statistical estimation method, and is about the image and noise matrix.Based on the random variables of image and noise , the output of the algorithm is adjusted by the variance of the image.The basic idea is:

$$e^2 = E\left\{\left[f(x, y) - f'(x, y)\right]^2\right\} = \min \tag{6}$$

In equation (6), *F*(x,y) represents the input image and *F'*(x,y) represents the estimated image,which is the optimization target.In the process of image acquisition, image degradation or noise will be caused by external interference.The model is as follows:

$$G(x, y) = H(x, y) * F(x, y) + \eta(x, y) \tag{7}$$

In equation (7), $*$ represents convolution symbol,G(x,y) represents degraded image, Hx,y) represents degradation function,and $\eta(x, y)$ represents noise function.When both degradation function and noise are considered,the formula is as follows:

$$F'(x, y) = \left[\frac{1}{H(x, y)} \frac{|H(x, y)|^2}{|H(x, y)|^2 + S_\eta(x, y) / S_f(x, y)}\right] G(x, y) \tag{8}$$

Where $S_\eta(x, y)$ is the power spectrum of the noise, $S_f(x, y)$ represents the power spectrum of the input image.If the power spectrum of the non degraded image is not known or cannot be estimated,the following formula is often used for approximate substitution:

$$F'(x, y) = \left[\frac{1}{H(x, y)} \frac{|H(x, y)|^2}{|H(x, y)|^2 + K}\right] G(x, y) \tag{9}$$

Where K represents a specific constant on all items in $|H(x, y)|^2$, and its value is chosen according to the effect of the processing.

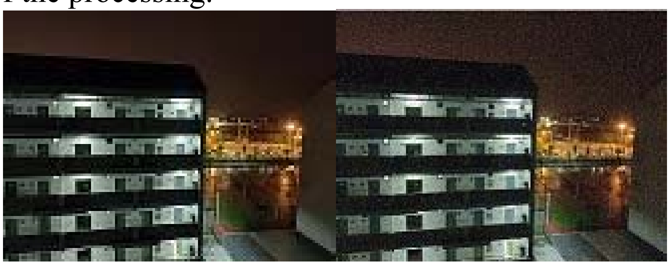

Fig.2 Original Image and Wiener Filter Denoising

Figure 2 shows the results of image processing with Wiener filtering algorithm,Wiener filtering algorithm can deal with degraded and noisy images under the condition of almost stable random.But in the actual measurement, many images can not meet the standard conditions of Wiener filtering.It is found that in practice, Wiener filter algorithm is easy to be disturbed by the outside world and is sensitive to noise, so it has not achieved a good processing effect.

2.3 Lime Enhanced Algorithm

Through the study of the first two algorithms, it is found that the former two algorithms do enhance the image to a certain extent, but the disadvantage is that they will over enlarge part of the image while enhancing the image, resulting in the final image can not achieve the desired effect.The LIME algorithm has strong versatility for image processing. Therefore, the algorithm is further studied and explored.The principle of the algorithm is to find the maximum value in three channels of R, G and B to estimate the illumination of each pixel. Then the initial image is refined, and the refined image is used as the last light mapping, thus generating the final enhanced image.The LIME algorithm model is as follows:

$$L = I * T \tag{10}$$

Where L is the image, I is the restoration of the image, T is the illumination image, and * is the multiplication of elements.The model shows that the image can be regarded as the product of the required scene and illumination image, and T is the key to image processing,and its image processing model is expanded as follows:

a) initial illumination map estimation

The algorithm first estimates the illumination by finding the maximum value of three channels, but it can only improve the overall illumination.In order to solve the problem of uneven illumination, the following initial estimate is adopted.

$$\hat{T}(x) = \max_{c \in \{R,G,B\}} L^c(x) \tag{11}$$

$\hat{T}(x)$ is not saturated,because

$$I(x) = \frac{L(x)}{\max_c L^c(x) + \varepsilon} \tag{12}$$

Where ε is a very small number, its purpose is to avoid denominator 0.

b) refine the illumination map

Illumination estimation can be obtained by local consistency,and the commonly used methods are as follows:

$$\hat{T}(x) = \max_{y \in \Omega(x)} \max_{c \in \{R,G,B\}} L^c(x) \tag{13}$$

$$\hat{T}(x) = \underset{y \in \Omega(x)}{mean} \max_{c \in \{R,G,B\}} L^c(x) \tag{14}$$

Where $\Omega(x)$ represents the area centered on pixel x,Y is the location index of $\Omega(x)$.This can enhance local consistency to a certain extent.However, in order to keep the overall structure and smooth details, the following formula is used for optimization:

$$\min_T \left\|\hat{T} - T\right\|_F^2 + \alpha \left\|W * \Delta T\right\|_1 \tag{15}$$

The first term represents the fidelity between the initial estimation image and the illumination image, and the second term represents the smoothness of the image.W is the weight matrix, which includes horizontal component and vertical component.The key to optimization is the design of W:

$$W_{h(x)} = \sum_{y\in\Omega(x)} \frac{G_\sigma(x, y)}{\left|\sum_{y\in\Omega(x)} G_\sigma(x, y)\Delta h\hat{T}(y)\right| + \varepsilon} \tag{16}$$

Where $G_\sigma(x, y)$ is generated from the Gauss interior of the standard deviation. $|*|$ is an absolute value operation.The W weight matrix is constructed based on T, which also indicates that W can be calculated only once, but its calculation speed is slow, so formula (15) is often replaced by the following sub-approximation

$$\min_T \left\|\hat{T} - T\right\|_F^2 + \alpha\sum_x \frac{Wh(x)\,(\Delta hT(x))^2}{\left|\Delta h\hat{T}(x)\right| + \varepsilon} + \frac{Wv(x)\,(\Delta vT(x))^2}{\left|\Delta v\hat{T}(x)\right| + \varepsilon} \tag{17}$$

Formula (17) can be calculated directly because it contains only two terms.

Due to the different magnification of image processing and the different noise level in different input areas, some important information modules will be deprived in image processing.Some unimportant areas are too smooth. To avoid this kind of image processing unevenness, the following methods are used to improve:

$$I_f = I * T + I_d * (1 - T) \tag{18}$$

Where Id and If represent the result of denoising and reconstructing, respectively. The denoising is put to the last step so that it can be connected with other image processing methods.

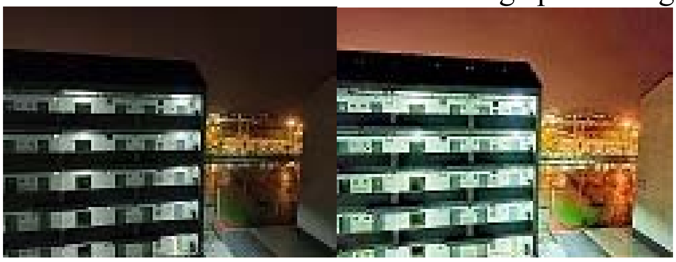

Fig.3 Original Image and Lime Algorithm Enhanced Image

Figure 3 shows the result of processing a night image with the LIME algorithm.By comparing with the original image, it is clear that the image processed with this algorithm is clearer and brighter.The key information in the picture can also be clearly displayed, and the algorithm is not disturbed by the strong light in the background of the image during processing.Overall, the image processed by this algorithm can better satisfy our visual perception and achieve a better processing effect.

3. Experimental Results and Analysis

Fig.4 Original Image, Wiener Filter Denoising, Grayed Image and Lime Algorithm Enhanced Image

Figure 4 is a comparison image processed by the above three algorithms. After analysis and comparison, it is summarized as follows:Gray square algorithm can enhance the local contrast, but the processed image will lose details.In the noise reduction algorithm, Wiener filter is more accurate in positioning and more effective in solving the noise near the zero point, but because it is not smooth and sensitive to noise, it can not achieve the ideal noise reduction effect.The LIME algorithm not only solves the problems of the above two algorithms, but also improves the contrast and brightness of the image processed by LIME algorithm. The detail information of the image is clearer without loss. It can meet the visual requirements better in all aspects and achieve better processing results.

4. Summary

The existing three algorithms for image processing, gray-scale histogram algorithm, Wiener filter noise reduction algorithm and LIME algorithm, are studied. The basic models and principles of these three algorithms are deeply explored, and the night image is enhanced and compared by using these three algorithms.The experimental results show that LIME enhancd algorithm can improve the clarity, brightness and contrast of the original image without distortion. The bright area of the image has been further improved, and the detailed information of the dark area has been clearly reflected. On the whole, the visual effect of the night image has been significantly enhanced, and it is more suitable for our visual experience.Therefore, it is concluded that the LIME algorithm is more suitable and effective for nighttime image processing.

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