Infrared Physics & Technology 55 (2012) 309–315

Contents lists available at SciVerse ScienceDirect

Infrared Physics & Technology

journal homepage: www.elsevier.com/locate/infrared

A new adaptive contrast enhancement algorithm for infrared images based on double plateaus histogram equalization

Kun Liang, Yong Ma *, Yue Xie, Bo Zhou, Rui Wang

Department of Electronics and Information Engineering, Huazhong University of Science and Technology, Wuhan 430074, PR China

ARTICLE INFO

Article history:
Received 18 January 2012
Available online 16 March 2012

Keywords:
Infrared image enhancement
Double plateaus histogram equalization
Adaptive algorithm
Target detection

ABSTRACT

In infrared images, detail pixels are easily immerged in large quantity of low-contrast background pixels. According to these characteristics, an adaptive contrast enhancement algorithm based on double plateaus histogram equalization for infrared images was presented in this paper. Traditional double plateaus histogram equalization algorithm used constant threshold and could not change the threshold value in various scenes, so that its practical usage is limited. In the proposed algorithm, the upper and lower threshold value could be calculated by searching local maximum and predicting minimum gray interval and be updated in real time. With the proposed algorithm, the background of infrared image was constrained while the details could also be enhanced. Experimental results proved that the proposed algorithm can effectively enhance the contrast of infrared images, especially the details of infrared images.

1. Introduction

Generally, infrared images have low contrast but highly bright background [1–3], therefore the detailed information is easily immerged in the background, making it difficult to distinguish the target from the background. In order to enhance the contrast of infrared image [4–9], the dynamic range of image gray levels needs to be enlarged. However, in most infrared images, traditional histogram equalization [10–13] algorithm produces an unsatisfactory outcome, where the background noise with typical gray levels gets amplified while the detailed information with atypical gray levels is constrained.

As an improvement of histogram equalization, plateau histogram equalization [14,15] is proposed for infrared image enhancement in particular. A threshold value is utilized in this algorithm to constrain background noise [16–20], so that the detailed information gets survived and the contrast of image can be properly enhanced. However, with plateau histogram equalization, some detailed information with atypical gray levels could still be combined with other gray levels, as a result the detailed information cannot be fully enhanced with plateau histogram equalization.

Double-plateau histogram equalization [21] is then proposed so that the detailed information can be further protected by adding a proper lower threshold value. As the upper threshold is used to constrain background noise and the lower threshold is used to protect and enhance the details, a critical issue of double-plateau histogram equalization is how to properly choose the upper and lower threshold values. Empirically, the value of upper threshold is set to be 20–30% of the total pixels number, while the lower threshold value is set to be 5–10% of it. The threshold values are therefore unchanged for images of the same size. However, even for images of the same size, the details and gray levels might be quite different in various scenes, and an optimal enhancement could not be obtained by fixed threshold values in various applications.

Based on double plateaus histogram equalization, a novel real time adaptive algorithm which can update the threshold value is proposed in this paper. According to the histogram of infrared image, the upper and lower threshold value could be calculated and updated in real time by searching and predicting local maximum and minimum gray interval. The algorithm can be used in various applications to effectively enhance infrared images, especially details in the images.

2. Adaptive double plateaus histogram equalization

Double plateaus histogram equalization [5,6] is an improvement of plateau histogram equalization. The upper threshold is utilized in the algorithm for preventing over-enhancement of background noise with typical gray levels, and the lower threshold is set for protecting detailed information with fewer pixels from being combined. The algorithm can be illustrated in the following equation [21]:

$$P_m(k) = \begin{cases} T_{UP} & (p(k) \geqslant T_{UP}) \\ p(k) & (T_{DOWN} \leqslant p(k) \leqslant T_{UP}) \\ T_{DOWN} & (0 < p(k) \leqslant T_{DOWN}) \\ 0 & (p(k) = 0) \end{cases} \quad (1)$$

* Corresponding author. Tel.: +86 2787556304.
E-mail address: mayong@hust.edu.cn (Y. Ma).

1350-4495/$ - see front matter © 2012 Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.infrared.2012.03.004

where k represents the kth gray level, T_{UP} is the upper threshold and T_{DOWN} is the lower threshold, $P_m(k)$ is the modified histogram after double-plateau histogram equalization, and $p(k)$ is the original histogram. The algorithm becomes plateau histogram equalization when T_{DOWN} is set to 0; and turns into histogram equalization if T_{UP} is larger than the maximum statistic value in the histogram $p_{max}(k)$ while T_{DOWN} is set to 0.

Since the upper and lower thresholds are key parameters of double-plateau histogram equalization, a new adaptive method for computing the two values is introduced in this paper. For each image a statistic histogram is constructed, then the upper threshold is determined by searching the local maximums; the lower threshold is calculated by estimating the accumulative statistic value. With the proposed method the threshold parameters could be computed and updated adaptively to improve the contrast of the infrared images.

2.1. Analysis of the upper threshold

It can be concluded from Eq. (1) that if the upper threshold is too large, the background noise could not be constrained enough; on the other hand, if it is too small, details of image will be lost and combined with other gray levels, even though the background noise could be greatly constraint.

The ideal upper threshold should be chosen as the histogram peak of details, $p(k_{detail})$, so that it is able to constrain all the background noise and simultaneously keep all the gray levels of details uncombined. However, it is difficult to locate the histogram peak of details, in other words, $p(k_{detail})$ could not be easily computed. Instead a method for estimating $p(k_{detail})$ was presented to approximate the ideal upper threshold.

Firstly, those gray levels with no pixels are removed from the histogram. And then, the search range of $p(k_{detail})$ is narrowed down by finding out the local maximums of the histogram, since the background and the details are corresponding to peaks in histogram. $p(k_{background})$ (the histogram peak of the background) and $p(k_{detail})$ have good chance to be one of the local maximums. It can be illustrated by the following equation:

$$p(k_{detail}),\ p(k_{background}) \in \{POLAR(r)|1 \leqslant r \leqslant P\} \subseteq \{N(s)|1 \leqslant s \leqslant L\} \tag{2}$$

And $$p(k_{background}) = \{POLAR(r)|1 \leqslant r \leqslant P\}_{MAX} = \{N(s)|1 \leqslant s \leqslant L\}_{MAX} \tag{3}$$

where $POLAR$ is the set of local maximums and P is its size, $POLAR(r)$ is the rth element in $POLAR$; N is the histogram with zero statistics removed, and L is the number of elements in N. s indexes the element in the set as $N(s)$.Briefly, $N(s)$ is a discrete sequence and $POLAR(r)$ is the set of local maximums in $N(s)$. For discrete sequences, elements that are larger than their neighbors are taken as local maximums. Therefore a one-dimensional window with length n(n is an odd number) is used to find the local maximums of $N(s)$. Fig. 1 shows the one dimensional window W, W_n stands for the nth element in W.

When the elements fit the following equation,

$$W_{(n+1)/2} \geqslant max\{W_1, \ldots, W_{(n-1)/2} \quad W_{(n+3)/2}, \ldots, W_n\} \tag{4}$$

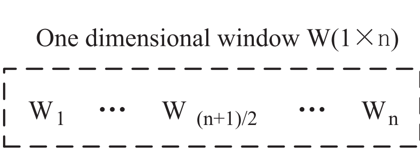


Fig. 1. Diagram of the 1 by n one dimensional window.

Then it can be concluded that $W_{(n+1)/2}$ is a local maximum, which can also be illustrated by the following equation,

$$W_{(n+1)/2} \in \{POLAR(r)|1 \leqslant r \leqslant P\} \tag{5}$$

According to the above method, local maximums are searched by sliding the one dimensional window along the discrete sequence $N_{(s)}$, the sliding process is illustrated in Fig. 2. By moving the window W step by step, each element in the middle of W is tested for whether or not it is a local maximum. In the end the local maximums set, $POLAR(r)$, can be generated.

The dashed box stands for the one dimensional window W, $N((n-1)/2)$, $N((n+1)/2)$, $N(k+(n-1)/2)$, $\ldots$, $N(L+(n-1)/2)$ from step 1 to step $L-(n-1)$ correspond to the middle element $W_{(n+1)/2}$ of the window, and any of them that makes Eq. (1) true will be put into the local maximum set $POLAR$.

In real-time infrared imaging, the details and targets are constantly changing in a random fashion, so their gray levels can be considered uniformly distributed in the histogram. Therefore, even though the exact position of $p(k_{detail})$ cannot be located, $p(k_{detail})$ can still be estimated by taking the average of the local maximums as show in Eq. (6).

$$p(k_{detail}) \approx POLAR_{avg} = \frac{POLAR(1) + \cdots + POLAR(r) + \cdots + POLAR(P)}{P} \tag{6}$$

This average value is then taken as upper threshold value:

$$T_{UP} = POLAR_{avg} \tag{7}$$

2.2. Analysis of the lower threshold

The lower threshold is used for protecting detailed information as well as small targets in infrared images. It determines the minimum gray interval so as to prevent atypical gray levels from being combined.

According to the principals of histogram equalization, reconstructed gray levels are determined by their proportions in accumulation histogram, as shown in Eq. (8) [17]

$$D(k) = \frac{M * F(k)}{F(M)} \tag{8}$$

where $F(k)$, $F(M)$ are the statistic accumulation value of gray level k and M, M is the total number of the original gray levels, $D(k)$ is the reconstructed gray level after double plateaus histogram equalization.

Then the gray interval between the adjacent gray levels after equalization, d, is

$$d = D(k) - D(k-1) = \frac{M * F(k)}{F(M)} - \frac{M * F(k-1)}{F(M)} = \frac{M * (F(k) - F(k-1))}{F(M)} = \frac{M * P(k)}{F(M)} \tag{9}$$

where the accumulation difference between gray level k and $k-1$ is also the statistic value for gray level k, which is $P(k)$. Since M is the total number of the original gray levels, $F(M)$ is summed up by all the statistic value for each gray level. Moreover, according the definition of lower threshold, the minimum statistic value is exactly the value of the lower threshold, T_{DOWN}. Therefore the minimum gray interval after double plateaus histogram equalization, d_{min} is

$$d_{\min} = \frac{M * T_{DOWN}}{Sta} \tag{10}$$

where Sta is the accumulative statistic of modified histogram, it is the sum of statistic of each individual gray level. In modified histo-

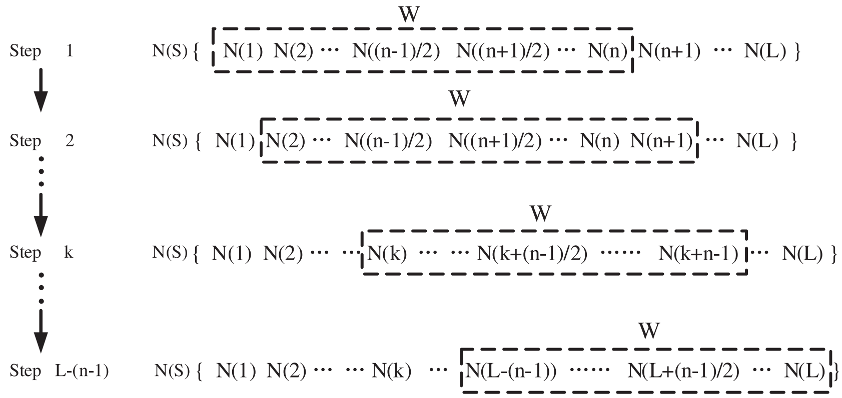


Fig. 2. the procedure of searching for local maximums.

gram, the minimum gray interval is 1. Therefore, d_{min} is set to 1 so that details are protected and properly enhanced.

$$d_{\min} = 1 = \frac{T_{DOWN}}{Sta} * M \tag{11}$$

Then we get the equation for computing the lower threshold:

$$T_{DOWN} = \frac{Sta}{M} \tag{12}$$

Since Sta is the accumulative statistic value of modified histogram, therefore it cannot be calculated before T_{DOWN} is determined. In order to calculate T_{DOWN}, Sta should be estimated in advance.

Firstly, it can be determined that Sta is smaller than the total pixel number of original image, N_{total}, as statistic of gray levels is limited by the upper threshold. Secondly, as T_{UP} stands for the maximum statistic of the modified histogram, when the total number of non-zero statistic is defined as L, then Sta must be less than $T_{UP} \times L$. Therefore the value of Sta could be estimated as the smaller one of the two values, N_{total} and $T_{UP} \times L$ and is shown as follows:

$$Sta \approx min\{N_{total},\ T_{UP} \times L\} \tag{13}$$

Therefore the equation to compute the lower threshold in Eq. (10) is modified to:

$$T_{DOWN} = \frac{min\{N_{total},\ T_{UP} \times L\}}{M} \tag{14}$$

2.3. Gray level reconstructing

After the two thresholds of double-plateau histogram equalization is computed and updated by the method mentioned above, histogram of original image is modified. Accumulative histogram is then obtained according to the modified histogram. Gray levels of the original image are reconstructed as follows:

$$F(k) = \sum_{j=0}^{k} P_m(j) \quad (0 \le k \le M) \tag{15}$$

$$D_m(k) = \left\lfloor \frac{M * F(k)}{F(M)} \right\rfloor \tag{16}$$

where $P_m(k)$ is the modified histogram after double-plateau histogram equalization, $D_m(k)$ is the reconstructed gray level of original gray level with value of k, and $\lfloor\rfloor$ rounds down a value to the nearest integer.

After the upper and lower thresholds are updated and the gray levels are remapped, infrared images can be adaptively enhanced by constraining the background noise while keeping and enhancing the details.

3. Experiment results and discussion

For better evaluating the proposed algorithm, performance of the proposed algorithm is compared with that of the traditional double-plateau histogram equalization. Experimental results are then fully analyzed.

Experiments are carried out for infrared images based on three different scenes: two outdoor scenes and one indoor scene. The performances are compared between the proposed algorithm and traditional double plateaus histogram equalization. In the experiments, the traditional algorithm chose 25% of the total image pixel number as its upper threshold and the lower threshold is taken as 7.5%; n is set as 5 for the one dimensional window in the proposed algorithm.

3.1. Experimental results

Enhanced images by the traditional algorithm and by the adaptive algorithm are shown in Fig. 3, the histograms and cumulative histograms of these images are also given. In Exp. 1, it can be observed that both of the two algorithms have effectively enhanced the contrast of the original infrared image; however, it can be seen that in the regions marked by the red rectangle, the details in Fig. 3a3 are better than those in Fig. 3a2. Moreover, the modified histogram in the proposed algorithm is more fully enlarged compared to that of traditional double plateaus histogram equalization with fixed threshold values. Overall, both of the two algorithms are efficient in contrast enhancement in Exp. 1, but the proposed algorithm can better enhance the image details.

In Exp. 2 and Exp. 3, it can be found out from the marked regions that traditional double plateaus histogram equalization did not effectively enhance contrast or image details; dynamic range of gray levels is not enlarged enough either. On the other hand, the cumulative histogram of enhanced image by the proposed algorithm is increasing much slower than the cumulative histogram of enhanced image by fixed double plateaus histogram equalization. This proved that the proposed algorithm enhanced the contrast and details, also it fully enlarged the dynamic range of gray levels of the original image.

The reason why traditional double plateaus histogram equalization will not function well in scenes as in Exp. 2 and Exp. 3 is that the upper and lower thresholds are fixed when the resolution of image is determined. The lower thresholds for traditional double plateaus histogram equalization are set too large in Exp. 2 and Exp. 3 so that the gray intervals were almost equal after equalization. Even though all the gray levels are protected by choosing large lower threshold, other typical gray levels get constrained as atypical gray levels are enhanced too much. The problem could

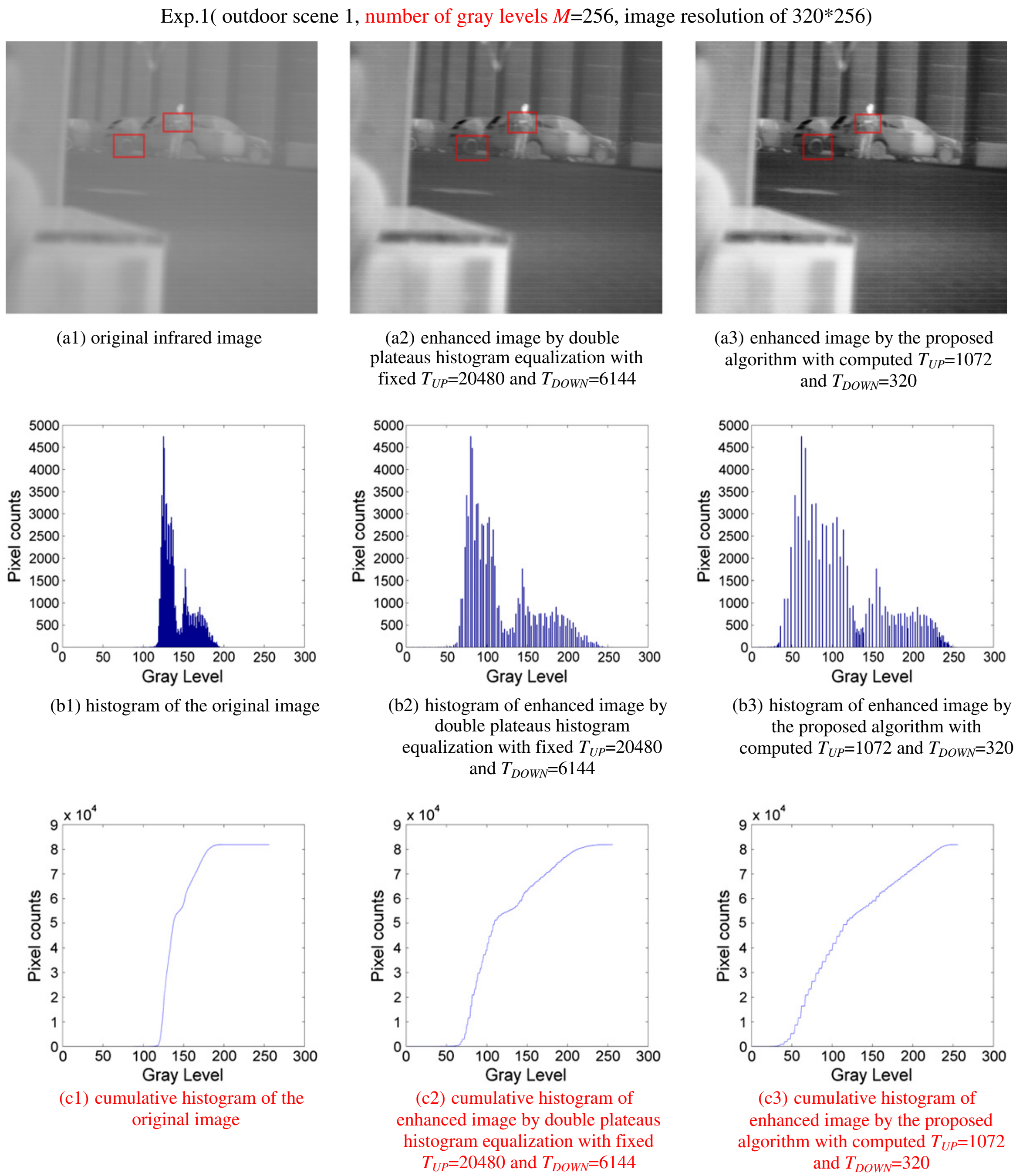


Fig. 3. Enhanced images and their histograms and cumulative histograms by the traditional algorithm and by the adaptive algorithm.

get even worse especially when there are too many atypical gray levels in infrared image.

For example, as shown in Fig. 3e2 of Exp. 2, there are totally 1359 pixels in red frames, which is 1.7% of the total pixels number; but they occupied 60.9% of the total gray levels. The rest 98.3% pixels were squeezed into 39.1% of the total gray levels, which means that most of the pixels are constrained. This did not happen in Exp. 1 because the original image does not have as many atypical gray levels as shown in Fig. 3b1.

3.2. Contrast improvement analysis

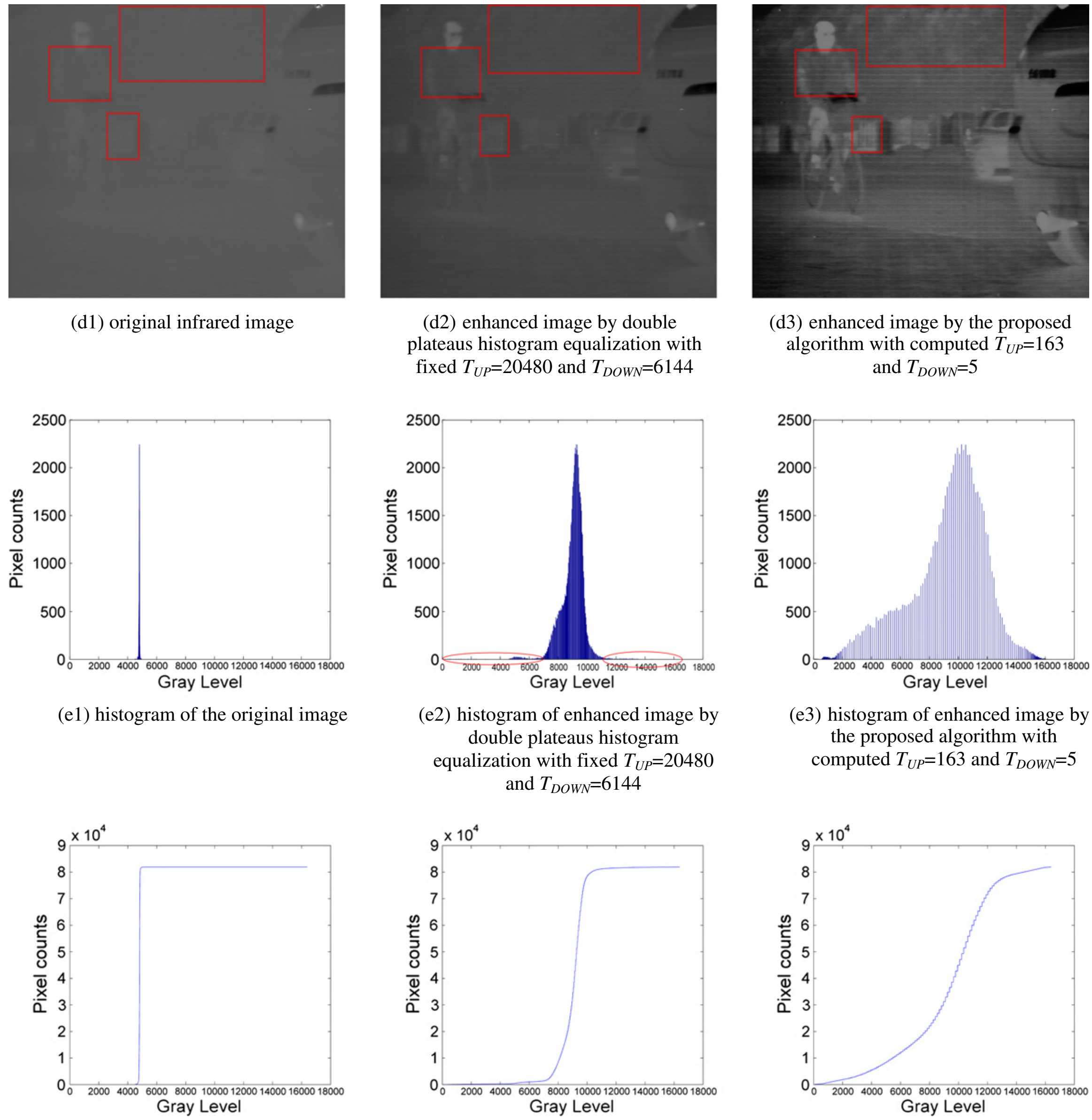
In order to further evaluate performance of the proposed algorithm, here the image contrast function [22], which calculates the deviation of gray levels, is chosen as our evaluation criteria. The following equation illustrates how the function works,

$$C_{contrast} = \frac{1}{PQ}\sum_{x=1}^{P}\sum_{y=1}^{Q} g^2(x,y) - \left|\frac{1}{PQ}\sum_{x=1}^{P}\sum_{y=1}^{Q} g(x,y)\right|^2 \quad (17)$$

where P is the width of the image and Q is the height of the image, $g(x, y)$ is the gray level of the pixel at (x, y). $C_{contrast}$ represents the deviation of gray levels. Higher value of $C_{contrast}$ implies larger dynamic range of gray levels and therefore better contrast and more detailed information of image.

P and Q are different in the three experiments, and the total number of gray levels is different as well. In order to compare the image contrast improvements in the three different

Exp.2(outdoor scene 2, number of gray levels M=16384, image resolution of 320*256)



(d1) original infrared image

(d2) enhanced image by double plateaus histogram equalization with fixed T_{UP}=20480 and T_{DOWN}=6144

(d3) enhanced image by the proposed algorithm with computed T_{UP}=163 and T_{DOWN}=5

(e1) histogram of the original image

(e2) histogram of enhanced image by double plateaus histogram equalization with fixed T_{UP}=20480 and T_{DOWN}=6144

(e3) histogram of enhanced image by the proposed algorithm with computed T_{UP}=163 and T_{DOWN}=5

(f1) cumulative histogram of the original image

(f2) cumulative histogram of enhanced image by double plateaus histogram equalization with fixed T_{UP}=20480 and T_{DOWN}=6144

(f3) cumulative histogram of enhanced image by the proposed algorithm with computed T_{UP}=163 and T_{DOWN}=5

Fig. 3 (*continued*)

experiments, the computed value of $C_{contrast}$ is taken logarithm as follow:

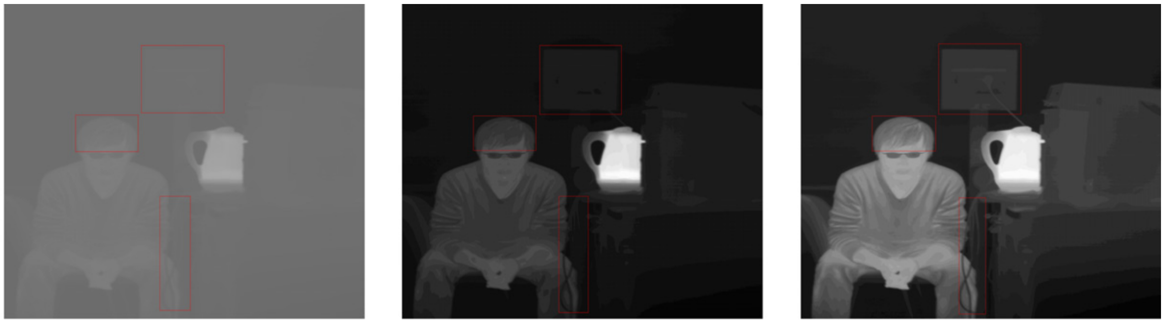
$$C^*_{contrast} = 10\log_{10}C_{contrast} \tag{18}$$

Contrast improvements are computed according to Eq. (17) and Eq. (18), their values are listed in the following Table 1.

It can be seen from the table that, in Exp. 1, the computed value of $C_{contrast}$ of enhanced image of the proposed algorithm is larger than that of enhanced image by double plateaus histogram equalization with fixed thresholds, and the difference is as large as 2.4213 dB; in Exp. 2 and Exp. 3, the difference is 9.9872 dB and 2.96 dB respectively. Overall, both of the two algorithms have greatly improved contrast of infrared images, while the proposed algorithm is more efficient. The proposed algorithm can fully remap gray levels so that new gray levels are uniformly distributed; contrast improvement is better with the proposed algorithm, so is the quality of enhanced images. Experimental results agree well with theoretical analysis of the proposed adaptive double plateaus histogram equalization algorithm.

It can be concluded from the experimental results and parameter analysis that the traditional double plateaus histogram equalization is not efficient for some kinds of infrared images, especially for those that contain many atypical gray levels. The proposed algorithm, however, can be utilized for enhancing various images as the thresholds are adaptively computed according to histogram of the image. In the proposed algorithm, upper and lower thresholds are unique for different images, the upper threshold properly constrains background noise while the lower

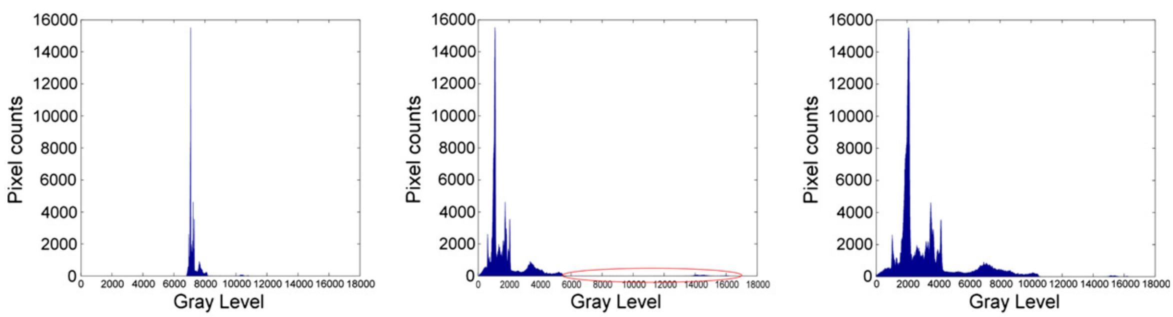
Exp.3(indoor scene, number of gray levels M=16384, image resolution of 1280*1024)



(g1) original infrared image

(g2) enhanced image by double plateaus histogram equalization with fixed T_{UP}=327684 and T_{DOWN}=98304

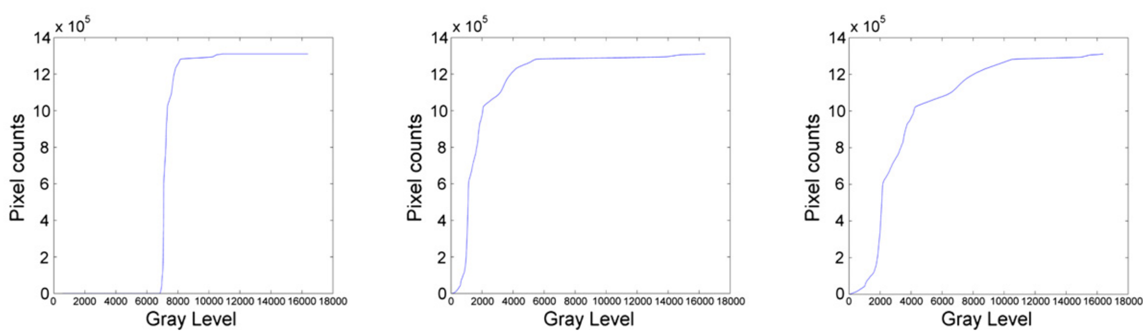
(g3) enhanced image by the proposed algorithm with computed T_{UP}=267 and T_{DOWN}=65



(h1) histogram of the original image

(h2) histogram of enhanced image by double plateaus histogram equalization with fixed T_{UP}=327684 and T_{DOWN}=98304

(h3) histogram of enhanced image by the proposed algorithm with computed T_{UP}=267 and T_{DOWN}=65



(i1) cumulative histogram of the original image

(i2) cumulative histogram of enhanced image by double plateaus histogram equalization with fixed T_{UP}=327684 and T_{DOWN}=98304

(i3) cumulative histogram of enhanced image by the proposed algorithm with computed T_{UP}=267 and T_{DOWN}=65

Fig. 3 (*continued*)

Table 1
Comparison of image contrast parameters.

	Original infrared image	Enhanced image by double plateaus histogram equalization with fixed thresholds	Enhanced image by the proposed algorithm
Exp. 1 $C^{*}_{contrast}$ (dB)	25.0695	32.5313	34.9526
Exp. 2 $C^{*}_{contrast}$ (dB)	32.9659	59.2587	69.2414
Exp. 3 $C^{*}_{contrast}$ (dB)	53.7222	65.8269	68.7869

threshold keeps and enhances detailed information in the image, and the overall quality of image is therefore magnificently enhanced.

4. Conclusion

In this paper a new adaptive contrast enhancement algorithm based on double plateaus histogram equalization is proposed and analyzed. By computing and updating upper and lower thresholds according to local maximums of non-zero histogram and the minimum gray interval, the proposed algorithm is efficient for enhancing infrared images in various scenes in real time. Based on experiments of image enhancement, the algorithm with two adaptive thresholds is proved capable of constraining background noise while enhancing image details. Compared with traditional double plateaus histogram equalization, the proposed algorithm can improve contrast enhancement by 2–10 dB.

Acknowledgements

The authors would like to thank National High Technology Research and Development Program of China (863 Program, Grant Nos. 2011AA7014047, 2011AA7044031) and Hubei Province Natural Science Foundation of China (Grant No. 2010CDB02702).

References

[1] Chih-Lung Lin, An approach to adaptive infrared image enhancement for long-range surveillance, Infrared Physics and Technology 54 (2) (2011) 84–91.
[2] Carlos Villaseñor-Mora, Francisco J. Sanchez-Marin, Maria E. Garay-Sevilla, Contrast enhancement of mid and far infrared images of subcutaneous veins, Infrared Physics and Technology 51 (3) (2008) 221–228.
[3] Rui Lai, Shangqian Liu, Bingjian Wang, Qing Li, A new adaptive enhancement algorithm for infrared image, Semiconductor Optoelectronics 27 (6) (2006) 767–769.
[4] Ching-Chung Yang, Image enhancement by adjusting the contrast of spatial frequencies, Optik International Journal for Light and Electron Optics 119 (3) (2008) 143–146.
[5] Xiangzhi Bai, Fugen Zhou, Bindang Xue, Infrared image enhancement through contrast enhancement by using multiscale new top-hat transform, Infrared Physics and Technology 54 (2) (2011) 61–69.
[6] Songfeng Yin, Liangcai Cao, Yongshun Ling, Guofan. Jin, One color contrast enhanced infrared and visible image fusion method, Infrared Physics and Technology 53 (2) (2010) 146–150.
[7] H. Gökhan İlk, Onur Jane, Özlem İlk, The effect of Laplacian filter in adaptive unsharp masking for infrared image enhancement, Infrared Physics and Technology 54 (5) (2011) 427–438.
[8] Jin-Hyung Kim, Jun-Hyung Kim, Seung-Won Jung, Chang-Kyun Noh, Sung-Jea Ko, Novel contrast enhancement scheme for infrared image using detail-preserving stretching, Optical Engineering 50 (7) (2011) 077002-1–077002-10.
[9] J.A. Stark, Adaptive image contrast enhancement using generalizations of histogram equalization, IEEE Transactions on Image Processing 9 (5) (2000) 889–896.
[10] S.S. Agaian, B. Silver, K.A. Panetta, Transform coefficient histogram-based image enhancement algorithms using contrast entropy, IEEE Transactions on Image Processing 16 (3) (2007) 741–758.
[11] Qian Chen, Lian-Fa Bai, Bao-Min Zhang, Histogram double equalization in infrared image, Journal of Infrared and Millimeter Waves 22 (6) (2003) 428–430.
[12] H. Ibrahim, N.S.P. Kong, Brightness preserving dynamic histogram equalization for image contrast enhancement, IEEE Transactions on Consumer Electronics 53 (4) (2007) 1752–1758.
[13] K.S. Sim, c.P. Tso, Y.Y. Ta, Recursive sub-image histogram equalization applied to gray scale images, Patter Recognition Letters 28 (10) (2007) 1209–1221.
[14] J. Silverman, Virgil E. Vickers, Display and Enhancement of Infrared Images, Rome Laboratory, New York, 1992. pp. 31–32.
[15] J. Silverman, Signal processing algorithms for display and enhancement of IR images, Proceeding of SPIE 2020 (1993) 440–445.
[16] Virgil E. Vickers, Plateau equalization algorithm for real-time display of high-quality infrared imagery, Optical Engineering 35 (7) (1996) 1921–1926.
[17] Bingjian Wang, Shangqian Liu, Huixin Zhou, Qing Li, Self-adaptive contrast enhancement algorithm for infrared images based on plateau histogram, Acta Photonica Sinica 2 (34) (2005) 299–301.
[18] Bing-Jian Wang, Shang-Qian Liu, Qing Li, Hui-Xin Zhou, A real-time contrast enhancement algorithm for infrared images based on plateau histogram, Infrared Physics and Technology 48 (1) (2006) 77–82.
[19] Rui Lai, Yintang Yang, Bingjian Wang, Huixin Zhou, A quantitative measure based infrared image enhancement algorithm using plateau histogram, Optics Communications 283 (21) (2010) 4283–4288.
[20] Chen Hee Ooi, N.S.P. Kong, H. Ibrahim, Bi, histogram equalization with a plateau limit for digital image enhancement, IEEE Transactions on Consumer Electronics 55 (4) (2009) 2072–2080.
[21] Song Yan-feng, Shao Xiao-peng, Xu Jun, New enhancement algorithm for infrared image based on double plateaus histogram, Infrared and Laser Engineeringi 37 (2) (2008) 308–311.
[22] Chang.-Jiang. Zhang, Fu. Meng-Yin, Mei. Jin, Qi-Hong Zhang, Approach to enhance contrast of infrared image based on wavelet transform, Journal of Infrared and Millimeter Waves 23 (2) (2004) 119–124.