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Contrast enhancement of infrared images using Adaptive Histogram Equalization (AHE) with Contrast Limited Adaptive Histogram Equalization (CLAHE)

Noor Kasim Faraj[1] and Loay Kadom Abood[2]

[1]Department of Physics, College of Science, University of Baghdad

[2]Al-Karkh University for Science, Baghdad, Iraq

E-mail: loayka@yahoo.com

Abstract

The objective of this paper is to improve the general quality of infrared images by proposes an algorithm relying upon strategy for infrared images (IR) enhancement. This algorithm was based on two methods: adaptive histogram equalization (AHE) and Contrast Limited Adaptive Histogram Equalization (CLAHE). The contribution of this paper is on how well contrast enhancement improvement procedures proposed for infrared images, and to propose a strategy that may be most appropriate for consolidation into commercial infrared imaging applications.

The database for this paper consists of night vision infrared images were taken by Zenmuse camera (FLIR Systems, Inc) attached on MATRIC100 drone in Karbala city. The experimental tests showed significant improvements.

Key words
Infrared images, contrast enhancement, histogram equalization, adaptive histogram equalization, contrast limited adaptive histogram equalization.

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تحسين التباين لصور الاشعة تحت الحمراء بأستخدام طريقة (AHE) مع (CLAHE)

نور قاسم فرج[1]، لؤي كاظم عبود[2]

[1]قسم الفيزياء، كلية العلوم، جامعة بغداد

[2]جامعة الكرخ للعلوم، بغداد، العراق

الخلاصة

ان الهدف من هذا البحث هو تحسين النوعية العامة لصور الأشعة تحت الحمراء عن طريق اقتراح خوارزمية تعتمد على ستراتيجية تحسين صور الأشعة تحت الحمراء. هذه الخوارزمية اعتمدت على طريقتين (AHE) مع (CLAHE) وقد يساعد هذا البحث في تحسين اجراءات التباين للصور الحرارية واقتراح استراتيجية قد تكون هي الانسب لتوحيدها في تطبيقات الاشعة تحت الحمراء.

ان البيانات المستخدمة في هذا البحث تتكون من صور حرارية ليلية وقد تم اخذ هذه الصور عن طريق استخدام كاميرا (ZENMUSE) من شركة (FLIR) مثبته على طائرة مسيرة من (MATRICE100) في مدينة كربلاء. وقد اظهرت النتائج التجريبية تحسينات كبيرة على صور الأشعة تحت الحمراء المستخدمة.

Introduction

The digital image processing can be defined as the set of techniques applied to digital images in order to improve quality of images generally and Infrared ones especially [1]. Infrared systems provide thermal information, which is invisible for human perception, as well as some limitations. This is because that thermal radiation from an object is affected from scattering due to the atmospheric conditions [2].

Infrared radiation (IR), sometimes referred to infrared, is a region of the electromagnetic radiation spectrum that wavelengths range from about 700 nanometers (nm) to 1 (mm) [3, 4]. (IR) images are typically degraded due to noise, low contrast (since IR image sensors cannot clearly distinguish objects from their backgrounds if they have a similar emissivity) and blur (due to the inhomogeneous photosensitive response of the infrared detector and non- ideal optics system) [5].

Infrared light is invisible to the human eye, even though longer infrared waves can be sensed as heat. Warm objects emit infrared energy and the hotter the object, the shorter the wavelength of IR energy emitted. This IR emission enables rescue workers equipped with long-wave IR sensors to locate a lost person in a deep forest in total darkness.

These wavelengths include most of the thermal radiation emitted by objects near room temperature. Images received through various infrared (IR) devices in many applications are distorted due to the atmospheric aberration mainly because of atmospheric variations and aerosol turbulence [6, 7].

In this paper the zenmuse XT thermal camera will be used with quadcopter MATRICE 100. Type As with other DJI systems, a 3-axis gimbal systems, the zenmuse XT stream alive HD view to DJI GO software.

Contrast enhancement

The main standard aims of contrast enhancement of infrared (IR) images are:

1- To make them very effective in an application.

2- Provide more appealing image, with easier differentiation of objects.

Contrast operator is one of the factors of low or perfect quality images. Because of an image cannot be said to be of good quality when it has very low contrast or too high contrast [8]. Contrast image enhancement techniques divided into three different categories [9]: Global enhancement, Local enhancement and Adaptive Enhancement.

Histogram equalization (HE) is a widely used global contrast enhancement technique for color and grayscale images together. The histogram equalization (HE) is a method to obtain a unique input to the output contrast transfer function. HE spreads out and flattens the histogram of the number of image pixels at each gray level value [10].

The main idea in adaptive histogram equalization (AHE) is to take into account histogram distribution over the local window and combine it with global histogram distribution.

The proposed technique

The proposed algorithm combines these two methods (AHE&CLAHE) and applied it on an images and compare these results with default algorithm.

The first step is dividing the image into several non over lapping regions of approximately equal sizes. The second step is calculating the histogram of each region. Then, based on the desired limit, obtain a clip limit for clipping histograms for contrast expansion. Next, redistributed each histogram in such a way that its height does not go beyond the clip limit.

The clip limit β is obtained by: [11, 12]

$$\beta = \frac{MN}{L}\left(1+\frac{\alpha}{100}(s_{max}-1\right) \quad (1)$$

where α is a clip factor, if clip factor is equal to zero the clip limit becomes exactly equal to (MNL), furthermore if clip limit is equal to 100 the maximum allowable slope is $Smax$. Finally, determined the cumulative distribution functions (CDF) of the resultant contrast limited histograms for grayscale mapping. The pixels are mapped by linearly combining the results from the mappings of the four nearest regions.

The proposed algorithm which combines the two methods (AHE) & (CLAHE) can be summarized as the following steps:

Step1: read the image.

Step2: convert image to grayscale.

Step3: enter a matrix of image size.

Step4: define the variable that will use to display the histogram image.

Step5: calculate the histogram of the image in the range [0, L-1] by using the discrete function: $p(r_k) = \frac{n_k}{n}$

Step6: plot the histogram distribution curve.

Step7: calculate the cumulative density function for the histogram that given by:

$$cdf_x(i) = \sum_{j=0}^{i} p(x_i)$$

Step8: calculate the histogram equalization using the new distribution relation:

$$s_k = (L-1)\sum_{j=0}^{x_k} p_r\left(r_j\right)$$

where S_k is the new distribution of the histogram. p_r (r_k) is related of the probability of occurrence of intensity level r_j in an image.

Step9: show the result of histogram equalization image.

Step10: normalize the image of histogram equalization

Step11: calculate the new distribution of the image histogram.

Step12: divide the image to three regions according to specification of every region that different from another region.

Step13: calculate the slop of every region.

Step14: calculate the clip limit by using the equation:

$\beta = \frac{MN}{L}\,(1+\frac{\alpha}{100}\,(s_{max}-1)$ where α is a clip factor that different from region to another, and can be determined according to the characteristic for each region.

Step15: Clip the histogram above the clip limit and use it to find CDF.

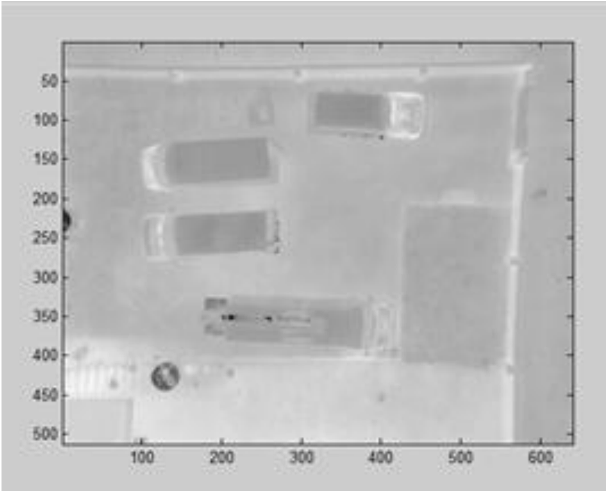
Step16: Now map this intensity into the output image with range [min max].

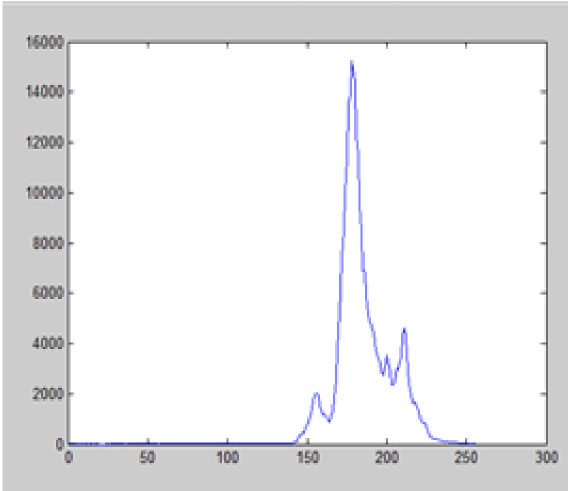
Step17: calculate the AHE for the image using MATLAB function and make comparing between this result and the result from our algorithm.

The experimental results and discussion

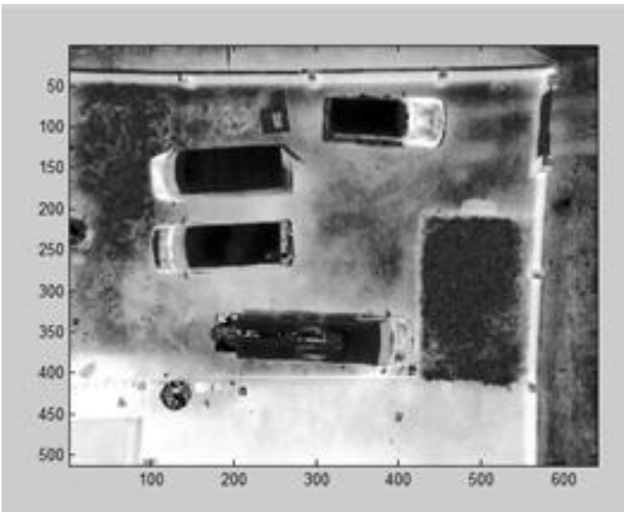
Areal images (vertical and horizontal thermal images) have been used in this research. These images have been taken from different heights. Some images were in size of (512x640) and the other of size (480x720), in addition to a different amount of noise. Different enhancement techniques were used in order to determine which method is the best for thermal image.

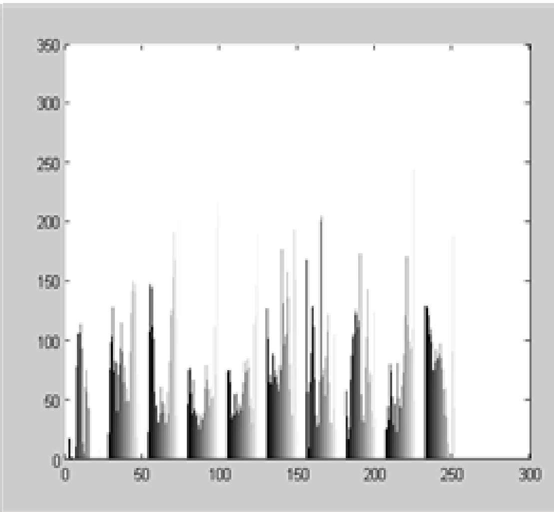
This algorithm was applied to all vertical and horizontal images. The results of this algorithm can be shown in Figs.1-4.





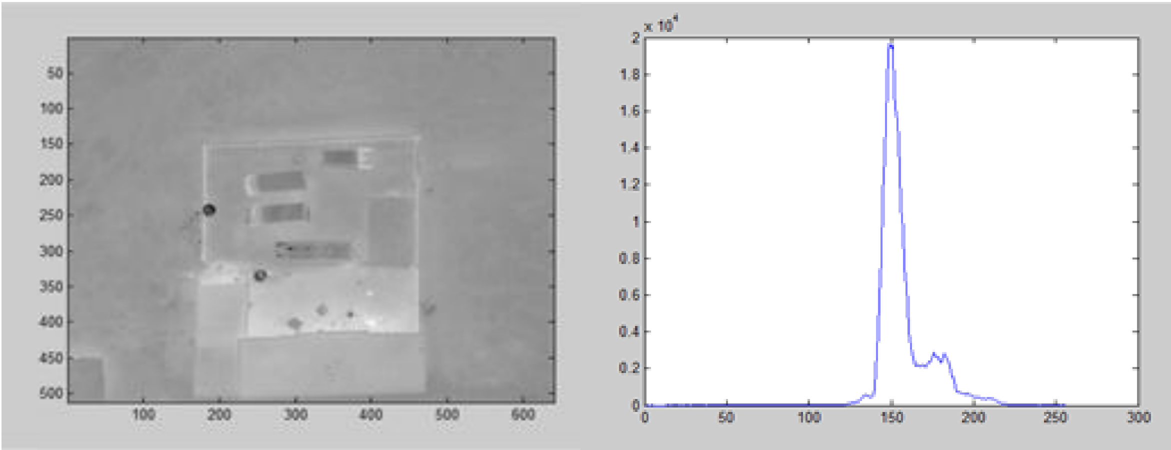
(a) Original image at a height (b) Histogram of of 50 meters



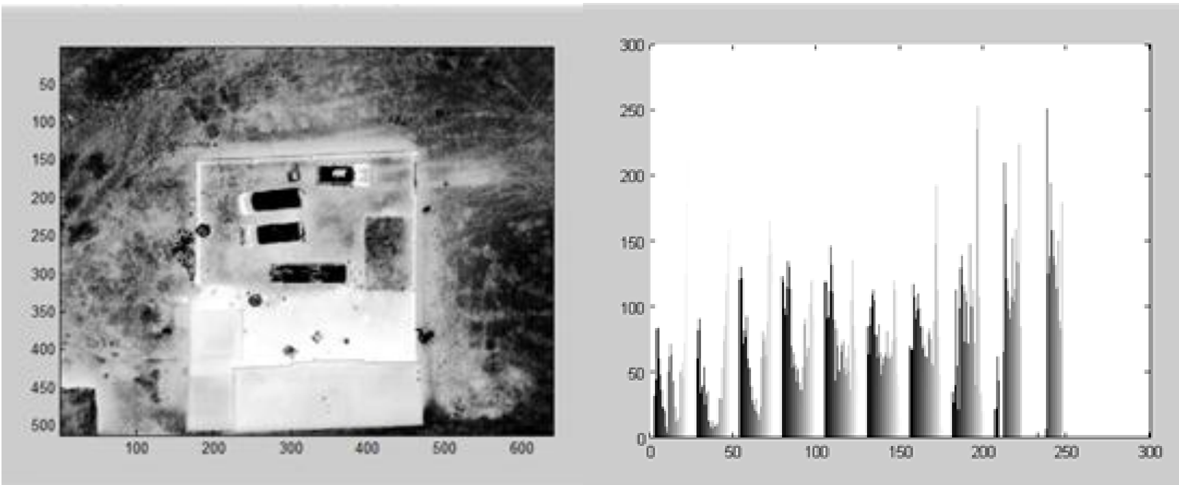


(c) The proposed (AHE&CLAHE) (d) Histogram of (d)

Fig. 1: (AHE & CLAHE) for image at a height 50 meters.

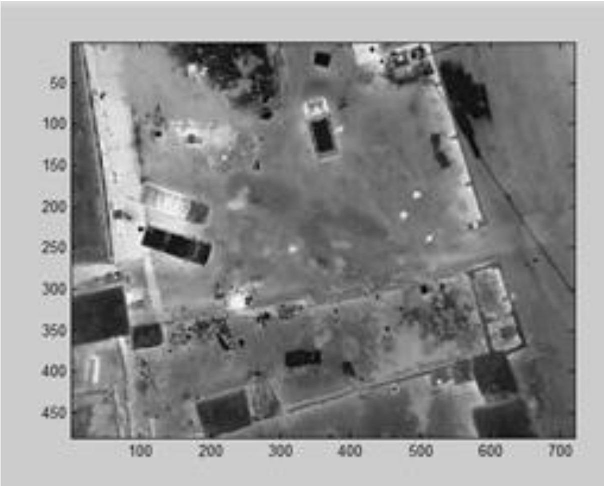


(a) Original image at a height of 100 meters (b) Histogram of (a)

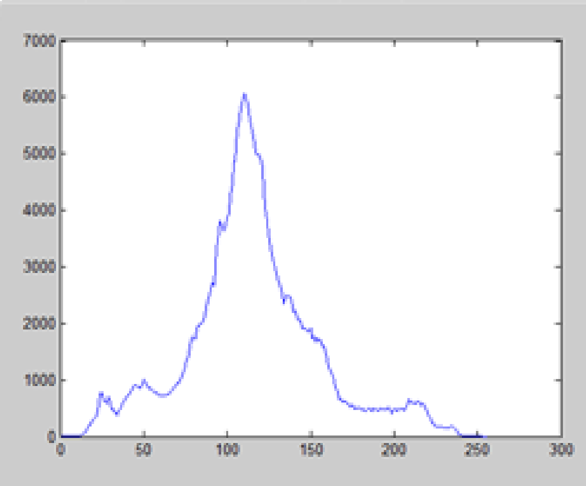


(d)The proposed (AHE&CLAHE) (c) Histogram of (d)

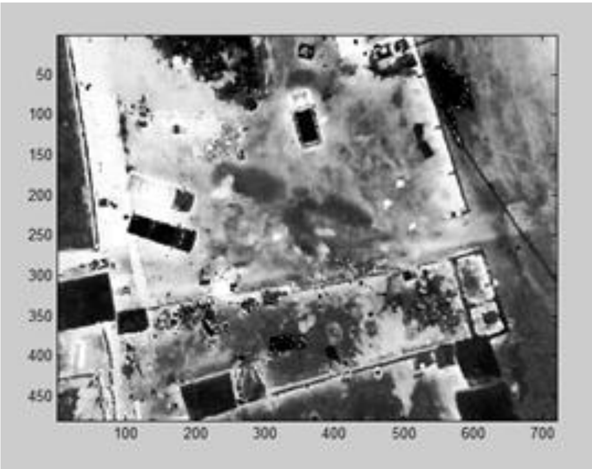
Fig. 2: (AHE & CLAHE) for image at a height 100 meters.



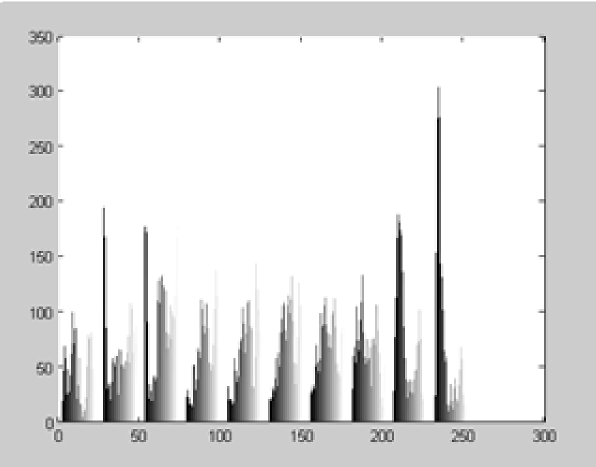
(a) Original image at a height of 200 meters



(b) Histogram of (a)

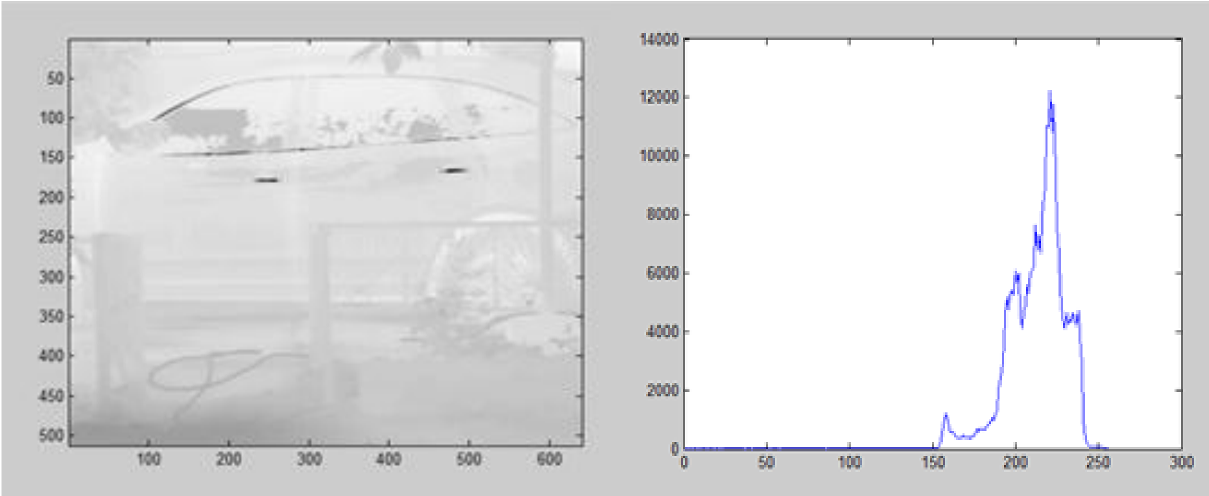


(c) The proposed (AHE&CLAHE)

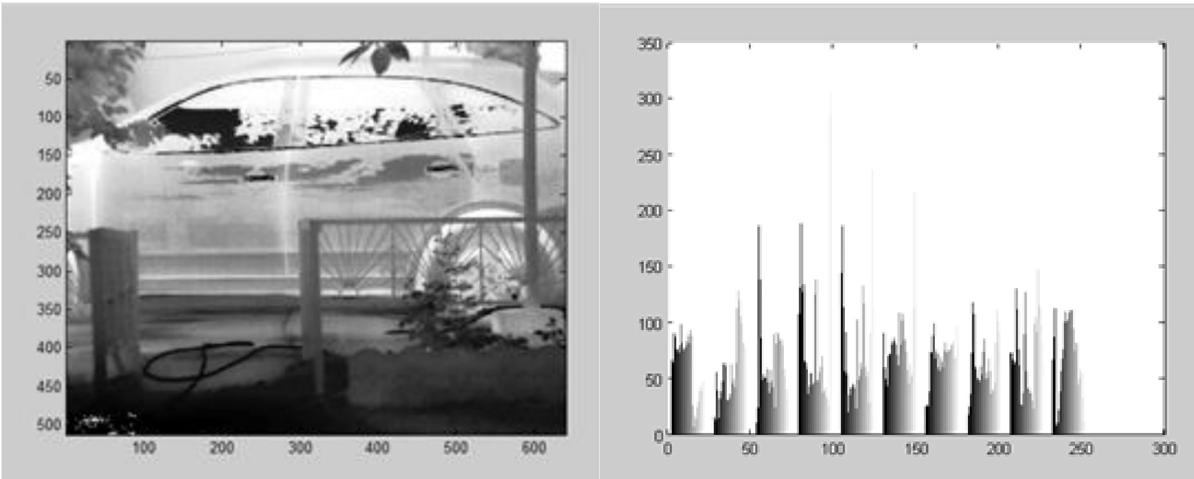


(d) Histogram of (d)

Fig. 3: (AHE & CLAHE)) for image at a height 200 meters.



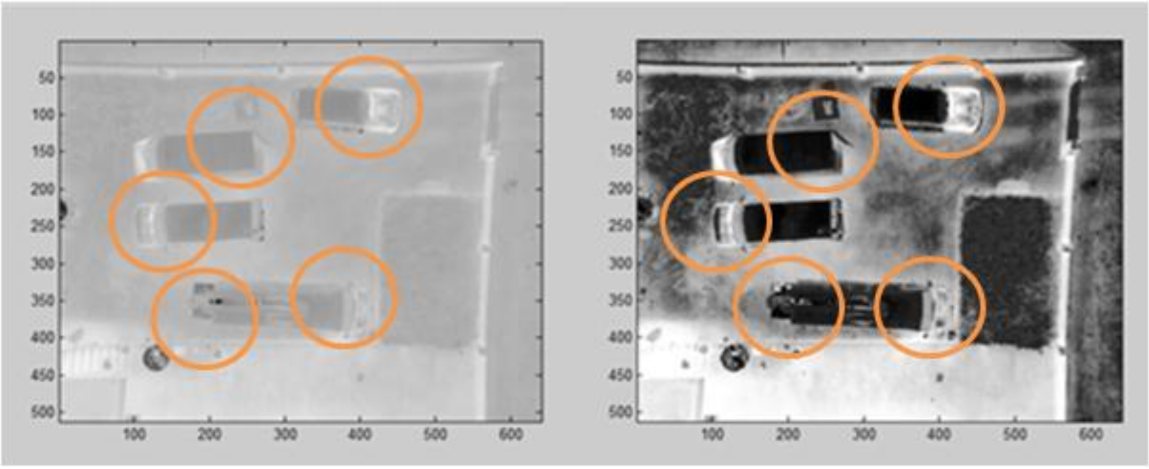
(a)Original horizontal image 20 meters away (b) Histogram of (a)



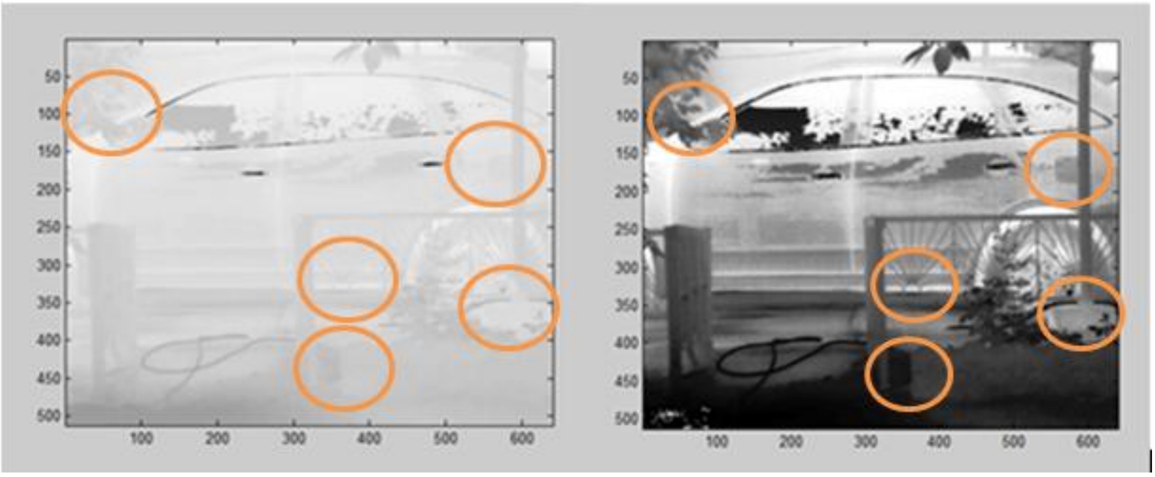
(d) The proposed (AHE&CLAHE) (c) Histogram of (d)

Fig. 4: AHE&CLAHE of image 20 meters away.

By making comparison between the original image and the result of the proposed algorithm we were found the differences were very clear to eyes as we as shown in Fig.5 for example of two vertical images and one horizontal image:



(a) Original image (b) Enhanced image



(c) Original image (d) Enhanced image

Fig.5: Comparing the results.

Conclusions

It is obvious when applying the proposed algorithm on the vertical and horizontal thermal images, there is a clearly changes in the images comparing with the original images in intensity distribution and as well as the histogram of the image was changed too and became more uniform, the edges became more sharpening.

The image that doesn't have too many variations in the levels of gray image was showed that AHE has not good results. To overcome this problem, the noise is suppressing by contrast limited enhancement and the result images is better. One important thing that AHE has the disadvantage that AHE enhances not only the image, but also it enhances the noise of the image, while this method enhances the image and suppresses the noise.

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