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Single Scale Retinex (SSR) and Multi Scale Retinex (MSR) Enhancement Algorithms for Thermal Night-Vision Images

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Abstract

Infrared technology advancements have led to an expansive set of infrared applications in both the private and public sectors. The b[lfdssx improvement procedures proposed for visible spectrum images specialty infrared pictures, and to propose a strategy that may be most appropriate for consolidation into commercial infrared imaging applications.The improvement of the general quality of aerial infrared images by proposes algorithms discussed briefly.

These algorithms were based on Single Scale Retinex SSR and Multi Scale Retinex MSR with histogram equalization HE. The database were used itconsists of night vision infrared images taken using a by Zenmuse camera (FLIR Systems, Inc) fixed on MATRIC100 drone in Karbala city.

Keywords: Infrared images, Thermal images, Contrast Enhancement, Grayscale, Single Scale Retinex, Multi Scale Retinex, Histogram equalization

خوارزميات مقياس ريتنكس المفرد (SSR) و مقياس ريتانكس المتعدد (MSR) لتحسين الصور الحرارية الليلية

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الخلاصة

ان تكنولوجيا تحسين الأشعة تحت الحمراء تقود الى مجموعة واسعة من التطبيقات في القطاعين العام والخاص . ان فائدة هذا البحث هو معرفة الأجراءات المقترحة لتحسين التباين للصور وبالأخص صور الأشعة تحت الحمراء ، واقتراح ستراتيجية قد تكون هي الأنسب لتوحيدها في التطبيقات التجارية لصور الأشعة تحت الحمراء . ان تحسين الجودة العامة للصور الجوية الحرارية عن طريق اقتراح خوارزميات تمت مناقشتها بشكل مختصر .

تعتمد هذه الخوارزميات على طريقتين هي : مقياس ريتنكس المفرد (SSR) ومقياس ريتانكس المتعدد (MSR) بالأعتماد على مخطط التسوية (HE) . البيانات المستخدمة في هذا البحث تتكون من مجموعة من الصور الحرارية الليلية العمودية والأفقية المأخوذة بأستخدام كاميرا نوع (ZENMUSE) من شركة (FLIR) مثبتة على طائرة مسيرة نوع (MATRICE 100) في مدينة كربلاء .

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Introduction

Thermal image interpretation is greatly influenced by the properties of an observed object and surrounding scenery. Obviously not only objective factors play important role in perceiving the image but also subjective, human-specific perception of visual information [1]. Thermal images are typically distinct from images registered in the visual spectral domain. For instance, the visibility of targets near the horizon may be significantly reduced due to a large difference in radiance between ground and sky or sea (horizon effect), while image variations over large areas with a homogeneous temperature distribution often represent noise. In addition, small and warm objects (such as engines or living beings) typically appear with excessive contrast and may be saturated [2].

Image Enhancement

The principal objective of enhancement is to process an image so that the result is very suitable for a special process. Image Enhancement can be divided into two categories [3]:

1. Spatial domain methods: The expression spatial domain refers to the image plane itself, and based on straight manipulation of pixels in an image. In this procedure, the operation takes place directly on the pixels of the image which in turn leads to contrast enhancement.
2. Frequency domain methods: In this method, the estimate of functions is performed with regard to frequency in the frequency domain method for the purpose of raising the quality of the image. It works using Fourier transform, discrete cosine and sine transform of the image as an example.

Contrast enhancement

The main standard aim of contrast enhancement of infrared (IR) images is to make them very effective in an application, provide the more appealing image, with easier differentiation of objects and improved clarity of object characteristics and surface details [4]. Commonly used contrast image enhancement techniques divided into three different categories [5], Global enhancement, Local enhancement and Adaptive Enhancement.

Image Histogram is a type of histogram that acts as a graphical representation of an image. Histogram is a plot of the distribution of intensities or gray levels in an image? The histogram of a digital image with gray levels in the range [0, L-1] can be represented by the discrete function:

$$p(r_k) = \frac{n_k}{n} \quad \ldots\ldots(1)$$

where r_k is the kth gray level, n_k is the number of pixels in the image with that gray level, n is the total number of pixels in the mage, and k = 0, 1, 2, …L-1.

Histogram Equalization

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, thus stretching the intensity values in the image over more of the available dynamic range of gray-levels and raising the apparent contrast in the image [6].

Let be consider a discrete grayscale image and n_i be the number of occurrences of gray level i. A normalized histogram of the image shows the probability of occurrence of a pixel of level i in the image, and would be given by a collection of probability values for each pixel level:

p (xi) = probability that pixel x has gray level i = ni / n

Where n = the total number of pixels in the image. The cumulative density function for this histogram would be given by:

$$cdf_x(i) = \sum_{j=0}^{i} p(x_i) \quad \ldots\ldots(2)$$

The Retinex algorithm

The idea of Retinex was proposed as a model of lightness and color perception of the human vision. The basic idea of Retinex algorithm is to separate illumination from the reflectance in a given image. Different algorithms have been developed to implement the Retinex model and concept:

Single-scale Retinex (SSR), Multiscale Retinex (MSR) and Multiscale Retinex with Color Restoration (MSRCR) have evolved since the idea of Retinex was first proposed [7-9].

This method calculates image contrast and evaluates image quality depending on computing a member of the class of center-surround functions where each output value of the function is determined by the corresponding input value (center) and its neighborhood (surround). For the Retinex the center is defined as each pixel value and the surround is a Gaussian function [7].

Algorithm can eliminate the foreground and background illuminance influence of the image and can have a high dynamic range indoor/outdoor scene. Let an image $F(i, j)$, the equation is given by:

$F(i, j) = R(i, j) I(i, j)$ ……………..……………………………………………………..(3)

Where $F(i, j)$ is obtained by observation or sensor reception, denotes the reflection component image, and $R(i, j) I(i, j)$ stands for the illuminance component image.
As shown in eq.4, two-dimensional Gaussian convolution function
$G(i, j)$ could estimate the illuminance component image $I(i, j)$ from the known image $F(i, j)$ and given by:

$$G(i,j) = \frac{1}{2\pi\sigma^2} e^{\frac{-i^2+j^2}{2\sigma^2}} \quad \text{……………………(4)}$$

Where σ is the standard deviation in Gaussian function.The image enhancement effect is by the standard deviation directly, that controls how many fine details are left. σ Is selected to satisfy the equation:

$$\iint G(i,j)didj = 1 \quad \text{……………(5)}$$

Single Scale Retinex

The Single Scale Retinex output is given by

$$log\,R(i,j) = log\,F(i,j) - log[G(i,j) \otimes F(i,j)] \quad \text{……………(6)}$$

here $F(i, j)$ is the Retinex input image, $I(i, j)$ is the illuminance component image, ⊗ is the Two-Dimensional Gaussian function stands for the convolution operation, denotes the coordinates of the pixels. [10], this method can eliminate the foreground and background luminance influence of the image, and have a high dynamic range indoor/outdoor scene This technique is the modification of the brightness to improve its brightness.

Multi Scale Retinex(MSR)

Because of the trade-off between dynamic range compression and color rendition, the choice of the right scale σ for the surround filter F(x, y) is crucial in Single Scale Retinex in eq.6.
Multiscale Retinex (MSR) seems to afford an acceptable trade-off between a good local dynamic range and a good color rendition. The MSR output is defined as a weighted sum of the outputs of several SSRs. The multiscale retinex formula:

$$R_{MSR_i} = \sum_{n=1}^{N} w_n R_{n_i} \sum_{n=1}^{N} w_n \left[log I_i(x,y) - \log\left(F_n(x,y) * I_i(x,y)\right)\right) \ldots \quad \text{(7)}$$

where N is the number of scales, w_n is the weight of each scale and

$$F_n(x;y) = C_n \exp\left[-\frac{(x^2+y^2)}{2\sigma_n^2}\right] \quad \text{……………(8)}$$

The flow chart of the Retinex algorithm is shown as in Figure-1.The source image is decomposed into two different images, i.e., the luminance component image and the reflection component image.

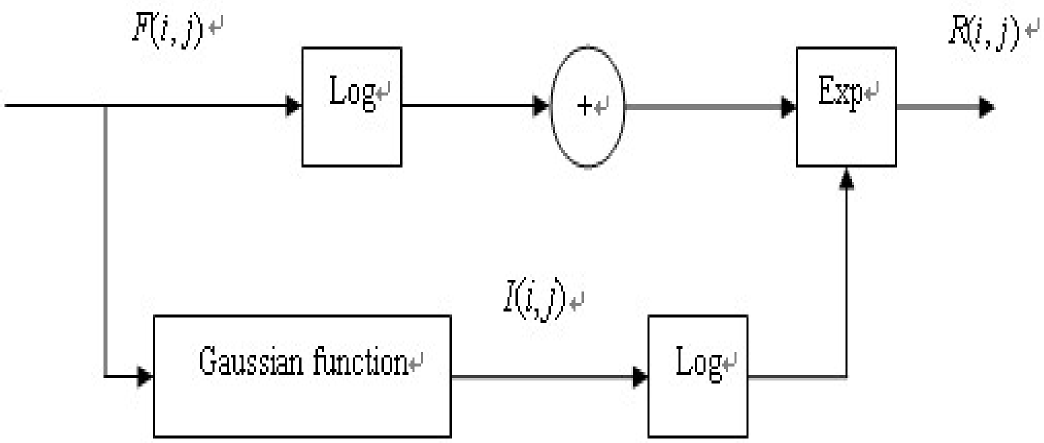


Figure 1- The flow chart of the Retinex algorithm [11].

The proposed techniques can be summarized as:

1- Single Scale Retinex

Retinex is based on the following image formulation model**:**

$s(x,y) = L(x,y)\times R(x,y)$…………………………………………………………………...…..(9)

Where the function S(x,y) represents an input image, every point (x,y) in the domain is equivalent a pixel on the image. The image S(x,y) is consist of two images: the illumination L(x,y) and reflectance R(x,y) images, then we can separate R(x,y) from L(x,y) in order to generate Retinex effect, the problem is known to be ill-posed mathematically. There have been many attempts to numerically estimate the illumination image. By using Matlab7.11. , Single Scale Retinex algorithm on vertical images

And the algorithm we proposed is:

Algorithm: Single Scale Retinex

Input: night thermal images vertical & horizontal

Output: enhanced image

Algorithm:

Step1: read the image

Step2: convert image to grayscale

Step3: enter a matrix of image size

Step4: define the variable we 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 by 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: generate a Gaussian convolution function G(i, j) by estimate the illuminance component image I (i, j) from the known image F(i, j) and given by: $G(i,j) = \frac{1}{2\pi\sigma^2} e^{\frac{-i^2+j^2}{2\sigma^2}}$ where σ is the standard deviation in Gaussian

Step11: apply Fourier transform for Gaussian image according to image dimensions

Step12: multiplying the resultant of the two previous steps

Step13: apply Fourier transform for the original image

Step14: calculate the invert factor for the resultant of the previous step

Step15: calculate the Single Scale Retinex by applying the equation:

$$\log R(i,j) = \log F(i,j) - \log[G(i,j)\otimes F(i,j)]$$

Where F(i, j) is the Retinex input image

Step16: multiplying the resulting image from the retinex method by the original image

Step17: show the result from the previous step

Step18: subtract the original image from the retinex image result

Step19: comparing the two previous results to know what result is the best

Step20: normalize the best image result and plot the histogram distribution for it to compare it with the original histogram

2- Multi Scale Retinex with HE

Multiscale Retinex (MSR) seems to afford an acceptable trade-off between a good local dynamic range and a good color rendition. The MSR produce is simply the weighted sum of several SSR's with various scales. The choice of scales is application dependent, but that for most applications at least three scales are required, and that equal weighting is usually enough.

Our algorithm of MSR with histogram equalization was applied on the vertical and horizontal images.The algorithm we proposed by using this method is:

Algorithm: Multi Scale Retinex with HE
Input: night thermal images vertical & horizontal
Output: enhanced image
Algorithm:
Step1: read the image
Step2: convert image to grayscale
Step3: enter a matrix of image size
Step4: define the variable we 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 by 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
Step8: show the result of histogram equalization image
Step9: generate a Gaussian convolution function G(i, j) by estimate the illuminance component image I (i, j) from the known image F(i, j) and given by: $G(i,j) = \frac{1}{2\pi\sigma^2} e^{\frac{-i^2+j^2}{2\sigma^2}}$ where σ is the standard deviation in Gaussian
Step10: apply Fourier transform for Gaussian image according to image dimensions
Step11: multiplying the resultant of the two previous steps
Step12: apply Fourier transform for the original image
Step13: calculate the invert factor for the resultant of the previous step
Step14: change the number of scales N as N = 4
Step15: calculate the Multi Scale Retinex by applying the equation:

$$R_{MSR_i} = \sum_{n=1}^{N} w_n R_{n_i} \sum_{n=1}^{N} w_n\ [\log I_i(x,y) - \log\big(F_n(x,y) * I_i(x,y)\big)$$

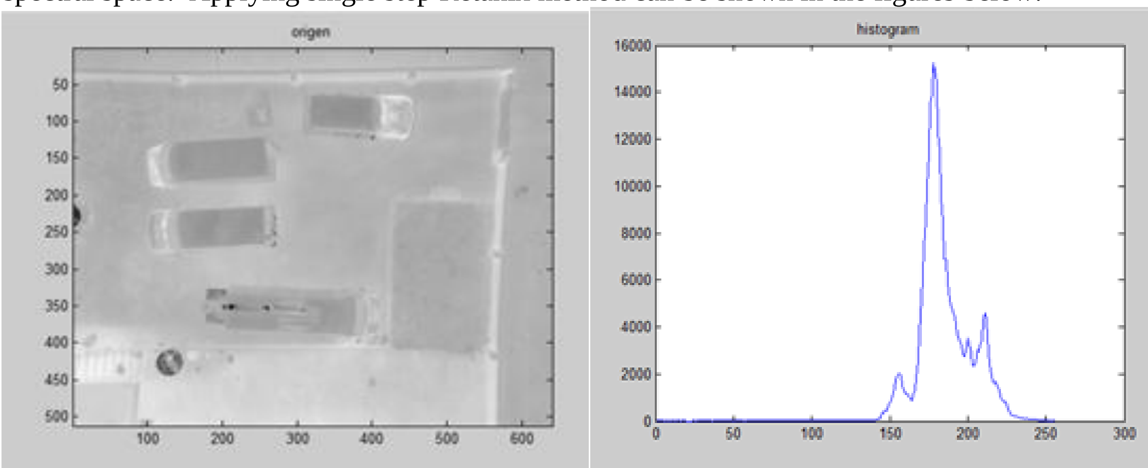
where N is the number of scales
Step16: subtract the original image from the retinex image result
Step17: show the result from the previous step
Step18: subtract the histogram equalization image from the retinex image result to prove that there is a difference between these two methods
Step19: normalize the retinex image result and plot the histogram distribution for it to compare it with the original histogram

Results and Discussion

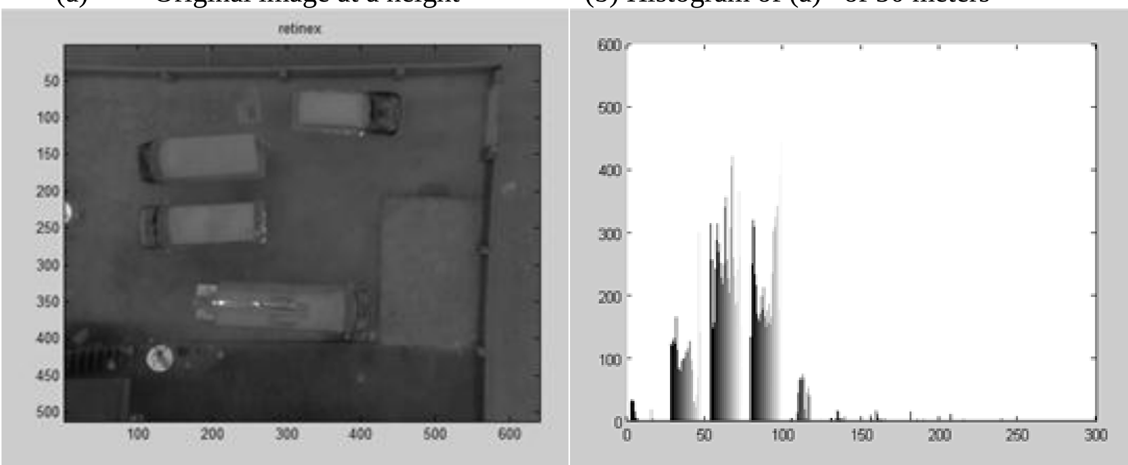
Areal images (vertical thermal images) have been used in this research. These images have been taken from different heights. Different enhancement techniques were used in order to determine which method is the best for thermal image. In this section, the Retanix algorithm has been implemented using Single Scale Retinex algorithm on vertical images to test the capabilities of this new payload, a flight was planned over Karbla city near Karblaa Thermston factory Figure-2.

Figure 2-Karblaa Thermston Factory Google map.

The proposed algorithm based on single scale Retinex method to enhance the difference of coloring or intensity distribution of an image. Retinex generates multiple Gauss distribution that made blur for the image. After that subtracting this image from the original image may generate changes until reaching to the best value utilizing convolution process, i.e Retanix method can be, achieve in spatial or spectral space. Applying single step Retanix method can be shown in the figures below:

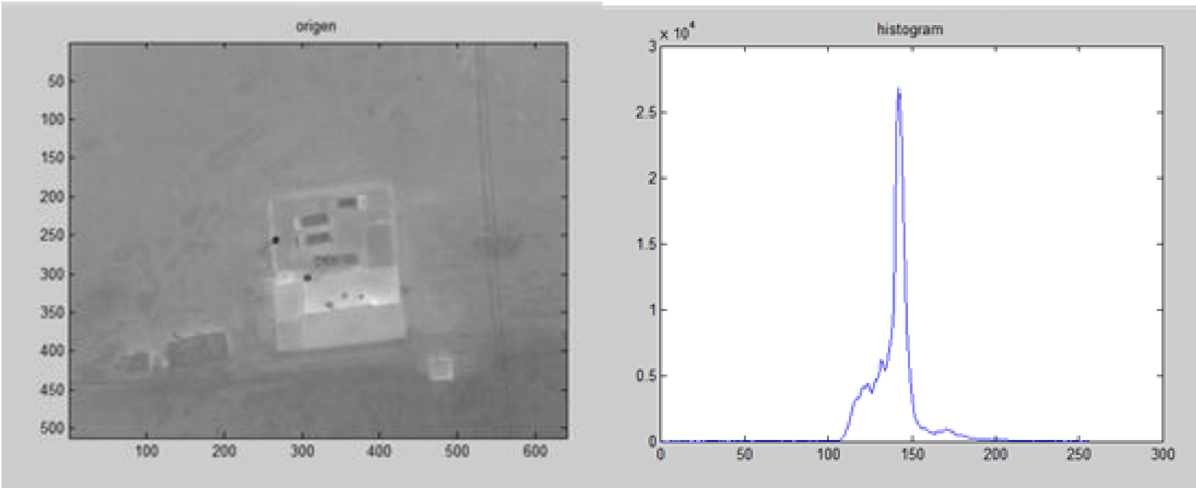


(a) Original image at a height (b) Histogram of (a) of 50 meters

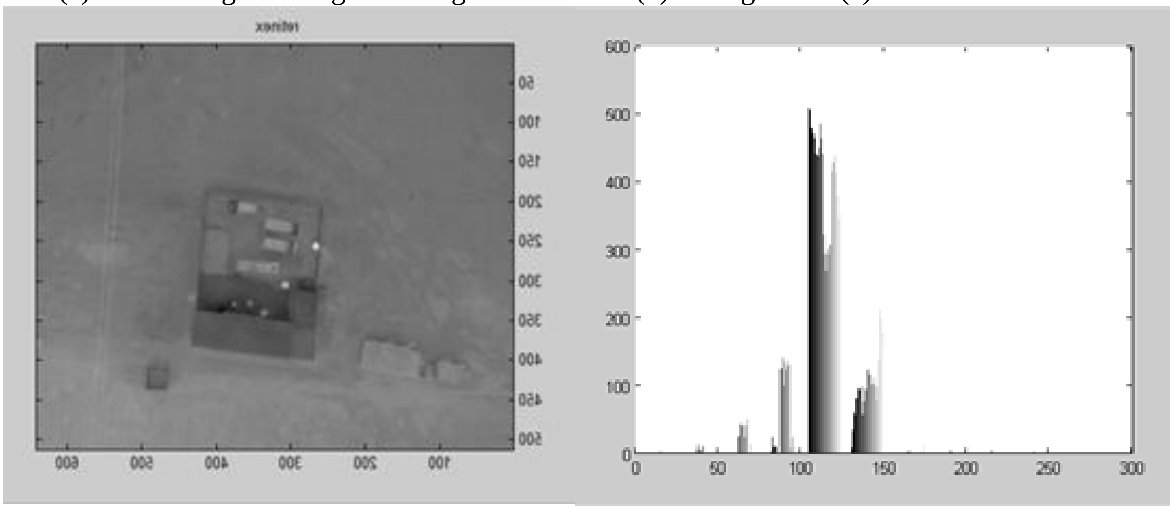


(c)SSR (d) Histogram of (c)

Figure 3-Single Scale Retinx of image at a height 50 meters



(a) Original image at a height (b) Histogram of (a) of 150 meters

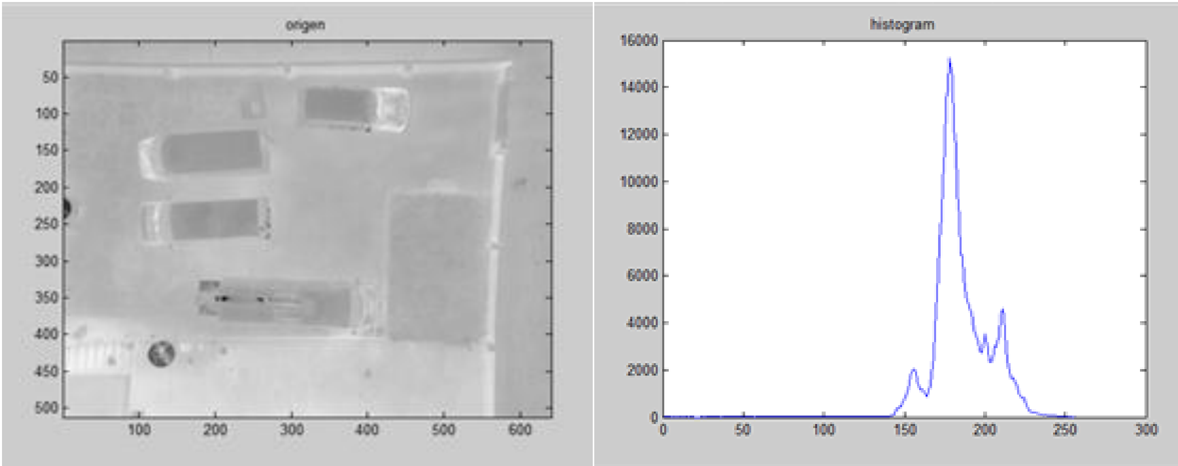


(c)SSR (d) Histogram of (c)

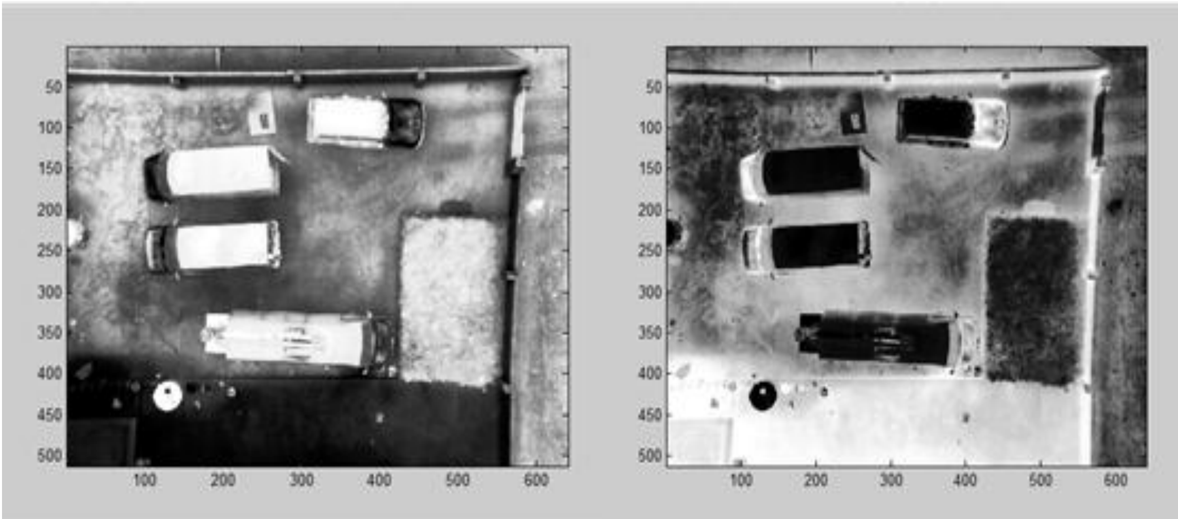
Figure 4- Single Scale Retinx of image at a height 150 meters.

Multi Scale Retinex (MSR) with Histogram Equalization (HE)

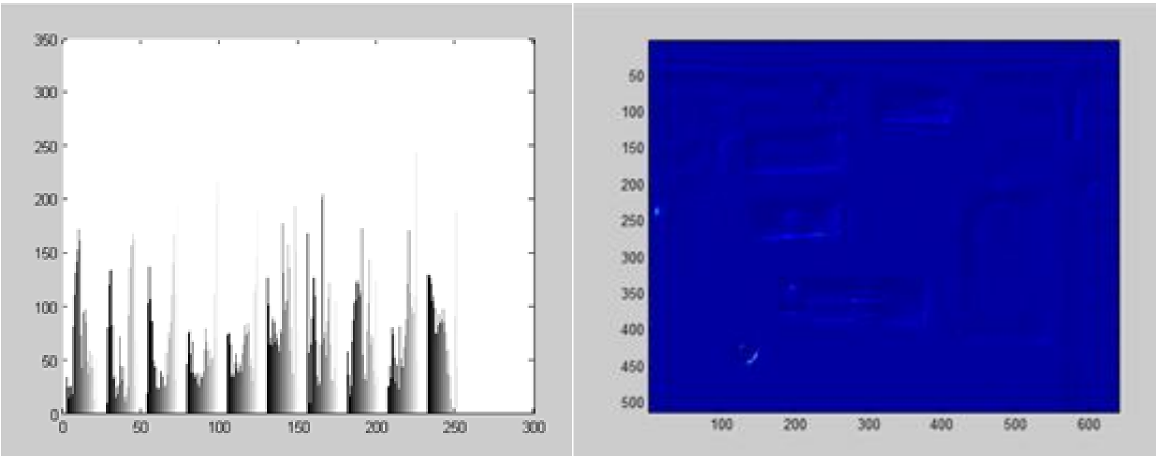
The MSR output represents by the sum of several SSR's with various scales. When single scale Retanix repeated with different scale represent MSR. In this case, the scale was changed to a limited extent. Here the scale k=4 was used, this is enough to obtain good results. The choice of scales is application dependent. Our algorithm of MSR with histogram equalization was applied on the vertical images; the results of this proposed method was good as shown in the figures below:



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

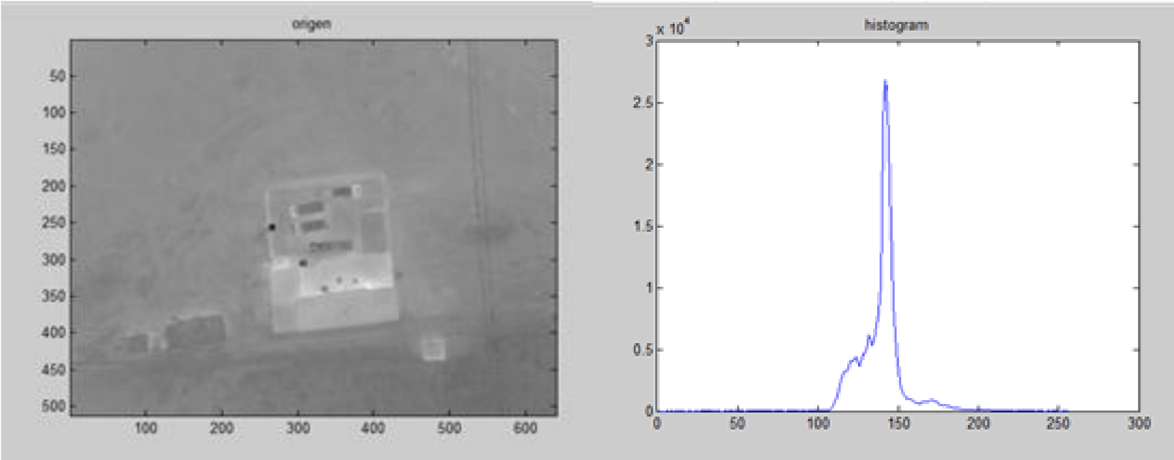


(c), MSR (d) MSR

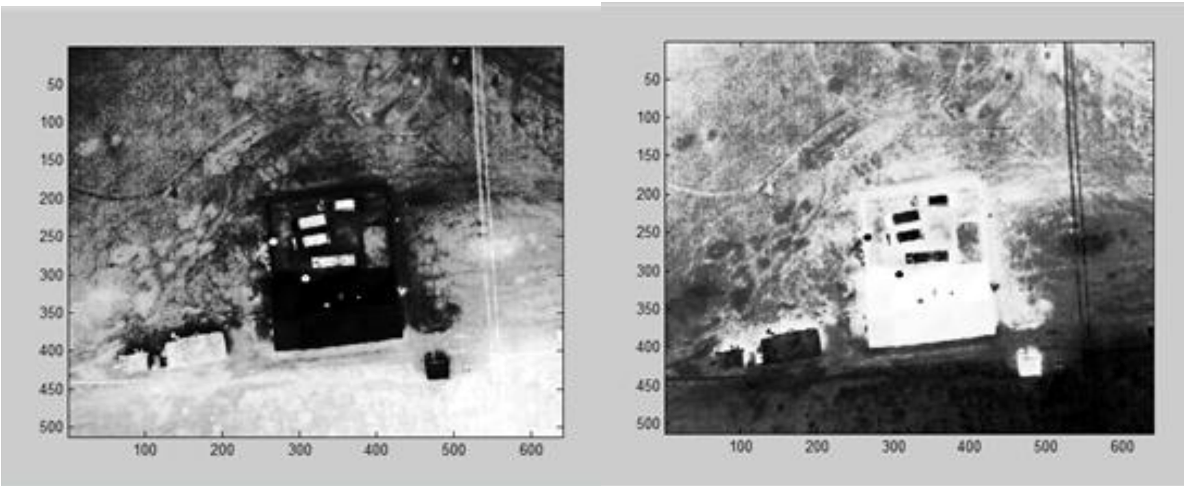


(e) Histogram of (d) (f) the difference between MSR & normal histogram

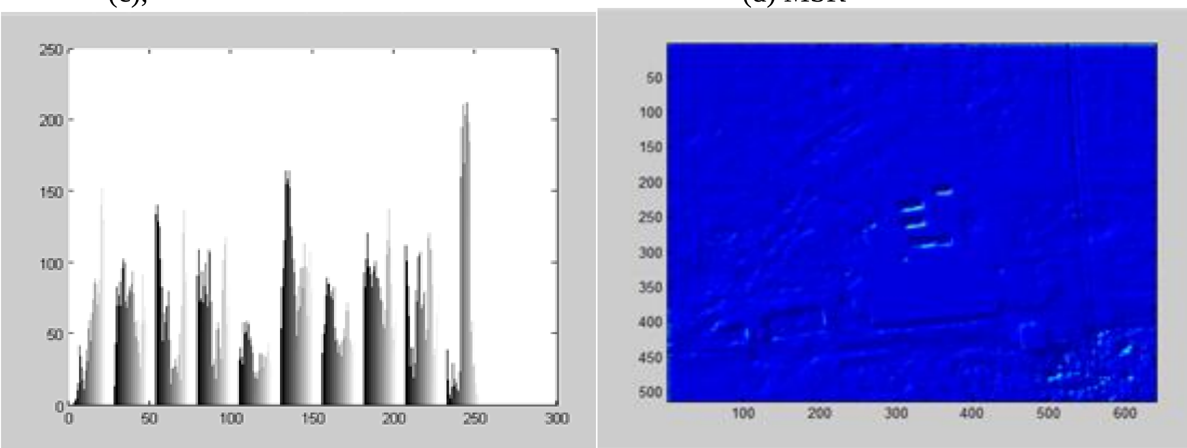
Figure 5-Multi Scale Retinex with HE at a height of 50 meters.



(a) Original image at a height (b) Histogram of 150 meters



(c), (d) MSR



(e) Histogram of (d) (f) The difference between MSR & normal histogram

Figure 6- Multi Scale Retinex with HE at a height of 150 meters.

Conclusions

The main conclusions that can be obtained from this work can be given:

1- By using single scale retinex, the results were so good in contrast and edges, more features start to appear in the image, moreover When multiple scale retinex used, extra features were appeared making the image clearer and better. And using (MSR) increase the contrast and more details appeared, as it can be seen in the images. So this algorithm proved its effectiveness in all used thermal images and it is very affected to enhance this type of images. The experimental results have demonstrated that this proposed algorithm is more adaptive and effective for contrast enhancement compared to the classic enhancement methods, it emphasizes local details in the image while limiting the noise, and it appeared nearly all needed details to recognize the persons and the features. 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.

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