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Evaluate Retinex Enhancement Method for Captured Images at Different Camera Aperture Using Minimum Distance Classifier

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Abstract

In this paper, have been studying the effects of changing camera aperture diameter on image quality, after that had been classified the captured images through using Minimum Distance Classification method, after that evaluating the statistical properties of the original images and analyzing the results. Next step is enhancing the original images, and using Multi Scale Retinex algorithm, and then classify the enhanced images and analyze the effects of classification for the enhanced images through evaluating its statistical properties. We concluded that there was a noticeable improvement in the results, comparing between the classified original images with the classified enhanced images, the original image had bad color appearance, after enhancement it become quite easy to distinguish between different image's classes, there was kind of consistency in the average values of each color band. The language used in this research is MATLAB language (ver. 2008).

تقييم طريقة تحسين الصور Retinex للصور الملتقطة باقطار فتحة كاميرة مختلفة باستخدام تقنية اقصر مسافة

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الخلاصة

الجوانب الرئيسية التي تم التركيز عليها في هذا البحث هي: دراسة تأثير تغير قطر فتحة الكاميرا على جودة الصورة، ثم تم بعد ذلك تصنيف الصور الملتقطة من خلال استخدام طريقة تصنيف المسافة الدنيا، ثم حساب الخصائص الإحصائية للصور الأصلية و تحليل نتائجها. بعد ذلك تم تحسين الصور الأصلية باستخدام خوارزمية Retinex متعددة النطاقات ، ثم قمنا بتصنيف هذه الصور المحسنة و تحليل النتائج من خلال تقييم الخصائص الإحصائية للصور المصنفة. وجدنا بأن هناك تحسنا ملحوظا في النتائج عند مقارنة الصور الأصلية المصنفة مع الصور المحسنة المصنفة، حيث أن الصور الأصلية كانت فاقدة للسمة اللونية، بعد التحسين أصبح من السهولة التمييز بين الأصناف المختلفة للصورة، حيث وجدنا ثبات في قيم معدل كل واحدة من الحزم اللونية. اللغة البرمجية المستخدمة في هذا البحث هي لغة MATLAB اصدارية 2008.

Introduction

Image enhancement processes consist of a collection techniques that seek to enhance the visual appearance of an image or to mutate convert the image to a form better suited for analysis by a human or machine [1]. Image enhancement is applied in every field where images are ought to be understood and analyzed [2]. The principle objective of image enhancement techniques is to process an image so that the result is more suitable than the original image for a specific application [1].

During this process, one or more attributes of the image are modified. The choice of attributes and the method they are modified are specific to a given task [2].There are many studies of Image enhancement that based on improve the contrast, and brightness will be given with brief description as following:
B. V. Funt et.al. (1997): introduced investigations into Multi-Scale Retinex algorithm approach to image enhancement to explain the effect of the processing from a theoretical standpoint [3]. In the same year they modified the multi-scale retinex approach to image enhancement so that the processing is more justified from a theoretical standpoint by suggested a new algorithm with fewer arbitrary parameters that is more flexible [4]. Zia-ur Rahman et.al. (1997):- were studied the performance of the multiscale retinex with color restoration (MSRCR) through compression with color adjustment methods such as gamma correction and gain/offset application, histogram modification techniques, and other more powerful techniques such as homomorphic filtering. The comparison is carried out by testing the suite of image enhancement methods on a set of diverse images. Though some of these techniques work well for some of these images, in this paper they found that only the MSRCR performed universally well on the test set [5]. Osmun Nuri and Capt Ender (2007): proposed an algorithm to enhance night senses and under no uniform lighting conditions, either the low intensity areas or the high intensity areas cannot be clearly seen depending on non linear transform [6]. Hanumantharaju M.C. et.al. (2011):- introduced a new technique for color image enhancement using multiscale retinex with modified color restoration. The basic steps of multiscale retinex algorithm have been analyzed, modified and various operations are performed in an orderly manner. The result show that the proposed method based on color restoration technique is an efficient and computationally inexpensive and this method not only provides true color fidelity for poor quality images but also averages the color components to gray value for balancing colors [7]. In this paper we focused on three aspects: first the affect of changing camera aperture diameter on image quality, second enhance the image using modified retinex algorithm, and finally using the minimum distance classification to evaluate the power of enhancement process.

Retinex Enhancement Method

Image enhancement is basically improving the interpretability or perception of information in images for human viewers and providing better input for other automated image processing techniques [8]. One of the most important quality factors in digital images comes from its contrast. Contrast enhancement is frequently referred to as one of the most important issues in image processing, and Contrast can be defined as the ratio of the maximum intensity to the minimum intensity over an image [9].

Numerous enhancement methods have been proposed but the enhancement efficiency, computational requirements, noise amplification, user intervention, and application suitability are the common factors to be considered when choosing from these different methods for specific image processing application .one of the widely used enhancement methods is Retinex method

Retinex is an image enhancement method that is used to improve the contrast, brightness and sharpness of an image mainly through dynamic range compression. Concurrently this method provides color constant output and therefore it removes the effects caused by different illuminants on a scene. It combines contrast enhancement and color constancy by performing a non-linear spatial/spectral transform [10].

The Retinex is a number of the class of center surround functions where each input value of the function is determined by the corresponding input value (center) and its neighborhood (surround) [11]. The input to the Retinex algorithm is an array of photoreceptor responses for each pixel in the image, this input represent as a three separate arrays of data one for each receptor class. Each of these spatial arrays contains the receptor class for each pixel in the image [12].

The algorithm estimates the spatial array of the lightness values for a single receptor class by computing a series of paths. Each path is computed as follows:

- Select a starting pixel (x_1).
- Randomly select a neighboring pixel (x_2).
- Calculate the difference of the logarithms of the sensor responses at the two positions.
- The value obtained by the pervious step is added to accumulator register for position of (pixel x_2) such that [12]:

$$A(x_2) = A(x_2) + \log(x_2) - \log(x_1) \quad \ldots\ldots\ldots\ (1)$$

Where: $A(x_2)$ accumulator registers for pixel (x_2).

- Counter Register $N(x_2)$ for position x2 is incremented to indicate that the path has crossed this position. At the start of computation all registers and counters are set to zero.

The path calculation proceeds iteratively with the random selection of a neighbor of pixel x_2. In general, the accumulation of position (x_i) on this path is updated by [12]:

$$A(x_i) = A(x_i) + \log(x_1) \quad \ldots\ldots\ldots\ldots (2)$$

And the corresponding counter register $N(x_i)$ is incremented. Note that the first element of the path plays a special role in the accumulation for that path calculation.

The Retinex is a number of the class of center surround functions where each input value of the function is determined by the corresponding input value (center) and its neighborhood (surround) [11]. For the Retinex the center is defined as each pixel value and the surround is a Gaussian function. The mathematical form of a Retinex is given by [12]:

$$R(x,y) = \text{Log}[I(x,y)] - \text{Log}[I(x,y) * F(x,y)] \quad \ldots. (3)$$

Where: I: is the input image and R: is the Retinex output image and F is the Gaussian filter (surround or kernel) defined by:

$$f(x,y) = k\, e^{\frac{-(x^2+y^2)}{2\sigma^2}} \quad \ldots\ldots\ldots\ldots(4)$$

Where: σ is the standard deviation of the filter and controls the amount of spatial detail that is retained, and k is a normalization factor that keeps the area under the Gaussian curve.

The Minimum Distance Classification

Image classification is a segmentation method that aggregates image pixels into a finite number of classes by certain rules so that each class represents a distinct entity with specific properties [13]. In general, it can be viewed as a label assignment by which image pixels sharing similar properties will be assigned to the same class. The minimum distance technique is a supervised method, which calculates the mean vectors for each class and calculates the Euclidian distance from each unknown pixel to the mean vector for each class. Then all pixels are classified to the nearest class unless a threshold is specified [14]. This technique is highly recommended in all image classification applications [15]. The advantage of this technique is that it not only is a mathematically simple and computationally efficient technique, but also provides better accuracy than others classification methods, in the case when the number of training samples is limited[16].

Statistical Digital Image Properties

There are several image properties can be calculated from image data, the most imported properties (mean μ, standard deviation σ, and single to noise ratio SNR) of the image or image regions [17].

The Mean (μ)

Image mean brightness is known as the mean brightness for the image elements (or sub image) and it determined from the following relationship [18]:

$$\mu = \frac{1}{MN}\sum_{X=1}^{M}\sum_{Y=1}^{N} I(X,Y) \quad \ldots\ldots\ldots\ldots (5)$$

Where M and N denotes the high and the width of the image (or sub image), the multiplication of them equals the number of image elements.

Standard Deviation (STD)

The standard deviation represents the mean of variations of the element values with respect to its mean and it determined from the following relationship [19]:

$$\sigma = \frac{1}{MN}\sqrt{\sum_{X=1}^{M}\sum_{Y=1}^{N}(I(x,y)-\mu)^2} \quad \ldots\ldots\ldots (6)$$

Single - to- Noise Ratio (SNR)

Single-to-Noise Ratio is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. The ratio of mean to standard deviation of a signal or measurement [20]:

$$SNR = \frac{\mu}{\sigma} \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Experimental Design

Following Figure 1 represent the System block diagram. It is shown that system architecture is consists of two steps: first is to classify the input image, second is to enhance the input image using Retinex method, and then classify it.

Figure (2) shows lighting system, which consists of two light source (one from the right another from the left). All images in this study are captured by (Canon 8 Mp Camera), the lens's diameter equals to (D=23.3 mm), these captured images are of the (JPEG) format. On the other side is placed the object to be captured. The object is three balloons with different colors (red, green and blue) and white background, the distance between the camera and the object equals to (1 meter). In this paper it have been studied the effect of changing the diameter of the camera's lens on the image contrast and lightness, through studying the statistic properties of the image (the mean, the standard deviation, and SNR). The changes of the lens diameter were vary from ΔD= -2 mm to ΔD = +2 mm.

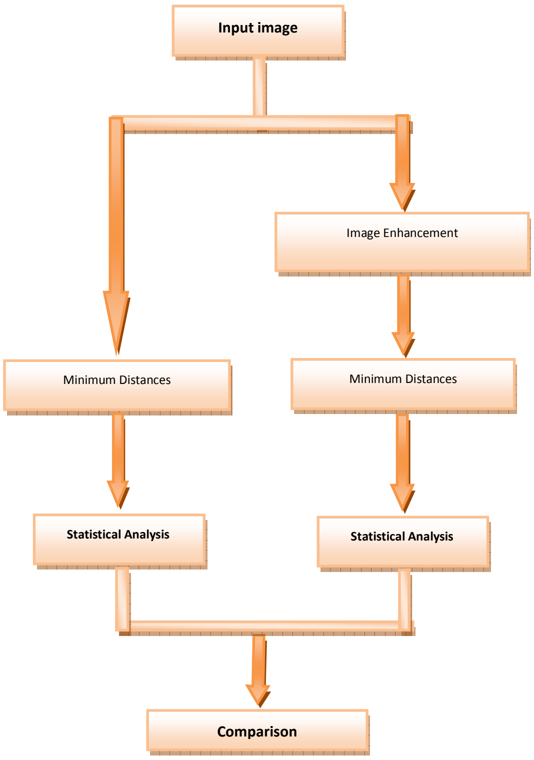

Figure 1- Block Diagram

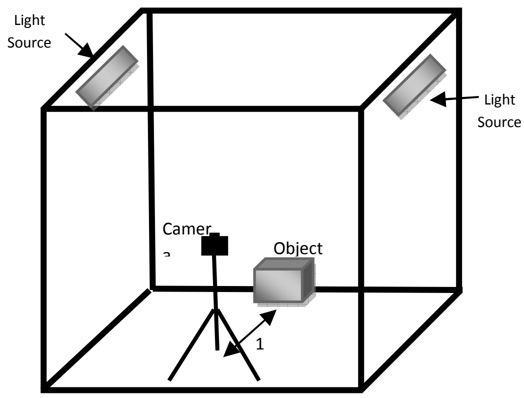

Figure 2- The Lighting

After capturing the images of the three balloons with different lens diameter, we extract 4 blocks from each target (red, green blue and white); the size of each block is equal to 20×20 pixels, so we could verify the effects of changing aperture diameter on the images. Next we used Minimum Distance Classification method to categorize each target and find out to which class it's belong. Then in order to analyze the effects of classification on original images it have been computing its statistic properties (the mean and SNR). This step was done through applying Minimum Distance and Evaluations of μ, σ, SNR Algorithm on the original images.

Algorithm (1): Minimum Distance and Evaluations μ, σ, SNR Algorithm:

Input: The input of the algorithm is the color image Img (x, y), where the values of Img are between 0 and 255, of size M×N.

Output: The outputs are the mean μ, σ, and SNR the standard deviation for each class (used 4 classes in this study).

Step 1: Extract 4 blocks from the input image; the size of each block is equal to 20×20 pixels.

Step2: Categorize each block and find out to which class it's belong using Minimum Distance Classification method as follow:

Mim = | Img(x,y) – V(k) |, where Img(x,y) represent the value of image in (x,y) position and V(k) represent the value of the block's mean k, and k value is from 1 to 4.

Step 3: calculate μ, σ, and SNR as follow: -

count = 20×20=400 (compute number of count in each extracted block)

sum = sum+Img (i,j)

μ = sum / count

$$\sigma = \sqrt{(\mathrm{Im}\,g(x,y)-\mu)\text{^}2\,/\,count}$$

$$SNR = \frac{\mu}{\sigma}$$

Step 4: end.

The next step is to enhance the original images, using Multi Scale Retinex method.

Algorithm (2): Multi Scale Retinex Algorithm

Input: The input of the algorithm is the color image $I_i(x,y)$, i= r,g,b.

Output: The output is enhanced image $I_{pi}(x,y)$.

Step 1: Calculated Gaussian surrounds function

$$F(x,y,c_n) = (k)\exp\left(\frac{-(x^2-y^2)}{c_n^{\;2}}\right)$$

where k is normalization constant, c_n, n=3, {c1=250, c2=120, c3=80}.

Step 2: Computed SSR from

$$R_i(x,y,c) = \log[I_i(x,y)] - \log[F(x,y,c_n) \otimes I_i(x,y)]$$

Step 3: Computed MSR from

$$R_{MSR}(x,y,w,c) = \sum_{n=1}^{N} W_n R_i(x,y,c_n)$$, where

N=3 and $\{w_1=w_2=w_3=1/3\}$.

Step 4: Calculated MSR with color restoration by:

$$I_i{}'(x,y,a,b) = b\log\left[1 + a\frac{I_i(x,y)}{\sum_{i=1}^{3} I_i(x,y)}\right],$$

where b=100, a=125.

Step 5: Output image obtained from gain offset by $I_{pi}(x,y)=0.35(I_i{}'(x,y,a,b)+0.56)$.

Step 6: end.

As have been done for the original images, here in same way applied for 4 blocks the enhanced image and perform Minimum Distance Classifier, the locations and the size of the blocks are identical to the original image's blocks. Beside that in this step we analyzed the effects of classification on enhanced images through evaluating its statistic properties (μ, σ and SNR). This step was done through applying Algorithm (1) on the enhanced image. In this study, one of the main scopes which been taken in account is to study the effects of classification on the original images and compare it to the effects of the classification on the enhanced images, this step was done through examining and analyzing the results of image's static properties evaluation.

Results And Discussion

In this research three colored balloons photography red, green, and blue, placed on a white background, under two fluorescent lighting and the distance between the camera and object to be photographed 1m, have been capture 5 images, using different aperture diameter (ΔD = -2 mm) to (ΔD = +2mm), by increment 1mm each time. Figure 3 shows the results of original captured images.

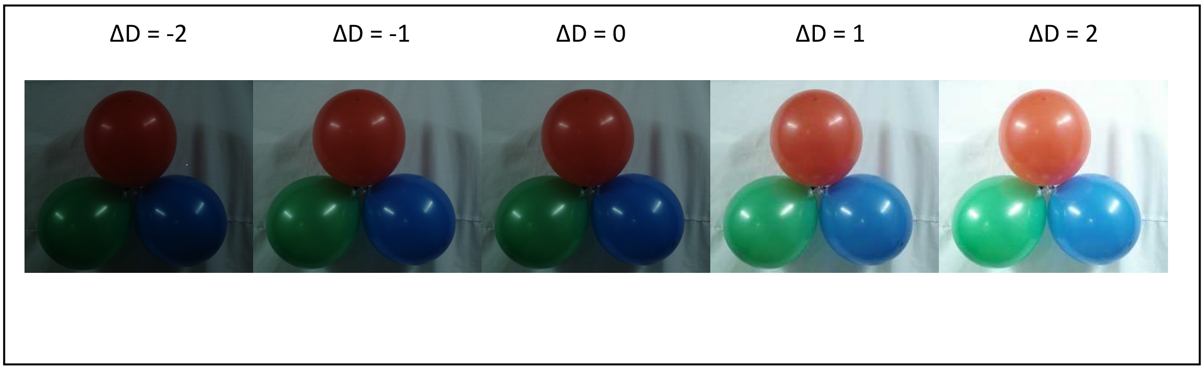

Figure 3- The Original Images

Four blocks have been extracted from each image in order to classify the original image target. These extracted blocks are shown in figure 4.

The resulted images after performing classification were shown in figure 5.

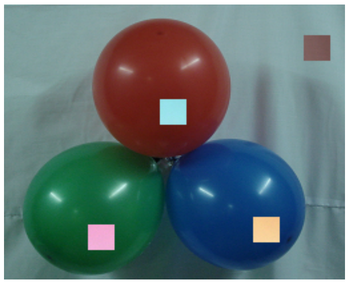

Figure 4- One Block for Each Target

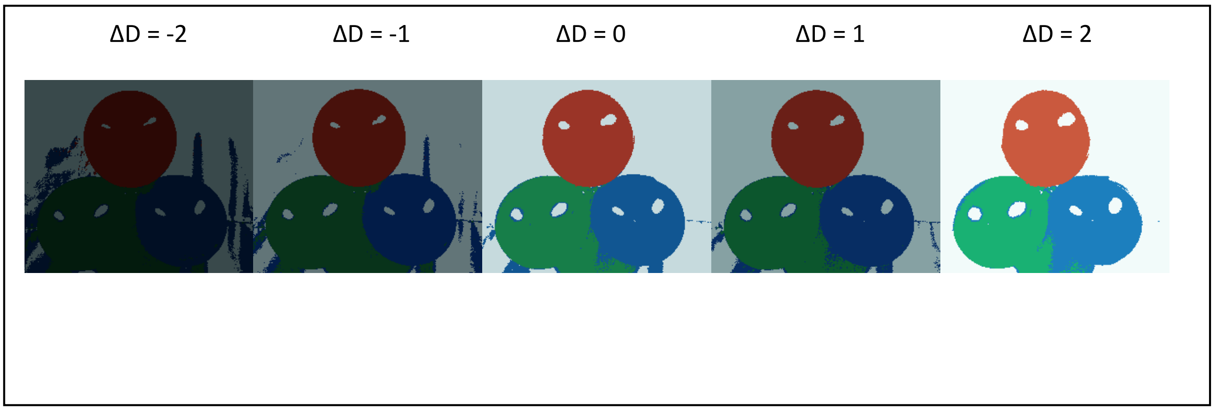

Figure 5- The Classified Original Images

We calculate the statistical properties of images the mean (μ) and the standard deviation (SNR) for each extracted homogeneous block from the 4 image target, where the statistical properties were drawn as a function of camera aperture diameter. And the results were shown in figurers (6, 7).

We calculate the statistical properties of each image, such as the mean (μ) value and the **single-to-noise ratio** (SNR) for each extracted homogeneous block from the 4 image target, where the statistical properties were drawn as a function of camera aperture diameter. And the results can be shown in figurers (6 and 7).

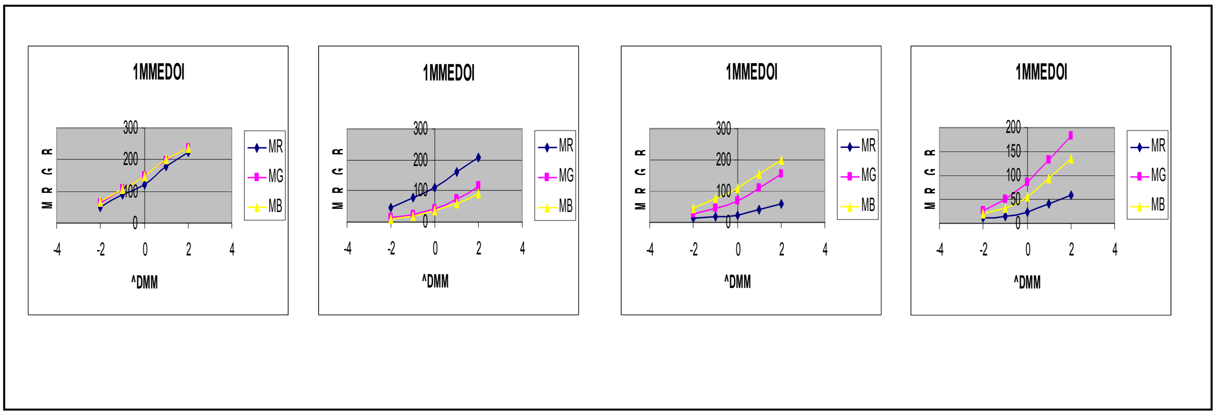

Figure 6- The Mean (μ) Of The Color Compound (RGB) For The Images As A Function Of Different Camera Diameter.

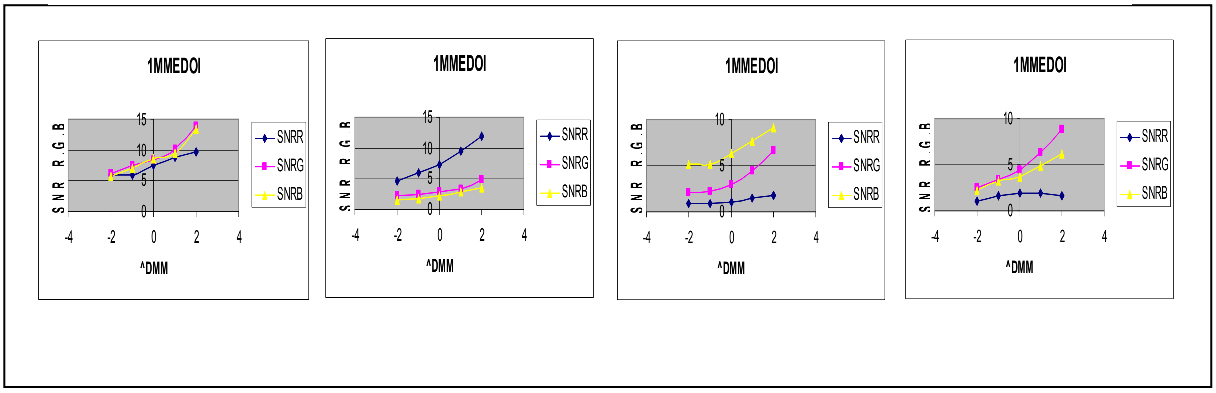

Figure 7- The Single-To-Noise Ratio (SNR) Of The Color Compound (RGB) For The Images As A Function Of Different Camera Aperture Diameter.

Figures 8 and 9 show the resulted images after applying Multi-Scale Retinex enhancement method on the original images before and after the minimum distance classification technique.

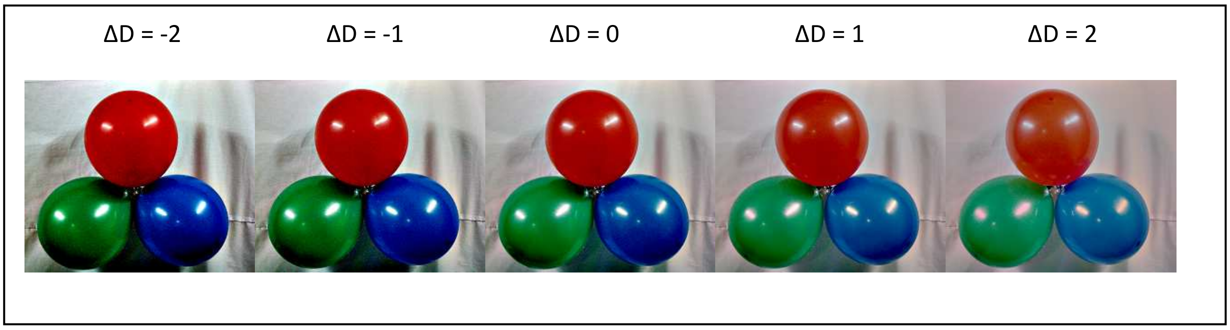

Figure 8- The Enhanced Images Using Multi-Scale Retinex Method

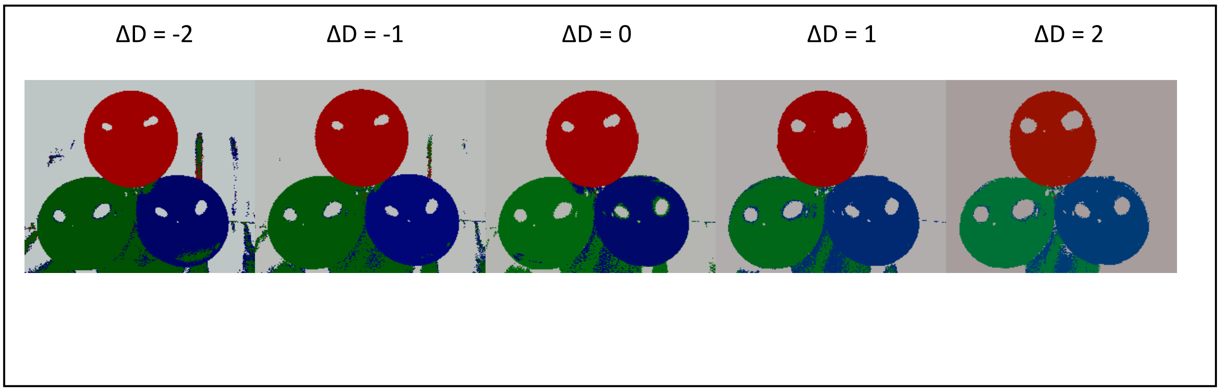

Figure 9- The Classified Enhanced Images

The statistical properties of enhanced and classified images the mean (μ) and the single-to-noise ratio (SNR) were calculated, and drawn as a function of different camera aperture diameter. The results were shown in figurers (10 and 11).

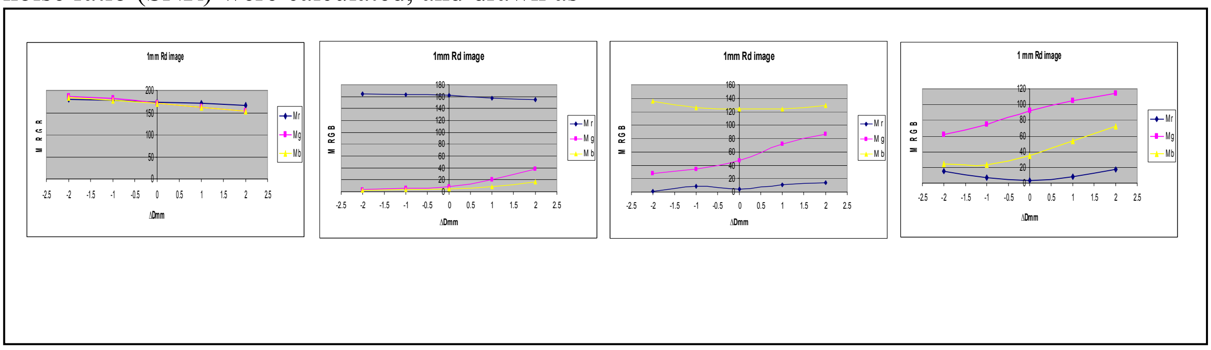

Figure 10- The (μ) of the Color Compound (RGB) for the Enhanced and Classified Images as a Function of Different Camera Aperture Diameter.

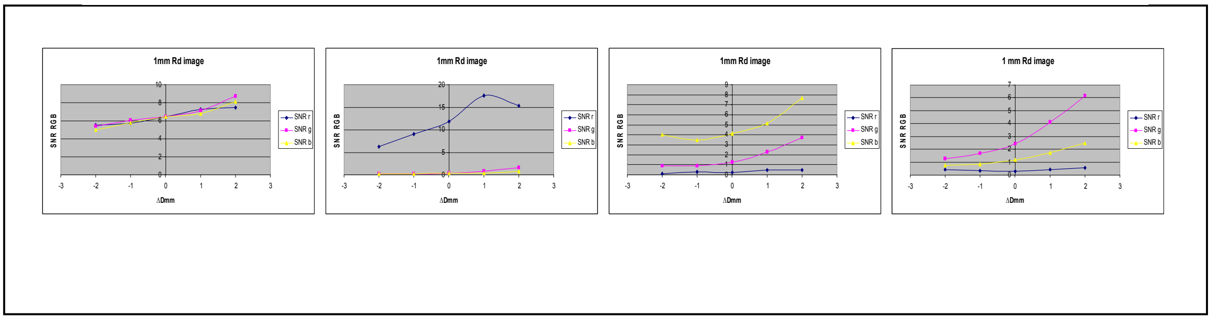

Figure 11- The Single-to-Noise Ratio (SNR) of the Color Compound (RGB) for the Enhanced and Classified Images as a Function of Different Camera Aperture Diameter.

Conclusions

1. It's obvious to notice the effects of ΔD (the variations in camera aperture diameter) on the original images, the image lightening increase by expanding the aperture diameter, but this does not represent indication for good quality images production.
2. Enhancing the images help us to improve the resulted images, in a way there was consistency in the lightness of each color, the color characteristic of the image is enhanced, so after enhancement it's become easy to distinguish between each classified color band.
3. From the figures of μ and SNR of the enhanced images, can be noticed that their values gradually increased. The recognition of different image's classes becomes more accurate.

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