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Using Statistical Methods to Increase the Contrast Level in Digital Images

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Abstract

This research deals with the use of a number of statistical methods, such as the kernel method, watershed, histogram and cubic spline, to improve the contrast of digital images. The results obtained according to the RSME and NCC standards have proven that the spline method is the most accurate in the results compared to other statistical methods.

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1. Introduction

In general, through the image, we can understand a lot of information about it, but images with poor contrast require us to find ways to treat poor contrast in them. By these methods, we mean performing calculations and using computer algorithms through which these methods are implemented in order to reach a clearer image than the original image.

Since the images transmitted through channels that depend on electrical signals may be exposed to some physical problems, such as fluctuations in the wavelengths of radio signals or to other technical problems, these factors must affect the quality of the image transmitted from the source, so the processing methods help in understanding the damaged images and how to extract information of which. Statistical methods invaded the digital image processing field, which increased its importance because it gave very accurate results and improved many of the images that needed an improvement machine or those that required saving them with the least storage space. Statistics is one of the most important sciences overlapping with other sciences. In the following a number of studies carried out by researchers in recent years to improve the contrast in digital images using statistical methods. Al-Nasser, A.M. and Al-Rawi, A.G. (2006) used multivariate methods to reduce sham dimensions in life sciences applications. Kaur et al. (2014) used the watershed method for image segmentation. AL-Rawi, A. G., Essa, Mohammed, A. M., (2018) producing some statistical algorithms in image segmentation for satellite images. Ngo et al. (2019) mentioned that multi-channel contrast enhancement is possible depending on the language-base-based capacitors. Xie et al. (2019) used the Histogram equalization method to improve digital image. AL-Rawi, A. G., Essa, A. M., (2019) stated that statistics plays an important role in many different life applications and is one of the most important sciences intertwined with other sciences. Maksymiv et al. (2021) used some methods to increase the contrast of the image. Edges are defined as local variations in image intensity and play an important role in image processing and analysis. Al Darwich et al. (2022) referred that edge detection is the most important step in retrieving information from digital images.

2. Material and Methods

The techniques of improving the contrast of digital images aim to result in an image that is more appropriate than before so that it can be employed for a specific application. These techniques consisted in converting a digital image of any kind into a gray-scale image to be processed later according to each of the aforementioned statistical methods, as the results obtained from these methods were good according to the root mean square error criterion.

2.1 Digital Images

Color is defined as a characteristic of the visual perception of light of a given wavelength. Every wavelength is described in a specific colour, so it is said that it is red, green, white...etc., according to the effect of light on the eye's retina. The colour has two classifications, where the first concerns colours with a chromatic hue except for white, black and gray gradations, while the second concerns with impure colours such as white and black and gray gradations. Color discrimination depends on three components called the HSV system for short. According to Al-Nasser et al. (2006) this system depends on describing the colour according to its reception from the human eye, where (H: Hue) represents the wavelength of the colour, which represents "the characteristic of light reflected from surfaces while (S: Saturation) represents the degree of colour saturation of a colour and it is pure whenever it is devoid of white, and therefore it is called a highly saturated colour as any addition to the white colour loses this designation to be under the name of the impure colour, whereas (V: value) represents the value of the lustre of the colour, that is the amount of light reflected from the body, which helps the human eye to see the colour. There are different kinds of digital images:

1- Binary Image: The values of the image matrix are made up of zero (black) and one (white). Shahla et al. (2013) said it is possible to convert all types of images to binary using (a threshold) where the pre-threshold is set to zero and after is equal to one.
2- Gray-Scale Image: In this type, we only have information about the brightness of the image, but we do not have any information about the colour. The range of the gray scales in this type is between zero and 255. It is also easy to convert this type of image to the first type after choosing the threshold. For example, if we assume that the threshold of a dummy matrix is at the gradient 127, then the values before this number will be zero, which will be the lighting is black, while the values above this number will be equal to one, which means the lighting will be white.
3- Colour Image: In this type, any pixel from the image matrix is represented by three boxes (3 - Bands), and each box represents eight bits belonging to one of the three colours red, green, and blue, which is known for its acronym RGB.

2.2 Stages of Digital Image Processing

Digital image processing methods are concerned with conducting operations to improve them according to specific criteria in order to extract some information from them. Many processors that may be basic in the science of digital image processing, where some of them depend on the iterative scheme of the image, while another part depends on methods of improving contrast and brightness. Hence the importance to study the image that is captured for several purposes, such as being used in geological studies, astronomical explorations, medical examinations, agricultural and industrial research, military exploration, and television broadcasting by satellite...etc. Khalil (2009) indicated that image processing helps us to convert image data into mathematical operations in order to obtain the largest amount of information within the image.

2.3 Image Contrast

Contrast is defined as the gradation and distribution of the values of digital image units on a scale from 0 to 255. In other words, it is a gradation from the dark areas in the image to the bright areas. The availability of sufficient lighting makes the image with high clarity and acceptable colour contrast, and this is known as good contrast. By Maksymiv et al. (2021) the "Contrast enhancement is a technique for increasing the contrast of an image to obtain better image quality". As for bad contrast, it is of two types: the first describes that the difference between the levels of illumination is slight, which makes the image faded and its features cannot be distinguished, and this is known as low contrast, or that the difference is large to the extent that some areas of the image are very dark while other areas are bright and such a case is called high contrast, and in both cases, images of this type need to be treated. From search Shahla et al. (2013) the improvement of contrast depends on the radical distribution of the light and dark areas in the image and images can be improved with this characteristic.

2.4 Detect the Edges of the Image

The intensity of the edge illumination is higher than its neighbours, as this is determined by the difference between pixels and neighbours, which is very large. The edges are revealed using the Convolution Mask. There are several of criteria that must be realized when starting to detect edges, as follows:
a-The size of the catcher used to detect the edge. The lower the dimension of the catcher array, the more sensitive it is in edge detection. Therefore, the (3×3) mask array is more sensitive than the (7×7) mask array.
b-Threshold of the gray level, if the threshold value is low, this will reduce the effect of noise. One of the edge detectors is the Sobel mask, which is used to find the value of the edge and the horizontal and vertical directions. It has the following two formulas:

$$\text{Row mask } (S_1) = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}, \text{ and Column mask } (S_2) = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

The edge is determined by the following equation:

$$Edge\ Magnitude = \sqrt{{S_1}^2 + {S_2}^2}. \quad (1)$$

Where: S_1 is a row mask and S_2 is a column mask.

Kaur et al. (2014) stated that noise is generally unwanted information that affects the nature of image data. The appearance of noise in images is due to several reasons, including:

a- Malfunction of the used photographic equipment.

b- An error occurred in the data transfer process, in addition to other reasons. Therefore, any distortion that affects the image often affects the amount of information contained in it and weakens its intensity. Several types of noise affect digital images, including:

1- Gaussian noise: The mathematical representation for this type of noise is defined as:

$$Histogram\ Gaussian = \frac{1}{\sqrt{\pi\sigma^2}}\ e^{-(g-\mu)^2/2\sigma^2}. \quad (2)$$

Where (g) is the gray intensity, (μ) is the mean, and σ^2 is the standard deviation.

2- Natural noise (Uniform noise): The probability density function for this type of noise is defined as:

$$P(Z) = \begin{cases} \frac{1}{b-a}, & if\ a \le z \le b \\ 0 & otherwise \end{cases} \quad (3)$$

The Mean Filter is one of the filters that is suitable for removing regular noise, and it is used as mentioned above to smooth the edges as well, and it can also be used to remove the natural noise (Uniform noise and its shape):

$$\text{Average filter} = \left(\frac{1}{9}\right)\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

2.5 Cubic Spline

The Cubic spline function is an efficient data interpolation method that produces an interpolated function that is continuous through to the second derivative. Splines tend to be more stable than fitting a polynomial through the $N+1$ points, with less possibility of wild oscillations between the tabulated points. By Ahmad et al. (2017) the goal of cubic spline interpolation is to get an interpolation formula that is continuous in both the first and second derivatives, both within the intervals and at the interpolating nodes.

Let us say we want to find the polynomial $q_i(x)$ where the point (x_0, y_0) and (x_n, y_n). We will consider one piece of the curve $q_i(x)$ to be interpolated from the point (x_1, y_1) and (x_2, y_2):

$$\begin{aligned} q(x_1) &= y_1 \\ q(x_2) &= y_2 \\ q'(x_1) &= k_1 \\ q'(x_2) &= k_2 . \end{aligned} \quad (4)$$

And the complete equation for $q_i\ (x)$ can be written in the symmetrical form:

$$q(x) = (1 - t(x))y1 + t(x)y2 + t(x)(1 - t(x))\,(1 - t(x))\,a + t(x)\,b \quad (5)$$

where:

$$\begin{aligned} t(x) &= \frac{x-x_1}{x_2-x_1} \\ a &= k_1(x_2 - x_1) - (y_2 - y_1) \\ b &= -k_2(x_2 - x_1) + (y_2 - y_1) \end{aligned} \quad (6)$$

To find these critical points k_1, k_2, we calculate:

$$q' = \frac{dq}{dx} = \frac{dq}{dt}\frac{dt}{dx} = \frac{dq}{dx}\frac{1}{x_2-x_1} \quad (7)$$

This implies to:

$$q' = \frac{y_2-y_1}{x_2-x_1} + (1-2t)\frac{a(1-t)+bt}{x_2-x_1} + t(1-t)\frac{b-a}{x_2-x_1}$$

$$q'' = 2\frac{(b-2a)+(a-b)3t}{(x_2-x_1)^2} \quad (8)$$

Putting $t = 0$ once and $t = 1$ again, we get:

$$q''(x_1) = 2\frac{(b-2a)}{(x_2-x_1)^2}$$

$$q''(x_1) = 2\frac{(a-2b)}{(x_2-x_1)^2}$$

$$q'(x_1) = k_1 \;\&\; q'(x_2) = k_2 \quad (9)$$

Now if we have (x_i, y_i) where $i = 0, 1, \ldots, n$, then:

$$q_i = (1-t)\,y_{i-1} + t\,y_i + t(1-t)((1-t)\,a_i + t\,b_i) \quad (10)$$

are n of polynomials of the third degree in interval $x_{i-1} \leq x \leq x_i$ where $i = 1, 2, \ldots, n$ and:

$$q'_i(x_i) = q'_{i+1}(x_i), \quad I = 1, 2, \ldots, n-1 \quad (11)$$

Therefore, n of the polynomials define the differentiable functions of the interval $x_0 \leq x \leq x_n$

$$a_i = k_{i-1}(x_i - x_{i-1}) - (y_i - y_{i-1})$$
$$b_i = -k_i(x_i - x_{i-1}) + (y_i - y_{i-1}), \text{ for } i = 1, 2, \ldots, n$$
$$k_0 = q'_i(x_0)$$
$$k_i = q'_i(x_i) = q'_{i+1}(x_i), \; i = ,1, \ldots, n-1$$
$$k_n = q'_n(x_n) \quad (12)$$

If the series k_0, k_1, ..., k_n is true, plus $q''_i(x_i) = q''_i + 1(x_i)$ is true for the values $i = 0,1,\ldots, n-1$. The resulting functions are continuous at their second derivative.

2.6 Histogram Method

Histogram method is based on determining the number of times a pixel (its color intensity) is repeated in the image matrix. The idea of the histogram is based on expanding the range of color intensity of the elements that make up the digital image in order to cover the entire color range 0-255, which leads to a clear contrast between the elements of the image and constitutes a deeper interpretation of its content. From Bagade et al. (2011) in the context of image processing, the histogram is the operation that displays the occurrences of each intensity value in the image, and histogram equalization is the method that widens the histogram's dynamic range. Histogram works on grayscale images only. The tools are used in data analysis because it provides us with abundant graphs; therefore, in the case of a color image, it must be converted to a grayscale image before applying the histogram format to it. But if we want the data to be distributed over the entire histogram instead of being confined to one place, then in this case, we resort to using the (Histogram equalization) technique, which is a technique used to adjust the contrast in digital images. The concept of histogram equalization uses the following mathematical law:

$$h(n) = (cdf(n) - cdf(min)) \times (255)/((m \times n) - 1) \quad (13)$$

2.7 Watershed Method

Image segmentation is one of the most important categories of image processing. The watersheds transformation is studied in this report as a particular method of a region-based approach to segmenting image. Watershed transform can be applied to gray scale images, textural images and binary images. From Kaur et al. (2014) the watershed transform has been widely used in many fields of image processing, including medical image segmentation. The basic concept of the watershed is based on visualizing a gray-level image in its topographic representation, which includes three basic notions: minima, catchment basins and watershed lines. There are three main methods to implement watershed such as distance transform approach, gradient method and marker controlled approach, where $f\ (x,y)$, $f^{\wedge}(x,y)$ represents the function of the original and improved images, and N is the image size.

2.8 Kernel Method

The kernel method offers an elegant solution to improve the learning process's effectiveness and efficiency in an image retrieval system. Kernel methods provide a way to obtain nonlinear decision boundaries from algorithms previously restricted to only handling linearly. By Doloc (2011) the kernel method was used in order to overcome the problem of high dimensions, where linear classifiers did not give good results on complex data such as images, for example, which are probably not linearly separable in image retrieval applications, it is useful to think of kernels as being measures of similarity between images, in the sense that the larger the kernel value between two images, the more similar the two images are often, image retrieval applications require the kernels to be directly comparable (i.e. to have values in the same range).

2.9 Signal-to-Noise Ratio (SNR)

According to Ismail (2014) the process of calculating the signal-to-noise ratio is one of the criteria used to check the quality of improved images, which depends on calculating the mean squared error represented by the following equation:

$$MSE = \frac{1}{M*N}\sum_{i=1}^{M}\sum_{j=1}^{N} \left(f(x_i,y_j) - f^*(x_i,y_j)\right)^2 \quad (14)$$

$$RMSE = \sqrt{MSE}, \quad (15)$$

where $f(x,y)$ is the original image of size $M*N$ and $f^*(x,y)$ is the resulting.

3. Discussion of Results

In this section, we choose five images of patients infected with the Corona epidemic.

IM1

IM2

IM3

IM4

IM5

Figure (1) The four statistical methods will process five images of corona patients.

The above original images are of different sizes and the contrast has been improved using a number of statistical methods whose details and results are shown in the following table.

Table 1: Comparison between methods for enhancing images.

IMAGES	SIZE		SPLINE		KERNEL		WATERSHED		HISTOGRAM		BEST METHOD
	WIDTH	HIGH	RSME	NCC	RSME	NCC	RSME	NCC	RSME	NCC	SPLINE
IM1	1105	650	0.0705	0.0199	0.6253	0	0.3756	0	0.9268	1	SPLINE
IM2	1105	650	0.0942	0.0081	0.5615	0	0.2570	0	0.9664	1	SPLINE
IM3	487	555	0.1649	0.0511	0.8086	0	0.4211	0.2223	0.5675	1	SPLINE
IM4	1105	650	0.0942	0.0081	0.5615	0	0.2570	0	0.9664	1	SPLINE
IM5	1105	650	0.1198	0.0036	0.6253	0	0.3756	0	0.9268	1	SPLINE

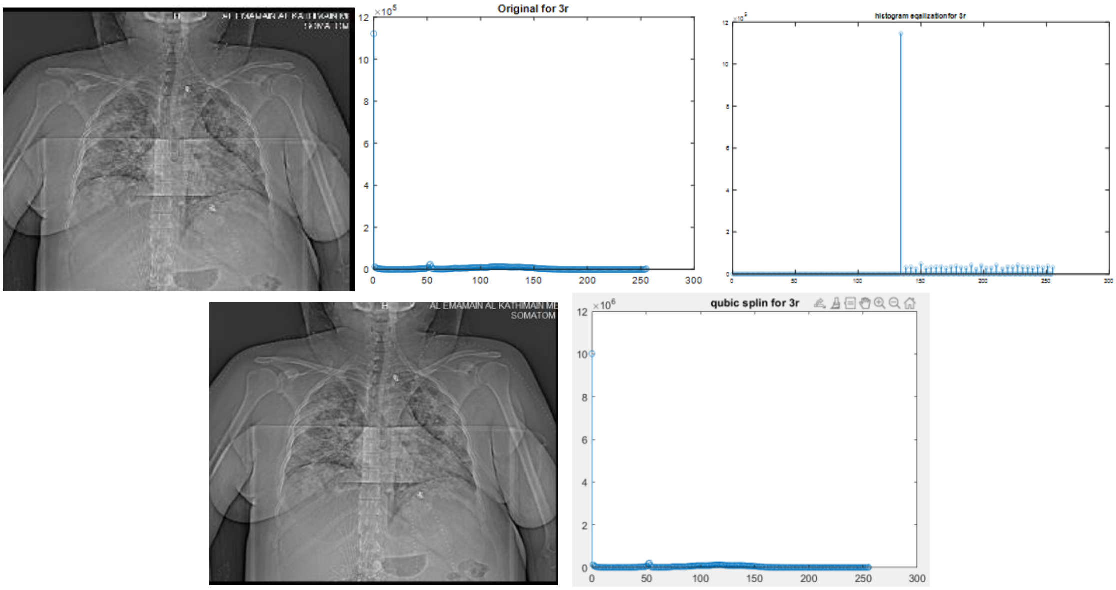

Figure (2): The original and improving image (1) - spline and histogram method

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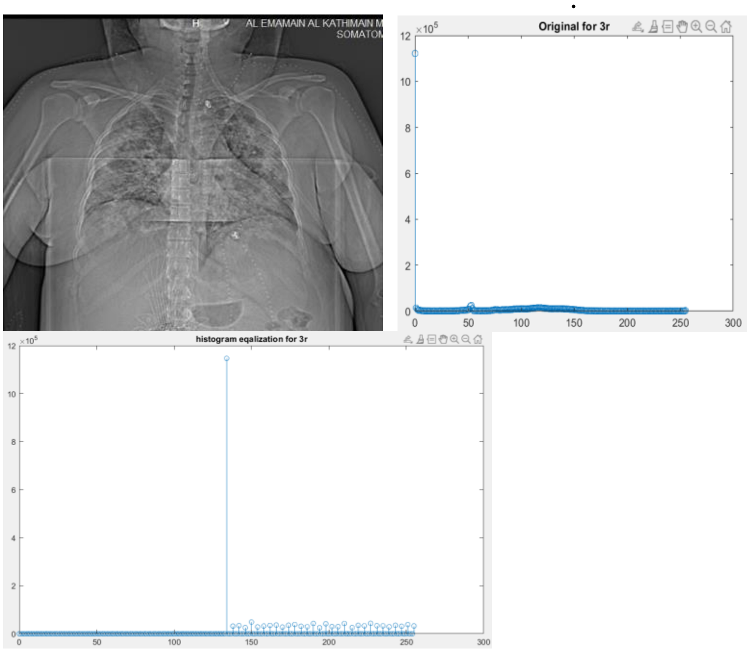

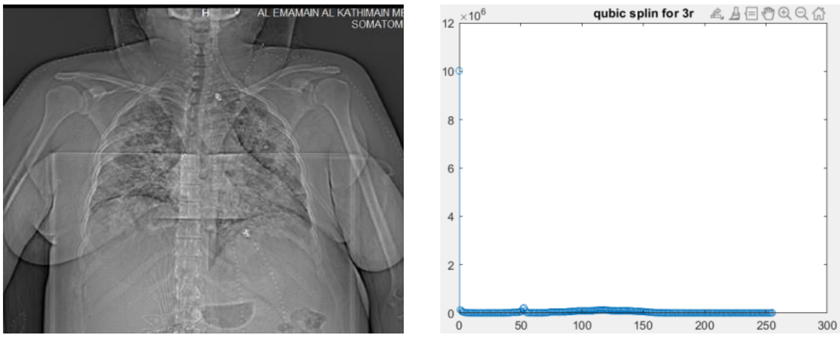

Figure (3): The original and improving image (2) - spline and histogram method

Figure (4): The original and improving image - watershed method

4. Conclusion

We have shown that the statistical methods proved highly efficient in improving the contrast of digital images of different sizes and extensions, through which we were able to obtain high-quality images according to the criterion of root mean square error (RMSE), and the method of cubic spline was more accurate than the rest of the other statistical methods used. The watershed method gives accurate results too (see table (1)).

5. Further Work

We recommend using other statistical methods such as the Laso method, and comparing the obtained results with the statistical methods used in this research, especially the spline method, with its application to other sizes and extensions of digital images with the use of more than one filter for processing.

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استخدام طرق احصائية لزيادة مستوى التباين في الصور الرقمية

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مستخلص البحث
يتناول هذا البحث استخدام عدد من الأساليب الإحصائية مثل طريقة الكيرنل ومستجمعات المياه والمدرج التكراري ومكعبات السبلاين لغرض تحسين تباين الصور الرقمية. أثبتت النتائج التي تم الحصول عليها وفقًا لمعايير RSME و NCC أن طريقة مكعبات السبلاين هي الأكثر دقة في النتائج مقارنة بالطرق الإحصائية الأخرى.

نوع البحث: ورقة بحثية.
المصطلحات الرئيسة للبحث: الصور الرقمية، تباين الصورة, طريقة مستجمعات المياه، طريقة مكعبات السبلاين، طريقة النواة، جذر خطأ مربع الوسط (RMSE).

***البحث مستل من اطروحة دكتوراه**