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A Review of Image Enhancement Methods

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Abstract

Today, face recognition is a technology that has been widely applied to various purposes, especially related to the image. Examples of the use of face recognition include face recognition for the manufacture of identity cards as well as driving identity cards. In addition, it is also widely used in a security system somewhere that can recognize the face of someone. Currently, face recognition has many variants. However, there are still some drawbacks due to the image capture technique or not optimal yet. This can be caused by poor image retrieval, insufficient shooting distance, and minimal lighting conditions. One solution that can be done to overcome the drawback to the image taken is by using the method of image enhancement.

Keywords: Face Recognition, Image Enhancement, Point Operation, Spatial Filter, Retinex.

INTRODUCTION

The use of the camera as a tool that enabled to take pictures has been very much used by the community today. Cameras are widely used for a variety of needs ranging from such uses to support security systems by identifying people caught by the camera. One of the information that can be used as identification is part of a human face. The face of a person has a unique characteristic that is different in each person.

Face recognition is a method where in a face represents a 3D image in which there are levels of brightness, lighting, pose, expression and others which then made the identification process to its 2D image. Face recognition sometimes can't be implemented perfectly so that the processed image can't be recognized properly. This makes the necessary process of image enhancement to obtain a better image quality again.

Face recognition techniques currently, growing rapidly with the emergence of variants of face recognition methods. By using face recognition, it can be done to identify someone based on the identity and characteristic of the person's face based on the image of the caught from the camera used.

But to note is that sometimes there are some images obtained do not have good visual form or still have noise. This can be caused by several factors, primarily due to the minimal level of illumination that can cause the image color to be different from the original color of the object. This is known as color constancy.

Color constancy is a color determination possessed by humans where the colors received by the human vision system still have a relatively constant color even though the object is in a place that has minimum lighting. To overcome this problem is used image enhancement method to improve the quality of the image.

Image enhancement is one of the initial processes in image processing. Image enhancement serves to improve the quality of the existing image. Some of the processes included in the image enhancement section include image brightness change, contrast enhancement, contrast stretching, image histogram conversion, image softening, sharpening, edge detection, histogram equalization and geometric alteration.

LITERATURE REVIEW

1. Point Operation

a. Brightness Adjustment

Image enhancement method by performing brightness adjustment is one of the methods of image repair which is quite simple. In general, each pixel is concentrated on one side of the histogram using a certain gray level range.

If the image brightness value is increased, then the image histogram will be shifted to the right. If the brightness value is lowered, then the image histogram will shift to the left which will impact on the brightness level of the image. Mathematically, brightness adjustment operation can be defined as follows:

$$f(x,y)' = f(x,y) \pm b \qquad (1)$$

Where $f(x,y)'$ is an image after using the brightness adjustment method and $f(x,y)$ is the original image that has not been through brightness adjustment.

Where b is the brightness intensity value used to make image brightness adjustment. If b has a positive operation, then the image will be brighter and if b has a negative operation then the image brightness level will decrease or dim. It can be seen, that the process of brightness adjustment is done by adding the value of each pixel with a certain constant.

If on the grayscale image pixel value after the brightness adjustment is more than the maximum intensity value that can be accommodated is 255 then the pixel value will be made 255. If the pixel the brightness adjustment is less than the minimum value that has been set that is equal to 0 then the pixel value will be made 0.

b. Gamma Correction

Gamma refers to the brightness of the image. Gamma self-regulation is used to determine the dim light of the displayed image. The purpose of the gamma correction is the same as the brightness adjustment method that improves the image from the illumination side. However, the brightness adjustment has a linear arrangement.

In the gamma correction, the arrangement is done by utilizing certain functions on each input that will determine the output of the image. When depicted in graphical form, the function of the gamma is curve-shaped.

The darkest and brightest areas of the gamma graph will not have much effect on different gamma arrangements. However, the middle area of the graph will have an effect by following the arrangement. The equation of gamma can be defined as follows:

$$f(x,y)' = f(x,y)^{\frac{1}{\gamma}} \qquad (2)$$

Where $f(x,y)'$ is the image of the gamma correction process and $f(x,y)$ is the original image that has not been through the gamma correction method. The symbol γ is a gamma correction factor with a value range of $0 < \gamma < 1$. If γ has a value less or less than 1 to near 0 then the resulting image will be brighter. If γ is equal to 1 then the resulting image will be like the input image used.

The use of gamma correction because the input signal provided is not enough to be able to display a good image. Thus, if no gamma adjustment is made then the resulting image will be difficult to see. The gamma correction method will produce a brighter and more natural image.

c. Contrast Stretching

Contrast stretching is represented in light and dark distribution in an image. Contrast itself can be divided into three types as follows:

1. Low contrast. Images that have low contrast are mostly bright or partially dark. Each pixel in the image will be concentrated in one region either in the left, right or middle regions of the histogram.
   When the pixel values converge on the left the image looks darker. If the pixel values are clustered on the right, then the image tends to be lighter. If the image pixel is assembled in the middle of the histogram then the resulting image is neither too bright nor too dark.

2. Good contrast. In the image with good contrast, the gray degree range is owned flat so that no one dominates. So that the histogram can be seen that there is no maximum point or minimum point.

3. High contrast. In high contrast, the width of the gray width is similar too good contrast. However, in the high contrast there are two colors that dominate the dark and light. Thus, in the resulting histogram there are two peaks is peaks with the low gray degree and peaks with the high gray degree.

d. *Histogram Equalization*

Histogram equalization is a method of contrast adjustment by using the histogram of the image. This histogram can improve the quality of the image. The workings of this histogram are to increase the peak of the histogram and decrease the minimum histogram point. This is done so that the spread of the value of each pixel can be done evenly or not much different.

Histogram equalization causes the dynamic range to stretch with the density distribution of the image made homogeneous so that the image contrast can be increased. The histogram equalization can be defined if the histogram of *I(x, y)* contained in a pixel with the gray level is *i* (where *i* is 0, 1, ..., k-1) and n_i is the number of pixels at *I(x, y)* by the gray level is *i*.

$$i = \sum_{i=0}^{k-1} \frac{n_i}{N} = \sum_{i=0}^{k=1} p(i) \qquad (3)$$

Where n_i is the number of pixels that have the gray degree and N is the total number of pixels in an image. In the above equation, it is stated that a mapping of any original pixel intensity value is 0 to 255.

It is also assumed that the equalization histogram changes the input value of rk to sk which then changes the value from s to be defined as follows:

$$V_k = T(S_k) = \frac{(L-1)}{n} \sum_{j=0}^{k} n_{rj} = s_k \qquad (4)$$

Where, L is defined as the gray level, n_{rj} is the number of pixel frequencies that appear in the image and *sk* defined as the gray intensity value of a pixel in the image.

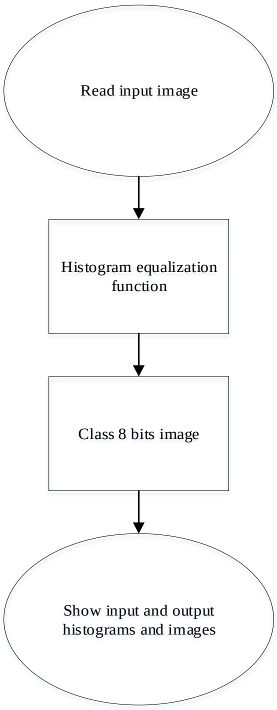

Figure 3: Histogram Equalization Flowchart

In figure 3, we can see about histogram equalization flowchart. For the first step, we must read the input image. Then, we use histogram equalization function with 8 bits from the image. The final steps show the output image and output histogram.

After that, the next process is to compare between the input image with the image of the results that have been using the histogram equalization image enhancement method. So, we can see the difference between the image before enhancement with image enhancement using histogram equalization.

e. Contrast Limited Adaptive Histogram Equalization

Basically, the contrast limited adaptive histogram equalization method has the same principle as the histogram equalization method. In this method, the image is divided into several sub-images with size NxN. After that, just done histogram equalization process in accordance with sub-image division that has been done before.

Contrast limited adaptive histogram equalization improves image contrast by changing the intensity value of the image. This method operates on a smaller pixel area range when compared to the histogram equalization method.

Each image pixel contrast is enhanced so that the output image histogram is compatible with the specified image. Using neighboring pixels is then merged using interpolation to remove the existing boundary. The contrast on a homogeneous region is restricted. This is done to avoid the appearance of noise in the image.

The steps in the contrast limited adaptive histogram equalization method are described as follows [1]:

a. The input image used is divided into several sub-images.
b. Then, from each sub-image that has been divided the calculation of the histogram for each sub-image.
c. Histogram results from sub-image in a clip. The pixel values in the sub-image are evenly distributed on each grade of gray in the image.

The average for each number of pixels at each degree of gray is defined as follows:

$$N_{avg} = \frac{N_{CR-XP} * N_{CR-YP}}{N_{gray}} \qquad (5)$$

Where N_{avg} is expressed as the average of the number of pixels available. The number of pixels with x coordinates in the sub-image is represented by N_{CR-XP} symbol. N_{CR-YP} represents the number of pixels in y coordinates in the sub-image. While N_{gray} is the number of gray degree values in the image.

Based on the above equation, the value of the clip-limit is defined as follows:

$$N_{C-L} = N_{CLIP}\ x\ N_{avg} \qquad (6)$$

Where N_{C-L} is the actual value of the clip-limit and N_{CLIP} is the maximum value of the average pixel on each grade of gray in the image.

In the input image histogram, a clip is performed if the total pixel is greater than the total N_{CLIP} value. The number of pixels is distributed evenly into each grade of gray degree which can be defined as follows:

$$N_d = \frac{N_{TC}}{N_{gray}} \qquad (7)$$

Where N_d is the number of distributed pixels and N_{TC} is the total pixel that is clipped. To calculate the distribution of the histogram that has been divided into several sub-images in the initial process we can define the equation as follows:

$$\begin{gathered} if\ H_{SI} > N_{CLIP}, H_{NSI}(i) = N_{CLIP} \\ else\ if\ H_{SI}(i) + N_d \geq N_{CLIP}, H_{NSI}(i) = N_{CLIP} \quad (8) \\ else\ H_{NSI}(i) = H_{SI}(i) + N_d \end{gathered}$$

Where H_{SI} is a pixel found at the gray level in each sub-image and *i* is the value of the gray degree of the image. After calculating the histogram distribution in the sub-image, the next process is to do the pixel distribution defined by the equation as follows:

$$S = \frac{N_{gray}}{N_{RP}} \qquad (9)$$

Where *S* is the result of the pixel distribution. While N_{RP} is the number of pixels that have been cut.

The use of contrast limited adaptive histogram equalization method will keep track of all pixel values from the minimum to the maximum.

Thus, this method will distribute each pixel in the image. If the tracking process stops before all pixels are distributed evenly then the process will be repeated starting from equation 9 until all pixels are disbursed separately and a new image histogram is obtained.

d. The limited contrast histogram of each sub-image is processed using histogram equalization and mapped using linear interpolation.

2. Spatial Filter

a. Linear Filter

1. Mean Filter

Mean filter is used to smoothing the image by calculating the average value of pixels in the image. Mean filter is included in the type of spatial filter because in the process include the pixels around it.

In the process, mean filtering involves surrounding pixels. The pixels to be processed are included in a matrix of dimension NxN. Mathematically, the mean filtering has the same weight as the neighboring pixel defined as follows:

$$f(x,y) = \frac{1}{mn}\sum_{k=1}^{m}\sum_{l=1}^{n} U(x+k-1, y+l-1) \quad (10)$$

Where $f(x,y)$ represents the image of the result. While, $U(x,y)$ represents the input image used. The upper bound value of *m* and *n* represent the size of the row and column of the mean filtering. If the mean filtering does not have the same weight as the neighboring pixels, then the process is using convolution.

2. Gaussian Filter

The gaussian filter is included in a linear type filter with a weight value for each pixel set in it by using the gaussian function. The gaussian filter is widely used for smoothing, blurring and eliminating noise in the image.

The linear process in the gaussian filter is done by multiplying each adjacent neighbor pixel and summing the result so that it gets the result for a certain coordinate point denoted as (x, y).

The mechanism of the linear spatial filter is to move the center of a filter mask from one point to another. In each pixel (x, y), the result of the filter at that point is the sum of the multiplication of the filter coefficients and the corresponding neighbor pixels in the filter mask range.

There are two components to note on the gaussian filter that is correlation and convolution. Correlation is the process of passing mask to the image. While the definition is defined as a process for obtaining pixel values based on their own pixel values, neighboring pixels and kernel matrices.

In the process, the kernel will be shifted along the rows and columns of the input image used so that the new pixel value of the resulting image will be obtained. In the gaussian filter itself, the convolution process first rotates the filter mask of 180^o and then passes the image.

Gaussian filters have two types of filters: one-dimensional gaussian filter and two-dimensional gaussian filter. The one-dimensional gaussian function is defined as follows:

$$G(x) = \frac{1}{\sqrt{2\pi\sigma}} \exp\left(\frac{-x^2}{2\sigma^2}\right) \qquad (11)$$

Where σ is expressed as the standard deviation of the distribution. As the value of σ gets larger then the distribution curve of the gaussian gets wider and the peak decreases.

The two-dimensional gaussian form is defined as follows:

$$G(x) = \frac{1}{2\pi\sigma^2} exp\left(\frac{-x^2 - y^2}{2\sigma^2}\right) \qquad (12)$$

Where σ is expressed as the standard deviation of the same distribution as the one-dimensional gaussian function. For x and y are expressed as coordinate points (rows and columns) in image pixels.

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b. Non-Linear Filter

1. Median Filter

The median filter is image enhancement method to reduce noise in the image. The median filter uses a way to extract certain data sections of a set of data, by eliminating the parts of undesirable data. There are several types of filter used in image processing one of which is a spatial filter.

Spatial filters are also called discrete convolution filters or filters that convolute an image with another image. The size of this image filter is usually small, relative to the image and is called convolution mask. This operation copies an image on a pixel resulting in a different effect. With spatial filters, the computations performed will only result in the value of the neighboring pixels and pixels.

In spatial frequency, the value of pixels is combined to form a single pixel value. The use of spatial filter techniques in the image, generally the point to be processed along with the points around it is inserted into a matrix of size NxN. This matrix is called matrix neighbor (neighboring matrix), where N is large depending on the need, but generally N this is always an odd multiplier because the point to be processed is placed in the middle of the matrix.

In addition to the use of the neighboring matrix, spatial filter techniques use a matrix that is matrix convolution (mask) the same size as the neighboring matrix.

One type of filter included in the spatial filter is the Median Filter. The median filter works by evaluating the brightness level of a pixel and determining which pixels whose brightness is the median value of all pixels.

The median value is determined and puts the pixel brightness on the stratified order and selects the middle value. So, that the number obtained from the existing pixel brightness becomes less than and more than the middle value obtained. The median filter will eliminate image pixels that differ considerably with another image.

2. Conservative Filter

Conservative filter is one technique to reduce existing noise on the image. In the median filter, the filter process uses the middle value of the processed neighboring pixels and pixels. In the conservative filter, the values used are the minimum and maximum values but excluding the processed middle pixels.

In the conservative filter, the calculation process is performed if the middle pixel is in the range between the minimum and maximum values, the new center pixel value will remain the same as the pre-existing value.

If the middle pixel is greater than the maximum value that exists in the surrounding pixel, then the middle pixel value is replaced with the maximum value. If the middle pixel is smaller than the minimum pixel value around it, the middle pixel value will be equal to the minimum value.

Retinex

Retinex is used to improve the quality of digital images that have a relationship with the quality of lighting while maintaining color constancy. Color constancy is the firmness of the object that has the perception that the color of the object is felt to remain constant in various lighting conditions.

When the dynamic range of an image exceeds the dynamic range of the medium, the visualization of color and detail appears to be weaker than the actual image. Color constancy aims to produce color to look the same as the difference in vision and lighting conditions.

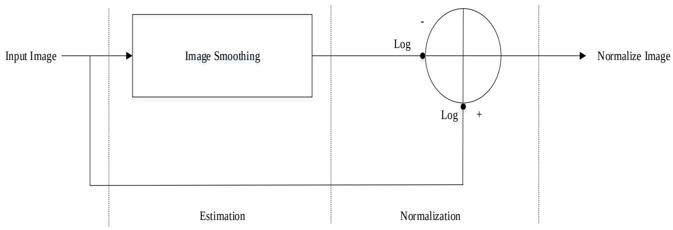

Figure 2: Retinex Diagram

In figure 2, as we can see above that the retinex method is divided into two stages. The first stage of illumination in the estimated input image is smoothed. Then the second stage is normalized by using logarithmic differences between the input image and illumination estimation.

At this time, retinex itself experienced a lot of development. Some of the development variants of retinex are Single-Scale Retinex (SSR) and Multi-Scale Retinex (MSR).

Single-Scale Retinex can be defined by the equation as follows:

$$R_i(x,y) = \log I_i(x,y) \log[F\ (x,y) * I_i(x,y)] \quad (13)$$

Where $R_i(x,y)$ is the output of retinex and $I_i(x,y)$ represent the image distribution in three spectral bands is spectral bands for red, green and blue. In the above equation, the symbol * represents the convolution. As for F (x, y) represents the gaussian function. The gaussian function is defined as follows:

$$I_R(x,y) = Ke^{(\frac{-r^2}{c})} \quad (14)$$

Where c is the gaussian constant which is usually used as the standard deviation and r is defined as follows:

$$r^2 = x^2 + y^2 \quad (15)$$

Where r defined as a gaussian constant. Small gaussian constants can provide good dynamic range compression. But, the color produced by the image is not very good. However, on a large scale the color will be better. For the value of K is defined as follows:

$$\iint F(x,y) = dxdy = 1 \qquad (16)$$

Where the above equation is used as the definition of the value of K. Up to this point, Single-Scale Retinex has been able to perform dynamic range compression on the image so that on a low scale can be done image reinforcement in the dark and weaken the bright image. On a large scale, Single-Scale Retinex is also capable of producing substantial image brightness and produce a more natural image.

REVIEW AND DISCUSSIONS

No.	Image Enhancement Methods	Description
1	Brightness Adjustment	Brightens the image by raising the image brightness level. The image histogram will shift to the right when the brightness level is raised and the image is brighter. If the brightness level is lowered then the image histogram will shift to the left and the resulting image will darken.
2	Gamma Correction	Gamma correction is also used to improve the brightness of the image. It is the same as the brightness adjustment method. The difference with brightness adjustment is gamma correction method using correction factor which has the range value $0 < \gamma < 1$. The higher the correction factor is, the image will be more like the input image. The smaller the correction factor the lighter the resulting image.
3	Contrast Stretching	Contrast stretching is done by distributing bright and dark pixels to the image. The use of contrast stretching method is very good used in low contrast image. This method works well on images that have gaussian distributions.
4	Histogram Equalization	Histogram equalization has a function in improving the image by distributing the intensity of the histogram to appear more evenly although it cannot be uniformed completely.
5	Contrast Limited Adaptive Histogram Equalization	This method is like histogram equalization method. However, the difference is in sub-image division. Each image is divided into several sub-images. Then, every block that has been divided is done histogram equalization process.
6	Mean Filter	The mean filter method serves to reduce the pixel intensity value with the next pixel. The mean filter calculates the value for the new pixel with the average value of the neighboring pixel and pixel in question.
7	Gaussian Filter	The gaussian filter is a filter that works for smoothing, blurring and eliminating noise in the image.
8	Median Filter	The median filter is included in a non-linear filter because it does not use a convolution process. The calculation process is done by sorting the intensity value of each pixel. Then, the original pixels will be replaced with new pixels that have been through the counting process. The function of this filter to smooth the image and reduce noise.
9	Conservative Filter	Conservative filters use the minimum point and maximum point of neighboring pixels.
10	Retinex	The retinex is a combination of words from the retina and cortex. The retinex method is used to improve image quality from the illumination side obtained by the image while maintaining color constancy. Color constancy is the firmness of color perception on an object. Thus, the color of an object is relatively fixed under various lighting conditions.

CONCLUSION AND FUTURE WORKS

This paper provides an overview of the concept of image processing. This paper is discussed from the various literature on image enhancement methods. Image enhancement methods are needed to help the quality of the image better. Thus, the resulting image gets a decent quality to be seen by the human vision system. In addition, by using the method of image enhancement can be seen the difference between the image before using image enhancement with the image after using the image enhancement methods.

In future research, it is necessary to discuss and research on other image improvement methods. Image enhancement method that needs to be developed in research is about of frequency domain methods and hybrid methods to improve image quality better. There are still many things that can be developed in improving image quality with various methods.

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