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Review Article

Survey on Image Enhancement Techniques for Digital Images

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Abstract: Image Enhancement involves the processing of an image for improving its visualization for different applications. Process involves processing the image by altering its structural features like contrast and resolution. Many image enhancement techniques are available but the choice of technique depends upon application for which image is being processed and image modality. Image enhancement can be categorized by spatial domain and frequency domain. Different image enhancement techniques are analyzed and their upsides and downsides are highlighted in the paper.
Keywords: Image Enhancement, spatial domain techniques, histogram equalization, spatial filters, frequency domain Techniques.

INTRODUCTION

Image enhancement is the process that consist of collection of techniques which are used to improve the visualization of the image for the human analysis. Image enhancement means increasing the appearance of an image by increasing the dominance of some features and decreasing ambiguity between different regions of the image. Image enhancement has vital role in many fields like high definition TV (HDTV), X-ray processing, motion detection, remote sensing and in studying medical images.

Goal of image enhancement is to process the given image to produce an another image with desired results and this goal can be attained by two schemes: One, image can be viewed properly which can help human to collect correct information or the image can be processed and required data can be preserved and undesired data can be rejected. To do so it is important to study image enhancement techniques. Image enhancement can be partitioned into two categories: spatial domain and frequency domain methods. In spatial domain method pixels of image are directly operated or manipulated to get desired results and in frequency domain method the image is processed and Fourier transformation of image is done, after that all the processing operations on the image are applied and inverse Fourier transformation is applied after this. A normal gray image have simple two-dimensional matrix whose numbers range from 0 to 255. All these numbers posses' different shades of gray. As between this range from 0–255 pure- black and pure- white is denoted by 0 and 255 respectively.

Objective of this paper is to put forward different image enhancement techniques

Intension behind applying enhancement is, to convert *f* into *g* with the help of *T*, where *f*, *g*and *T* are original image, converted image and transformation respectively. The pixel values of image *f is* given by *r* andthe pixel values of image *g*is given by *s* and these pixel values of both the images holds the relation given below:

$s = T(r)$ --(i)

Here *T* is transformation which map the pixel values of *r* into *s.*

Enhancement techniques

Spatial Domain

Spatial domain method is carried out on the pixels of the image. Direct operations are performed on the pixels of image. The objective of thetechnique is to increase the understandability of the data that ispossessed by the image [1] Formula for spatial domain method is:

$g(X, Y) = T[f(X, Y)]$(A)

which can be defined as follow:

$g(X, Y)$denotes Output Image
$f(X, Y)$ denotes Input Image
And 'T' represents transformation that is applied on input image.
Spatial domain method further has many categories.

Gray Level Transformation

Gray level transformation is applied when the neighborhood of the pixel is pixel itself. In this type, equation will be same as equation (i) that is:

$s = T(r)$

where, T will be called as gray level transformation function.

Gray level transformation can be classified into following type

Image negative

In this technique the areas which are not required are diminished or turned to negative; and the required are enhanced. Negative image in gray level have pixel values ranging from 0 – 255.

The image in which black areas are present in more proportion, we use this technique to highlight white or gray areas in the image [2]. The equation given below explains, how negative image is obtained:

Negative(r, c) = 255 - I(r, c)---------------------------- (ii)

where, I: input image
Negative: Negative of original image
r, c : row and column of image/size of image

In equation (ii) each pixel of original image is subtracted from 255 which in result produces the negative image.

Contrast stretching

Intensity difference between two adjacent pixels is defined as contrast. The quality of picture can be improved by increasing its contrast in some cases. So, contrast stretching technique is used to enhance the image by increasing the dynamic range of gray level in image [3].

Threshold transformation

Threshold transformation is used in the areas where image needs to be segmented. In this the desired portion of the image is separated from the background [4].

If f(x,y) is the original image and g(x,y) is normalized or processed image then we can easily locate threshold image because it possess pixel value of '0' or '1'.

Gray level slicing

The main focus of gray level slicing is to highlight and diminish the gray levels according to the interest.[5] The gray level at the area of interest are enhanced by using contrast level in order to brighten those areas in the image and the remaining area is left as such or diminished according to the need. To enhance the imperfections in the X-Ray or to enhance water areas in satellite image we use gray level slicing [1].

Logarithmic Transformation

Logarithmic transformations are used in the situation where input values of gray level are very large [6].

General formula for this type of transformation is:

*S = C * log (1+r)*---------------------------------------(iii)

Mostly, C is taken as '1' and gray level values must limit between (0.0 – 1.0)

This transformation converts the low range of input values into higher range of output values [7]. We can also use the inverse of log to obtain opposite results. So, the representation:

S = log (1+r) --- (iv)

Power-Law Transformation

This transformation shows the relation between pixels of f(x,y) and g(x,y) that is of original and enhanced image. General notation used in this transformation is:

$s = cr^{\gamma}$--(v)

Or it can also be understood as:

$I\ output\ (i, j) = c\ (\ I\ input\ \ (i, j)^{\gamma}\ )$

In Power Law Transformation each pixel value is raised to fixed power. This transformation is used for converting small and dark range of input pixel into larger and brighter range of output pixels or vice-versa.

In equation *(v)*, c and r, are positive constants, possible transformations can be obtained by varying the values of r and keeping c= 1; r results in increasing the contrast of certain regions in input image with high value against low regions.

Histogram Processing

Histogram processing is important tool used in spatial domain method. It is mainly used in processing of real time images. The 1gray level of range [0, L-1] in digital images is a discrete function,

$h(r_k) = n_k$--(vi)

In equation (vi)

r_k : k isk^{th}gray level and

n_k : no. of pixels in the image with k^{th} gray level

Histogram put forward the frequency by which various gray level occurs. Two different images can have the same histogram, histogram is invariant to rotation. We have to normalize the histogram and it can be normalized by dividing values of histogram by total no. of pixels in the image, suppose PxR is the image then normalized histogram can be denoted as:

$P(r_k) = \frac{n_k}{n}$ or n_k/PxR --------------------------------*(vii)*
where, k ranges from (0.1,…..L-1)

In equation (vii) P(r_k) results in giving probability of occurrence of r_k^{th} gray level.

The objective of histogram processing is to increase dynamic range of the image. Dynamic range was increased in this method but no. of pixels remained unchanged at all levels, for the uniform distribution of pixels other method named histogram equalization is used.

Histogram equalization

Histogram equalization is the method used to obtain uniform distribution of pixels at all gray level among the image [8]. Histogram of dark image will be gathered near lower gray level whereas histogram of the brighter image will be gathered near higher gray level. So, histogram of low contrast image will be narrow as it will not spread equally and for image with high quality histogram spread will be equal among gray level [9]. Histogram modification leads to improve quality of image.

Steps to perform histogram equalization are:

Step1: Perform running sum of histogram values i.e. CFD (Cumulative frequency distribution).
Step 2: Divide each result from step 1 with total no. of pixels.
Step 3: Multiply result from step 2 by maximum gray level Value.
Step 4: Using One-to-One correspondence, map gray level Values in result obtained from step 3.

Histogram matching

Histogram matching technique is used to specify the shape of histogram that we want a processed image to have. We set the shape of histogram manually and transformation function is constructed accordingly [10]. We will match two equalized histograms, one is of input image and other of specified histogram of output image.

Assuming r and z two continuous variables in which 'r' represents gray level or pixel intensity level of input image and 'z' represents gray level of processed image. Here $P_r(r)$ *and* $P_z(z)$ are probability density functions of r *and* z
Respectively. We need to estimate $P_r(r)$ whereas $P_z(z)$ is manually specified probability density function that we want output image to have [11].

To obtain PDF of input image 'r' we will assume random variables 's' which holds property:

$s = T(r) = \int_0^r P_r(w)dw$ ---------------------------*(viii)*

We take random variable 'z' and obtain histogram of output image 'z'

$$s' = G(z) = \int_0^z P_z(w)dw$$

Taking inverse we get
$z = G^{-1}(s')$

s' *and* s Are equal because both images have same histogram. Therefore,
$s' = s$
So,
$Z = G^{-1}(s') = G^{-1}(s) = G^{-1}(T(r))$

$Z = G^{-1}(T(r))$--*(ix)*

This process helps in matching gray level distribution in two images.

Spatial Filtering

Filter is word derived from frequency domain process, filtering refers to filter frequency bands i.e. accepting or rejecting frequencies [12]. Filters are of 2 type low-pass and high-pass, filter that passes low frequencies is called low-pass filter. Low pass filter is used to blur or to smoothen the image. Using spatial masks we can directly smoothen the images.

Spatial filter consist of two main things, one is neighborhood and second is predefined operation to be performed on image pixels. When filtering is done, in result it produces a new pixel whose co-ordinates are equal to the co-ordinates of the center of neighborhood and its value is outcome of filtering operation. The filter is known as linear spatial filter, when the image whose pixel are going through operation is linear [13].

Spatial filter can be categorized into two types:

- Smoothing spatial filters
- Sharpening spatial filters

Both type of filters can be linear or non-linear. In linear filter each value of pixel from processed image is an average of pixel contained in the neighborhood of the filter mask. Non-linear filter operation depend on value of pixels in the neighborhood.

The expression of linear spatial filter of image with size 'M x N' and filter of size 'm x n' is given by:

$g(x,y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s,t)\, f(x+s, y+t)$----- *(x)*

where,

W represents filter with coordinates ‘s’ and ‘t’ and values of ‘x’ and’y’ are varied in order to make each pixel in ‘w’, visits each pixel in input image ‘f’.

Spatial Correlation and Convolution

Spatial Correlation and Convolution are two processes that are to be studied while performing linear spatial filtering. In spatial correlation the filter mask ‘w’ is moved all over the image ‘f’ and the sum of product at each location is generated. Whereas convolution is same method but the filter ‘w’ is first rotated to 180 degrees before passing through image ‘f’.

So correlation of the filter w(x, y) of size m x n with the image f(x, y) is denoted by w(x, y)*f(x, y), and the equation will be same as equation *(x)*i.e.

$$g(x,y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s,t)\, f(x+s, y+t)$$

Similarly, the equation of convolution of w(x, y) and f(x, y)
Will be given as:

$g(x,y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s,t)\, f(x-s, y-t)$------*(xi)*

In this minus sign on the right side rotate ‘f’ by 180 degree, rotation and shifting of ‘f’ is done to follow convention.

Smoothing spatial filter

Term ‘smoothing’ in image enhancement refer to smoothen the image by blurring it. The filters are used to reduce noise and blurring of image by removing small gaps between curves and lines, results in achievement of noise reduction. Smoothing filtration can be categorized into two types:

Smoothing linear filters
Order- statistics filters
(a). Smoothing linear filters:

Linear spatial filter is weighed sum of pixels that are contained by the neighborhood of the filter mask. Due to this, these filters are called ‘averaging filters’ or ‘low-pass filters’ the main purpose in implementing this process is to change the value of pixel in an image by the weighed sum of the gray levels in the neighborhood defined by filter mask [14]. Resulting image from the process is the image with reduced sharp intensities.

The expression for filtration of ‘M x N’ image with the weighted averaging filter of size ‘m x n’ is given by:

$$g(x,y) = \frac{\sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s,t)\, f(x+s, y+t)}{\sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s,t)}$$

(b). Order-statistics filters: Order statistics filter are of category of non-linear spatial filters the result for these filters depend upon ranging or ordering the pixels possessed in the image area encompassed by the filter after that value of the result of ranking replaces the value of center pixel. This process is also called as ‘median filter’. These filters are popular reason behind the fact that they reduces noise in a better way with less blurring then linear filters. Median filters results in good performance in impulse-noise.

Sharpening spatial filters

Sharpening filters aims to enhance the blurred areas of the image that has been blurred due to some error or as a result of any filtration method of image smoothening. Sharpening can be attained by spatial differentiation.

Frequency domain techniques

Frequency domain method is other technique used for image enhancement. Process of this technique is different from spatial domain. Spatial domain deals with the frequency and phase of image or it represents image according to frequency distribution [8]. Frequency domain is reversible so, if we immediately perform inverse Fourier transformation after performing Fourier transformation, we will obtain same image. The two components involved in orthogonal transformation are magnitude and phase, where magnitude represents frequency content of image and phase is useful in converting image back in spatial domain.

From equation (A) and equation (i), we know that
f, g are input and output image respectively and *s = T(r)* is formula which mapspixel value of ‘r’ into ‘s’; and r , s are pixel value of f and g respectively.

Now, we want to enhance input image ‘f’ using frequency domain transformation in which we will apply Fourier transformation, multiplying result with filter and obtaining inverse Fourier transformation, one after another on input image f (x ,y) and obtain enhanced image g (x ,y).

We can view combine formula for transformation as:

$G(u,v) = H(u,v)F(u,v)$

Where,

$G(u,v) \rightarrow$ *Enhanced image*
$H(u,v) \rightarrow$ *Transfer function*
$F(u,v) \rightarrow$ *Input image*

Step wise elaboration for the formula is:

i. Preprocessing of input image f(x,y)
ii. Fourier transform of input image f(u,v)
iii. Multiplying it by filter function H(u,v)
iv. Obtaining inverse Fourier transformation G(u,v)
v. Post processing and obtaining enhanced image g(x,y).

CONCLUSION

We have studied various image enhancement techniques in this paper, more emphasis is given on spatial domain techniques. The enhancement of gray level images is discussed upon, the same methods of methods of enhancement can also be used for colored images. All these techniques results in enhanced images with reduced noises and improved visibility but if taken, combination of some techniques can yield even more satisfactory results as contrast stretching and Power Law transformation can result in image which is free from noise and other hindrance plus the image structural appearance is preserved and there will be no degradation in the quality of image.All the methods of gray level transformation place important role in enhancement of images, Image Negative has role in medical images as it enhances white regions that are suppressed by black areas. Histogram equalization also provide us technique to distribute gray levels uniformly among all pixels. Histogram of image helps in concluding very crucial information about image. Talking about filters, filtering techniques helps in accepting and rejecting several frequencies on requirement bases. Spatial filters are more versatile, reason behind this is that they can also be used for Non-Linear filtering, that can't be done in frequency domain.

All algorithms are effective but, then selection of algorithm for real-time application is purely task specific and aspects like computational cost and outcome etc. can be noticed upon while choosing one for enhancement of image.

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