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An Inclusive Analysis on Various Image Enhancement Techniques

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Abstract: *Digital Image enhancement is the process of adjusting digital images so that the results are more suitable for display or further image analysis. It provides a multitude of choices for improving the visual quality of images or to provide a "better transform representation for future automated image processing. The enhancement technique differs from one field to another field. The existing techniques of image enhancement can be classified into two categories: Spatial Domain and Frequency domain enhancement. Many images like satellite images, medical images, aerial images and even real life photographs suffer from poor contrast and noise. It improves the quality (clarity) of images for human viewing by eradicating blurs, noise, increasing contrast, and revealing image details.*
Keywords: *Geometric Corrections, Gray Scale Manipulation, Frequency based domain enhancement, Spatial based domain enhancement, Histogram Equalization.*

I. INTRODUCTION

Image enhancement is a process of enhancing the visual quality of images due to nonideal image acquisition process. It emphasizes and sharpens the image features for display and analysis. The aim of image enhancement is to improve the interpretability or perception of information in images for human viewers, or to provide `better' input for other automated image processing techniques. The enhancement doesn't increase the inherent information content of the data, but it increases the range of the selected features so that they can be detected easily. The major difficulty in image enhancement is quantifying the criterion for enhancement and therefore, a large number of image enhancement techniques are empirical and require interactive procedures to obtain satisfactory results.

II. IMAGE ENHANCEMENT

The principal objective of image enhancement is to process a given image so that the result is more suitable than the original image for a specific application. It enhances the image features such as boundaries, edges, or contrast to make a graphic display more helpful for analysis. Image enhancement methods can be based on either spatial or frequency domain techniques.

2.1 Spatial domain enhancement methods

Spatial domain techniques are performed to the image plane itself and they are based on direct manipulation of pixels in an image. The operation can be formulated as $g(x, y) = T[f(x, y)]$, where g is the output, f is the input image and T is an operation on f defined over some neighborhood of (x, y). According to the operations on the image pixels, it is separated into 2 categories: Point operations and spatial operations.

Spatial domain $g(x, y) = f(x, y) * h(x, y)$ Equation

2.2 Frequency domain enhancement methods

These methods enhance an image f(x, y) by convoluting the image with a linear, position invariant operator. The 2D convolution is performed in frequency domain with DFT.

Frequency domain $G(W_1, W2) = F(W_1, W2)\, H(W_1, W2)$

2.3 Operations on Images

Point operations - each pixel is modified according to a particular equation that is not contingent on other pixel values. Mask operations - each pixel is modified according to the values of the pixel's neighbors Global operations - all the pixel values in the image are taken into consideration.

III. Image Enhancement Techniques

3.1 Filtering with morphological operators

Morphological image processing is a collection of non-linear operations related to the shape or morphology of features in an image, such as boundaries, skeletons, etc. Morphological techniques probe an image with a small shape or template called a structuring element. It is positioned at all possible locations in the image and it is compared with the corresponding neighborhood of pixels. Few operations test whether the element "fits" within the neighborhood, while others checks whether it "hits" or intersects the neighborhood. Morphological operations rely only on the relative ordering of pixel values, not on their numerical values, and therefore are especially suited to the processing of binary images. Fig. 1 and Fig. 2 shows that morphological operations can also be applied to greyscale images such that their light transfer functions are unknown and therefore their absolute pixel values are of no or minor interest.

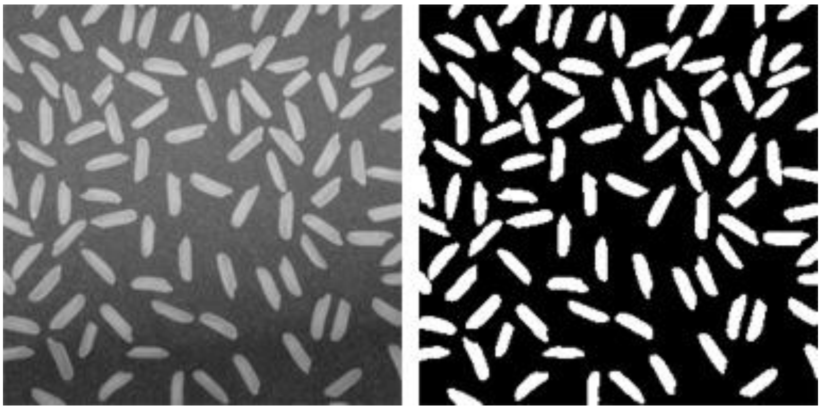

Fig. 1 Correcting nonuniform illumination with morphological operators

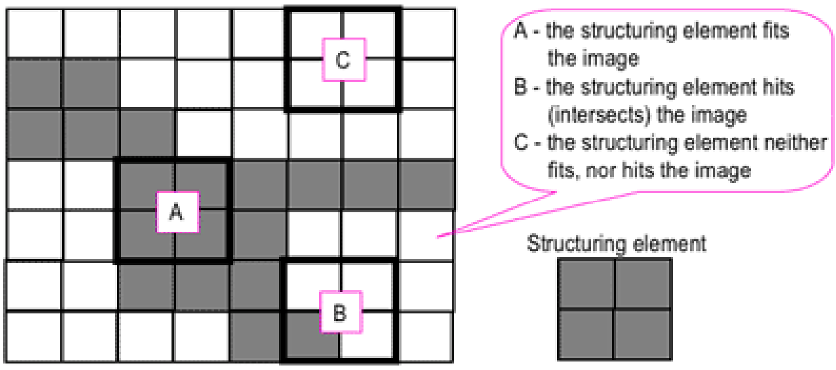

Fig. 2 Morphological filtering

3.2 Histogram equalization

Histogram equalization is a technique for adjusting image intensities to enhance contrast and it is depicted in Fig. 3 to Fig.6. Let f be a given image represented as a m_r by m_c matrix of integer pixel intensities ranging from 0 to L − 1. L is the number of possible intensity values. Let p denote the normalized histogram of f with a bin for each possible intensity. So

$$P_n = \frac{\text{number of pixels with intensity } n}{\text{total number of pixels}} \qquad \text{where } n = 0, 1, \ldots, L-1$$

The histogram equalized image g will be defined by

$$g_{i,j} = \text{floor}\left((L-1)\sum_{n=0}^{f_{i,j}} p_n\right)$$

where floor() rounds down to the nearest integer. This is equivalent to transforming the pixel intensities, k, of f by the function

$$T(k) = \text{floor}\left((L-1)\sum_{n=0}^{k} p_n\right)$$

Fig. 3 Original Image

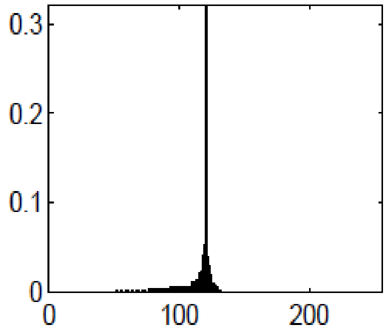

Fig. 4 Original Histogram

Fig. 5 Transformed Image

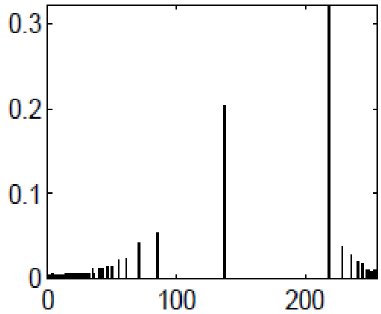

Fig. 6 Transformed Histogram

3. 3 Noise removal using a Wiener filter

Wiener filter is the most important technique for removal of blur in images due to linear motion or unfocussed optics. Generally blurring due to linear motion in a photograph is the result of poor sampling. Each pixel in a photograph should represent the intensity of a single stationary point in front of the camera. If the shutter speed is too slow and the camera is in motion, a given pixel will be an amalgram of intensities from points along the line of the camera's motion as shown in Fig 7 to Fig. 10. This is a two-dimensional analogy to

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

where F is the fourier transform of an "ideal" version of a given image, and H is the blurring function.

Fig. 7 Original Image

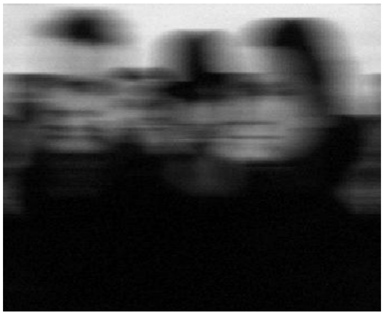

Fig. 8 Blurred Image

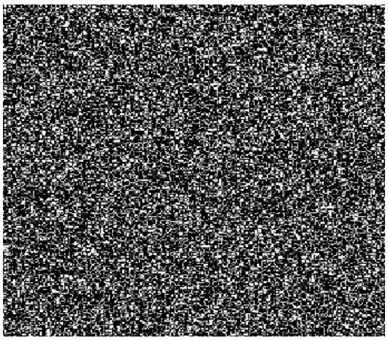

Fig. 9 Random gaussian noise

Fig. 10 Reconstructed photograph

3.4 Linear contrast Enhancement

Linear contrast enhancement, also referred to as a contrast stretching, linearly expands the original digital values of the remotely sensed data into a new distribution. The entire range of sensitivity of the display device can be utilized as shown in Fig. 11 by expanding the original input values of the image. It also makes subtle variations within the data more obvious. Such enhancements are best applied to remotely sensed images with Gaussian or near-Gaussian histograms and all the brightness values fall within a narrow range of the histogram and only one mode is apparent. The various types of linear contrast enhancement namely Minimum-Maximum Linear Contrast Stretch, Percentage Linear Contrast Stretch and Piecewise Linear Contrast Stretch.

In Minimum-Maximum Linear Contrast Stretch, the original minimum and maximum values of the data are assigned to a newly specified set of values that utilize the full range of available brightness values.

The Percentage Linear Contrast Stretch maps each grid cell value in the input raster image (z) onto a new scale that ranges from a lower-tail clip value (L) to the upper-tail clip value (U), with the user-specified number of total values (n), such that: zn = (z - L) / (U - L) × n, where zn is the output value. The values of L and U are determined from the frequency distribution and the user-specified Tail clip value.

The Piecewise Linear Contrast Stretch involves the identification of a number of linear enhancement steps that expands the brightness ranges in the modes of the histogram. A series of small min-max stretches are set up within a single histogram. As piecewise linear contrast stretch is a very powerful enhancement procedure, image analysts must be very familiar with the modes of the histogram and the features they represent in the real world.

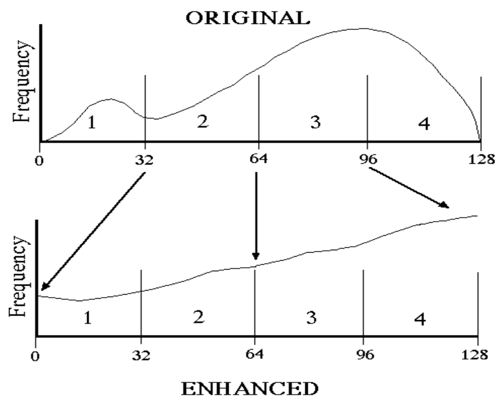

Fig. 11 Contrast Enhancement

3.5 Median Filtering

Median filtering is a nonlinear process useful in reducing impulsive or salt-and-pepper noise. It is also useful in preserving edges in an image while reducing random noise. Such noise can occur due to a random bit error in a communication channel. The median intensity value of the pixels within the window becomes the output intensity of the pixel being processed as the window slides along the image. Like lowpass filtering, median filtering smoothens the image and is thus useful in reducing noise. It preserves discontinuities in a step function and can smooth a few pixels whose values differ significantly from their surroundings without affecting the other pixels.

Figure 13 shows a 1-D sequence with two values that are significantly different from the surrounding points. Figures 14 and 15 show the result of a lowpass filter and a median filter, respectively.

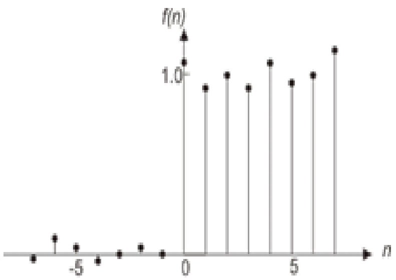

Fig. 12 1-D Sequence

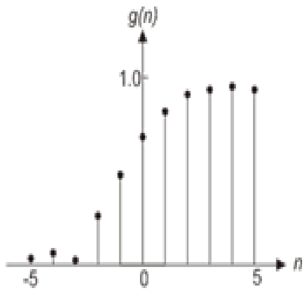

Fig. 13 Lowpass filter

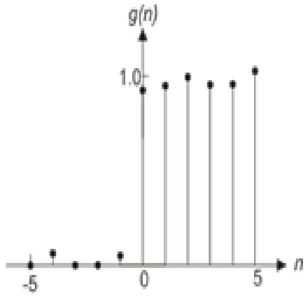

Fig. 14 Median filter

3.6 Unsharp mask filtering

The unsharp filter is a simple sharpening operator which derives its name from the fact that it enhances edges via a procedure which subtracts a smoothed or unsharp version of an image from the original image. It is commonly used in the photographic and printing industries for crispening edges. The unsharped mask is then combined with the negative image to create an image that is less blurry than the original. The resulting image may be a less accurate representation of the image's subject. It has parameters that allow it to have variable effect to affect the strong edges in the image, and to exclude the smoother low-contrast areas. The sharpening process works by utilizing a slightly blurred version of the original image. The resultant image is then subtracted away from the original to detect the presence of edges, creating the unsharp mask .Contrast is then selectively increased along these edges using this mask leaving behind a sharper final image.

Original Image

Blurred Copy

Unsharp Mask

Higher Contrast Original

Unsharp Mask

Original Image

Sharpened final Image

3.7 Contrast-limited adaptive histogram equalization (CLAHE)

CLAHE operates on tiles which are small regions in the image, rather than the entire image. The histogram of the output region approximately matches the histogram specified by the distribution parameter by enhancing each tile's contrast. Artificially induced boundaries are eliminated by combining neighboring tiles using bilinear interpolation. The contrast can be limited to avoid amplifying any noise that might be present in the image. It limits the amplification by clipping the histogram at a predefined value before computing the CDF. The value at which the histogram is clipped (clip limit) depends on the normalization of the histogram and thereby on the size of the neighborhood region.

3.8 Decorrelation stretch

Decorrelation Stretch is used to remove the high correlation commonly found in multispectral data sets and to produce a more colorful color composite image. The highly correlated data sets produce quite bland color images. It requires three bands for input. These bands should be stretched byte data or may be selected from an open color display. Its intended use is to highlight differences in an image that are too subtle for a human to see.

IV. CONCLUSION

In this paper, we present an image enhancement approaches based on the filtering with Morphological operators, Histogram equalization, Noise removal using a Wiener filter, Linear contrast Enhancement, Median Filtering, Unsharp mask filtering, Contrast-limited adaptive histogram equalization and Decorrelation stretch to enhance the quality of an image and help in better matching in any recognition systems. These approaches offer a wide variety of styles for modifying images to achieve visually acceptable images. The choice of such techniques is a function of the specific task, image content, observer characteristics, and viewing conditions.

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