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Image Enhancement and Filters Using Fourier Transformation

Abegail P. Untay[1], Ma. Theresa C. Cayabyab[2], Anna Clarice Yanday[3], Hazel Mae R. Diza[4]
Pangasinan State University, Lingayen Campus[1, 2, 3, 4]

Abstract *– Digital image enhancement techniques give a lot of choices for improving the visual quality of pictures or images. Image enhancement aims to process an image so that the result is more suitable than the original image for a specific application. This study presents the frequency domain and spatial domain methods for image enhancement, with particular reference to Fourier transformation and mask processing. Comparative analysis of frequency and spatial domain image enhancement algorithm was done and tested for different images with the aid of MATLAB. Upon testing the different algorithms, this study shows that two algorithms do great work on a particular kind of images. Spatial domain methods are good for removal of noises in an image and frequency domain methods are good for sharpening an image. On the other hand, the combination of the two domain techniques results in an image with a noise-free sharp image in very good quality.*

Keywords *– Image Enhancement, Frequency Domain Method, Spatial Domain Method*

INTRODUCTION

Pictures or images speak a thousand words. Is it a cliché? Yes, it is. People habitually take pictures that happen around them, whether they are pictures of people, sceneries, objects, or events. Long before the invention of camera phones and smartphones which became the majority trend that has made snapping pictures easier than ever, we would still have some of those times where we go into a photoshop and ask to be photographed. We capture photos of the people and the things that resonate `with our emotions at the moment. More often, we feel that these pictures would reflect our thoughts and feelings at that moment when others see it. Sometimes, photographs remind us of the important things and memories of our life. Capturing photographs is one of the best ways of preserving our history, our life, and our journey.

The focus of this research is image enhancement. The term enhancement indicates a process to improve the visual quality of the image. Image enhancement is widely used in computer graphics. Image enhancement (IE) is a technique to transform images to provide a better representation of the subtle details. This technique improves the image quality so that the resultant image is better than the original image or to make the result more suitable than the original image for a specific application. The main purpose of this technique is to increase contrast in a low contrast image or to bring out detail that is hidden in an image. [11]

The image enhancement techniques can be divided into two broad categories, that is, spatial domain methods and frequency domain methods. A method that operates directly on pixels is called spatial domain methods. While the frequency domain method operates on the Fourier Transform of an image. Unfortunately, for determining what is good image enhancement, there is no general theory when it comes to human perceptions. [6]

As mentioned, a Fourier Transform is used to operate the frequency domain of an image. Transformation is used to get a new representation of the incoming pictures. This new representation can be more convenient for the particular properties of the picture. One of the most important uses of Fourier transforms is providing a frequency representation of the image. Fourier transform is important in mathematics, engineering, and the physical sciences. The Fourier Transform is a mathematical technique that transforms a function of time into a function of frequency. Performing the Fourier transform in a fast and efficient manner has been one of the greatest breakthroughs of science and technology. It will allow us to view and introduce the use and

application of Fourier transform in image processing and filtering. [10]

OBJECTIVES OF THE STUDY

This research is aimed to enhance an image that is suffering from various types of defects such as noise, low contrast, and fuzzy boundaries. This research will be using the frequency and spatial domain algorithms with the help of MATLAB software to enhance an image. Also, the two algorithms and the comparison of these two will be presented in this study.

MATERIALS AND METHODS

This study focuses on digital image processing, which involves the use of computer software to change the nature of a digital image. Frequency domain and spatial domain methods are used for image enhancement, operated by Fourier transformation and mask processing with the use of MATLAB. These two aspects represent two different but equally important aspects of image processing.

MATLAB Software

MATLAB is a multi-paradigm numerical computing environment and proprietary programming language developed by MathWorks. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation.

Fourier Transformation

The Fourier Transform of $f(t)$ (symbolized by $F(\omega)$ is defined by:

$$F(\omega) = \int_{-\infty}^{\infty} f(t)e^{-i\omega t}dt$$

It is an important image of its sine and cosine components. The output image of the transformation is the Fourier or frequency domain and the input image is the spatial domain equivalent. It is a powerful tool for, image analysis, image filtering, image enhancement, image reconstruction, and image compression.

Spatial Domain Method

The spatial filter is used to change the grey level of a given pixel by using the value of the grey levels in a small neighborhood of pixels around the given pixel. The idea is to move a "mask" over the given image. As we do this, we create a new image whose pixels have grey values calculated from the grey values under the mask, as shown in Figure 1.

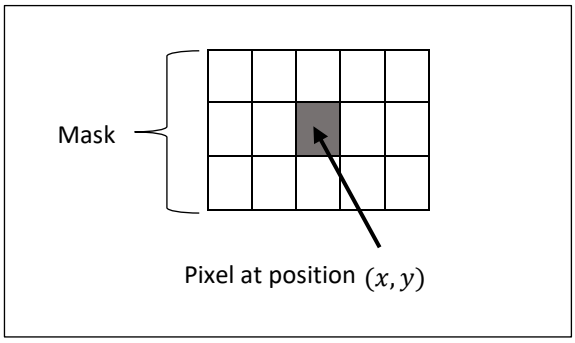

Figure 1: Using a spatial mask on an image

The spatial filtering requires three steps, that is,

1. Positioning the mask over the current pixel,
2. Forming all products of filter elements with the corresponding elements of the neighborhood,
3. Adding up all the products.

This must be repeated for every pixel in the image.

Frequency Domain Method

Frequency domain techniques are suited for processing the image according to the frequency content. The principle behind the frequency domain methods of image enhancement consists of computing a 2-D discrete unitary transform of the image, for instance, the 2-D DFT, manipulating the transform coefficients by an operator M, and then performing the inverse transform.

The concept of filtering is easier to visualize in the frequency domain. Therefore, enhancement of image $F(u, v)$ can be done in the frequency domain based on DFT. This is particularly useful in convolution if the spatial extent of the point spread sequence $H(u, v)$ is large then convolution theory.

$\boldsymbol{G}\ (\boldsymbol{u}, \boldsymbol{v}) = \boldsymbol{H}(\boldsymbol{u},\boldsymbol{v}) * \boldsymbol{F}(\boldsymbol{u},\boldsymbol{v})$
where $G(u, v)$ is an enhanced image.

There are three basic steps to frequency domain filtering:

1. The image must be transformed from the spatial domain into the frequency domain using the Fast Fourier transform.
2. The resulting complex image must be multiplied by a filter.
3. The filtered image must be transformed back to the spatial domain.

RESULTS AND DISCUSSION

Noise is a very common problem in data transmission: all sorts of electronic components may affect data passing through them, and the results may be undesirable. The two methods, frequency and spatial domain methods, were both applied to the same image that was corrupted by noise. The result was shown in Figure 2.

Figure 2.a) Original Image

The original image shown in Figure 2(a) has 20% pixels that have been corrupted by salt & pepper noise. The effect can again be demonstrated by the 'imnoise' function in MATLAB software. In Figure 2(b), the researchers used the frequency method to remove the noise. To perform this method in MATLAB, the researchers used the 'fspecial' function, multiply it by the image transform, and invert the result. Unfortunately, the result tends to blur the image. However, this method prepared to trade-off blurring for noise reduction, then reducing noise significantly by this method.

The next method used is the median filtering of the spatial method shown in Figure 2(c). The filtering is calculated by first sorting all the pixel values from the surrounding neighborhood of the image into numerical order and then replacing the pixel being considered with the middle pixel value. If the neighborhood under consideration contains an even number of pixels, the average of the two middle pixel values is used.

The researchers noticed how the image became "better" than the noisy image for the two methods that researchers used but the effect is even more pronounced in using the median filtering of spatial domain method than the frequency domain method.

Figure 2.b) Result Image using Frequency Domain Method

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Figure 2.c) Result Image using Spatial Domain Method

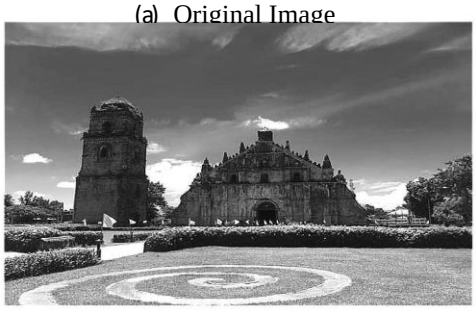
Figure 2: Removing Noise in the Image

Next image enhancement is image sharpening or edge enhancement. The idea of sharpening an image is to subtract a scaled "unsharp" version of the image from the original. In practice, the researchers achieve this effect by subtracting a scaled blurred image from the original. The results for these two methods are shown in Figure 3 below.

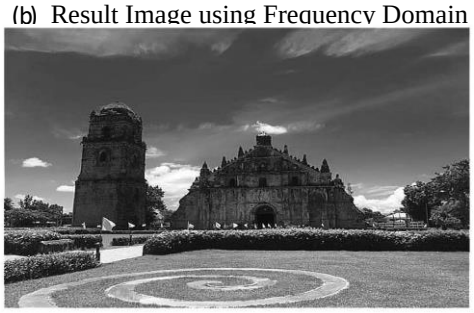
The original image is shown in Figure 3(a) was captured by an ordinary cellphone. The researchers used the two methods to enhance the edges of our original image to have a clearer detailed of this image. By using MATLAB function 'fspecial' with frequency and spatial domain methods produce an image which is shown in Figure 3(b) and Figure 3(c).

Suppose that x is the image shown in Figure 3(a), then the result of sharpening the original image using the frequency-domain method is in Figure 3(b) while using spatial domain method is given in Figure 3(c). The results appear to be a better image than the original; the edges are more clearly defined but the result of the frequency-domain method in Figure 3(b), is much smoother and brighter than the result using the spatial method. So, it is more appropriate for image sharpening than spatial domain method.

(a) Original Image



(b) Result Image using Frequency Domain



(c) Result Image using Spatial Domain Method

Figure 3. Image Sharpening

Figure 2: Remo

CONCLUSION AND RECOMMENDATION

This study used two techniques for image enhancement: frequency-domain filtering and spatial domain filtering. In this research, the researchers used the idea behind Discrete Fourier Transform and pixel mask. Frequency domain filtering which operates the Fourier Transform of an image possesses the different properties of two-dimensional Discrete Fourier transform while spatial domain filtering involves the manipulation of pixel values.

The frequency-domain method is easily used, and the parameters are easily manipulated even though it is not simple to smoothly distribute the gray tones. Spatial domain methods are good for removal of noises. While frequency-domain method is good for sharpening an image. On the other hand, the combination of the two domain

techniques results in an image with a noise-free sharp image in very good contrast. The above discussion and various results obtained lead to the conclusion that it is easier to comprehend the concepts of digital image processing and specifically various image enhancement techniques with the help of their simulation on MATLAB. As it is evident from the results, both ways of filtering (frequency and spatial) domain are more or less the same. When needed to enhance an image with a small neighborhood, the researchers would like to advise to use the spatial domain, instead of the frequency domain that is operated by Fourier transformation because it will take some time and knowing that the spatial domain is fast and less complex than the frequency domain.

Besides the two methods used in this research, there also have other methods of image enhancement and point out promising directions on research for image enhancement that can use by future researchers but there are no general image enhancement methods that can enhance all the images. Depending on your application and the image source, the future researchers can select the best method. Some of these methods are histogram equalization, point processing, Weiner filter, dilation, and erosion. Furthermore, they may try the above-mentioned methods in other types of digital images like binary, indexed and true-color images.

The researchers also highly recommend to future researchers to do a work that will apply the Fourier Transform like power distribution system and wireless system that is greatly helped in various domains. In power system proposed method easily analyzes the fault, harmonics, and disturbance while in a wireless system, it's identifying the noise and calculating the losses in an easier way.

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PLEASE INCLUDE CONTACT INFORMATION

NAME: HAZEL MAE R. DIZA
CONTACT NO: 09777537328
EMAIL ADDRESS:
HMDIZA.LINGAYEN@PSU.EDU.PH