Application of 2D Convolution in Digital Image Processing

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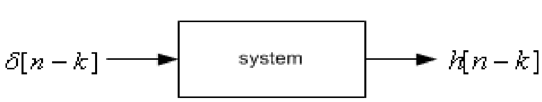
***Abstract*—The document contains methodology and manifest results of application of 2D convolution in digital image processing using MATLAB, and how different filters respond in image filtering brightening and smoothing along with edge detection and enhancement in a particular gray scale image. filters used in the research are Averaging, Gaussian and Laplacian filter, where Averaging and Gaussian filters are used mainly for image smoothing and noise reduction and Laplacian filter is used for edge detection and enhancement. Section I gives the introduction to the basis of convolution in 1D. Section II gives information and basic idea of 2D convolution in image processing Section III and IV relates to the function of filters used and their results obtained. Section V and VI delivers analogy of image detection and edge enhancement and Section VII concludes the entire research paper followed by the references.**

***Keywords:* Convolution, Gaussian filter, Laplacian filter**

I. Introduction

Convolution is a mathematical way of combining two signals to form a third signal. It is the single most important technique in Digital Image Processing. Using the strategy of impulse decomposition, systems are described by a signal called the impulse response. Convolution is important because it relates the three signals of interest: the input signal, the output signal, and the impulse response. The keystone of understanding convolution is laid behind impulse response and impulse decomposition.Impulse response is the output of a system resulting from an impulse function as input and it is denoted as h[n].

If the system is time-invariant, the response of a time-shifted impulse function is also shifted as same amount of time.



By combining the properties of impulse response and impulse decomposition, we can finally construct the equation of convolution. In linear and time-invariant system, the response resulting from several inputs can be computed as the sum of the responses each input acting alone.

Furthermore, there is an important fact under convolution; the only thing we need to know about the system's characteristics is the impulse response of the system, *h*[n]. If we know a system's impulse response, then we can easily find out how the system reacts for any input signal.

II. 2D Convolution in Image Processing

A 2D convolution is simply the application of a mask to a 2D image, conceptually the same as a "blur" operation in computer graphics. The output of linear and time invariant system can be written by convolution of input signal *x* [m, n], and impulse response, *h*[m,n] as follow;

$$y[m,n] = x[m,n] * h[m,n] = \sum_{j=-\infty}^{\infty} \sum_{i=-\infty}^{\infty} x[i,j] \cdot h[m-i, n-j]$$

Notice that the kernel (impulse response) in 2D is centre originated in most cases, which means the centre point of a kernel is *h*[0, 0]. For example, if the kernel size is 5, then the array index of 5 elements will be -2, -1, 0, 1, and 2. The origin is located at the middle of kernel.2-D convolution therefore can be directly applied for filtering and image enhancement purpose.

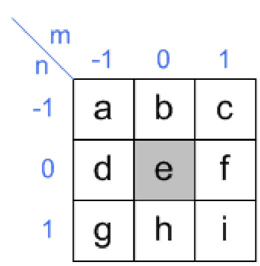


Fig. 1: Gaussian Kernel

III. AVERAGING AND GAUSSIAN FILTERS

In signal processing, a filter is a device or process that removes from a signal some unwanted component or feature. Filtering is a class of signal processing, the defining feature of filters being the complete or partial suppression of some aspect of the signal. Most often, this means removing some frequencies and not others in order to suppress interfering signals and reduce background noise. Linear filtering is used to remove certain types of noise. Certain filters, such as *averaging or Gaussian filters*, are appropriate for this purpose. For example, an averaging filter is useful for removing grain noise from a photograph. Because each pixel gets set to the average of the neighboring pixels, local variations caused by grain are reduced.The Gaussian and averaging filter smoothing operator therefore is a 2-D *convolution operator* that is used to `*blur*' images and remove details (such as edges and high frequency components) and noise.

IV. ANALYSIS AND RESULTS OBTAINED

A. Effect of increasing the filter order

Filter order 3x3, 5x5, 7x7 and 9x9 are used for monitoring the effect of increasing the filter order. Filtering of images, either by correlation or convolution can be performed. In this particular research '*conv2*' command is used for Multidimensional image filtering and as it is evident from the results the by increasing the filter order the image's edges are smoothened and are producing more blurred results .

Fig. 2, shows the original image. Fig. 3, 4, 5, and 6 show blurring effect on original image after applying 3x3, 5x5, 7x7 and 9x9 Gaussian kernel respectively.

Fig. 2: Original Image

Fig. 3: 3x3 Filter Result

Fig. 4: 5x5 Filter Result

Fig. 5: 7x7 Filter Result

Fig. 6: 9x9 Filter Result

B. Addition of Guassian (White) Noise

An independent white noise whose terms are all normally distributed is called a Gaussian white noise. White noise with different parameters is illustrated below, we can see by increasing the parameter the background is producing a bright effect on the image this type of noise therefore can be used where brighter version of image is required. Fig. 6, shows the image with white noise. Fig. 7, 8, and 9 show the filtered image using Gaussian kernel of size 5x5 and 0.5, 0.1 and 0.01 filter parameter respectively.

Fig. 6: Image with Added Noise

Fig. 7: G.F order 5x5 with parameter 0.5

Fig. 8: G.F order 5x5 with Parameter 0.1

Fig. 9: G.F order 5x5 with Parameter 0.01

V. EGDE DETECTION AND ENHANCEMENT

Edge enhancement is an operation commonly employed in image processing. Usually the edge slope is steepened by the applying a linear filter that amplifies the high spatial frequency content of an image. This often results in the amplification of noise and in ringing or over-enhancement of edges that is already sharp.

The Laplacian filter highlights areas in which intensity changes rapidly producing a picture of all the edges in an image. The Laplacian filter is a standard Laplacian of Gaussian convolution. This is a second derivative function designed to measure changes in intensity without being overly sensitive to noise. The function produces a peak at the start of the change in intensity and then at the end of the change. The Laplacian filter separates itself from the other edge enhancement filters because it uses second derivative information about the intensity changes in an image through a difference equation.

What is happening is that the difference of the centre pixel is taken with every surrounding pixel, and then averaged. At edges this differential will be large and elsewhere it will be small, leaving highlights only in the areas where sharp differentials, or edges, occur.

A. Effect of Laplacian filtered image

As it can be seen in the Laplacian filtered image (Fig. 10) the edges are completely enhanced but the picture is somehow appearing to be negative. The Laplacian 3x3 filter is used with 2D kernel as shown below:

Table 1: Laplacian Kernel

-1	-1	-1
-1	8	-1
-1	-1	-1

Fig. 10: Laplacian filtered image

B. Effect of edge enhancement on a noisy image

If a noise is added in the image then upon enhancement of edges the noise intensity will also increase accordingly which is exactly happening in this case the edges are seen enhanced vividly but noise in turn is also enhanced.

Noise intensity is increased apparently by enhancing the edges.

In order to get the true colour image with enhanced edges back by eliminating the negative effect in the image. The image is either subtracted by or added with the original image observing which operation gives more sharpened and noise free result which in our case is delivered by using addition operation of edge enhanced image with original image.

Fig. 11: Image with Added Noise

Fig. 12: Edge Enhanced noisy image

Fig. 13: Image after Subtraction

Fig. 14: Image after Addition

VI. CONCLUSION

Digital image processing occupies a vast area of application such as in digital systems satellite imagery, wire photo standards conversion, medical-imaging, video-phone, character recognition, and photograph enhancement. Digital image processing has become the most common form of image processing and generally, is used because it is not only the most versatile method, but also the cheapest.

REFERENCES

[1] Gonzalez, Rafael C., and Richard E. Woods. Digital Image Processing. New York: Addison-Wesley Publishing Company, 1993.

[2] R. Bala and K. Braun, "Color-to-grayscale conversion to maintain discriminability,"*Proc. SPIE*, vol. 5293, pp. 196–202, 2004.

[3] Y. Bai, S. J. Harrington, and J. Taber, "Improved algorithmic mapping of color to texture," *Proc. SPIE*, vol. 4300, pp. 444–451, 2000.

[4] G. Strang and T. Nguyen, *Wavelets and Filter Banks*. Wellesley, MA: Wellesley-Cambridge, 1996.

[5] W. B. Pennebaker and J. L. Mitchell, *JPEG: Still Image Compression Standard*.New York: Van Nostrand Reinhold, 1993.

[6] R. L. de Queiroz, *Compression of Color Images, in the Handbook on Transforms and Data Compression*, G. Sharma, Ed. Boca Raton, FL: CRC, 2002.

[7] R.W. G. Hunt, *The Reproduction of Color*. Toolworth, U.K.: Fountain, 2000.

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