

STUDY AND IMPLEMENTATION OF VARIOUS MORPHOLOGY BASED IMAGE CONTRAST ENHANCEMENT TECHNIQUES

*Suman Thapar, ** Shevani Garg
Assistant Professor

*CSE Department, ** IT Department
Ludhiana College of Engineering & Technology, Katani Kalan, Ludhiana, Punjab.
er.suman_thapar@yahoo.co.in, gargshevaani@gmail.com

Abstract: This paper gives brief introduction to Morphology and its operations. Morphology can be used in contrast enhancement field. Top-Hat and Bottom Hat are two such operations in morphology which are used in image contrast enhancement. PSNR metric can be used to check peak signal to noise ratio in each enhanced image produced as result of various image contrast enhancement techniques.

I. INTRODUCTION

Morphology is a broad set of image processing operations that can process images based on shapes. Morphological operations apply a structuring element to an input image then creating an output image of the same size. In a morphological operation, the value of each pixel in the output image is based on a comparison of the corresponding pixel in the input (original) image with its neighbors. By choosing the size and shape of the neighborhood, you can construct a morphological operation that is sensitive to specific shapes in the input image.

The most basic morphological operations are dilation and erosion. Dilation adds pixels to the boundaries of objects in an image, while erosion removes pixels on object boundaries. The number of pixels added or removed from the objects in an image depends on the size and shape of the structuring element used to process the image. In the morphological dilation and erosion operations, the state of any given pixel in the output image is determined by applying a rule to the corresponding pixel and its neighbors in the input image. The rule used to process the pixels defines the operation as dilation or erosion. This table lists the rules for both dilation and erosion.

Rules for Dilation and Erosion

Operation	Rule
Dilation	The value of the output pixel is the maximum value of all the pixels in the input pixel's neighborhood. In a binary image, if any of the pixels is set to the value 1, the output pixel is set to 1.
Erosion	The value of the output pixel is the minimum value of all the pixels in the input pixel's neighborhood. In a binary image, if any of the pixels is set to 0, the output pixel is set to 0.

Table 1: Showing rules for Dilation and Erosion

II. MORPHOLOGICAL OPERATIONS

A. Opening morphology

In mathematical morphology, opening is the dilation of the erosion of a set A by a structuring element B:

$$A \circ B = (A \ominus B) \oplus B,$$

where \ominus and \oplus denote erosion and dilation, respectively. Together with closing, the opening serves in computer vision and image processing as a basic workhorse of morphological noise removal. Opening removes small objects from the foreground (usually taken as the dark pixels) of an image, placing them in the background, while closing removes small holes in the foreground, changing small islands of background into foreground. These techniques can also be used to find specific shapes in an image. Opening can be used to find things into which a specific structuring element can fit (edges, corners).

One can think of B sweeping around the inside of the boundary of A, so that it does not extend beyond the boundary, and shaping the A boundary around the boundary of the element.

B. Closing morphology

In mathematical morphology, the closing of a set (binary image) A by a structuring element B is the erosion of the dilation of that set,

$$A \bullet B = (A \oplus B) \ominus B,$$

where \oplus and \ominus denote the dilation and erosion, respectively. In image processing, closing is, together with opening, the basic workhorse of morphological noise removal. Opening removes small objects, while closing removes small holes. Graylevel closing consists straightforwardly of a graylevel dilation followed by a graylevel erosion. Closing is the dual of opening, i.e. closing the foreground pixels with a particular structuring element, is equivalent to closing the background with the same element.

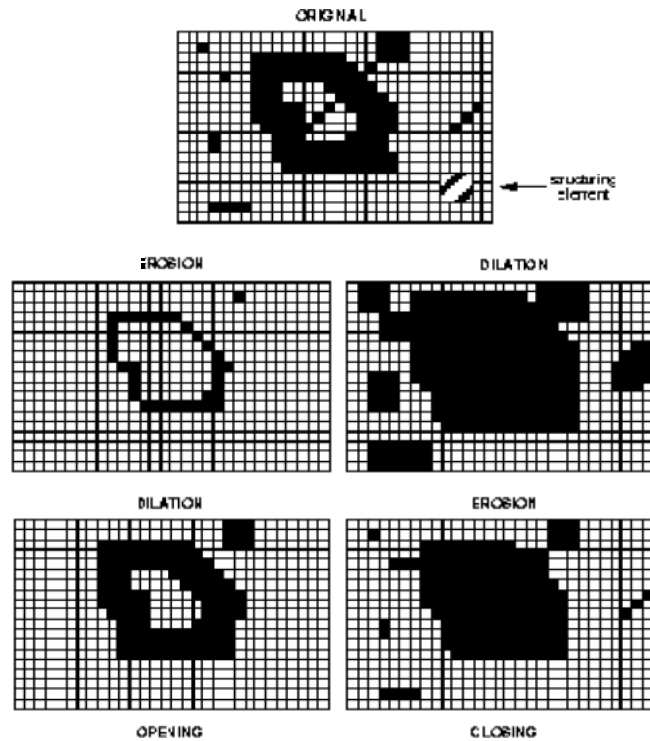


Fig.1: example of various basic morphological operations

C. Top-Hat Transformation

In mathematical morphology and digital image processing, top-hat transform is an operation that extracts small elements and details from given images. There exist two types of top-hat transform: The white top-hat transform is defined as the difference between the input image and its opening by some structuring element; the black top-hat transform is defined dually as the difference between the closing and the input image. Top-hat transforms are used for various image processing tasks, such as feature extraction, background equalization, image enhancement, and others.

Mathematical definitions

Let $f : E \mapsto R$

be a grayscale image, mapping points from an Euclidean space or discrete grid E (such as R^2 or Z^2) into the real line. Let $b(x)$ be a grayscale structuring element. Then, the white top-hat transform of f is given by:

$$T_w(f) = f - f \circ b,$$

Where \circ denotes the opening operation.

The black top-hat transform of f is given by:

$$T_b(f) = f \bullet b - f,$$

Where \bullet is the closing operation.

Properties

The white top-hat transform returns an image, containing those "objects" or "elements" of an input image that: Are "smaller" than the structuring element (i.e., places where the structuring element does not fit in), and are brighter than their surroundings. The black top-hat returns an image, containing the "objects" or "elements" that: Are "smaller" than the structuring element, and are darker than their surroundings. The size, or width, of the elements that are extracted by the top-hat transforms can be controlled by the choice of the structuring element b . The bigger the latter, the larger the elements extracted. Both top-hat transforms are images that contain only non-negative values at all pixels.

Syntax: $IM2 = \text{imtophat}(IM, SE)$

Description: $IM2 = \text{imtophat}(IM, SE)$

Performs morphological top-hat filtering on the grayscale or binary input image IM . Top-hat filtering computes the morphological opening of the image (using imopen) and then subtracts the result from the original image. imtophat uses the structuring element SE , where SE is returned by

strel. SE must be a single structuring element object, not an array containing multiple structuring element objects.

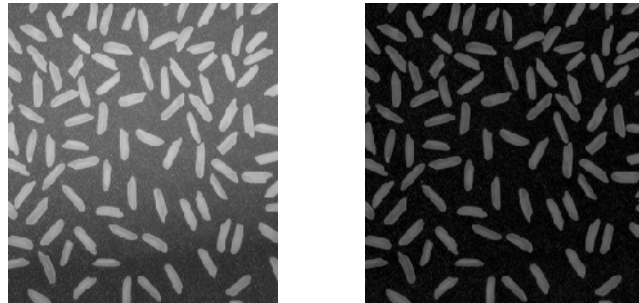


Fig.2: Image Before and After TOP-HAT Transformation

D. BOTTOM-HAT TRANSFORMATION

One principal application of these transforms is in removing objects from an image by using an SE in the opening and closing that does not fit the objects to be removed. The difference then yields an image with only the removed objects. The top-hat is used for light objects on a dark background and the bottom-hat – for dark objects on a light background. An important use of top-hat transformation is in correcting the effects of non-uniform illumination. Bottom-hat morphological operator subtracts input image from result of morphological closing on the input image. Applied to binary image, the filter allows getting all object parts, which were added by closing filter, but were not removed after that due to formed connections/fillings.

Syntax: $IM2 = imbothat (IM, SE)$

Description: $IM2 = imbothat (IM, SE)$

performs morphological bottom-hat filtering on the grayscale or binary input image, IM, returning the filtered image, IM2. The argument SE is a structuring element returned by the strel function. SE must be a single structuring element object, not an array containing multiple structuring element objects.



Fig.3: Before and after Bottom-Hat Transformation

E. HISTOGRAM EQUALIZATION

Histogram equalization is a method in image processing of contrast adjustment using the image's histogram. This method usually increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values.

The method is useful in images with backgrounds and foregrounds that are both bright or both dark. In particular, the method can lead to better views of bone structure in x-ray images, and to better detail in photographs that are over or under-exposed. A key advantage of the method is that it is a fairly straightforward technique and an invertible operator. So in theory, if the histogram equalization function is known, then the original histogram can be recovered. The calculation is not computationally intensive. A disadvantage of the method is that it is indiscriminate. It may increase the contrast of background noise, while decreasing the usable signal.

Histogram equalization often produces unrealistic effects in photographs; however it is very useful for scientific images like thermal, satellite or x-ray images, often the same class of images that user would apply false-color to. Also histogram equalization can produce undesirable effects (like visible image gradient) when applied to images with low color depth. For example, if applied to 8-bit image displayed with 8-bit gray-scale palette it will further reduce color depth (number of unique shades of gray) of the image. Histogram equalization will work the best when applied to images with much higher color depth than palette size, like continuous data or 16-bit gray-scale images.

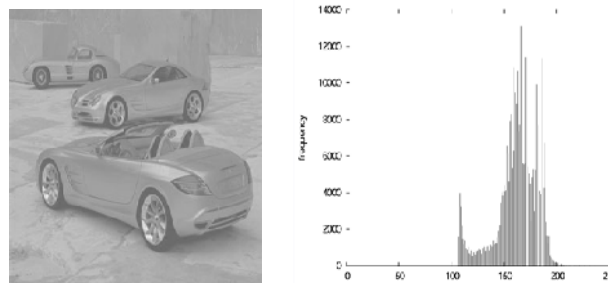


Fig.4: Image and its histogram before equalization

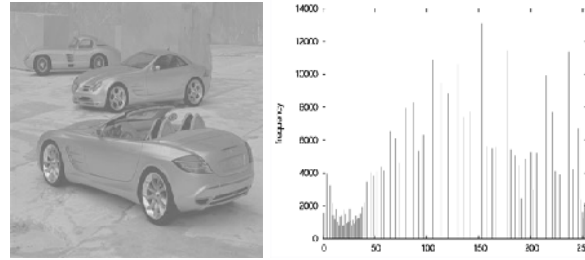


Fig.5: Image and its histogram after equalization

II. PSNR (PEAK SIGNAL-TO-NOISE RATIO) METRIC

Compressing an image is significantly different than compressing raw binary data. Of course, general purpose compression programs can be used to compress images, but the result is less than optimal. This is because images have certain statistical properties which can be exploited by encoders specifically designed for them. Also, some of the finer details in the image can be sacrificed for the sake of saving a little more bandwidth or storage space. This also means that lossy compression techniques can be used in this area. Lossless compression involves with compressing data which, when decompressed, will be an exact replica of the original data. This is the case when binary data such as executables, documents etc. are compressed. They need to be exactly reproduced when decompressed. On the other hand, images (and music too) need not be reproduced 'exactly'. An approximation of the original image is enough for most purposes, as long as the error between the original and the compressed image is tolerable.

Error Metrics

Two of the error metrics used to compare the various image compression techniques are the Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR). The MSE is the cumulative squared error between the compressed and the original image, whereas PSNR is a measure of the peak error. The mathematical formulas for the two are:

$$MSE = \frac{1}{MN} \sum_{y=1}^M \sum_{x=1}^N [I(x,y) - I'(x,y)]^2$$

$$PSNR = 20 * \log_{10} (255 / \text{sqrt}(MSE))$$

where $I(x,y)$ is the original image, $I'(x,y)$ is the approximated version (which is actually the decompressed image) and M,N are the dimensions of the images. A lower value for MSE means lesser error, and as seen from the inverse relation between the MSE and PSNR, this translates to a high value of PSNR. Logically, a higher value of PSNR is

good because it means that the ratio of Signal to Noise is higher. Here, the 'signal' is the original image, and the 'noise' is the error in reconstruction. So, if you find a compression scheme having a lower MSE (and a high PSNR), you can recognize that it is a better one.

III. METHODOLOGY

The project contains the following steps:-

1. Applying Morphological operation (Top-Hat & Bottom-Hat Transformation) for image Enhancement.
2. Finding histogram of original and each enhanced image.
3. Enhance via Histogram Equalization. Find and compare PSNR values.

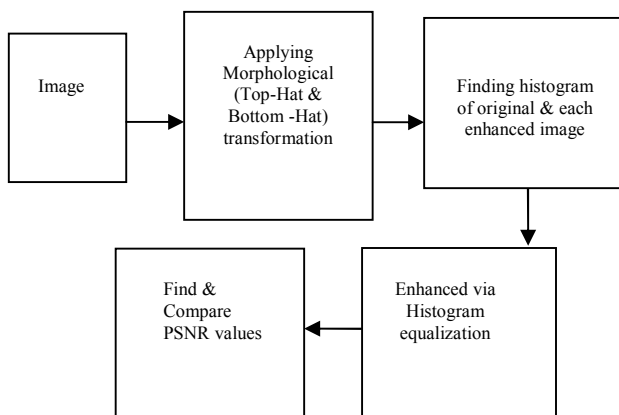


Fig.6: Methodology used for implementation.

IV. IMPLEMENTATION:

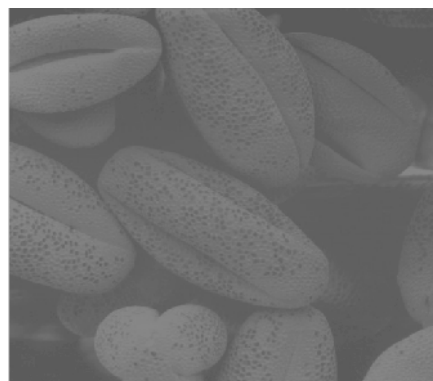


Fig.7: Original Image used in project

Above fig.7 is the original image having very poor contrast. The aim is to enhance the image by changing its contrast using different morphology based contrast enhancement technique.

Below image fig.8: is the result of enhancement in the image after applying Top-Hat Transformation. Top-Hat transformation is one of the contrast enhancement techniques based on morphology.

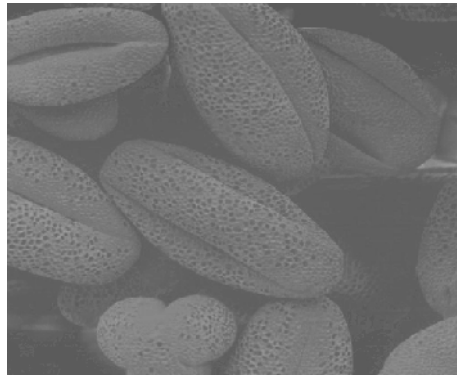


Fig.8: Image after Top-Hat Transformation

Below image fig.9: is the result of enhancement in the image after applying Bottom-Hat Transformation. Bottom-Hat transformation is one of the contrast enhancement techniques based on morphology.

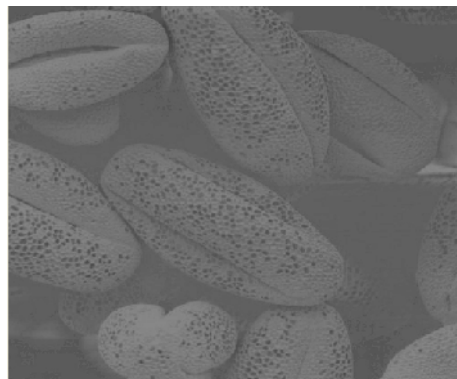


Fig.9: Image after Bottom-Hat Transformation

Below image Fig.10: is the result of enhancement in the image after applying Image after adding then subtracting Top-Hat and Bottom Hat Transformation. So this is the result after applying Both Top-Hat and Bottom Hat Transformation.

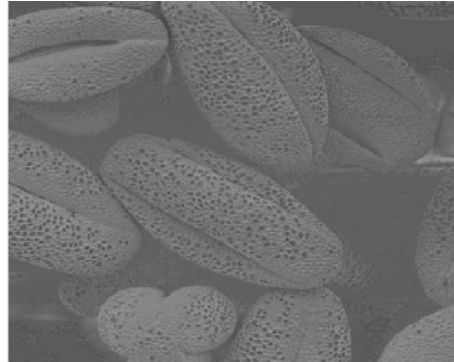


Fig.10: Image after adding then subtracting Top-Hat and Bottom Hat Transformation



Fig.11: Image after Histogram Equalization

Above image Fig.11: is showing the result produced after applying Histogram Equalization technique on original image.

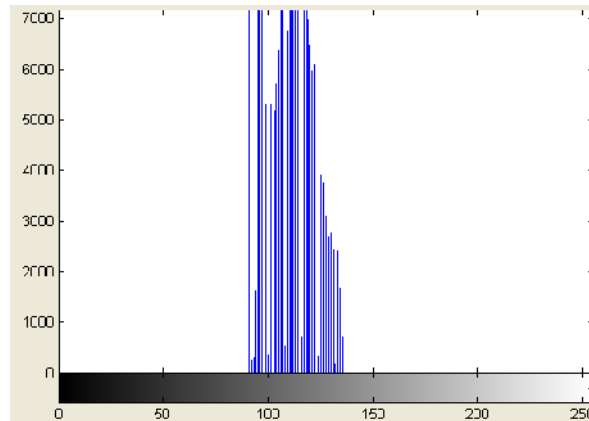


Fig.12: Original Image Histogram

Above image Fig.12: showing the histogram of original image. Below images Fig.13: and Fig.14: showing Histogram of image after Top-Hat Transformation (which is having more Black portion in the image), Histogram of image after Bottom-Hat Transformation (Having less Black Portion in image as compare to fig.13:) respectively. Fig .16: showing Histogram of an image after Histogram Equalization (spread the frequencies.)

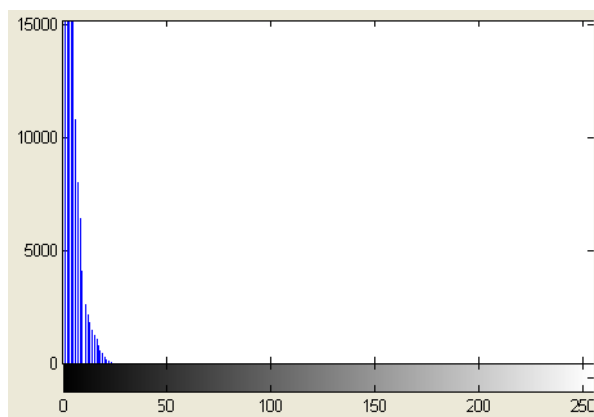


Fig.13: Histogram of image after Top-Hat Transformation

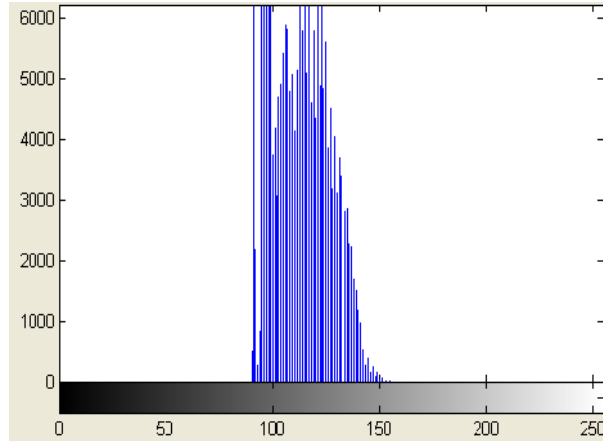


Fig.14: Histogram of image after Bottom-Hat Transformation

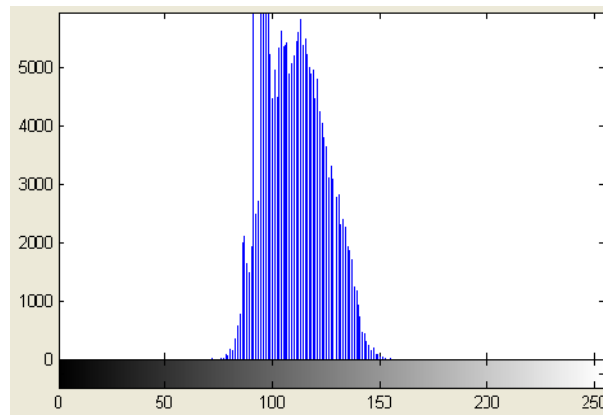


Fig.15: Histogram of an image after Top-Hat & Bottom-Hat Transformation

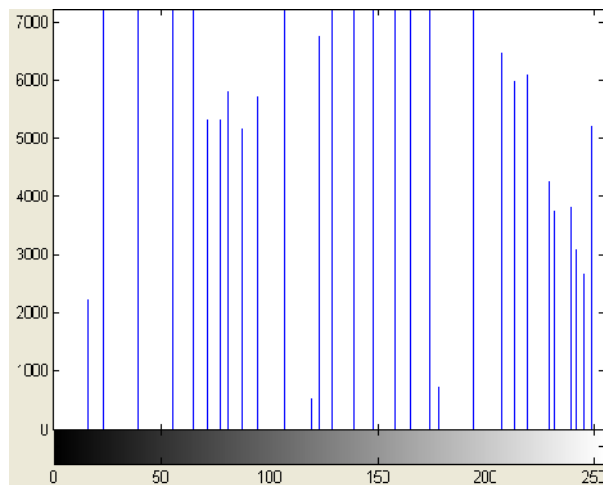


Fig.16: Histogram of an image after Histogram Equalization

Fig.17: mentioned below showing difference between PSNR value of image produced after applying each technique for contrast enhancement.

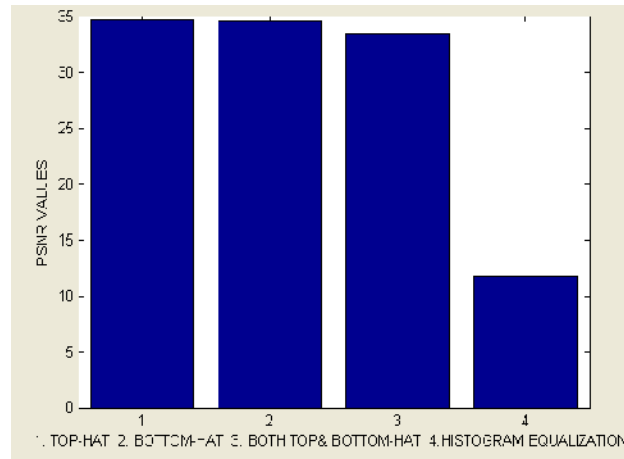


Fig.17: PSNR value comparison of enhanced image produced after applying various contrast enhancement techniques.

CONCLUSION:

Morphology plays very important role in contrast enhancement of an image. By enhancing the contrast we can make lighter portion of an image; darker, darker portion of an image; lighter. So that visibility of that image can be improved. Histogram equalization is also one of the techniques which are used to improve the contrast of an image. It basically varies the frequency of an image all over the plot. But histogram equalization method is not good for all type of images. PSNR is one the matrices which is used to check peak signal to noise ratio, and to judge the better technique from various techniques. The technique whose PSNR ratio is high is better than technique whose PSNR ratio is less.

V.REFERENCES:

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