A Novel Approach for Local Contrast Enhancement of Medical Images using Mathematical Morphology

Ritika

Assistant Professor, Department of Computer Science & Engineering, SSCET, Badhani

***Abstract*— This paper presents a novel approach for enhancing the contrast of medical images using morphology. The proposed method uses multiscale structuring element. White (bright) and black (dark) image regions are extracted at various scales of the image corresponding to different scales of the structuring element. Then, these features are combined with the original image to reconstruct the final enhanced image. The features of the image are clearer on application of the proposed algorithm. Comparisons with the results obtained using other standard methods for contrast enhancements are also discussed in the paper. On comparison with those resulting images, the proposed algorithm gives better visual results.**

***Keywords*— Contrast Enhancement, Mathematical Morphology, Multiscale Morphology, Top Hat Transformation.**

I. Introduction

One of the best techniques for monitoring the person's health condition is Medical Imaging which involves creation of images of the human body for clinical purposes seeking to reveal, diagnose or examine diseases. This helps to detect and diagnose many diseases, so it is widely used nowadays. The information gathered through imaging technique always affects the result of diagnosis. One of the problems that physicians encounter while using medical images is the low quality of the medical images which causes difficulty in diagnosis. Therefore, it is necessary to improve the quality of the medical images. The field of medical Imaging provides a wide scope for research on the development of new algorithms and mathematical tools for the advanced processing of medical and biological images.

Image enhancement is the technique usually adopted for improving the quality of the degraded images. Contrast is one of the aspects of an image for enhancement. Contrast enhancement is used to improve the contrast in an image in order to make various features more easily perceived.

There are two types of contrast in an image: local and global. In certain images, there may be exhaustive utilization of the entire dynamic range of grayscale of the image but the contrast over a small region may be poor. These types of images suffer from poor local contrast. Many contrast enhancement algorithms have been developed over the years. Conventional image enhancement techniques are broadly classified into two categories, including the spatial domain techniques and the frequency domain techniques. Usually, the problem of poor contrast is solved in the spatial domain, by gray level modification or by histogram equalization technique. The conventional histogram equalization technique treats the image globally. This technique has certain drawbacks which are discussed in subsequent sections. This technique is not suitable for local contrast enhancement of images. Local contrast enhancement techniques increase the local contrast of the image while preventing an increase in global contrast thus avoiding over enhancement of the images.

Mathematical morphology provides an excellent tool in image processing based on shape concept from the set theory. It provides a unified and powerful approach to different image processing problems. Mathematical morphology is based on shape concept from the set theory. The identification of objects and object features through their shape makes mathematical morphology become an obvious approach for various machine vision and recognition processes.

This paper presents a novel approach for contrast enhancement using multiscale morphology. The usual notations of digital image processing and mathematical morphology have been adopted. Section II gives a discussion on various techniques for contrast enhancement. mathematical morphology, multiscale morphology and top hat transformation. Section III gives an overview of the literature reviewed for developing the proposed algorithm. Section IV introduces the steps of the proposed algorithm. Section V gives a visualization of the results of computer simulation of the standard enhancement techniques and the proposed technique. Section VI illustrates different experimental results. Section VII compares the proposed algorithm with standard techniques like histogram equalization. Finally, the work is concluded in Section VIII.

II. CONTRAST ENHANCEMENT

Contrast enhancement is a necessary pre-processing step in many image processing algorithms. Contrast is defined as the difference between the highest and lowest intensity values of the image. There are various reasons due to which some images suffer from poor contrast. These factors can be poor illumination, lack of expertise of the operator or adverse external conditions such as foggy weather at the time of image acquisition. These degraded images cannot be successfully used for further analysis or processing by various image processing applications. Contrast enhancement increases the total contrast of an image by making light colours lighter and dark colours darker at the same time.

III. CONTRAST ENHANCEMENT TECHNIQUES

There are several techniques for contrast enhancement of images. Some techniques are used for enhancing the local contrast and some are used for enhancing the global contrast of the images. The suitability or performance of these techniques depends on the quality of the image to be enhanced.

A. Histogram Equalization

Histogram Equalization is one the most well-known methods for contrast enhancement. Such an approach is generally useful for images with poor intensity distribution. This technique is commonly employed for image enhancement because of its simplicity and comparatively better performance on almost all types of images. The operation of HE is performed by remapping the gray levels of the image based on the probability distribution of the input gray levels. It flattens and stretches the dynamic range of the image's histogram and resulting in overall contrast enhancement. However, histogram equalization suffers from major drawbacks especially when implemented to process digital images. Firstly, histogram equalization transforms the histogram of the original image into a flat uniform histogram with a mean value that is in the middle of gray level range. Accordingly, the mean brightness of the output image is always at the middle – or close to it in the case of discrete implementation – regardless of the mean of the input image. For images with high and low mean brightness values, this means a significant change in the image outlook for the price of enhancing the contrast. Secondly, histogram equalization performs the enhancement based on the global content of the image and in its discrete version large bins cannot be broken and redistributed to produce the desired uniform histogram In other words, histogram equalization is powerful in highlighting the borders and edges between different objects, but may reduce the local details within these objects, especially smooth and small ones. Another consequence for this mergence between large and small bins is the production of over enhancement and saturation artifacts [6]. Some researchers have also focused on improvement of the conventional histogram equalization.

B. Mathematical Morphology

Conventional techniques for contrast enhancement such as histogram equalization suffer from various drawbacks as discussed earlier. Morphology offers a unified and powerful approach to different image processing problems. This approach is based on the concepts from set theory. In morphology, objects present in an image are treated as sets. All morphology algorithms are based on operations between two sets: the image or some part of the image and the second set is the structuring element. Structuring element (SE) is applied to an input image, creating an output image of the same size. The shape and size of the SE is defined according to the purpose of the associated application. There are two fundamental morphological operations: Dilation and erosion.

1) Dilation and Erosion

There are two other important morphological operations, opening and closing that are formed through the combination of Erosion and Dilation. Opening is defined as erosion, followed by dilation and Closing is defined as dilation, followed by erosion.

Mathematically, the dilation and erosion operation on a grayscale image $f(x, y)$ by a structuring element g are defined as follows:

$$\text{Dilation}(f, g) = \max\{f(x-k, y-l) \mid (k, l) \in g\} \quad (1)$$

$$\text{Erosion}(f, g) = \min\{f(x+k, y+l) \mid (k, l) \in g\} \quad (2)$$

The opening and closing operations are defined as follows:

$$(f \circ g) = \text{Dilation}(\text{Erosion}(f, g), g) \quad (3)$$

$$(f \bullet g) = \text{Erosion}(\text{Dilation}(f, g), g) \quad (4)$$

Where f is the gray scale image and g is the structuring element, o denotes the opening operation and ● denotes the closing operation.

The shape of the structuring element g plays a crucial role in extracting features or objects of given shape from the image. However, for a categorical extraction of features or objects from the image based on shape and size we must incorporate a second attribute to the structuring element which is its scale. A morphological operation with a scalable structuring element can extract features based not only on shape but also on size. Also features of identical shape but of different size are now treated separately. Such a scheme of morphological operations where a structuring element of varying scale is utilized is termed as multiscale morphology [ ].

2. Multiscale Morphology

Multiscale morphology is used to perform morphological operations on the image at various scales corresponding to the size of the structuring element.

Multiscale opening and closing operations are defined, respectively as:

$$(f \bigcirc g) = \text{Dilation}(\text{Erosion}(f, ng), ng) \quad (5)$$

$$(f \bullet g) = \text{Erosion}(\text{Dilation}(f, ng), ng) \quad (6)$$

where f represents the image, g is structuring element and n is the scale of the structuring element. ng is obtained by dilating g recursively n - 1 times with itself.

3. Multiscale Top Hat Transformation

The top hat transform is one of the important operations of mathematical morphology used to extract image features related to the used structuring element. The top hat transform has two versions: white top hat and black top hat transformation. The white top hat transform (*WTH*) is used to extract bright or white features of image related to the used structuring element. It is given as the difference of the original image and the opened image. It is defined as:

$$WTH(f) = f - (f \bigcirc g) \quad (7)$$

where f is the image and g is the structuring element.

Similarly, the black top hat transformation is used to extract the darker or black features of image related to the used structuring element. The black top hat transform (*BTH*) is the difference between the closed image and the original image. It is defined as:

$$BTH(f) = (f \bullet g) - f \quad (8)$$

On extending the above concepts using multiscale morphology, structuring element at different scales can be used to extract scale-specific bright (dark) features from the image. The multiscale top hat transforms are described as follows:

$$WTH(f) = f - (f \bigcirc ng) \quad (9)$$

$$BTH(f) = (f \bullet ng) - f \quad (10)$$

where, g is a structuring element of a definite shape and n is the integer representing the scale factor of the structuring element.

A basic idea of image enhancement is to enlarge the contrast between the white and black regions of image. Then, one way of image enhancement based on top-hat transform is adding the white image regions on and subtracting the black image regions from the original image as follows:

$$f_{En}= f + f_w - f_b \quad (11)$$

where, f is the original image. f_{En} is the final enhanced image. f_w represents the extracted white image regions. f_b represents the extracted black image regions.

IV. LITERATURE SURVEY

Bai and Zhou (2010) in their paper, "Multi Structuring Element Top-hat Transform to Detect Linear Features" proposed a multi structuring element top hat transform for detaecting the linear features of the image at various scales. [1]

Bai and Zhou (2010) in their paper, "Multi Scale Top-hat Transform Based Algorithm for Image Enhancement" proposed a multi scale top-hat transform based algorithm for efficiently enhancing images. [2]

Bai and Zhou (2010) in their paper, "Unified Form for Multi-Scale Top-hat Transform Based Algorithms" proposed a unified form of multiscale top hat transform based approach that would simplify the algorithm design using parallel property and through the selection of certain variables. [3]

Boccigone and Picariello (1997) in their paper, "Multiscale Contrast Enhancement of Medical Images", presented a multiscale contrast enhancement method using anisotropic diffusion. [4].

Derong et al. (2005) in their paper, "Fast Computation of Multiscale Morphological Operations for Local Contrast Enhancement" improved an existing method by using few feature levels in an efficient way. In the method proposed in this paper, black features have been removed. [6]

Kaur et al. (2011) in their paper, "Survey of Contrast Enhancement Techniques based on Histogram Equalization" presented a review of various techniques based on Histogram Equalization and their drawbacks. [7]

Kimori Yoshitaka (2011) in the paper, "Mathematical morphology-based approach to the enhancement of morphological features in medical images" proposed a new method for enhancing morphological features of masses and other abnormalities in medical images. [8]

Mukhopadhyay and Chanda (2000) in their paper, "Local Contrast enhancement of Grayscale Images using Multiscale Morphology" presented a method for local enhancement of a gray-level image using multiscale morphology.[9]

Mukhopadhyay and Chanda (2000) in their paper, "A multiscale morphological approach to local contrast enhancement" proposed a new scheme for enhancing local contrast of images using multiscale morphology. [10]

Stojic and Reljin (2005) in their paper, "Local Contrast Enhancement of Digital Mammography by using Mathematical Morphology" proposed a new algorithm for local contrast enhancement and background texture suppression in digital mammographic images. [11]

Sun and Sang (2003) in their paper, "Enhancement of Vascular Angiogram by Multiscale Morphology" presented a new scheme for local contrast enhancement of coronary artery based on multiscale morphology. [12]

Wei et al. (2007) in their paper, "X-ray Image Enhancement Based on Multiscale Morphology" presented a method for enhancing x-ray images using multiscale morphology with multi scale structuring elements. [13]

Wenzhong Yan (2009) in the paper, "Mathematical Morphology based Enhancement for Chromosome images" proposed an enhancement algorithm for enhancing chromosome images using mathematical morphology. [14]

Wirth et al. (2004) in their paper, "Contrast enhancement of microcalcifications in mammograms using morphological enhancement and non-flat structuring elements" presented an approach to enhancing the contrast of microcalcifications using non-flat structuring elements. [15]

Zadorozony and Zhang (2009) in their paper, "Contrast Enhancement using Morphological Scale Space" introduced a new morphology based contrast enhancement algorithm designed specifically for segmentation applications in which an image contains multiple objects of different sizes. [16]

V. PROPOSED ALGORITHM

In mathematical morphology, the contrast of an image is enhanced by using the top hat transformation. The top hat transformation is used to extract the white and black features of the image. The proposed algorithm is used for enhancing the contrast of the image by extracting the features at different scales of the image using top hat transformation.

Suppose, there is a sequence of multiscale structuring elements with the same shape and increasing sizes: g_0, g_1, $g_2,\ldots,g_m$, where g_i is obtained as the result of i times the dilation of g_0 with g_0 , $1\leq i \leq m$. The white *(WTH)* and black *(BTH)* image regions at the ith scale can be extracted as follows. [ ].

$$WTH_i = f - (f \circ g_i) \quad (12)$$

$$BTH_i = (f \bullet g_i) - f \quad (13)$$

The proposed algorithm works through the extraction of two types of features from the image: multiscale image regions at each scale and multiscale image regions between neighboring scales.

The first type of multi scale image features is the extracted multi scale image regions at each scale. At each scale, the white and black image regions are first extracted through the top hat transformation as given in Eq (12) and (13). Compute the sum of white and black image regions extracted separately at all scales as follows.

$$fwc = \sum_{i=1}^{m} WTH_i \quad (14)$$

$$fbc = \sum_{i=1}^{m} BTH_i \quad (15)$$

where, *fwc* is the extracted white multi scale image regions and *fbc* is the extracted black multi scale image regions at all scales.

The second type of multi scale image regions is extracted between neighboring scales. The white and black detail image regions between neighboring scales *i* and *i*+1 can be expressed as follows. [2].

$$WTH_{i(i+1)} = WTH_{i+1} - WTH_i \quad (16)$$

$$BTH_{i\,(i+1)} = BTH_{i+1} - BTH_i \quad (17)$$

Now, again compute the sum of white and black image regions between all neighboring scales, respectively. This is done as follows.

$$fwd = \sum_{i=1}^{m} WTH_{i(i+1)} \quad (18)$$

$$fbd = \sum_{i=1}^{m} BTH_{i(i+1)} \quad (19)$$

where, *fwd* represents the final multi scale white detail image regions and *fbd* represents the final black detail image regions.

In the next step, add the both type of regions i.e. the image regions extracted at all scales with the image extracted between neighboring scales.

$$fw = (0.5)*(fwc + fwd) \quad (20)$$

$$fb = (0.5)*(fbc + fbd) \quad (21)$$

where *fw* denote the final white regions and *fb* denote the final black regions.

The contrast of an image can be enhanced by adding the white regions and subtracting the black regions from the original image as given in Eq (11). Using the same approach, the final extracted white and black image regions given by *fw* and *fb* in Eqs (20) and (21), the image *f* could be enhanced as follows.

$$f_r = f + fw - fb \quad (22)$$

where f_r denotes the resulting enhanced image obtained using the proposed algorithm.

VI. FLOWCHART

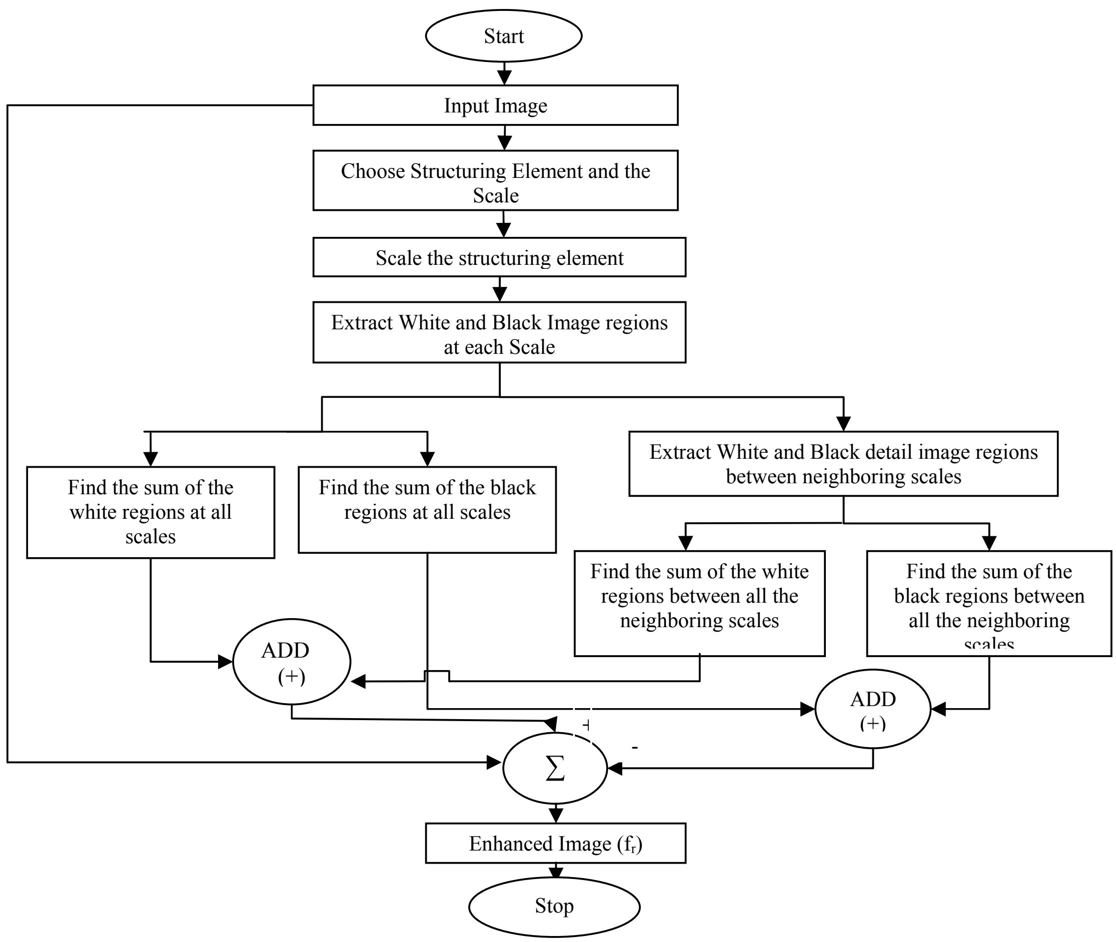
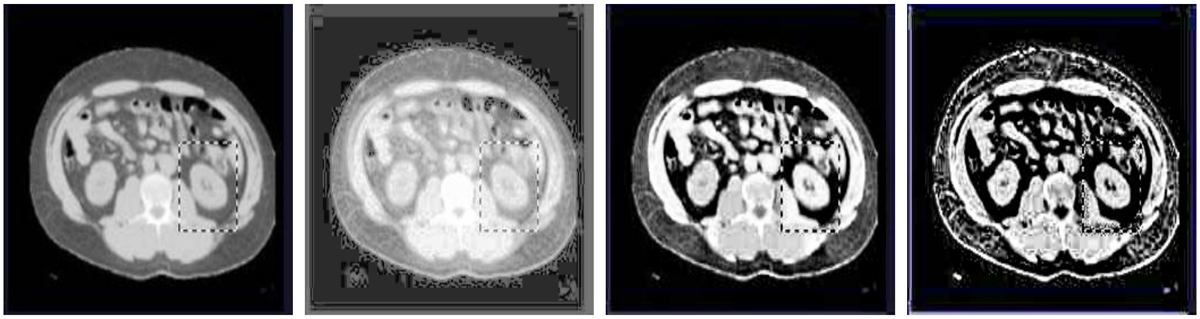


Fig 1: Flowchart of the proposed Algorithm

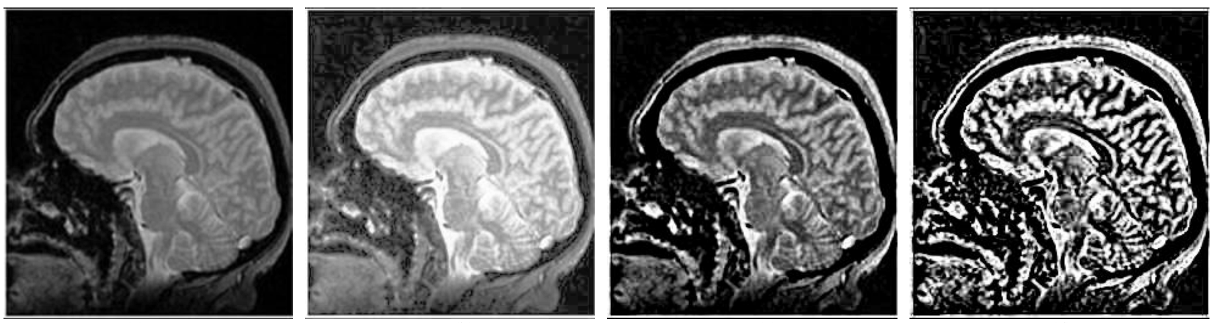
VI. COMPUTER SIMULATED RESULTS

The proposed algorithm has been tested on a set of medical images and the results have been compared with that of other techniques like histogram equalization.



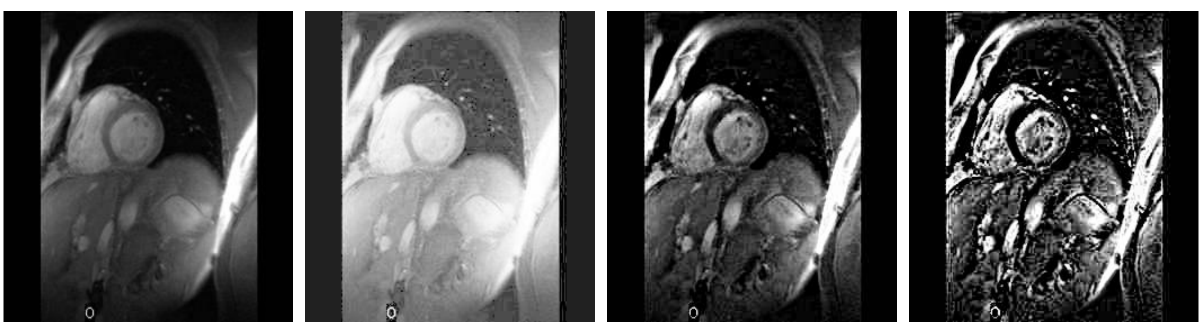
(a) (b) (c) (d)

Fig 2. Contrast Enhancement of synthetic image of kidney taken from [5]. (a) Original Image; (b) Enhancement using Histogram Equalization; (c) Morphological Enhancement using Multiscale Morphology as proposed by Bai and Zhou; (d) Enhancement using proposed algorithm.



(a) (b) (c) (d)

Fig. 3. Contrast Enhancement of image of human brain. (a) Original Image; (b) Enhancement using Histogram Equalization; (c) Morphological Enhancement using Multiscale Morphology as proposed by Bai and Zhou; (d) Enhancement using proposed algorithm.



(a) (b) (c) (d)

Fig. 4. Contrast Enhancement of cardiac image. (a) Original Image; (b) Enhancement using Histogram Equalization; (c) Morphological Enhancement using Multiscale Morphology as proposed by Bai and Zhou; (d) Enhancement using proposed algorithm.

VII. DISCUSSION OF RESULTS

The proposed algorithm has been implemented on MATLAB and the shape of the structuring element used is "disk", the size of g_0 is 1 and the scale, m=6.

Fig. 2, Fig. 3 and Fig. 4 shows the visual results of the implementation and execution of various enhancement techniques on the medical images. The original image is not very clear. It is of poor local contrast as the objects in the image are not easily perceivable. Histogram Equalization has been used to enhance the contrast of the original image, but the details of the white region get over enhanced and the image worsens. The Multiscale morphology method proposed by Bai and Zhou is efficient in enhancing the images but there is still some scope left for contrast enhancement in certain regions. The proposed algorithm gives better results in terms of contrast enhancement of the images avoiding the over enhancement. The techniques are also tested for a synthetic image [5] as given in Fig 2. There is a major improvement in the local contrast of the image using the proposed algorithm as compared to other techniques.

Hence, the proposed algorithm is the best method for local contrast enhancement as compared to other techniques

VIII. CONCLUSION

In this paper, I propose a novel scheme for contrast enhancement of medical images using multiscale morphology. This method extracts the white and black image regions at various scales. Then the white and black image regions are combined with the original image to obtain an image whose local contrast is enhanced. The proposed algorithm has been implemented and executed on a set of gray-scale medical images including a synthetic image obtained through Monte Carlo Simulation method as given in [ ]. The results have been compared with those of various standard methods like histogram equalization. The results due to the proposed method have been found reasonably satisfactory. However, there is slight amplification of noise which can be reduced in future and this algorithm can be further extended through the use of non-flat structuring elements.

REFERENCES

[1] Bai X, Zhou F, “Multi Structuring Element Top-hat Transform to Detect Linear Features”, ICSP 2010 Proceedings, pp.877- 880.

[2] Bai X, Zhou F, “Multi Scale Top-hat Transform Based Algorithm for Image Enhancement”, ICSP2010 Proceedings, IEEE, pp.797-800.

[3] Bai X, Zhou F, “ Unified Form for Multi-Scale Top-hat Transform Based Algorithms”, 3rd International Congress on Image and Signal Processing, IEEE, pp.1097-1100.,2010.

[4] Boccigone G, Picariello A, “Multiscale Contrast Enhancement of Medical Images”, IEEE, pp. 2789-2792, 1997.

[5] Chen J. Z, Pizer S. M, Chaney E. L and Joshi S, “Medical Image Synthesis via Monte Carlo Simulation” MICCAI, 2002, pp. 347-354.

[6] Derong, Y, Yuanyuan Z, Dongguo L, “Fast Computation of Multiscale Morphological Operations for Local Contrast Enhancement”, Proceedings of the 2005 IEEE, pp.3090-3092.

[7] Kaur M,Kaur J,Kaur J, “Survey of Contrast Enhancement Techniques based on Histogram Equalization” , IJACSA, Vol. 2, No. 7, 2011, pp. 137-141.

[8] Kimory Y, “Mathematical morphology-based approach to the enhancement of morphological features in medical images” Journal of Clinical Bioinformatics, 2011, pp.1-10.

[9] Mukhopadhyay S, Chanda B, “Local Contrast Enhancement of Grayscale Images using Multiscale Morphology”, 2000.

[10] Mukhopadhyay S, Chanda B, “A multiscale morphological approach.to local contrast enhancement”, Signal Processing, pp.685-696, 2000.

[11] Stojic T, Reljin I., “Local Contrast Enhancement of Digital Mammography by using Mathematical Morphology”, IEEE, 2005.

[12] Sun K, Sang N, “Enhancement of Vascular Angiogram by Multiscale Morphology”, IEEE, pp.1311-1313, 2003.

[13] Wei Z, Hua Y, Hui-Sheng S, Hong-Qi F, “X-ray Image Enhancement Based on Multiscale Morphology”, IEEE, 2007, pp. 702-705.

[14] Wenzhong Y. (2009), “|Mathematical Morphology Based Enhancement for Chromosome Images”, IEEE, pp.1-3.

[15] Wirth M, Fraschini M, Lyon J, “Contrast Enhancement of micro calcifications in mammograms using morphological enhancement and non-flat structuring elements”, Proceedings of the 17th IEEE Symposium on Computer-based Medical systems, 2004.

[16] Zadorozony A, Zhang H, “Contrast Enhancement using Morphological Scale Space”, Proceedings of the IEEE International Conference on Automation and Logistics, pp.804-807, 2009.