Volume 3, Issue 4, April 2013 ISSN: 2277 128X

International Journal of Advanced Research in Computer Science and Software Engineering

Research Paper

Available online at: www.ijarcsse.com

Improved Colour Image Enhancement Scheme using Mathematical Morphology

C. Vaishnavi[*],
Department of Computer Science and Engineering,
Alagappa University
Karaikudi, India

Dr. P. Eswaran
Department of Computer Science and Engineering,
Alagappa University
Karaikudi, India

Abstract— ***This research work deals with enhancement which is used to detect the background in color images characterized by poor contrast. Image enhancement has been carried out by the two methods based on the Weber's law notion. The first method employs information from image background analysis by blocks, while the second transformation method utilizes the opening operation, closing operation, which is employed to define the multi-background colour images. Morphological transformations (Opening by reconstruction, Erosion-Dilation method) and Block Analysis is used to detect the background of colour images. Filtering the salt and pepper noise during the time of background detection .For aiding better results, the compressed domain (DCT) technique is used exclusively for color image enhancement. The results of each technique are illustrated for various backgrounds, majority of them in poor lighting condition. Finally calculate the simulation time for each working sectors. The complete image processing is done using MATLAB simulation model.***

Keywords— ***Image Background Analysis, weber's law notion, opening operation, closing operation, Erosion-dilation method***

1. INTRODUCTION

The image enhancement problem in digital images can be approached from various methodologies, among which is mathematical morphology (MM). Such operators consist in accordance to some proximity criterion, in selecting for each point of the analysed image, a new grey level between two patterns (primitives). Even though morphological contrast has been largely studied, there are no methodologies, from the point of view MM, capable of simultaneously normalizing and enhancing the contrast in images with poor lighting. On the other side, one of the most common techniques in image processing to enhance dark regions is the use of nonlinear functions, such as logarithm or power functions ; otherwise, a method that works in the frequency domain is the homomorphism filter. However, the main disadvantage of histogram equalization is that the global properties of the image cannot be properly applied in a local context, frequently producing a poor performance in detail preservation. In a method to
enhance contrast is proposed; the methodology consists in solving an optimization problem that maximizes the average local contrast of an image. This paper deals with the detection of background in images with poor contrast. The complete image processing is done using MATLAB simulation model.

The optimization formulation includes a perceptual constraint derived directly from human super threshold contrast sensitivity function. The authors apply the proposed operators to some images with poor lighting with good result. In this way, even though the reported algorithms to compensate changes in lighting are varied, some are more adequate than others. In this work, two methodologies to compute the image background are proposed. Also, some operators to enhance and normalize the contrast in grey level images with poor lighting are introduced. Contrast operators are based on the logarithm function in a similar way to Weber's law the use of the logarithm function avoids abrupt changes in lighting. Also, two approximations to compute the background in the processed images are proposed. The first proposal consists in an analysis by blocks, whereas in the second proposal, the opening by reconstruction is used given its following properties:

- It passes through regional minima, and
- It merges components of the image without considerably modifying other structures.
- Filtering the noise from the background detected images.
- Calculating the simulation time for each working sector

Morphological transformation and Weber's law presents a brief background on Weber's law and some morphological transformations. Image background approximation to the background by means of block analysis in conjunction with transformations that enhance images with poor lighting. The multi-background notion is introduced by means of the opening by reconstruction. A comparison among several techniques to improve contrast in images. Finally, conclusions are presented. The aim of the paper is to detect the background image and enhance the contrast in color image with poor lighting. First operator applies information from block analysis and second operator's uses opening by reconstruction.

1.1 An analysis of related work

The range of intensity i.e. the difference between highest and lowest intensity values in an image gives a measure of its contrast. There are standard techniques like histogram equalization, histogram stretching for improving the poor contrast of the degraded image[4]. However there is a need for devising context-sensitive techniques based on local contrast variation since the image characteristics differ considerably from one region to another in the same image and also the local histogram does not necessarily follow the global histogram. The enhancement level is not significant and provides good results only for certain images but fails to provide good results for most of the images, especially those taken under poor lighting. In other words, it doesn't provide good performance for detail preservation[2].

In a method to enhance contrast is existed only; the methodology consists in solving an optimization problem that maximizes the average local contrast of an image [1]. The optimization formulation includes a perceptual constraint derived directly from human threshold contrast sensitivity function. The authors apply the proposed operators to some images with poor lighting with good results [2]. On the other hand a methodology to enhance contrast based on statistics grey scale from a training set of images which look visually appealing is presented. Here, the basic idea is to select a set of training images which look good perceptually

Drawbacks:

1. Using grey-scale images and then extended to color images
2. Time complexity.
3. Noise will be occurs at the time of reconstruction.

2. Proposed work

This proposed work can detect the image background also can enhance the contrast in color images with poor lighting. For background detection two methodologies are used. One is image background detection by blocks. Secondly morphological transformations such as opening by reconstruction are used. Morphological contrast enhancement transformations based on Weber's law, which normalize the color image intensities and avoid sudden changes in illumination. Mean filtering is a common image enhancement technique for removing salt and pepper noise. Because this filtering is less sensitive than linear techniques to extreme changes in pixel values, it can remove salt and pepper noise without significantly reducing the sharpness of an image. In this topic, use the contra-Harmonic Mean Filter block to remove salt and pepper noise from an intensity image. This research work will be reducing the time complexity of color image enhancement. Finally calculate the simulation time for each working sector and then compare to existing work. In this way, even though the reported algorithms to compensate changes in lighting are varied, some are more adequate than others.

2. Morphological Transformations And Weber's Law

2.1. Morphology

Morphology is a technique of image processing based on shape and form of objects. Morphological methods apply a structuring element to an input image, creating an output image at the same size. The value of each pixel in the input image is based on a comparison of the corresponding pixel in the input image with its neighbours. By choosing the size and shape of the neighbour, you can construct a morphological operation that is sensitive to specific shapes in the input image. The morphological operations can first be defined on color images where the source image is planar .

2.2. Morphological Operations

Morphological operations such as erosion, dilation, opening, and closing. Often combinations of these operations are used to perform morphological image analysis. There are many useful operators defined in mathematical morphology. They are dilation, erosion, opening and closing. Morphological operations apply structuring elements to an input image, creating an output image of the same size. Irrespective of the size of the structuring element, the origin is located at its Centre. Morphological opening is $\gamma\mu\beta\,(f)(x)$ and Morphological closing is $\varphi\,\mu\beta\,(f)(x)$ [14]

$$\gamma_{\mu\beta}(f)(x) = \delta_{\mu\beta}(\varepsilon_{\mu\beta}(f))(x)$$

$$\varphi_{\mu\beta}(f)(x) = \varepsilon_{\mu\beta}(\delta_{\mu\beta}(f))(x)$$

Where μ a homothetic parameter, size is μ means a square of $(2\mu+1)\times(2\mu+1)$ pixels. B is the structuring element of size 3×3 (here $\mu = 1$).

MATHEMATICAL MORPHOLOGY

A shape (in blue) and its morphological dilation (in green) and erosion (in yellow) by a diamond-shape structuring element.

Topological and geometrical continuous-space concepts such as size, shape, convexity, connectivity, and geodesic distance, were introduced by MM on both continuous and discrete spaces. MM is also the foundation of morphological image processing, which consists of a set of operators that transform images according to the above characterizations MM was originally developed for gray scale images, and was later color functions and images. The subsequent generalization to complete lattices is widely accepted today as MM's theoretical foundation.

Erosion

The erosion of the color image *A* by the structuring element *B* is defined by:

$$A \ominus B = \{z \in E | B_z \subseteq A\}, \qquad \text{…….. (1)}$$

where B_z is the translation of *B* by the vector *z*, i.e.,

$$B_z = \{b + z | b \in B\}, \forall z \in E \qquad \text{……….(2)}$$

When the structuring element *B* has a center (e.g., *B* is a disk or a square), and this center is located on the origin of *E*, then the erosion of *A* by *B* can be understood as the locus of points reached by the center of *B* when *B* moves inside *A*. For example, the erosion of a square of side 10, centered at the origin, by a disc of radius 2, also centered at the origin, is a square of side 6 centered at the origin.

The erosion of *A* by *B* is also given by the expression:

$$A \ominus B = \bigcap_{b \in B} A_{-b}. \qquad \text{……….(3)}$$

Example application: Assume we have received a fax of a dark photocopy. Everything looks like it was written with a pen that is bleeding. Erosion process will allow thicker lines to get skinny and detect the hole inside the letter "o".

Dilation

The dilation of *A* by the structuring element *B* is defined by:

$$A \oplus B = \bigcup_{b \in B} A_b \qquad \text{…………(4)}$$

The dilation is commutative, also given by:

$$A \oplus B = B \oplus A = \bigcup_{a \in A} B_a \qquad \text{…..(5)}$$

If *B* has a center on the origin, as before, then the dilation of *A* by *B* can be understood as the locus of the points covered by *B* when the center of *B* moves inside *A*. In the above example, the dilation of the square of side 10 by the disk of radius 2 is a square of side 14, with rounded corners, centered at the origin. The radius of the rounded corners is 2.

The dilation can also be obtained by:

$$A \oplus B = \{z \in E | (B^s)_z \cap A \neq \varnothing\}, \qquad \text{…………(6)}$$

where B^s denotes the symmetric of *B*, that is,

$$B^s = \{x \in E | -x \in B\} \qquad \text{…………..(7)}$$

Example application: Dilation is the dual operation of the erosion. Figures that are very lightly drawn get thick when "dilated". Easiest way to describe it is to imagine the same fax/text is written with a thicker pen.

Opening

The opening of *A* by *B* is obtained by the erosion of *A* by *B*, followed by dilation of the resulting image by *B*:

$$A \circ B = (A \ominus B) \oplus B \qquad \text{…………….(8)}$$

The opening is also given

$$A \circ B = \bigcup_{B_x \subseteq A} B_x \qquad \text{…………..(9)}$$

by which means that it is the locus of translations of the structuring element *B* inside the image *A*. In the case of the square of side 10, and a disc of radius 2 as the structuring element, the opening is a square of side 10 with rounded corners, where the corner radius is 2.

Example application: Let's assume someone has written a note on a non-soaking paper and that the writing looks as if it is growing tiny hairy roots all over. Opening essentially removes the outer tiny "hairline" leaks and restores the text. The side effect is that it rounds off things. The sharp edges start to disappear.

Closing

The closing of *A* by *B* is obtained by the dilation of *A* by *B*, followed by erosion of the resulting structure by *B*:

$$A \bullet B = (A \oplus B) \ominus B. \qquad \text{……..(10)}$$

The closing can also be obtained by

$$A \bullet B = (A^c \circ B^s)^c, \qquad \text{……….(11)}$$

where X^c denotes the complement of *X* relative to *E* (that is, $X^c = \{x \in E | x \notin X\}$).

The above means that the closing is the complement of the locus of translations of the symmetric of the structuring element outside the image *A*.

The dilation is associative, i.e.,

$$(A \oplus B) \oplus C = A \oplus (B \oplus C)$$ ……(12) Moreover, the erosion satisfies

$$(A \ominus B) \ominus C = A \ominus (B \oplus C)$$ ….(13)

Erosion and dilation satisfy the duality $A \oplus B = (A^c \ominus B^s)^c$ …………(14)

Opening and closing satisfy the duality $A \bullet B = (A^c \circ B^s)^c$.

- Opening is anti-extensive, i.e., $A \circ B \subseteq A$, whereas the closing is extensive, i.e., $A \subseteq A \bullet B$.

Weber's Law

The study of contrast sensitivity has dominated visual perception research. In psycho-visual studies, the contrast C of an object with luminance L max against its surrounding luminance L min is defined as follows[3] ;

$$C= \frac{L\max \quad L\min}{L\min}$$ ……(15)

C – Contrast of the image, L max - Luminance of the image and L min – Luminance of the Surroundings

If $L\min = L$ and $\Delta L = L\max - L\min$, (8) can be rewritten as

$$C= \frac{\Delta L}{L}$$ …………(16)

On the other hand, in, a methodology to compute the background parameter was proposed. The methodology consists in calculating the average between the smallest and largest regional minima. However, the main disadvantage of this proposal is that the image background is not detected in a local way. As a result, the contrast is not correctly enhanced in images with poor lighting, since considerable changes occur in the image background due to abrupt changes in luminance.

In this paper, an approximation to Weber's law is considered by taking the luminance L as the grey level intensity of a function (image); Δ (log L) is proportional to C ; therefore Weber's law can be expressed as

$$C = k \log L + b \qquad L > 0$$ ………(17)

This law has a logarithmic relation. This technique is applied to image processing to enhance the image effectively. Where 'C' is the contrast, 'k' and 'b' are constants, 'b' being the background parameter and 'k' being the scaling factor for enhancement. Weber's law can be best understood from the following example. Consider a photo taken in a dark room. The obtained photo actually consists of 2 different things. One is what we visually perceive in that image and the other is what is actually present in that image. Weber's law simply states that the relation between these two is logarithmic.

In our case, an approximation to Weber's law is considered by taking the luminance L as the grey level intensity of a function (image); in this way, expression is written as

$$C = k \log f + b \qquad f > 0$$ ……….(18)

3. Image Background Analysis By Blocks

Morphological transformations (Opening by reconstruction, Erosion-Dilation method) and Block Analysis is used to detect the background of grey level and colour images. These techniques are first implemented in grey scale and are then extended to colour images by individually enhancing the colour components. For aiding better results, the compressed domain (DCT) technique is used exclusively for colour image enhancement. The major advantage of the DCT method is that it can be used for any type of illumination. In all the above methods, the enhancement of the background detected image is done using Weber's law (modified Weber's law for compressed domain) a critical analysis of the various advantages and drawbacks in each method are performed and ways for overcoming the drawbacks are also suggested.

Here, the results of each technique are illustrated for various backgrounds, majority of the minimum poor lighting condition [6]. In image acquisition, background detection is necessary in many applications to get clear and useful information from an image which may have been pictured in different conditions like poor lighting or bright lighting, moving or still etc. This Section deals with background analysis of the image by blocks. In this project, D represent the digital space under study, with $D = Z * Z$ and Z and Z is the integer set. For each analysed block, maximum ($M\ i$) and minimum ($m\ i$) values are used to determine the background measures. τi is used to select the background parameters. Background parameters lie between clear ($f > \tau\ i$) and dark ($f \le \tau\ i$) intensity levels. If ($f \le \tau\ i$) is the dark region then background parameters takes the maximum intensity levels ($M\ i$) then ($f > \tau\ i$) is the clear region, background parameters takes the minimum intensity levels ($m\ i$).

Enhance images are we get after applying the below equation

$$\Gamma_{\tau(x)}(f) = \begin{cases} k_{\tau(x)} \log(f+1) + \delta_\mu(f)(x), & f \leq \tau(x) \\ k_{\tau(x)} \log(f+1) + \delta_\mu(f)(x), & \text{otherwise} \end{cases}$$

and

$$k_\tau(x) = \frac{255 - \tau(x)}{\log(256)}$$

δ - Dilation operation, ε - Erosion operation

Dilation and erosion are the two most common morphological operations used for back ground analysis by blocks.

3.1. Block Analysis for color images

Let f be the original image which is subdivided into number of blocks with each block is the sub-image of the original image. For each and every block n, the minimum intensity m_i and maximum intensity M_i values are calculated m_i and M_i values are used to find the background criteria τ_i in the following way [2]:

$$\tau_i = \frac{m_i + M_i}{2} \qquad \forall i = 1,2,3\ldots\ldots\ldots\ldots n$$

τ_i is used as a threshold between clear ($f > \tau_i$) and dark ($f = \tau_i$) intensity levels. Based on the value of τ_i , the background parameter is decided for each analyzed block. Correspondingly the contrast enhancement is expressed as follows:

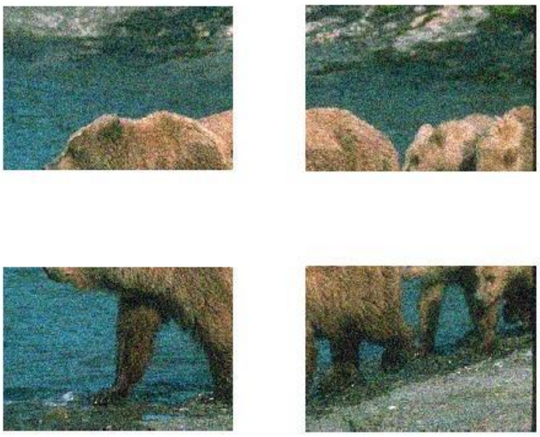
$$\Gamma_{\tau_i}(f) = \begin{cases} k_i \log(f+1) + M_i, & f \leq \tau \\ k_i \log(f+1) + m_i, & \text{otherwise} \end{cases} \qquad \ldots\ldots\ldots\ldots(19)$$

It is clear that the background parameter entirely is dependent up on the background criteria τ_i value. For $f = \tau_i$, the background parameter takes the maximum intensity value M_i within the analysed block, and the minimum intensity value m_i otherwise. In order to avoid in determination condition, unit was added to the logarithmic function

$$\textit{Where} \quad k_i = \frac{255 - m_i^*}{\log(256)} \qquad \forall i = 1,2,3\ldots\ldots\ldots, n \qquad \ldots\ldots\ldots\ldots(20)$$

$$\textit{With} \quad m_i^* = \begin{cases} M_i, & f \leq \tau_i \\ m_i, & f \geq \tau_i \end{cases} \qquad \ldots\ldots\ldots\ldots(21)$$

The more is the number of blocks; the better will be quality of the enhanced image. In the enhanced images, it can be seen that the objects that are not clearly visible in the original image are revealed. As the size of the structuring element increases it is hard to preserve the image as blurring and contouring effects are severe. The results are best obtained by keeping the size of the structuring element as 2 (μ=2). Sample output image.



4. Reconstruction Of Color Images

This method is similar to block analysis in many ways; apart from the fact that the manipulation is done on the image as a whole rather than partitioning it into blocks. Firstly minimum Imin (x) and maximum intensity I max (x) contained in a structuring element (B) of elemental size 3 × 3 is calculated. The above obtained values are used to find the background criteria τ_i as described below

$$\tau(x) = \frac{I_{\min}(x) \;\; I_{\max}(x)}{2} \qquad \ldots\ldots.(22)$$

Where I min (x) and I max (x) corresponds to morphological erosion and dilation respectively,

Therefore

$$\tau(x) = \frac{\varepsilon_{\mu}(f)(x)+\delta(f)(x)}{2} \qquad \ldots\ldots \; \ldots.(23)$$

By employing Erosion-Dilation method we obtain a better local analysis of the image for detecting the background criteria than the previously used method of Blocks. This is because the structuring element μ_B permits the analysis of eight boring pixels at each point in the image. By increasing the size of the structuring element more pixels will be taken into account for finding the background criteria. It can be easily visualized that several characteristics that are not visible at first sight appear in the enhanced images. The trouble with this method is that morphological erosion or dilation when used with large size of μ to reveal the background, undesired values maybe generated. Closing By Reconstruction (μ=2)

In general it is desirable to filter an image without generating any new components. The transformation function which enables to eliminate unnecessary parts without affecting other regions of the image is defined in mathematical morphology which is termed as transformation by reconstruction. We go for opening by reconstruction because it restores the original shape of the objects in the image that remain after erosion as it touches the regional minima and merges the regional maxima. This particular characteristic allows the modification of the altitude of regional maxima when the size of the structuring element increases thereby aiding in detection of the background criteria as follows[2]:

$$\tau(x) = \gamma_{\mu B}(f)(x)$$
$$\gamma_{\mu B}(f)(x) = \lim_{n \to \infty} \delta^{n}_{f}(\varepsilon_{\mu B}(f))(x) \qquad ....(24)$$

It can be observed from the above equation that opening by reconstruction first erodes the input image and uses it as a marker. Here marker image is defined because this is the image which contains the starting or seed locations. For example, here the eroded image can be used as the marker. Then dilation of the eroded image i.e. marker is performed iteratively until stability is achieved. Image background obtained from the erosion of the opening by reconstruction

Background parameter b(x) is calculated by eroding the above obtained background criterion τ(x) which is described below:

$$b(x) = \varepsilon_1[\gamma_{\mu}(f)](x) \qquad \ldots\ldots\ldots(25)$$

As it is already mentioned that morphological erosion will generate unnecessary information when the size of the structuring element is increased, in this study, the image background was calculated by choosing the size of the structuring element as unity. Contrast enhancement is obtained by applying Weber's law as expressed below :

$$\xi_{\gamma\mu}(f) = k(x)\log(f+1) + \varepsilon_1[\gamma_{\mu}(f)]$$

and

$$k(x) = \frac{\max \text{int} - \varepsilon_1[\gamma_{\mu}(f)]}{\log(\max \text{int} + 1)} \qquad \ldots\ldots\ldots(26)$$

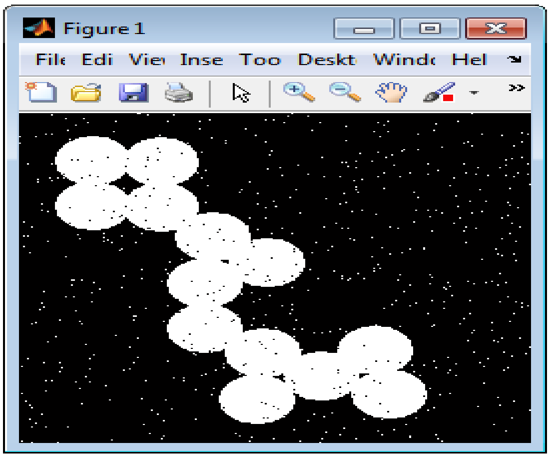
Where, max int refers to maximum color intensity which is equal to 255. If the intensity of the background increases, the image becomes lighter because of the additive effect of the whiteness (i.e. maximum intensity) of the background. It is to be remembered that it is the objective of opening by reconstruction to preserve the shape of the image components that remain after erosion.

4.1 Contra-Harmonic Mean filter:

The contra harmonic mean filtering operation yields a restored image based on the expression.

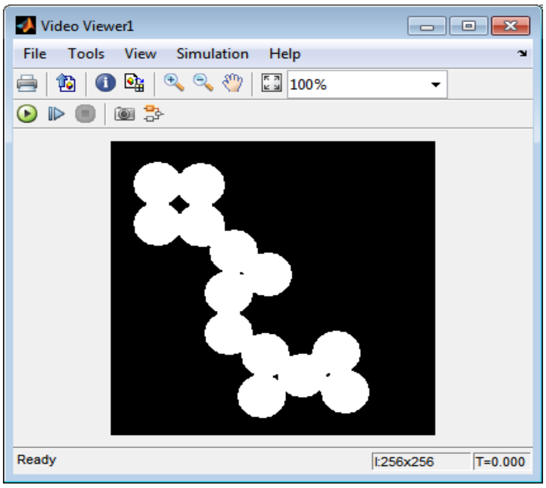
$$f(x,y)=\frac{\sum_{(s,t)\in S_{xy}} g(s,t)^{Q+1}}{\sum_{(s,t)\in S_{xy}} g(s,t)^{Q}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(27)$$

Where Q is called the order of the filter. This filter is well suited for reducing or virtually eliminated the effects of salt and pepper noise[10].



For positive values of Q the filter eliminates pepper noise. For negative values of Q it eliminates salt noise. contra harmonic filter reduces to the arithmetic mean filter if Q=0 and to the harmonic mean filter if Q=-1

Sample output



5. Conclusion

In this paper, a framework for image enhancement based on mathematical morphology has been presented. In this method, to overcome the many image enhancement schemes like histogram equalization that improve the contrast and filtering the noise is proposed; the methodology consists in solving a time complexity problem, filtering the noise presented in grey scale images. The optimization formulation includes a perceptual constraint derived directly from human threshold contrast sensitivity function. The method applied the proposed operators to some images with poor lighting with good results. On the other hand these work is to enhance contrast based on color statistics from a training set of images which look visually appealing is presented. Here, the basic idea is to select a set of training images which look good perceptually, next salt and pepper noise has been filtered by contra-harmonic mean .Finally calculating the simulation time for each working sector .In this way, even though the reported algorithms to compensate changes in lighting are varied, some are more adequate than others.

Future Enhancement

In future, for the enhancement purpose more images can be taken from the different application fields so that it becomes clearer that for which application which particular technique is better both for Grey Scale Images and color Images. Particularly, for color images there are not many performances measurement parameter considered. So, new parameters can be considered for the evaluation of enhancement techniques. New color models can also be chosen for better comparison purpose. Optimization of various enhancement techniques can be done to reduce computational complexity as much as possible.

References

[1]. K.Sreedhar and B.Panlal ," Enhancement of images using morphological transformation" .IJCS&IT, vol. 4, no. 1, 2012.

[2]. K.Narasimhan, C.R.Sudarsan, Nagarajan Raju" A Comparision of contrst Enhancement Techniques in poor illuminated gray level and color images", in IJCA ,vol.24.no.2 , 2011.

[3]. I.R. Terol-Villalobos, "Morphological image enhancement and segmentation with analysis," P. W. Hawkes, Ed. New York: Academic, 2005, pp. 207–273.

[4]. Muhammad shahzed and shiraz latif, "efficient image enhancement Techniques," JI&CT, vol. 3, pp. no.1, 2009.

[5]. Alok singh,Umesh Ghanekar,"An efficient image salt and pepper noise detector" IJAN&A vol. 2,ISSUE 5, 2011..

[6]. B.Thamotharan,M.Menaka,:Survey on image processing in the field of de-noising Techniques and Radiogram Image," JT&AIT.,vol.41.no.1, 2005.

[7]. Henk J.A.M.Heijmans" Mathematical morphology: A modern approach in image, "society for industrial and applied mathematics. vol.37, no. 4, 1995.

[8]. A. K. Jain, Fundamentals of Digital Images Processing. Englewood Cliffs, NJ: Prentice-Hall, 1989.

[9]. J. Short, J. Kittler, and K. Messer, "A comparison of photometric normalization algorithms for face verification," presented at the IEEE Int. Conf. Automatic Face and Gesture Recognition, 2004.

[10]. C. R. González and E.Woods, Digital Image Processing. Englewood Cliffs, NJ: Prentice Hall, 1992.

[11] S. Mukhopadhyay B. Chanda"Hue Preserving Color Image Enhancement using Multi-scale Morphology"**4**(3): (2007)

[12]. A.Saradha Devi, S. Suja Priyadharsini, S. Athinarayanan"A BLOCK BASED SCHEME FOR ENHANCING LOW LUMINATED IMAGES" The International journal of Multimedia & Its Applications (IJMA) Vol.2, No.3, August 2010

[13]. Angélica R. Jiménez-Sánchez, Jorge D. Mendiola-Santibañez, Iván R. Terol- Villalobos, Gilberto Herrera-Ruíz, Damián Vargas-Vázquez, Juan J. García-Escalante, and Alberto Lara-Guevara,"Morphological Background Detection and enhancement of Images with Poor Lighting" IEEE Trans. Image Process. **18**(3), pp. 613-623 (2009)

[14]. L. Vincent and E. R. Dougherty, "Morphological segmentation for textures and particles," in *Digital Image Processing Methods*, E. R. Dougherty, Ed. New York: Marcel Dekker, 1994, pp. 43–102.

[15] Jayanta Mukherjee*, Senior Member, IEEE*, and Sanjit K. Mitra*, Life Fellow, IEEE "*Enhancement of Color Images by Scaling the DCT Coefficients" IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 17, NO. 10, OCTOBER 2008

[16] D. J. Jobson, Z. Rahman, and G. A. Woodell, "A multi-scale retinex for bridging the gap between color images and the human observation of scenes," *IEEE Trans. Image Process.*, vol. 6, no. 7, pp. 965–976, Jul. 1997.

[17] J. Tang, E. Peli, and S. Acton, "Image enhancement using a contrast measure in the compressed domain," *IEEE Signal Process. Lett.*, vol. 10, no. 10, pp. 289–292, Oct. 2003.

[18] J. Kasperek, "Real time morphological image contrast enhancement in virtex FPGA," in *Lecture Notes in Computer Science*. New York: Springer, 2008

[19] J. S. Lee. Refined filtering of image noise using local statistics.*Computer Graphics and Image Processing-4*, 15:380–389, 1981

[20] J. S. Lee. Digital image enhancement and noise filtering by use of local statistics. *IEEE Trans. on Pattern Analysis and Machine Intelligence*, PAMI-2:165–, 1980..

