A REVIEW ON IMAGE CONTRAST ENHANCEMENT TECHNIQUES USING HISTOGRAM EQUALIZATION

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ABSTRACT. *Contrast enhancement with histogram equalization is one of the most important and widely used techniques of DIP. Histogram equalization (HE) is simple that uniformly distributes the pixels intensity levels as a result of which the image has more visual effects. The traditional HE method produces some unwanted effects in the processed image. In this paper some fundamental terms of DIP are lightly reviewed and then the specific area contrast enhancement and new enhancing techniques in this regard are reviewed in detail. The main difference among the histogram equalization techniques is the input histogram separation style. Some methods separate it based on mean, median etc. like BBHE separates it on the basis of mean grey level while DSIHE takes into account median value. MMBEBHE takes value which provides maximum mean. RMSHE and BHENM are the extensions of BBHE.*

Keywords: Histogram equalization, Mean brightness, Preservation, Image processing, Contrast Enhancement, Specification

1. INTRODUCTION

An image is a grid of pixels where pixel is the smallest unit of picture element that is displayed on any digital display device like television screen, computer monitor etc. and has a specific height and width. Every pixel has a settled down size on a given plane [1]. A Digital Image has two dimensional shape which represents grey level also called pixels and are collectively called image or a two dimensional image represented in binary form known as binary image [2]. 2D image has only two dimensional structures (X-axes and y-axes) on a given plane OR it is an image which has only x and y coordinates. 3D image is constructed with three coordinates (x, y and z) axes. Some preprocessing is required to obtain 3D view of an image from the 2D image [1]. Digital image processing (DIP) is a series of operations that are applied to an image and as a result the image has more visual properties. Image processing system has three main elements i.e., image acquisition, image processing and image display as described in [3]. There are three main levels of processing in DIP i.e., low, middle and high level. Operations included in low level are image sharpening, image enhancement[4] and reducing noise [5] from the image. In fact, the inputs and outputs of images are in the form of low level of image processing. Middle level operations are normally image segmentation[6; 7], image recognition [8], reconstruction [9] and rendering [10] etc. Inputs of this level are normally images but their outputs are the attributes extracted from those images. The higher and last level of image processing is analyzing the image [11-13].

Contrast Enhancement: Images which have a more grey level are considered as good contrast images. The fundamental aim of contrast enhancement is to visualize hidden information of an image for human sight or for a given application. An image with a good contrast has automatically an excellent quality but it is not normally ideal due to several reasons such as noisy environment, poor lighting effects and failure of capturing device etc. So, contrast enhancement is one of the more essential steps in image processing applications [1]. A simple example of contrast enhancement is shown in [14] where contrast is increased and noise is removed from the image which automatically provides visibility.

A number of contrast enhancement techniques have been introduced such as histogram specification, histogram equalization etc.

2. SPECIFICATION

Histogram specification is one of the contrast enhancement methods where the original image histogram is changed into a desired one [15]. Exact histogram [16; 17] and automatic histogram [18; 19] specification for contrast enhancement surely provide the desired histogram. Exact histogram specification provides inflexible pair of the image pixels and the local mean for contrast enhancement.

3. HISTOGRAM EQUALIZATION (HE)

Histogram Equalization is one of the most common, simplest and effective methods for enhancing the contrast of image [20; 21]. Histogram Equalization uniformly distributes the grey level of the original image histogram as a result of which a good contrast enhanced image is obtained. Histogram equalization is used in several fields as an enhancing technique such as voice recognition system [22-24], texture analysis [25-27] and medical image processing [28; 29]. Histogram Equalization (HE) fundamental function is to enhance and increase the grey level of image but this technique has some drawbacks as well e.g., it assigns one grey level to two nearest grey levels with different strength and secondly it has the washout effects if it assigns grey level to the higher intensity which affects its performance. To improve the efficiency of HE, several techniques have been proposed in literature. In 2012 T.L.Tan done image enhancement using background brightness preserving histogram equalization [30]. In this technique image histogram is divided into different levels and each level is enhanced individually. This method has the capability to preserve the image background while enhancing the image. M.Farhan [31] proposed a mean brightness preserving method which also removes the noise present in the image. In this method the overall histogram of image first becomes smooth and then can be decomposed into several segments by using specific threshold value after which each segment is enhanced individually. In [32] Gaussian mixture model was presented which dispersed the input image grey level and the crossing point of that model was used to divide the range of image level so that an equalized image is obtained by changing the input image grey level interval into proper output image grey level interval. This Gaussian mixture model algorithm is also called automatic image enhancement technique because it is applied to the input image to execute nonlinear image mapping for creating equalized image. Other HE techniques such as object based [33] and dynamic range based [34] techniques are especially for consumer use and have a less computational time. A method for reducing noise from an image is presented in [30] and a resonance technique for the low contrast images is proposed in [35] whose performance is superior to other existing techniques without any color loss. A weighted histogram equalization method was proposed for enhancing the image contrast. This method provides a reasonable image quality as a result and its hardware implementation is easy [36]. A technique is introduced which is applied to graphical information of the input image [37]. NOSHP (Non-overlapped Sub-blocks and Local Histogram Projection) is presented in [38] which provide pleasant visual effects in the image also used in real time systems. A method is presented in [39] which enhanced different grey levels in the input image whereas single grey levels contain edge information of the image [40]. In [41] piecewise linear approximation of cumulative distribution function has been described and limited adaptive enhancement technique has been proposed in [42] to enhance local details of the image. Global histogram equalization is one of the simplest methods concerned only with global features of the image [43]. This technique gets failed in a situation where we are only interested in local information of the image.

3.1. Brightness Preserving Bi-Histogram Equalization (BBHE)

This method was proposed in 1997 which eliminated the limitation of HE. BBHE takes one image as input and splits it into two parts based on the mean. The first part of sub image contains the pixels values which are up to the mean and the second part contains pixels which are above the mean of original image. In this method the input mean presents the mean intensity of all pixels of an image having histogram range from 0 to M-1. The first histogram contains pixels from 0 to the mean and the second is from mean+1 to M-1. BBHE is applied to both sub images independently after which both equalized images are combined. BBHE can enhance any input image and used for the consumer electronic while preserving the mean brightness [44; 45]. The quantized bi-histogram is discussed in [46].

3.2. Dualistic Sub-Image Histogram Equalization (DSIHE)

This technique was proposed in 1999 by Wan et al [47]. It is also the contrast enhancement technique similar to BBHE but in this technique the image is separated into two equal parts on the basis of its median value instead of the mean grey level after which both sub images are equalized and then combined to have equal area dualistic sub image HE. In this technique the division of image is for the purpose of maximizing the entropy according to the resultant image [48]. For this purpose the input image is divided into two sub equal parts containing the equal property as one dark and the other bright. The resultant image obtained by DSIHE is average of the input image. There is not any visible change in the brightness of input image and output image according to the authors. This technique not only efficiently enhances the image but keeps its originality as well [49; 50].

3.3. Minimum Mean Brightness Error Bi-Histogram Equalization (MMBEBHE)

MMBEBHE is the extended form of BBHE and unlike the previous methods it works to split the image based on the threshold value. The core difference between BBHE, DSIHE and MMBEBHE is the selection of threshold value that decomposes the input image into two parts I [0 to Lt] and I [lt+1 to L-1] for obtaining the minimum brightness. This method is defined by the following three steps. First mean brightness is calculated. Secondly, the selection of proper threshold is done on the basis of AMBE. Finally, it splits the input histogram into two parts based on minimum AMBE and then equalizes them independently [51; 52]. This method is efficiently applicable for real time applications.

3.4. Recursive Mean-Separate Histogram Equalization (RMSHE)

It is an extended form of BBHE which recursively decomposes the given image up to r and 2r sub parts after which each sub image is enhanced independently. When r=0 this means that there is no sub image. This technique not only preserves the brightness but also effectively enhances the image. In this technique more brightness is required in order to separate its final histogram based on its recursive mean [53]. RSIHE (Recursive Sub-image Histogram Equalization) is discussed in [54] but it has a drawback of multiple decompositions.

3.5. Mean Brightness Preserving Histogram Equalization (MBPHE)

Basically MBPHE method can be classified into two parts; bisection MBPHE and multi section MBPHE. The bisection method simply divides the input histogram into two parts and equalizes them independently. This method can preserve the mean in some cases when the input histogram is uniformly distributed around its division origin [55]. But this property is considered as a failure because every histogram can have this property. Splitting the input image histogram into two parts is not sufficient for preserving the mean brightness. So the concept of separating the input image histogram into more than two parts was first introduced by [56; 57]. In multi section MBPHE the input histogram can be divided into more than one part and can equalize them independently. In this technique the sub image histogram is equalized by taking median or mean value recursively and has a good result as compared to the bisection method. Its hardware implementation is complicated and much computational time is required for consumer electronic. Owing to high constraints, this method cannot produce much better results [58].

3.6. Brightness Preserving Dynamic Histogram Equalization (BPDHE)

This method was proposed to overcome the weaknesses of HE. It produces the resultant image intensity in detail which is equal to the mean of input image intensity [59]. In BPDHE method first the Gaussian Filter is applied to the input histogram which makes it smooth and then on the basis of its local maximum the smoothed histogram is separated in parts after which dynamic range is assigned to it. Finally each partition is equalized through equalization process [6062]. The weaknesses of this technique are removed in [63] by using BPDFHE (Brightness Preserving Dynamic Fuzzy Histogram Equalization). Multi Histogram Equalization is presented in [64].

3.7. Dynamic Histogram Equalization (DHE)

Dynamic histogram equalization is an extension of the traditional HE. It produces results with more detail and without any loss of information. DHE divides the input image histogram into number of sub parts and then the dynamic grey level ranges are allocated to each part. This can prevent washout out effect of the input image and also presents moderate of the input image. Basically this technique has three main steps; division of input histogram, allocating ranges and finally applying the HE on each sub part of histogram [56].

3.8. Multilevel Component Based Histogram Equalization (MCBHE)

In this technique the input image is decomposed into two sub images known as background and foreground sub images. The multi grey level of each sub image is processed and its component is analyzed just like handwritten recognition, components are identified which are below or above each threshold value. As the threshold level changes, it is able to capture the image grey level variation. This technique is efficiently used for enhancing local detail of the image [65; 66].

3.9. Weighted Mean Separate Sub Histogram Equalization (WMSHE)

In this technique the input histogram is separated in several sub parts based on its weight mean function and then the transformation function is applied to equalize the sub parts for achieving the good contrast. This technique is better suited for digital image to get effective contrast [67].

3.10. Adaptive Contrast Enhancement Methods with Brightness Preserving

It is an extended technique of BBHE which preserves the brightness of an image and enhances it. In this technique the original image histogram is divided into two sub parts using threshold value in order to efficiently retrieve image from the background. Mean brightness is calculated between the original image and equalized image [68]. It is also known as adaptive contrast enhancement with histogram equalization.

3.11. Contrast Stretching Recursively Separated Histogram Equalization (CSRSHE)

The unusual objective of this technique is to preserve the brightness and enhance the image contrast [69]. In CSRSHE technique one image is taken as input and a new grey level is assigned to both local and global pixels of that image. Secondly, the histogram is separated in sub parts recursively based on its mean and then each part is equalized independently.

3.12. Contrast Enhancement using Bi-Histogram Equalization with Neighborhood Metric (BHENM)

It is an extended form of BBHE known as BHENM. It enhances the image contrast while preserving its brightness. This new technique has two stages; first the histogram bins are divided into sub bins and secondly mean is taken to divide the original image histogram in two parts. Then each part is enhanced through BHENM [70].

Table1. Performance of HE Techniques

S#	Techniques	Dataset	Advantages	Limitations
1	HE [21]	Image data set of *couple, hands and F16*	Enhances the contrast of image through dynamic stretching histogram range	Annoying artifacts, spoils the visual quality and brightness change
2	BBHE [46]	Image data set of *couple, hands and F16*	Brightness preservation of the test images, natural enhancement	Complicated hardware required for this method as compared to Histogram equalization
3	DSIHE [50]	Image data set of *hands*	Luminance of input is well preserved, image visual information is enhanced	Requires higher degree of preservation, artifacts annoying
4	MMBEBHE [51]	Image dataset of *arctic hare, U2, copter, F16, hands*	Increased brightness preservation, removed unpleasant artifacts, natural enhancement, better background color preservation	-
5	RMSHE [54]	Image dataset of *arctic hare, girl and jet*	Natural enhancement and well brightness preservation as compared to HE, BBHE, DSIHE	Recursion level selection is not automatic
6	BPDHE [61]	80 test images	Avoids saturation effect, changing of image focus and enhancement of partial volume effects. Successfully maintains the input mean brightness	-
7	DHE [56]	Tests are synthetic, natural and medical images	Preserved image details, smooth enhancement, simple and computationally effective	-
8	MCBHE [67]	Dataset: *Couple, Einstein, and Zelda*	Enhancement of global and local contrast , minimum distortion	-
9	WMSHE [68]	Dataset: *Einstein*	Robust visual quality with better PSNR	-
10	CSRSHE [69]	65 CT images	Accurate brightness preservation	-
11	BHENM [70]	Image dataset	Better preservation of brightness with minimum execution time	-

Those components are identified which are below or above each threshold value. As the threshold level changes, it is able to capture the grey image [39; 71; 72].

The performance of histogram equalization techniques is highlighted in the below table on the basis of specific datasets.

4. CONCLUSION

A detailed review of histogram equalization techniques shows that the earlier enhancement techniques like HE, BBHE, DSIHE etc., which do not provide the required enhancements are now handled by the extension of these earlier methods like MMBEBH, RMSHE. Although these techniques have some side effects yet they provide maximum enhancement as compared to earlier techniques. Dynamic HE method has no side effects and retains the image details. Brightness preserving dynamic histogram equalization keeps the mean brightness as compared to earlier methods. Weighted Mean Separate Sub Histogram Equalization can achieve good image visual quality. Adaptive Contrast Enhancement Methods with Brightness Preserving divide the histogram by using threshold values and preserve the brightness. BHENM method can also efficiently enhance the image and preserve the brightness as compared to other existing methods.

REFERENCES

1. Woods R. C. G. a. R. E., *Digital Image Processing*, Addison-Wesley.(1992)
2. Pratt W. K., Digital image processing: PIKS inside, *John Wiley & Sons, Inc*, 189-236 (2001)
3. Gonzalez R. C., Woods R. E. and Eddins S. L., Digital image processing using MATLAB, *Upper Saddle River, N. J: Pearson Prentice Hall*, (2004)
4. Yasmin M., Sharif M., Masood S., Raza M. and Mohsin S., Brain image enhancement-A survey, *World Applied Sciences Journal*, **17(9)**, 1192-1204 (2012)
5. Sharif M., Mohsin S., Jamal M. J. and Raza M., Illumination Normalization Preprocessing for face recognition, *Proceedings of the 2nd Conference on Environmental Science and Information Application Technology*, 44-47 **(2010)**
6. Shahzad A., Sharif M., Raza M. and Hussain K., Enhanced watershed image processing segmentation, *Journal of Information & Communication Technology*, **2(1)**, 01-09 (2008)
7. Haider W., Sharif M. and Raza M., Achieving accuracy in early stage tumor identification systems based on image segmentation and 3D structure analysis, *Computer Engineering and Intelligent Systems*, **2(6)**, 96-102 (2011)
8. Yasmin M., Sharif M. and Mohsin S., Survey Paper on Diagnosis of Breast Cancer Using Image Processing Techniques, *Research Journal of Recent Sciences ISSN*, **2277**, 2502 (2013)
9. Yasmin M., Sharif M., Masood S., Raza M. and Mohsin S., Brain image reconstruction: A short survey, *World Applied Sciences Journal*, **19(1)**, 52-62 (2012)
10. Raza M., Sharif M., Yasmin M., Masood S. and Mohsin S., Brain Image Representation and Rendering: A Survey, *Research Journal of Applied Sciences*, **4**, (2012)
11. Russ J. C. and Woods R. P., The image processing handbook, *Journal of Computer Assisted Tomography*, **19(6)**, 979-981 (1995)
12. Yasmin M., Mohsin S., Sharif M., Raza M. and Masood S., Brain Image Analysis: A Survey, *World Applied Sciences Journal*, **19(10)**, 1484-1494 (2012)
13. Masood S., Sharif M., Yasmin M., Raza M. and Mohsin S., Brain Image Compression: A Brief Survey, *Research Journal of Applied Sciences*, **5**, (2013)
14. Garg R., Mittal B. and Garg S., Histogram equalization techniques for image enhancement, *International Journal of Electronics & Communication Technology*, **2(1)**, 107-111 (2011)
15. Coltuc D., Bolon P. and Chassery J.-M., Exact histogram specification, *Image Processing, IEEE Transactions on*, **15(5)**, 1143-1152 (2006)
16. Coltuc D., Chassery J. and Bolon P., Image authentication by exact histogram specification, *Multimedia Signal Processing, 2001 IEEE Fourth Workshop on*, IEEE, 499-504 **(2001)**
17. Sen D. and Pal S. K., Automatic exact histogram specification for contrast enhancement and visual system based quantitative evaluation, *Image Processing, IEEE Transactions on*, **20(5)**, 1211-1220 (2011)
18. Sen D. and Pal S. K., Novel automatic exact histogram specification for contrast enhancement in images, *Communications and Signal Processing (ICCSP), 2011 International Conference on*, IEEE, 56-60 **(2011)**
19. Yeganeh H., Ziaei A. and Rezaie A., A novel approach for contrast enhancement based on histogram equalization, *Computer and Communication Engineering, 2008. ICCCE 2008. International Conference on*, IEEE, 256-260 **(2008)**
20. Maria Petrou and Bosdogianni P., *Image processing: The fundamental*, John Wiley & Sons Ltd.(2000)
21. De La Torre Á., Peinado A. M., Segura J. C., Pérez-Córdoba J. L., Benítez M. C. and Rubio A. J., Histogram equalization of speech representation for robust speech recognition, *Speech and Audio Processing, IEEE Transactions on*, **13(3)**, 355-366 (2005)
22. Lee P.-H., Wu S.-W. and Hung Y.-P., Illumination compensation using oriented local histogram equalization and its application to face recognition, *Image Processing, IEEE Transactions on*, **21(9)**, 4280-4289 (2012)
23. Pizer S. M., Johnston R. E., Ericksen J. P., Yankaskas B. C. and Muller K. E., Contrast-limited adaptive histogram equalization: speed and effectiveness, *Visualization in Biomedical Computing, 1990., Proceedings of the First Conference on*, IEEE, 337-345 **(1990)**
24. Wahab A., Chin S. and Tan E., Novel approach to automated fingerprint recognition, *Vision, Image and Signal Processing, IEE Proceedings-*, IET, 160-166 **(1998)**
25. Pei S.-C., Zeng Y.-C. and Chang C.-H., Virtual restoration of ancient Chinese paintings using color contrast enhancement and lacuna texture synthesis, *Image Processing, IEEE Transactions on*, **13(3)**, 416-429 (2004)
26. William W. K. and Pratt K., *Digital Image Processing*, New York, Wiley.(2001)
27. Pizer S. M., The medical image display and analysis group at the University of North Carolina: Reminiscences and philosophy, *Medical Imaging, IEEE Transactions on*, **22(1)**, 2-10 (2003)
28. Wong K.-Y. K. and Wong K.-Y., Segmenting lumbar vertebrae in digital video fluoroscopic images through edge enhancement, *Control, Automation, Robotics and Vision Conference, 2004. ICARCV 2004 8th*, IEEE, 665-670 **(2004)**
29. Tan T., Sim K. and Tso C. P., Image enhancement using background brightness preserving histogram equalisation, *Electronics letters*, **48(3)**, 155-157 (2012)
30. Khan M. F., Khan E. and Abbasi Z., Weighted average multi segment histogram equalization for brightness preserving contrast enhancement, *Signal Processing, Computing and Control (ISPCC), 2012 IEEE International Conference on*, IEEE, 1-6 **(2012)**

31. Celik T. and Tjahjadi T., Automatic image equalization and contrast enhancement using Gaussian mixture modeling, *Image Processing, IEEE Transactions on*, **21(1)**, 145-156 (2012)
32. Maragatham G., Mansoor Roomi S. and Prabu T. M., Contrast enhancement by object based Histogram Equalization, *Information and Communication Technologies (WICT), 2011 World Congress on*, IEEE, 1118-1122 **(2011)**
33. Iwanami T., Goto T., Hirano S. and Sakurai M., An adaptive contrast enhancement using regional dynamic histogram equalization, *Consumer Electronics (ICCE), 2012 IEEE International Conference on*, IEEE, 719-722 **(2012)**
34. Zhang D., Park W.-J., Lee S.-J., Choi K.-A. and Ko S.-J., Histogram partition based gamma correction for image contrast enhancement, *Consumer Electronics (ISCE), 2012 IEEE 16th International Symposium on*, IEEE, 1-4 **(2012)**
35. Jha R. K., Biswas P. and Chatterji B., Contrast enhancement of dark images using stochastic resonance, *Image Processing, IET*, **6(3)**, 230-237 (2012)
36. Yun S.-H., Kim J. H. and Kim S., Contrast Enhancement using a weighted histogram equalization, *Consumer Electronics (ICCE), 2011 IEEE International Conference on*, IEEE, 203-204 **(2011)**
37. Thomas G., Flores-Tapia D. and Pistorius S., Histogram specification: a fast and flexible method to process digital images, *Instrumentation and Measurement, IEEE Transactions on*, **60(5)**, 1565-1578 (2011)
38. Celik T. and Tjahjadi T., Contextual and variational contrast enhancement, *Image Processing, IEEE Transactions on*, **20(12)**, 3431-3441 (2011)
39. Liu B., Jin W., Chen Y., Liu C. and Li L., Contrast enhancement using non-overlapped sub-blocks and local histogram projection, *Consumer Electronics, IEEE Transactions on*, **57(2)**, 583-588 (2011)
40. Murahira K. and Taguchi A., A novel contrast enhancement method using differential gray-levels histogram, *Intelligent Signal Processing and Communications Systems (ISPACS), 2011 International Symposium on*, IEEE, 1-5 **(2011)**
41. Sivakumar P., Maguesway K. and Rajaram M., Image contrast enhancement using singular value decomposition for gray level images, *Signal Processing, Communication, Computing and Networking Technologies (ICSCCN), 2011 International Conference on*, IEEE, 1-5 **(2011)**
42. Kim S.-Y., Han D., Choi S.-J. and Park J.-S., Image contrast enhancement based on the piecewise-linear approximation of CDF, *Consumer Electronics, IEEE Transactions on*, **45(3)**, 828-834 (1999)
43. Pizer S. M., Amburn E. P., Austin J. D., Cromartie R., Geselowitz A., Greer T., Ter Haar Romeny B., Zimmerman J. B. and Zuiderveld K., Adaptive histogram equalization and its variations, *Computer vision, graphics, and image processing*, **39(3)**, 355-368 (1987)
44. Guanzhang L., Wusheng L., Pei L. and Haibao L., Fusion Enhancement of Color Image Based on Global Histogram Equalization, *Computer Science and Software Engineering, 2008 International Conference on*, IEEE, 205-208 **(2008)**
45. Lim J. S., Two-dimensional signal and image processing, *Englewood Cliffs, NJ, Prentice Hall, 1990, 710 p.*, **1**, (1990)
46. Kim Y.-T., Contrast enhancement using brightness preserving bi-histogram equalization, *Consumer Electronics, IEEE Transactions on*, **43(1)**, 1-8 (1997)
47. Kim Y.-T., Quantized bi-histogram equalization, *Acoustics, Speech, and Signal Processing, 1997. ICASSP-97., 1997 IEEE International Conference on*, IEEE, 2797-2800 **(1997)**
48. Leman K. R. C., *Digital Image Processing*, Englewood Cliffs, New Jersey, Prentice Hall.(1996)
49. Shannon C. E., A mathematical theory of communication, *ACM SIGMOBILE Mobile Computing and Communications Review*, **5(1)**, 3-55 (2001)
50. Wang Y., Chen Q. and Zhang B., Image enhancement based on equal area dualistic sub-image histogram equalization method, *Consumer Electronics, IEEE Transactions on*, **45(1)**, 68-75 (1999)
51. Chen S.-D. and Ramli A. R., Minimum mean brightness error bi-histogram equalization in contrast enhancement, *Consumer Electronics, IEEE Transactions on*, **49(4)**, 1310-1319 (2003)
52. Umbaugh S. E., *Computer Vision and Image Processing: A Practical Approach Using Cviptools with Cdrom*, Prentice Hall PTR.(1997)
53. Wongsritong K., Kittayaruasiriwat K., Cheevasuvit F., Dejhan K. and Somboonkaew A., Contrast enhancement using multipeak histogram equalization with brightness preserving, *Circuits and Systems, 1998. IEEE APCCAS 1998. The 1998 IEEE Asia-Pacific Conference on*, IEEE, 455-458 **(1998)**
54. Sim K., Tso C. and Tan Y., Recursive sub-image histogram equalization applied to gray scale images, *Pattern Recognition Letters*, **28(10)**, 1209-1221 (2007)
55. Belhaj M., Jbara O., Odof S., Msellak K., Rau E. and Andrianov M., An anomalous contrast in scanning electron microscopy of insulators: The pseudo-mirror effect, *Scanning*, **22(6)**, 352-356 (2000)
56. Abdullah-Al-Wadud M., Kabir M. H., Dewan M. a. A. and Chae O., A dynamic histogram equalization for image contrast enhancement, *Consumer Electronics, IEEE Transactions on*, **53(2)**, 593-600 (2007)
57. Wang C. and Ye Z., Brightness preserving histogram equalization with maximum entropy: a variational perspective, *Consumer Electronics, IEEE Transactions on*, **51(4)**, 1326-1334 (2005)
58. Chen S.-D. and Ramli A. R., Contrast enhancement using recursive mean-separate histogram equalization for scalable brightness preservation, *Consumer Electronics, IEEE Transactions on*, **49(4)**, 1301-1309 (2003)
59. Kim M. and Chung M., Recursively separated and weighted histogram equalization for brightness preservation and contrast enhancement, *Consumer Electronics, IEEE Transactions on*, **54(3)**, 1389-1397 (2008)
60. Ooi C. H., Kong N. S. P. and Ibrahim H., Bi-histogram equalization with a plateau limit for digital image enhancement, *Consumer Electronics, IEEE Transactions on*, **55(4)**, 2072-2080 (2009)
61. Ibrahim H. and Kong N. S. P., Brightness preserving dynamic histogram equalization for image contrast enhancement, *Consumer Electronics, IEEE Transactions on*, **53(4)**, 1752-1758 (2007)
62. Ibrahim H. and Kong N. S. P., Image sharpening using sub-regions histogram equalization, *Consumer Electronics, IEEE Transactions on*, **55(2)**, 891-895 (2009)
63. Sheet D., Garud H., Suveer A., Mahadevappa M. and Chatterjee J., Brightness preserving dynamic fuzzy histogram equalization, *Consumer Electronics, IEEE Transactions on*, **56(4)**, 2475-2480 (2010)
64. Kong N. S. P. and Ibrahim H., Color image enhancement using brightness preserving dynamic histogram equalization, *Consumer Electronics, IEEE Transactions on*, **54(4)**, 1962-1968 (2008)
65. Wu S. and Amin A., Automatic thresholding of gray-level using multistage approach, *Document Analysis and Recognition, 2003.*

Proceedings. Seventh International Conference on, IEEE, 493-497 **(2003)**

66. Jafar I. and Ying H., Multilevel component-based histogram equalization for enhancing the quality of grayscale images, *Electro/Information Technology, 2007 IEEE International Conference on*, IEEE, 563-568 **(2007)**
67. Wu P.-C., Cheng F.-C. and Chen Y.-K., A weighting mean-separated sub-histogram equalization for contrast enhancement, *Biomedical Engineering and Computer Science (ICBECS), 2010 International Conference on*, IEEE, 1-4 **(2010)**
68. Ooi C. H. and Isa N. a. M., Adaptive contrast enhancement methods with brightness preserving, *Consumer Electronics, IEEE Transactions on*, **56(4)**, 2543-2551 (2010)
69. Jagatheeswari P., Kumar S. S. and Rajaram M., Contrast Stretching Recursively Separated Histogram Equalization for Brightness Preservation and Contrast Enhancement, *Advances in Computing, Control, & Telecommunication Technologies, 2009. ACT'09. International Conference on*, IEEE, 111-115 **(2009)**
70. Sengee N., Sengee A. and Choi H.-K., Image contrast enhancement using bi-histogram equalization with neighborhood metrics, *Consumer Electronics, IEEE Transactions on*, **56(4)**, 2727-2734 (2010)
71. Menotti D., Najman L., Facon J. and De Araujo A., Multi-histogram equalization methods for contrast enhancement and brightness preserving, *Consumer Electronics, IEEE Transactions on*, **53(3)**, 1186-1194 (2007)
72. Armato S. G., Giger M. L., Moran C. J., Blackburn J. T., Doi K. and Macmahon H., Computerized Detection of Pulmonary Nodules on CT Scans 1, *Radiographics*, **19(5)**, 1303-1311 (1999)