ISSN 2229-5518

Novel Weighted Mean Separated Histogram Equalization for Contrast Enhancement of Underwater Images

Dr. S. A. Hariprasad, Arunlal. K. S, Vikhar Ahmed

Abstract— Underwater acoustic is growing interest because of its applications in scientific research and technology. Its applications such as mine detection, marine biology and military operations requires a high quality of images. In underwater environment, quality of image is degraded by scattering of light and absorption of light which results in low contrast, poor visibility, blurring of image. Histogram equalization (HE) is the conventional method of enhancing the contrast of an image, but HE creates unwanted visual artifacts, which lead to over enhancement of image, loss of image details and loss of natural look of image. Recursively Mean Separated Histogram Equalization (RMSHE) is one of the modifications to HE to overcome from the limitations of HE. This method will reduce the visual artifacts and enhance the contrast of image but still there is a loss of image details. In this paper a modified RMSHE referred as Weighted Mean Separated Histogram Equalization (WMSHE) is presented which will enhance the contrast of image along with reduction of visual artifacts. The method preserves image details and brightness. In this method Histogram is divided into four sub-Histograms based on weighted mean value and then apply clipping limit to each sub-Histogram followed by equalization of each sub-Histogram. Performance of the algorithm is measured in terms of Absolute Mean Brightness Error (AMBE), Entropy of image and difference in Standard Deviation (SD). It is found that with proposed method AMBE is improved by 52.57%, SD is improved by 39.64% as compared to RMSHE, and Entropy of image with proposed method is 6.6221 whereas Entropy with RMSHE is 6.4746.

Index Terms— Brightness Preservation, Clipped Histogram Equalization Contrast Enhancement, Entropy, Histogram Equalization, Image Detail Preservation, Pixel.

1. INTRODUCTION:

Underwater acoustic is having a greater focus because of its applications in scientific research and technology. Applications, such as mine detection like resources available for the extraction of gold, copper, silver, zinc, cobalt and manganese, underwater power and telecommunication cables, pipelines, marine biology like fishes, invertebrates, reptiles, sea grasses and fungi, and submarines for civil and military purpose. These applications require high quality of underwater images. Underwater images are essentially characterized by their poor visibility because light is exponentially attenuated as it travels in the water, and the scenes result poorly contrasted and hazy. Light attenuation limits the visibility distance at about twenty meters in clear water and five meters or less in turbid water.

The light attenuation process is caused by absorption and scattering, which influence the overall performance of underwater imaging systems. Forward scattering generally leads to blur of the image features. Absorption and scattering effects are not only due to the water itself but also due to the components such as a dissolved organic matter. The visibility range can be increased with artificial illumination of light on the object, but it produces non-uniform of light on the surface of the object and producing a bright spot in the center of the image with poorly illuminated area surrounding it. The amount of light is reduced when we go deeper, colors drop off depending on their wavelengths. The blue color travels across the longest in the water due to its shortest wavelength. Underwater image suffers from limited range visibility, low contrast, non-uniform lighting, blurring, and bright artifacts. A lot of work have been done to overcome from the problem of underwater images.

The conventional method for enhancing the contrast of an image is Histogram Equalization. This method will redistribute gray levels of entire histogram of an image and make brighter part more brighter and darker part darker. This method creates unwanted visual artifacts and significantly change the brightness of image, which lead to over enhancement of image, loss of image details and loss of natural look of image. Many researchers have tried to overcome from the limitations of conventional HE. Yu Wang, et al[1] have proposed 'Image Enhancement Based on Equal Area Dualistic Sub-Image Histogram Equalization Method(DSIHE)' in which histogram of an image is divide into two parts based on image median value followed by Histogram equalization of each part and it reduces the visual artifacts to some extent. Yeong Teag Kim [2] has proposed 'Contrast Enhancement Using Brightness Preserving Bi-Histogram Equalization (BPBHE)' in which histogram is

Dr. S. A. Hariprasad, is Vice Principal & HOD in Electronics & Communication Engineering Dept of BMSIT, Yelahanka, Bangalore, India– 560064. Email – harivat2002@yahoo.co.in.

Mr. Arunlal. K. S is pursuing his Ph.D from VTU Belgaum and currently with R. V. College of Engineering Bangalore as Research Scholar. Email – arunlalks1@yahoo.com.

Mr. Vikhar Ahmed has completed M.Tech in Communication Systems from R. V. College of Engineering Bangalore.

divided into two parts based on mean value of image followed by Histogram equalization of both parts, in this case more artifacts are reduced as compared to previous method. Soong-Der Chen, et al[3] have proposed 'Minimum Mean Brightness Error Bi-Histogram Equalization in Contrast Enhancement (MMBEBHE)' in which histogram is divided into two parts based on some threshold value followed by equalization of both parts and tried to reduce the difference between mean brightness of input image and enhanced image which results in brightness preservation. Chao Wang, et al[4] have proposed 'Brightness Preserving Histogram Equalization with Maximum Entropy (BPHEME): A Variational Perspective' in which each gray level is weighted with some threshold value followed by histogram equalization, in this process brightness and entropy of an image is preserved. M. Abdullah-Al-Wadud[5], et al have proposed 'A Dynamic Histogram Equalization for Image Contrast Enhancement' in which the image histogram is partitioned based on local minima and assigns specific gray level ranges for each partition before equalizing them separately. These partitions further go through a repartitioning test to ensure the absence of any dominating portions. This method enhance the contrast well without introducing severe visual artifacts. Mary Kim et, al[8] have proposed 'Recursively Separated and Weighted Histogram Equalization for Brightness Preservation and Contrast Enhancement' in which histogram is separated based on either mean value of image or median value of image followed by applying weighted threshold to each sub-Histogram followed by equalization of each sub-Histogram. This method will enhance the contrast with reduction of artifacts. . K.S. Sim et al [9] have proposed 'Recursive sub-image histogram equalization applied to gray scale images (RSIHE)' in which the histogram is divided recursively into four parts based on mean and median values on image followed by histogram equalization on each sub-histogram, this method will reduce the visual artifacts to greater extent but still some of the image details will be lost. Chen HeeOoi, et al[12] have presented 'Bi-Histogram Equalization with a Plateau Limit for Digital Image Enhancement' in which histogram is first divided into two sub-Histograms followed by applying plateau limits or threshold limits, which can be computed by average frequency of occurrence of gray levels in each of the sub-Histograms, after that histogram equalization is applied to each sub-Histogram, this method will reduces the artifacts to greater extent preserves entropy and enhance contrast of image. Haidi Ibrahim, et al[13] have proposed 'Image Enhancement with Noise Suppression Ability using Histogram Manipulations' in which histogram is inverted first followed by histogram equalization to reduce visual artifacts and to enhance contrast. Pei-Chen Wu et al[18] have proposed 'A Weighting Mean-Separated Sub-Histogram Equalization for Contrast Enhancement' in which histogram is divided into six parts based on weighted mean value followed by equalization of each part, this method will greatly preserves the brightness of image by reducing visual artifacts and enhance the contrast of image.

This paper is organized as. Section 2 will briefly explain Histogram Equalization and Recursively mean Separated Histogram Equalization, Section 3 will present the Proposed Method of Weighted Mean Separated Histogram Equalization. 4 Explains Image Enhancement parameters used in this work 5 The Results will be shown and Section 6 is our Conclusion and Future Work.

2.CONTRAST ENHANCEMENT TECHNIQUES:

A. Histogram Equalization:

Consider an image X with gray levels 'k' varies from k = 0, 1, 2, 3, ------------------L-1, 'L' is total number of gray levels

Let f(k) be frequency of occurrence of gray level 'k'. Probability of occurrence of gray levels in an image is known as Probability Density Function (PDF) which is given by 'p(k)' of gray level 'k' is

$$p(k) = \frac{f(k)}{N} \qquad k = 0, 1, 2, ---L-1 \qquad (1)$$

Cumulative Density Function (CDF) of gray level 'k' is given by

$$CDF(k) = \sum_{k=0}^{L-1} p(k) \qquad (2)$$

Now using CDF, Transfer Function is computed which maps input image into output image for entire range of gray levels. Transfer Function is given by

$$F(k) = (L-1) * CDF(k) + lower\ gray\ level \qquad (3)$$

Now output image Y (i, j) can be obtained by using above transfer function as

$$Y(i,j) = F\big(X(i,j)\big) \qquad (4)$$

Histogram Equalization will enhance the contrast of an image but it increases the contrast of higher gray level regions and compresses the contrast in lower gray level regions, when the object of interest in an image only occupies a small portion of the image, this object will not be successfully enhanced by histogram equalization. Limitations of conventional Histogram Equalization are:

a) Creation of visual artifacts
b) Significant change in brightness of output image.
c) Over enhancement
d) Unnatural look of image
e) Washed out appearance

B. Recursively Mean Separated Histogram Equalization (RMSHE):

This is another approach of enhancing the contrast of an image with Brightness preservation [8], in which Histogram is divided into several segments and each of the segments is

ISSN 2229-5518

equalized separately using Histogram equalization technique. Division of Histogram into several parts will reduce the unwanted artifacts (overshooting and undershooting of pixel values) to a greater extent. In this method histogram is divided into four segments based on mean values. Fig 2.1 shows division of histogram into four sub-Histograms.

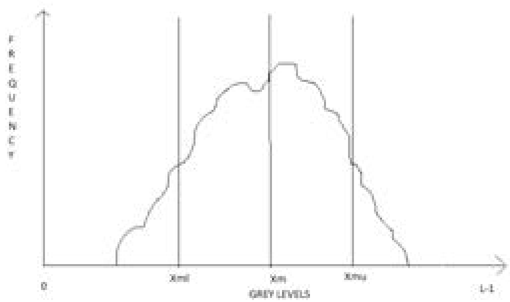

Fig 2.1: Dividing Histogram of image into four sub-Histograms

In Fig 2.1 shows the entire range X= {0, 1, 2, 3, ……….. L-1} of the Histogram is divided into four parts. Mean value X_m can be calculated by using the Relation:

$$X_m = \frac{\sum_{x=0}^{L-1} x * PDF(x)}{\sum_{x=0}^{L-1} PDF(x)} \qquad (5)$$

Where 'x' is gray level and PDF(x) is probability of occurrence of gray level 'x'. and X_m is mean value. Now using X_m divide Histogram into two parts, again considering two sub-Histograms as separate Histogram find their mean values and divide two sub-Histograms into four sub-Histograms. Histogram Equalization is carried out separately on each of the sub-Histograms. In this entire process contrast of an image is enhanced and unwanted artifacts will be suppressed, hence brightness is preserved.

3. PROPOSED METHOD OF WEIGHTED MEAN SEPARATED HE:

In this proposed method Histogram Specification is carried out. In which an image Histogram is specified so as to get a desired enhanced image. Process involves dividing Histogram into four sub-Histograms based on weighted mean values, computing threshold limits by taking average of frequency of gray levels in each sub-Histogram followed by applying threshold limits to each sub-Histogram and carrying out Histogram equalization on each part separately. In this process visual artifacts are reduced, contrast enhancement is controlled and image details are preserved which results in an output image rich in details having good quality and natural look.

A. Computing Weighted Mean Values:

Let $X = \{K_0, K_1, K_2, K_3, \ldots \ldots \ldots \ldots \ldots L-1\}$ be gray levels of test image and h(k) is frequency of occurrence of gray level k.

$$PDF(k) = \frac{h(k)}{N} \qquad (6)$$

p(k)be Probability Density Function of gray level 'k'.
N = Total Number of Pixels.
Mean value of image is compute as:

$$Xm = \frac{\sum_{k=0}^{L-1} k * p(k)}{\sum_{k=0}^{L-1} p(k)} \qquad (7)$$

Histogram of image is now divided into two sub-Histograms X_L and X_U.
X_L will have gray levels $\{K_0, K_1, K_2, \ldots \ldots \ldots . . K_m\}$
X_U will have gray levels $\{K_{m+1}, K_{m+2}, K_{m+3}, \ldots \ldots \ldots . . L-1\}$

Further mean values of X_L and X_U are computed in the same way and X_L and X_U are divided. After that each sub-Histogram is clipped by a threshold limit. The histogram in these ranges will be clipped in order to avoid intensity saturation in the output image. Frequency of occurrence of gray in four sub-Histograms are denoted by h_a, h_b, h_c and h_d.

B. Applying Threshold Limits:

Threshold limits can be computed as follows

$$T_1 = \frac{1}{X_{ml}+1} \sum_{k=0}^{X_{ml}} h_a(k) \qquad (8)$$

$$T_2 = \frac{1}{X_m - 1 - X_{ml}} \sum_{k=X_{ml}+1}^{X_m} h_b(k) \qquad (9)$$

$$T_3 = \frac{1}{X_{mu} - 1 - X_m} \sum_{k=X_m+1}^{X_{mu}} h_c(k) \qquad (10)$$

$$T_4 = \frac{1}{L - 1 - X_{mu}} \sum_{k=X_{mu}+1}^{L-1} h_d(k) \qquad (11)$$

Frequency of occurrence of gray levels in each sub-Histogram is clipped by threshold limits. Fig 3.1 shows applying threshold limits

$$h_1(k) = \begin{cases} T_1 & if\ h_a(k) \geq T_1 \\ h_a(k) & elsewhere \end{cases} \qquad (12)$$

$$h_2(k) = \begin{cases} T_2 & if\ h_b(k) \geq T_2 \\ h_b(k) & elsewhere \end{cases} \qquad (13)$$

$$h_3(k) = \begin{cases} T_3 & if\ h_c(k) \geq T_3 \\ h_c(k) & elsewhere \end{cases} \qquad (14)$$

$$h_4(k) = \begin{cases} T_4 & if\ h_d(k) \geq T_4 \\ h_d(k) & elsewhere \end{cases} \qquad (15)$$

After applying threshold limits to each sub-Histogram, conventional Histogram Equalization is carried out on each sub-Histogram separately. Output enhanced image Y (i , j) can be obtained from input image K(i , j) as:

$$Y(i,j) = F\big(K(i,j)\big) \qquad (16)$$

ISSN 2229-5518

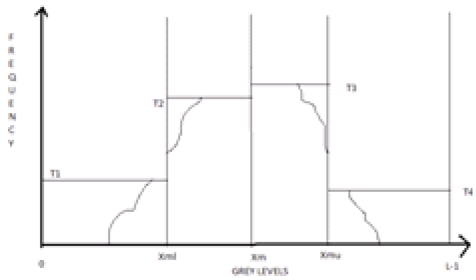

Fig 3.1: Dividing Histogram into 4 parts and applying clip limit to each sub-histogram

4. IMAGE ENHANCEMENT PARAMETERS:

A. Absolute Mean Brightness Error (AMBE):

This is defined as difference in mean brightness of input image and mean brightness output image. When image is over enhanced, unwanted artifact will be created, brightness of the output image changes drastically and image will lose its natural appearance. That is lesser the value of AMBE better the equality of image.

Let Ex be mean brightness of input image and Ey be mean brightness of output image. AMBE can be given by equation as in [18]

$$AMBE = |E_X - E_Y| \qquad (17)$$

$$E_x = \sum_{x=0}^{L-1} x * p(x)$$

$$E_y = \sum_{y=0}^{L-1} y * p(y)$$

Where p(x) and p(y) are Probability Density Function of Input and output image gray levels respectively.

B. Entropy of image:

This is defined as measure of richness of details present in an image. When contrast of an image is enhanced, details of an image may be lost. So entropy of an image should be same after enhancement or difference between Entropy of an image before enhancement and after enhancement should be very less. Entropy is given by

$$Entropy = \sum_{k=0}^{L-1} p(k) * log_2 p(k) \qquad (18)$$

Where p(k) is Probability Density Function of gray level 'k.

C. Difference in Standard Deviation (SD):

Standard Deviation gives the contrast of image. Difference in Standard Deviation between input image and output image measures the contrast enhancement of an image. If an image is over enhanced the difference will be high. So for desired enhancement difference should be less. Variance, SD and contrast enhancement is given by.

$$variance = \sum_{x=0}^{L-1} (x - E)^2 * p(x)$$

$$SD = \sqrt{variance}$$

$$Contrast\ Enhancement = SD_{output} - SD_{input} \qquad (19)$$

E is mean brightness of image. p(x) is PDF.

5. RESULTS:

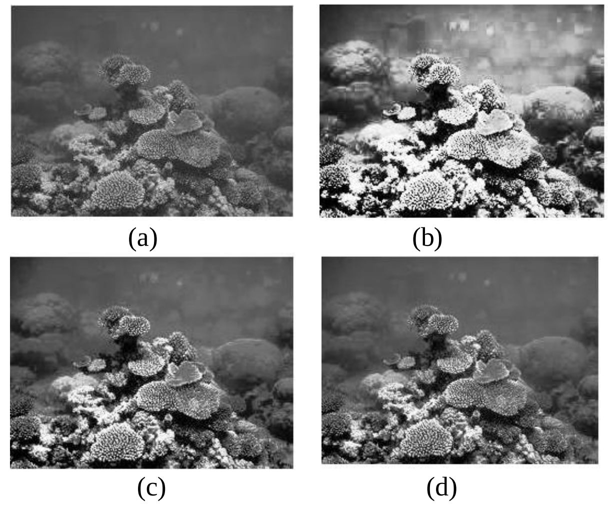

Fig 5.1 (a) Original image (b) Output of HE (c) Output of RSMHE (d) Output of Proposed Method

(Above image is taken from the website: www.photostockplus.com)

TABLE 5.1 COMPARISION OF DIFFERENT PARAMETERS ON HE , RMSHE AND PROPOSED METHOD

	AMBE	Entropy	Difference in SD
HE	35.90	6.4606	45.25
RMSHE	2.0346	6.4746	21.92
Proposed	0.965	6.6221	13.23

From table 5.1 it can be noticed that an image of Entropy 6.6360 is taken and HE will perform equalization on entire histogram and creats visual artifacts which results in over enhancement and resultant image will have a unnatural appearance. RMSHE has reduced the visual artifacts to maximum extent and results in less difference between brightness of input image and processed image , hence output image of RMSHE has natural appearance. Proposed mathod has successfully reduced the artifacts and has preserved the details of image hence output image of proposed method is having natural look and rich in details.

6. CONCLUSION AND FUTURE WORK:

Contrast of underwater images vary due to scattering, attenuation and absorption of light. In this work an underwater image of Entropy 6.6360 is taken and conventional Histogram Equalization and different modified Histogram

Equalization algorithms are implemented and their results are compared.

- Conventional Histogram Equalization results high value of AMBE of 35.90, high difference in SD of 45.25and reduced entropy of 6.4606 due to, creation of visual artifacts and loss of image details leading to over enhancement, which results in unnatural appearance of output image.
- RMSHE Successfully reduced the visual artifacts but still there is a loss in details of output image. AMBE is improved to 2.0346 and difference in SD is improved to 21.92, Entropy improved to 6.4746.
- Proposed method is Modified RMSHE which will successfully reduce AMBE value to 0.965 by reducing visual artifacts to greater extent and also reduce the difference in SD to 13.23, along with this it preserves the image details hence entropy of output image is 6.6221which is nearly equal to entropy of input image.

Though the proposed method will enhances the image but still there are traces of artifacts in the output image. In ideal case value of AMBE should be zero for no artifacts but in this method value of AMBE is not zero which indicates the presence of traces of artifacts. These artifacts can be removed by further dividing the histogram recursively into several segments at the rate of 2^r where 'r' is recursion level. Each segment is equalized separately using Histogram Equalization.

REFERENCES

[1] Yu Wang, Qian Chen, Baomin Zhang "Image Enhancement Based on Equal Area Dualistic Sub-Image Histogram Equalization Method" IEEE *Transactions on Consumer Electronics*, February 1999 Vol. 45, No. 1, pp 68-75.

[2] Yeong-TaekGi "Contrast Enhancement Using Brightness Preserving Bi-Histogram Equalization" IEEE 2002 February 1997 Vol. 43, No. 1 pp 1-8

[3] Soong-Der Chen, Abd. Rahman Ramli "Minimum Mean Brightness Error Bi-Histogram Equalization in Contrast Enhancement" IEEE *Transactions on Consumer Electronics* November 2003 , Vol. 49, No. 4. pp 1310-1319

[4] Chao Wang and Zhongfu Ye, "Brightness preserving histogram equalization with maximum entropy: a variational perspective", IEEE *Trans. Consumer Electron*., Nov. 2005. vol. 51, no. 4, pp. 1326-1324,.

[5] M. Abdullah-Al-Wadud, Md. Hasanul Kabir, M. Ali AkberDewan, and OksamChae, "A Dynamic Histogram Equalization for Image Contrast Enhancement" IEEE *Transactions on Consumer Electronics,* MAY 2007 Vol. 53, No. 2, pp 593-600.

[6] David Menotti, Laurent Najman, Jacques Facon, and Arnaldo de A. Araújo, "Multi-Histogram Equalization Methods for Contrast Enhancement and Brightness Preserving", IEEE *Transactions on Consumer Electronics*, August 2007 Vol. 53, No. 3, pp. 1186- 1194,

[7] Nymlkhagva Sengee, and Heung Kook Choi, "Brightness preserving weight clustering histogram equalization", IEEE *Trans. Consumer Electronics,* August 2008. vol. 54, no. 3, pp. 1329 - 1337,

[8] Mary Kim and Min Gyo Chung, "Recursively separated and weighted histogram equalization for brightness preservation and contrast enhancement", IEEE *Trans. Consumer Electronics,* August 2008 vol. 54, no. 3, pp. 1389 - 1397,

[9] K. S. Sim, C. P. Tso, and Y. Y. Tan, "Recursive sub-image histogram equalization applied to gray scale images", *Pattern Recognition Letters*, 2007. vol. 28, no. 10, pp. 1209-1221,

[10] TarikArici, SalihDikbas, "A Histogram Modification Framework and ItsApplication for Image Contrast Enhancement" IEEE *Transactions on Image Processing,* September 2009 VOL. 18, NO. 9, pp 1921- 1935.

[11] Gyu-Hee Park, Hwa-Hyun Cho, and Myung-Ryul Choi "A Contrast Enhancement Method using Dynamic Range Separate Histogram Equalization" 2008 IEEE *Transaction on Consumer Electronics* October 13 pp 1981-1987.

[12] Chen HeeOoi, Nicholas SiaPik Kong, and Haidi Ibrahim "Bi-Histogram Equalization with a Plateau Limit for Digital Image Enhancement" IEEE *Transactions on Consumer Electronics,* November 2009 Vol. 55, No. 4, pp 1752-1758

[13] Haidi Ibrahim, and Nicholas SiaPik Kong, "Brightness Preserving Dynamic Histogram Equalization for Image Contrast Enhancement", IEEE *Transactions on Consumer Electronics*, Nov. 2007 Vol. 53, No. 4, pp. 1752-1758,

[14] ZhiyuanXu, Xiaoming Liu, Na Ji "Fog Removal from Color Images using Contrast Limited Adaptive Histogram Equalization" IEEE *2009* pp 1-5.

[15] Yisu Zhao, Nicolas D. Georganas, Emil M. Petriu "Applying Contrast-limited Adaptive Histogram Equalization and Integral Projection for Facial Feature Enhancement and Detection" IEEE *2010* pp 8161-8166.

[16] Manali S. Rathi, Atul H. Karode, and Shekhar R. Suralkar "Contrast Enhancement and Smoothing Using Histogram Modification Method for Medical Images" IJCTA | Sept-Oct 2012

[17] Rajesh kumarRai, PuranGour, and Balvant Singh "Underwater Image Segmentation using CLAHE Enhancement and Thresholding" IJETAE January 2012 .2, Issue 1,

[18] Pei-Chen Wu, Fan-Chieh Cheng and Yu-Kumg Chen "A Weighting Mean-Separated Sub-Histogram Equalization for Contrast Enhancement" National Science Council under the project NSC 98-2221-E-211-013. *2010* IEEE *Transaction on consumer Electronics* pp 1-4

[19] Mohd. Farhan Khan, Ekram Khan and Z.A. Abbasi "Weighted Average Multi Segment Histogram Equalization For Brightness Preserving Contrast Enhancement" IEEE *2012Transaction on consumer Electronics* pp 1-6

[20] Norsilabt Shamsuddin, Wan Fatimah bt Wan Ahmad, Baharum b Baharudin and MohdKushairi b MohdRajuddin "Significance Level of Image Enhancement Techniques for Underwater Images" 2012 IEEE *Transaction on consumer Electronics* pp 490-494.