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Image Enhancement using Recursive Standard Intensity Deviation Based Clipped Sub Image Histogram Equalization

Sandeepa K S, Basavaraj N Jagadale, J S Bhat

Abstract: ***The low exposure image enhancement has become indispensable inimage processing for better visibility. The most challenging in image enhancement is especially to curtail over-enhancement problems. This paper presents a method, performs the separation of the histogram based on respective standard intensity deviation value and then recursively equalizes all sub histograms independently. The over-enhancement problem is minimized by this method. It applies more in an underwater image, because of its low light conditions. The experiment results are analyzed in terms of entropy and output image inspection. The proposed method results show significant improvement over earlier recursive based histogram equalization algorithms.***

Keywords: ***Recursive standard intensity deviation basedhistogram equalization, clipped histogram, entropy.***

I. INTRODUCTION

The histogram equalization [HE] [1] is a common technique used for flattens and enlarges the dynamic grey level of the input image. It is less used in many applications because it does not preserve image brightness, lead over enhancement and introduce undesirable artefacts [2]. To overcome this problem, different brightness preservation HE based algorithms have been proposed.

The Brightness preserving histogram equalization like (BBHE) [3] and (DSIHE) [4] methods were proposed. These methods bisect the histogram based on mean and median value and then equalizes both sub-images independently. These techniques are capable of preserving brightness into a certain extent and shows result better than HE. The main limitations of these two methods are not being suitable for images requiring a higher degree of brightness preservation and causes over enhancement because of the separation done once.

To overcome the limitation of BBHE and DSIHE, multi histogram approaches like [RMSHE] [5] and [RSIHE] [6] are proposed. RMSHE performs BBHE recursively based on the mean value, whereas RSIHE performs division of histogram-based on a median value. Although, the recursive nature implies scalable brightness preservation, these methods fail to control over enhancement problem. The over enhancement problem caused due to blown out of the image details it can be slightly controlled by clipping the frequency bins greater than a selected threshold. It helps in preserving image details and avoids saturation effect [7], [8].

In a recent approach, the exposure intensity-based sub-image HE [ESIHE] was adopted [9], which performs image subdivisionby using exposure threshold value. This work is extended further into the recursive and recursive separate approach. Recursive ESIHE [R_ESIHE] iteratively performs ESIHE until the threshold value reached and recursive separate ESIHE splits the histogram into two or more sub-images based on a parameter isseparate exposure threshold [10]. These methods also use clipped histogram for minimizing over enhancement but over enhancement, problem persists.

The standard intensity deviation (SID) based clipped sub-image HE [11] method uses a defined threshold value for histogram subdivision and equalization. The output image preserves maximum information and control over enhancement by reducing the gap between adjacent pixels. The limitation of the SIDCSIHE is not stretching the dynamic range up to the last intensity value for some low light images. In this work, an extension of SIDCSIHE is proposed by studying the performance of RMSHE, RSIHE, and RESIHE. This method has a benefit in using the intensity information of the image, redefine the threshold value and produces sub-images recursively.The recursive approaches have been claimed to preserve more brightness and enhance image contrast. The equalization process reallocates pixel information and produces an enhanced output image.

The organization of the paper as follows; in section 2, describe the RSIDCSICHE. The results and conclusions are given in Section 3 and 4 respectively.

II. PROPOSED METHOD

This work mainly differs from previous approaches [5], [6], [7] to enhance image contrast by the way ofmodifying the pixel intensity. This method is a generalization of SIDCSIHE, here defined threshold value is used up to certain recursive level. It helps to reallocate image intensity range as required and the gap between adjacent pixels are minimizing.

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* Correspondence Author

Sandeepa K S*, Department of Electronics, Kuvempu University, Jnanashyadri, Shimoga, India. Email: saan.ks@gmail.com.

Basavaraj N Jagadale, Department of Electronics, Kuvempu University, Jnanasahyadri, Shimoga, India. Email: basujagadale@gmail.com.

J S Bhat, Indian Institute of Information Technology, Surath,, India. Email: jsbhat.iiits@gmail.com

The fig 1, illustrates the comparison of previous recursive approaches is RMSHE, RSIHE, RESIHE with its respective histograms. These methods show the over enhancement problems in terms of a large gap in the higher intensity pixels [12]. The RSIDCSIHE algorithm has three main stages are SID value calculation, histogram clipping, recursive sub histogram, and equalization.

A. SID value calculation

The standard deviation functionσ, is the difference of corresponding intensity value and mean of the image as given in equation (1) [13].

$$\sigma = \left(\frac{\sum_{i=1}^{L}(i-H_\mu)^2 xH(i)}{\sum_{i=1}^{L}H(i)}\right)^{1/2}. \quad (1)$$

The mean image histogram is given by equation (2).

$$H_\mu = \frac{\sum_{i=1}^{L}H(i)\, i}{\sum_{i=1}^{L}H(i)}, \quad (2)$$

where $H(i)$, represents corresponding intensity value$i$ and L the total grey levels. The normalized value is obtained between arange [0.1] and is expressed in equation (3).

$$\sigma_{norm} = \left(1-\left({}^{\sigma}/_{L}\right)\right). \quad (3)$$

Another parameter X_{SID} is given by

$$X_{SID} = L * \sigma_{norm} \quad (4)$$

where σ_{norm} is the normalized value used for histogram modification.

B. Histogram Clipping

In the procedure of clipping histogram, threshold value,T_C, is calculated as shown in equation (5).

$$T_c = mean\ (H(i)) \quad (5)$$

$$H_c(i) = T_c \ \ for\ H(i) \geq T_c, \quad (6)$$

where $H(i)$ and $H_C(i)$ are the original and clipped histograms, respectively.

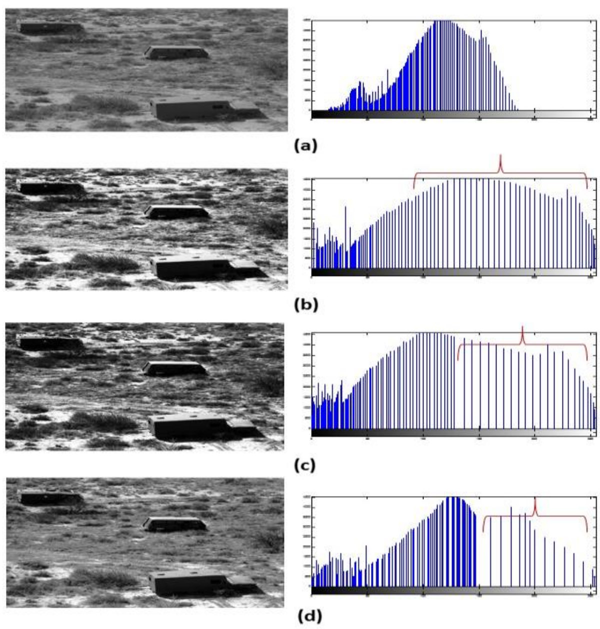

Fig. 1: The result of a field image and its histogram (a) original_image, (b) RMSHE, (c) RSIHE, (d) RESIHE.

The greater histogram bins than the clipping threshold are clipped, as given by equation (6). The entire clipping process is done as shown in Fig. 2b. This is an efficient process because it consumes lesser time andfewer computations [9].

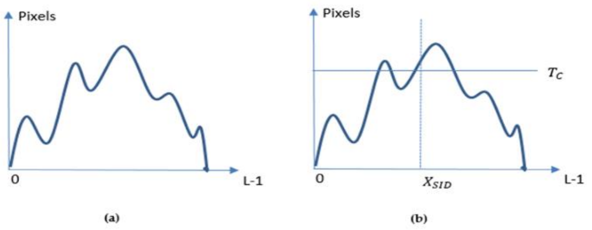

Fig 2: Subdivision and clipping (a) Image histogram (b) process of image subdivision and clipping.

C. Recursive SIDvalue Based Clipped Histogram Sub deviation and Equalization.

In (RSIDCSIHE), the number of recursions depends on the selected recursion level r. In this method, we have selected r as 2. At the first step, clipped input histogram bisect into two sub-images I_{low} and I_{up}based on standard intensity deviation value X_{SID} ranging from 0 to X_{SID} and X_{SID}+1 to $L-1$, respectively. The sub-images probabilities are $P_{low}(i)$ and $P_{up}(i)$.

$$P_{low}(i) = {}^{H_c(i)}/_{N_{low}} \quad for\ \ 0 \leq i \leq X_{SID} \quad (7)$$

and

$$P_{up}(i) = {}^{H_c(i)}/_{N_{up}} \quad for\ X_{SID} \leq i \leq L-1 \quad (8)$$

respectively, with N_{low} and N_{up} being the total number of pixels in each sub-images and the corresponding cumulative distribution functions$C_{low}(i)$ and $C_{up}(i)$, are defined as

$$C_{low}(i) = \sum_{i=0}^{X_{SID}} P_{low}(i) \quad (9)$$

and

$$C_{up}(i) = \sum_{i=X_{SID}+1}^{L-1} P_{up}(i) \quad , \quad (10)$$

respectively. The next step is the individual histogram equalization process by using the transfer function $F(i)$is given by

$$F(i) = \begin{cases} X_{SID} * \quad C_{low} & for\ 0 \leq i \leq X_{SID} \\ (X_{SID}+1) + (L-X_{SID}+1) * C_{up} & for\ X_{SID+1} \leq i \leq L-1 \end{cases} . \quad (11)$$

The last stage is getting the final image by two sub-images are combined using transfer function F(i). The successive iterations are decided based on the recursion level r. The processed image shown in Fig (3b) indicates overcoming the problem of SIDCSIHE (fig 3a) and over enhancement. The proposed method histogram starched to maximum range and minimized gap between the adjacent pixels compared to other recursive approaches leading to better image quality.

D. Algorithm

1. Compute the histogram of the input image H_i.
2. Compute SID value and threshold parameter X_{SID}.
3. Compute clipping threshold T_c.For the Histogram clipping $H_c(i)$.
4. The two sub-images of the input clipped histogram are obtained based on X_{SID} .
5. Apply Histogram equalization to individual sub-image histograms.
6. Integrate both images to get the final image.
7. Repeat the steps 1-6 till the recursion level reaches the chosen value r

The simulated results of the proposed method are compared with RMSHE, RSIHE, RESIHE and SIDCSIHE methods for quantitative and qualitative analysis. To compare, low exposure underwater images (Fish, Fish2, Tree, Reef, and Seafloor) and low exposure images (Girl, Couple, Field, Mosque and Plane) are taken.

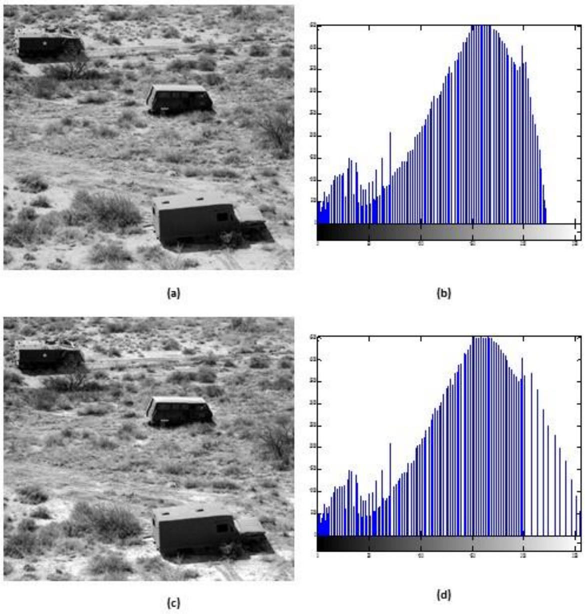

Fig 3. The processedfield image (a) SIDCSIHE(b) RSIDCSIHE.

III. QUANTITATIVE ANALYSIS

The quantitative analysis has been performed based on entropy measurement. The entropy value measures the information content of the image and the richness of the image details. According to information theory, entropy is defined as [13],

$$Entropy(p) = -\sum_{k=0}^{L-1} p(k)\log\, p(k) \qquad (12)$$

where $p(k)$ is the probability density function at the intensity level with k and L is the total number of grey levels of the image. The higher the entropy value, the more image details, and better quality.

The table-I contains entropy values of the various recursive based methods (for all ten images). From the table, it is clear that the entropy value of the proposed method is more as compared to other methods and hence, the proposed method is well suited for bringing out information content. The entropy values for fish, fish2, Tree, field and mosque images are very close to original image entropy.

IV. QUALITATIVE ANALYSIS

The qualitative analysis is important along with quantitative analysis. The visual quality aspects like annoying artefacts, over-enhancement and unnatural look, can be judged through qualitative analysis. To prove the strength and usefulness of the proposed methods, the standard low exposure images are taken from various fields for analysis as shown in fig 4-8.

Table- I. Average entropy values of comparisons methods

Input Image	**Original**	**RMSIHE**	**RSIHE**	**RESIHE**	**SIDCSIHE**	**RSIDCSIHE**
Fish	5.05	5.01	5.038	5.048	5.049	**5.049**
Fish2	4.49	4.471	4.436	4.487	**4.489**	4.487
Tree	5.32	5.273	5.281	5.292	5.315	**5.317**
Reef	6.282	6.216	6.216	6.247	6.253	**6.261**
Seafloor	6.865	6.8	6.807	6.824	6.829	**6.839**
Girl	6.42	6.182	6.182	6.351	6.353	**6.354**
Couple	7.052	6.833	6.857	6.945	6.957	**6.966**
Field	6.563	6.491	6.529	6.503	6.547	**6.547**
Mosque	6.263	6.102	6.188	**6.258**	**6.258**	6.255
Plane	6.097	5.902	5.845	5.995	6.012	**6.024**
Average	6.040	5.928	5.938	5.995	6.006	**6.010**

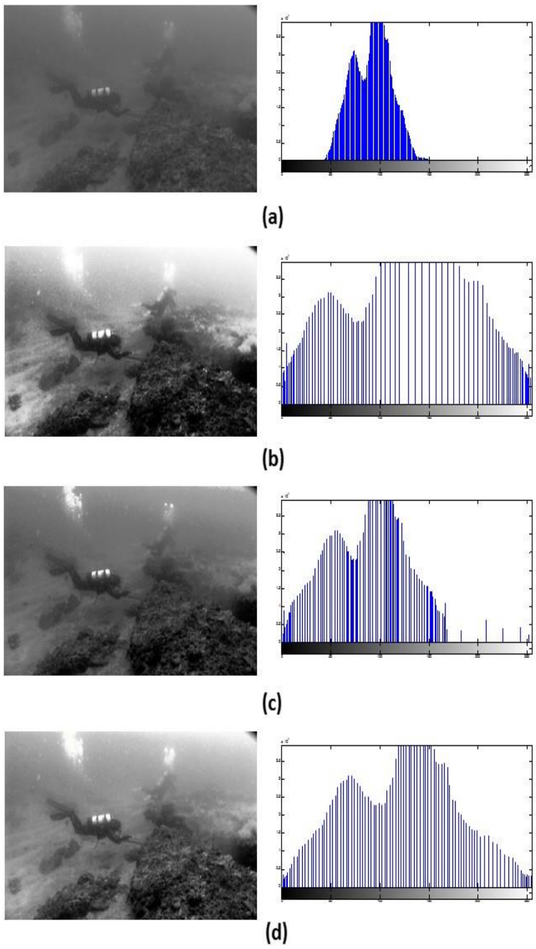

Fig 4. Reef_image and its histogram (a) original_image (b) RMSHE ;(c) RESIHE; (d) RSIDCSIHE.

Fig. 4a is a low exposure reef image and its respective histogram. Fig 4b is processed by RMSHE leads to over-enhancement and some information cannot be identified and the corresponding histogram of the image also justifies over enhancement problem. Fig 4c is processed by RESIHE is dark compared to other images. However, its histogram detail appears to equalize in a lower intensity region and producing large gap at a higher intensity region. Fig. 4d is proposed by RSIDCSIHE, the image contrast is enhanced and have better visual quality along with well-equalized histogram as compared to other methods.

Fig. 5a is a low exposure seafloor image and its respective histogram. The result of contrast enhancement can be seen in fig 5d. The result of RMSHE has an over enhancement problem as shown in fig 5b. Fig 5c is processed is by RESIHEtechnique is incapable to enhance image contrast to a great extent as compared RSIDCSIHE. The RSDCSIHE minimizes the over-enhancement problem by reducing the grey level gap at the higher intensity level.

Fig 6a is an underwater fish image. Fig 6b, 6c are processed by RMSHE and RSIHE methods, respectively. These images seem to look dark and the features are not seen clearly. Fig 6d is the result of RESIHE method, showing better enhancement. Fig 6e and 6f show the results obtained through SIDSICHE, and RSIDSICHE. These methods enhance the contrast in a balanced way, not only in scales of fish or pebbles or rock surfaces but also in the surrounding dark area of the image. They are looking more accepted with improved visual excellence than the last methods.

Fig 7a is a tree image processed by RMSHE. The resultant of tree image shows over enhancement at the middle and bottom portion of the image. The image processed under RSIHE method is dim as equated to all other methods. Fig 7f is the result of the proposed method RSIDCSIHE, having well contrast and visual quality as compared to other remaining methods.

The low exposure girl image and the sovereignty of RSIDCSIHE can be analyzed by matching it with the fig 6b-d of RMSHE, RSIHE, and RESIHE respectively. Due to the over-enhancement problem, in the existing methods, image information is uncertain particularly, the background curtain, hair of the girl and nose surroundings, which is highlighted by square boxes. Fig 8f obtained by the proposed RSIDCSIHE method, shows improved contrast and visual eminence approaching its natural look.

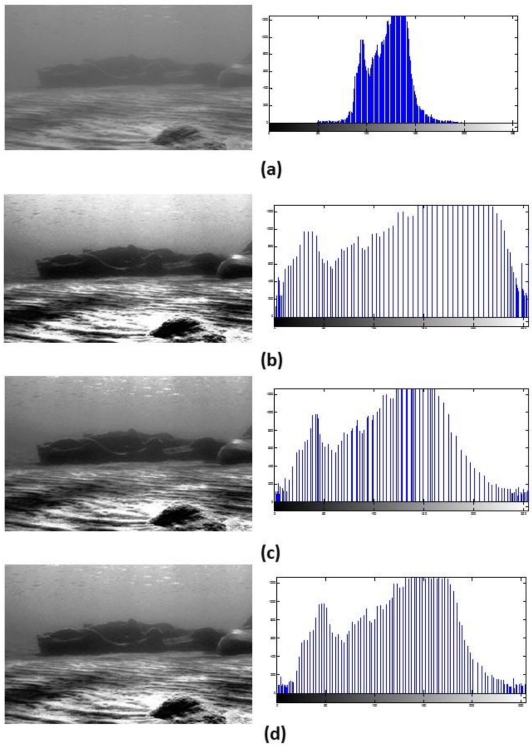

Fig 5. Seafloor_image and its histogram (a) original_image (b) RMSHE ;(c) RESIHE; (d) RSIDCSIHE.

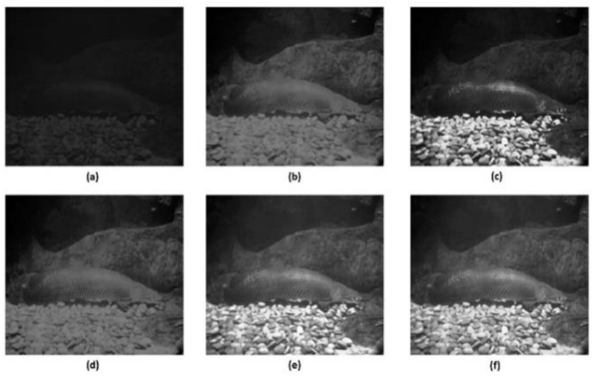

Fig 6. Fish_image (a) original_image (b) RMSHE ;(c) RSIHE; (d) RESIHE; (e) SIDCSIHE; (f) RSIDCSIHE.

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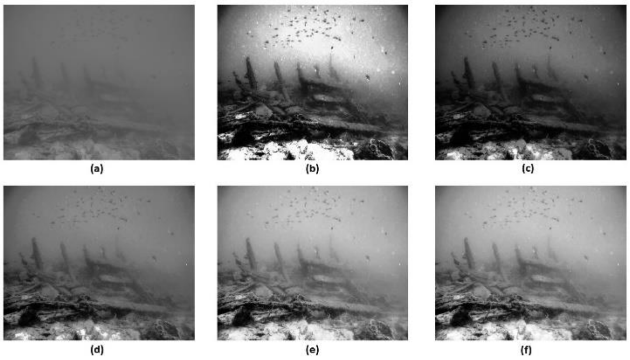

Fig 7. Under_tree_image (a) original_image (b) RMSHE ;(c) RSIHE; (d) RESIHE; (e) SIDCSIHE; (f) RSIDCSIHE.

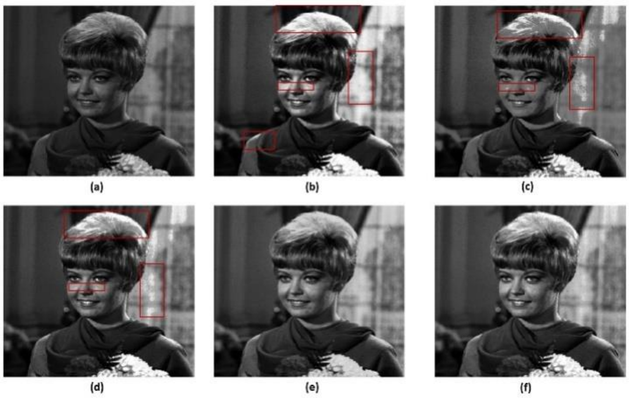

Fig 8. Girl_image (a) original_image (b) RMSHE, (c) RSIHE, (d) RESIHE; (e) SIDCSIHE and (f) RSIDCSIHE.

V. SUMMARY AND CONCLUSION

The objective of this paper is to establish an advantage of a recursive approach to the existing SIDCSIHE method in achieving contrast enhancement. The balanced histogram equalization is achieved and over enhancement can be controlled by minimizing the gap between two adjacent grey values.

After a qualitative and quantitative analysis, it is found that the proposed method improves image contrast in comparison to previous methods. It provides the maximum entropy among comparison and shows the richness of details of the image and is well suitable for low exposure and underwater images.

The recursive SID based clipped sub-image histogram equalization algorithm is effective for enhancing the contrast of the low exposure and underwater images, acquired in the dim light conditions. The final histogram equalization provides control over enhancement by minimizing the large gap between the adjacent pixels which is the reason for the over enhancement problem. The visual quality and entropy values show the strength of the presented method in comparison to the existing recursive algorithm for a variety of images.

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AUTHORS PROFILE

Dr. Sandeepa K S, is received his M.Sc. (Electronics) and Ph.D. from Kuvempu University, Shimoga, India. He is currently working as a lecturer at the same University. His research interest is in signal and image processing, machine learning, artificial intelligence.

Dr. Basavaraj N Jagadale, is currently an Assistant Professor in the Department of Electronics, Kuvempu University, Shimoga, India. He received the Ph.D., from Karnataka University, Dharwad, India. He has worked in the Radiology Dept., University of Pennsylvania, USA under UGC Raman fellowship sponsored by the govt. of India. His research interest includes the signal and image processing domain.

Prof. J. S. Bhat, is a Director of IIIT, Surat. He had a Ph.D. on "semiconductor nanostructures" from Karnataka University, Dharwad in 1993. He worked as a reader in electronics and a professor of physics (electronics) at Karnataka University, Dharwad. His areas of research are Semiconducting Nano devices, Metal Oxide Thin Films, and Digital Signal Processing. He has published 52 research papers in refereed journals and conferences. He has guided 6 students for Ph.D. and 6 for M.Phil. Degrees and several M.Sc. (Electronics) projects. He has visited several institutions as chairman/coordinator/member of the NAAC peer team.