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Image Enhancement of Underwater Digital Images by Utilizing L*A*B* Color Space on Gradient and CLAHE based Smoothing

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ABSTRACT
The underwater digital images generally suffer from blur, low contrast, non-uniform lighting, and diminished color. This research paper proposed a preprocessing technique based on image to improve the quality of underwater digital images. The mixed Contrast Limited Adaptive Histogram Equilization (CLAHE) has actually neglected the utilization of L*A*B color image space to improve the image in an effective way. Also the uneven illumination problem is also ignored by many researchers. To conquer the problems of on hand technique a brand new L*A*B color image space as well as CLAHE based digital image enhancement technique is proposed in this paper. To conquer the problem of uneven illumination in the resultant image of the CLAHE image output has been further removed by utilizing the smoothing process of image gradient. The main objective of the planned algorithm is to enhance the accuracy of the underwater digital image enhancement methods/techniques. Various types of digital images will be considered for experimental point of view to estimate the efficacy of the image enhancement methods or techniques. Also, various types of image top-quality metrics have been utilized in order to check the significant improvement of the recommended technique over the offered techniques. The significant improvements have shown in the comparative analysis of the proposed algorithm over the available mixed CLAHE.

Keywords
Preprocessing Underwater Image, CLAHE, L*A*B* Color Image Space, Image Gradient, Image Enhancement, Image Smoothing

1. INTRODUCTION
Virtually no analytical evaluation has been carried out on underwater images. The light quantity is reduced once as we go deeper into the water and so colors disappear one-by-one depending upon the wavelength. The red color goes away approx. at depth of 3 meter. Orange colorization disappears at approximately 5m depth. At 10 m depth, the yellow color goes off and lastly the purple and green color disappears at depths which are beyond 10m. As the blue color has the shortest wavelength so, it travels more deeply in the water. The underwater digital images are consequently dominated by a mix blend of blue-green color. These underwater images enforce various problems mainly due to denser medium, light scattering, light absorption and light reflection. These problems lead to the poor visibility of the images. Light energy is removed by absorption and scattering modifies the light path direction. These effects are not only the result of water however also the result of various other components like floating particles and dissolved organic matter.

There are mainly 2 types of scattering:

1. Forward scattering and
2. Backward scattering

Forward scattering leads to blurring of the various image features whereas backward scattering generally reduces the image contrast.

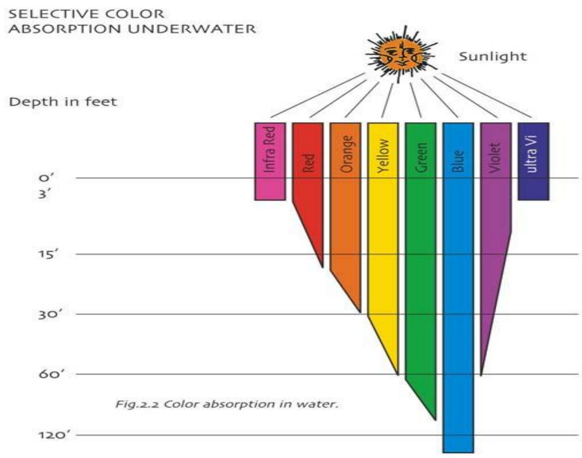

Figure 1: How Color Changes as we go deeper in Underwater

This research paper suggests a new technique in L*A*B color space. The primary goal is to improve the quality of the image and smoothing the various underwater pictures. The following section highlight the literature review and also gives you the idea how to convert RGB space to L*A*B color space. The next section shows the recommended methodologies. In section 4, comparative analysis is carried out by using different available techniques. And lastly the conclusion section of the proposed work.

2. LITERATURE SURVEY
Chen Hee et al. [6] have shown that various HE (Histogram Equalization) based brightness preservation techniques often produce undesirable artifacts. So, they presented two techniques to overcome the downsides in which the previous approach divides the image histogram based on the parameter median, and iteratively partition into the upper and lower sub-histograms, in order to generate all-in-all 4 sub-histograms. The partitioning points in the upper and lower sub-histograms are generally assigned to a brand new DR (Dynamic Range) and then the process of clipping is carried out to each image sub-histogram. They presented that later technique is the usually extension of the BHEPL (Bi-Histogram Equalization

Plateau Limit) that divides the histogram of an input image according to its mean value and after that, the process of clipping is carried out to every sub-histogram as per their median value. Nyaml Sengee et al. [7] have recognized the one broadly approved contrast enhancement technique which is GHE (Global Histogram Equalization). This achieves comparatively far better performance on usually all different types of digital image however sometimes leads to disproportionate visual deterioration. Therefore, they presented a new technique which is normally the extension of BHE (Bi-Histogram Equalization) called BHENM (Bi-Histogram Equalization with Neighborhood Metric) which includes two stages. They have shown that in the primary stage, large image histogram container leads to washout artifacts, are divided into sub-bins by utilizing neighborhood metrics. In this the same values of intensities of the very first image are organized with the help of neighboring info. In the following stage, histogram of the very first image is divided into 2 sub-histograms according to the mean of the histogram corresponding to the first image; after that the sub-histograms are properly equalized independently by utilizing refined histogram equalization that generates flatter histograms. They discussed in analytical results that BHENM concurrently preserves the brightness and also improves the original image's local contrast. Zohaib Hammed et al. [8] have identified that the performance and efficiency of various edge detection algorithm could be affected by severe intensity and noise in homogeneities. Thus they suggested a technique aiming at recognizing image edges with varieties of degradation regarding gradient signal which consist of two steps: AHE (Adaptive Histogram Equalization) and filtering process of gradient modulation to enhance the contrast of a signal in a discriminative way. They discovered that this method is effective and applicable to identify edges of poor and dull images.

Yeong-Kang et al. [9] have presented that TFT LCD (Thin-film Transistor liquid crystal display) is broadly utilized in handheld and portable mobile devices however it takes 20% to 45% of overall system power because of different apps. They likewise recognized that by managing the backlight current brightness can be reduced and the LCDs contrast can reduce the total power consumption however this might cause significant modifications in visual perception. Therefore they presented new technique to reduce the consumption of energy and they also improved the visual changes. They presented two brand new algorithms on content analysis: the NBDA (newest backlight-dimming algorithm) and the NIEA (newest image enhancement algorithm). They analyzed that these proposed algorithms can concurrently reduce the consumption of power by 47% and amplify the ratio of image enhancement by 6.8%. In their proposed algorithm they make use of the SSIM (structural-similarity index metric) to gauge the quality of the image. Seung Jung et al. [11] have presented a brand-new GCEA (global contrast enhancement algorithm) by utilizing the histograms of depth and color images. They have performed this algorithm on the basis of the image histogram-modification framework, the depth and color histograms are primarily divided into various subintervals by utilizing the Gaussian mixture model. The positions segmenting the color histogram are after that adjusted with the aim that spatially neighboring image pixel with the similar depth and intensity values can be clubbed into the similar sub-interval. They stated that by calculating the mapping curve corresponding to contrast enhancement for every sub-interval, the image can have the enhanced global image contrast without over-boosting the local contrast of the image.

Gurvir Singh et al. [12] have identified that in digital image enhancement numerous enhancement techniques have been employed for enhancing images which incorporates gray scale image manipulation, HE (Histogram Equalization) and filtering. They proclaimed that existing methods produce images which don't look as all-natural as the input image and Histogram Equilization tends to generate some infuriating artifacts and deviant enhancement. Therefore to sort these limitations, they presented that various existing brightness preservation techniques are utilized to inspect their performance measurement. Comparison has also been performed as per the objective and subjective parameters. They also stated that subjective parameters are computation time and visual quality and objective parameters are Error, Contrast and PSNR (Peak signal-to-noise ratio). Shiwam Thakarel et al. [13] have presented comparative analysis of different enhancement methods for such type of underwater images. They recognized that underwater pictures suffers from low resolution and contrast due to the conditions of poor visibility, hence the identification of an object become the regular task. The processing of the captured underwater image is necessary as it affects the underwater images quality and these types of images results in serious problems when the comparison is done on the images which are captured from a clean and clearer environment. They also have recognized that that lot of noise occurs because of the natural light absorption, low contrast, non-uniform lighting, poor visibility conditions, and little variations in color, and effect of blurring in the underwater pictures. So they stated that there is a need to prevent these underwater images by utilizing various filtering methods. John Chiang et al. [14] have presented that color change and light scattering are two main sources of underwater photography distortion and no existing processing techniques of underwater images can handle color change and light scattering distortions suffered by these underwater images, and the presence of artificial lighting concurrently. So they presented a novel methodical technique to improve underwater images with the help of dehazing algorithm, in order to compensate the discrepancy of attenuation along with the propagation path. They stated that efficiency of this proposed algorithm for WCID (wavelength compensation and image dehazing) is analyzed both subjectively and objectively by using color patches and video downloaded from the corresponding YouTube site. They have listed in results that underwater images with considerably enhanced visibility and better-quality color fidelity are tracked by the WCID proposed algorithm.

Pooja Sahu et al. [17] have presented the underwater image enhancement techniques to improve underwater image. They also discovered that the underwater image processing is essential as these image cause some severe problems for example excessive noise which results in low contrast, non-uniform lighting, poor visibility conditions and little variations in color, blur effect and pepper noise in the underwater images when contrasting to clearer environment images. They employed median filter for the improvement of underwater images. It helps to judge the level of depth map and enhance the image quality by wiping out noise particles. Another technique which utilized for the enhancement of underwater images is RGB CLS (Color Level Stretching). Balvant Singh et al. [18] have depicted the performance of CLAHE. The performance of this technique is compared with

HE method and contrast stretching. For performance analysis, they have utilized MSE (mean square error) and Signal-to-noise (SNR) ratio as parameters. They implemented this method for testing purpose on different type of underwater images. They identified that underwater image experience low resolution and contrast because of poor visibility conditions, therefore identification of object under water is a challenging task. They also showed comparative analysis of different contrast enhancement methods on underwater images. Sowmyashree S et al. [17] have introduced that the main sources for underwater image distortion are change in color, light scattering. So, underwater images experience low contrast, limited range visibility, blurring, noise and color variation. So they depicted the comparative study of the several image enhancement methods for the enhancement of submerged images. Cosmin Ancuti et al. [18] have recommended a book strategy to enhance underwater images and videos and designed the fusion principles. This proposed technique takes the input and the weight is measures from the degraded image. In order to overcome such underwater image limitations, they introduced 2 inputs which represent color correction and version of contrast enhancement of the primary underwater image; however the 4 weight maps which aim to enhance the visibility of the remote objects corrupted or degraded due to absorption and medium scattering. They stated that this particular technique can be a single underwater image approach which doesn't demand specialized scene structure, information or hardware. Additionally they stated that fusion framework likewise supports image temporal coherence among adjacent frames by just implementing a prolific edge preservation noise reduction technique. The enhanced videos and images are characterized by better exposedness of the image dark regions, reduced noise level, and improved global image contrast whilst the best possible edges and details are enhanced drastically.

Pulung Nurtantio [20] has presented that Success of SIFT (scale-invariant feature transform) image registration is applied to those images where camera footage of underwater images results in poor image quality. To handle this problem, they have presented a new technique to the preprocessing of color imagery of underwater images with the help of CLAHE algorithm. In this algorithm the distribution function of the underwater image intensity values is affected by Rayleigh scattering. The noise is also removed by the function itself. They stated that if implementing the image enhancement CLAHE method, the success of SIFT transform is improved by 41% as compared to the reference method (i.e. contrast stretching technique). Muhammad S. Hitam et al. [13] have presented the technique which improves the quality of the underwater image which was distorted due to the physical properties. This research paper introduces a new technique called Mixed CLAHE color models which specifically designed for underwater images. The technique applies CLAHE on HSV and RGB color models. The results of both are then combined all together by utilizing the Euclidean norm. The experimental results indicate that the designed technique significantly enhances the visual quality of the images by simply enhancing contrast, and reducing artifacts and noise.

3. PROPOSED APPROACH

The comprehensive algorithm of the proposed technique is shown below:

Step #1: Preprocessing of input image: Initially, you need to preprocess the input image. This is due to the reason that underwater images impose some problems. These problems are due to light scattering, light absorption, denser medium and light reflection. These types of problems lead to poor visibility of the images. The amount of light is generally reduced once when we approach deeper into the water and so colors disappear one-by-one relying upon the wavelength. After this process, we calculate the size of the image by utilizing the following equation:

$$[\mathrm{p\ c\ d}] = \mathrm{size}\ \mathrm{F}(\mathrm{x}, \mathrm{y})$$

Where, p and c represents the number of rows and columns respectively, d represent the size of input image $\mathrm{F}(\mathrm{x}, \mathrm{y})$.

Step #2: Convert RGB image to L*a*b color space- Converts the image color intensity values of the input image $\mathrm{F}(\mathrm{x}, \mathrm{y})$ to the L* A* B* color space by making use of color transformation structure i.e. makecform. This transformation requires several parameters. This is the reason why RGB image do not produce good results. So in order to overcome this problem we apply L* A* B* for image enhancement.

$$\mathrm{L}a\mathrm{b\_img} = \mathrm{applycform}\left(\mathrm{inpt\_img}, \mathrm{makecform}('\mathrm{srgb2lab}')\right)$$

Steps #3: Extraction of L component (light component)

(a) Implement CLAHE on Light (L) component.

$$\mathrm{LabCLAHE\_opadapteq}\left(\mathrm{lab\_img}(:,:,1), '\mathrm{NumTiles}', \ldots [8,8], '\mathrm{Cliplimit}', 0.005\right);$$

$$\mathrm{Lab\_op} = \mathrm{cat}\left(3, \mathrm{LABCLAHE\_op}, \mathrm{lab\_img}(:,:,2), \mathrm{lab\_img}(:,:,3)\right);$$

Step #4: Convert L*A*B color place to RGB plane

$$\mathrm{Output\_image} = \mathrm{applycform}\left(\mathrm{Lab\_op}, \mathrm{makecform}('\mathrm{lab2srgb}')\right);$$

Step #5: Implement gradient based smoothing- Now apply image gradients in order to remove the uneven illumination problem. Image gradients can be utilized to extract useful information from different images. After finding image gradients, those image pixels that have large gradient values turn out to be the possible candidate of edge pixels. The image pixels having large gradient values in the gradient direction results in edge pixels. The edges can be traced in the perpendicular direction to the gradient direction. This is implemented to get the right edges corresponding to the hue component.

Implement GBS (gradient based smoothing) on RGB plane

$$\mathrm{New}(:,:,1) = \mathrm{GBS}\left(\mathrm{output\_image}(:,:,1)\right);$$

$$\mathrm{New}(:,:,2) = \mathrm{GBS}\left(\mathrm{output\_image}(:,:,2)\right);$$

$$\mathrm{New}(:,:,3) = \mathrm{GBS}\left(\mathrm{output\_image}(:,:,3)\right);$$

Step #6: You will get the final output image and this image is visibly stronger when compared to the input image.

4. EXPERIMENTAL RESULTS

The quality of the enhanced underwater image is judged by both ways: subjective as well as objective. In subjective ways they take into account the visual appeal as well as the presence of superfluous color artifacts. The various types of underwater images are utilized for experimental result. The seven metrics which are utilized to compare the underwater image quality of the enhanced images are listed beneath:

- MSE (Mean Square Error),
- RMSE (Root Mean Square Error),
- PSNR(Peak Signal Noise Ratio),
- NCC(Normalized Cross-Correlation),
- MD(Maximum Difference),
- AD(Average Difference),
- NAE(Normalized Absolute Error)

The Mean Square Error (MSE) represents the growing squared error amid the original image and the enhanced image, while PSNR gives the peak error measure. As the RMSE and NAE should be reduced, so the proposed approach is giving the better results when compared to other methods of RMSE where it's less in every individual case.

4.1 Mean Square Error (MSE)

The Mean Square Error (MSE) is computed by the following formula:

$$\mathrm{MSE} = \frac{\sum_{M,N}[\mathrm{IM}_1(m,n) - \mathrm{IM}_2(m,n)]^2}{M * N}$$

Where, IM_1& IM_2represents the original and enhanced image respectively. The size of the image must be compatible with each other and it is represented by $M * N$.

4.2 Peak Signal Noise Ratio (PSNR)

In order to calculate the PSNR value, we make use of MSE .The PSNR is estimated by the following formula:

$$\mathrm{PSNR} = 20\log_{10} \frac{2^{\beta} - 1}{\sqrt{(\mathrm{MSE})}}$$

Where β represent the bit/sample. In this proposed work, we used β=8. The reason behind is color images which range from 0 to 255 are taken into account in this experiment.

4.3 Root Mean Square Error (RMSE)

The Root Mean Square Error (RMSE) is computed as:

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{M,N}[\mathrm{IM}_1(m,n) - \mathrm{IM}_2(m,n)]^2}{M * N}}$$

4.4 Normalized Absolute Error (NAE)

Now we talk about Normalized Absolute Error (NAE). Higher value of NAE signifies that image has poor quality. It is defined by the following formula:

$$\mathrm{NAE} = \frac{\sum_{i=1}^{N}\sum_{j=1}^{M} \mathrm{Abs}(E(i,j))}{\sum_{i=1}^{N}\sum_{j=1}^{M}(I(i,j))}$$

Here, Abs denotes the Absolute Error and Mand N denotes rows and columns of the image respectively.

4.5 Normalized Cross-Correlation (NCC)

The Normalized Cross-Correlation (NCC) is generally used to figure out the similarities between the registered image and the input image. It is calculated with the help of following equation:

$$\mathrm{NCC} = \frac{\sum_{i=1}^{N}\sum_{j=1}^{M} I(i,j) * O(i,j)}{\sum_{i=1}^{N}\sum_{j=1}^{M} I(i,j) * I(i,j)}$$

4.6 Maximum Difference (MD)

Maximum Difference calculates the difference between any 2 image pixels in such a manner that larger image pixel appears right after the smallest image pixel. Larger value of MD shows that image has poor quality.

$$\mathrm{MD} = \max(E)$$

Where E denotes the error.

4.7 Average Difference (AD)

The AD corresponds to those image pixels which have values less than the image pixel in original input image. The AMD (Average Minimum Difference) represents those image pixels which have a value more than the image pixel in original input image. The AD is defined as the difference between maximum value and minimum value. The motive should be to minimize the average difference.

$$\mathrm{AD} = \sum_{i=1}^{N}\sum_{j=1}^{M} \frac{E(i,j)}{M * N}$$

Here, M and N represents the number of rows and columns respectively. The parameter E is calculated by the following formula

$$E = I(i,j) - O(i,j)$$

The calculated values of AD, MD, NCC, NAE, PSNR, RMSE and MSE are listed in following tables (i.e. Table 1-Table 7). It is understandable from the results that the CLAHE L*A*B color space model not only gives better results. It also enhances the quality of the image. When we compare the MSE value with CLAHE-Mix, then we noticed that MSE value of proposed approach is decreased approximately in every case. The quality of the enhanced underwater images which is analyzed by the Root Mean Square Error (RMSE) value has described that CLAHE L*A*B is usually low in every image test. The PSNR values has depicted that CLAHE L*A*B is generally highest for all type of test images. If the MD has larger value then it signifies that image has poor quality. The Average Difference value has to be minimized. If the value of NAE is larger, then it also shows poor image quality just like MD. As the value of NCC has to approximately equal to 1, so proposed algorithm is giving the better results as compared to other available methods. This is only as the value of NCC is approx. equal to 1 in every image test case.

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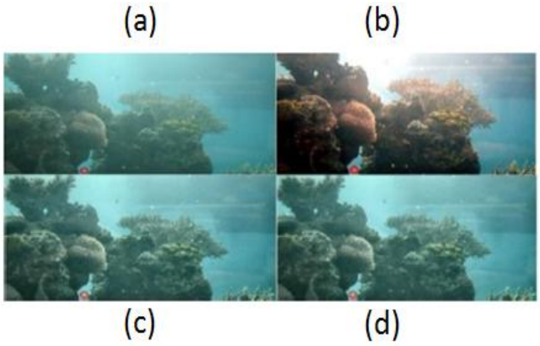


Figure 2: (a) Original Image (b) Mix-CLAHE image (c) L*A*B CLAHE image (d) New enhanced image

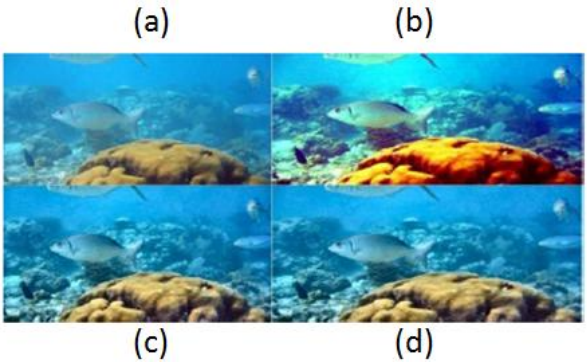


Figure 3: (a) Original Image (b) Mix-CLAHE image (c) L*A*B CLAHE image (d) New enhanced image

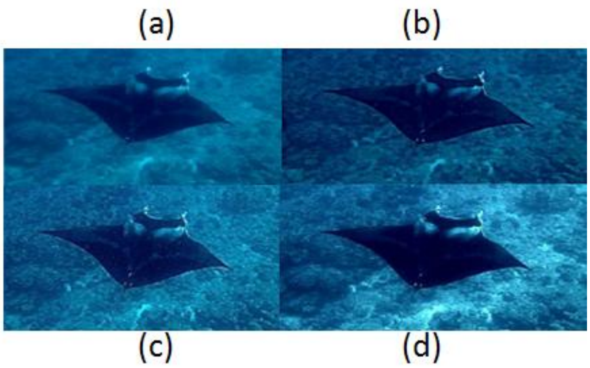


Figure 4: (a) Original Image (b) Mix-CLAHE image (c) L*A*B CLAHE image (d) New enhanced image

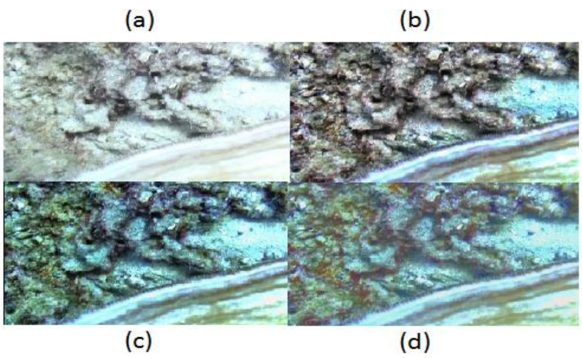


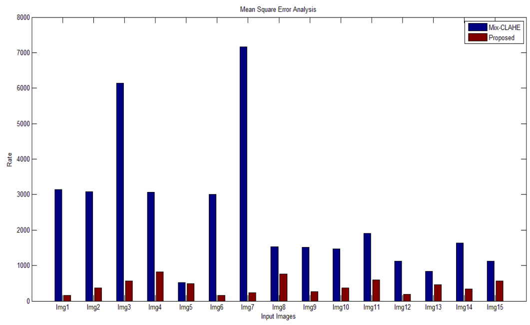
Figure 5: (a) Original Image (b) Mix-CLAHE image (c) L*A*B CLAHE image (d) New enhanced image

4.8 Mean Square Error

Table 1. Comparison of Mean Square Error (MSE) with Mix CLACHE and Proposed Approach

Input Image	Mix-CLAHE	Proposed Approach
Img1.jpg	3145.80	161.34
Img2.jpg	3082.72	363.56
Img3.jpg	6146.35	570.06
Img4.jpg	3066.35	821.23
Img5.jpg	512.56	489.67
Img6.jpg	3012.20	151.12
Img7.jpg	7160.15	232.06
Img8.jpg	1532.14	761.54
Img9.jpg	1521.13	257.32
Img10.jpg	1473.45	366.53
Img11.jpg	1905.11	599.08
Img12.jpg	1128.87	194.54
Img13.jpg	835.67	452.49
Img14.jpg	1629.67	336.32
Img15.jpg	1127.45	560.07

In Graph 1, we presented the quantized analysis of MSE corresponding to different underwater images by utilizing Mix CLAHE image enhancement transform and this is shown in Blue Color, whereas the quantized analysis of proposed L*A*B image enhancement approach is shown by Red color.



Graph 1: MSE Analysis of Proposed & Existing Approach for different underwater images

As you can notice with our proposed approach there is a decrease in Mean Square Error value of underwater images as compared to other methods. The decrease in MSE values signifies the enhancement of image quality.

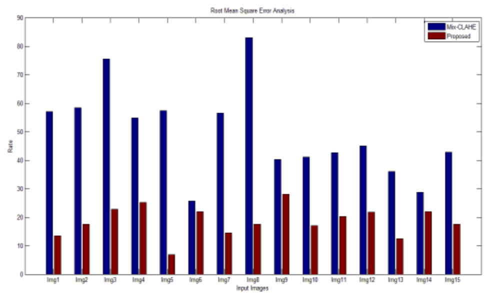
4.9 Root Mean Square Error

Table 2. Comparison of Root Mean Square Error (RMSE) with Mix CLACHE and Proposed Approach

Input Image	Mix-CLAHE	Proposed Approach
Img1.jpg	57.10	13.54
Img2.jpg	58.32	17.56
Img3.jpg	75.45	22.76
Img4.jpg	54.76	25.09
Img5.jpg	57.45	6.78
Img6.jpg	25.67	21.89
Img7.jpg	56.54	14.43
Img8.jpg	82.92	17.56
Img9.jpg	40.23	28.09

Img10.jpg	41.05	17.03
Img11.jpg	42.67	20.25
Img12.jpg	45.08	21.78
Img13.jpg	35.96	12.48
Img14.jpg	28.67	21.95
Img15.jpg	42.84	17.56

Graph 2 shows the quantized analysis of RMSE corresponding to different underwater images. The results of Mix-CLAHE image enhancement transform is shown in Blue Color, whereas the quantized analysis of proposed L*A*B image enhancement approach is shown in Red color.



Graph 2: RMSE Analysis of Proposed & Existing Approach for different underwater images

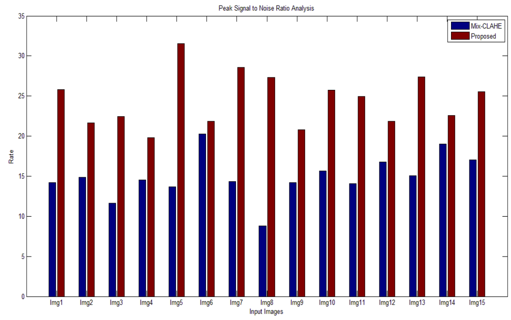
As you can notice with our proposed approach there is a decrease in Root Mean Square Error value of underwater images as compared to other methods. The decrease in MSE values signifies the enhancement of image quality.

4.10 Peak Signal Noise Ratio

Table 3. Comparison of Peak Signal Noise Ratio (PSNR) with Mix CLACHE and Proposed Approach

Input Image	Mix-CLAHE	Proposed Approach
Img1.jpg	14.23	25.78
Img2.jpg	14.87	21.67
Img3.jpg	11.63	22.43
Img4.jpg	14.56	19.78
Img5.jpg	13.67	31.57
Img6.jpg	20.26	21.85
Img7.jpg	14.35	28.58
Img8.jpg	8.79	27.30
Img9.jpg	14.20	20.78
Img10.jpg	15.67	25.74
Img11.jpg	14.09	24.93
Img12.jpg	16.78	21.86
Img13.jpg	15.09	27.38
Img14.jpg	19.04	22.56
Img15.jpg	17.05	25.51

Graph 3 shows the quantized analysis of PSNR corresponding to different underwater images. The results of Mix-CLAHE image enhancement transform is shown in Blue Color, whereas the quantized analysis of proposed L*A*B image enhancement approach is shown in Red color.



Graph 3: PSNR Analysis of Proposed & Existing Approach for different underwater images

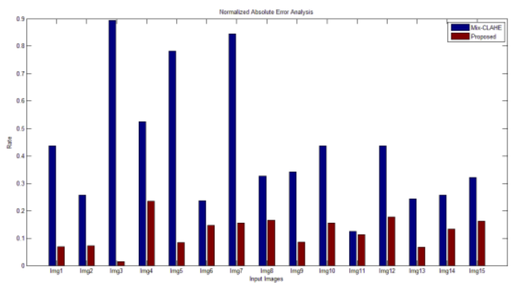
It is clear from the above graph that there is increase in PSNR values as compared to other methods of image enhancement. This increase in PSNR values shows that the enhancement is done in a proper way on underwater images and results are satisfactory in contrast to other enhancement methods. Higher value of PSNR means better image quality.

4.11 Normalized Absolute Error

Table 4. Comparison of Normalized Absolute Error (NAE) with Mix CLACHE and Proposed Approach

Input Image	Mix-CLAHE	Proposed Approach
Img1.jpg	0.4356	0.0689
Img2.jpg	0.2567	0.0723
Img3.jpg	0.8945	0.0147
Img4.jpg	0.5247	0.2354
Img5.jpg	0.7823	0.0836
Img6.jpg	0.2356	0.1467
Img7.jpg	0.8452	0.1547
Img8.jpg	0.3262	0.1658
Img9.jpg	0.3421	0.0853
Img10.jpg	0.4372	0.1548
Img11.jpg	0.1254	0.1134
Img12.jpg	0.4367	0.1765
Img13.jpg	0.2437	0.0675
Img14.jpg	0.2564	0.1325
Img15.jpg	0.3214	0.1620

Graph 4 shows the quantized analysis of NAE corresponding to different underwater images. The results of Mix-CLAHE image enhancement transform is shown in Blue Color, whereas the quantized analysis of proposed L*A*B image enhancement approach is shown in Red color.



Graph 4: NAE Analysis of Proposed & Existing Approach for different underwater images

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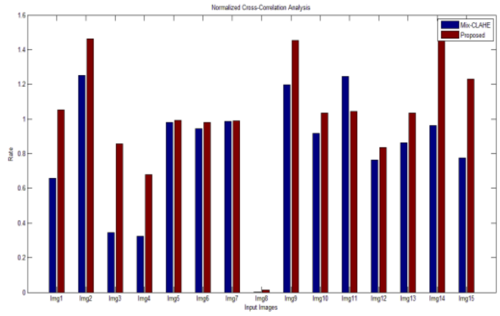
As you can notice with our proposed approach there is a decrease in NAE value of underwater images as compared to other methods. The decrease in NAE values signifies the enhancement of image quality.

4.12 Normalized Cross-Correlation

Table 5. Comparison of Normalized Cross-Correlation (NCC) with Mix CLACHE and Proposed Approach

Input Image	Mix-CLAHE	Proposed Approach
Img1.jpg	0.6573	1.0546
Img2.jpg	1.2532	1.4630
Img3.jpg	0.3457	0.8564
Img4.jpg	0.3245	0.6794
Img5.jpg	0.9802	0.9934
Img6.jpg	0.9457	0.9820
Img7.jpg	0.9878	0.9907
Img8.jpg	0.001	0.0124
Img9.jpg	1.1985	1.4527
Img10.jpg	0.9178	1.0346
Img11.jpg	1.2463	1.0452
Img12.jpg	0.7651	0.8352
Img13.jpg	0.8626	1.0342
Img14.jpg	0.9623	1.563
Img15.jpg	0.7754	1.2310



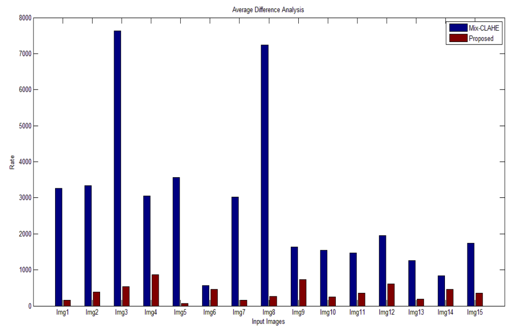
Graph 5: NCC Analysis of Proposed & Existing Approach for different underwater images

Graph 5 shows the quantized analysis of NCC corresponding to different underwater images. The results of Mix-CLAHE image enhancement transform is shown in Blue Color, whereas the quantized analysis of proposed L*A*B image enhancement approach is shown in Red color. As the values of NCC should be near to 1, so our proposed algorithm is giving better results as compared to other available methods of enhancement. This increase in NCC value represents the enhancement in image quality.

4.13 Average Difference

Table 6. Comparison of Average Difference (AD) with Mix CLACHE and Proposed Approach

Input Image	Mix-CLAHE	Proposed Approach
Img1.jpg	3267.87	161.56
Img2.jpg	3342.45	378.28
Img3.jpg	7627.30	538.69
Img4.jpg	3056.38	867.50
Img5.jpg	3562.89	66.36
Img6.jpg	563.72	456.68
Img7.jpg	3026.14	157.28
Img8.jpg	7246.60	256.38
Img9.jpg	1637.69	734.70
Img10.jpg	1548.38	248.59
Img11.jpg	1463.68	357.02
Img12.jpg	1945.26	610.45
Img13.jpg	1256.02	189.38
Img14.jpg	840.26	457.28
Img15.jpg	1745.27	356.37



Graph 6: AD Analysis of Proposed & Existing Approach for different underwater images

Graph 6 shows the quantized analysis of NCC corresponding to different underwater images. The results of Mix-CLAHE image enhancement transform is shown in Blue Color, whereas the quantized analysis of proposed L*A*B image enhancement approach is shown in Red color. As you can notice the value of AD is less in each case. This represents the improvement in image quality.

4.14 Maximum Difference

Table 7: Comparison of Maximum Difference (MD) with Mix CLACHE and Proposed Approach

Input Image	Mix-CLAHE	Proposed Approach
Img1.jpg	75	190
Img2.jpg	130	160
Img3.jpg	70	84
Img4.jpg	19	100
Img5.jpg	80	87
Img6.jpg	40	249
Img7.jpg	39	87
Img8.jpg	69	195
Img9.jpg	64	173
Img10.jpg	55	255
Img11.jpg	85	255
Img12.jpg	46	255
Img13.jpg	67	255
Img14.jpg	98	255
Img15.jpg	84	255

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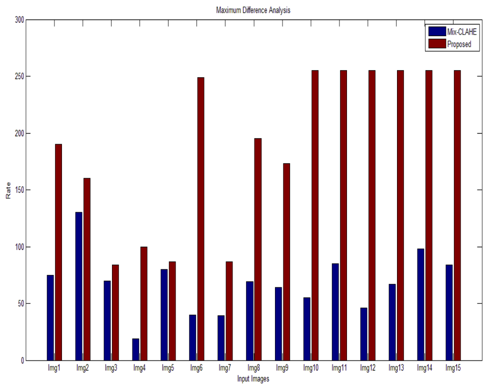

Graph 7: AD Analysis of Proposed & Existing Approach for different underwater images

Graph 7 shows the quantized analysis of NCC corresponding to different underwater images. The results of Mix-CLAHE image enhancement transform is shown in Blue Color, whereas the quantized analysis of proposed L*A*B image enhancement approach is shown in Red color. The increase in Maximum difference value signifies the enhancement in image quality.

5. CONCLUSION & FUTURE WORK

To resolve the various problems of existing methods a new image enhancement technique based on CLAHE and L*A*B color space is presented in this research paper. To overcome the problem of the uneven illumination in the CLAHE output image has been removed by utilizing the image enhancement gradient based smoothing. The key idea of the proposed technique is to enhance the accuracy of the different underwater image enhancement methods. We have highlighted various measures in this regard like MSE, PSNR, RMSE, NAE, NCC, MD and AD. A comparative study is also performed in this research work. So, in future a new algorithm can be proposed based on the use of joint trilateral filter in order to overcome the various limitations of the prior techniques. This can be done with the help of improved dark channel. This dark channel will make use of decision making which is totally based on the concept of fuzzy logic. It is the ability of fuzzy decision making that with the help of this you can identify different alternative for similar scene and from those alternatives, the best 1 will be chosen for final output. In order to develop numerous alternatives intended for fuzzy set theory, AHE (adaptive histogram equalization) plus dark channel with different various restoration levels will be utilized.

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