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Color Balance for Underwater Image Enhancement

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Abstract*: Image Enhancement is a process of improving the quality of an image by contrast improvement of the image. The most important attributes to acquire and extract more information from underwater images are color and contrast. But underwater images usually suffer from low-contrast, motion blur effect due to turbulence in the flow of water and non-uniform illumination. This paper shows a comparative study of different Histogram based techniques for improving the color and contrast of underwater images and introduces a suitable color balance method for underwater image enhancement.
Keywords: Histogram of color images, underwater images, White balancing

I. INTRODUCTION

Underwater image processing is one of the major area in Digital image processing which is applied in various fields. Such as marine habitats monitoring. It also simplifies inspection of piping in the field of engineering. Underwater imaging is very challenging field because of the physical properties of underwater environment. Mainly related to diffusion and absorption of light.

Underwater images lose contrast and suffering from degradation mainly due to poor visibility conditions and effects such as light absorption, light reflection, bending and scattering of light . In latest research work Underwater image processing becomes an effective field of the digital image processing. The methods for underwater image enhancement are briefly discussed in the next section. The balance of the paper managed as different Histogram equalization techniques, and our proposed Color Balance method for underwater image enhancement .performance analysis of different Histogram equalization techniques with our proposed Color Balance method, experimental results respectively.

II. HISTOGRAM BASED TECHNIQUES

Underwater image enhancement by using histogram based techniques are classified in to three types as shown below

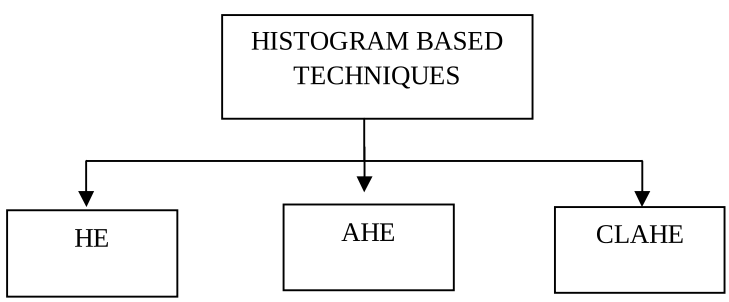

Fig.1. HISTOGRAM BASED TECHNIQUES

A. histogram Equalization (he)

Histogram equalization (HE) is a popular image enhancement method. HE works by stretching and equalizing the histogram through the intensity range by means of probability distribution function (PDF) and cumulative distribution function (CDF). HE is used as a basic method in the enhancement process by many researchers.

The histogram is a graph which shows the frequency of occurring of data in the whole data set. It plots the number of pixels for each tonal value. Consider an image with M total possible intensity levels. Then, the histogram of the image in [0, M-1] is defined as a discrete function: $P(r_k)=n_k/n$ Where, rk is the kth intensity level in the interval. nk is the number of pixels in the image whose intensity level is rk. n is the total number of pixels in the image.

Histogram equalization is an image enhancement technique which enhances the contrast of an image by spreading the intensity values over the entire available dynamic range. This is achieved through a transformation function T(r), which can be defined by the Cumulative Distribution Function (CDF) of a given Probability Density Function (PDF) of gray levels in an image.

B. Continuous Case

This is for intensity levels that are continuous quantities normalized to the range [0, 1].

Let, Pr(r) is the PDF of the intensity levels. Then, the required transformation on the input levels to obtain the output level S is:

$$S = T(r) = \int_0^r P_r(w)dw \qquad (1)$$

where w is a dummy variable of integration. Then, it can be shown that the PDF of the output levels is uniform, i.e.,

$$P_s = \begin{cases} 1, for 0 \le s \le 1 \\ 0, otherwise \end{cases} \qquad (2)$$

The above transformation generates an image whose intensity levels are equally likely and also, it covers the entire range [0, 1].

This intensity level equalization process results in an image with increased dynamic range with a tendency to have higher contrast.

C. Discrete Case

In the case of discrete quantities, we deal with summations and hence, the equalization transformation becomes:

$$S_k = T(r_k) = \sum_{j=1}^{k} P_r(r_j)$$

$$= \sum_{j=1}^{k} n_j / n \text{, for k =1, 2, 3,…, L} \qquad (3)$$

where Sk is the intensity value of the output image corresponding to value rk in the input image.

B. Adaptive Histogram Equalization(ahe)

It is different from ordinary histogram equalization in the sense that it is not global and it computes many histograms corresponding to different sections of an image . So, it is possible to enhance the local contrast of an image through AHE. With AHE, the information of all intensity ranges of an image can be viewed simultaneously and thereby solving the problem of many ordinary devices which are unable to depict the full dynamic intensity range. Here, first, a contextual region is defined for every pixel in the image. The contextual region is the region centered about that particular pixel. Then, the intensity values for this region are used to find the histogram equalization mapping function. The mapping function thereby obtained is applied to the pixel being processed in the region and hence, the resultant image produced after each pixel in the image is mapping differently. This results in the local distribution of intensities and final enhancing are based on local area rather than the entire global area of the image. This is the main advantage of AHE. But, sometimes, AHE tends to over enhance the noise content that may exist in some homogeneous local block of the image by mapping a short range of pixels to a wide one.

C. Contrast Limited Adaptive Histogram Equalization(clahe)

The major difference between Adaptive histogram equalization(AHE) and Contrast limited adaptive histogram equalization(CLAHE) is contrast limiting. The CLAHE produces clipping limit for histogram to overcome the noise amplification problem. The CLAHE method divides the image in to relative regions and applies the histogram equalization process to each region. CLAHE has two parameters clip limit(CL) and block size which are mainly control image enhancement quality. By increasing the clip limit the image brightness will be increased. Similarly by increasing block size the range becomes larger due to these the image contrast also increases. CLAHE is one of the most widely and established method for the successful enhancement of low-contrast images.

The CLAHE method consists the following 7 steps

A. Dividing the original intensity image into non-overlapping contextual regions. The total number of image tiles is equal to *MXN* and 8X8 is a good value to preserve the image chromatic data.

B. Calculating the histogram of each contextual region according to gray levels present in the array image.

C. Calculating the contrast limited histogram of the contextual region by clipping limit value.

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D. Redistribute the remain pixels until the remaining pixels have been all distributed.
E. Enhancing intensity values in each region by Rayleigh distribution.
F. Reducing abruptly changing effect
G. Calculating the new gray level assignment of pixels within a sub-matrix contextual region by using a bi-linear interpolation between four different mappings in order to eliminate boundary artifacts.

D. Histogram Stretching and Clip-Limit Process

Under- and over-contrast occur in an underwater image whereas the amount of pixels is cumulatively concentrated at low and high intensity levels. Hence, stretching and clip-limit processes are applied to the image histogram of respective regions to prevent under- and over-contrast effects. For this purpose, the histogram of a region from the previous step is generated and the LUT is built. The clip-limit visual process is shown in Fig. 2, in which the spikes in the histogram higher than the clip limit will be cut off. The excessive numbers of pixels are equally distributed to all intensity levels, thereby increasing the number of pixels at all intensity levels. In this case, a normalized value of the clip limit is set at 0.01.

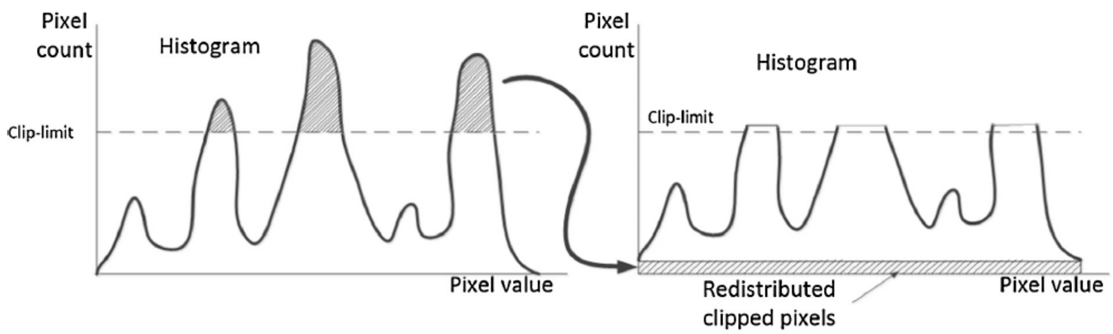

Fig. 2. Applying clip limit to the histogram of image.

E. Rayleigh Distribution

The linear stretching is given by

$$P_{out} = (P_{in} - i_{min})\left(\frac{o_{max} - o_{min}}{i_{max} - i_{min}}\right) + o_{min} \qquad (4)$$

Rayleigh Distribution is the most appropriate distribution for underwater imaging. It refers to the bell-shaped histogram distribution in which most of the pixels are concentrated at the middle of the intensity level. The pixel number at the minimum and maximum sides of the distribution is the lowest to minimize the pixel amount from having too low or too high intensity values. Therefore, RD reduces the pixel number of under- and over-contrasted areas that may be produced in the resultant image. Fig. 3 illustrates the RD in which most of the pixels are concentrated around the middle intensity values. The clip-limit process is applied to the image histogram to reduce excessive pixels for the dominant intensity level. Image histogram reflecting the PDF and CDF is then mapped with the RD. The PDF and CDF of the RD is given by Eqs. (5) and (6), respectively

$$PDF_{Rayleigh} = \left(\frac{x}{\alpha^2}\right)e^{\left(\frac{-x^2}{2\alpha^2}\right)}, \qquad (5)$$

$$CDF_{Rayleigh} = 1 - e^{\left(\frac{-x^2}{2\alpha^2}\right)}, \qquad (6)$$

where x refers to the input data while a indicates the RD parameter. In this study, a value is set at 0.4 . To obtain the PDF of Rayleigh-stretched distribution, PDFR stretch, Eq. (4) is integrated with Eq. (5) to obtain Eq. (7). The stretching process of the output histogram occupied is from 0 to 255; thus, the value of omin can be substituted with 0 to derive Eq. (8).

(7)

$$PDF_{Rstretch} = \left(\frac{((P_{in} - i_{min})o_{max})}{\alpha^2(i_{max} - i_{min})}\right)\exp\left(\frac{(-(P_{in} - i_{min})o_{max})^2}{2\alpha^2(i_{max} - i_{min})}\right) \qquad (8)$$

Therefore, the CDF of Rayleigh-stretched distribution, CDF Rstretch; is given by

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$$CDF_{Rstretch} = 1 - \exp\left(\frac{\left(-(P_{in} - i_{min})o_{max}\right)^2}{2\alpha^2 (i_{max} - i_{min})}\right) \tag{9}$$

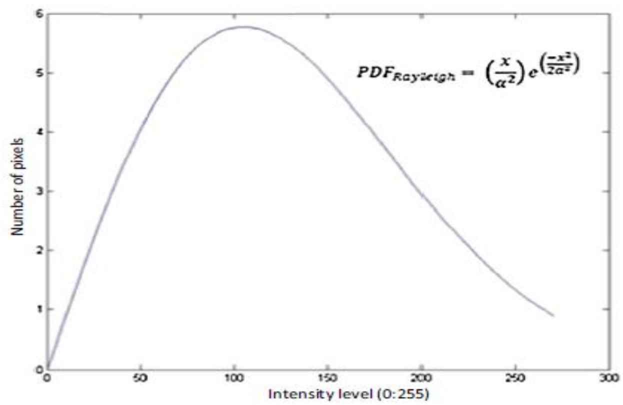

Fig. 3. RD with most of the pixels concentrated at the middle intensity values.

III. COLOR BALANCE AND FUSION METHOD

This paper introduces a novel approach to remove the haze in underwater images our approach builds on the white balanced version of a single native input image. The white balancing stage aims at removing the color cast induced by underwater light scattering

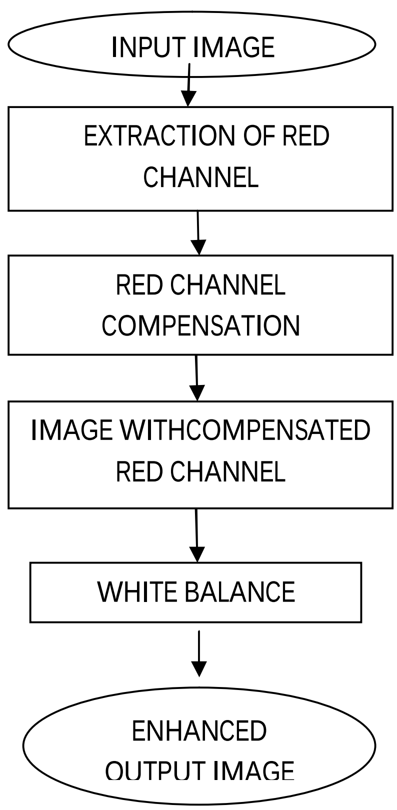

Fig. 4. Color Balancing Based Underwater Image Enhancement method

A. Underwater White Balance

White-balancing aims at improving the image aspect, primarily by removing the undesired color castings due to various illumination or medium attenuation properties. In underwater the perception of color is highly correlated with the depth, and an important problem is the green-bluish appearance that needs to be rectified. As the light penetrates the water, the attenuation process affects

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selectively the wavelength spectrum, thus effecting the intensity and the appearance of a colored surface. Since the scattering attenuates more the long wavelengths than the short ones, the color perception is affected as we go down in deeper water. In practice, the attenuation and the loss of color also depends on the total distance between the observer and the scene we therefore primarily aim to compensate for the loss of the red channel.

1) To compensate for the loss of red channel, we build on the four following observations/principles:The green channel is relatively well preserved under water, compared to the red and blue ones. Light with a long wavelength, i.e. the red light, is indeed lost first when traveling in clear water;
2) The green channel is the one that contains opponent color information compared to the red channel, and it is thus especially important to compensate for the stronger attenuation induced on red, compared to green. Therefore, we compensate the red attenuation by adding a fraction of the green channel to red.
3) The compensation should be proportional to the difference between the mean green and the mean red values
4) The enhancement of red should primarily affect the pixels with small red channel values, and should not change pixels that already include a significant red component. In other words, the green channel information should not be transferred in regions where the information of the red channel is still significant. Thereby, we want to avoid the reddish appearance introduced .Basically, the compensation of the red channel has to be performed only in those regions that are highly attenuated. In a second step, white balancing algorithm will be adopted to compute the enhanced image.

IV. EXPERIMENTAL RESULTS

The work is executed on MATLAB Software with various images. The underwater images are Taken from the internet source. First our proposed White Balance method is applied to the images and then compared with the different Histogram based techniques mentioned in the previous section.

A. Underwater image A

Underwater Image A

Red Channel

Red Channel (He)

Original With Red Channel (He)

Image Compensated

Result Of He

Result Of Ahe

Result Of Clahe (Cl=0.01)

Result Of Clahe (Cl=0.1)

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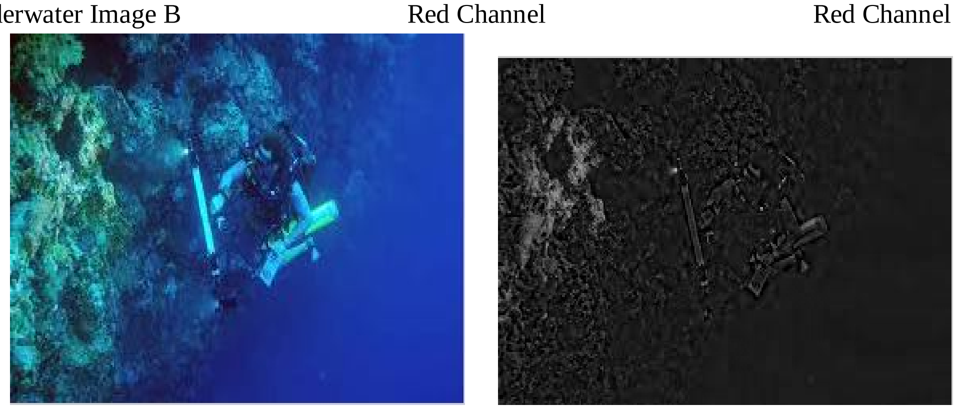
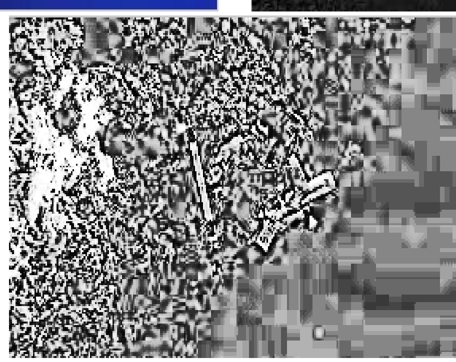
Result of our white balance
Method to image compensated

Fig5: Performance of HE, AHE, CLAHE and white balance method on Underwater image

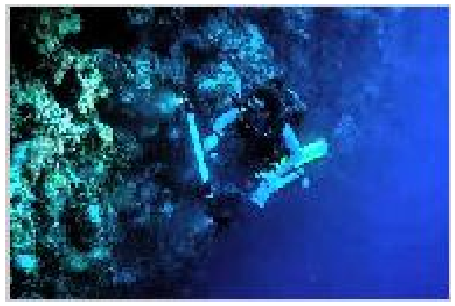
B. Underwater Image B

Underwater Image B | Red Channel | Red Channel (He)

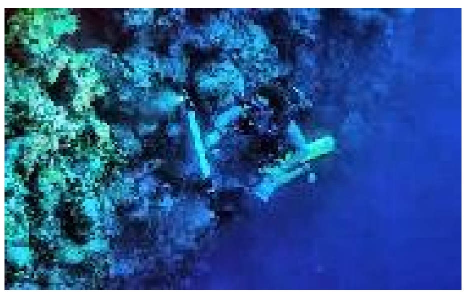


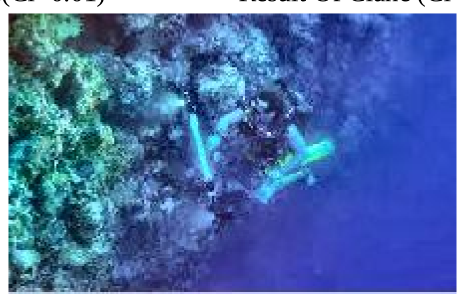


Original With Red Channel Eq Image Compensated Result Of He



Result Of Ahe Result Of Clahe(Cl=0.01) Result Of Clahe (Cl=0.1)



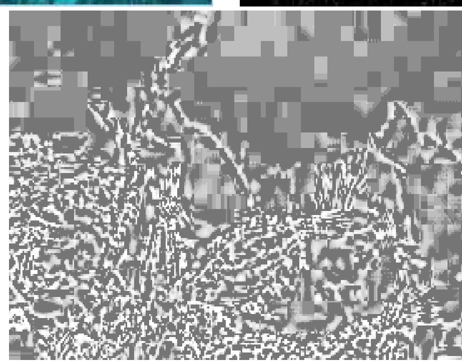


Result of our white balance
Method to image compensated

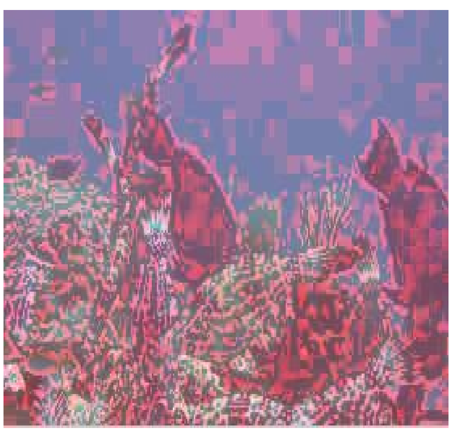
Fig6: Performance of HE, AHE, CLAHE and white balance method on Underwater image A

C. Underwater Image C:

Underwater Image C Red Channel Red Channel (He)



Original With Red Channel Eq Image Compensated Result Of He



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Result Of Ahe

Result Of Clahe(Cl=0.01)

Result Of Clahe (Cl=0.1)

Result of our white balance method to image compensated

Fig7: Performance of HE, AHE, CLAHE and white balance method on Underwater image A

IV. CONCLUSION

In this Work Different Histogram based techniques are applied on different Underwater images. We have presented an alternative approach to enhance underwater images. Our strategy builds on the White balance principle and does not require additional information than the single original image It was clearly observed that our proposed White Balance method produce better results compare to Histogram equalization (HE), Adaptive Histogram equalization (AHE), and CLAHE techniques . Future work focus on extending the algorithms by using advanced methods to improve the results.

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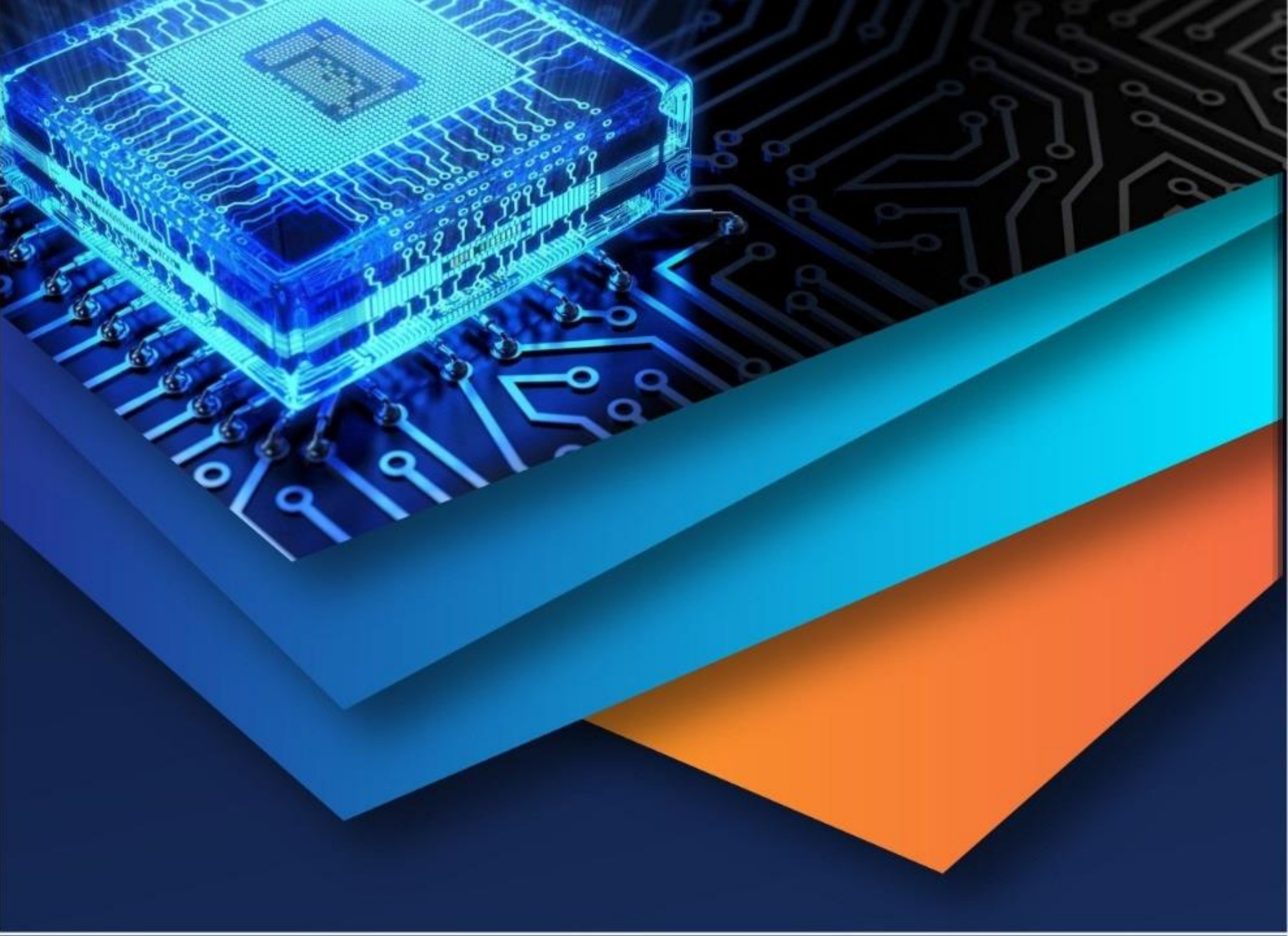

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