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Underwater Image Enhancement Techniques: A Review

Priyanka P. Madhumatke[1], Dr. Pankaj Agarwal[2]
[1]Department of Electronics and Communication Engineering, G.H.R.A.E.T. Nagpur, Maharashtra, India

Abstract*: Underwater images mainly suffer from the problem of poor color contrast and poor visibility. These problems occurred due to the scattering of light and refraction of light while entering from rarer to denser medium. Scattering causes the blurring of light and reduces the color contrast. These effects of water on underwater images are only not due the nature water but also because of the organisms and other material present in the water. Image enhancement is the process of improving the quality of the input image so that it would be easily understood by viewers in the future. Image enhancement improves the information content of the image and alters the visual impact of the image on the observer. Image enhancement intensifies the features of images. It accentuates the image features like edges, contrast to build display of photographs more useful for examination and study. Active range of the chosen features of images is amplified by enhancement so that they can be detected simply. Many techniques and methods are established by researchers to solve the problem of underwater image enhancement. In this work different underwater image enhancing techniques have been studied.

***Keywords*: Homomorphic Filtering, Histogram Equalization, Bilateral filtering, Contrast Stretching, CLAHE**

I. INTRODUCTION

From last few years, underwater image processing area has received a great attention of researchers to explore the mysterious underwater world. Underwater surveys have numerous scientific applications in the field of archaeology, geology and biology, involving tasks such as ancient shipwreck prospection, environmental damage assessment etc. To capture a clear underwater image has a crucial importance in oceanic engineering [1]. Clear underwater images have a great importance in scientific operations like taking a census of sea population, include the discovery of objects in liquids or the image analysis needed to identify targets submerged in a liquid. There have also been studied that attempted to identify targets suspended in a solution. These studies could be useful for defense applications.

For capturing a clear visible underwater image, water must be a limpid or clear, but naturally all the water is turbid with particles such as sand, planktonsor , minerals. As outdoor images are distorted because of particles present in the air, like that underwater images also get distorted because of particles present in the water. Underwater Images becomes more and more hazy or less visible as water depth increases. Generally underwater images get distorted because of two reasons. One is light scattering effect and second is color change effect. Therefore, the processing of underwater image captured is necessary because the quality of underwater images affect and these image leads due to low contrast, poor visibility conditions (absorption of natural light), non uniform lighting and little color variations, pepper noise and blur effect in the underwater images because of all these reasons number of methods are existing to cure these underwater images different filtering techniques are also available in the literature for processing and enhancement of underwater images.

Image enhancement has found to be probably the most important vision applications because it has ability to enhance the visibility of images. It enhances the perceivability of poor pictures. Image enhancement uses qualitative subjective criteria to produce a more visually pleasing image and they do not rely on any physical model for the image formation. These kinds of approaches are usually simpler and faster than deconvolution methods. The foremost purpose of image enhancement is to bring out detail that's hidden in an image or to expand contrast in a low contrast image. It provides a multitude of selections for bettering the visible quality of images. An object can easily normally possibly be seen as appearance, their color, sometimes and their size of it or maybe the structure. Within an marine natural environment .it is hard to understand the item through watching its colour due to the fact inside the subaquatic method, your kit is limited by simply attenuation and are certainly not continual while using the mileage. Nonetheless, as looking known regarding materials, colour stays a simple and effective element. Inwards subaqueous environment, pictures experience low distinction, sounds, confined visibility, for example. The quantity of lighting that will penetrate water in addition starts off reducing because degree will increase inside ocean h2o. The research along marine picture processing we could follow resolved by a pair of different perspectives- effigy repair and also image enlargement.

II. CAUSES OF UNDERWATER IMAGE DISTORTION

The two main causes of underwater image distortion are light scattering and color change effect. We will discuss these two causes in this section.

A. *Light Scattering*

Light scattering is a form of scattering in which light is the form of propagating energy which is scattered. When camera light incident on objects then it get reflected and deflected number of times by particles present in the water before reaching the camera [6], this phenomenon is known as a light scattering. This light scattering results in a poor visibility and low contrast in the underwater image. Light scattering depends on the frequency or wavelength of the light being scattered. Forward scattering generally leads to blur of the image and results into the low contrast of image.

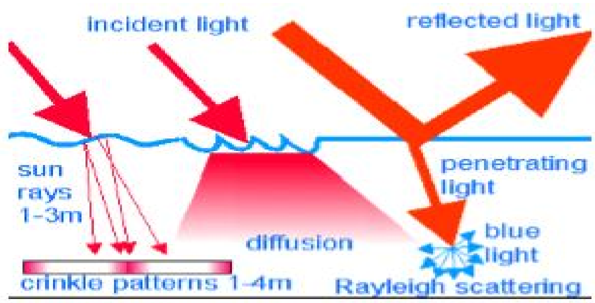

Fig 1: light scattering effect

B. *Color Change Effect*

The second cause for underwater image distortion is color change. This problem is related to the density of the water in the sea which is considered 800 times denser than air. Therefore, the underwater images are getting darker and darker as the depth increases. Not only the amount of light is reduced when we go deeper but also colours drop off one by one depending on the wavelength of the colours. For example, first of all red colour disappears at the depth of 5m. Secondly, orange colour starts disappearing while we go further. At the depth of 10m, the orange colour is lost. Thirdly most of the yellow goes off at the depth of 20 m and finally the green and purple disappear at further depth [17]. This is shown diagrammatically in Figure 2. As a matter of fact, the blue colour travels the longest in the water due to its shortest wavelength. This is what makes the underwater images having been dominated only by blue colour. In addition to excessive amount of blue colour, the blur images contain low brightness, low contrast and so forth.

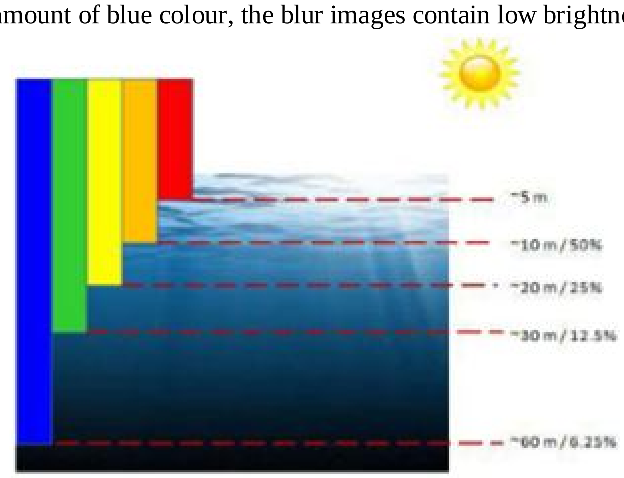

Fig 2 Color change effect

III. UNDERWATER IMAGE ENHANCEMENT

Image enhancement is considered as one of the most important techniques in image research. The main aim of image enhancement is to enhance the quality and visual appearance of an image, or to provide a better transform representation for future automated image processing. Many images like medical images, satellite, aerial images, real life photographs and also underwater images suffer from poor and bad contrast and noise. It is necessary to enhance the contrast and remove the noise to increase image quality. The enhancement technique differs from one field to another depending on its objective.

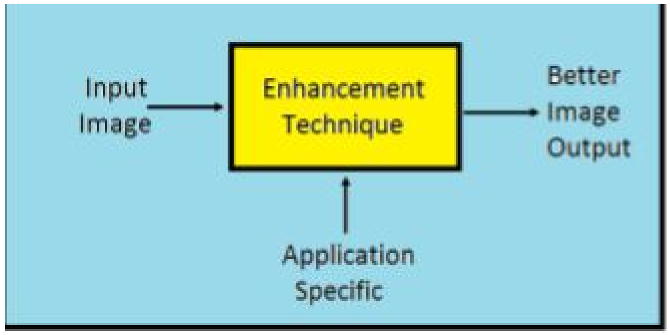

Fig 3 Basic block diagram of image enhancement

Image enhancement improves the information content of the image and alters the visual impact of the image on the observer. Image enhancement intensifies the features of images. It accentuates the image features like edges, contrast to build display of photographs more useful for examination and study. Image enhancement includes many operations such as contrast stretching, noise clipping, pseudocoloring, noise filtering etc to improve the view of images. Active range of the chosen features of images is amplified by enhancement so that they can be detected simply. Underwater images mainly suffer from the problem of poor color contrast and poor visibility. These problems occurred due to the scattering of light and refraction of light while entering from rarer to denser medium. Scattering causes the blurring of light and reduces the color contrast. Many techniques and methods are established by researchers to solve the problem of underwater image enhancement.

The existing techniques of image enhancement can be classified into two categories: Spatial Domain and Frequency Domain Enhancement. In this paper, we present an overview of Image Enhancement Processing Techniques in Spatial Domain. More specifically, we categorise processing methods based representative techniques of Image enhancement. Thus the contribution of this paper is to classify and review Image Enhancement Processing Techniques as well as various noises has been applied to the image. Also we applied various filters to identify which filter is efficient in removing particular noises. This is identified by comparing the values obtained in PSNR and MSE values.

IV. DIFFERENT IMAGE ENHANCEMENT TECHNIQUES

A. Homomorphic Filtering

Homomorphic blocking is often a frequency filtering approach. These technique all of us used by correcting not for uniform miniature. It truly is promotes the particular comparison from the photograph. Homomorphic filtering provides improvement over some other tactics as it corrects not consistent easy as well as hones the advantage at the same time . Homomorphic filtering utilizes two variables called while light gene along with coefficient of reflection issue. Brightness gene symbolizes very low frequencies inside Fourier convert on the impression along with coefficient of reflection component presents substantial wavelengths. Through increasing number these factors abject wavelengths usually are suppressed [5] distinct this brightness as well as coefficient of reflection elements through the logarithm of the impression. The particular logarithm switches your multiplicative in a great component a single. Large go selection is actually placed on the actual Fourier change Cipher your opposite Fourier convert to come back from the special area and then go ahead and take advocator to obtain the blocked picture .

B. Histogram Equalization

Histogram is defined as the statistical probability distribution of each gray level in a digital image (Balvant Singh, Ravi Shankar Mishra, Puran Gour, 2011Histogram equalization is a technique inside impression control of contrast modification while using the images histogram. This process normally enhances the global contrast of countless photos, particularly your useful data on the impression data is represented by near compare values. A great impression offers similar quantity of pixels to all it's dull quantities. This method are known as as Histogram Equalization (He / she).That flattens along with stretches the particular dynamic selection of the whole image histogram as well as ends in boiler suit distinction enhancement. The process pays to inwards photographs having rear-coffee grounds in addition to forward-good grounds which can be each vibrant or maybe equally dark. Histogram Equalization may be generally used when the graphic most of us requires development however; it may substantially change the lighting of your stimulation effigy as well as lead to injury in many purposes in which perfection ongoing availability is necessary

C. Bilateral Filtering

Bilaterally symmetrical filtration is a borders-preserving along with sound lowering removing separate out. Bilaterally symmetric blocking smoothness the photographs while keeping edges, through a not-along blend of neighbourhood picture ideals. Taking that approach main bilaterally symmetrical blocking would be to liquidate the number of the effigy what exactly classic filter systems waste the knowledge domain, This kind of weight will be based upon Gaussian submission technique. This particular preserve astute perimeters by simply systematically looping via each image element as well as in accordance weights to the nearby pixels accordingly .The usual notion root isobilateral filtering is always to waste kids associated with an target precisely what conventional filter systems waste it's knowledge domain . Ii pixels we can come close to each other that is certainly, occupied close by spatial location or we could follow a lot like one other. Isobilateral selection is a simple, not-iterative system intended for sharpness keeping smoothing. (Prabhakar C.J., Praveen Kumar P.U., and 9 December 2011).

D. Empirical Mode Decomposition

EMD is a versatile and based on the local moment period function of the figures[9]. So, it is suitable to help nonlinear along with non-stationary data so that it is an incredibly adept opportunity for real-life software. The EMD method is exceptionally direct, and the fundamental procedure is to carry out sifter operations on the new data arrangements until the final data series are stationary, and subsequently disintegrate the whole signal into many Intrinsic Mode Functions (IMFs) and a residue. EMD is connected to the Red, Green, Blue channels independently. The original image is break up into several intrinsic mode functions by EMD process and a final residue.

E. Red Channel Method

In this method, colors associated to short wavelengths are recovered, as expected for underwater images, leading to a recovery of the lost contrast [10]. The first thing in this method to estimate is the color of the water. Pick a pixel that lies at the maximum depth with respect to the camera. It is assumed that degradation of image depend upon location of pixel. After estimating the waterlight transmission of the scene is estimated. Then Color correction is done.

F. Contrast Stretching

In local contrast measure is proposed in this project for enhancement. Contrast is stretched between the limit of lower threshold and upper threshold. It is an intensity based contrast enhancement method as Io (x,y) = f (I (x,y)) , where the original image is I (x,y),the output image is Io (x,y) after contrast enhancement, and f is the transformation function .The contrast stretching is a method to make brighter portion more brighter and darker portion more darker. The transformation function T (r) is given as :

$$S = \begin{cases} l * r & 0 < r < a \\ m * (r - a) + v & a < r < b \\ n * (r - b) + w & b < r < L - 1 \end{cases}$$

------(1)

The transformation function is given here, Where l, m, n are the Slopes of the three regions shown in Fig.1. It is clear that l & n are less than one. The S is the modified gray levels and r is the original gray levels. Where a and b are the limit of lower and upper threshold. The identity transformation is shown by doted line. The slope of blue lines is taken 0.5 and the slope of the red line is taken as 1 or greater than 1. so making the brighter portion more brighter and darker portion more darker.

The contrast stretching algorithm is used to enhance the contrast of the image. This is carried out by stretching the range of the colour values to make use of all possible values. The contrast stetching algorithm uses the linear scaling function to the pixel values. Each pixel is scaled using the following function:

P_o = (Pi- c) x (b -c) / (d-c) + a-----(2)

"Where

- P_o is the normalized pixel value;
- Pi is the considered pixel value;
- a is the minimum value of the desired range;
- b is the maximum value of the desired range;
- c is the lowest pixel value currently present in the image;

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- d is the highest pixel value currently present in the image”

. Firstly, we use contrast stretching of RGB algorithm to equalize the colour contrast in the images. Secondly, we apply the saturation and intensity stretching of HSI to increase the true colour and solve the problem of lighting. The proposed approach is shown in Figure 3.

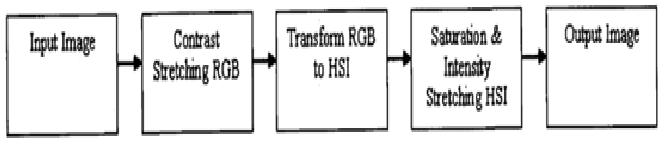

Fig 4 Methodology for underwater image enhancement method

When the contrast stretching algorithm is applied to colour images, each channel is stretched using the same scaling to maintain the correct colour ratio. The first step is to balance the red and green channel to be slightly the same to the blue channel. This is done by stretching the histogram into both sides to get well-spread histogram. In the second step we transform the RGB image into HSI, using the saturation and intensity transfer function to increase the true colour and brightness of underwater images. Using the transform function we have been able to stretch the saturation and intensity values of HSI colour model. Using the saturation parameters we can get the true colour of underwater images. Brightness of the colour is also considered to be important for underwater images. The HSI model also helps to solve the lighting problem using Intensity parameters.

The HSI model provides a wider colour range by controlling the colour elements of the image. The Saturation (S) and Intensity (I) are the element that generates the wider colour range. In a situation when we have the blue colour element in the image it is controlled by the 'S' and 'I' value in order to create the range from pale blue to deep blue, for instance. Using this technique, we can control the contrast ratio in underwater images either by decreasing or increasing the value. This is carried out by employing a histogram of the digital values for an image and redistributing the stretching value over the image variation of the maximum range of the possible values [14]. Furthermore linear stretching from 'S' value can provide stronger values to each range by looking at the less output values. Here a percentage of the saturating image can be controlled in order to perform better visual displays [15].

G. Contrast Limited Adaptive Histogram Equalization

Contrast Limited Adaptive Histogram Equalization (CLAHE) is a generalization of Adaptive Histogram Equalization (AHE). CLAHE was originally developed for enhancement of low-contrast medical images [7]. CLAHE differs from ordinary AHE in its contrast limiting. CLAHE limits the amplification by clipping the histogram at a user-defined value called clip limit. The clipping level determines how much noise in the histogram should be smoothed and hence how much the contrast should be enhanced. A histogram clip (AHC) can also be applied. AHC automatically adjusts clipping level and moderates over-enhancement of background regions of images. One of the AHC that normally used is Rayleigh distribution which produces a bell-shaped histogram. The function is given by

$$\text{Rayleigh } g = g_{min} + \left[2(\alpha^2)\ln\left(\frac{1}{1-P(f)}\right)\right]^{0.5} \qquad \text{---(3)}$$

where gmin is a minimum pixel value, P(f) is a cumulative probability distribution and is a nonnegative real scalar specifying a distribution parameter. In this study, clip limit is set to 0:01 and value in Rayleigh distribution function is set to 0:04.

1) *CLAHE on RGB color model:* RGB color space describes colors in terms of the amount of red (R), green (G) and blue (B) present. It uses additive color mixing, because it describes what kind of light needs to be emitted to produce a given color. Light is added to create form from out of the darkness. The value of R, G, and B components is the sum of the respective

$$R = \int_{300}^{830} S(\gamma)R(\gamma)d\gamma$$
$$G = \int_{300}^{830} S(\gamma)G(\gamma)d\gamma$$
$$B = \int_{300}^{830} S(\gamma)B(\gamma)d\gamma$$

2) *Sensitivity Functions and the Incoming Light:* where S(γ) is the light spectrum, R(γ), G(γ), B(γ) are the sensitivity functions for the R, G and B sensors respectively. In RGB color space, CLAHE can be applied on all the three components individually. The result of full-color RGB can be obtained by combining the individual components.

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3) *CLAHE on HSV Color Model:* HSV color space describes colors in terms of the Hue (H), Saturation (S), and Value (V). The model was created by A.R. Smith in 1978. The dominant description for black and white is the term, value. The hue and saturation level do not make a difference when value is at max or min intensity level. The HSV model takes RGB components to be in the range [0; 1]. The value V is computed by taking the maximum value of RGB or can be described formally by:

$$V = \max(R, G, B)$$

$$S = \frac{V - \min(R,G,B)}{V} \quad \text{--------(5)}$$

The saturation S is controlled by how widely separated the RGB values are. When the values are close together, the color will be close to gray. When they are far apart, the color will be more intense to pure. Finally, hue H, which determines whether the color is red, blue, green, yellow and so on, is the most complex to compute. Red is at 0°, green is at 120°, and blue is at 240°. The maximum RGB color controls the starting point, and the difference of the colors determines how far we move from it, up to 60° away (halfway to the next primary color). To calculate the hue, we must calculate R', G', and B':

$$R' = \frac{V - R}{V - \min(R,G,B)} \quad \text{---(6)}$$

$$G' = \frac{V - G}{V - \min(R,G,B)} \quad \text{----(7)}$$

$$B' = \frac{V - B}{V - \min(R,G,B)} \quad \text{-----(8)}$$

If $S = 0$ then hue is undefined, otherwise

$$H = \begin{cases} 5 + B' & R = \max(R,G,B) \text{ and } G = \min(R,G,B) \\ 1 - G' & R = \max(R,G,B) \text{ and } G \neq \min(R,G,B) \\ R' + 1 & G = \max(R,G,B) \text{ and } B = \min(R,G,B) \\ 3 - B' & G = \max(R,G,B) \text{ and } B \neq \min(R,G,B) \\ 3 + G' & B = \max(R,G,B) \\ 5 - R' & \text{otherwise} \end{cases} \quad \text{--(9)}$$

Since there is a hue discontinuity around 360°, arithmetic operations is difficult to perform in all components of HSV. Therefore, CLAHE can only be applied on V and S components.

V. CONCLUSION

Thus we can conclude that in this work we have been able to study the various underwater image enhancement techniques.

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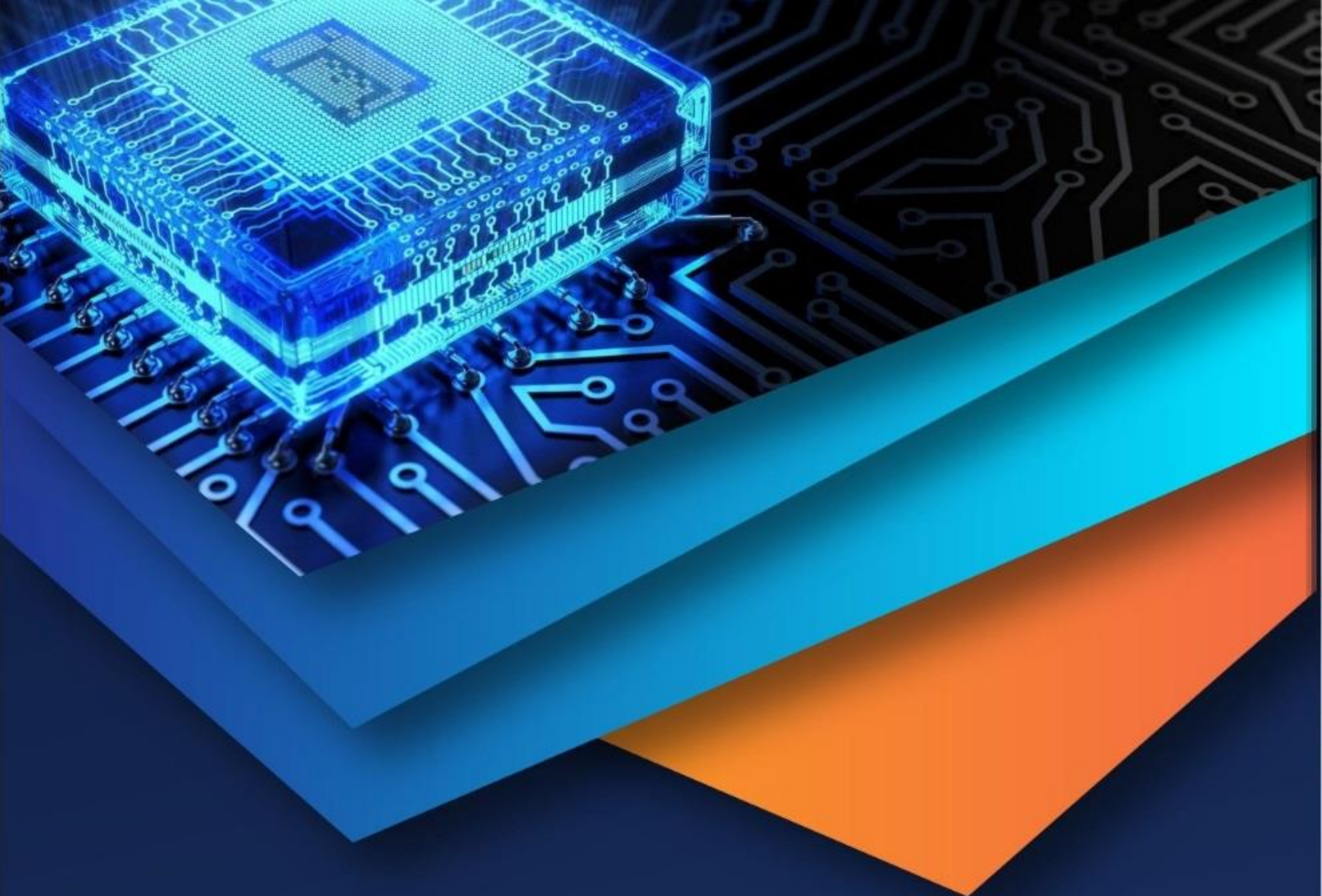

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