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Enhanced Digital Image Haze (Fog) Removal Using Multi-Objective Differential Evolution Based Dark Channel Prior

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***Abstract:* Haze reduces the visibility of outdoor images. Therefore, haze removal is a demanding and significant task for visual multispectral information improvement. In this paper, differential evolution and dark channel prior integrated with adaptive histogram equalization based haze removal algorithm is proposed. The dark channel prior can automatically extract the global atmospheric light and roughly eliminate the atmospheric veil. To make dark channel prior more effective, to reduce the color distortion, restoration model of DCP is also refined by using adaptive histogram equalization to produce a haze free image in more optimistic manner. The experimental results indicate that the proposed technique provides better results.**
***Keywords:* Image defogging; differential evolution; dark channel prior; adaptive histogram equalization**

I. INTRODUCTION

Outdoor images suffer from poor environmental conditions, which limit their analysis for future vision applications. Haze is a conventional environment occurrence in which elements like smoke, dust, etc. obscure the clarity of environment [18]. Therefore, in hazy environment, the captured images have poor illumination [2]. Thus, haze reduces the visual information of objects as the effect of scene radiance sprinkled through the haze particles. Therefore, dehazing techniques are required to remove the effect of haze from hazy images [5] is a difficult task because the haze transmission (*Tx*) depends upon unknown depth which fluctuates according to situations [14]. Tan et al. [17] and Kawakami et al. [8] restored hazy images by utilizing the local contrast values. Though these techniques are successful in segments which have significant haze gradient and the color of restored image is frequently over saturated [9]. Thus, the contrast maximization comes up with the over-saturation problem. The physics-based restoration techniques have ability to overcome the oversaturation problem [4]. He et al. have proposed a simple but effective dehazing technique using Dark channel prior (DCP) [11]. However, [6] and [7] suffer from halo artifacts and color distortion problems. To overcome haze from picture, several visibility restoration methods are placed on the image to make it better. Guo [1] presented a unique fog removal factor selection algorithm centered on genetic algorithm (GA) which concentrated on the approach to choose optimum constants for image defogging. This method put on two main fog removal algorithms by selecting main constants and then optimizes them using the genetic algorithm. But there is an issue regarding speed because there are different formulas which are used to acquire the optimized result. To overcome this issue, differential evolution is proposed because it has fast convergence speed and there is only one equation used for the entire optimization rather than different formulas for different operators.

A. Image Defogging

*S*ingle image defogging is a term used to illustrate any approach that eliminates scattering of light (e.g., fog) from an image. When an image gets hazed, it is not seen clearly or we can say that the contrast of an image gets reduced which makes the image dull. To eliminate this dullness from an image, there are several defogging algorithms that have the power to make the better quality image.

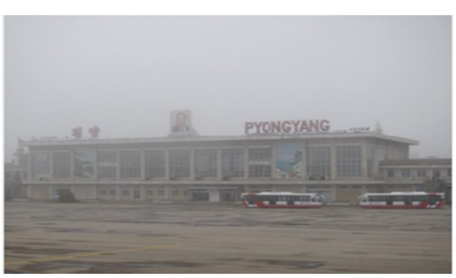
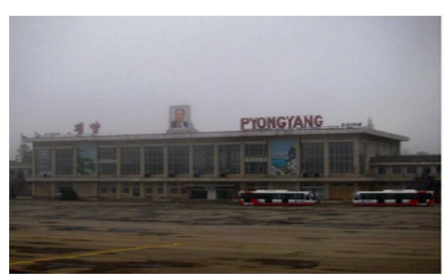


Fig.1 Foggy Image



Clear Image

II. PROPOSED WORK

A. Differential Evolution

In evolutionary computation, differential progress (DE) is actually a technique which optimizes an issue by iteratively seeking to improve a candidate answer with regard to the way of measuring quality. DE optimizes a problem by preserving a population of individual solutions and generating completely new solutions by mixing pre-existing versions determined by the uncomplicated formulae, and after that maintaining whichever candidate solution has the ideal fitness on the whole problem[13]. By doing this, this optimization dilemma is considered as a black box that gives a measure involving quality candidate solution. A purpose of differential evolution is a lot like genetic algorithms approach. This permits each one subsequent generation of solutions to develop out of the earlier generation. It may possibly be applied to real-valued challenges quicker above a continuous space than genetic algorithms. The principle concept at the rear of differential evolution is that the difference between a pair of vectors yields an impact vector which is often utilized to process the complete problem space[16]. Initially, a random population is selected just as in genetic algorithms to form new offsprings or population, an equal number of donor vectors are produced with the help of following equation:

$$\forall i \in n : D_i = X_{r1,G} + F(X_{r2,G} - X_{r3,G}) \qquad (1)$$

where i, r1,r2,r3 are distinct. X_{r2} and X_{r3} are randomly chosen and X_{r1} is selected either randomly or as the most effective candidate in population (depending on candidate encodings).

Algorithm: Differential Evolution(DE)

1. Generate initial population
2. Do
3. select three vectors $x_{r1,G}, x_{r2,G}, x_{r3,G}$ where 1< (r1, r2, r3) <N and r1≠r2≠r3
4. Generate random integer $i_{rand} = 1\ to\ N$
5. For each parameter i
6. $v_{i,G+1} = x_{r1,G} + F(x_{r2,G} - x_{r3,G})$
   $u_{j,i,G+1} = \{v_{j,i,G+1}\ if\ rand_{j,i} \leq CR\ or\ j = i_{rand}\}$
   $else\ u_{j,i,G+1} = x_{j,i,G}$
7. $x_{i,G+1} = \{u_{i,G+1}\ if\ u_{i,G+1} \leq f(x_{i,j}\}$
   else
   $x_{i,G+1} = x_{i,G}$
8. End For
9. Repeat step 6 and 7 until required condition is achieved.

B. Dark Channel Prior

Dark channel prior (DCP) operates based on the subsequent statement on haze -free outdoor pictures: in a lot of the non-sky areas, a number of color channels possess surprisingly low intensity in many pixels[2]. In other words, the minimum intensity on this point ought to contain a very low value. Technically, for an image **I**,

$$I_{dark}(x) = min_{c\epsilon\{r,g,b\}}(min_{y\epsilon\Omega(x)}(C_c(y))) \qquad (2)$$

where C_c is a color channel of **I** and Ω(**x**) is a local patch placed on **x**. Observation says that in non-sky regions, the intensity of I_{dark} is low and can leads to zero. If **I** is really a clear outdoor image, I_{dark} can be known as the dark channel of **I.** There can be three different reasons of darkness in images[11]:

1) Shadows. *e.g.*, this shadows connected with automobiles, architectural structures along with the inside of windows with cityscape illustrations or photos;
2) Bright colored things or perhaps surfaces. *e.g.*, virtually any item (for example, green grass/tree/plant, reddish or perhaps yellow-colored flower/leaf) lacking colors in any channel can lead to low values in dark channel;
3) Darkish things or perhaps surfaces. *e.g.*, stone. While the natural outdoor illustrations or photos are typically rich in shadows and colors, the dark channels of photos are extremely dark.

Fig.2 Input image DCP image

C. Adaptive Histogram Equalization

Adaptive histogram equalization (AHE) is a contrast enhancement method designed to be mostly valuable and exhibiting effective results. Contrast of a graphic is set by its dynamic range, which can be defined as the ratio of the brightest and the darkest intensities of pixels. There are various application areas where contrast enhancement methods are used for improving visual quality of images which have low contrast. AHE is also called local histogram equalization. For each pixel, it performs histogram equalization within local surroundings of this point, as well as take the results as the output value for that pixel. Being able to accomplish this depends upon the area of the neighborhood: as size increases, the strategy results in being much less efficient [10]. In some of the cases, when size becomes maximum AHE is comparable to typical histogram equalization. Given that AHE can easily efficiently pack local peak variants with somewhat modest measurement as well as global peak variants with large measurement, during this, AHE is carried out with different sizes as well as carry the average with the resulting peak areas as the final output.

III. RELATED WORK

Guo, et al. [1] presented a unique fog removal factor selection algorithm centered on genetic algorithm (GA). It concentrated on the approach to choose optimum constants for image defogging. This method put on two main fog removal algorithms by selecting main constants and then optimizes them using the genetic algorithm. Jin-BaoWang et al. [2] introduced a particular graphic dehazing process that is dependent on a physical unit along with the dark channel prior principle. Selecting a airlight value is usually responsible for color authenticity and contrast of the final picture. In addition to it, they recommended a quick transmission estimation to lessen the computing time. Jiafeng Li et al. [3] presented change of detail (CoD) prior to eliminate haze from a single resource image. It is based upon the multiple scattering trend while in the propagation of airlight. It is necessary to measure the depth of errors successfully to recoup a superior quality fog-free image. What's more, because the CoD prior is especially sensitive to regional facts on the picture rather than shade and intensity. In addition to, this procedure has the capability to deal with each shade in addition to grayscale images. Xia Lan [7] presented a three- step algorithm for fog elimination. It considered sensor blur and noise. Firstly, the degraded image is preprocessed as well as blur/noise interference is eliminated to measure the fog in an image. Secondly, dark channel prior method is utilized to measure the transmission map and atmospheric light. In last step, a regularized method is proposed to recoup the source image. Sun Wei et al. [9] presented an algorithm that can estimate the airlight correctly in addition to raise the speed and also correctness involving atmospheric scattering purpose solving. This particular makes it possible for an instant implementation. Yong-Qin Zhang [10] proposed crystal clear image with no fog by calculating the depth of fog. By means of Monte Carlo simulators by using parallel evaluation with the coarse atmospheric veil by using an average filtration system, much better errors coating will be obtained. Dark channel prior will be utilized to calculate normalized transmitting coefficient to recuperate fog-free productivity image. He et al. [15] presented an easy and efficient process to eliminate errors from just one input image. By using dark channel prior with the haze imaging process, depth of fog can properly predicted and it also really helps to get back a fogless image of substantial quality. Madhu et al. [12] presented that adaptive histogram equalization produced beneficial output, however now there is an issue which impression remains to be less than clear. This sharpness plus the backdrop details are poor. Furthermore, plane remains to be fogged plus very poor around contrast. Alpha rooting is actually used to render the complete picture in a very dark color. Swagatam Das [13] presented in-depth presentation of principle methods of differential evolution along with a survey of its key alternatives; it is multi-objective application, large, in addition to unclear optimization difficulties, along with the theoretical scientific studies about differential evolution. Qin et al. [16] displayed a self-adaptive DE (SaDE) algorithm in which either donor vector generating procedures as well as their connected regulate parameter ideals are extremely self-adapted by means of gaining knowledge from its past know-how with producing improved results. As a result, a far more desirable generating procedure and its parameter configurations can be driven adaptively to fit different steps of the search procedure.

IV. GAPS IN LITERATURE

FanGuo, et al. [1] discussed that digital haze removal algorithms are more appropriate for numerous vision applications. By conducting the review, almost all of the existing researches have mistreated numerous subjects. The several research gaps which are concluded using the literature survey are described as follows:-

A. The presented methods have ignored the use of multi-objective optimization to improve the adaptivity of digital image haze removal algorithms.

B. The restoration level is taking statically i.e. 95% in most of the existing techniques.

C. The problem of the saturated pixel is also ignored by the number of the researchers.

V. METHODOLOGY

A. Steps

1) Firstly, generate random population for Differential Evolution (DE) after taking an input image.

2) Evaluate multi-objective fitness function (MOF) by using following formula:

$$\text{MOF} = w_1 {*}\text{CG} + w_2 \left(\frac{1}{PSP}\right)$$

3) where CG is contrast gain and PSP is percentage of saturated pixels.

4) Repeat until stopping criteria is not met

5) If stopping criteria not met

6) Apply mutation operator on population, then apply reproduction operator and apply the fitness value after it.

7) If current individual is better than existing, then make current as best, otherwise go to step3.

8) If stopping criteria met i.e. best population found, then

9) Apply dark channel prior on the source image

10) Apply adaptive histogram equalization on each color channel, and then concatenate each channel to get the final output image.

B. Methodology

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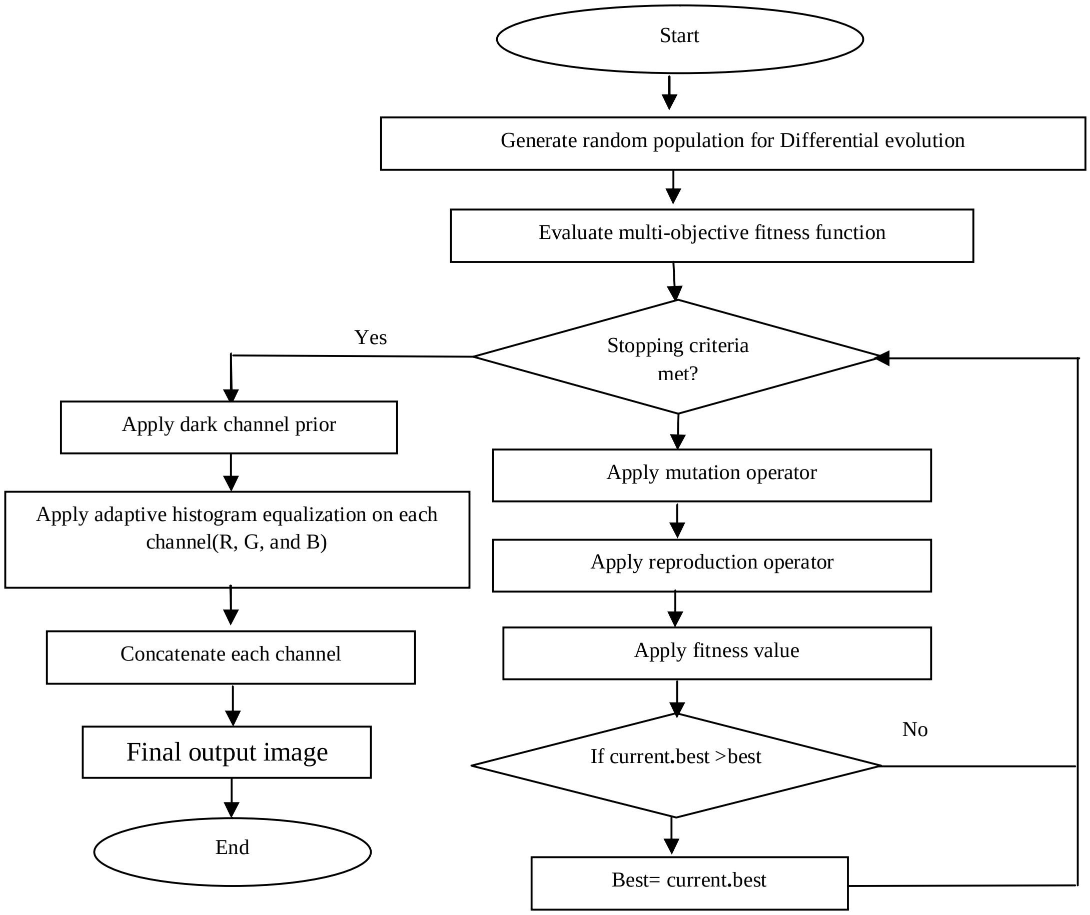

VI. EXPERIMENTAL RESULTS AND ANALYSIS

This section offers strategy considering qualitative measures. MATLAB 2010 is used to perform these parameters.

A. *Test Images and Statistical Parameters*

Evaluation associated with outdoor images which contain fog or haze. These foggy images can be converted fog-free by going through DCP and adaptive histogram equalization technique. The analysis of these images can be done with the help following parameters.

Fig. 3 (a) (b) (c) (d)

Fig. 4 (a) (b) (c) (d)

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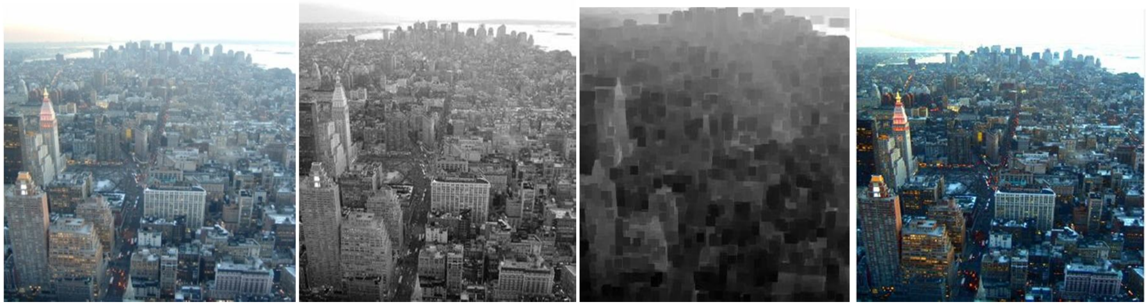

Fig.5 (a) (b) (c) (d)

Fig.6 (a) (b) (c) (d)

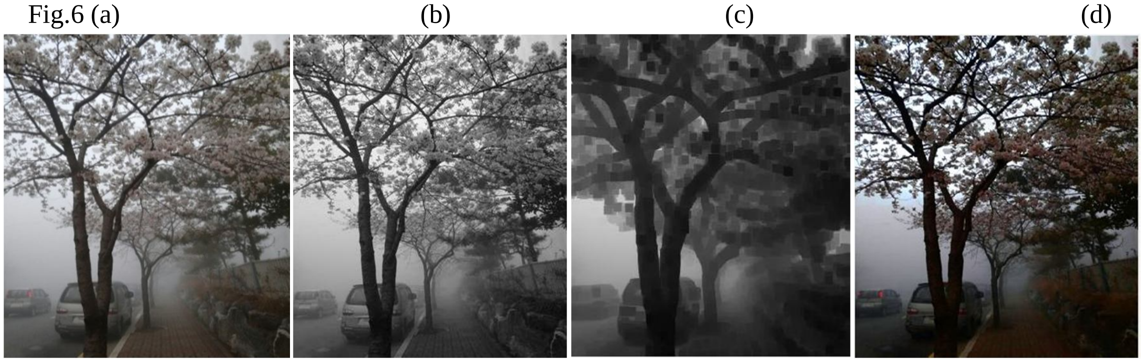

Fig.7 (a) (b) (c) (d)

In all above figures, the fig(a) shows the input image(foggy image) , fig(b) shows the dark channel prior image, fig(c) represents the transmission map and fig(d) shows the enhanced output image by using adaptive histogram equalization . So, the output enhanced image is without fog by using the following parameters:

1) *Peak Signal to Noise Ratio (PSNR):* The phrase peak signal-to-noise ratio (PSNR) is a symbol with the ratio among the ideal value (power) of an indication as well as the effectiveness of muffling disturbance which has effects on the caliber of the representation. For the reason that lots of indicators have got a wide dynamic range, (ratio between the greatest as well as most basic possible values of modifiable quantity) .It will likely be conveyed throughout logarithmic decibel scale.

$$\text{PSNR} = 10.\, log_{10}\left(\frac{MAX^2{}_I}{MSE}\right) \qquad (3)$$

2) *Mean Square Error (MSE):* This MSE is the collective squared problem between compacted in addition to an original image. In other words, MSE means to measure the mean of squares of the problems or perhaps deviations which are, the real difference between foggy in addition to fog-free graphic here.

$$\text{MSE} = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(x(i,j) - x'(i,j))^2 \qquad (4)$$

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3) *Bit Error Rate (BER) :* It is described as the rate during which errors occur inside of some sort of transmitting system. That is really immediately became the number of errors occur inside of a chain of any pointed out number of bits. Bit error rate can be described as a following equation:

$$BER = \frac{Number\ of\ errors}{Total\ number\ of\ bits\ sent} \qquad (5)$$

B. Analysis of Proposed Parameters

Following table shows the results of different parameters based on different images.

TABLE I
ANALYSIS OF DIFFERENT PARAMETERS

Images	PSNR	MSE	BER
Img1	68.6896	0.0087926	0.014558
Img2	65.2002	0.019637	0.015337
Img3	64.7232	0.021916	0.01545
Img4	60.5596	0.057163	0.016513
Img5	70.518	0.0057714	0.014181
Img6	66.1105	0.015923	0.015126
Img7	61.3282	0.047892	0.016306
Img8	63.7238	0.027587	0.015693
Img9	60.3012	0.060668	0.016583
Img10	63.7254	0.027577	0.015692

C. Graphs of Different Parameters

These graphs show the variation of values between different images.

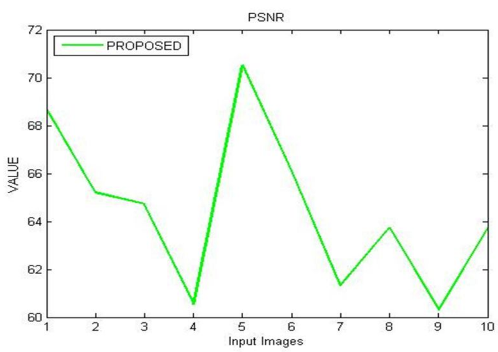
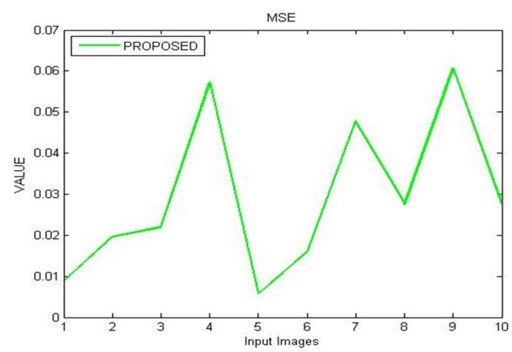
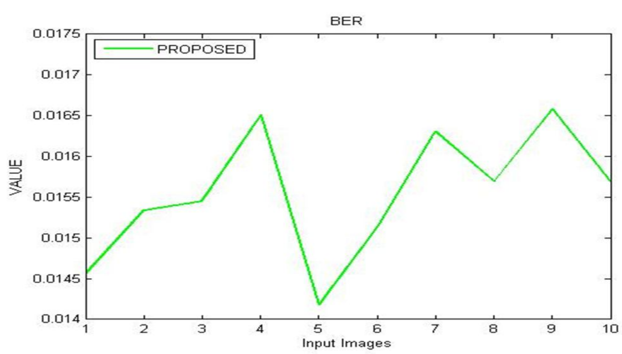


Fig.7 (a)



(b)



(c)

Fig. 7 (a) Analysis of PSNR (b) Analysis of MSE (c) Analysis of BER

VII. CONCLUSION

In this paper, differential evolution has been proposed which has improved the speed of selecting optimistic parameters and dark channel prior for effective fog removal and to enhance the contrast level in the restored image. The results have shown that the proposed approach has significantly removed the haze from outdoor images with the help of various parameters like Peak signal to noise ratio in which significant improvement upto 62% is reflected, on the other hand mean square error is minor which shows the negligible error in the resulted output image and there is too small bit error rate value and hence high quality final image. It is further integrated with adaptive histogram equalization to overcome the problem of color distortion that is not covered in this publication.

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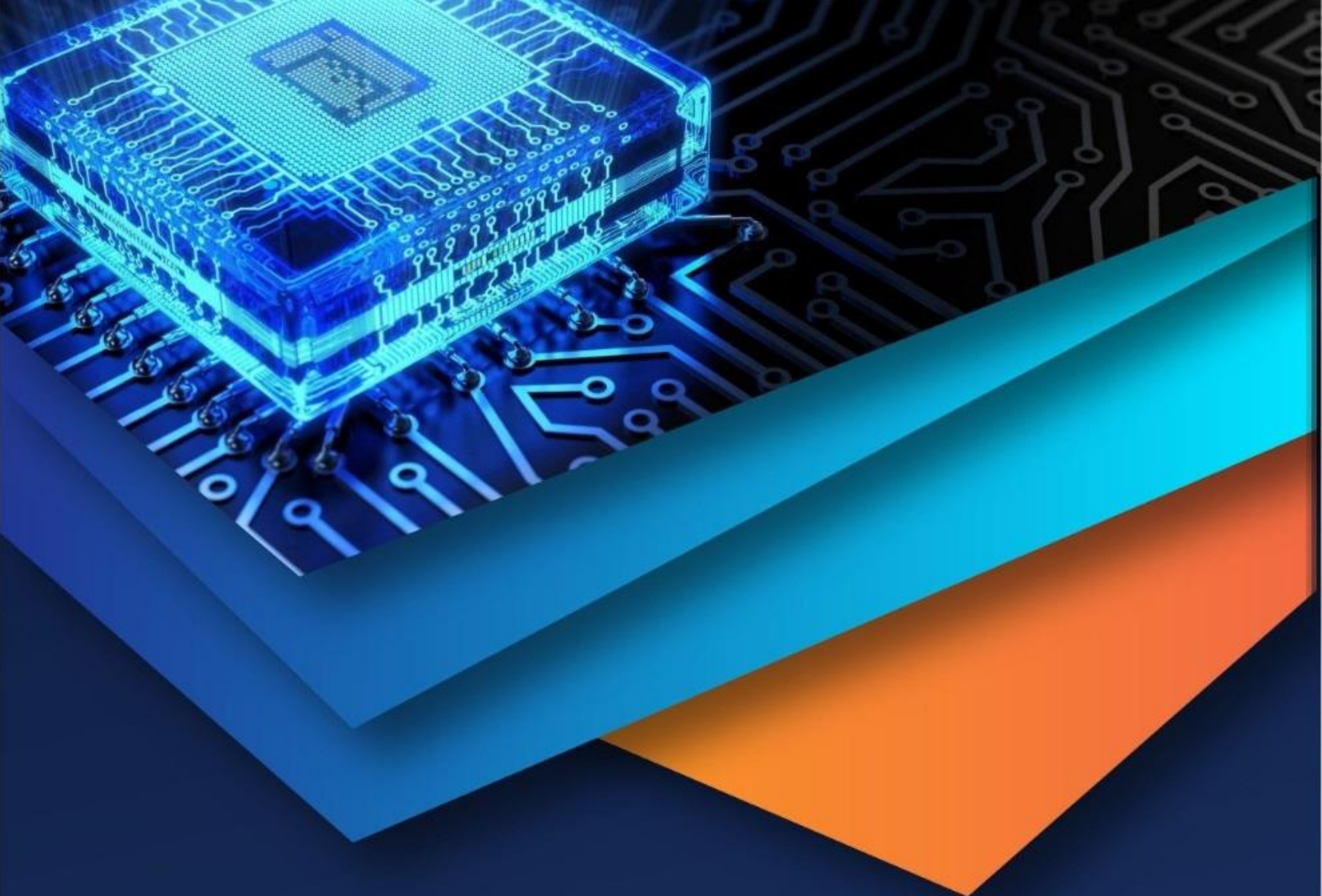

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