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A Review on Image Denoising using Bilateral Filtering

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***Abstract*: The bilateral filter is a non-linear technique that can denoise an image while respecting strong edges. Its ability to decompose an image into different scales without causing haloes after modification has made it ubiquitous in computational photography applications such as tone mapping, style transfer, relighting, and denoising. Even introduction in the field of 3D images new enhanced bilateral filter had been proposes. This content gives a graphical, natural introduction to bilateral filtering, a practical guide for efficient implementation and an overview of its various applications, and in addition mathematical analysis.**

***Keywords:* Mean Filtering, Median Filtering, Gaussian Filtering, Bilateral Filtering, Denoising, Edge Preserving and Image Smoothening.**

I. INTRODUCTION

Image is an important source of information. People can know the intension of information through the image processing technology. Digital image noise removal involves optical systems, micro-electronics technology, computer science, mathematical analysis and other fields. That is a very complex edge science. It is already a comprehensive theoretical system. Its practice is widely used in medicine, military, art, agricultural field. Enhancing useful information of image, it was a distortion process in image field. The aim of image enhancement was to improve visual image. For the given image application, people can emphasize the overall image or local characteristics. And then make the original image become clear or emphasize certain traits of interest [5]. This step also can enlarge division of different object feature in image. In this way, it is possible to improve the image quality and rich amount of information. Image generation and transmission is often under various noise interference and influence. It will reduce image quality. Similarly, it will affect the follow-up image processing (such as segmentation, compression and image understanding, etc.). There are many different types of noise, such as: electrical noise, mechanical noise, channel noise and other noise. In image processing field, image de-noising is an eternal theme.

II. DENOISE FILTER

In fact, each captured image contains noise. Due to various interferences, noise, the image definition gets bad influence. At the same time, noise making the image blurred. The bad condition was submerged fully. It gives analysis big difficulty. Therefore, people need to suppress unwanted noise to improve image quality. For digital image noise reduction, the basic filtering algorithms are used. It includes mean filtering, median filtering, Gaussian filtering, and bilateral filtering.

A. Mean Filter Denoising

Mean filter is a linear filter algorithm. That means it increases a template on the target pixel, and then uses all the average of pixel value instead of the original pixel value. The template size and shape can often be based on the characteristics of images to be processed to determine size.

(a) before processing (b) after processing

Figure 1: Comparison using Mean Filter [10].

Figure 1 shows the mean filterer processing. The mean filter is blurring at the expense of noise suppression. When the template is enlarged, the picture becomes clearer than before. It is important to note that details of the picture are a little vague [10].

B. Median Filter Denoising

Median filtering is a nonlinear smooth technology. Each pixel of the gray value of a neighborhood has its own pixel gray value of the median. That means all pixels within the neighborhood sort by gray value, taking the median of the group as a neighborhood center pixel output value. Figure 2 shows that through the median filtering processing, the picture is clearer than before [2]. When a pixel in the neighborhood of pixels is odd, take the gray value of pixels in the field. That means the middle of the order value. When a pixel neighborhood of pixel number is even, take the pixel gray value of the field. That means the middle of sort value of two scales [13].

(a) before processing (b) after processing

Figure 2: Comparison using Median Filter [13].

C. Gaussian Filter Denoising

The Gaussian filtering is an important space for the weighted mean filter. It is based on the shape of the Gaussian function to select the right value of linear smoothing filter. It usually uses the Gaussian function of discrete two-dimensional by zero-mean to be smoothing filter.

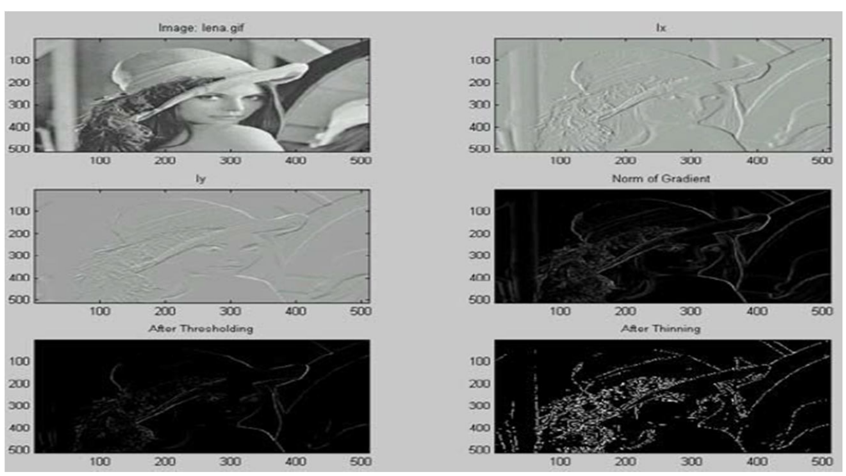
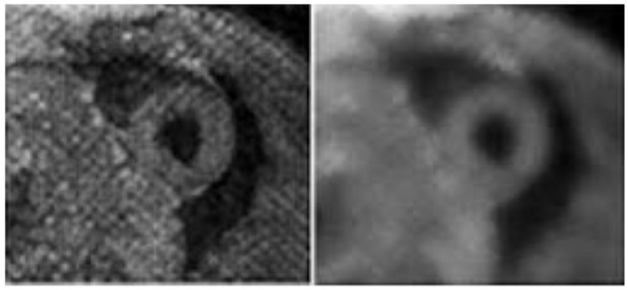


Figure 3: Comparison using Gaussian Filter [6].

It is possible to learn through Figure 3 how to use a more intuitive picture to process the Gaussian filtering. The Gaussian filter for the elimination of the Gaussian normal distribution noise is very effective [6].

D. Bilateral Filter Denoising

If the image point in traditional low-pass filter is similar to gray point, the noise is irrelevant. The edge on both sides of a point on it has a very different point. The filtering processing has high-frequency components. In addition to the image, the result shows in the loss of the edge. Bilateral filtering method is based on the Gauss filtering method proposed in dealing with each adjacent pixel gray values. Not only does it take into account the close relationship between space, but also takes into account the gray similar relationship. It is mainly aimed at Gauss filtering, the Gaussian weighting coefficient direct convolution with image filtering principle. The filter optimizes the image brightness into the Gauss function and products information. The researcher optimize the weights before and after the image information for convolution, so it will be able to filter the image information taking into account the edge information in images. The image is filtered in the normal Gaussian filtering maintained clear and smoother edge. This method for color and grayscale images of the filter is applicable, and highly practical. [7]



(a) before processing (b) after processing

Figure 4: Comparison using Bilateral Filter [7].

The following picture is a set of bilateral filtering processed pictures and results shown in Figure 4.This spatial proximity and gray will be a combination of the similarity method. It is called bilateral filtering. Bilateral filter is characterized by the image of each point with its close proximity and gray-scale pixel average to replace the original value. Then it is possible to achieve the filtering effect. It can be seen that a small neighborhood of gray image has not a big change. It is approximately constant. The standard bilateral filter will enter into the low-pass spatial filter. Bilateral filtering can achieve not only the effect of filtering but also the image of the edge detail. So, this is a great method for application value filtering. [4]

Bilateral filtering is a strategy to smooth pictures while saving edges. If the image point in traditional low-pass filter is similar to gray point, the noise is irrelevant. The edge on the two sides of a point on it has an altogether different point. The filtering handling has high-frequency parts. Notwithstanding the picture, the outcome appears in the loss of the edge. Bilateral Filtering technique depends on the Gauss separating strategy proposed in managing each neighboring pixel gray esteems. Not exclusively does it consider the cozy connection between spaces, yet in addition considers the gray comparative relationship. It is for the most part gone for Gauss separating, the Gaussian weighting coefficient coordinate convolution with picture filtering standard. The filter or channel advances the picture brilliance into the Gauss capacity and items data. The analyst streamlines the weights when the picture data for convolution, so it will have the capacity to channel the picture data considering the edge data in pictures. The picture is separated in the typical Gaussian filtering kept up clear and smoother edge. This technique for shading and grayscale pictures of the channel is relevant, and highly practical. The f(x) represents that using the low-pass filter in space. It can be get the image I(x), shown equation 1:

$$I(x) = k_d^{-1}(x) \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} f(\varepsilon) c(\varepsilon, x) d\varepsilon \qquad (1)$$

Where $c(\varepsilon, x)$represent the center and its neighboring point ε of the degree of spatial proximity. Assuming x=(x1, x2), ε = (ε1, ε2) are the space coordinates of image. If the low-pass filter retains the signal of the DC branch, shown equation 2:

$$k_d(x) = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} c(\varepsilon, x) d\varepsilon \qquad (2)$$

On the off chance that the filter has shift invariance, $c(\varepsilon, x)$ is the vector difference between ε and x. Similarly, the filtering method in grayscale is similar to space domain method. The result is showed as equation 3:

$$I(x) = k_r^{-1}(x) \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} f(\varepsilon) s(f(\varepsilon), f(x)) d\varepsilon \quad (3)$$

Where $s(f(\varepsilon), f(x))$ represents the center point of x and ε. At this point, it can be shown in equation 4:

$$k_r(x) = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} s(f(\varepsilon), f(x)) d\varepsilon \qquad (4)$$

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With fluctuating degrees of spatial proximity, gray image have many differences with a two gray scale value. According to last two equations, the next function can be created. The output image shown equation 5:

$$k_r(x) = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} c(\varepsilon, x)s(f(\varepsilon), f(x))d\varepsilon \qquad (5)$$

The bilateral filter has a couple of characteristics that clear up its prosperity [8]:

1) Its definition is basic: every pixel is supplanted by a weighted ordinary of its neighbors. This perspective is critical in light of the fact that it makes it simple to acquire intuition about its behavior, to adapt it to application-specific requirements, and to implement it.
2) It depends just on two parameters that exhibit the size and complexity of the components to safeguard.
3) It can be used in a non-iterative way. This makes the parameters easy to set since their effect is not cumulative over several iterations.
4) It can be enrolled at intelligent speed even on large images, because of proficient numerical plans, and even progressively if illustrations equipment is accessible.

III. RELATED WORK

The comparative examination related to Bilateral Filter and Pollination Based Optimization as shown below. according to that comparative examination of Bilateral Filter as shown in Table 1 and comparative examination of Pollination Based Optimization as shown in Table 2 respectively.

Table 1: Comparative examination related to Bilateral Filter.

S/N	Authors	Published Year	Image Type	Technique Used
1	Giuseppe et al	2016	3D Rock Samples	Implementation of Bilateral Filtering by optimal expansion of Filter Kernel
2	Pham C C et al	2015	Digital Image	Adaptive Guided Image Filtering
3	Kenjiro et al	2015	RGB Image	Compressive Bilateral Filtering
4	Shengdong et al	2014	Digital Image	Optimal O(1) Bilateral Filter with arbitrary spatial and range kernels using sparse approximation
5	Tang J et al	2012	3D Ultrasound Image	3-D Bilateral Filter
6	Ke Zhang et al	2012	Digital Photography	Constant time joint Bilateral Filtering using joint integral histograms
7	Chaudhary et al	2011	Gray and Color Image	Bilateral Filter realized by using trigonometric range kernels.
8	Bahadir et al	2011	Digital Image	Bilateral Filter with arbitrary range and domain kernels.
9	Zhang et al	2008	Natural and Text Image	Adaptive Bilateral Filter.

Table 2: Comparative examination related to PBO.

S/N	Authors	Published Year	Image Type	Technique Used
1	Priyanka et al	2016	Natural and Text Image	Lossless image compression for storage reduction using pollination based optimization.
2	Navjot et al	2013	Digital Image	An Efficient Edge Detection Approach Based On PBO.
3	Gaganpreet et al	2013	RGB Image	Color Image Quantization using PBO

IV. EDGE PRESERVING WITH BILATERAL FILTER

The bilateral filter is furthermore described as a weighted ordinary of neighboring pixels, in a way in a general sense the same as Gaussian convolution. The refinement is that the reciprocal channel thinks about the qualification in motivating force with the neighbors to spare edges while smoothing. The key idea of the bilateral filter is that for a pixel to affect another pixel, it should have an adjoining territory and additionally have a relative regard [5]. The bilateral filter, signified by $[BF[I]_p]$ is defined by:

$$BF[I]_p = \frac{1}{W_p}\sum_{q \epsilon S} G_{\sigma_s}(\|p-q\|)G_{\sigma_r}(\|I_p - I_q\|)I_q \qquad (6)$$

Where normalization factor W_P ensures pixel weights sum to 1.0:

$$W_P = G_{\sigma_s}(\|p-q\|)G_{\sigma_r}(\|I_p - I_q\|) \qquad (7)$$

Parameters σ_s and σ_r will specify the amount of filtering for the image I shown in Figure 5.

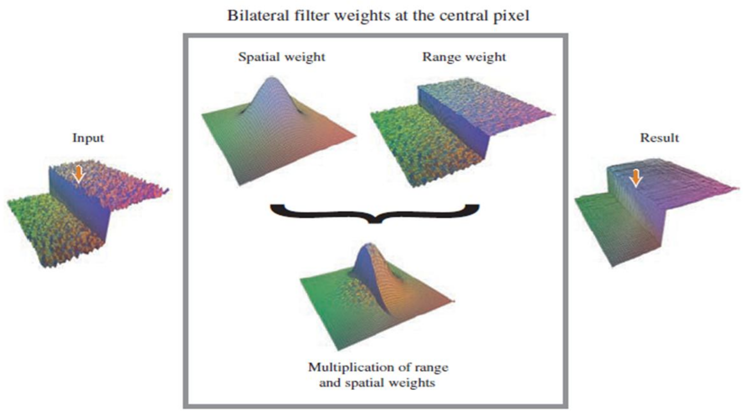

Figure 5: Edge Preserving Filtering with Bilateral Filter [5].

Condition of $BF[I]_p$ is a standardized weighted normal where G_{σ_s} is a spatial Gaussian weighting that that declines the impact of inaccessible pixels, G_{σ_r} is a range Gaussian that decreases the impact of pixels q when their intensity values differ from I_p.

A. Parameters

The bilateral filter is controlled by two parameters: σ_s and σ_r. Figure delineates their impact.

1) As the range parameter σ_r expands, the bilateral filter steadily approximates Gaussian convolution all the more intently in light of the fact that the range Gaussian G_{σ_r} augment and levels, i.e., is is almost consistent over the force interim of the picture.
2) Extending the spatial parameter σ_s smoothes bigger features.

In practice, in the context of denoising, show that altering the range parameter σ_r to evaluations of the neighbourhood noise level yields all the more fulfilling outcomes. The creators prescribe a linear dependence: $\sigma_r = 1.95\sigma_n$, where σ_n is the local noise level estimate [12].

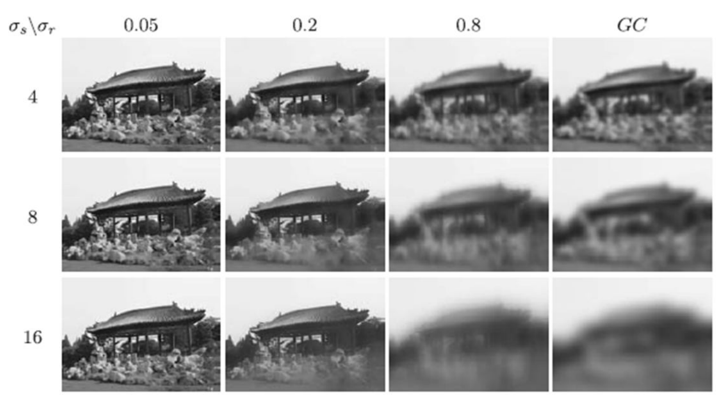

Figure 6: Parameter Effect [12].

An essential normal for bilateral filtering is that the weights are expanded: if both of the weights is almost zero, no smoothing happens. For instance, a huge spatial Gaussian combined with slender range Gaussian accomplishes constrained smoothing notwithstanding the huge spatial degree. The range weight implements a strict protection of the shapes.

B. Computational Cost

At this phase of the introduction, perusers may have officially chosen that the bilateral filter is a nonsensically expensive estimation to figure when the spatial parameter σ_s is large, as it develops each yield pixel from an extensive neighborhood, requires the computation of two weights, their items, and an exorbitant normalizing venture also.

C. Iteration

The bilateral filter can be iterated. This prompts to come about that are for all intents and purposes piecewise steady as showed in Figure 4. In spite of the fact that this yields smoother pictures, the impact is not quite the same as expanding the spatial and range parameters. As showed in Figure 7, extending the spatial parameters σ_s has a limited effect unless the range parameter σ_r is likewise expanded [15].

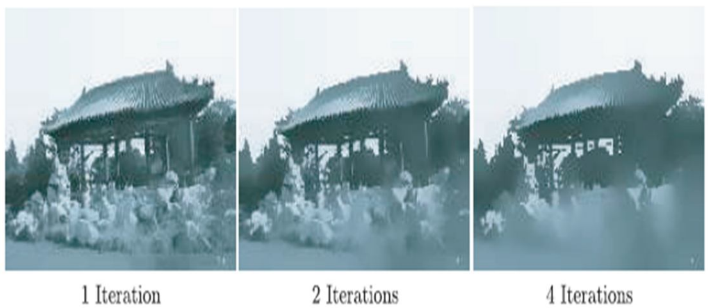

Figure 7: Iteration [15].

Although a large σ_r additionally creates smooth yields, it has a tendency to darken the edges however accentuating jam the strong edges, for instance, the edge of the housetop in Figure 4 while removing the weaker unpretentious components, for instance, the tiles. This kind of impact is alluring for applications, for example, stylization that try to digest away the little points of interest, while computational photography strategies [5] tend to utilize a solitary cycle to be nearer to the underlying picture content.

D. Seperation

The bilateral filter can section a photo into two sections: the separated picture and its “residual” picture. The separated picture holds only the huge scale highlights, as the bilateral filter smoothed away local variations without influencing solid edges [15].
The residual picture, made by subtracting the filtered picture from the first, holds just the picture partitions that the filter removed. Contingent upon the settings and the application, this removed little scale part can be interpreted as noise or texture, as appeared in Figure 8.

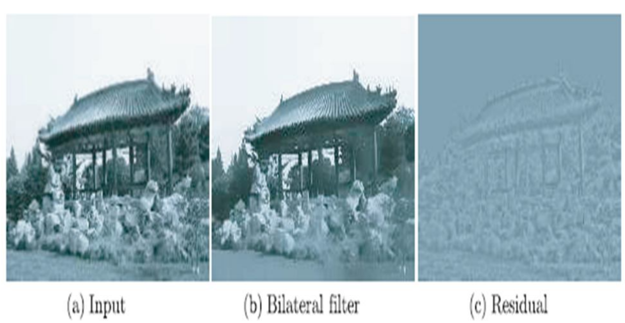

Figure 8: Separation [15].

V. CONCLUSION

As indicated by past methodologies, bilateral filtering highlights several features for future research. According to previous approaches, the fast implementation of bilateral filtering is displayed which depends on an ideal development of the filter kernel into a sum of factorized terms. The approaches proposed to speed up Bilateral Filtering for denoising the image. The bilateral filter is also often used to extract the texture of an image. For further extent of work according to previous methodologies, a new Artificial Intelligence (AI) can be proposed for better enhancement of Bilateral Filter in terms of denoising.

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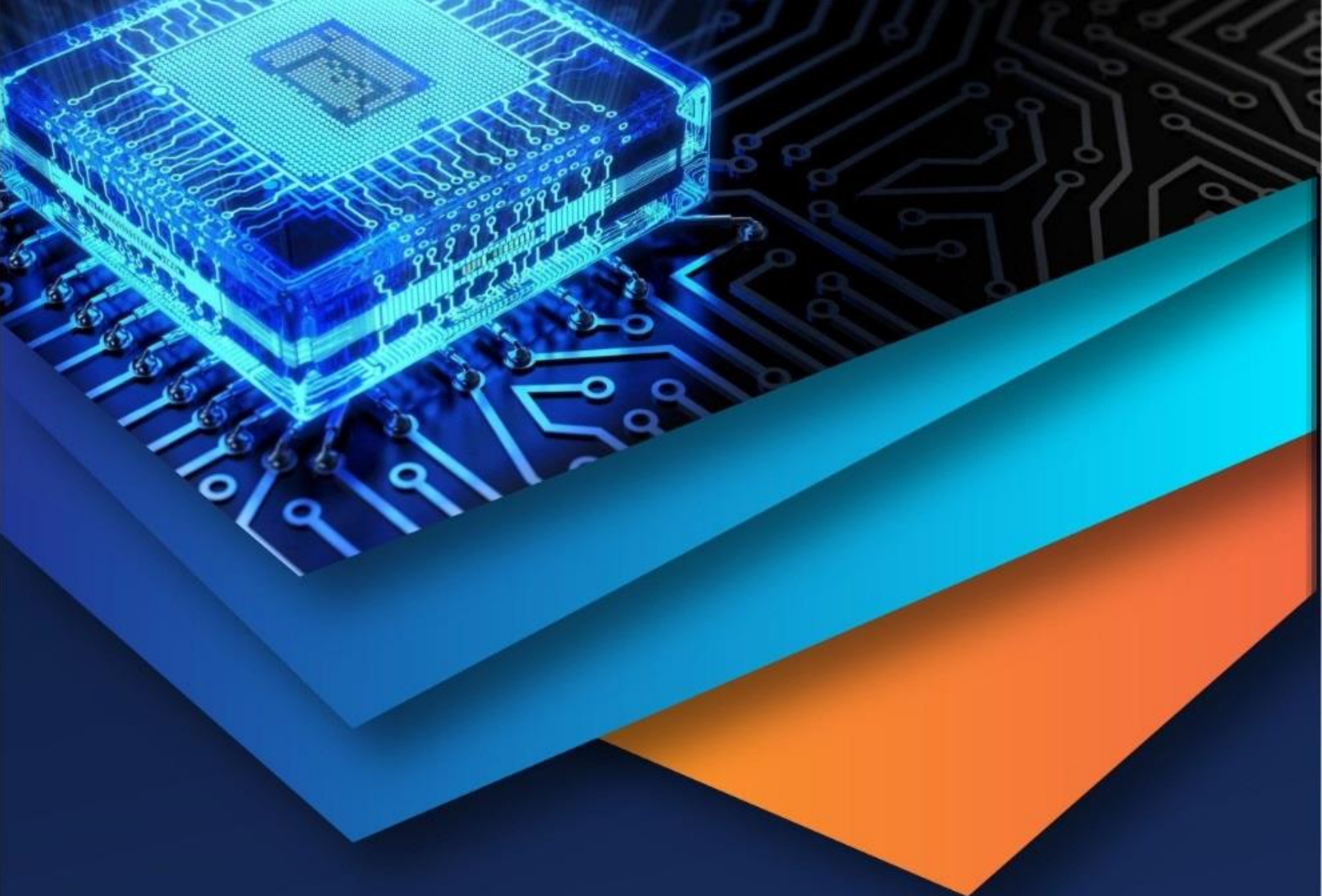

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