iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 Issue: VII Month of publication: July 2022

DOI: https://doi.org/10.22214/ijraset.2022.45490

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VII July 2022- Available at www.ijraset.com

Image Quality Enhancement and Noise Reduction in Kidney Ultrasound Images

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Abstract: Kidney disease should not be ignored as kidney failure can endanger our lives. Hence, early detection and prevention are essential to prevent various kidney problems in patients. One of the most important medical diagnostic techniques for examining kidney stones and other kidney-related problems, is ultrasound imaging. Moreover, ultrasound imaging is efficient, radiation-free, cost-effective, and real-time. However, low contrast, speckle noise, gaussian noise, and other aberrations still limit access to ultrasonic scanning facilities. So, improved image quality is a major need for diagnosing renal problems. As a result, it is important to improve the image quality to detect kidney problems. Appropriate imaging techniques are available for preprocessing, noise reduction, and image enhancement to address these issues. An important way to get high quality images from noisy images is to improve the image and restore it. Because of the high-frequency rate, noise appears in the kidney ultrasound images. Preprocessing is the initial stage in obtaining a high-quality image. In this process, the image quality is improved. The preprocessing involves the use of various filtering techniques to filter the image and eliminate noise. The problems of speckle, salt-and-pepper and Gaussian noise in ultrasound images can be overcome using various filters like mean, medium, wiener and many more. The research work presents an overview of the various techniques for ultrasound image preprocessing and quality enhancement. Moreover, the objectives of these techniques and their performance are explained.
Keywords: Kidney ultrasound imaging, speckle noise, pre-processing, image enhancement.

I. INTRODUCTION

Ultrasound imaging is non-invasive, radiation-free, cost-effective, and real-time methods of obtaining a picture of a person's internal structure, which can help doctors, detect dangerous diseases or abnormal tissues. Due to its absorption and speed, ultrasound has proven to be a great imaging technique for large medical applications. Ultrasound imaging, on the other hand, is often affected by signal dependence, which limits the resolution of comparisons and makes human interpretation and diagnosis challenging. As a result, in medical ultrasound image processing, speckle noise reduction is a critical issue. In [1], one of the research authors investigates a patch based low-level technique to reduce the noise in ultrasound images. To begin with, a patch group is created by selecting several related patches for each key patch. The patch group is then regularised using the weighted nuclear norm, resulting in a nonconvex variational model. Furthermore, they use the ADMM approach to approximate the solution of the suggested nonconvex model. Finally, to create ultrasound images of the cut, all the adjacent patches must return to their original position. Medical specialists primarily employ ultrasound imaging as one of the most important and common modalities of diagnosis. Many medical applications rely heavily on ultrasonic imaging analysis. Medium filters, Gaber filters, Weiner filters, and Gaussian filters [2] [3] are some of the ways to eliminate speckle noise. Ultrasound images must be despecked in order to improve image quality. This helps to separate the adjacent tissue boundaries. The linear elastic theory is proposed in [4] for calculating the depth of shock wave scattering by determining the pressure in a fluid. Various types of kidney stones are treated by immersing them in fluid externally. This might be caused by poor illumination, aperture size, shutter size, and other factors. Each pixel's range and grey level are affected by these flaws. Contrast can be enhanced in such circumstances by using contrast enhancement [5] [6].

In [7] author stated, speckle refers to the granular models that appear in ultrasound images due to wave impedance. Speckle removal can significantly increase the infrastructure deviation in ultrasound imaging, as well as the post-handling that follows. A fuzzy logic approach is used to create a framework for speckle removal. The image's noise can conceal and lessen the sight of various properties of the things included within it. As a result, it can't be upgraded further. SRAD with a guided filter is described in [8]. The author presented a speckle noise reduction and edge preservation technique based on speckle reducing anisotropic diffusion (SRAD) and a guided filter. SRAD is used to eliminate speckle, which is multiplicative noise. A logarithmic transformation is used to convert the residual noise in the filtered picture to additive noise. A guided filter is used to eliminate any excess noise that remains in the filtered picture. Finally, the exponential transform was used to create a noise-free picture.

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When compared to traditional filtering algorithms, experimental findings reveal that the proposed algorithm performs very well in terms of speckle noise reduction and edge retention. In addition, the author proposed a novel algorithm based on speckle noise characteristics and filtering methods such as SRAD filtering, discrete wavelet transform (DWT) using symmetry characteristics, gradient domain guided image filtering (GDGIF), and weighted guided image filtering (WGIF) [9]. Because it may be applied immediately to a medical US picture with speckle noise without requiring log-compression, the SRAD filter is used as a preprocessing filter. The advantage of the wavelet domain is that it suppresses additive noise. As a result, the multiplicative noise is transformed into additive noise via a homomorphic transformation. After two-level DWT decomposition is used to suppress residual noise of an SRAD filtered image, WGIF and GDGIF are used to minimise noise. Many researchers have looked into filters for removing or depressing speckle noise, which is present in ultrasonic images, in order to enhance the metrological evaluation of their biological applications in recent years. In the study [10], 27 strategies for smoothing or removing speckle noise in medical ultrasound images are described in depth. The purpose of this study is to emphasise the relevance of enhancing smoothing and elimination, which are closely connected to numerous processes reported in prior studies. Furthermore, the explanation of this set of methodologies makes it easier to conduct more focused assessments and studies. This research first looks at several traditional methods like spatial filtering, wavelet filtering, and diffusion filtering, as well as Dynamic Analysis-Based Techniques, Modern Techniques (SBF), Wavelet-Based Methods, SAR-Based Methods, Modern Techniques (OBNLM), Modern Techniques (SRBF), Machine Learning-Based Techniques, and Hybrid Techniques. The author has proposed a novel noise reduction method in [11]. The method is based on a mix of multiscale approaches, wiener filters, and a novel fast bilateral filter. In [12], the study described a denoising approach that uses a nonlinear diffusion tensor and a logarithmic transformation.
This paper is organised into four sections. Preprocessing and image quality enhancement are discussed in Section II. Section III has discussions about preprocessing techniques, and Section IV represents the conclusion of the research paper.

II. PRE-PROCESSING AND IMAGE QUALITY ENHANCEMENT

A. Kidney Ultrasound Imaging

Ultrasound imaging is an optimal system that uses sound waves to create images that help doctors identify and treat diseases. The kidneys are the only silent organs in the body. Figure -1 shows a pair of bean-shaped organs located below the rib cage on either side of the spine. These organs, which are each around the size of a fist, filter your blood and remove waste and excess water. The waste is largely made up of nutritious components that have broken down, such as calcium. The kidneys convert waste into urine, which is then supplied to the bladder via tubes until it is expelled from the body, all while maintaining the right balance of beneficial components [13].

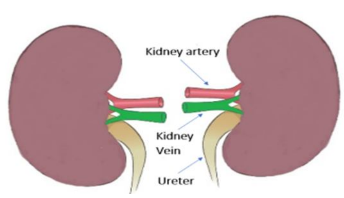
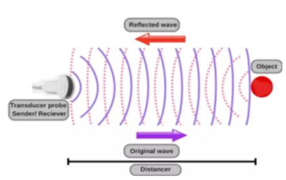


Figure-1 kidney

Ultrasound methods are called ultrasound scanning, sonography, and ultrasound imaging. In addition, ultrasonic scanning, which includes a computer, a small transducer, and a screen display, is used for this purpose. A transducer, commonly known as a probe, is a small hand-held device that attaches an image to a cable [14]. The ultrasonography approach is depicted in Figure-2. To begin, a layer of gel is placed on the skin in the area where kidney imaging is required. The transducer then glides across the skin, obtaining an image from the inside. To record inside photos, the probe sends out high-frequency sound waves ranging from 1 to 20 megahertz (MHz) into the body via the gel. These sound waves bounce back and forth, accumulating on a transducer and being analysed by a computer to produce a kidney image [15].

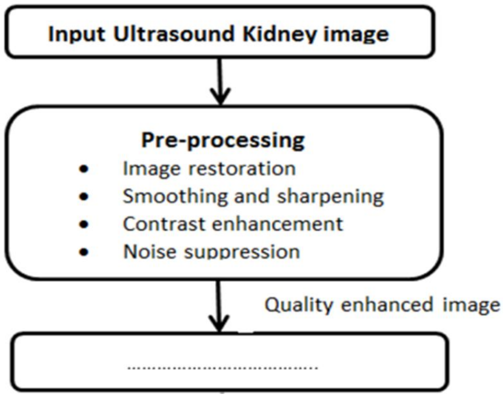


Source:// https://www.scienceabc.com[15]

Figure-2: General procedure of ultrasound

B. Pre-processing

Low contrast and speckle noise are issues with ultrasound images. However, there are certain methods that may be used to improve image quality and system performance.



To eliminate undesirable noise from kidney ultrasound images, such as speckle noise, acoustic noise, gaussian noise, and other irregularities, preprocessing is necessary. Noise suppression, image restoration, contrast enhancement, smoothing, and sharpening are all part of this phase, which is used to improve the quality of ultrasound images. They are shown in figure- 3. Suppressing noise, conserving essential information, clarifying the borders of an item, enhancing the difference between the region of interest and decreasing background speckle are some of the approaches used to improve the quality of an ultrasound image.

1) *Image Restoration:* The purpose of image restoration is to eliminate or reduce the degradation that happened during the ultrasonic image capture process. A level set function is utilised for appropriate orientation.
2) *Smoothing and Sharpening:* Smoothing and sharpening are employed to achieve optimal resolution in both the spatial and frequency domains, as well as to emphasise object edges and small details. Many filters, such as the Gabor filter and the Gaussian function, are utilised for this purpose.
3) *Contrast Enhancement:* Contrast enhancement is a technique for enhancing the clarity of ultrasound images. By adjusting the range of values in an image, histogram equalisation is used to increase contrast and achieve a consistent intensity [16] [17].
4) *Noise Suppression:* This noise replaces certain pixels in the original image with new pixels in order to degrade the image. The image's visual quality is degraded by noise. Noise may occasionally obscure important details in an image, such as edges, the shape of small objects, and so on. In ultrasound imaging, speckle noise is frequent. Speckle noise, like signal-dependent noise, is unsystematic and multiplicative in nature, degrading the original image. Speckle noise obscures crucial details in an image, such as the edge, shape, and intensity value, and can make it difficult to identify objects [18]. To reduce noise in ultrasound images, the following approaches, or combinations of these approaches, are used: Filters: Linear or Nonlinear Mean filter, Median filter, Gaussian low pass filter, Wavelet filter, Gabor filter, Wiener filter, and so on. T. Rahman and M. S. Uddin created and deployed a system that can segment the kidney from an ultrasound image and assist the surgeon during surgery. The Gabor filter was employed to decrease speckle noise, and histogram equalisation was applied to improve the image quality. Furthermore, two segmentation approaches were defined and compared: region-based segmentation and cell segmentation. To acquire better results, they employed a region-based segmentation algorithm using MATLAB to develop the system [18].
5) *Image Quality Enhancement:* Histogram equalisation and the contrast enhancement technique [19] are both extensively used to improve image quality. To increase the quality of the supplied image, image enhancement is needed. Contrast, spatial resolution, brightness, and noise removal are all important components of image quality. To increase an image's quality characteristics, image enhancement techniques are employed. A histogram summarises the distribution of grey levels in an image by showing the frequency of grey level occurrence. This graph depicts the image's global appearance distribution, which is used to measure image quality. Objective and subjective fidelity criteria are used to classify image quality measurements. The objective fidelity standards are used to assess the image quality and inaccuracy [20]. Figure-4 depicts the process of preprocessing and image enhancement.

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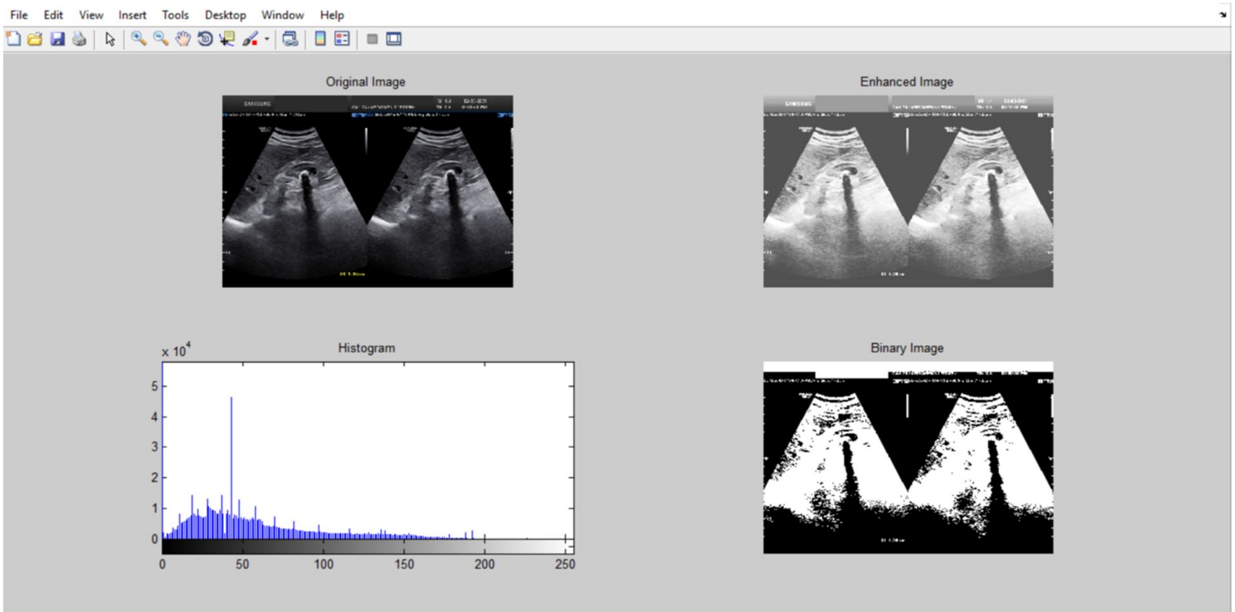

Figure-3

III. PRE-PROCESSING AND IMAGE ENHANCEMENT TECHNIQUES

Techniques	Description
1. SpatialDomain [20]	The point transforms or grey level scaling transformations used to construct the matching pixels in the out-take image are only dependent on the pixels in the intake image in this domain.
1.1. Linear Point Transformations[20]	One essential change requires many essential changes, one of which is inversion. In a binary image, inverse transformation changes a black pixel to a white one and vice versa to reverse the image.
1.2. Nonlinear Transformations[20]	Both the input and output variables have a non-linear relationship. The squared function is used to increase the contrast of a given image. The logarithmic and exponential functions are used to enhance details in high-value regions of the image and decrease the dynamic range in low-value regions, respectively, and the power transformation is used to calculate the c, which is a positive constant.
2. Histogram Processing [20]	In image processing applications, histogram approaches are practical and beneficial. It's a tool for adjusting an image's contrast and brightness. It can be shown as a probability density function or an intensity distribution.
3. Spatial Filtering [20]	The term "spatial filtering" refers to image filtering procedures that are done directly on the pixels. Image smoothing, sharpening, and noise reduction are all done using it. As the mask's centre advances over each pixel in the input image, a filtered image is created.
3.1 Linear Filter [20]	It's used to get rid of certain kinds of noise. The filtering process is linear if the output is a weighted sum of the input pixels. It is most effective when dealing with gaussian noise. It's easy to do and softens the rough edges. It's used to get rid of the lines and other characteristics in the image. Linear filters such as Gaussian and mean are often employed.
3.2 Non-linear Filters[20]	It's used to keep edges sharp and is a good way to get rid of impulsive noise. Non-linear filters outperform linear filters in terms of performance. Non-linear filters reduce noise without distorting the image's edges. Non-linear filters are most typically employed with the median filter.
3.3 Gaussian Filter[20]	When accidental values are added to an image as a result of signal changes, this is known as Gaussian noise. The probability density function of this noise has a normal distribution. It occurs during the capture and transmission of digital photographs. Mean, median, and Gaussian filters are all used to reduce Gaussian noise.
4.Scalar Filters[21]	Scalar filters are based on a ratio of local statistics that increases smoothing in homogeneous portions of the image where speckle is fully formed while reducing smoothing in other regions of the image to maintain valuable features. The two most basic forms of scalar filters are mean and median filters, which are covered in this table.
4.1 Mean Filter[21]	Pomalaza-Raez designed this simple and obvious filter in 1984. It does not completely eliminate speckle noise, but it does help to minimise it. It operates on an average basis, meaning that the centre pixel is replaced by the average of all pixels. As a result, this filter blurs the photos, making them the least suitable way for removing speckle noise due to the loss of features.
4.2 Median Filter[21]	Pitas devised the non-linear filter in 1990. It outperforms the average filter by a long shot. The median value of all pixels replaces the centre pixel in this case, resulting in less blurring. It is used to minimise impulsive speckle noise because of its nature. The edges are retained, which is a benefit. The downside is that computing the

	median value for sorting N pixels takes extra time. O is the level of temporal complexity (N log N).
5. Adaptive Filters[21]	By altering window size and keeping properties like edges, many adaptation strategies are offered to attain a better outcome. In this table, we'll look at filters that are adaptive in nature.
5.1. Frost filter[21]	It is a linear, convolutional filter invented by Frost in 1982 to eliminate multiplicative noise from images. It is an exponentially-weighted average filter and has an adaptable character when compared to mean and median filters. The Frost filter is based on the coefficient of variation, which is the ratio of the corrupted image's local standard deviation to its local mean. The weighted sum of values of the neighbourhood in the kernel replaces the centre pixel value in the n-by-n kernel size. As we go away from the intriguing pixel, the weighting factor lowers and increases with variation. It is based on the assumption of multiplicative noise.
5.2. Lee Filter [21]	Jong Sen Lee came up with the idea in 1981. In terms of edge preservation, it outperforms the previous filters. It employs local statistics to retain features and is based on the multiplicative speckle model. The Lee filter operates on a variance basis, which means that if the area's variation is low, it executes smoothing operations, but not if the variance is large. That is, it can maintain information in both low and high-contrast situations, indicating that it is adaptable.
5.3 Kuan filter [21]	It was created in 1987 by Kuan, Nathan, and Kurlander. It's a multiplicative noise local linear minimum mean square error filter. It is far more sophisticated than the Lee filter in that it does not rely on approximation. The multiplicative speckle model is transformed.
5.4. Enhanced Frost and Enhanced Lee Filter [21]	Lopes proposed it in 1990, and it operates on the basis of a threshold value. When the local coefficient of variation falls below a certain threshold, averaging is performed. When the local coefficient of variation exceeds the higher threshold, the filter behaves strictly as an all-pass filter. The balance between averaging and identity is struck when the local variation is between the two criteria.
5.5. Gamma Map Filter [21]	Lopes (1993) used coefficient variation and contrast variation in his research. It outperforms the Frost and Lee filters while also reducing texture information loss. The Gamma Map filter works similarly to the Enhanced Frost filter, with the exception that if the local coefficient of variation falls between two thresholds, the pixel value is reduced.
5.6 Wiener Filter [21]	Norbert Wiener suggested it in the 1940s, and it was published in 1949. The Least Mean Square Filter is another name for it. It is capable of restoring photos that have been corrupted or blurred. It removes noise in an image by comparing it to a noise-free image. The Wiener filter operates on the basis of a local image variance calculation. As a result, when the image's local variation is high, less smoothing is done; when the local variance is low, more smoothing is done. When compared to linear filtering, this technique of Wiener filtering produces superior results.
5.7 SRAD filter[22]	It eliminates speckle noise while preserving the image's borders. It's also known as a speckle-minimizing anisotropic diffusion. Because of the edge and image features, it is commonly referred to as a speckle minimising anisotropic diffusion. This filter has a higher success rate.

IV. CONCLUSION

Enhancement of an input image is the most important task in image processing. In this paper, commonly used techniques for preprocessing and image quality enhancement of B-mode kidney ultrasound images have been discussed. Despite the fact that physicians prefer ultrasonic imaging since it is radiation-free and less expensive than other procedures, it is a difficult task because the introduction of noise into these images causes a variety of issues. Furthermore, poor contrast, speckle noise, gaussian noise, and other abnormalities plague ultrasound imaging. As a result, greater image quality is required to extract the region of interest. Appropriate image processing approaches, such as preprocessing, noise reduction, and quality improvement procedures, have been described to tackle this difficulty. For removing the noise from the ultrasound images, various filters are discussed for different types of noisy ultrasound images

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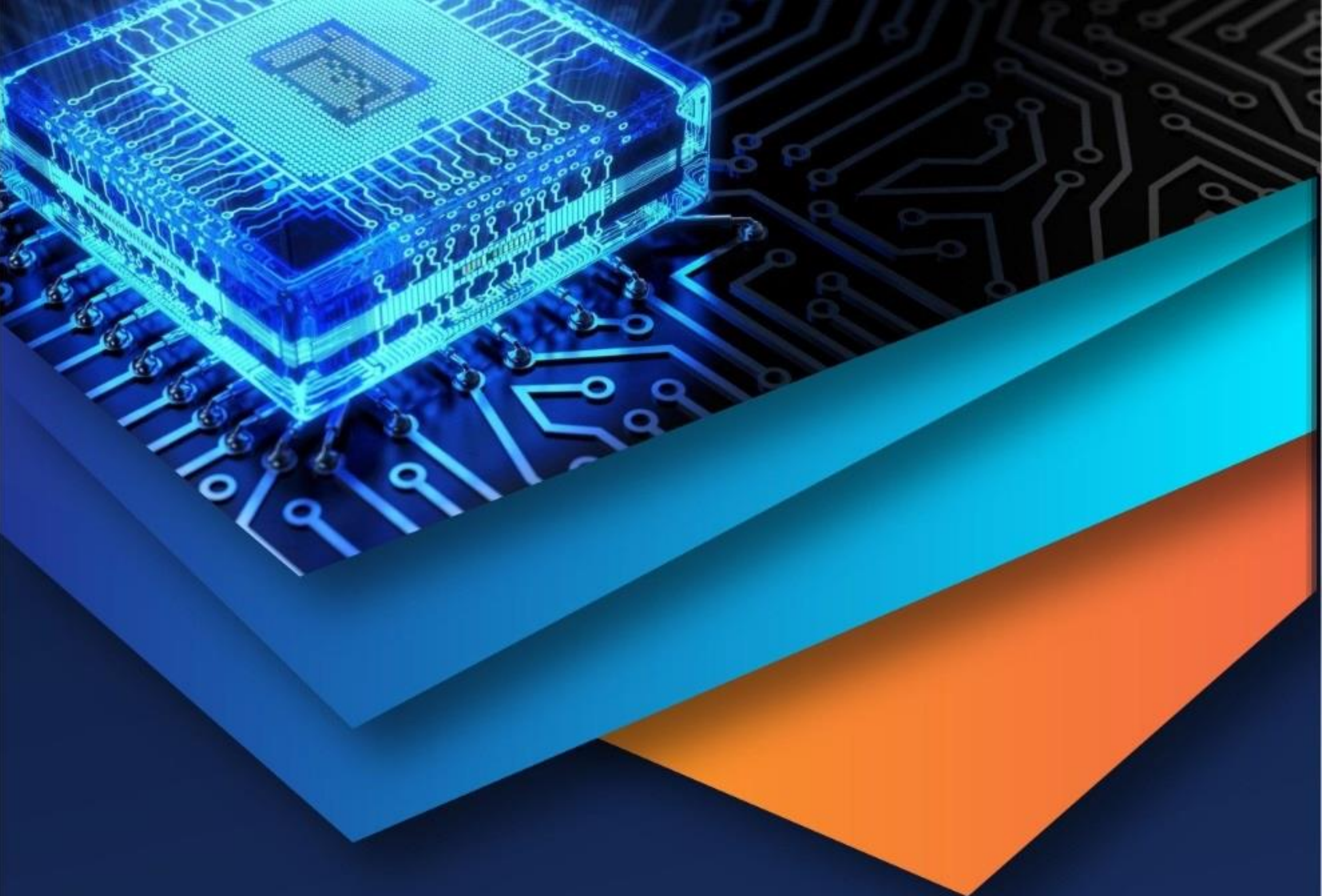

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