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Fusion of Medical Images using Multiresolution Techniques

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Abstract: The aim of the medical image fusion is to combine two or more medical images or some of their characteristics into one image, without introducing any noise or artifacts.A new algorithmfor fusion ofComputer Tomography (CT) and Magnetic Resonance Imaging (MRI) imagesbased on curvelet transform has beenintroduced. The proposed fusion algorithmis splited into three phases. Inthe first phase input images are decayed into two segments: low and high frequency elements. In the second phase, low frequency elementss of the input images are combined utilizing simple averaging strategyand entropy value based selection rule and high frequency elements are fused using adaptive weighted method based on entropy values. In the third phase, inverse curvelet transform is performed on the combinedlow and high frequency parts to get a final fused image. To evaluate the performance of proposed algorithm and quality of fused images three quantitative metrics namely entropy, mean and standard deviation are used. The trail results demonstrate that the proposed method providesbetter fusion results.

Keywords- Curvelet Transform, Image Fusion, Wavelet transform, CT, MRI

I. INTRODUCTION

Image fusion can be outlined as the approach of mixing more than one input images or a few of their attributes into a single image without the presentation of distortion or damage of data. It extracts multisensor, multitemporal and multiview information from a collection of input images and produces a solitary output image of better quality. The meaning and measurement of the term quality depends upon specific application.The output image must have additional absolute information which is useful for individuals and device opinion and in numerous applications for example remote sensing, medical image processing, object identification, target identification etc. [1],[2]. The fused images can be obtained by means of integrating information from single modality images or multimodality images and would contain both complementary and redundant information from input images. Without fusion complementary information captured by different sensors cannot be obtained into a solitary image. Image fusion in medical imaging is used for medical diagnostics and treatment[3].National Aeronautics and Space Administration (NASA) is presently working in image fusion to assist specialists to look at space traveler's hearts in the space. During this procedure, apparent, sharp, high-determination and examined images of space travelers taken on Earth will be consolidated with less sharp images taken on board shuttle to upgrade those images. These enhanced images will empower specialists to see the conditions of the main organs of space travelers in a better way [4].In medical imaging, different imaging instruments such as Computer Tomography (CT) and Magnetic Resonance Imaging (MRI) capture images with diverse radiation power and carry different levels of information accuracy and specificity in different application contexts. CT provides detailed cross-sectional images of bones, but does not provide information about soft tissues or muscles. So, CT cannot distinguish tumors from scar tissues. An MRI image gives data about delicate tissues, organs and blood vessels etc. but does not provide information about boundaries. Every single modality images have their own shortcoming, so cannot provide sufficient and accurate anatomies about a patient when a certain levels of details are required [1],[5].For various purposes such as researches, precise disease diagnosis, monitoring and treatment process like surgery planning, doctors or radiologists needs high spatial and spectral information into a single image. Doctors can combine different modality images manually, but different doctors with different experience evaluate different information from the same images. So, there is need of standard technique to fuse the different modality images for reducing doctor's workload and for consistent diagnosis system [6].In this paper a new image fusion algorithm based on curvelet transform using wrapping function is presented.

II. CURVELET TRANSFORM

To overcome the constraints of wavelet transform a new multiscale transform was proposed by Candes and Donho (1999). The transform was developed to represent boundaries and different singularities on curves additional effectively than other transform techniques.Wavelets do better in one dimension, but do not represent singularities effectively in higher dimensions due to poor directional selectively. Curvelets have higher directional selectivity than wavelets. The curvelet transform obeys anisotropic scaling law i.e. $\text{width} \approx \text{length}^2$, whereas wavelets obey isotropic principle. The curvelet decomposition procedure is divided into four steps: suband decomposition, smooth partitioning, renormalization, ridgelet analysis [7].

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A. Subband Decomposition

The target object is decomposed into subbands as below:

$$\rightarrow (P_0 f, \Delta_1 f, \Delta_2 f \ldots \ldots \ldots) \qquad \ldots (2.1)$$

In case of image processing, this step decayess an image into number of resolution levels. Each level includes details about different frequencies. Here, P_0 refers to lowpass filter and $\Delta_1, \Delta_2 \ldots$ refer to highpass filters.

B. Smooth Partition

Every subband well divided into squares using windowed function..

C. Renormalization

Every square is renormalized to unit scale.

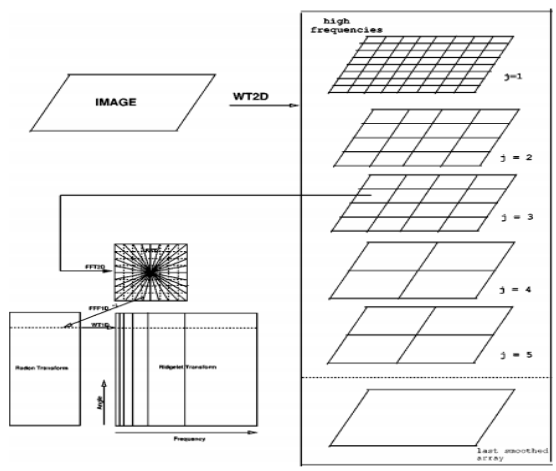

Figure 1.Flowchart of Curvelet Transform [8]

The flowchart in Figure 1 demonstrates the curvelet transform process. In the figure, decomposition of an image into subbands followed by partition of each subband. Then, ridgelet transform is applied to each block.

The continuous curvelet transformation has passed through 2 main reviews. A complicated sequence of stages, including ridgelet analysis of radon transform of an image used in the first version of curvelet transform, also called as “Curvelet 99” [9]. The performance of algorithm was extremely slowand updated in 2003 by Candes and donoho [10]. In this new algorithm, the tight frame is taken as new curvelet approach. The computation speed increases due to elimination of ridgelet transform. The Figure 2 illustrates the Curvelet support in frequency domain, where $U_{j,l}$ refers to a wedge.

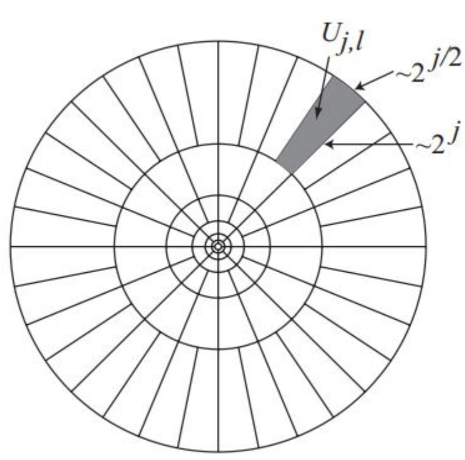

Figure 2.Curvelet tiling in frequency domain [11]

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Digital curvelet transform can be executed into two ways: Unequally Spaced-Fast Fourier Transforms (USFFT) and wrapping based method [12]. In USFFT, the fourier coefficients are irregularly sampled to choose curveletcofficients .In the wrapping method unique samples of fourier transform are wrapped around origin. These two implementations are diverse from each other based on the grid chosen to transform the curvelet at each scale and angle. Both implementations give same output, but wrapping method takes less computation time. Figure 3 demonstrates the support of wedge before and after wrapping .

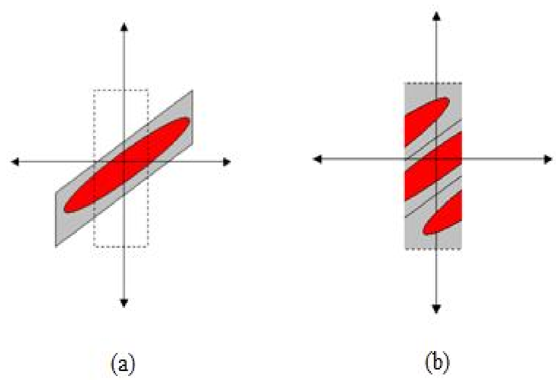

Figure 3.Support of wedge in wrapping method, (a) wedge before wrapping,
(b) wedge after wrapping [12]

III. PROPOSED STRATEGY OF IMAGE FUSION

The proposed method is based on the selection of CT and MRI images of the same organ as input. Curvelet transform, based on wrapping method, multiresolution technique is used for image fusion. The proposed algorithm is divided into the following major steps:

Take two images as input.

Apply curvelet transform on input images.

Apply proposed low frequency fusion rule on low frequency coefficients and high frequency fusion rule on high frequency coefficients.

Apply inverse curvelet transform on fused low and high frequency parts to obtain a final fused image.

Compare the proposed method with the existing fusion techniques.

Inthe1st step, the input images are converted into grayscale images. Consider the input images as A_image and B_image. Then curvelet transform using wrapping method is applied on these images. The curvelet wrapping method decomposes the source images into low and high frequency groups. Let coarse_A and coarse_B are the low frequency coefficients of the source images, $fine\_A_{j}$ and $fine\_B_{j}$ are the high frequency coefficients, where j represents a scale number.

A. *Low Frequency Fusion Rule*

Fusion rule for low frequency sub-bands is described as follows. The rule includes simple averaging and entropy value based selection of coefficients.

1) Calculate the average of the sources images low frequency coefficients as follows:

$$coarse\_Avg=(coarse\_A+coarse\_B)/2 \quad ... (3.1)$$

2) Calculate entropy values of low frequency parts.

3) Select a low frequency part based on the following proposed formula.

$$\text{Coarse\_image} = \begin{cases} \text{coarse\_A}, & if\ \text{en\_A} - \text{en\_B} <= 1 \\ \text{coarse\_B}, & if\ \text{E\_A} - \text{E\_B} > 1 \end{cases} \quad ...(3.2)$$

Here, en_A and en_B are entropy values of source images A_image and B_image respectively. Coarse_imgrepresentsthe low frequency coefficients selected after comparing entropy values.

4) Apply following proposed formula to get fused low frequency coefficients.

$$coarseFused\_img=(Coarse\_img+coarse\_Avg)/Th \quad ... (3.3)$$

where, Th=1.5. It is an experimental parameter.

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Here, coarseFused_img is the fused low frequency coefficients obtained by applying equation (3.3) on input images low frequency sub-bands coefficients. In the proposed algorithm average information and entropy value based information are combined to get higher information from the low frequency parts, because entropy performs lossless fusion for input images.

B. High Frequency Fusion Rule

Fusion rule for high frequency sub-groups, $fine\_A_j$ and $fine\_B_j$ is described as follows. In this rule, coefficients are selected based on comparison of entropy values of high frequency sub-bands.In this rule, coefficients are selected based on comparison of entropy values of high frequency sub-bands.

1) Calculate entropy of fine scale coefficients of source images A_image and B_image. Let $en\_A_{j,w}$ be the entropy of high recurrence coefficients of A_image and $en\_B_{j,w}$ entropy of B_image at level j and wedge w.
2) Compute weighted factor values namely K_1 and K_2 using the following proposed formula.

$$K_1 = en\_A_{j,w}^2/(en\_A_{j,w} + en\_B_{j,w}) \ldots \quad (3.4)$$

$$K_2 = en\_B_{j,w}^2/(en\_A_{j,w} + en\_B_{j,w}) \ldots \quad (3.5)$$

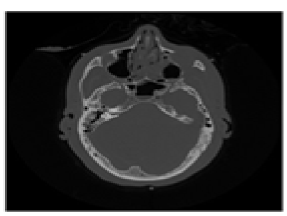
3) Compare the computed weighted factors and apply following proposed formula.

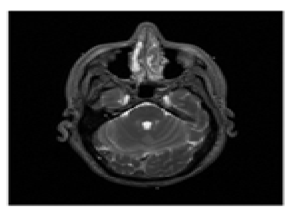
$$fused\_coff_{j,w} = \begin{cases} K_1 * en_{A_{j,w}} + K_2 * en_{B_{j,w}} & if \ en\_A_{j,w} < en\_B_{j,w} \\ K_1 * en\_B_{j,w} + K_2 * en\_A_{j,w} & if \ en\_A_{j,w} >= en\_B_{j,w} \end{cases} \quad (3.6)$$

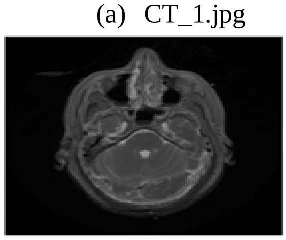
Here, $fused\_coff_{j,w}$ represents fused high frequency coefficients of images A_image and B_image at scale j and wedge w. In the last step, inverse curvelet transform is applied on combined low frequency coefficients coarseFused_img and high frequency coefficients $fused\_coff_{j,w}$ to construct output combined image.

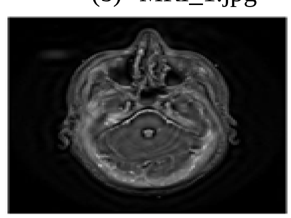
IV. EXPERIMENTAL RESULTS AND ANALYSIS

To evaluate the performance of the proposed fusion algorithm some experiments are performed on 5 datasets of gray scale medical images. The extent of source images [13],[14] is 256×256. The experiments are carried out using MATLAB software. The image fusion algorithm discussed in this paper is compared with other two fusion algorithms namely lifting waveletmethod andcurvelet transform method given by Xue-jun and Ying [15] and [16] respectively.


(a) CT_1.jpg


(b) MRI_1.jpg


(c) LWT method


(d) Curvelet method

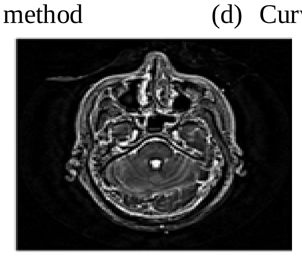

(e) Proposed method

Figure 4.Comparison of various image fusion methods with proposed method for “CT_1.jpg” and “MRI_1.jpg”

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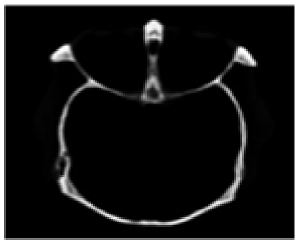
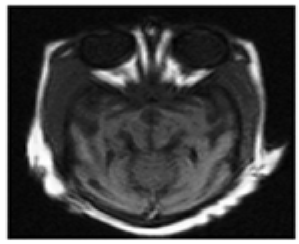
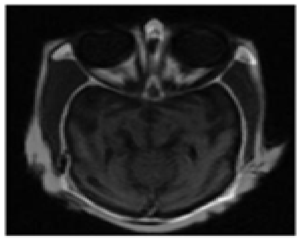


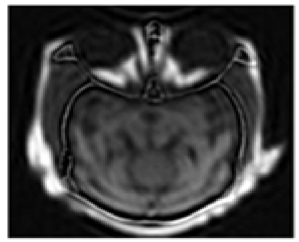
(a) CT_2.jpg



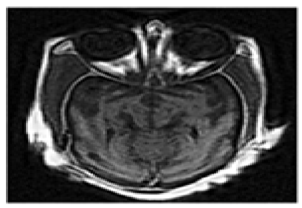
(b) MRI_2.jpg



(c) LWT method



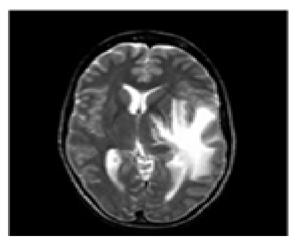
(d) Curvelet method



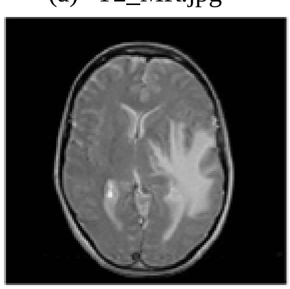
(e) Proposed method

Figure 5 :Comparison of various image fusion methods with proposed method for “CT_2.jpg” and “MRI_2.jpg”

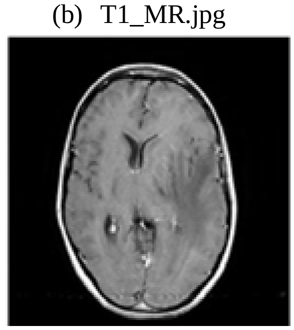
(a) T2_MR.jpg



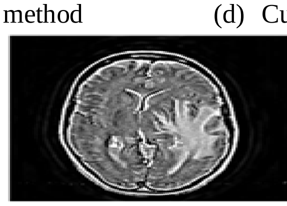
(b) T1_MR.jpg



(c) LWT method



(d) Curvelet method



(e) Proposed method

Figure 6: Comparison of various image fusion methods with proposed method for “T2_MR.jpg” and “T1_MR.jpg”

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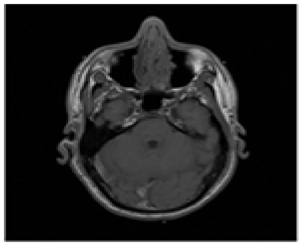
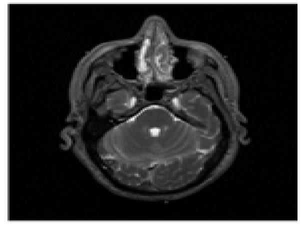
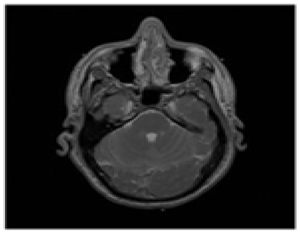
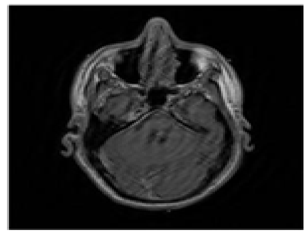
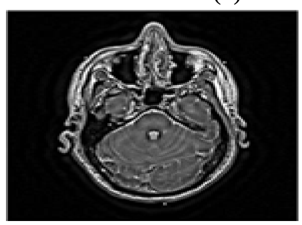



(a) T1_MRI.jpg (b) T2_MRI.jpg

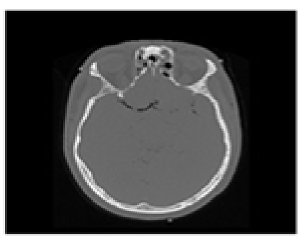
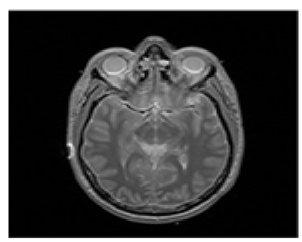



(c) LWT method (d) Curvelet method

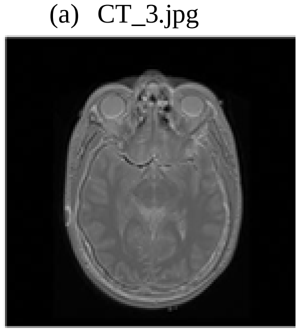
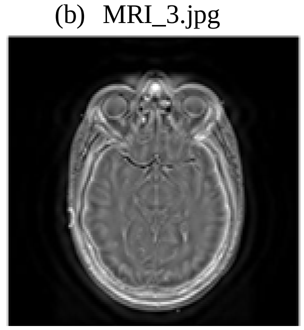


(e) Proposed method

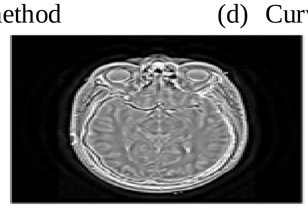
Figure 7: Comparison of various image fusion methods with proposed method for "T1_MRI.jpg" and "T2_MRI.jpg"

(a) CT_3.jpg (b) MRI_3.jpg

(c) LWT method (d) Curvelet method



(e) Proposed method

Figure 8: Comparison of various image fusion methods with proposed method for "CT_3.jpg" and "MRI_3.jpg"

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Three quantitative metrics such as mean, entropy and standard deviation are used to compare the performance of the proposed algorithm with other fusion methods [17].

A. *Mean*

Mean value of an image gives information about its average intensity. The higher mean value means high information in the image. If X is an image its mean value $\bar{x}$ can be calculated as given below:

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i = \frac{x_1+x_2.....+x_N}{N} \ldots (4.1)$$

B. *Entropy*

It represents the the quantity of datapresent within the image. Higher entropy value indicates more information present in the image. Here, p refers to probability of pixel x_i .

$$E = -\sum_{i=1}^{N} p(x_i) log_2 p(x_i) \ldots (4.2)$$

C. *Standard Deviation*

Standard deviation gives information about the contrast of an image. Higher standard deviation value means an image has higher contrast and low value means lower contrast. The standard deviation of an image can be calculated as below:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2} \ldots (4.3)$$

Here, $\bar{x}$ refers to mean value of the image. These quantative metric's values for fused images are tabulated in the following three tables:

Table 1.Results of quantitative metrics for "CT_1.jpg" and "MRI_1.jpg"

Method Name	Entropy	Mean	Standard Deviation
Lifting wavelet method	4.9569	26.2060	33.3700
Curvelet transform method	5.4750	28.2733	36.9876
Proposed method	5.7622	37.0333	52.1199

Table 2.Results of quantitative metrics "CT_2.jpg" and "MRI_2.jpg"

Method Name	Entropy	Mean	Standard Deviation
Lifting wavelet method	6.0214	31.4080	33.7114
Curvelet transform method	6.9462	52.9400	54.3658
Proposed method	7.0421	55.8295	60.3879

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Table 3.Results of quantitative metrics for “T2_MR.jpg” and “T1_MR.jpg”

Method Name	Entropy	Mean	Standard Deviation
Lifting wavelet method	4.4471	50.7405	60.9075
Curvelet transform method	4.4230	57.0442	68.5591
Proposed method	5.2966	66.2510	83.7022

Table 4. Results of quantitative metrics for “T1_MRI.jpg” and “T2_MRI.jpg”

Method Name	Entropy	Mean	Standard Deviation
Lifting wavelet method	4.4201	24.7771	35.0382
Curvelet transform method	4.6872	25.3439	37.0058
Proposed method	5.2657	35.6202	56.5681

Table 5.Results of Quantitative metrics for “CT_3.jpg” and “MRI_3.jpg”

Method Name	Entropy	Mean	Standard Deviation
Lifting wavelet method	4.8775	43.3703	51.7746
Curvelet transform method	5.4292	47.5410	57.8258
Proposed method	5.6925	61.0413	75.8912

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By observing the values of quantitative metrics from Table 1-5, it is clear that the proposed fusion method is better than other methods. According to quantitative metric's results obtained, the proposed fusion method has higher entropy, mean, standard deviation values These values indicate that the proposed fusion method provides superior fusion results.

V. CONCLUSION AND FUTURE SCOPE

In this paper, a new image fusion method for medical imagesbased on curvelet transform using wrapping method has been proposed. Experiments were done with five different datasets. Performance evaluation of fusion results were done with three quantitative metrics. Based on quantitative and visual analysis, the proposed fusion method is found superior than other fusion methods such as lifting wavelet transform and curvelettransform method. This method is helpful for preserving average and detail information such as edges, corners etc in better way.

Medical image fusion is in experimental research stage and its applications are not widespread. However, later on, image fusion will have more extensive utility in the discipline of medical image processing. The proposed algorithm is used to fuse Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) images. However, it can be enhanced to fuse color images such as Positron Emission Tomography (PET), Single Photon Emission Tomography (SPECT) etc. Using, the proposed fusion algorithm only two images are fused. The algorithm can be extended to fuse more than two images.

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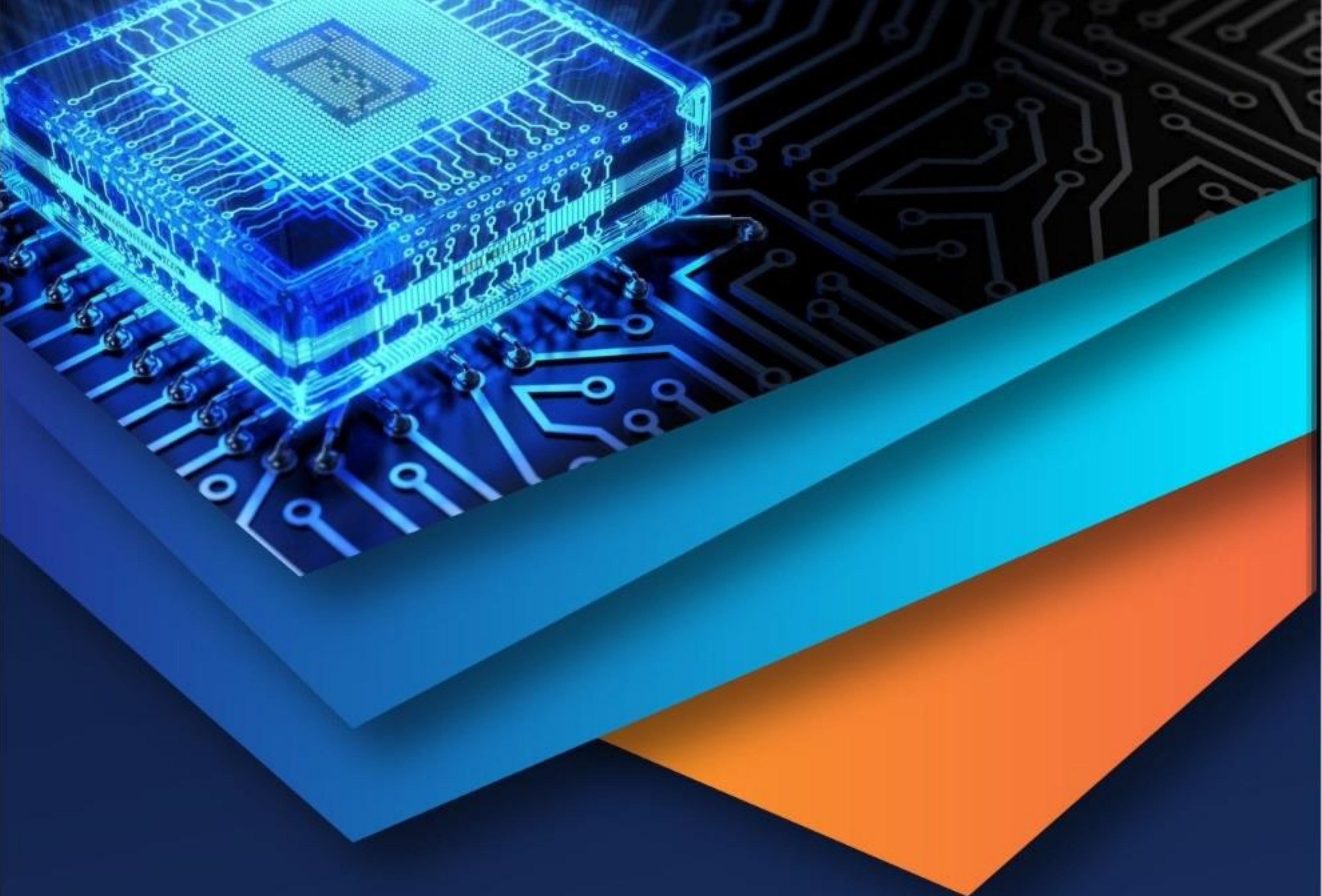

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