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Earlier Detection of Glaucoma using Empirical Wavelet Transform

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Abstract: Glaucoma is an ocular disorder caused due to increased fluid pressure in the optic nerve. It damages the optic nerve subsequently causes loss of vision. The available scanning methods are Heidelberg Retinal Tomography (HRT), Scanning Laser Polarimetry (SLP) and Optical Coherence Tomography (OCT). These methods are expensive and require experienced clinicians to use them. So, there is a need to diagnose glaucoma accurately with low cost. Hence, in this project, present a new methodology for an automated diagnosis of glaucoma using digital fundus images based on Empirical Wavelet Transform (EWT). The EWT is used to decompose the image and correntropy features are obtained from decomposed EWT components. These extracted features are ranked based on t value feature selection algorithm. Then, these features are used for the classification of normal and glaucoma images using Least Squares Support Vector Machine (LS-SVM) classifier. The LS-SVM is employed for classification with Radial Basis Function (RBF), Morlet wavelet and Mexican-hat wavelet kernels. The classification accuracy of proposed method is 95% using three-fold cross validation.
Keywords: Glaucoma, Empirical Wavelet Transform, correntropy

I. INTRODUCTION

Glaucoma is an eye disease in which the optic nerve damages by the elevation in the intraocular pressure inside the eye caused by a build-up of excess fluid. This pressure can impair vision by causing irreversible damage to the optic nerve and to the retina. It can lead to the blindness if it is not detected and treated in proper time. Glaucoma result in peripheral vision loss, and is an especially dangerous eye condition because it frequently progresses without obvious symptoms. This is why it is often referred to as "The Silent Thief of Sight." There is no cure of glaucoma yet, although it can be treated. The damage to the optic nerve from glaucoma cannot be reversed. However, lowering the pressure in the eye can prevent further damage to the optic nerve and further peripheral vision loss.

In order to overcome these difficulties, automated diagnosis methods are preferred for glaucoma diagnosis. Selections of robust features are necessary to develop a robust system. Recent studies have shown that texture features are very effective for glaucoma image detection. Higher Order Spectra (HOS) coupled with texture features are used to improve the classification accuracy. In, Discrete Wavelet Transform (DWT) energies are used as features for glaucoma detection. The HOS bi-spectrum features and wavelet energy features are used for glaucoma diagnosis in eye. The DWT has a set of fixed basis functions that are signal independent. The working principle of EWT depends upon frequency spectrum of the signal. In this work, we are proposing a novel method for the classification of glaucoma images based on EWT and correntropy features. EWT decomposes the image into various frequency bands. Correntropy is extracted from the decomposed EWT components. The features are normalized and ranked on the basis of significant criteria. Least Squares Support Vector Machine (LS-SVM) classifier with various kernels such as Radial Basis Function (RBF) and wavelet kernels such as Morlet and Mexican-hat are used for the classification. Three-fold and ten-fold cross validation strategies are used to develop the automated glaucoma diagnosis system.

We have used two-dimensional (2D) EWT with Littlewood-Paley as a empirical wavelet. The EWT decomposes the signal into components of different frequency bands. The normal and glaucoma image samples are decomposed into number of components.The R, G, B components and gray scale of fundus images are subjected to 2D EWT. The R, G, B components of image consist of significant details in the form of variation of gray pixel intensities. The information present in R, G, B components are used to extract features for automated diagnosis of glaucoma.

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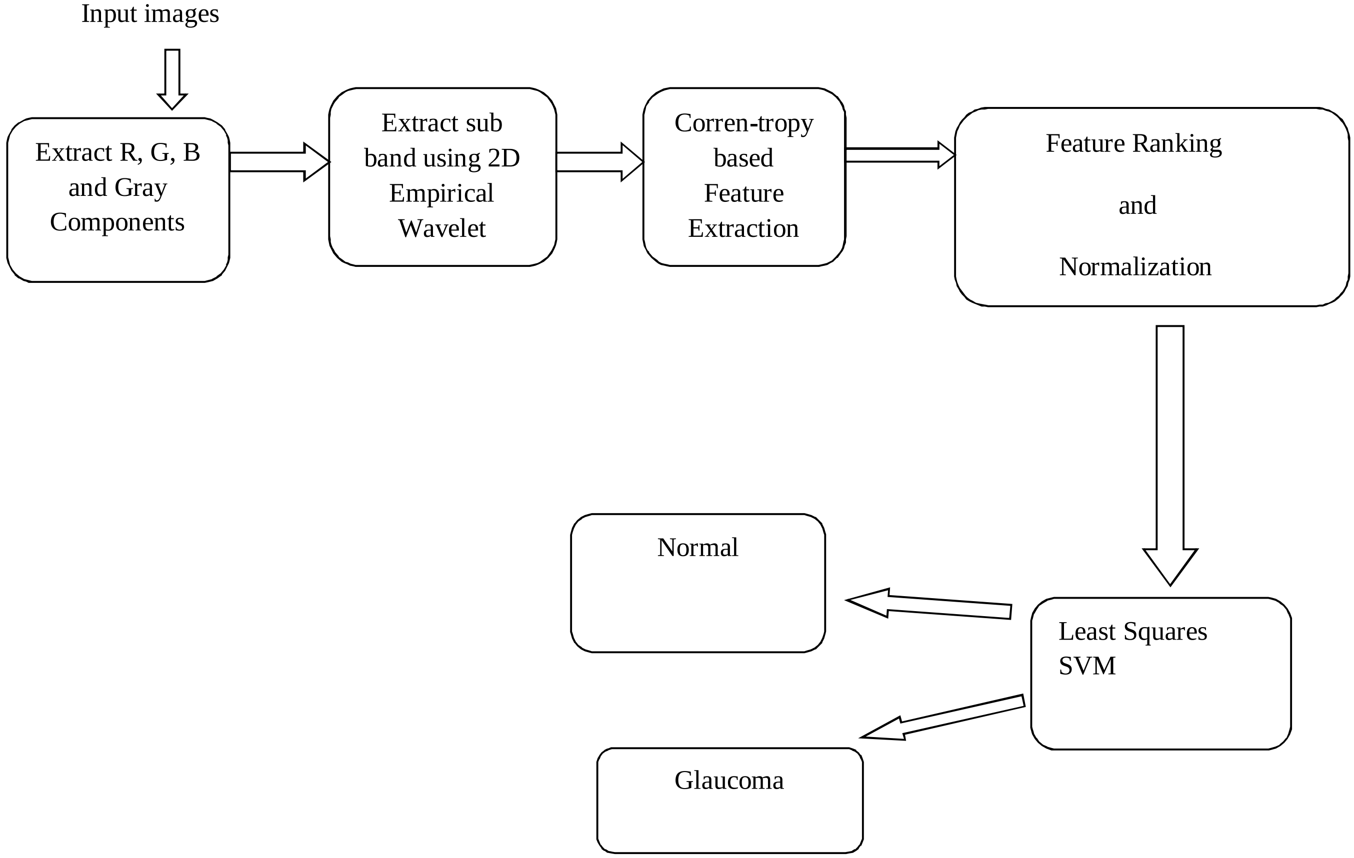
A. Block Diagram



II. EMPERICAL WAVELET TRANSFORM

The Empirical Wavelet Transform (EWT) aims to decompose a signal or an image on wavelet tight frames which are built adaptively. In 1D, the procedure consists in detecting the supports of some "modes" in the Fourier spectrum and then using these supports to build Littlewood-Paley type wavelets. In 2D, based on the same principle, we propose empirical versions of the tensor wavelet transform, a 2D Littlewood-Paley transform, the Ridgelet transform and the Curvelet transform. The advantage of this empirical approach is to keep together some information that otherwise would be split in the case of dyadic filters. The provided Matlab toolbox performs all these transforms.

In this project, the EWT method is used forsignal decomposition. In signal analysis, EWT is signal dependent method and does not use pre-defined basis functions like in Fourier and wavelet transform. EWT is an adaptive method of signal decomposition based on the information content of the signal. In EWT, the Fourier spectrum in the range 0 to is segmented into M number of parts. Each segment limit is denoted by l_m, whereas the starting limit is l_0 = 0 and the ending limit is l_M =1. The transition phase T_m is centered around l_m has width of $2\%_m$ where $\%_m = l_m$ for 0 < < 1.

A. Feature Extraction

Nonlinearity tests play an important role in system analysis and modeling because of complexity involved in analysis and modeling. The correntropy has been used as feature in the proposed methodology. We have extracted correntropy from the decomposed components of 2D EWT. The correntropy is discussed as follows.

B. Correntropy

Correntropy is a non-linear kernel based mea-sure of similarity which preserves both statistical and temporal information. It measures correlation in nonlinear domain of multiple delayed samples of the signal. The correntropy based nonlinear features can be used to measure the distribution of texture in the decomposed image components. It has been applied to diagnose of Coronary

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Artery Disease (CAD).

C. Feature Selection

Feature selection plays an important role in performance evaluation. Highly discriminatory features are selected using Student's t-test algorithm for further analysis. The t-test discriminates two classes on the basis of population mean. The t-test assumes the normal distribution of feature sets corresponding to different classes. Features are ranked based on the t value. Features with higher t value are more discriminatory and are chosen for performance evaluation process. We have obtained four EWT components from each image and computed three correntropy features from each single decomposed component. Hence, twelve entropy features are computed from each image. All these features are further processed using Student's t-test process. The processed features are arranged according to decreasing t values and six features have been selected on the basis of arranged t values. Tables I-IV depict the distribution of all six significant normalized features and t values of Red (R), Green (G) and Blue (B) channels and grayscale of images respectively. CE_{xy} denotes y^{th} correntropy feature of x^{th} decomposed EWT component. These features are then chosen for further analysis.

D. Feature Standardation

In this process, the features are standardized with zero mean and unit standard deviation. The process is known as z-score normalization. The normalization is done by subtracting mean from the data and dividing the resultant with standard deviation. The normalized data have zero mean and unit deviation.
The ranked features are classified using the Least Squares Support Vector Machine (LS-SVM) classifier with kernels such as Radial Basis Function (RBF), Morlet wavelet and Mexican-hat wavelet. LS-SVM is a supervised machine learning algorithm used to discriminate two or more classes using linear or non-linear hyper planes. It has been used in different biomedical applications such as diabetes diagnosis using heart rate signals, cardiac disease using heart sound signals, CAD, seizure detection using Electroencephalogram (EEG), and glaucoma diagnosis using fundus images.

III. LS SVM CLASSIFIER

The ranked features are classified using the Least Squares Support Vector Machine (LS-SVM) classifier with kernels such as Radial Basis Function (RBF) Morlet wavelet and Mexican-hat wavelet LS-SVM is a supervised machine learning algorithm used to discriminate two or more classes using linear or non-linear hyperplanes. It has been used in different biomedical applications such as diabetes diagnosis using heart rate signals cardiac disease using heart sound signals CAD, seizure detection using Electroencephalogram (EEG) and glaucoma diagnosis using fundus images.

A. Results

We have extracted 12 entropy values features from R,G, and channel and Grayscale fundus image. Significant features for private database as shown in table with their corresponding t value. The t-test discriminates whether the mean value of the classes is significantly different. The classifier kernel parameters σ1,σ2 and σ3 values are varied from 0.1 to 1with step size of 0.1 and w_0 is set to 0.3 for Morlet wavelet kernel by trial and error method. We have chosen the value of σ1,σ2 and σ3 which yielded maximum accuracy. The plot of accuracy verses σ1,σ2 and σ3 kernel parameters for three-fold and ten-fold cross validation strategies for private database.
We have obtained maximum classification accuracy of 98.33% using RBF and morelet wavelet kernel for three folds cross validation. We have also obtained maximum accuracy of 96.67% using RBF mexician-hat wavelet kernels with tenfold cross validation.
In our proposed methodology, EWT based correntropy features are extracted from the decomposed components. Correntropy is a non-linear kernelized similarity measure. This feature effectively captured the subtle variations in the pixels and yielded high classification accuracy.
Glaucoma is characterized by regular damage of Retinal Nerve Fibre (RNF). Fractal and power spectral features are used to analyse RNF. Support Vector Machine (SVM) clas-sifier yielded a classification accuracy of 74%. Various morphological features are obtained from the fundus images and fed to the Artificial Neural Network (ANN). Their method reported sensitivity and specificity of 100% and 80%, respectively. Normal eye Glaucoma eye

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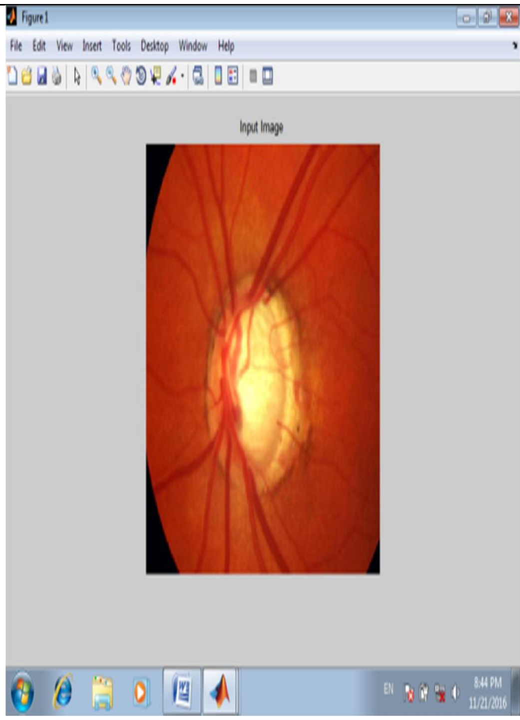

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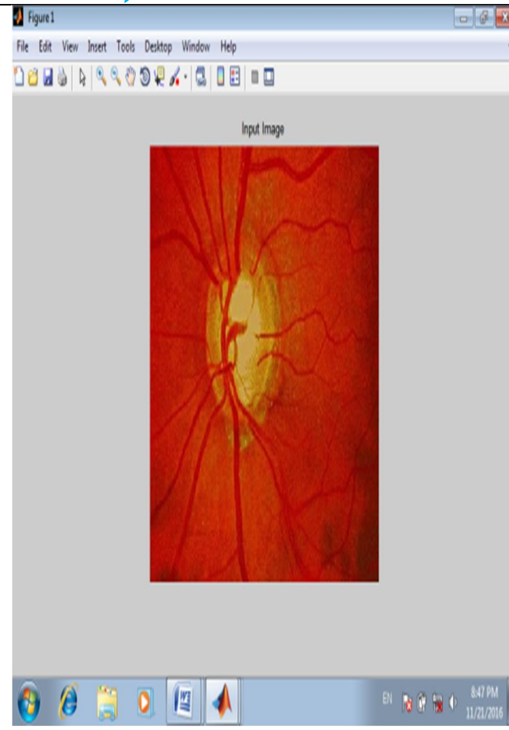

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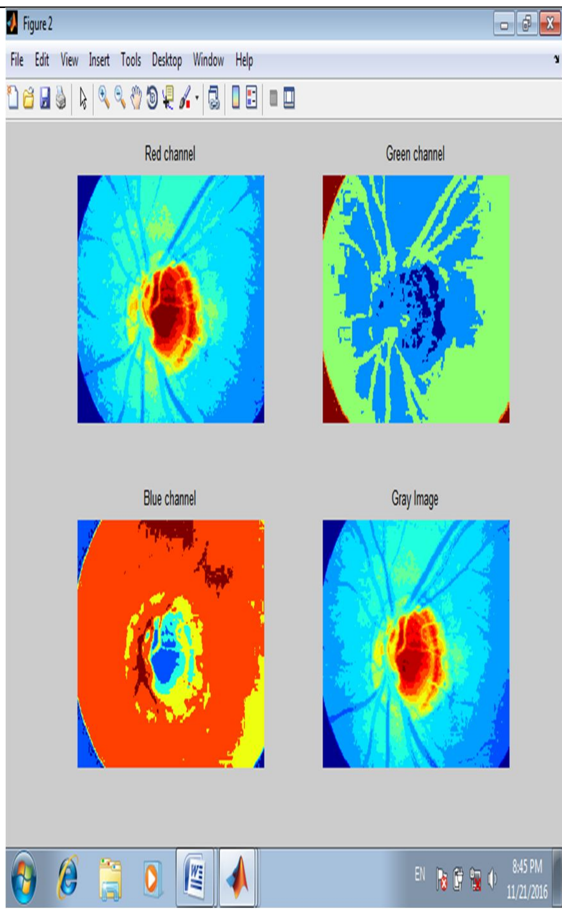
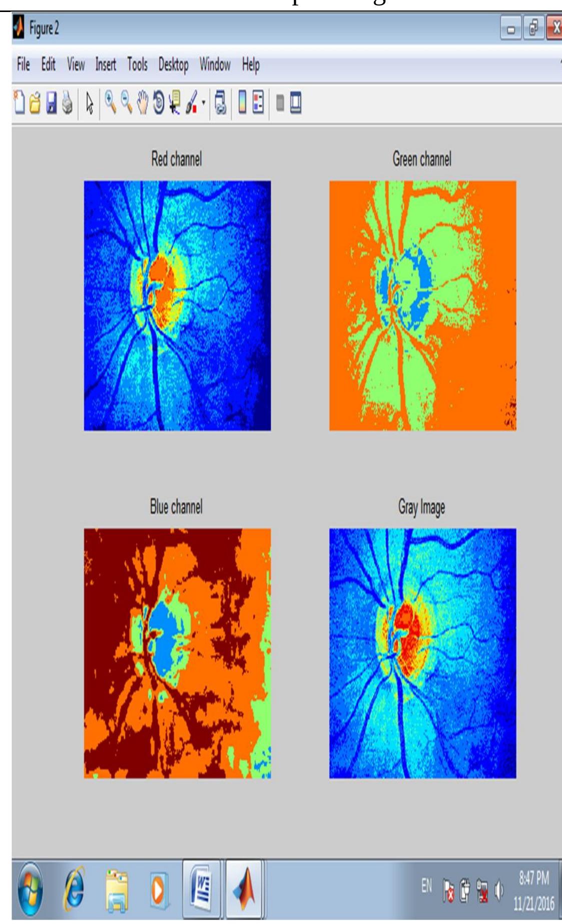
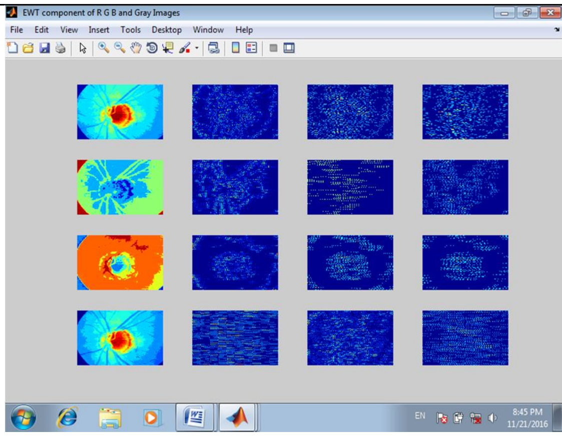


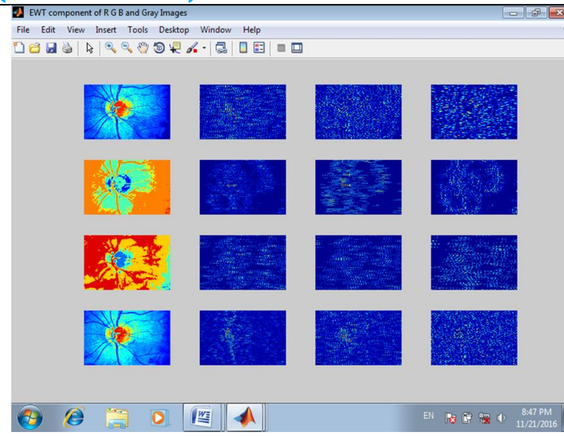
R,G,B, Gray channel images



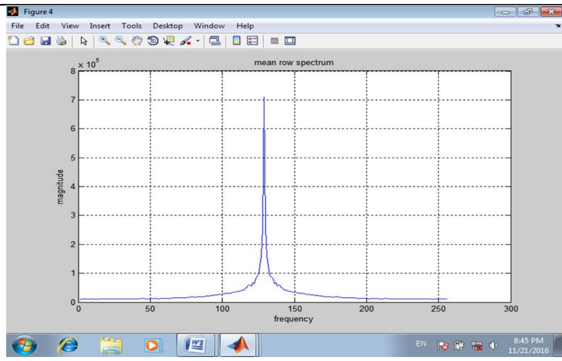
R,G,B, Gray channel images



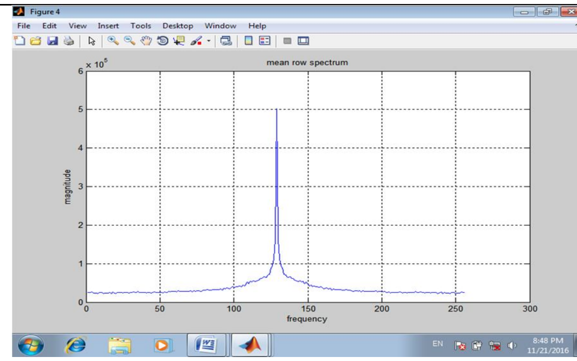
EWT component of R,G,B,Gray images



EWT component of R,G,B,Gray images



Mean spectrum filter bank



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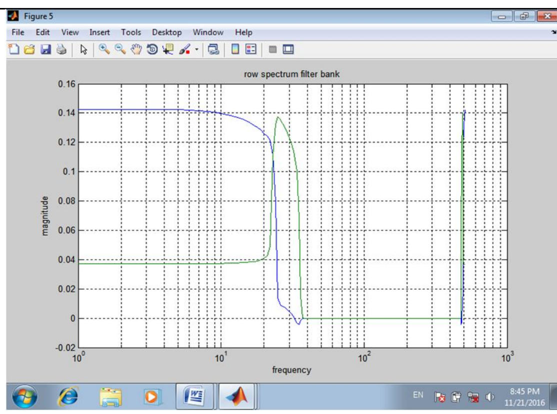
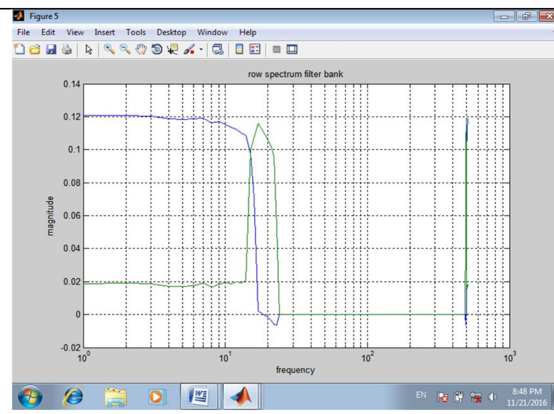


Row spectrum filter bank



Row spectrum filter bank

IV. CONCLUSION

In this paper, we have developed an automated diagnosis of glaucoma system. The EWT based correntropy features are extracted from fundus images. Features with high t value are used for classification. We have used different kernels for classification and found that RBF and Morlet wavelet kernels yielded the highest accuracies. It can be concluded that the empirical wavelet based entropy features are useful for glaucoma diagnosis. Proper selection of kernel functions and its parameters can improve classification accuracy. We have also observed that, the green channel of colour image yielded the highest accuracy as compared to other channels.

The proposed methodology need to tested for huge database and also can be extended to diagnose glaucoma at an early stage. In the proposed method, the correntropy features are computed based on the texture of decomposed components of different frequency bands. The same idea can be extended to diagnosis of other diseases like diabetes retinopathy, fatty liver disease, thyroid cancer and ovarian cancer etc.

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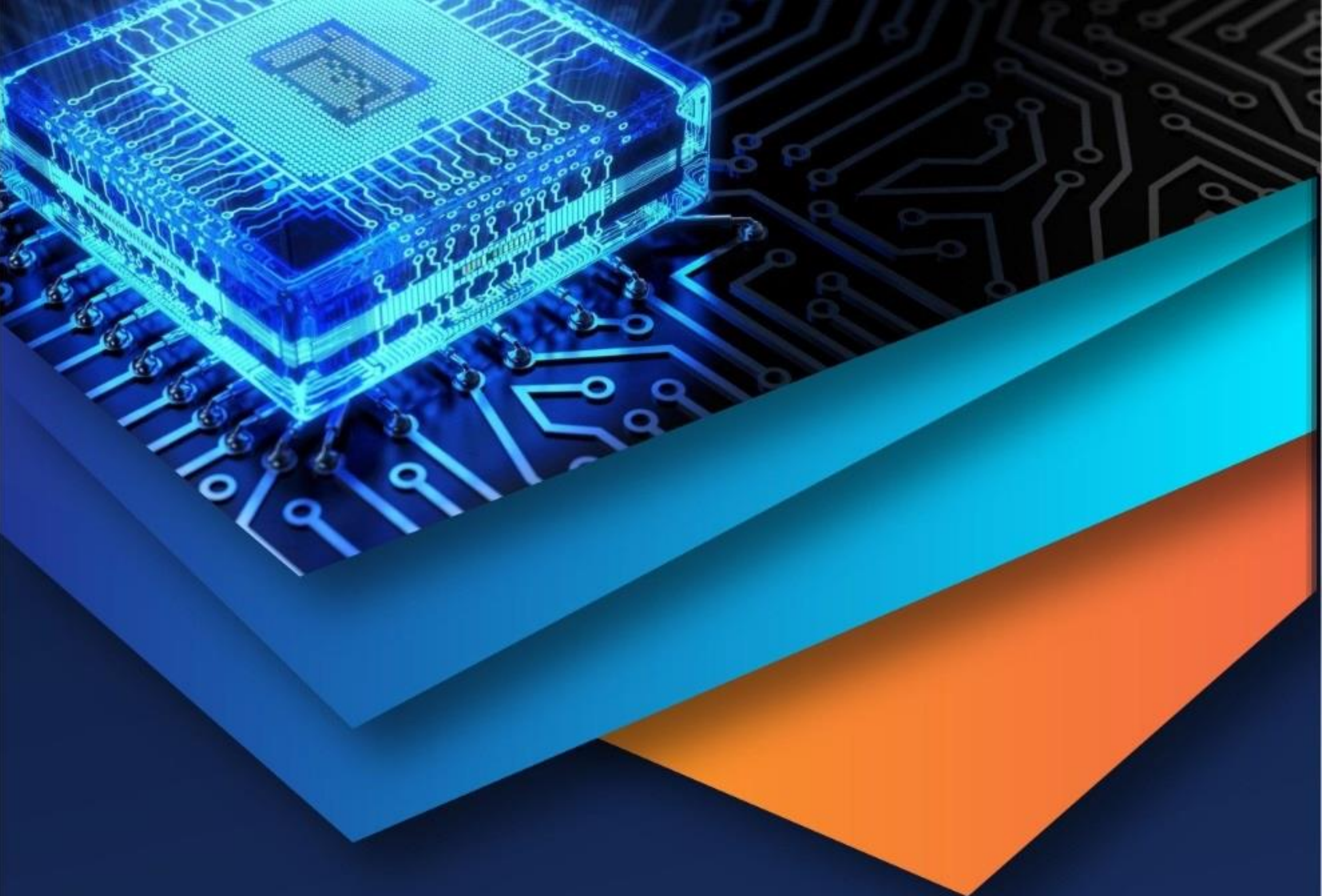

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