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Retinal Vessel Analysis for Detection of Glaucoma

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Abstract: Glaucoma, a disease of the optic nerve is caused by the increase in the intraocular pressure of the eye and results in damage to the optic nerve and vision loss. The main characteristic of glaucoma is an elevated intraocular pressure (IOP) and also the blood vessels get narrower. Vessel segmentation is one of the main steps in retinal automated analysis tools. Retinal vessel segmentation and delineation of morphological attributes of retinal blood vessels are utilized for diagnosis, screening, treatment, and evaluation of various cardiovascular and ophthalmologic diseases. Since, the numbers of blood vessels are more in the glaucomatous eye , glaucoma is detected by means of ISNT ratio. The image processing operations are performed on glaucomatous and normal eyes. We have chosen ten images of each from the database and ISNT ratio is calculated to get the area of blood vessels in each of the four quadrants of the eye and hence glaucoma is detected.
Keywords: Blood vessel segmentation, glaucoma, intraocular pressure, ISNT ratio, morphological attributes.

I. INTRODUCTION

Vessel segmentation is one of the main steps in retinal automated analysis tools. Retinal vessel segmentation and delineation of morphological attributes of retinal blood vessels are utilized for diagnosis, screening, treatment, and evaluation of various cardiovascular and ophthalmologic diseases and this task becomes difficult due to the presence of bright and dark lesions in fundus images. Among eye diseases, glaucoma is considered as the second leading case that can result in neurodegeneration illness. It is necessary to detect glaucoma at an early stage due to following facts: i) There are no perceptible indications in its preliminary stages. ii) It is a severe disorder as the damage it causes is irremediable. iii) It leads to perpetual loss of sight if not cured promptly. iv) There is no prophylactic treatment for glaucoma, but it is possible to avoid blindness by detecting, treating and managing glaucoma at an initial stage. The blood vessels in the fundus image should be segmented and analyzed to get an idea of the disease affecting the eye like glaucoma and diabetic retinopathy. Reliable glaucoma detection in digital fundus images is still an open issue in biomedical image processing. Currently, there is no effective method for detection of glaucoma. The existing ways of detecting glaucoma like , detection of glaucoma through Optical Coherence Tomography (OCT) and Heidelberg Retinal Tomography (HRT) are very expensive. Approaches based on OCT are commonly employed for the diagnosis and monitoring of glaucoma. OCT based techniques are applied by many researchers using different classifiers and despite the development and the advantage of OCT most of the clinics and physicians are not taking proper benefit of this powerful and efficient tool. The OCT scans of optic discs are widely taken and the scan of the parts that contain macula are usually missed due to which vital parts to be examined are missed. Manual analysis of ophthalmic images is fairly time-consuming and accuracy depends on the expertise of the professionals. Hence, automatic analysis of retinal images is an important tool and automation aids in the detection, diagnosis, and prevention of risks associated with the disease. The proposed method involves blood vessel segmentation and calculation of ISNT ration for the detection of glaucoma. We have made use of retinal fundus images of glaucomatous and normal eyes. The area of blood vessels is calculated in all four quadrants (temporal, inferior, nasal and superior) after the segmentation of blood vessels . A mask is generated for one quadrant and is rotated by 90 degrees to obtain masks for all four quadrants respectively. The blood vessels in each quadrant is obtained by masking the segmented image. Then the area of blood vessels in each quadrant is calculated. The ISNT rule is such that the area of the blood vessels in the segments follows - inferior > superior > nasal > temporal. The ratio of the blood vessel area covered by inferior and superior regions to the area covered by nasal and temporal regions is taken . The ratio is lower for glaucomatous eyes. From the results obtained, we can also conclude that segmented blood vessels from healthy fundus images cover more area than those from glaucomatous.

II. LITERATURE SURVEY

1) According to "*Blood Vessel Segmentation In Fundus Images And Detection Of Glaucoma*" by LekshmiShyam and Kumar G S [International Conference on Communication Systems and Networks (ComNet), 21-23 July 2016] . A method based on high pass filtering and morphological operation is introduced in the proposed method for vessel segmentation. The blood vessel segmentation in turn helps to provide a method for the detection of Glaucoma. In many of the earlier detection methods, analysis of cup to disc ratio is performed. But here the glaucoma is detected by means of ISNT ratio. The proposed method provides a means to distinguish Glaucoma from normal eyes.

2) According to "*Earlier glaucoma detection using blood vessel segmentation and classification*" by E.Deepika, Dr.S.Maheswari [Proceedings of the Second International Conference on Inventive Systems and Control (ICISC 2018)] to detect the abnormality, preprocessing methods such as filtering, green channel extraction and CLAHE are proposed and for feature extraction namely optic disc ratio, active contour and blood vessel segmentation are proposed. Extracted Features are given as the input for classification based on ANFIS and SVM. Then sensitivity, specificity and accuracy of two classifiers are compared to attest an efficient diagnosis system for screening the Glaucoma disorder.
3) According to "*Retinal Blood Vessel Segmentation by Using Matched Filtering and Fuzzy C-means Clustering with Integrated Level Set Method for Diabetic Retinopathy Assessment*" by Memari, N., Ramli, A.R., Saripan, M.I.B. [Journal of Medical and Biological Engineering (2019) 39:713–731] an automatic retinal vessel segmentation utilising fuzzy c-means clustering and level sets is proposed. Retinal images are contrast-enhanced utilising contrast limited adaptive histogram equalisation while the noise is reduced by using mathematical morphology followed by matched filtering steps that use Gabor and Frangi filters to enhance the blood vessel network prior to clustering. Proposed segmentation method was able to achieve comparable accuracy to other methods while being very close to the manual segmentation provided by the second observer in all datasets.
4) According to "*Automated Diagnosis of Glaucoma Using Digital Fundus Images*" by Jagadish Nayak, Rajendra Acharya U, P. Subbanna Bhat, Nakul Shetty, Teik-Cheng Lim [J Med Syst (2009) 33:337–346] Fuzzy sets were used to provide a method for handling the uncertainty inherently present in the process of medical diagnosis. Features like cup to disc (c/d) ratio, ratio of the distance between optic disc center and optic nerve head to diameter of the optic disc were validated by classifying the normal and glaucoma images using a neural network classifier. The system proposed can identify the presence of glaucoma to the tune of 90%. This system can be used as an adjunct tool by the physicians to cross check their diagnosis.
5) According to "*A retinal image enhancement technique for blood vessel segmentation algorithm*" by A. M. R. R. Bandara, P. W. G. R. M. P. B. Giragama [IEEE International Conference on Industrial and Information Systems (ICIIS), 2017] presents an assessment of the suitability of a recently invented contrast enhancement algorithm namely SAUCE for retinal blood vessel segmentation in fundus images. The results of both the qualitative and quantitative analysis showed the superiority of SUACE in enhancing retinal images for blood vessel segmentation, hence we can conclude that SUACE is not only suitable for this application but also outperforms all other enhancement techniques which are used in the comparison.

III. METHODOLOGY

Glaucoma is a chronic ocular disorder which can cause blindness if left undetected at an early stage and is often called "silent thief of sight" as it has no symptoms and if not detected at an early stage it may cause permanent blindness. Glaucoma progression precedes some structural changes in the retina which aid ophthalmologists to detect glaucoma at an early stage and stop its progression. Automatic analysis of retinal images is an important tool and automation aids in the detection, diagnosis, and prevention of risks associated with the disease. The images from DRIVE , STARE and HRF databases are used. The image processing operations are performed on glaucomatous and normal eyes. We have chosen ten images of each from the database. The proposed method involves blood vessel segmentation and calculation of ISNT ration for the detection of glaucoma. We have made use of retinal fundus images of glaucomatous and normal eyes. The area of blood vessels is calculated in all four quadrants (temporal, inferior, nasal and superior) after the segmentation of blood vessels . A mask is generated for one quadrant and is rotated by 90 degrees to obtain masks for all four quadrants respectively. The blood vessels in each quadrant is obtained by masking the segmented image. Then the area of blood vessels in each quadrant is calculated. The ISNT rule is such that the area of the blood vessels in the segments follows - inferior > superior > nasal > temporal. The ratio of the blood vessel area covered by inferior and superior regions to the area covered by nasal and temporal regions is taken . The ratio is lower for glaucomatous eyes. From the results obtained, we can also conclude that segmented blood vessels from healthy fundus images cover more area than those from glaucomatous.

1) *Software Implementation:* The software implementation of the proposed method is done using OpenCV. OpenCV (Open Source Computer Vision Library) is an open source computer vision and machine learning software library. OpenCV was built to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in the commercial products. Being a BSD-licensed product, OpenCV makes it easy for businesses to utilize and modify the code.The library has more than 2500 optimized algorithms, which includes a comprehensive set of both classic and state-of-the-art computer vision and machine learning algorithms.

A. Algorithm

The algorithm for the proposed method is given below :

a) Input image is selected from the database.
b) The input images are resized and the green channel is extracted.
c) The CLAHE algorithm is used for contrast enhancement on the preprocessed images.
d) The background image removal was done by subtracting the median filtered image and contrast enhanced image .
e) Image segmentation is done using global thresholding to obtain the blood vessels.
f) Mask is generated to filter one quadrant.
g) Area occupied by the blood vessels and ISNT ratio are calculated.
h) Detection of glaucoma based on ISNT ratio.

B. Flow Chart

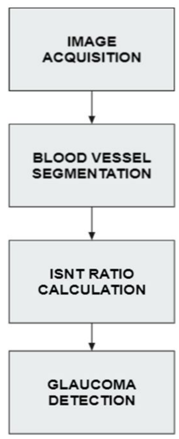

Fig.1. Block diagram of Glaucoma Detection

1) Data

a) The STARE dataset contains twenty fundus images including their ground truth images. The images are captured by a fundus camera with 35 degree FOV (field of view)
b) DRIVE dataset contains 40 images with 45◦ FOV including their ground truth image. This dataset is separated by its authors into a training set (DRIVE Train) and a test set (DRIVE Test) with 20 images in each set. The DRIVE Train set of images are annotated by one human observer.
c) HRF database which contains high resolution fundus images.The database is publically available.

2) Blood Vessel Segmentation

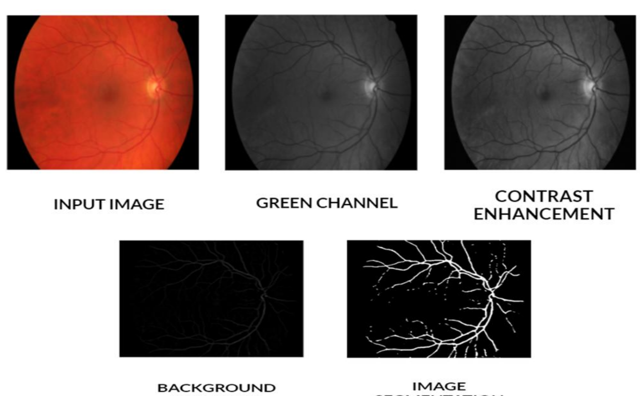

Fig. 2. Proposed method of blood vessel segmentation

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a) Image Pre-Processing: Image pre-processing is the name for operations on images at the lowest level of abstraction whose aim is an improvement of the image data that suppress undesired distortions or enhances some image features important for further processing. It does not increase image information content. The first step in image pre - processing is resizing the input images.

b) Green Channel Extraction: The Red-Green-Blue (RGB) images were converted to green-channel images. The green channel provides a higher intensity and maximum local contrast between the background and the foreground when compared to the other two channels.

c) Contrast Enhancement: A Contrast-Limited Adaptive Histogram Equalization (CLAHE) was used as it proved most efficient with small non-intersecting areas of so-called tiles on the image. Histogram equalization was applied to each such tile. Upon completion, adjacent tiles are combined using bilinear interpolation to eliminate artificially induced boundaries.

d) Background Exclusion: Background fluctuations in the luminance of the image were eliminated so the objects in the foreground would be easier to analyze. This algorithm uses median filtering with a kernel of 25 × 25. This kernel size is used to blur the image and smooth the foreground. The background image removal was done by subtracting the median filtered image (fmedian) and contrast enhanced image ($I_{contrasted}$) : $f = f_{median} - I_{contrasted}$. The median filter replaces the pixel value f (x, y) with the median of all pixels in the neighborhood, which can be described by the equation : $f_{median}(x, y) = \text{median}_{(i,j)\in Wxy} \{I_{constrasted}(i, j)\}$. Here, Wxy refers to the area around the center (x, y) in the image.

e) Image Segmentation: Image thresholding is used to provide a representation of an image in a simplest form which requires less space. This representation is called segmented image and the process is image segmentation. Thresholding is the most simple method and has the least computation cost. Global threshold is totally dependent on the histogram of the image. The histograms of images may be affected with noise, contrast, hue, saturation, shadow etc. So, the global threshold selection has been aided with the use of local properties of image.

3) ISNT Ratio Calculation

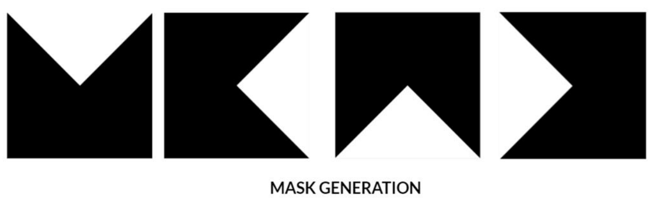

Fig. 3. Masks generated for four quadrants

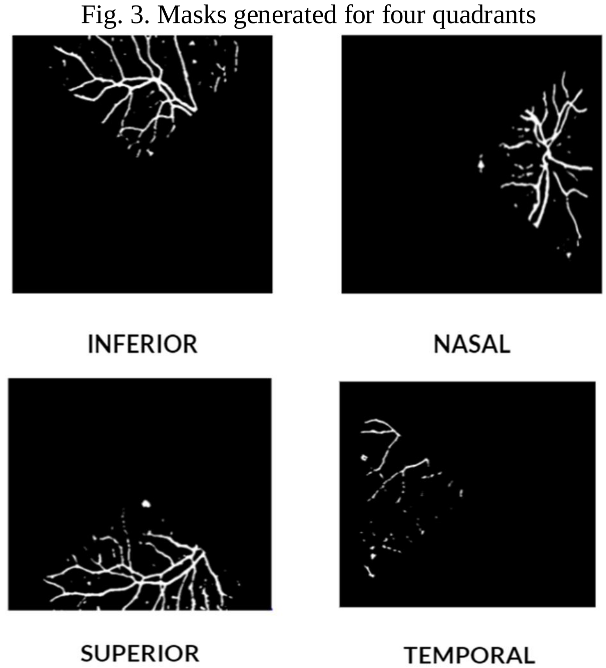

Fig. 4. Blood vessels in the four quadrants

The main characteristic of glaucoma is an elevated intraocular pressure (IOP) and also the blood vessels get narrower . The proposed method involves blood vessel segmentation and calculation of ISNT ratio for the detection of glaucoma. We have made use of retinal fundus images of glaucomatous and normal eyes. The area of blood vessels is calculated in all four quadrants (temporal, inferior, nasal and superior) after the segmentation of blood vessels . A mask of size 512*512 is generated for one quadrant and is rotated by 90 degrees to obtain masks for all four quadrants respectively. The blood vessels in each quadrant is obtained by masking the segmented image. Then the area of blood vessels in each quadrant is calculated. The ISNT rule is such that the area of the blood vessels in the segments follows - inferior > superior > nasal > temporal. The ratio of the blood vessel area covered by inferior and superior regions to the area covered by nasal and temporal regions is taken . The ratio is lower for glaucomatous eyes. From the results obtained, we can also conclude that segmented blood vessels from healthy fundus images cover more area than those from glaucomatous.

The ISNT ratio is calculated by the following formula :

ISNT ratio = (area of inferior blood vessel + area of superior blood vessel)/(area of nasal blood vessel+area of temporal blood vessel)

4) *Detection of Glaucoma:* The analysis is performed on Glaucomatous and normal eyes. Ten images of each are collected from the database and ISNT ratio is calculated on each. The ISNT ratio is lower for glaucomatous eyes and high for normal persons. From the analysis performed on 10 images, it is observed that the ISNT ratio for normal eyes is 2.166 ± 0.19 and for Glaucoma eyes is 1.755± 0.08.The number of blood vessels will be higher in the nasal region for glaucomatous eyes. Therefore the blood vessels occupy more area in the nasal quadrant which makes the ISNT ratio lower for glaucomatous eyes.

IV. RESULTS AND DISCUSSION

The main characteristic of glaucoma is an elevated intraocular pressure (IOP) and also the blood vessels get narrower . The proposed method involves blood vessel segmentation and calculation of ISNT ratio for the detection of glaucoma. We have made use of retinal fundus images of glaucomatous and normal eyes. The area of blood vessels is calculated in all four quadrants (temporal, inferior, nasal and superior) after the segmentation of blood vessels . After the blood vessels are segmented, a mask of (512*512) size is generated. First a temporal mask is generated. Then it is rotated 90 degrees each to obtain the superior,nasal and inferior. The blood vessels in the temporal, inferior, nasal and superior regions are obtained by making use of the respective masks.

The ISNT ratio is calculated by the following formula :

ISNT ratio = (area of inferior blood vessel + area of superior blood vessel) / (area of nasal blood vessel + area of temporal blood vessel)

Table I. . ISNT Ratios of Glaucoma Affected People Calculated on ten Images

IMAGE NUMBER (GLAUCOMATOUS)	ISNT RATIO
1	1.84
2	1.80
3	1.75
4	1.79
5	1.64
6	1.67
7	1.77
8	1.78
9	1.76
10	1.71

Table II. ISNT ratios of Normal Persons
Calculated on ten Images

IMAGE NUMBER (HEALTHY)	ISNT RATIO
1	2.0
2	1.96
3	1.94
4	1.92
5	2.03
6	2.08
7	2.1
8	2.0
9	1.98
10	1.97

The analysis is performed on Glaucomatous and normal eyes. Ten images of each are collected from the database and ISNT ratio is calculated on each. The ISNT ratio is lower for glaucomatous eyes and high for normal persons. From the analysis performed on 10 images, it is observed that the ISNT ratio for normal eyes is 2.166 ± 0.19 and for Glaucoma eyes is 1.755± 0.08.The number of blood vessels will be higher in the nasal region for glaucomatous eyes. Therefore the blood vessels occupy more area in the nasal quadrant which makes the ISNT ratio lower for glaucomatous eyes.

V. CONCLUSION

Glaucoma is a chronic ocular disorder which can cause blindness if left undetected at an early stage and is often called "silent thief of sight" as it has no symptoms and if not detected at an early stage it may cause permanent blindness. Glaucoma progression precedes some structural changes in the retina which aid ophthalmologists to detect glaucoma at an early stage and stop its progression. Automatic analysis of retinal images is an important tool and automation aids in the detection, diagnosis, and prevention of risks associated with the disease.The retinal images used for the proposed method are collected from STARE, DRIVE and HRF databases. The main characteristic of glaucoma is an elevated intraocular pressure (IOP) and also the blood vessels get narrower . The proposed method involves blood vessel segmentation and calculation of ISNT ratio for the detection of glaucoma. We have made use of retinal fundus images of glaucomatous and normal eyes. The area of blood vessels is calculated in all four quadrants (temporal, inferior, nasal and superior) after the segmentation of blood vessels . The analysis of the results show that the ratio will be in the range 2.166 ± 0.19 for normal persons and 1.755 ± 0.08 for Glaucoma affected patients. The proposed method provides a means to distinguish Glaucoma from normal eyes.

VI. SCOPE AND FUTURE WORK

Medical imaging systems are used to create the pictorial representation of the human body to monitor various types of diseases and public health-care systems rely on these technologies. Digital image processing and computer vision techniques are used in various health-care systems to detect diseases. Glaucoma is a type of persistent eye disorder that gradually damages the optic nerve and can lead to permanent blindness. The inappropriate intraocular pressure within the human eye is reported as the main cause of this disease and glaucoma is declared as the second leading cause to the loss of sight. The use of image analysis can assist the clinicians to execute the work more effectively. Future scope of this project is to detect eye diseases from affected images thus making mankind beneficial to a large extent, so that by diagnosing diseases prevent loss of vision power or blindness. We can further work on improving the processing speed, efficiency, accuracy and performance of the system and include optimal methods or combining of some techniques.

VII. ACKNOWLEDGEMENT

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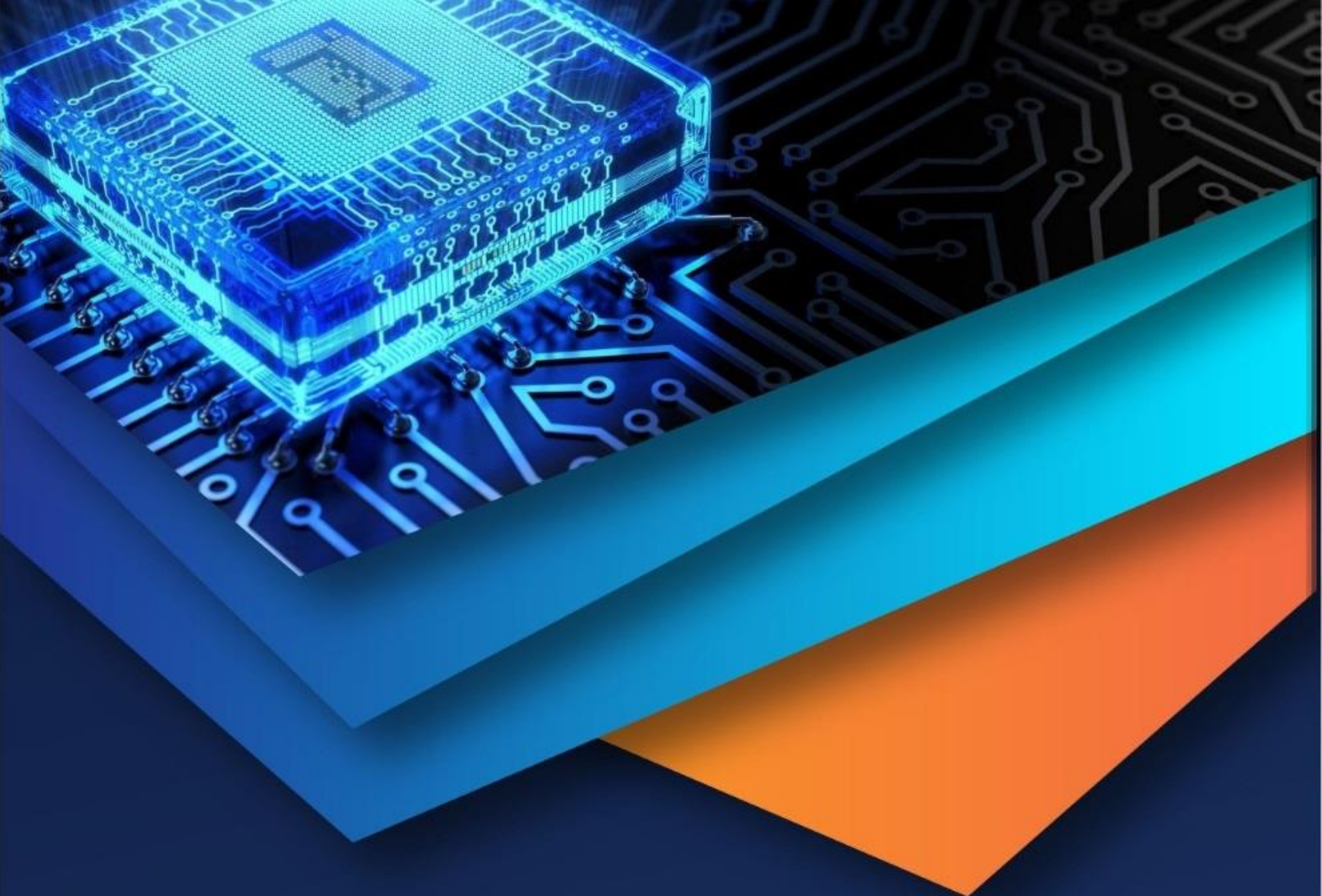

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