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Thresholding Technique for Color Image Segmentation

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Abstract - Image processing is a form of signal processing that manipulates an image by means of a processor. Computer vision is a high level image processing that includes methods for acquiring, processing, analyzing, understanding images and high dimensional data from the real world in order to produce numerical or symbolic information. Image segmentation is one of the basic problems of the image processing and computer vision. The image is divided into a number of sets that do not mutual overlapping zones. These zones either have meaning to explain correspondence between them and the actual object or some parts of object. One of the properties of an image is color. This proposed system works on a color image segmentation method based on color space Otsu Method. In an image, one needs to isolate the objects in it and have to find relation among them. The color supposed by human is a combination of three colors such as Red, Green and Blue forms a color space. In the color image segmentation color images applying through the recursive Otsu's method to segment the small size object and to remove the large amount of noise. The resultant image is passing through median filter for the effective result. Still the selection of the threshold value is maximum and to minimize the selection time of the image, in the pre processing step the image passes through neural network, Fuzzy logic and Ant Colony Optimization (ACO) for optimizing the threshold values and processed through the Otsu thresholding method for the better segmentation.
Keywords — Color Image Segmentation, Median Filter, Otsu Method, Thresholding.

I. INTRODUCTION

One of the most important problems in color image analysis is that of segmentation. The fundamental idea in color image segmentation is to consider color uniformity as a relevant criterion to partition an image into significant regions. People are only interested in certain parts of the image. These parts are frequently referred as foreground or target and other is called background. Image segmentation is a technique and process which divide the image into different feature of region and extract out the interested target. It divides an image into a number of discrete regions such that the pixels have high similarity in each region and high contrast between regions. Properties like intensity, texture, depth, gray-level, color help to recognize similar regions, such properties are used to form groups of regions having a similar meaning. Segmentation is a valuable tool in many fields including health care, industry, remote sensing, image processing, content based image, pattern recognition, traffic image, video and computer vision. A particular type of image segmentation method can be found in application involving the recognition, measurement of objects and detecting objects in an image. Many researches have focused on gray-level image segmentation, whereas the color images carry most of the information. Segmentation techniques can be classified into the following categories: Edge-based, Cluster-based, Threshold based, Neural Network based, Region-based and Hybrid. Image segmentation based on thresholding is one of the oldest and powerful technique, since the threshold value divides the pixels in such a way that pixels having intensity value less than threshold belongs to one class while pixels whose intensity value is greater than threshold belongs to another class. Segmentation based on edge detection attempts to resolve image by detecting the edges between different regions that have sudden change in intensity value are extracted and linked to form closed region boundaries. Region based methods, divides an image into different regions that are similar according to a set of some predefined conditions. The Neural Network based image segmentation techniques reported in the literature can mainly be classified into two categories: supervised and unsupervised methods. Supervised methods require expert human input for segmentation. Usually this means that human experts are carefully selecting the training data that is then used to segment the images. Unsupervised methods are semi or fully automatic. User intervention might be necessary at some point in the process to improve performance of the methods, but the results should be more or less human independent. An unsupervised segmentation method automatically partitions the images without operator intervention.

II. RELATED WORKS

The segmentation is used to separate the image in parts that represents an interest object. There are several methods in that intend to perform such task that can adapt to different types of images that are very complex and specific. The goal of segmentation is to simplify and change the representation of an image into something that is easier to analyze and more meaningful. In the computer vision field to understanding images the information extracted from them can be used for other tasks for example identification of an airport from remote sensing data detection of cancerous cells, extracting malign tissues from body scans, navigation of robots. Now there is a need of a method, to understand images and extract information or objects, image segmentation fulfill above requirements. Practical application of image segmentation range from medical applications are Treatment planning, filtering of noisy images, Locate tumors, Measure tissue volumes, Diagnosis, Computer guided surgery, study of anatomical structure, Locate objects in satellite images like forests and roads, Face Recognition and Finger print Recognition. Many segmentation methods have been proposed in this literature survey. Segmentation technique are chooses over the level of segmentation are decided by the particular type of image and characteristics of the problem being considered. Nobuyuki Otsu (1979) proposed a nonparametric and unsupervised method of automatic threshold selection for image segmentation. From the input image an optimal threshold is selected by the differentiate criterion, so as to maximize the separability of the resultant classes in gray levels. This procedure is very simple, utilizing only zeroth and first order cumulative moments of the gray level histogram. A flexible system for a complex form of thresholding to utilize multiple thresholds was introduced by Ralf Kohler (1979). The algorithm consists of two major components. First is a threshold selection component and a relaxation component. It automatically selects a threshold so as to maximize the global average contrast of edges detected by the threshold across the image. The threshold selection algorithm can be applied recursively to select additional thresholds by ignoring any edges that have already been detected by previously selected thresholds. Reddi et al (1984) introduced a semi-automatic segmentation method for a fast search scheme for finding single and multiple thresholds as a speed improvement to Otsu's scheme. The correspondence point out explicitly that their fast search procedure does not coverage to the optimal threshold if the inner class variance has not the unique maximum. This method is often influenced by the local maxima or minima of the interclass variance. Peng-Yeng Yin et al (1997) introduced an iterative scheme starts with bi-level thresholding it uses the initial results to obtain higher order thresholds, this algorithm is recursive and the convergence is determining the number of thresholds automatically as well as saving a significant amount of computation time. Liju Dong et al (2008) proposed an iterative algorithm for finding optimal thresholds that minimize a weighted sum of squared error objective function. This method is mathematically equivalent to the well known Otsu's method. The computational complexity is linear with respect to the number of thresholds to be calculated as against the exponential complexity of the Otsu's algorithm. K-Means method is compared to that of classical Otsu's method in multilevel thresholding by Dongji Liu et al (2009). This both method are based on a same criterion that minimizes within class variance. Otsu's method is an exhaustive algorithm of searching the global optimal threshold k-means is a local optimal method. K-means does not require computing a gray level histogram firstly. K-means can be more efficiently extended to multilevel thresholding method than Otsu's method. K-means method performs well with less computing time than Otsu's method does on three dimensional image thresholding. Numbers of methods are proposed for image segmentation on color and gray scale images that involves features extraction and image segmentation. The problems in image segmentation are slower processing time, long latency, and large memory storage. The Otsu's Thresholding algorithm is widely used in image segmentation that encounters the problem of computational time. Triclass thresholding technique is proposed for color and complex images also that reduces the computation time.

III. THRESHOLDING TECHNIQUE FOR COLOR IMAGE SEGMENTATION

Archana Chaudhari (2013) refers segmentation is the process of partitioning a digital image into multiple regions. The goal of segmentation is to simplify and change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is Resulting features form the basis of approaches for recognizing both weak objects and small object categories.

A. Histogram

Histogram has been extensively used in image processing because they provide overall measures of the statistical content of image. The information that is conveyed by a histogram can concern any point (pixel) property. The most commonly used is the gray level, the distribution of which is of the most important in changing the dynamic whenever images are to be analyzed. Each pixel of an n-bit digital image is labeled by its line and column i and j, respectively. The image at each point is u*(i,j)*, the associated histogram *H(k)* measured the number of pixels that have an image equal to *k*.

$$\sum_{k=0}^{2^n-1} H(k) = 1$$

and provide a good estimation of the probability distribution associated with the overall image forming procedure. The distribution function F(k) at point k is defined by.

$$F(k) = \sum_{l=0}^{k} H(l)$$

Where *F (k)* rises monotonically and is less than or equal to unity. It produces a smooth curve, differential geometry would give use its intrinsic characteristics. The arc length and the curvature torsion is not needed because it produce a plane curve.

B. Histogram Equalization

Histogram equalization method usually increases the global contrast of images, the usable data of the image is represented by close contrast values. The intensities of the input image can be better distributed on the histogram. It process in the areas of lower local contrast to gain a higher contrast of the image. Histogram equalization accomplishes by effectively spreading out the most frequent intensity values of the image. Histogram equalization is useful in separating the object from backgrounds and foregrounds that are both bright or both dark. This method can lead to better views of bone structure in x-ray images in better detailed in photos that are over or under-exposed. The advantage of the method is that it is a fairly straight forward technique and an invertible operator. Consider a discrete grayscale image $\{x\}$ and let n_i be the number of occurrences of gray level j. The probability of a image intensity occurrence level is *j* calculated in the below equation.

$$p(x = j) = p_x(j) = \frac{n_j}{n}$$

The cumulative distribution function is defined as.

$$cdf_x(i) = \sum_{j=0}^{i} p_x(j)$$

C. Iterative Otsu Method

The performance of Otsu's method is not a function of signal to background ratio. The iterative Otsu's method introduce the notion of distance ratio is define as the ratio of the distance in mean between the foreground and background to the full pixel range of an image. The distance ratio measures a posteriori, for an image segmented into two classes by techniques such as Otsu's method means of the two classes are measured in terms of full pixel range of the image. Denote an image f such that its pixel value at location (x, y), x = 1,...,M, y = 1,...,N is f(x, y), mathematically express the distance ratio γ is given in the Equation.

$$\gamma = \frac{|\mu_1 - \mu_0|}{\text{Max}\{f(x,y)\} - \text{Max}\{f(x,y)\}}$$

Where by definition $0 \le \gamma \le 1$. In special cases, $\gamma = 0$ image is a constant, $\gamma = 1$ image has only two pixel values, one for the background and the other for the foreground. Evaluating the performance of the algorithm introducing the notion of distance ratio is measures a posteriori of an image or region for Otsu's method of segmentation. The efficiency of the new algorithm is evaluated on both synthetic and real microscopic images. By assigning very strong and weak pixels to the tentative background and foreground classes, the new method is less biased toward the class with a large variance than classical Otsu's method. For an image f, at the first iteration step, Otsu's method is applied to find a global threshold $T^{[1]}$ where the superscript denotes the number of iteration. The means of the two classes separated by $T^{[1]}$ as $\mu_0^{[1]}$ and $\mu_1^{[1]}$ for the background and foreground respectively.

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Classify regions by pixel values greater than $\mu_1^{[1]}$ as foreground $F^{[1]}$ and regions pixel values less than $\mu_0^{[1]}$ as background $B^{[1]}$. For the remaining pixels f(x, y) such that $\mu_0^{[1]} \leq u(x, y) \leq \mu_1^{[1]}$ is denote as the To Be Determined (TBD) class $\Omega^{[1]}$.

Iterative process assumes that the pixels that are greater than the mean of the tentatively determined foreground are the true foreground. Pixels with values less than μ^0 are the background of the image. But the pixels in the To Be Determined (TBD) class are the ones that typically cause misclassifications in the standard Otsu's method are not decided at once and will be further processed. By defining in the Equation.

$$U = F^{[1]}. \cup B^{[1]}. \cup \Omega^{[1]}$$

where ∪ is the logical union operation. At the second iteration, again applies Otsu's method to find threshold $T^{[2]}$ on region $\Omega^{[1]}$ only. The iteration stops by the difference between two consecutive threshold |T [n+1] − T [n] | is less than a preset threshold. At the last iteration [n + 1], Ω[n+1] is separated into two instead of three classes. This method is to iteratively define the TBD regions to gain a high distance ratio, it produces result in better segmentation by applying iterative Otsu's method.

The iterative method is a parameter free except for the preset threshold to terminate the recursive process. The computational cost is added and minimal as the process usually stops in a few iterations and it processes only in a monotonically shrinking TBD region.

D. Iterative Otsu Method Preliminaries

The basic principle in Otsu's method is to split the image into two classes that are the objects and the background. Automatic threshold is obtained through finding the maximum variance between the two classes. In an gray scale image f(x,y) intensity vary from I(1,L), where L is the maximum intensity in that image and p_i is the probability of each level and f_i is the number of pixel in gray level is given in Equation.

$$p_i = \frac{f_i}{N}$$

The automatic threshold that divides the range into two classes that are $C_0 = [1, \dots, t]$ and $C_1 = [t, \dots, L]$. The probability distributions for two classes are shown the below Equations.

$$C_0 = \left[\frac{p_1}{\sum_{i=1}^{t} p_i}, \frac{p_2}{\sum_{i=1}^{t} p_i}, \dots, \frac{p_t}{\sum_{i=1}^{t} p_i}\right]$$

$$C_1 = \left[\frac{p_{t+1}}{\sum_{i=t+1}^{L} p_i}, \frac{p_{t+2}}{\sum_{i=t+1}^{L} p_i}, \dots, \frac{p_L}{\sum_{i=t+1}^{L} p_i}\right]$$

Mean for the classes C_0 and C_1 are given in the below Equation.

$$\mu_0 = \frac{\sum_{i=1}^{t} i.p_i}{\sum_{i=1}^{t} p_i}$$

$$\mu_1 = \frac{\sum_{i=t+1}^{L} i.p_i}{\sum_{i=t+1}^{L} p_i}$$

μ_T is the overall mean of the whole image is calculated by the Equation.

$$\mu_T = \beta_0\mu_0 + \beta_1\mu_1$$

where β_0 and β_1 are given in the below Equation

$$\beta_0 = \sum_{i=1}^{t} p_i$$

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$$\beta_1 = \sum_{i=t+1}^{L} p_i$$

Class variance of C_0 and C_1 is shown in the Equation.

$$\sigma^2 = \beta_0(\mu_0 - \mu_T)^2 + \beta_1(\mu_1 - \mu_T)^2$$

E. An Iterative Thresholding Technique For Color Image Segmentation

The system starts with applying the standard Otsu's method for automatic thresholding segmentation for each of R, G and B array in the digital image. The implementation of Otsu's method was implemented separately. For each of R, G and B channels may be treated as a gray channel. The obtained segmented image for each channel is iteratively calculated different threshold to segment the image. The symbolic representation in this paper for the three thresholds for R, G and B are T_R, T_B and T_G respectively. The new segmented image may be obtained by merging R, G and B channels together. The median filtering technique could be applied to smooth the resulted image. Increasing in the window size in the median filtering process, noticeable blurring results may be clear for the human eye.

E. Color Image Segmentation Algorithm

The steps for segment the weak objects and the complex objects from real and microscopy images the following steps are carried out.

Step 1: Test image is selected from dataset FIJI.

Step 2: Convert the image into three Red, Green and Blue channel respectively.

Step 3: Apply the Otsu's thresholding for each channel separately to calculate mean and from that measure the posteriori distance ratio.

Step 4: Repeat the Step 2 on the posteriori distance and calculate the new mean and measure the posteriori distance ratio for further segmentation.

Step 5: Continue the process until reach the consecutive posteriori distance are minimum.

Step 6: The new segmented image may obtained by merging the thresholded R, G, and B channels together.

Step 7: The resulted image suffers from some kind of distortion. To get rid of this distortion median filter is used to smooth the image and to increase the segmented region.

The algorithm for color image segmentation is carried out over the microscopy challenging dataset called FIJI. FIJI consists of 6 set of color images with challenging 720 images. Color Image Segmentation experiments are performed above segmenting algorithm to determine the weak objects and their fine details of real images and microscopic images. Threshold chooses from the iterative method quickly decreases after the first or second iteration. It shows the fast to reach satisfactory results. The proposed work will mainly focus on generalizing the color image segmentation method to other fields such as Neural Network, Fuzzy logic, and Ant Colony Optimization (ACO) for optimizing the threshold values and for the better segmentation.

IV. PROPOSED METHOD

The proposed system uses the following methodologies based on the type of images used such as complex images, real images and low intensity images.

Ant Colony Optimization.

Fuzzy logic.

Neural Network.

A. Ant Colony Optimization

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Ant colony optimization (ACO) algorithm is a novel simulated evolutionary algorithm. Image segmentation based on ant colony algorithms can be taken as the process of clustering intensity, which is similar to the process of finding food source by ants. Ants can always find the optimal path to a source of food in nature environments. The process of image segmentation based on ant colony optimization follows: Every intensity of an image is taken as an ant and the cluster center is taken as food source. The visual range of ant is small, so in the beginning, the search is blind. The ants will leave pheromone on the path. The other ants determine the direction of search according to the amount of pheromone and leave their own pheromone on the path. After so many cycles, the ants will leave more pheromone on the optimal path, which leads more ants pass on it. The searching process is a positive feedback mechanism and the ants will have their own way to find the optimal path as such the same technique is applied on the image to find the optimal threshold value for the better segmentation.

METHODOLOGY

Step 1: Take a color image as input image.

Step 2: Place all the pixel in a cell of the array.

Step 3: Initialize the cluster for the all data items with 0 and their availability with 1.

Step 4: Initialize the cluster index with 1. Introduce an ant,

Step 5: Initialize the ant by choosing a data item randomly and place the ant.

Step 6: Assign the current cluster index

for each data item do

If the data item is not covered,

Calculate similarity measure S (distance)

Select threshold measure of similarity TH

If S < TH

Add the data set with the current cluster and assign the current cluster index

Move to the next neighbor.

Endif

Endif

End-for

Step 7: If any item in the cluster-space is available

Increase the cluster index by 1

Repeat with the next ant

Else

Break

End if

Ant Colony Optimization technique is used on the low intensity images to find the threshold value faster than the other techniques. It provides the better segmentation results in the experiments.

B. Fuzzy Logic

The fuzzy logic is the areas of applications are very wide: management, process control, operations research decision making and the most important classification and pattern recognition. Dealing with simple ‘white’ and ‘black’ answers is no longer satisfactory enough; a degree of membership became a new way to segment the images. Fuzzy set is a set each pixels have degrees of membership. A pixel element of a fuzzy set can be partial member or a full member. The membership value assigned to 0, 1 or any value in-between 0 and 1. The degree of a pixel element's membership is mathematically in a fuzzy set is called membership function. An idea to solve the problem of image segmentation in fuzzy logic results dealing with supervised segmentation.

1) *Fuzzy Logic Controller*: Fuzzy logic controller properly performs in nonlinear systems. Fuzzy Logic Controller consists of four categories as fuzzification, Fuzzy engine, Rule Controller and defuzzification. In the first section, numerical pixel values are converted into fuzzy variable known as linguistic variable. Fuzzy engine defines controller output in order to fuzzified input, rule base and fuzzy inference methods. Rule Controller section contains the fuzzy condition to segment the image based on the pixel values. Finally output linguistic terms are converted to numerical value in defuzzification section. Fuzzy Logic Control consists of input and on output. The output membership functions are nominated as binary pixel values. Fuzzy technique is used on the real images which are the images that obtained from the real world where as the intensity levels are changes based on the reflection and illumination of the object. It provides the better segmentation from the threshold value which is obtained in this method.

C. Neural Network

Neural Networks try to simulate a structure similar to the one that having the complex structure. The engineering approach of neural networks develops software or hardware by the complex structure. Neural Networks consist on a series of nodes or neurons that will act upon a series of inputs. Each cell is densely interconnected receives a primary input and a great number of lateral interconnections from the output of other units. The lateral coupling of the neurons is thought of as a function of the distance in two ways: excitatory and inhibitory. The excitatory is a short range up to a certain radius, and inhibitory surrounds the excitatory area up to s bigger radius. This approach follows the two basic equations: matching and finding the neurons determined by the minimum Euclidean distance to the input and the update of the position of neurons inside the cluster.

METHODOLOGY

Step 1: The color image is taken as an input I.

Step 2: Find the global threshold or determine the optimal threshold.

Step 3: Based on the input image intensity levels similarities between the intensities are grouped.

Step 4: Using the excitatory and inhibitory functions, the input I produces the output vectors J which construct from the global threshold value.

Step 5: Train the system with set I and without supervision. After training, the neurons of the output competition layer define the J classes.

Step 6: Using the entire neural network, the vector I(x,y) of every image pixel of the original color image is classified to one of the J classes.

Neural Network technique is used on the complex images, those images having the multiple threshold values. From that the clustering of the pixel values are made and it calculated the optimal threshold value. It provides the better segmentation from the threshold value obtained in this method.

V. RESULTS AND DISCUSSION

A number of color image segmentation experiments are performed on novel challenging dataset called FIJI containing 6 set of color images each one represented with real world pictures downloaded from web resulting into a collection of 720 images. The color image segmentation is performed on microscopy dataset called FIJI containing 4 set of 300 color microscopy images are downloaded. Table 1 contains the different threshold values obtained using various segmentation methods for complex, real and low intensity images.

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Table 1: Threshold Value Analysis

Image Type	Otsu Method	Ant Colony Optimization	Fuzzy logic	Neural Network
Complex Image	769	627	427	360
Real Image	593	411	369	423
Low intensity image	173	160	167	176

a)
b)
c)


Segmentation for various images a) complex image b) real imges, c) Low intensity image

VI. CONCLUSION

As Otsu's method is widely used as a pre processing step to segment images, it is important to achieve a high accuracy. A new approach for color image segmentation has been presented that is based on the Otsu's method applied to the R, G, and B channels, these channels will produce some kind of noise and to remove this kind of noise a median filtering process was proposed. The selection of the median filter may cause some blurring in image once increase the window size. It shows the fast to reach satisfactory results. Still the computation time of this Otsu thresholding technique is high. In order to decrease the computation time the threshold values are initialized to Otsu method. The threshold values are calculated based on the type of image used. For the complex images the Neural Network technique, for the real images the Fuzzy Logic is used, and for the low intensity images Ant Colony Optimization technique are used to find the threshold. The calculated threshold value is given as an input to the Otsu method and it quickly decreases after the first or second iteration. The projected method is a faster and can achieve better segmentation result in challenging cases.

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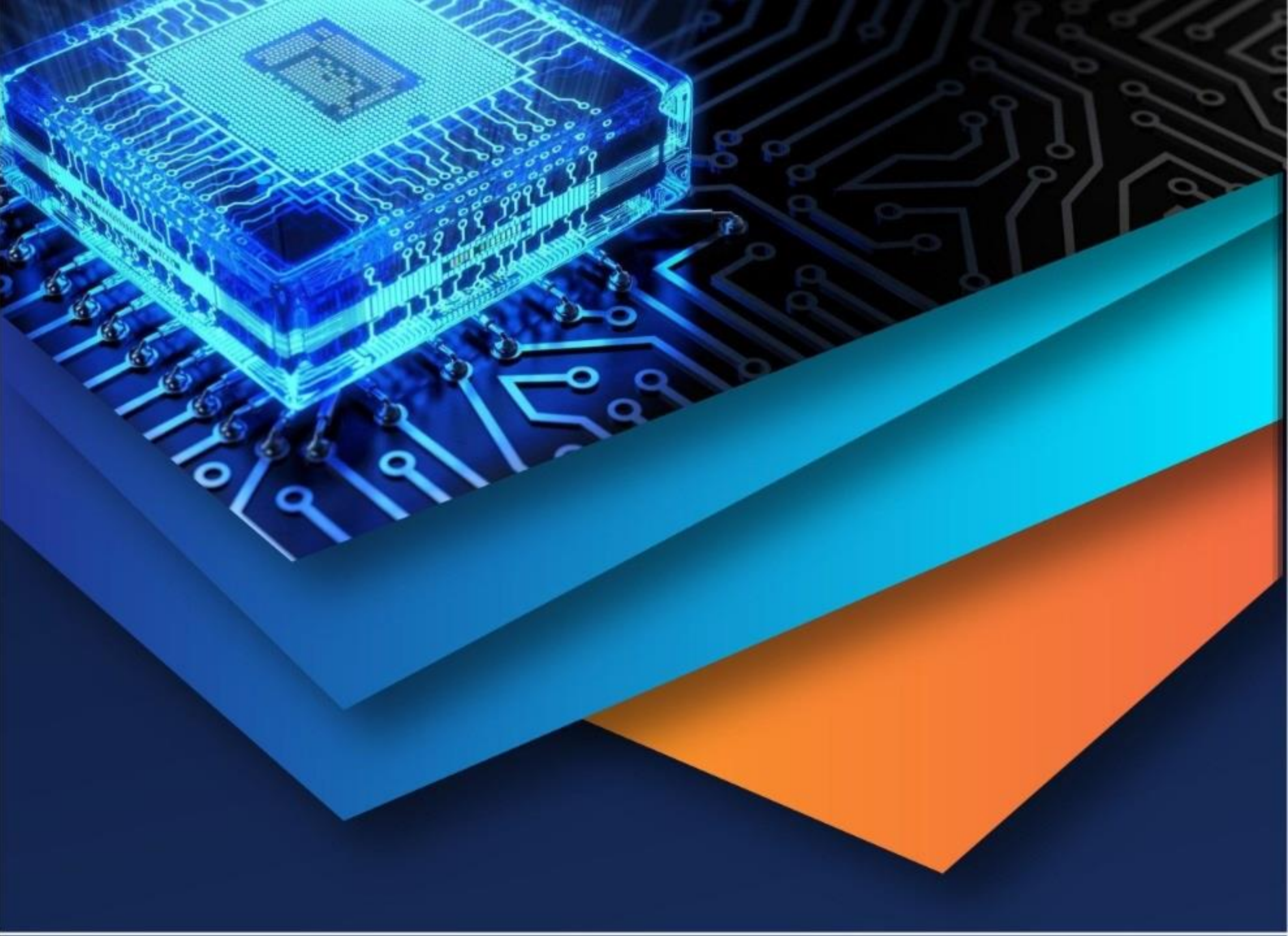

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