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Multimodal Biometric Authentication for Smartphones

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Abstract: Smartphones have become a crucial way of storing sensitive information; therefore, the user's privacy needs to be highly secured. This can be accomplished by employing the most reliable and accurate biometric identification system available currently which is, Eye recognition. However, the unimodal eye biometric system is not able to qualify the level of acceptability, speed, and reliability needed. There are other limitations such as constrained authentication in real time applications due to noise in sensed data, spoof attacks, data quality, lack of distinctiveness, restricted amount of freedom, lack of universality and other factors. Therefore, multimodal biometric systems have come into existence in order to increase security as well as to achieve better performance.[1] This paper provides an overview of different multimodal biometric (multibiometric) systems for smartphones being employed till now and also proposes a multimodal biometric system which can possibly overcome the limitations of the current biometric systems.

Keywords: Biometrics, Unimodal, Multimodal, Fusion, Multibiometric Systems

I. INTRODUCTION

In the age of information technology, verification of identity has become crucial.Verification requires high security standards for personal data and protection of privacy against unauthorized usage. As of now, using a Personal Identification Number (PIN), Patterns are some of the most common methods used, but these methods have a myriad of vulnerabilities, especially with the progress of technology. Employing biometric techniques on smartphones offer more dependable identification methods based on unique traits or characteristics possessed by humans. The possible impacts of unauthorized access could be threatening personal data. Thus, there is a trend of adding a novel authorization application which depends on an iris pattern to identify the smartphone user. Iris recognition is considered one of the most reliable biometric techniques to protect the device, its applications, and sensitive data. But no single biometric system is expected to effectively satisfy all the requirements when it is deployed in real world applications. Unimodal biometric systems like iris recognition systems have their own set of limitations.

The Unimodal biometric system has to tackle a diversity of conundrums like noisy sensor data, non-universality, intra-class variation, inter-class similarities, failure-of-enrolment, spoof attacks, restricted degree of freedom, unacceptable error rate, and many more. Multimodal biometric system utilizes information from more than one modality or multiple processing techniques or even both. Therefore, Multimodal biometric systems are ones which coalesce more than one physiological or/and behavioural characteristics for enrolment, verification, or identification to enhance performance and reliability of the recognition system.

Some commonplace multimodal biometrics are: face and iris, iris and fingerprints, face and fingerprints, face and voice, face, fingerprints and iris, face, fingerprint and signature, etc. In the paper we will be focusing on a multimodal eye biometric system which combines the features of iris, pupil, and sclera multiple modalities or multiple processing techniques or both.[1, 5]

Therefore, Multimodal biometric systems are those which integrate more than one physiological or/and behavioral characteristics for enrollment ,verification, or identification to improve performance and reliability. Some common multimodal biometrics are :face and iris, iris and fingerprints, face and fingerprints, face and voice, face, fingerprints and iris, face, fingerprint and signature, etc.

II. BIOMETRIC SYSTEM

Biometrics is constantly evolving especially in the field of secure IDs such as national identity documents, passports, or driver's licenses. Biometric systems make life safer and practical. Passwords, PINs, Smart Cards are some of the traditional ways of authentication. [3]General biometric systems capture the trait in the form of raw biometric data,processes data, and build an extract feature set that is a representation of the trait, the matching and comparing process generates score based on how closely the sample images in database,decision making phase decides whether to accept or decline the input based on score of input and the data in the database.[5]

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III. MULTIMODAL BIOMETRIC SYSTEM

Multimodal biometric system takes information from two or more biometric traits. Multimodal biometric systems are way more secure than unimodal biometric systems for authentication. Unimodal biometric systems can face problems such as lack of confidentiality, lack of universal space for samples, maximum comfort and user freedom while working with the system, attacks of database data fraud, etc. In a multimodal biometric system if one of the traits are absent due to some noise following trait value can be discarded and other trait values can be taken into consideration for matching the score. Hence unimodal biometric systems are preferred considering the security of the user.

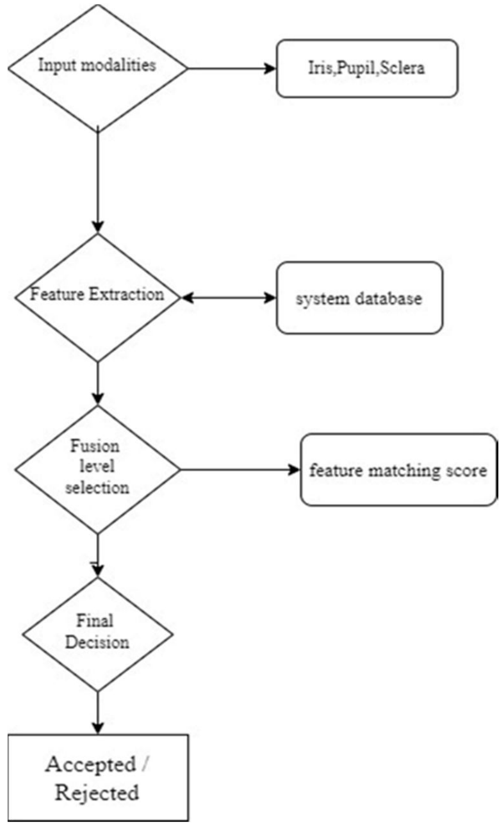

Fig.1: Diagram of multimodal biometric authentication system

Figure 1 outlines the complete execution of the multimodal biometric authentication system. The input modalities which are biometric traits, iris, pupil and sclera are taken as inputs by the system. The next step in the execution flow of the system is feature extraction. The prominent and important features required by the authentication system are extracted by this stage. In the next step,which is Fusion, values of the features of all three modalities are combined together. Here, a score of the image is created, which is further used in the last stage to compare it with the score of the test image. Depending on the similarity between the score of the test and train image, the decision of accepting or rejecting the authentication takes place.

IV. LITERATURE SURVEY

A. *Preprocessing*

Preprocessing enhances the input image by eliminating unwanted extra information like shadow, eyelash, reflection from the input image. One of the papers discusses Feature Level Fusion of Iris and Sclera using Entropy Based CNN Features to Improve the Performance of Biometric Authentication. Initially, input image is taken from the database which is then transformed from RGB photograph to gray photo to maintain the computational complexity. Min-max normalization is used to carry out linear transformation on input photos to fit the data in particular range.[1] Later, the non linear bilateral filtering is used for smoothing purposes by keeping the edges as it is. In one of the proposed systems, MSRCR is used to minimize the effect of nonlinear illumination with canny edge detection to identify the iris inner and outer circle boundaries .

B. Segmentation

Eye segmentation is done to find out iris and sclera area boundaries for front and off angle images. One of the proposed methods used CDM for segmentation to obtain required parts of iris and sclera and excluding noises like eyelashes, shadow or reflections. As a result valid regions of iris and sclera are obtained from an input image.Two binary maps obtained from eye images with noise are fused together based on their CDM for better sclera segmentation.

In addition to this, the proposed system also used the Blurred Image Detection method in which a blurred filter was applied for smoothing the blurry eye images in which a high energy frequency component was suppressed to increase clarity of image. Another segmentation method for iris ,sclera and pupil regions is by using convolutional neural networks(CNN) based on entropy values. In the proposed system, entropy is derived from contour based colour ,texture and brightness features. Convolutional neural community is used to cluster iris, sclera and pupil vicinity based on similarity obtained by using entropy measures.

C. Feature Extraction

In the eye biometric system color, texture and shape are the promising and reliable features which are stable over its lifetime for iris, sclera and pupil which can be used to generate the feature vector for correct authentication. In one of the proposed systems we extracted the color and texture information from segmented iris and pupil region which is combined with the Y-shaped features extracted from sclera. Color histogram algorithm is used to extract the color features whereas log Gabor filter is used to extract the texture features. Sclera of the human eye is compromised with different layers which form the stable blood vessel pattern which is unique for every person . These blood vessels form Y shaped branches which are stable and used to calculate sclera descriptor value. In the proposed system to find out Y-shape features (Shape), we look for the nearest set of neighbors in all line segments at regular distance and classify the angles between these neighbors to derive structure.In another method texture features for both iris and sclera are extracted by combining GLCM and Wavelet Transform.

1) *Grey Level CO-OCCURRENCE MATRIX(GLCM):* Grey Level Co-Occurrence Matrix (GLCM) is a texture feature extraction method results of which are better as compared to other textural feature extraction algorithms.[3] Difficulties in this are high computational complexity and also lack of global information. In this method two pixels separated by a definite distance in an image always have spatial relationships due to variation in their gray scale which describe the image from the interval of neighboring pixels, direction and degree of variation.
2) *Contour Feature Extraction:* Contours are characteristics of visual patterns available in the image which are obtained based on features like color, texture and brightness.[3] So contours are the subsets of features which helps to perform segmentation accurately with less quantity of features.
3) *Entropy Features Extraction:* It is a measurement of the degree of uncertainty that exists in a system. [3]Shannon's entropy is an important measure for evaluating patterns and structures in the data which can be used to characterize texture in the input image. The entropy is obtained for the potent segmentation of iris pupil and sclera regions. In the proposed system these entropy values are calculated to recognize iris, sclera and pupil regions based on texture in the contour image.

D. Matching

We use these methods to compare the support match score value of test data with the values stored in a trained database.In one of the papers, matching scores for both iris and sclera is calculated separately using Hamming Distance (HD) method. HD measures the similarity between two bit patterns. Then iris and sclera scores are normalized using the min-max rule. Then weighted score level fusion based on the sum rule is used and before addition weighting factor is multiplied with individual normalized scores corresponding to the iris and sclera.

Euclidean distance is used for pixel wise comparison of images. If the calculated distance is lesser than threshold value it is recognized otherwise rejected. Euclidean distance algorithm compares the stored data with the test data.

E. Fusion

Multimodal fusion in biometric system is generally classified into two categories:

1) *PRE-Classification:* In this, before applying any classification method or matching algorithm the information is integrated. Pre-classification fusion categories are:
   a) *Data Level (Sensor Level):* This is the process of combining multiple data representing signals from a similar modality source. It is vulnerable to noise and failures because there is no preprocessing involved here. It is not very oftenly used.[3]

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b) *Feature Level (Early Fusion):* Raw input data from different biometric traits is used in this.[3] Features extracted from tightly coupled or time synchronized modalities are initially blended and then analysis is executed.
- *Pre Classification:* In this, information is combined before the decision of classifiers.
- *Post Classification:* In this, information is combined after the decision of classifiers.

c) *Dynamic Classifier Selection:* It estimates the accuracy of each classifier in the local region surrounding the input pattern which is to to be classified and chooses the classifier which is most likely to give the correct decision . It requires large data sets for estimating local classifier accuracy.
d) *Rank Level Fusion:* In this fusion, each classifier has a rank with respect to every enrolled identity. The output from each biometric matcher is a subset of possible matches ranked in descending order of confidence values. Fusion can be done by taking into consideration more than two biometric matching scores associated with an identity and finding out a new rank that would be used in the final decision.
e) *Matching Score Level Fusion:* In match score similarity between input data and data from database are compared and matched. Combining can be done at matching score level. It is also known as measurement or confidence level fusion or confidence level fusion.
f) *Decision Level Fusion:* Here, feature extraction from each biometric trait is done and after matching modules these extracted features are classified as accept or reject. The final output of multiple classifiers for different modalities is then fused.

V. MODES OF OPERATION

Multimodal biometric system works in three modes of operation:

A. *Parallel Mode*

Numerous sources of information are simultaneously obtained for recognition.

B. *Serial Mode*

The output of one biometric trait is used at first to reduce the number of possible identities, after that it moves to the next trait. As more than one source of information is not acquired simultaneously, recognition time is reduced.

C. *Hierarchical Mode*

In this, individual classifiers are fused in a tree-like structure. It is used when there are a large number of classifiers matching score level ie. when output from each biometric matching module is a set of possible matches along with the quality of each matching score and with confidence values.

VI. COMPARATIVE ANALYSIS

A. *Pre-Processing*

Table I: Comparative analysis of Preprocessing methodologies

Sr. No	Author	Traits	Methodology	Remarks
1	Mrunal Pathak , Nulaka Srinivasu, Vinayak Bairagi	Iris, Sclera, Pupil.	1. RGB to Gray image transformation 2.Min-max normalization 3.Bilateral filter.	1. Reduced computational complexity. 2. Set image into a particular range. 3.The performance of image segmentation is improved.
2	Vrishab Krishna, Yi Ding , Aiwen Xu, Tobias Höllerer,	Eye	MNE package	ERPs generated in a motor imagery task.

3	Mrunal Pathak, Dr. Vinayak Bairagi, Dr.N. Srinivasu	Sclera, Iris	MSRCR	1. Image enhancement 2. Reduction of noise is done by excluding extra information like shadow, eyelash, reflection from captured image.
4	Ahmed Shamil Mustafa, Aymen Jalil Abdulelah and Abdullah Khalid Ahmed	Finger Print, Iris	OCT	1. Iris camera used. 2. Colored fingerprint is converted to Gray image.
5	Mrunal Pathak1 , Dr. Nukala Srinivasu , Dr. Vinayak Bairagi	Iris, Sclera, Pupil.	1. RGB to Gray image transformation 2.Min-max normalization 3.Bilateral filter.	1. Reduced computational complexity. 2. Set image into a particular range. 3.The performance of image segmentation is improved.
6	Fenghua Wang, Jiuqiang Han	Face , iris , palm	1.Localization of iris and eyelids, transformation, mask generation 2. Image enhancement.	1.Localization of the inner and outer iris boundaries, and eyelid boundaries, transformation from polar coordinates . 2. Image enhancement is done .

In the above table, various preprocessing techniques are stated and are described in detail. The preprocessing is done according to the traits used for the system. For instance, in the first paper, the traits are iris, pupil and sclera, and the preprocessing includes RGB to gray image transformation, min-max normalization,and bilateral filter.
In one of the papers for iris and sclera preprocessing MSRCR was used for image enhancement and to reduce noise in the image. For fingerprint preprocessing OCT technique is used and for iris preprocessing an iris camera was used.

B. Segmentation

Table II: Comparative analysis of Segmentation methodologies

Sr. No	Author	Traits	Methodology	Remarks
1	Mrunal Pathak , Nulaka Srinivasu, Vinayak Bairagi	Iris, Sclera, Pupil.	.Entropy based segmentation	.E-CNN was used to identify iris, sclera and pupil region independently based on entropy value.
2	Vrishab Krishna, Yi Ding , Aiwen Xu, Tobias Höllerer,	Eye	NA	NA
3	Mrunal Pathak, Dr. Vinayak Bairagi, Dr.N. Srinivasu	Sclera, Iris	1. CDM 2.RANSAC	1.Separation of valid region of Iris & Sclera 2. For fitting to estimate parameters from outliner data.

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4	Ahmed Shamil Mustafa, Aymen Jalil Abdulelah Abdullah Khalid Ahmed	Finger Print, Iris	NA	NA
5	Mrunal Pathak , Nulaka Srinivasu, Vinayak Bairagi	Iris, Sclera, Pupil.	Entropy based segmentation using color, texture and brightness features.	Iris, sclera and pupil region are clustered based on similarity obtained by entropy measures.
6	Fenghua Wang, Jiuqiang Han	Face , iris , palm	NA	NA

Segmentation is necessary to segment the regions of interest. Various segmentation techniques like Entropy based segmentation, Color Distance Map(CDM) and RANSAC are studied in this paper.

C. Feature Extraction

Table III: Comparative analysis of feature extraction methodologies

Sr .No	Author	Trait	Methodology	Remarks
1	Mrunal Pathak , Nulaka Srinivasu, Vinayak Bairagi	Iris, Sclera, Pupil	Color Histogram algorithm with Log Gabor Filter.	1.Extraction of the color features of iris and pupil and Log Gabor Filter for texture features.
2	Vrishab Krishn, Yi Ding, Aiwen Xu, Tobias Höllerer	Eye	The unnormalized cross-correlation	A template matching procedure is done between the 64 electrode signal pairs from the samples and then being compared.
3	Mrunal Pathak, Dr. Vinayak Bairagi, Dr.N. Sriniv-asu	Sclera, Iris	1.GLCM 2.Wavelet Transformation	1.GLCM is to describe properties like energy, homogeneity, correction,autocorrelation, dissimilarity, contrast, inertia, etc 2.Wavelet is used to represent continuous time signals into different scale components.
4	Ahmed Shamil Mustafa, Aymen Jalil Abdulelah and Abdullah Khalid Ahmed	Finger Print, Iris	KNN	1.Classification of iris and figure print is done using KNN . 2.Using features from the test image for comparison with the related feature in the features database based on the Euclidean distance is done.
5	Mrunal Pathak, Nulaka Srinivasu, Vinayak Bairagi	Iris, Sclera, Pupil	1.Color Histogram algorithm with 2. Log Gabor Filter.	1.Extraction of the color features of iris and pupil . 2. Log Gabor Filter for texture features.For sclera, Y-shape features.
6	Fenghua Wang, Jiuqiang Han	Face, iris, palm	2D Log-Gabor filters	1.Extraction and gained the phase information about iris. 2.2D Log-Gabor filters. The feature of iris can be described as certain binary codes.

Various feature extractions methodologies are employed in different papers mentioned above. For instance, the first paper which has employed iris, sclera and pupil as traits, has used Color histogram for extraction of the color features of iris and pupil and Log Gabor Filter for texture features. For sclera, Y-shape features which are stable during eye movements are used.

D. Matching

Table IV: Comparative analysis of matching methodologies

Sr. no	Author	Traits	Methodology	Remarks
1	Mrunal Pathak, Dr. Vinayak Bairagi, Dr.N. Srinivasu	Iris, Sclera, Pupil	Euclidean distance	The matching score between training and testing images are gained based on SVBF score.
2	Vrishab Krishna, Yi Ding , Aiwen Xu, Tobias Höllerer,	Eye	1.EMVIC dataset And 2.EEG MMI Dataset	Matching a participant in the EEG MMI dataset to create a fused dataset of hypothetical subjects with Motor imagery and Eye Tracking data.
3	Mrunal Pathak, Dr. Vinayak Bairagi, Dr.N. Srinivasu	Sclera, Iris	Hamming Distance (HD)	Matching score for Iris,Sclera is calculated.
4	Ahmed Shamil Mustafa, Aymen Jalil Abdulelah and Abdullah Khalid Ahmed	Finger Print, Iris	1.Fingerprint classifier 2.Iris Classifier	The output from the fingerprint classifier and the output from the iris classifier will be fused together .
5	Mrunal Pathak, Dr. Vinayak Bairagi, Dr.N. Srinivasu	Iris, Sclera, Pupil	Euclidean distance	1.The support match score value of test data with estimated values stored in trained and compared with the enrollment database.
6	Fenghua Wang, Jiuqiang Han	Face , iris , palm	HD	1.The difference between two iris was measured 2.The matching score of the iris verifier is obtained

Various matching techniques are used taking the type of fusion used into consideration. Most prominently used methods for matching are the Euclidean distance and Hamming distance methods.

E. Fusion Method

Table 4: Comparative analysis of fusion techniques

Sr.No	Author	Traits	Methodology	Remarks
1	Mrunal Pathak, Dr. Vinayak Bairagi, Dr.N. Srinivasu	Iris, Scler, Pupil	Supp-ort value based fusion	Support value is estimated from the extracted features for iris, sclera and pupil region. These values are fused together for matching.
2	Vrishab Krishna, Yi Ding , Aiwen Xu, Tobias Höllerer,	Eye	Matc-h score level fusion	Fusion methods like weighted mean and fusion by SVM with linear kernels have been implemented :each providing a normalized match-score from the individual predictions.
3	Mrunal Pathak, Dr. Vinayak Bairagi, Dr.N. Srinivasu	Sclera Iris	Matc-h Score Level Fusion	It is used to combine the score to check the possibility of increased performance
4	Ahmed Shamil Mustafa, Aymen Jalil Abdulelah and Abdullah Khalid Ahmed	Finger Print, Iris	Decis-ion Fusion Technique	The output from the fingerprint classifier and the output from the iris classifier will be combined together to find whether the system recognizes or denies based on thresholding value.
5	Mrunal Pathak, Dr. Vinayak Bairagi, Dr.N. Srinivasu	Iris, Scler, Pupil	Featu-re Level Fusion	Features are extracted from biometric trait iris , sclera and pupil . These features are fused together to obtain joint feature vector known as support value for matching.
6	Fenghua Wang, Jiuqiang Han	Face , iris , palm	Multi--ple parallel SVMs fusion strategy	1.After score normalization, a multimodal score vector can be constructed. The next step is fusion at the matching score level. 2.The score vector is combined to generate a single scalar score, which is used to make the final decision.

By using appropriate fusion techniques it improves recognition rates. Various fusion level techniques are discussed. Fusion at feature level fusion works better because of easy implementation. Suitable fusion techniques should be chosen considering the time, space and computational complexity.

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F. Accuracy And Equal Error Rate

Table V: Analysis of Accuracy and Equal Error Rate

Sr. No	Author	Traits & Fusion Method	EER	Accuracy
1	Mrunal Pathak , Nulaka Srinivasu, Vinayak Bairagi	Traits: Iris, Sclera, Pupil Fusion: Support value based fusion	-	97.99%
2	Vrishab Krishn, Yi Ding, Aiwen Xu, Tobias Höllerer.	Traits: Eye Fusion: match-score level fusion	3.4%	98%
3	Mrunal Pathak, Dr. Vinayak Bairagi, Dr.N. Srinivasu	Traits: Sclera Iris. Fusion: Match Score Level Fusion	1.GLCM: 2.07% 2.GLCM+Wavelet: 1.21%	-
4	Ahmed Shamil Mustafa, Aymen Jalil Abdulelah and Abdullah Khalid Ahmed	Traits: Finger Print, Iris. Fusion:Decision Fusion Technique	-	90%
5	Mrunal Pathak , Nulaka Srinivasu, Vinayak Bairagi	Traits: Iris, Scler, Pupil Fusion: Feature Level Fusion of Iris and Sclera	-	Accuracy for MMU =93.33% UBIRIS.v2=97.99%
6	Fenghua Wang, Jiuqiang Han	Traits: Face , Iris , Palm Fusion: Multiple parallel SVMs fusion strategy	0.63%	-

VII. CONCLUSION

In the earlier section, we have seen various papers with their respective biometric traits for the multimodal biometric systems. We even compared their preprocessing, segmentation methodologies, feature extraction techniques, fusion and matching methods. We also found out the multimodal biometric system with highest accuracy among other systems.Various Traits and their fusion methods are studied in this paper. Analysis on the basis of accuracy and equal error rate is analysed. We will use feature level fusion in our proposed model as it fulfils all the requirements and can be considered the best for our multimodal biometric system.

Finally, we have come up with our proposed method for a multimodal eye biometric system. This system will take biometric traits iris, sclera, and pupil as their regions of interest. Being a multimodal system, the biometric system will have higher accuracy compared to a unimodal system. In this system,we will be using entropy based CNN in order to segment the iris, pupil, and sclera. Color histogram algorithm is used to extract the color features whereas the log Gabor filter is used to extract the texture features. The Y-shape features of sclera can be used for the feature extraction. The fusion method feasible for this biometric system is feature level based fusion method.In feature level fusion, different biometric traits are pre-processed and feature vectors are extracted separately. All these feature vectors, in this case iris, pupil and sclera are combined to form a composite feature vector. This composite vector is used in the classification process. Due to rich information available in this level of fusion it is expected to perform better than score level and decision level fusion.

Unimodal biometric systems are not completely reliable, they also suffer from spoofing attacks due to lack of invariant representation and noisy input. Therefore multiple biometric traits are combined together to achieve better performance of eye biometric authentication. We saw different multimodal biometric systems in this paper. Our proposed eye biometric system combines the prominent features of iris, sclera and pupil to improve the accuracy of recognition for the images acquired in unconstrained or relaxed environments. Entropy based feature selection reduces time required for segmentation because of selection of optimal set of feature selection. And the feature level fusion method is selected from the range of fusion methods considering that it is expected to perform better than score level and decision level fusion.

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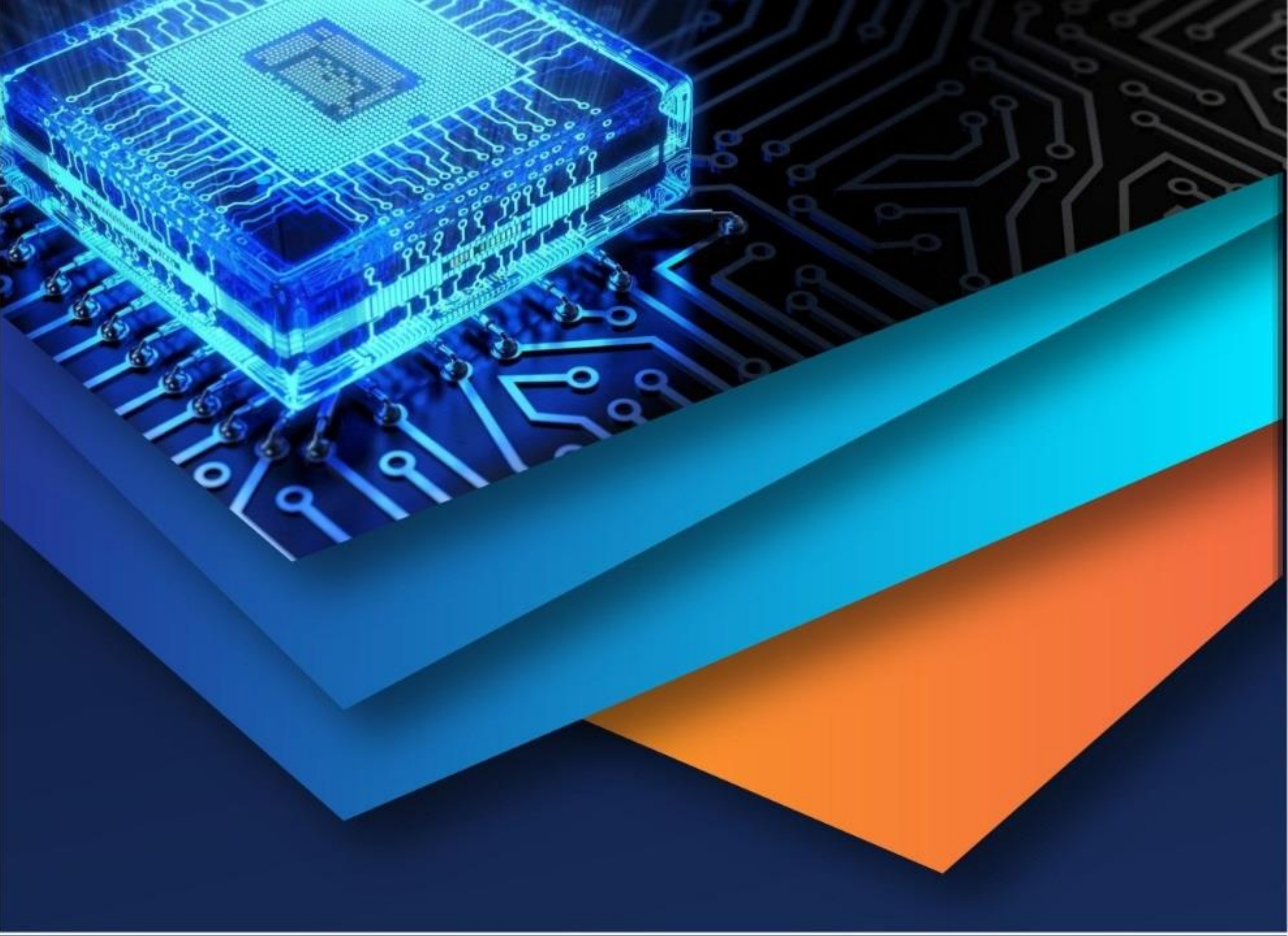

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