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Enhanced Fingerprint Detection and Rectification System

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Abstract: Information security is the process of securing the information or data from unauthorized access. Fingerprint authentication is proven to be more secure because it authorizes the unique feature of on finger. Fingerprint recognition system has been suffering through Positive and Negative classifications. In positive classification, the physical access control systems and user should negotiate for self-identification. The false case classification broadly talks about low quality of images in case of user identification may authenticate malicious user. Distortion detection can be categorized in two classification problems, which can be solved using the registered ridge orientation map and period map of a fingerprint which is used as the feature vector and CNN is trained to perform the classification and rectification (or equivalently distortion field estimation) task which can be viewed as a regression problem, where the input is a distorted fingerprint and the output is a distortion field. For such problem, Detection and Rectification of the distorted fingerprint is must. Distortion rectification is used to transform a distorted fingerprint into a normal one so as to increase the recognition rate of existing fingerprint recognition algorithms for distorted fingerprints. CNN is an efficient distortion rectification method and the processing speed is significantly faster than other methods.

Keywords: Distortion rectification, point core index method, Convolution neural network

I. INTRODUCTION

Biometric technology is able to recognize a person based on the basis of the unique features of their face, fingerprint, signature, DNA or iris pattern. Biometric authentication is unique for each and every individual in which they can be identified by their own physiological or behavioural traits. Physiological characteristics such as the form or composition of the body (eg., fingerprint, face recognition, DNA, palm print, handling geometry, iris recognition) and Behavioural characteristics such as the behavior of a person (eg., gait, voice etc). Biometric recognition system offers greater security and convenience than traditional methods of personal identification. Biometrics are used for identification and access management for distinguishing the people among the group of members (eg., police investigation). It is a secure and convenient method for authentication purpose. Biometric systems are easy to use because the users cannot remember their passwords or PIN numbers. The basic truth of identity verification is that each fingerprint is exclusive. Fingerprint recognition is one of the best known and most widely used biometric technologies among the users as well as manufacturers. Fingerprint is a feature pattern of one finger. Fingerprint consists of the ridges (lines across fingerprints) and valleys (spaces between ridges). The pattern of the ridges and valleys is unique for each individual. The three basic patterns of fingerprint ridges are the arch, the loop, and the whorl (Fig.1 represent these three patterns). Fingerprint recognition system has been suffering through positive and negative classifications.

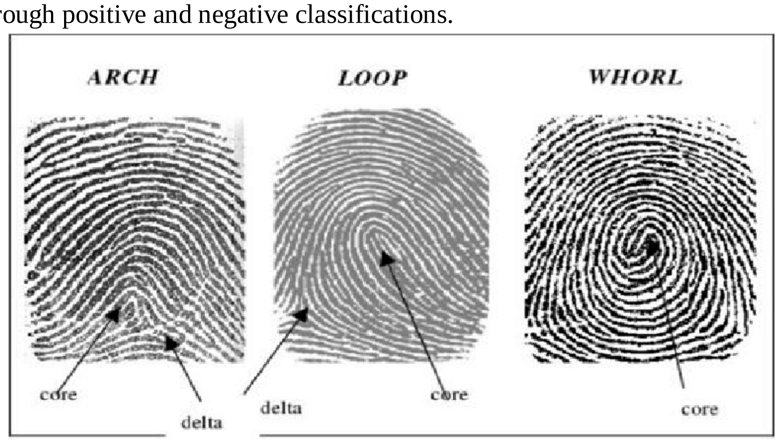

Fig 1: Fingerprint type

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A number of things could contribute to the degradation of fingerprint image quality, as well as little finger space, cuts and abrasions on the finger, wet or dry finger, dirt on the finger or detector, and skin distortion. Distortion is the reshaping of the first patterns of the friction ridges. One of the main reasons for the widespread adoption of fingerprint recognition techniques is that the error rate of fingerprint recognition algorithms are very low on fingerprints of high or medium quality. However, recognition rate for low quality fingerprints is still far from satisfactory, and low quality fingerprints are not uncommon. One type of low quality fingerprints are distorted fingerprints, which are usually caused when users press their fingerprints on sensors improperly. The idea of distortion rectification is to transform a distorted fingerprint into a normal one so as to increase the recognition rate of existing fingerprint recognition algorithms for distorted fingerprints. A recent study shows that distortion rectification can effectively rectify the distorted fingerprints.

II. PROPOSED WORK

When the fingerprint is subjected to identification, it may be unidentified due to distortion in the fingerprint. Once the fingerprint is identified as distorted fingerprint, the following process tends to enhance the fingerprint to identify the distortion and to rectify them so that the accuracy of matching is improved.

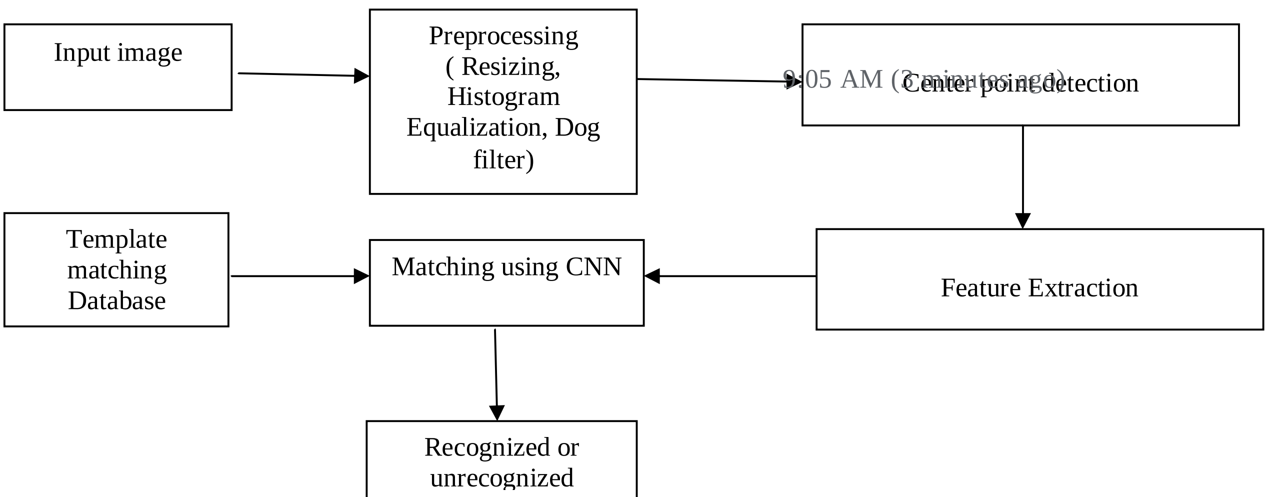

Fig. 2: Architectural Diagram

In proposed system, there are four stages,

A. Preprocessing

The preprocessing image aims at selectively removing the redundancy present in captured images without affecting the details. The preprocessing plays a key role in the overall process. In preprocessing stage, when the fingerprint is identified as distorted, then enhancing of the image and filtering of the image is done. For image enhancement, the adaptive histogram equalization is used and for filtering, DOG filter is used.The Preprocessing stage involves the following basic steps:

1) *Adaptive Histogram Equalization:* Adaptive histogram equalization is a image processing technique used to improve contrast in images and also used to redistribute the lightness values in the image. In adaptive algorithm, each pixel is modified based on the pixels that are in a region surrounding that pixel. This region is called contextual region. Adaptive histogram equalization has a tendency to over amplify the noise.

Fig 3: Histogram Equalization

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Adaptive histogram equalization improves by transforming each pixel with a transformation function derived from a neighbourhood region. Fig3 shows adaptive histogram equalization. The adaptive histogram equalizations is computationally intense. For this reason, it developed some methods to increase the speed of the original method.

2) *DOG:* The Difference of Gaussian module is a filter used to identify the edges. The DOG filter performs edge detection by performing a Gaussian blur on an image at a specified theta (also known as sigma or standard deviation). The resulting image is a blurred version of the source image. Fig:4 represent the resulting image of dog filter. The module performs another blur with a sharper theta that blurs the image less than previously. The final image is calculated by replacing each pixel with the difference between the two blurred images and detecting when the values cross zero, i.e. negative becomes positive and vice versa. The result zero crossings will be focused at the edges or areas of the pixels that have some variation in their surrounding neighborhood.

Fig 4: Edge Detection

The image is first involved by convolution with Gaussian kernel of certain width σ_1

$$G_{\sigma_1}(x,y) = \frac{1}{\sqrt{2\pi\sigma_1^2}} \exp\left(-\frac{x^2+y^2}{2\sigma_1^2}\right)$$

to get

$$g_1(x,y) = G_{\sigma_1}(x,y) * f(x,y)$$

With different width σ_2, second smoothed image can be obtained:

$$g_1(x,y) = G_{\sigma_1}(x,y) * f(x,y)$$

It can show that the difference of these two Gaussian smoothed images, called the difference of Gaussian (DOG), can be used to detect edges in the image. $g_1(x,y) - g_2(x,y) = G_{\sigma_1} * f(x,y) - G_{\sigma_2} * f(x,y) = (G_{\sigma_1} - G_{\sigma_2}) * f(x,y)$

$$= DoG * f(x,y)$$

The DOG operator or convolution kernel is defined as

$$DoG \triangleq G_{\sigma_1} \quad G_{\sigma_2} = \frac{1}{\sqrt{2\pi}}\left(\frac{1}{\sigma_1} e^{-(x^2+y^2)/2\sigma_1^2} \quad \frac{1}{\sigma_2} e^{-(x^2+y^2)/2\sigma_2^2}\right)$$

The difference of Gaussian can be utilized to increase the visibility of edges and other details present in a digital image. Wide variety of alternative edge sharpening can be done by enhancing high frequency detail, because random noise also has a high spatial frequency. Many of these sharpening filter tend to enhance noise, which can be undesirable artifact. The difference of Gaussian algorithm remove high frequency and this approach is most suitable for processing images with a high degree of noise.

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B. Centre Point Detection

As for digital fingerprint images, a core point has a Poincare index valued as1, a core point as 1/2 and a delta point as −1/2. Let θ (x, y) denote the direction of the pixel and (x ,y) in an M×N fingerprint image.Fig:5 represent the center point detection

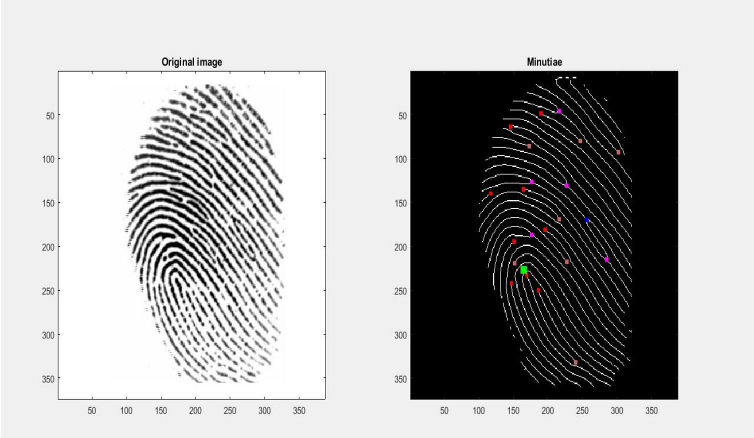

Fig 5: Center point detection

Fig 6: Orientation Direction

The Poincare Index method at pixel (x, y) which is enclosed by a digital curve (with N points) that can be computed as follows:

$$PC(i,j) = \frac{1}{2\pi}\sum_{k=0}^{N_p-1} \Delta(k)$$

$$\Delta(k) = \begin{cases} \delta(k), & if\,\delta(k) < \frac{\pi}{2} \\ \pi + \delta(k), & if\,\delta(k) < -\frac{\pi}{2} \\ \pi - \delta(k), & otherwise \end{cases}$$

$$\delta(k) = O'\left(P_x(k'), P_y(k')\right) - O'\left(P_x(k), P_y(k)\right)$$

$$k' = (k+1) \bmod N_p$$

Where

$P_x(k)$ and $P_y(k)$ - are the x and y coordinates of the kth point on the closed curve centered at the given point (i, j).

N_p - Number of Pixels

K= 1,2,3…n

O' - denotes a fingerprint orientation field.

$\delta(k)$ - Delta Point

$\Delta(k)$- Core Point

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C. Feature Extraction

The orientation of the ridges is one of the intrinsic properties of a fingerprint image. The image is divided into a number of non-overlapped blocks. Then, the dominant local direction of the ridges in the block is considered as the orientation of that block. Different algorithms are used for estimation of the orientation ridge in a fingerprint image. One of the algorithm is based on the computation of gradient of each pixel and compute the overall orientation for a block.

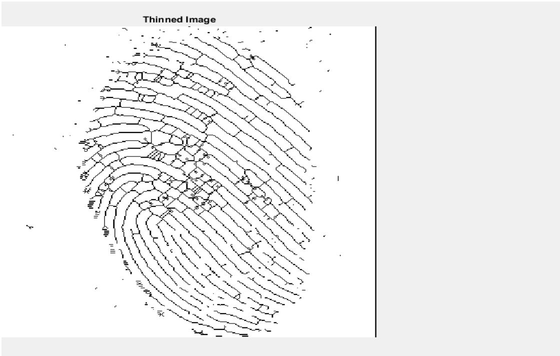

Fig 7: Thinned image

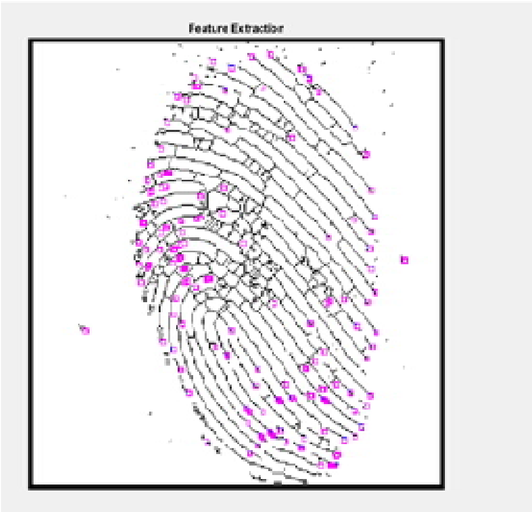

Fig 8:Feature Extraction

The dominant orientation of an image block is estimated by least square method based on the gradients because it provides high efficiency. The steps are as follows:

1) *Step 1:* Divided the fingerprint image into non overlapping blocks of size W×W pixels. The size of the block should be sufficient enough to be able to obtain a good estimate of the local ridge flow and cannot be too large as the change in the local orientation need to be captured in order to locate the global characteristic of the fingerprints. The block size is W=8 is used for estimating block orientation in this work as the average width of the ridges are 5 to 8 pixels.
2) *Step 2:* Compute the gradients Gx and Gy of each pixel with respect to the horizontal and vertical directions respectively. The Sobel convolution mask is used to determine the components of the gradient.
3) *Step 3:* Estimate the local orientation field of the block by gradient squared averaging method. The orientation field serve to decide the pattern of the input fingerprint image.

Fig:6 represent the orientation field. Feature vectors is needed in distortion detection and rectification. Features are uniformly sampled in the ridge period map and orientation map of the registered fingerprint. The sampling interval is 16 x 16 pixels in both maps. Similar to the sampling grid in the orientation map covers only the area above the center because the upper area of the orientation map is similar to the lower area and usually produces greater variations than the lower area if the fingerprint is distorted. The sampling grid in the period map covers all the fingerprint area. It is similar to that in the procedure of pose estimation, but it is dimensional vector, where Fig 8 represent the number of the sampling points in the orientation map and period map, respectively.

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D. Classification and Rectification

Classification and rectification performed by Convolution neural network. Convolution neural network is a system of interconnected artificial neurons that exchange messages between each other. The connections have numeric weights that are tuned during the training process, so that a properly trained network will respond correctly when presented with an image or pattern to recognize.

Four type of layers

1) *Convolution layer:* The convolution operation extract the different features of the input. The first convolution layer extracts the low-level features like edges, lines, corners. Higher-level layers extract the higher-level features. For this case when N = 32 and k = 5, there are 28 unique positions from left to right and 28 unique positions from top to bottom that the kernel can take. Corresponding to these position, for each feature, the output will contain 28x28 (i.e., (N-k+1) x (N-k+1)) elements. For each position of the kernel in a sliding window process, k x k x D elements of input and k x k x D elements of kernel are element-by element multiplied and accumulated. In order to create one element of one output feature, k x k x D multiply-accumulate operations are required.
2) *Pooling/Sub Sampling Layer:* The pooling /sub sampling layers are reduces the resolution of the features. It makes the feature robust againstthe noise and distortion. There are two ways to pooling: max pooling and average pooling. In both cases, input is divided into non-overlapping two-dimensional spaces. The input is of size 4x4. For 2x2 is sub sampling, a 4x4 image is divided into four non-overlapping matrices of size 2x2. In the case max pooling, the maximum value of four values in the 2x2 matrix is the output. In case of average pooling working the average of the four values is the output. Note the output with index (2, 2), the result of averaging is a fraction that has been rounded to nearest integer.
3) *Non-Linear Layer:* Neural networks in general and CNNs in particular rely on a non-linear “trigger” function to signal distinct identification of likely features on each hidden layer. CNN may use variety of specific functions such as rectified linear units and continuous trigger (non-linear) functions to efficiently implement this non-linear triggering. It increases the nonlinear properties of the decision function and overall network without affecting the respective fields of the convolution layer.
4) *Fully Connected Layer:* Fully connected layers is the final layers of a CNN. These layers mathematically sum a weighting of the previous layer of features, indicating the precise mix of “ingredients” to determine a specific target output result. CNN give the best performance in pattern/image recognition problem and even outperform than humans in certain cases. Cadence has achieved best-in-industry results using algorithms and architectures with CNN.

E. Performance Analysis

In existing system the, the filtering of noises is performed by LADCT whereas in proposed system,the filtering of noises is performed by DOG filter(Difference of Gaussian). Fig 9 represent the comparison between DOG filter and LADCT.DOG filter provides more efficiency.

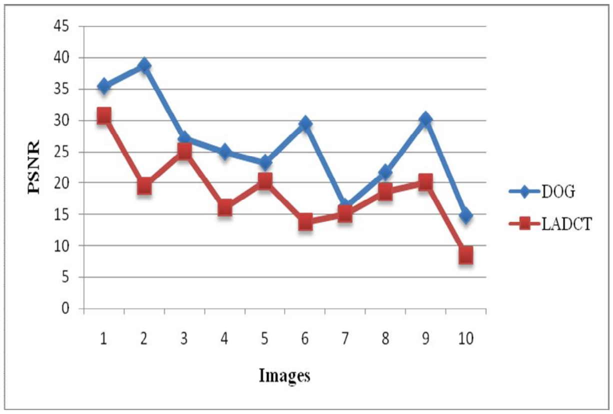

Fig 9:comparison between DOG filter and LADCT

Fig:10 represent the core point detection. In existing system the core point is detected by walking method but in proposed system the core point is detected by point care method where it provides more efficiency. Fig :11 represent the comparison of processing time between SVM classifier and CNN method. In Existing system the SVM classifier is trained to perform the classification task .where as in proposed system the CNN is trained to perform the classification task

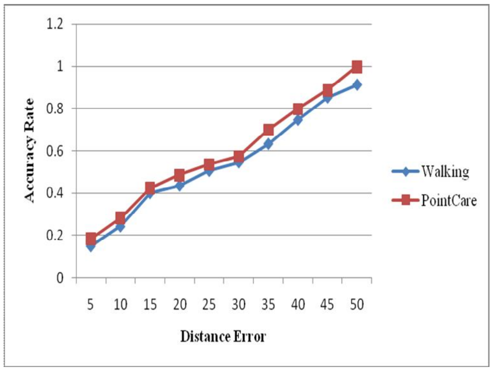

Fig 10: Core point detection

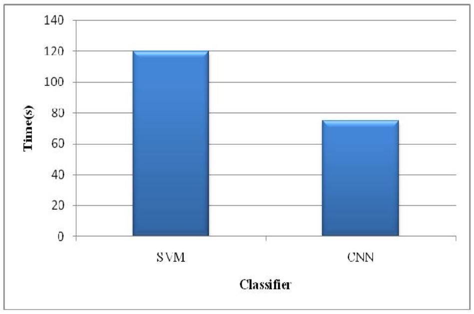

Fig 11:processing time

III. CONCLUSION

Distortion in fingerprint makes a serious problem in identifying criminals & terrorists. This type of distortion generates a serious security hole in fingerprint recognization system. Distortion in fingerprint has been purposely created by a malicious user who does not have a intension to identify them. It also causes the serious issues in government institution where the original employee has not been identified due to elastic distortion caused in the fingerprint. For this reason, it is necessary to develop the fingerprint distortion detection & rectification algorithm. This paper describes about how the distorted fingerprint can be rectified and can be matched to the fingerprint corresponding to the fingerprint in the database. Once the fingerprint is identified as distorted, it is subjected to many process like enhancing, filtering, & finally the value has been detected by using the feature vector (period map &orientation map)and finally the distortion in fingerprint has been rectified &classified by the convolution neural network. By using this method, efficiency has been improved.

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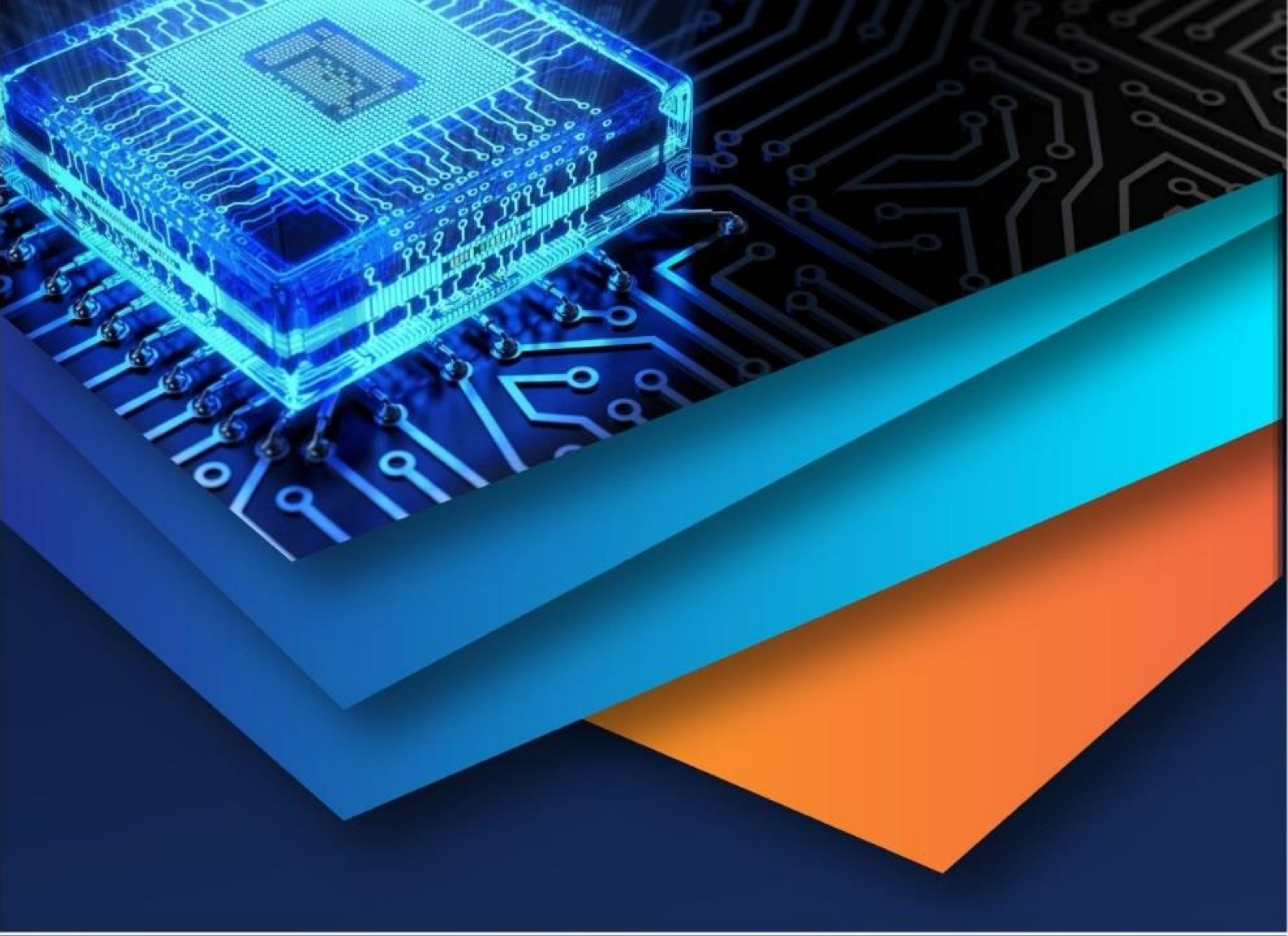

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