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A Survey and Analytical Approach on Image Compression for DICOM Images

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Abstract: ***As medical imaging move towards digital imaging, medical information compression play major role in tele radiology application development. A DICOM standard work as an interface to send data from vendor independent equipment (Picture archiving and Communication System) to PDA based tele radiology system. With the help of DICOM file format, radiologist can view images in different file format. For excessing, viewing and examining patient information and images, information transmission and compression are key issues in case of such platform usage. This Paper served available compression techniques like JPEG, JPEG-LS, JPEG2000. The propose paper also analyse and compare different lossy and lossless techniques based of domain, principle and methods used. In this paper there is a survey of literature related to Image Hierarchical Coding and different Wavelet family and Wavelet Transform.***

Keywords: ***Digital Imaging and Communication in Medicine, Personal Digital Assistant, Joint Photographic Experts Group***

I. INTRODUCTION

In dealing with images it is necessary to work with both the concept of analog and digital images. An analog image is a 2D image F(x, y) which has infinite precision in intensity at each special point (x, y). Digital image is a 2D image I(r, c) which is represent by a discrete 2D array of intensity sample. Different coordinate system used for image representation like raster oriented uses row and column, Cartesian coordinate frame [1]. Images are classify in to five following types.

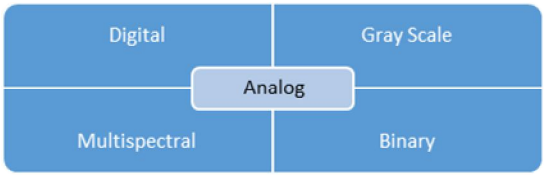

Fig. 1 Image types

Any image is processing using four mode. Sequential, Progressive, Hierarchical, Lossless mode. In sequential mode image component is encoded in single left to right or top to bottom scan. In the progressive mode low quality spectral followed by high quality spectral passes. It is work on progressive spectral selection approach. In this approach all DCT coefficient are transmitted first with lower frequency and then higher coefficient. In the hierarchical mode the image is compressed to multiple resolution level hence low resolution levels are target to the system directly without decompression of entire system [2].

The following paper is ordered as follows: Section II represents a short-lived survey of the related literature. Section III which discusses the Image Hierarchical coding methods for DICOM medical and the comparison between Image Hierarchical coding and Wavelet family are presented in Section IV. Finally, the conclusions are whole up in Section V.

II. A SURVEY ON FILE FORMAT AND COMPRESSION METHODS USED FOR DICOM IMAGES

A. File format used by DICOM images

Image file formats provide a standardized way to organize image data in to image file and how the pixel data understand by the software for correct loading and visualization and analysis. The major file format current useful in medical imaging is DICOM format. The DICOM format includes some information that can be useful for image registration, such as position and orientation of the image with respected to the data acquision device and patient information with respected to voxel size. DICOM file format design consideration is based on following concept such as pixel depth, photometric interpretation, metadata, and pixel data. The DICOM file format is created by addition of header size and pixel data [3][4]. Mathematical

Equation are as follows

DICOM File Format = Header Size + Pixel Data Size

Pixel Data Size = Rows*Columns*Pixel Depth*Number of Frames

The more popular formats used in daily practice are the JPEG, JPEG 2000, TIFF, GIF, and PNG formats. In contrast to DICOM images, images saved in these formats can be viewed on any personal computer without the need for dedicated viewers. File format are design with the help of image conversion technique and coding schemes [5]. Following are the survey of JPEG file format [6].

TABLE I
SURVEY OF JPEG FILE FORMAT

S. No.	File Format	Image Conversion Technique used	Coding Scheme Used	Advantages	Disadvantage
1	JPEG	DCT	Huffman	Small Size, Portable	Image Quality degraded at high compression rate
2	JPEG-LS	DCT	Run length Coding	Fast, Simple	Complex working , poor compression
3	JPEG 2000	Wavelet base	Huffman	Many feature support, based on tiling	Complex working, slow processing

During the past ten years various compression methods have been developed to solve major problem and challenges handled by DICOM viewers. The compression methods can be classified broadly into reversible (lossless) and irreversible (lossy) compression.

B. Lossless Method

Lossless compression can completely recover the original data but this reduces the compression ratio to around 2:1. In DICOM viewer, lossless compression has been a need because it facilitates accurate diagnosis due to no degradation on the original image [7].

TABLE.II
LOSSLESS METHODS IN DIFFERENT DOMAINS

S. No.	Domain	Principle Used	Methods
1	Coding	The symbol codes are of variable length.	Arithmetic, Huffman's, LZW, Run Length Coding
2	Special	Variable Block Size Compression	JPEG, JPEG-LS
3	Transform	Exploit special frequency information contained in the image to achieve compression	Multiresolution Transform, Wavelet Transform

C. Lossy Method

Generally lossy compression work in three step. Firstly in transform that eliminate the redundancy in inter pixel. Secondly

quantize to remove psych visual redundancy and thirdly efficient encoding. Following are the hierarchical tree for classification of lossy compression technique used in DICOM image compression.

TABLE.III
DIFFERENT LOSSY COMPRESSION METHODS AND SCHEME

S. No.	Compression Methods	Compression Schemes
1	Quantization	Scalar and Vector
2	Transform Based	KLT, DFT, DCT
3	Block Transform Coding	JPEG
4	Full Frame Transform Coding	Sub band Coding (DWT)

Following factor are consider for selection of compression technique for DICOM image:

1) Sensitive to input image type
2) Operational bit rate
3) Implementation issue
4) Encoder/ Decoder Asymmetry
5) System capability

III. IMAGE HIERARCHICAL CODING FOR LOSSLESS COMPRESSION

In the hierarchical coding the image data are encoded in such a way that it is possible to access a given image at different quality level or resolution. The image hierarchical coding is classify in to two parts; fixed resolution and variable resolution.

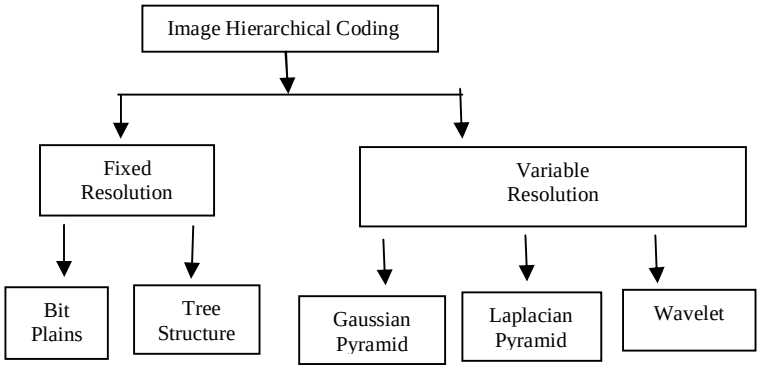

Fig. 2 Image Hierarchical coding

A. Fixed Resolution

In the fixed resolution the original image and the value at any particular pixel location is retired as one moves from level to level. Fixed resolution is classify into two parts; Bit plane, Tree Structure.

1) *Bit Plane:* In the bit plane method; an n bit image can be represented by n bit planes, each of the same dimension as the original image. This method start with most significant bit plane and end with least significant bit plane. The bit plane is a binary image compression technique that can be used to reduce the bit rate [8].Served bit plane method works as follow:

a) Load the uncompressed gray scale input image size M*N.
b) To convert gray scale image in to eight bit plane image. The image can be represented by an 8 bit vector. Bit Planes = b7, b6, b5, b4, b3, b2, b1, b0
c) Discard the lower plane(0 to 3) and consider only upper plane(4 to 7)
d) Apply run length coding to bit plane (4 to 6) and lossless predictive coding to bit plane 7.

Following is the example of Bit plane and Ren length coding.

1101	0111	1000
1100	1011	1001

Fig.3 (a) A 3x2 4-bit grayscale image

1	1	0
0	1	1

Fig.3 (b) b0 Bit Plane

0	1	0
0	1	0

Fig.3 (c) b1 Bit Plane

1	1	0
1	0	0

Fig.3 (d) b2 Bit Plane

1	0	1
1	1	1

Fig.3 (e) b3 Bit Plane

2) Tree Structure: In this method an image is divide into four equal sized sub region. The sub region are described in the preceding paragraph. Each sub region is often represented as a region which is called as quad tree. Each node of a quad tree contains either zero or four children and represents a rectangular region of two dimensional space. Any node having no children is called as a leaf node. Leaf node is completely filled by one color. Any node having four children is called an internal node. Internal node filled with various colors. Following are the example of quad tree representation [9**]**

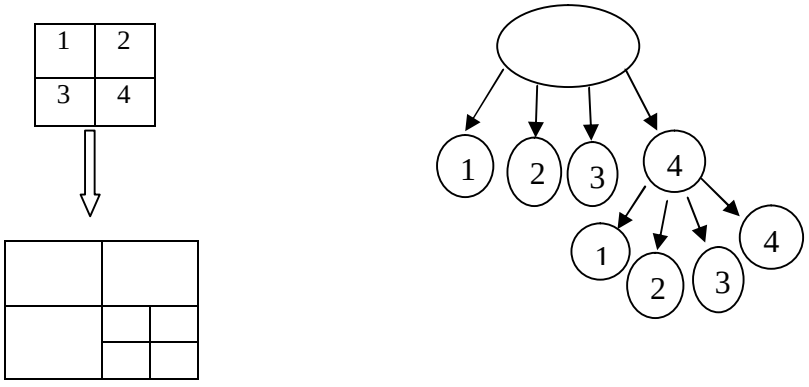

Fig. 4 Quad tree representation of an image

B. Variable Resolution

This approach is useful for Pyramid representation. The pyramid representation use full resolution with one level move up. This is probably well suited to multiscale and multiuse environment supporting device and for progressive transmission.

1) *Formula for generation of Laplacian Pyramid:* The scheme used to generate Gaussian Pyramid in to two levels; firstly low pass filter is useful to attenuate the high spatial frequency and secondly subsampling the remaining pixels. Thirdly pixel data is converted in to decimated image [10].

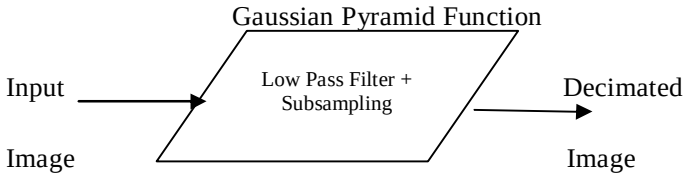

Fig.5 The structure of Gaussian Pyramid

$L_L = G_L - G'_{L+1}$ $0 \le L \le N-1$ (1)

G_L = Input image

G'_L = Gaussian Pyramid Function

L_L = Decimated Image

2) *Generation of Gaussian Pyramid Function:* The image is initially represented by one dimension array where G0 is contains (i, j) columns and rows. By applying level 1 image on G1 (i, j) and again by applying level 2 image is on G2 (i, j). Now here we have selected the size of weighting function is until level 2 using 5 by 5 pattern is generated [11].

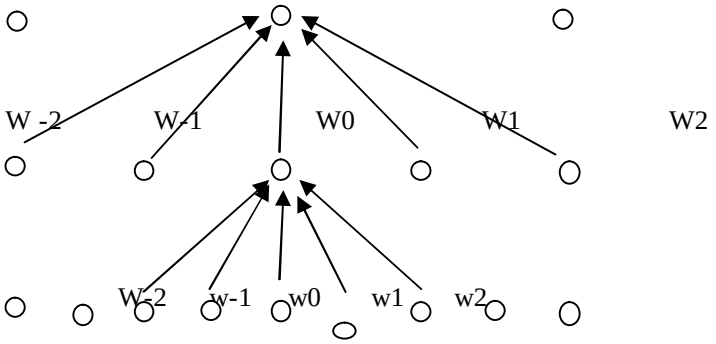

Fig.6 The 5 by 5 pattern generation of Gaussian Pyramid

The levels averaging processing is formulated using following formula.

$G_{l+1} = Reduce(G_l)$ (2)

Where $G_l = G_0, G_1, G_2 - - - - G_{N-1}$ and H is the heights of Pyramid

$G_{l+1}(i,j) = \sum_{m=-2}^{2} \sum_{n=-2}^{2} W(m,n) G_{l}(2i+m, 2j+n)$

Where W ( ) is the weighting function.

$G'_{l}(i,j) = 4 \sum_{m=-2}^{2} \sum_{n=-2}^{2} W(m,n) \left(\left(\frac{i-m}{2}\right) \left(\frac{j-n}{2}\right) \right)$ (5) $G'_L = Expand(G_{l+1})$ (4)

C. Wavelets

The wavelet means varying frequency in limited duration. The wavelet transform had numerous applications in the signal processing. In 1988, Stephane Mallat and Meyer proposed the concept of multiresolution. In the same year, Ingrid Daubechies found a systematical method to construct the compact support orthogonal wavelet. In 1989, Mallat proposed the fast wavelet transform [12]. Wavelet transformations have become some of the best established tools. Two main reasons for their use may be given: firstly, certain signal processing operations are more readily and more efficiently performed in the transform domain (i.e. correlation are linear filtering through the Fourier Transform), and secondly the important information may be compressed into fewer terms [13]

Wavelets has three basic characteristics:

1) Ability to generate function: We can generate infinite series of wavelet using a single scaling function by scaling and translation operation.

2) Multiresolution ability: The ability to represent a function at different level, by different weighted sums, which is derived from the original function

3) Ability to generate low level coefficient from higher level coefficients: This is archive through tree structured filters called filter banks The basic approach of Wavelet based image compression are as follows:

a) To compute the two dimensional wavelet transform

b) Alter the transform coefficients

c) To compute the inverse transform

There are three methods for DICOM image compression using wavelet.

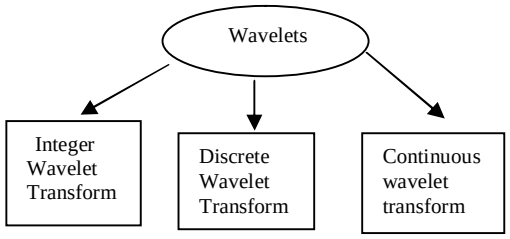

Fig. 7 Wavelet Classification

4) *Using Integer Wavelet Transform and Predictive Coding:* The integer wavelet transform method is applied on the image F(n) which divides the image into four subbands ss, sd, ds, dd and . Now predictive coding is applied on the four different bands separately giving outputs D0, D1, D2, and D3. IWT is based on Haar Filters with forward scheme. This technique split input signal in to even and odd signal [14][15].

$Split(Sj) = (Odd$ j-1, Even j-1) (6)

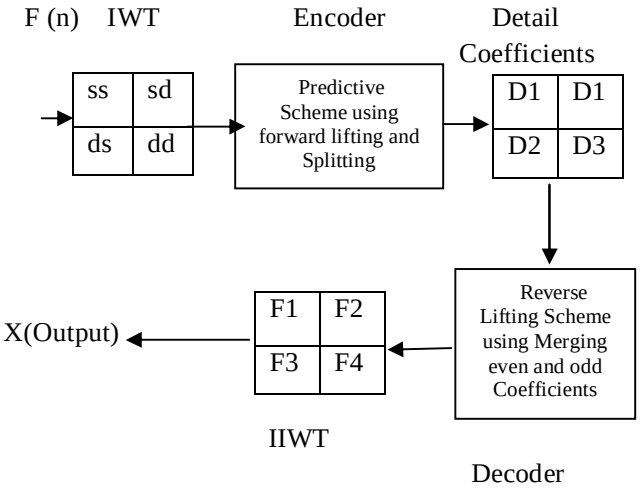

Fig. 8 Block Diagram of IWT and Predictive Coding

5) *Using Discrete Wavelet Transform and Subband Coding :* The discrete signal in terms of the wavelet coefficients can be written as,

$$S(n) = \frac{1}{\sqrt{M}} \sum_{k} W\varnothing(j0,k)\varphi j0,k(n) + \sum_{j=0}^{\infty} \sum_{k} W\varnothing(j,k)\varphi j,k(n) \qquad (7)$$

Where $\varnothing$ is scaling function and φ is work as wavelet function. The two dimensional DWT is implemented through sub band coding. In case of subband coding input image is extracted in to approximate form in both horizontal (n1) and vertical direction (n2). The two-dimensional DWT of an image function S (n1, n2) of image size is represented as[16]

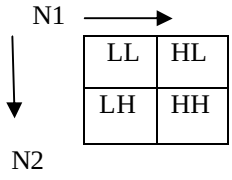

Fig. 9 Block Diagram of subband partitions

This analysis of 2-D signals require the use of following two-dimensional four different filter functions through the product, as defined below.

$$\emptyset(n1,n2) = \emptyset(n1)\emptyset(n2) \ldots\ldots\ldots (8)$$
$$\varphi H(n1,n2) = \emptyset(n1)\varphi(n2) \ldots\ldots\ldots (9)$$
$$\varphi V(n1,n2) = \varphi(n1)\emptyset(n2) \ldots\ldots\ldots (10)$$
$$\varphi D(n1,n2) = \varphi(n1)\varphi(n2) \ldots\ldots\ldots (11)$$

The above equations are represented the approximated signal, signal with horizontal details, signal with vertical details and signals with diagonal details respectively [17]

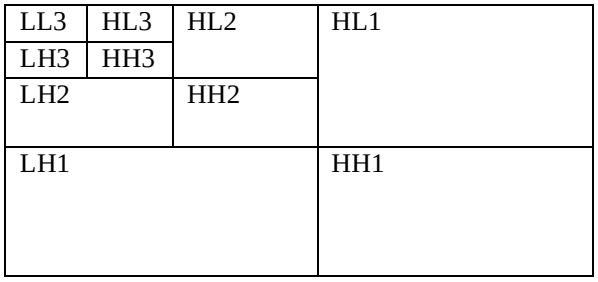

Fig. 10 DWT Subband analysis is for level 3

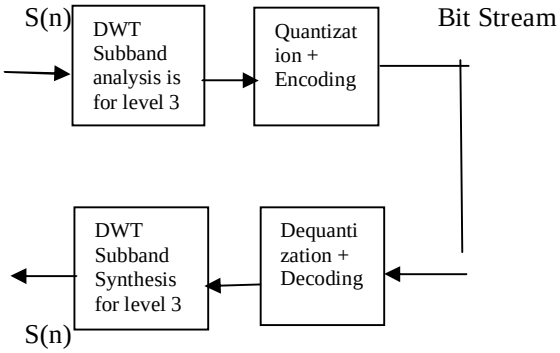

Fig. 11 Three Level Image Compression System using DWT

IV. COMPARATIVE ANALISIS

TABLE IV
COMPARISON OF TRANSFORMS

Transform	Basic Properties	Characterizes
Fourier	Sines +Cosines	Not localized in space Localized in Frequency
Gaussian Pyramid	Gaussian Filters	Localized in space Not localized in Frequency
Laplacian Pyramid	Laplacian Filters	Localized in space Not localized in Frequency
Wavelet Pyramid	Wavelet Filters	Localized in space Localized in Frequency

TABLE V
COMPARISON OF WAVELETS FAMILY

Type	Advantage	Disadvantage	Property Support	Application
Haar	First, ,Fast and Simple, Memory efficient	Discontinuous and does not approximate continuous signal very well	Orthogonal, Symmetric	Modern Camera with high resolution
Daubechiess	Compact, Supported	no explicit expressions and can only be calculated through recursion	orthonormal	solving a broad range of problems, e.g. self-similarity properties of a signal or fractal problems, signal discontinuities, texture feature analysis
Biorthogonal Wavelet	More design freedom for analyzing and synthesis of wavelet	is a very restrictive request, it cannot be fulfilled for the odd number of dilatation equation coefficients, e.g. the linear spline and matched wavelet	symmetry	Study of atmospheric layer turbulence.
Coiflet wavelet	Compactly supported wavelets	There is no any formula for coiflets for arbitrary genus, and there is no formal proof of their existence for arbitrary genus at this time.	highest number of vanishing moments	fingerprint image compression
Symlet	different level of decompositi ons, so the filter order is going to increase, compression is increasing	visual quality of compressed image is degraded	"least asymmetric	Symlet Wavelet can be used with such functions as discreet wavelet transform and Wavelet Phi, etc

V. CONCLUSION

Now we conclude, our literature survey said that the math involved in compression and decompression of Wavelet based images (e.g. JPEG 2000) takes more computational cost (meaning decompression take longer time). The literature analyze that lossy compression approach is not feasible for medical image compression, but still radiologist want some advantage like high degree of compression and better perceptual quality compare to lossless compression. In day to day life medical professional required pre and post compression for examining patient images. So, qualitative approach is important than quantitative approach. Lastly the discussed DWT and subband coding method is an efficient method of compression. But when the level of decomposition is increase pixel resolution is decrease in newly created subband.

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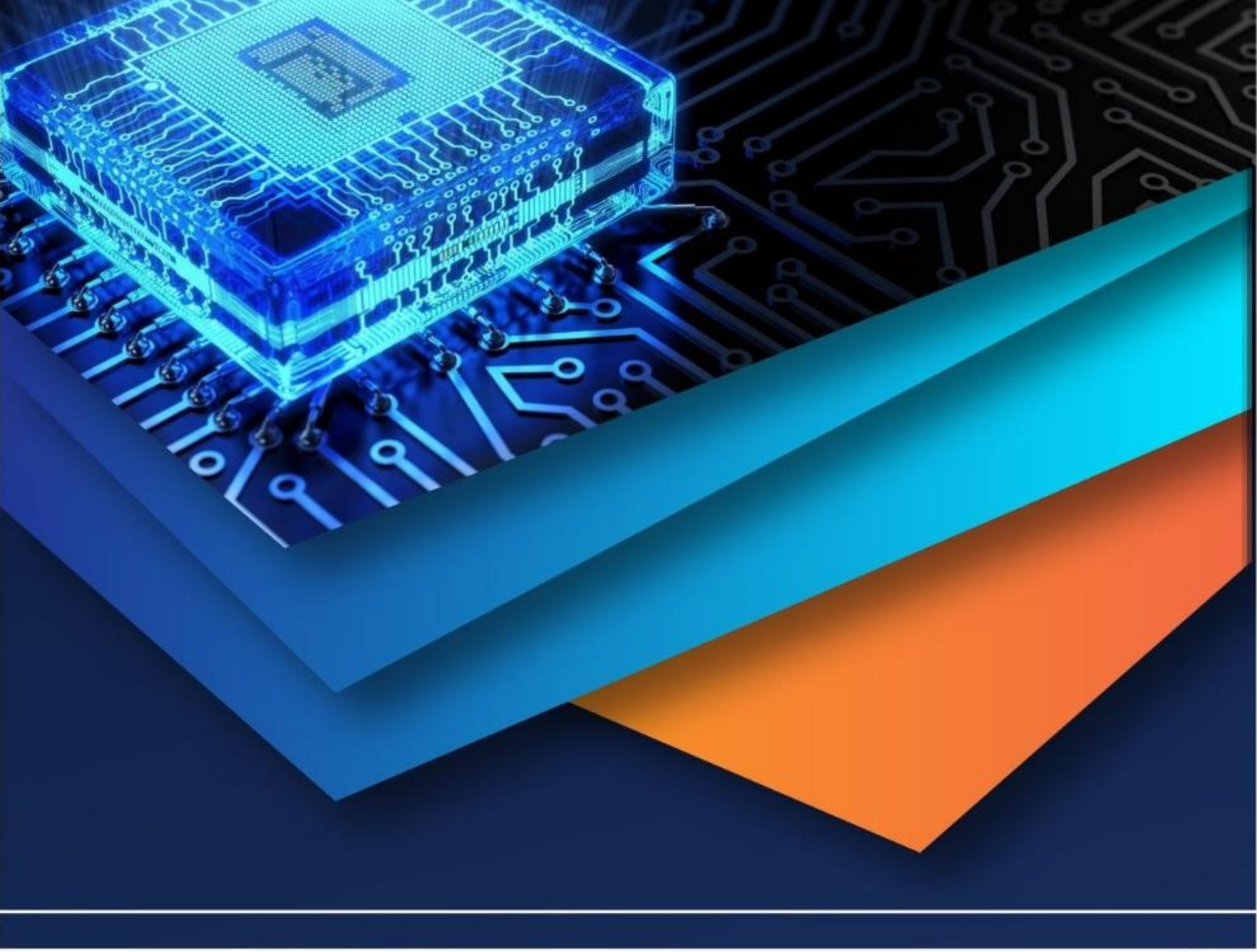

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