iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** XII **Month of publication:** December 2017

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor :6.887
Volume 5 Issue XII December 2017- Available at www.ijraset.com

Information Hiding in Image using Combined Approach of Pixel Mapping Method and Pixel Value Differencing Method

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Abstract: The staggering growth in communication technology and usage of public domain channels has greatly facilitated the transfer of data. However, such open communication channels have greater vulnerability to security threats causing unauthorized information access resulting popularity of Information Hiding over the past few decades. The security and fair use of the information with guaranteed quality of services is important, yet challenging topics. Steganography is an area of information hiding which means "secret or covered writing". In this paper, the authors have proposed an image based steganography technique for hiding information within the spatial domain of the grayscale image. The developed approach works by dividing the cover image into 3 by 3 blocks and then embeds the secret information in the difference of the 8-neighborhood pixels in the two adjacent blocks using 2-bit, 3-bit or 4-bit Pixel Mapping Method. Experimental results through qualitative and quantitative metrics show that the proposed approach has better embedding capacity compared to the original 2-bit or 4-bit Pixel Mapping Method and produces stego image with high imperceptibility.
Keywords: Pixel Mapping Method (PMM), Pixel Value Differencing (PVD), Steganography, Qualitative and Quantitative Similarity Metrics, Cover Image, Stego Image.

I. INTRODUCTION

Steganography is used to hide information inside other. The word steganography is derived from the Greek word, which literally means "Covered Writing" [1]. Steganography techniques allow communication between two certified users without an observer being responsive that the communication is actually happening. The useful steganography system must provide a method to embed data in an imperceptible manner, allow the data to be readily extracted, promote a high embedding capacity and incorporate a certain extent of robustness.

In this work the authors have presented an efficient image steganography method for hiding information with the extended approach of Pixel Mapping Method (2-bit or 4-bit) with a combination of Pixel Value Differencing method and try to incorporate a 2-bit, 3-bit, 4-bit PMM approach together to hide the information.

The rest of this paper is organized as follows: Section 2 introduces some data hiding methods in spatial domain. Section 3 and Section 4 deal with the proposed methodology and solution methodology. Section 5 contracts with algorithm and different experimental measures used to test the algorithm have shown in Section 6. Section 7 is compared with other existing steganography methods and the conclusion is drawn in Section 8.

II. REVIEW AND RELATED WORKS

A. Data Hiding through LSB

One of the most common techniques of data hiding is Least-significant-bit (LSB) [2] modification. It is done by replacing the LSB portion of the cover-image with message bits. LSB methods naturally accomplish high capacity embedding, but unluckily LSB insertion is exposed to slight image operation such as compression or cropping technique.

B. Gray Level Modification (GLM)

The GLM has proposed by Potdar et al.[3], which is a mapping technique used to modify the gray level value of the image pixels. Gray level modification Steganography is the technique to map data by modifying the gray level values of the image pixels without embedding or hide. GLM technique uses the scheme of odd and even numbers for mapping the data within an image. It is the one-to-one mapping concept among the binary data and selected pixels of the image. From a particular image, a set of pixels is chosen based on a mathematical function. The gray level values of those pixels are observed and compared to the bit stream that is to be mapped into the image. Gray level values of the selected pixels, i.e. the odd pixels are made even by changing the gray level by one unit. Once the entire selected pixel has an even gray level, it is compared with bit stream, which is to be mapped. If the bit is '0', then selected pixel is not modified. If the bit is '1', then the gray level value of selected pixel is decremented by '1' to make it odd.

C. Pixel Value Differencing

Wu and Tsai [4] proposed pixel-value differencing (PVD) method which can successfully provide both high embedding capacity and exceptional imperceptibility of the stego-image. This method segments the cover image into non overlapping blocks holding two connecting pixels and modifies the pixel difference in each block (in pair) for data embedding. A larger difference in the original pixel values permits a greater modification. In the extraction process, the original range table is indispensable. It is used to partition the stego-image by the same method as used in the cover image. Various diverse approaches have also been proposed based on this PVD method. Chang et al. [5] developed a new method using tri-way pixel-value differencing and this is better than original PVD method with respect to embedding capacity and PSNR value.

D. Pixel Mapping Method (PMM)

Pixel Mapping Method [6], [7] is a method developed for information hiding within the spatial domain of any gray scale image. Numbers of research work has been done in these methods. Embedding pixels are selected based on one mathematical function which is depending on the pixel intensity value of the seed pixel. The eight neighbors of the seed pixels are taken in a counterclockwise direction. Before embedding a checking has been done to find out whether the selected embedding pixels or its neighbors are lying at the boundary of the image or not. Data embedding is done by mapping pair of two or four bits from the secret message in each of the neighbor pixels with the help of some features of that pixel. Extraction process starts again by selecting the same seed pixels that were used in embedding. Reversal operations are carried out to get back the original message at the receiver side.

III. PROPOSED METHODOLOGY

The proposed method is a combination of Pixel Value Differencing (PVD) and Pixel Mapping Method (PMM) which significantly differs from both the conventional PVD and PMM methods. In this method, first the image is divided into some 3 by 3

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
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non-overlapping blocks. Then two consecutive, adjacent blocks are selected. The 8-neighbor pixels (P_i) of the first block is chosen in anti-clockwise direction, whereas for the other block, the neighbor pixels are selected in clockwise direction (P_i+1). The difference (d) between the pixel intensity values (8-neighbors) of the two adjacent blocks is determined as in PVD method. Embedding is done on the differences of the pixel values in PMM method. Initially, the difference of the intensities of the center pixels is determined. Depending on the difference value of the center pixels, it is decided whether 2-bit or 3-bit or 4-bit PMM would be implemented. Table 1 describes the decision of embedding bits.

TABLE I

DATA EMBEDDING TECHNIQUE DETERMINATION

Difference of center pixels	PMM
ODD	2-bit
PRIME	3-bit
EVEN	4-bit

Data embedding is done by mapping two or three or four bits of the binary form of secret message in the difference of the neighbor pixels established on some features of the difference value. Table 2, Table 3 and Table 4 shows the mapping information for embedding two bits, three bits and four bits respectively.

TABLE II

PIXEL MAPPING TECHNIQUE FOR TWO BITS

MSG BIT	PIXEL INTENSITY VALUE	NO.OF ONES(BIN)
00	EVEN	EVEN
01	EVEN	ODD
10	ODD	EVEN
11	EVEN	EVEN

TABLE III

PIXEL MAPPING TECHNIQUE FOR THREE BITS

MSG BIT	2^{ND} SET-RESET BIT	PIXEL INTENSITY VALUE	NO.OF ONES(BIN)
000	EVEN	EVEN	EVEN
001	EVEN	EVEN	ODD
010	EVEN	ODD	EVEN
011	EVEN	ODD	ODD
100	ODD	EVEN	EVEN
101	ODD	EVEN	ODD
110	ODD	ODD	EVEN
111	ODD	ODD	ODD

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TABLE IV
PIXEL MAPPING TECHNIQUE FOR THREE BITS

MSG BIT	3RD SET-RESET BIT	2ND SET-RESET BIT	PIXEL INTENSITY VALUE	NO.OF ONES(BIN)
0000	EVEN	EVEN	EVEN	EVEN
0001	EVEN	EVEN	EVEN	ODD
0010	EVEN	EVEN	ODD	EVEN
0011	EVEN	EVEN	ODD	ODD
0100	EVEN	ODD	EVEN	EVEN
0101	EVEN	ODD	EVEN	ODD
0110	EVEN	ODD	ODD	EVEN
0111	EVEN	ODD	ODD	ODD
1000	ODD	EVEN	EVEN	EVEN
1001	ODD	EVEN	EVEN	ODD
1010	ODD	EVEN	ODD	EVEN
1011	ODD	EVEN	ODD	ODD
1100	ODD	ODD	EVEN	EVEN
1101	ODD	ODD	EVEN	ODD
1110	ODD	ODD	ODD	EVEN
1111	ODD	ODD	ODD	ODD

After embedding the difference of the 8-neighbors get modified. The modified difference is d'. The difference of the gray value is then adjusted in each pixel pair (each from different block) so that the difference value causes unnoticeable and imperceptible changes.

B. Mathematics Schemes

$$
\begin{aligned}
P_i^{'} &= p_i; m = 0 \\
P^{'}_{i+1} &= p_{i+1}; m = 0 \\
P^{'}_{i} &= p_i - m; m > 0, p_i > p_{i+1} \\
P^{'}_{i} &= p_i + abs(m); m < 0, p_i > p_{i+1} \\
P^{'}_{i+1} &= p_{i+1} - m; m > 0, p_i < p_{i+1} \\
P^{'}_{i+1} &= p_{i+1} + abs(m); m < 0, p_i < p_{i+1}
\end{aligned}
$$

……………………………………….(1)

where, m=d-d'; $P_i^{'}$ and $P^{'}_{i+1}$ are modified pixel values after adjustment of the modified difference value.

The extraction procedure starts by choosing the same seed pixels that were used during embedding. The reverse operations are carried out to get back the original information on the receiver zone. Fig.1 and Fig.2 illustrate the block diagram of proposed methodologies.

IV. SOLUTION METHODOLOGY

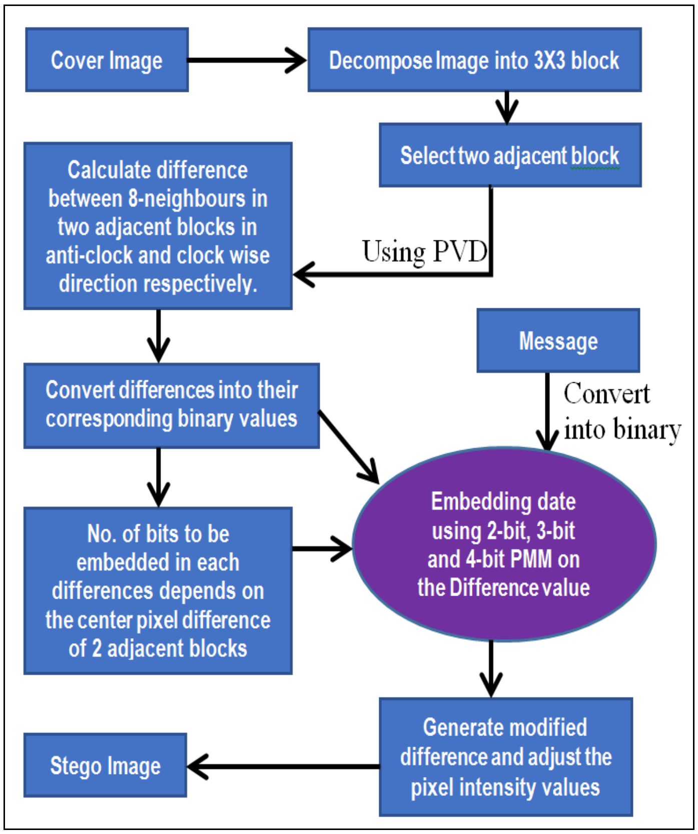


Fig.1 Sender side block diagram of proposed method

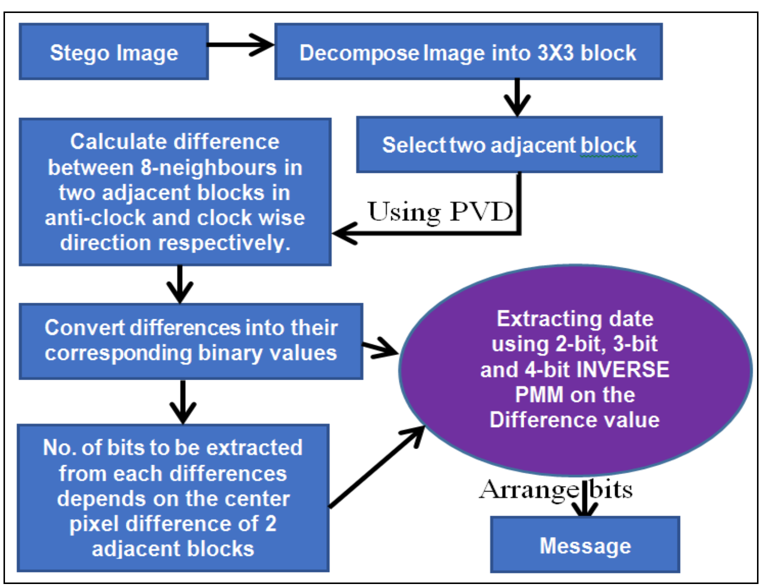


Fig.2 Receiver side Block diagram of proposed method

A. Let's consider this 9X9 Cover Image

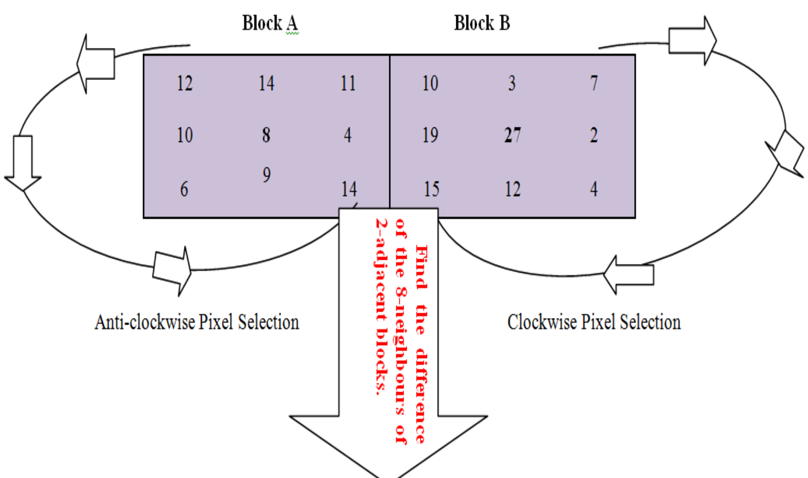
12	14	11	10	3	7	9	5	13
10	**8**	4	19	**27**	2	31	**17**	15
6	9	14	15	12	4	11	34	17
Block A			**Block B**			**Block C**		
21	16	11	19	13	5	8	7	18
32	**28**	8	2	**10**	7	26	**9**	24
13	28	8	3	18	11	25	3	4
Block D			**Block E**			**Block F**		
15	30	2	7	9	8	20	11	5
18	**35**	11	5	**8**	10	32	**14**	12
11	7	3	5	18	6	4	2	10
Block D			**Block E**			**Block F**		

Fig.3 9X9 Cover Image

B. The Image is divided into some 3 by 3 non-overlapping blocks. Then two adjacent blocks (A&B, D&E and G&H) are selected.

C. The secret message is "GOD BLESS U CHILD". Its binary form is 010/001/110/101/000/001/000/100/0100/0010/0100/1100/0100/0100/0101/0100/01/01/01/00/01/ 01/01/10.

D. Now finding the differences of Pixel Intensity Values of neighboring pixels (Fig.4).



Difference of pixel intensity values					Binary Form
12	-	7	=	5	00000101
10	-	2	=	8	00001000
6	-	4	=	2	00000010
9	-	12	=	3	00000011
14	-	15	=	1	00000001
4	-	19	=	15	00001111
11	-	10	=	1	00000001
14	-	3	=	11	00001011

Fig.4 Block wise difference of cover image

The difference of the center pixels is found out i.e. 8-27=19, which is a prime number. So 3-bit secret message embedding will be done in the difference of the 8-neihbours of the two adjacent blocks. So 010 is embedded in 00000101(5) to produce 00000001 i.e Similarly in all other seven differences the rest of the bits will be embedded. The modified differences are 1, 8, 7, 4, 0, 8, 0, and 12 respectively.

E. Adjustments

1) Case1**:** $m = d - d' = 5 - 1 = 4$;as m>0 and $P_i > P_{i+1}$

So, $P'_i = P_i - m = 12 - 4 = 8$

2) *Case:* $m = d - d' = 8 - 8 = 0$; so no adjustment is required.

Similarly the adjustments are done for all the 8 cases.

F. Now getting the modified blocks (fig.5)

Block A			Block B		
8	15	10	10	3	7
10	**8**	4	12	**27**	2
9	9	14	14	13	4

Fig.5 Modified block of cover image

G. The stego image is now sent to the receiver side where the reverse operations are performed to find the hidden message. Initially, the difference of the center pixels is found out = 8-27=19, which is a prime number. So 3-bit will be extracted from the difference of the 8-neighbors of two adjacent blocks according to the rule shown in Table 1.

H. Now finding the differences of Pixel Intensity Values of neighboring pixels and the hidden message are found using the table 5.

I. Now getting the entire secret message by assembling all the bits. The binary form is as follows:-

010/001/110/101/000/001/000/100/0100/0010/0100/1100/0100/0100/0101/0100/01/01/01/00/01/01/01/10

The message deciphered is: “GOD BLESS U CHILD”. Fig.6 shows the cover and stego for this development.

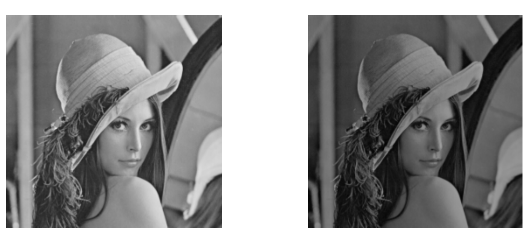


Fig. 6 Cover and Stego

TABLE V

HIDDEN MESSAGE EXTRACTION PROCESS

Difference of pixel intensity values					Pixel Intensity Value	Binary Form	NO.OF ONES (BIN)	2nd SET-RESET Bit	Extracted 3-Bit
8	-	7	=	1	ODD	00000001	EVEN	EVEN	010
10	-	2	=	8	EVEN	00001000	ODD	EVEN	001
9	-	4	=	5	ODD	00000101	EVEN	ODD	110
9	-	13	=	4	EVEN	00000100	ODD	ODD	101
14	-	14	=	0	EVEN	00000000	EVEN	EVEN	000
4	-	12	=	8	EVEN	00001000	ODD	EVEN	001
10	-	10	=	0	EVEN	00000000	EVEN	EVEN	000
15	-	3	=	12	EVEN	00001100	EVEN	ODD	100

V. ALGORITHMS

The proposed approach is a spatial domain approach and it has been used in grayscale images. The different algorithms used in approach are shown below:

A. Algorithm for Data Embedding

1) Divide a grayscale image into 3 by 3 non-overlapping blocks and select two adjacent blocks from the left side simultaneously.

2) Consider the difference between each 8-neighbors of one block in anticlockwise direction with each 8-neighbors of another block in clockwise direction.

3) The no. of bits to be embedded in each of the difference of the value depends on the difference of center pixels of the two adjacent blocks.

4) Convert the difference values into their corresponding binary values.

5) Select a secret message and convert it into its binary form.

6) Map 2-bit or 3-bit or 4-bit of the binary form of secret message in every difference of the neighboring pixels based on intensity value, no. of one's (in binary), 2nd set-reset and 3rd set-reset bit present in that difference value.

7) Modified difference will be generated. Adjust it in two neighbor pixel pair each belonging from one of two consecutive blocks and obtain the modified blocks.

8) Repeat the process for all the adjacent blocks and obtain the stego image.

B. Algorithm for Data Extraction

1) Select the stego image and divide into 3 by 3 non-overlapping blocks. Select two adjacent blocks from the left side simultaneously.
2) Consider the difference between each pixel intensity value of one block in anticlockwise direction with each pixel intensity value of another block in clockwise direction.
3) The no. of bits to be extracted from each of the difference of the value depends on the difference of center pixels of the two adjacent blocks.
4) Convert the difference values into their corresponding binary values.
5) Match the binary value of the differences with the properties of its corresponding PMM table and obtain corresponding 2 bits or 3 bits or 4 bits of the binary form of secret message.
6) Arrange the obtained bits in an orderly manner and get the required secret information.

VI. RESULTS AND ANALYSIS

In this section the authors have presented experimental results of the proposed method based on two benchmark techniques for evaluating the hiding performance. First one is the data hiding capacity and the second one is the imperceptibility of the stego image. The quality of the stego image should be acceptable to human eyes. The experiments have been performed on two well-known images: Lena and Pepper. The quality of the stego images created by the developed method has been tested by different qualitative and quantitative similarity metrics. The quantitative values are illustrated in Table.5.

A. Qualitative Similarity Metrics

The quality of stego image produced by the proposed methods and the stego image has been tested thorough statistical parameters like Mean, Standard Error Mean, Tr Mean, Standard Deviation, Variance, CoefVar, Sum, Sum of Squares, First quartile (Q1), Median (Q2), Third quartile (Q3), Range, Interquartile (IQR), Mode, N for Mode, Skewness, Kurtosis, MSSD, Covariance etc. Then examined the relative error for the steganography methods with respect to embedding rate of each methods by calculating the parameters value. Relative errors are plotted on a graph and it shows that the error rate of developed method is less than the LSB and PVD method. The quality of the steganography approach is depending upon the relative error graph. When the relative error is less than or equal to the others method, the performance is better.

B. Mathematical Schemes

E_{st} = Statistical parameters, R_{err} = Relative Error

Calculate E_{st} and $E_{Average} = Average(E_{st})$

Estimate the relative error $R_{err} = \dfrac{Stego\,(E_{Average}) - Cover\,(E_{Average})}{Cover\,(E_{Average})}$ ....(2)

All these $R_{err} \in (0,1)$. Here Stego denotes the statistical parameter values of each methods and Cover denotes the cover image

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used in this method.

Plot the R_{err} in a graph.

Table 6 illustrates the parameter values as well as relative error. In the equation "2", Stego denotes the statistical parameter values of LSB, PVD and PMM Variable Bit. Figure 7 shows the graph that shows the relative errors.The details of the tests are discussed below:

1) *Mean:* In statistics and probability, the mean [8] is used to denote one measure of the central tendency either of a probability distribution or random variable which is characterized by distribution. For a data set, the mathematical expectation, arithmetic mean and at times average are used to refer to a central value of a discrete set of numbers: definitely, the sum of the values divided by the number of values. For a finite population, the population mean of a property is equal to the arithmetic mean of the given property while considering every member of the population. For example, the population mean height is equal to the sum of the heights of every individual divided by the total number of individuals. The sample mean may differ from the population mean, especially for small samples. The law of large numbers dictates that the larger the size of the sample, the more likely it is that the sample mean will be close to the population mean.
2) *Standard Error Mean:* The standard error (SE) [9] is the standard deviation of the sampling distribution of a statistic, most commonly of the mean. The term may also be used to refer to an estimate of that standard deviation, derived from a particular sample used to compute the estimate.
3) *Trimmed Mean:* A truncated mean or trimmed mean [10] is a statistical measure of central tendency, much like the mean and median. It involves the calculation of the mean after discarding given parts of a probability distribution or sample at the high and low end, and typically discarding an equal amount of both. This number of points to be discarded is usually given as a percentage of the total number of points, but may also be given as a fixed number of points.
4) Standard Deviation: In statistics, the standard deviation [11] (SD, also represented by the Greek letter sigma, σ) is a measure that is used to quantify the amount of variation or dispersion of a set of data values. A standard deviation close to 0 indicates that the data points tend to be very close to the mean (also called the expected value) of the set, while a high standard deviation indicates that the data points are spread out over a wider range of values.
5) *Variance:* In probability theory and statistics, variance [12] measures how far a set of numbers is spread out. A variance of zero indicates that all the values are identical. Variance is always non-negative: a small variance indicates that the data points tend to be very close to the mean (expected value) and hence to each other, while a high variance indicates that the data points are very spread out around the mean and from each other.
6) *Coefficient of Variation:* In probability theory and statistics, the coefficient of variation (CV) [13] is a standardized measure of dispersion of a probability distribution or frequency distribution. It is defined as the ratio of the standard deviation σ to the mean μ. It is also known as unitized risk or the variation coefficient. The absolute value of the CV is sometimes known as relative standard deviation (RSD), which is expressed as a percentage. The coefficient of variation (CV) is defined as the ratio of the standard deviation σ to the mean μ

$$c_v = \frac{\sigma}{\mu}$$

7) *Quartile:* In descriptive statistics, the quartiles [14] of a ranked set of data values are the three points that divide the data set

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into four equal groups, each group comprising a quarter of the data. A quartile is a type of quantile. The first quartile (Q_1) is defined as the middle number between the smallest number and the median of the data set. The second quartile (Q_2) is the median of the data. The third quartile (Q_3) is the middle value between the median and the highest value of the data set.

In applications of statistics such as epidemiology, sociology and finance, the quartiles of a ranked set of data values are the four subsets whose boundaries are the three quartile points. Thus an individual item might be described as being "in the upper quartile".

a) First quartile (designated Q_1) also called the lower quartile or the 25th percentile (splits off the lowest 25% of data from the highest 75%)
b) Second quartile (designated Q_2) also called the median or the 50th percentile (cuts data set in half)
c) Third quartile (designated Q_3) also called the upper quartile or the 75th percentile (splits off the highest 25% of data from the lowest 75%)
d) Interquartile range (designated IQR) is the difference between the upper and lower quartiles. (IQR = Q_3 - Q_1)

8) Range: In arithmetic, the range [15] of a set of data is the difference between the largest and smallest values. However, in descriptive statistics, this concept of range has a more complex meaning. The range is the size of the smallest interval which contains all the data and provides an indication of statistical dispersion. It is measured in the same units as the data. Since it only depends on two of the observations, it is most useful in representing the dispersion of small data sets.

9) Mode: The mode [16] is the value that appears most often in a set of data. The mode of a discrete probability distribution is the value x at which its probability mass function takes its maximum value. In other words, it is the value that is most likely to be sampled. The mode of a continuous probability distribution is the value x at which its probability density function has its maximum value, so, informally speaking, the mode is at the peak.

10) Skewness: In probability theory and statistics, skewness [17] is a measure of the asymmetry of the probability distribution of a real-valued random variable about its mean. The skewness value can be positive or negative, or even undefined. The qualitative interpretation of the skew is complicated. For a unimodal distribution, negative skew indicates that the tail on the left side of the probability density function is longer or fatter than the right side – it does not distinguish these shapes. Conversely, positive skew indicates that the tail on the right side is longer or fatter than the left side. In cases where one tail is long but the other tail is fat, skewness does not obey a simple rule. For example, a zero value indicates that the tails on both sides of the mean balance out, which is the case both for a symmetric distribution, and for asymmetric distributions where the asymmetries even out, such as one tail being long but thin, and the other being short but fat. Further, in multimodal distributions and discrete distributions, skewness is also difficult to interpret. Importantly, the skewness does not determine the relationship of mean and median.

11) Kurtosis: In probability theory and statistics, kurtosis [17] (from Greek: κυρτός, kyrtos or kurtos, meaning "curved, arching") is any measure of the "peakedness" of the probability distribution of a real-valued random variable. In a similar way to the concept of skewness, kurtosisis a descriptor of the shape of a probability distribution and, just as for skewness, there are different ways of quantifying it for a theoretical distribution and corresponding ways of estimating it from a sample from a population. There are various interpretations of kurtosis, and of how particular measures should be interpreted; these are primarily peakedness (width of peak), tail weight, and lack of shoulders (distribution primarily peak and tails, not in between).

12) MSSD: The mean of the squared successive differences (MSSD) [18] is used as an estimate of variance. It is calculated by taking the sum of the differences between consecutive observations squared, then taking the mean of that sum and dividing by

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two. Two common applications are: Basic Statistics - A common application for the MSSD is a test to determine whether a sequence of observations is random. In this test, the estimated population variance is compared with MSSD. Control Charts - MSSD can also be used to estimate the variance for control charts when the subgroup size is 1.

13) *Covariance:* In probability theory and statistics, covariance [19] is a measure of how much two random variables change together. If the greater values of one variable mainly correspond with the greater values of the other variable, and the same holds for the smaller values, i.e., the variables tend to show similar behavior, the covariance is positive. In the opposite case, when the greater values of one variable mainly correspond to the smaller values of the other, i.e., the variables tend to show opposite behavior, the covariance is negative. The sign of the covariance therefore shows the tendency in the linear relationship between the variables. The magnitude of the covariance is not easy to interpret. The normalized version of the covariance, the correlation coefficient, however, shows by its magnitude the strength of the linear relation.

TABLE VI

RELATIVE ERROR OF STATISTICAL PARAMETERS FOR LSB, PVD & PMM VARIABLE BIT

	Relative Error			Error Change Rate		
Embedding Rate	LSB	PVD	PMM Variable Bit	LSB	PVD	PMM Variable Bit
0.01	0.594135	0.594145	0.594132	-	-	-
0.02	0.594137	0.594147	0.593864	0.000330457	0.000330452	-0.045127106
0.03	0.594139	0.594149	0.59394	0.000330454	0.000330449	0.012793753
0.04	0.59414	0.59415	0.593941	0.000165365	0.000165362	0.000165417
0.05	0.594141	0.594151	0.593943	0.000248028	0.000248024	0.000248116
0.06	0.594144	0.594154	0.593946	0.000495448	0.00049544	0.000495604
0.07	0.594145	0.594155	0.593996	0.000248109	0.000248104	0.008500794
0.08	0.594147	0.594157	0.593998	0.000248009	0.000248005	0.000248077
0.09	0.594151	0.594161	0.594001	0.000660326	0.000660314	0.000660489
0.10	0.594157	0.594167	0.594008	0.001072732	0.001072714	0.001073002
0.20	0.618186	0.614178	0.60789	4.044193122	3.36791274	2.337099567
0.30	0.643722	0.644226	0.618369	4.130839167	4.892384589	1.723758207
0.40	0.67025	0.671285	0.624742	4.121022483	4.200281168	1.03054472
0.50	0.701124	0.701328	0.633479	4.606251606	4.475347783	1.398625563
0.60	0.730485	0.729378	0.647099	4.187745064	3.99951526	2.149919873
0.70	0.764325	0.759445	0.654036	4.632494072	4.122372437	1.07213002
0.80	0.798682	0.794491	0.661533	4.495126382	4.614706708	1.146205085
0.90	0.833222	0.824524	0.676717	4.324619269	3.780116807	2.295205632
1.00	0.867316	0.861552	0.691837	4.091835981	4.490828953	2.23431625

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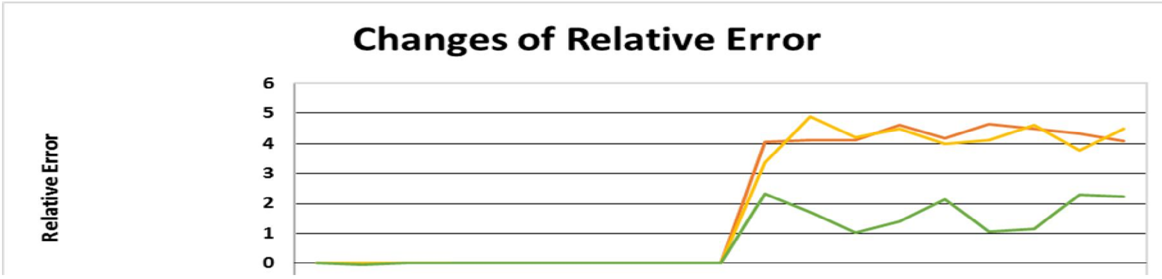

It has been observed that the developed method is robust and secure, which has been verified with the help of relative error graph and various statistical parameters. Thus the developed method works better than LSB, PVD mechanisms.

C. Quantitative Similarity Metrics

1) *Peak Signal-to-Noise Ratio (PSNR):* A mathematical extent of image quality is Signal–to-noise ratio (SNR) [20], which is based on the pixel difference between two images [21]. The SNR measure the estimate of Stego image and cover image. PSNR is shown in equation (3).

$$PSNR = 10\log_{10}\frac{S^2}{MSE} \qquad (3)$$

Where, S is for the maximum possible pixel value of the image. When the PSNR is greater than 36 DB, the visibility looks same in between the cover and stego image; in that case the HVS is not identifying the changes.

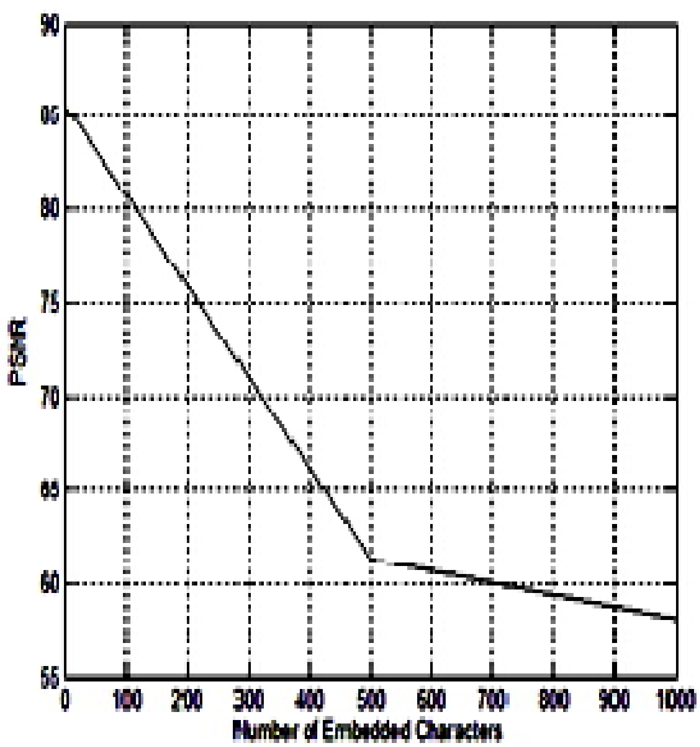

Fig. 8 Graphical representation of PSNR

2) *Mean Square Error (MSE):* It is computed by averaging the squared intensity of the cover and stego image pixels [20]. The equation (4) and fig.9 shows the MSE.

$$MSE = \frac{1}{NM}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} e(m,n)^2 \text{.................}(4)$$

Where NM is the image size (N x M) and e(m,n) is the reconstructed image.

Root Mean Square Error (RMSE): RMSE [22] is a frequently used measure of difference in between Cover and Stego intensity values. These individual differences called residuals and RMSE aggregate them into a single measure of analytical power. The RMSE shows in equation (5) and fig.9.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i} - X_{model,i})^2}{n}} \text{....}(5)$$

X_{obsi} and X_{modeli} are two image vectors, i.e. cover and stego

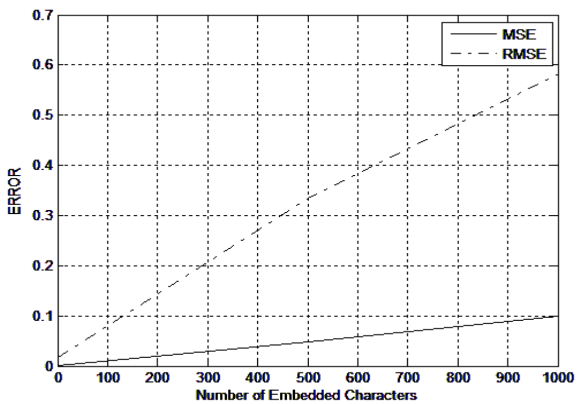

Fig. 9: Graphical representation of MSE and RMSE

3) *Correlations:* Pearson's correlation coefficient [23] is widely used in statistical analysis as well as image processing. Here to apply it in, Cover and Stego image, to see the difference between these two images. The Correlation shows in equation (6) and fig.10.

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})\cdot(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \cdot \sum_{i=1}^{n}(y_i - \bar{y})^2}} \text{.........}(6)$$

The X_i and Y_i are the cover image and bar of X and Y are stego image positions.

4) *Structural Similarity Index (SSIM):* Wang et. al[24], proposed Structural Similarity Index [21] concept between original and distorted image. The Stego and Cover images are divided into blocks of 8 x 8 and converted into vectors. Then two means and two standard derivations and one covariance value are computed. After that the luminance, contrast and structure comparisons based on statistical values are computed. Then The SSIM computed between Cover and Stego images. SSIM shows in equation (7) and fig.10.

$$SSIM = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\mu_x^2 + \mu_y^2 + C_2)} \text{.....}(7)$$

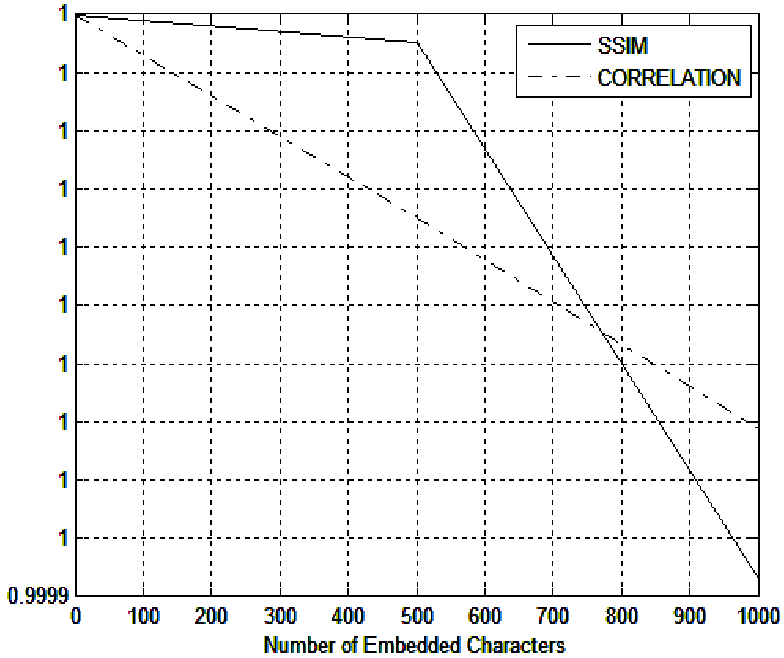

Fig. 10 Graphical representation of Correlation and SSIM

5) *KL divergence:* With the help of probability density function (PDF) for each Image (cover and stego) estimating the Kullback-Leibler Divergence [25]. KL divergence shows in equation (8) and fig.11.

$$D(p\,||\,q)=\sum_{x} p(x)\log\frac{p(x)}{q(x)} \qquad \text{..........}(8)$$

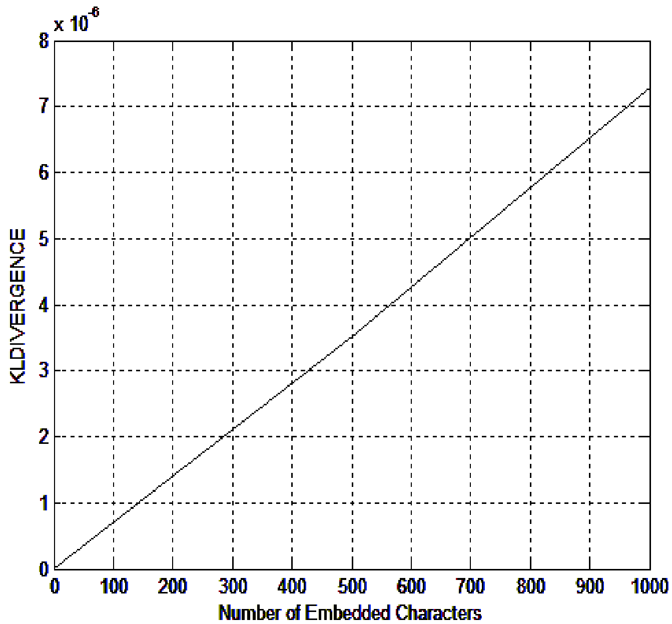

Fig. 11: Graphical representation of Kullback-Leibler Divergence

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor :6.887
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TABLE VII

VARIOUS IMAGE SIMILARITY METRICS FOR THE PROPOSED METHOD

Images	Metrics	Length of Embedding Character					
		100	500	1000	10000	15000	20000
Lena 512*512	PSNR	68.5963	61.25872	58.1536	47.3525	45.4913	44.0919
	MSE	0.009	0.0486641	0.0995	1.1963	1.8363	2.5345
	RMSE	0.1114	0.335352	0.5823	5.6511	8.5742	11.3996
	SSIM	1	0.9999976	1	0.9978	0.9968	0.9958
	Correlation	1	0.9999826	1	0.9996	0.9993	0.9991
	KL divergence	6.81E-07	3.52E-06	7.28E-06	1.12E-04	1.70E-04	2.42E-04
	Entropy	7.42E-05	7.42E-05	7.42E-05	7.42E-05	7.42E-05	7.42E-05
Lena 256*256	PSNR	62.4378	54.5582	51.3446	40.0599	N/A	N/A
	MSE	0.0371	0.2276	0.4771	6.4135	N/A	N/A
	RMSE	0.1986	0.8059	1.732	18.9569	N/A	N/A
	SSIM	1	0.9987	0.9962	0.9689	N/A	N/A
	Correlation	1	1	1	0.9988	N/A	N/A
	KL divergence	1.76E-06	1.11E-05	2.51E-05	4.41E-04	N/A	N/A
	Entropy	0	0	0	0	N/A	N/A
Lena 128*128	PSNR	54.9411	47.3213	43.9515	N/A	N/A	N/A
	MSE	0.2084	1.2049	2.6177	N/A	N/A	N/A
	RMSE	0.5378	2.594	5.3829	N/A	N/A	N/A
	SSIM	0.9997	0.9944	0.9903	N/A	N/A	N/A
	Correlation	1	0.9998	0.9995	N/A	N/A	N/A
	KL divergence	1.06E-05	7.35E-05	1.49E-04	N/A	N/A	N/A
	Entropy	0	0	0	N/A	N/A	N/A

TABLE VIII

COMPARISON OF EMBEDDING CAPACITY

IMAGE	IMAGE SIZE	PVD	GLM	AHMAD et al.	PMM(2 bit)	Proposed Method
Lena	512*512	50960	32768	40017	45340	58254
	256*256	**	8192	10007	10012	14564
	128*128	**	2048	2493	2393	3641
Pepper	512*512	50685	32768	39034	46592	58254
	256*256	**	8192	9767	11694	14564
	128*128	**	2048	2443	2860	3641

TABLE IX

COMPARISON OF PSNR VALUES BETWEEN PMM 4-BIT AND PROPOSED METHOD

Image	PSNR		
	Character length	PMM(4 bit)	Proposed Method
Lena512*512	100	63.4131	68.5963
	500	59.309	61.2563
	1000	56.309	58.1536
	10000	47.7562	50.0027
	15000	44.5811	47.3525
	20000	41.3445	44.0919

6) *Entropy:* Entropy [26] is a measure of the uncertainty associated with a random variable. Here, a 'message' means a specific realization of the random variable. The equation (9) and fig.12 shows it.

$$\Delta S = \int \frac{dQ_{rev}}{T} \text{......(9)}$$

Where, S is the entropy and T is the uniform thermodynamic temperature of a closed system divided into an incremental reversible transfer of heat into that system (dQ).

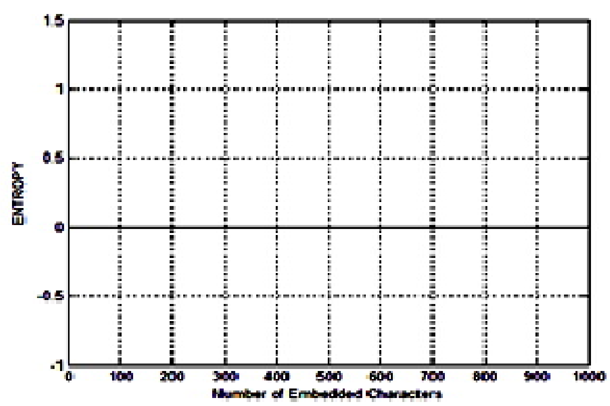

Fig.12 Graphical representation of Entropy

VII. COMPARISON WITH EXISTING METHODS

A comparative study of the proposed methods with some other existing methods like PVD, GLM and the methods proposed by Ahmad T et al. is discussed in this section. TABLE VIII shows the comparison of different methodologies with the help of embedding capacity.

TABLE IX shows the comparison of PSNR values of PMM (4 bit) and the proposed method.

VIII. CONCLUSION

A new and efficient steganography method for embedding secret messages in grayscale images has been proposed here. The experimental results through qualitative and quantitative similarity metrics clearly indicate that the embedding capability of this method is much higher than both conventional PMM and PVD methods. In future authors will work on biometric steganography using the variable embedding technique using PMM two, three and four bit simultaneously.

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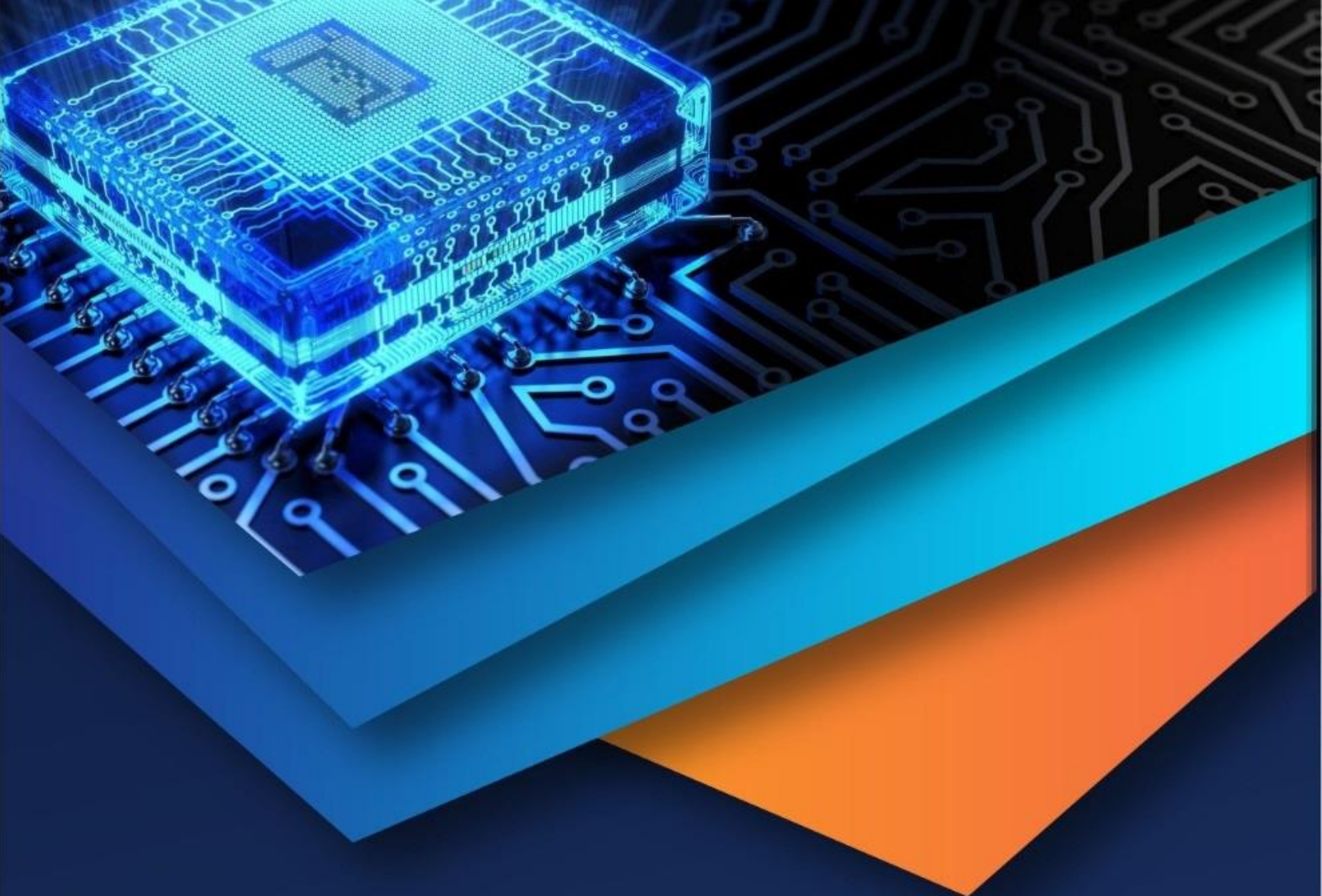

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