iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** IV **Month of publication:** April 2017

DOI: http://doi.org/10.22214/ijraset.2017.4082

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Volume 5 Issue IV, April 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

A Steganographic Technique using Reverse-S-Space Filling Curve

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Abstract: ***A space-filling curve (SFC) maps the multi-dimensional space into the one-dimensional space. Mapping the multi-dimensional space into one-dimensional domain plays an important role in many application. For embedding the secret data in an image, Reverse-S-space filling curve can be used. This paper proposes a technique of steganography in which the information is hidden exclusively in the form of images, where it adopted Multi-dimensional Surface Fitting (MSF), the technique is based on the essentials of secret codes written in MATLAB.***
Keywords: Space-filling curve, Steganography, Multi-dimensional Surface Fitting, Reverse-S-SFC, Secret data.

I. INTRODUCTION

The rise of the Internet one of the most important factors of information technology and communication has been the security of information. In the image data-hiding area numerous methods have been developed for embedding message data within visual information with the idea to make it undetectable and an integral part of the cover image. [1]

In general, random embedding scheme requires a specific key with variable size to retrieve the embedded confidential data at the receiving end. In order to overcome this drawback, the concept of space filling curve (SFC) has been adapted for embedding the secret data in an image where reverse-s-space filling curve is used. Space-filling curve will be used to go through the image pixel values.

II. STEGANOGRAPHY AND SPACE FILLING CURVE

Steganography is the art and science of invisible communication. Its aim is the transmission of information embedded invisibly into carrier data. The goal of steganalysis is to discover steganographic alterations to carrier data. In image steganography the information is hidden exclusively in images. [2]

Basically, the purpose of steganography is to provide secret communication. Steganography can be used to cloak hidden messages in image, audio and even text files. Breaking a steganographic system needs the attacker to detect that steganography has been used and he is able to read the embedded message. In addition, the security of classical steganography system relies on secrecy of the data encoding system.[11] [13]

Space-filling curve is a continuous curve in that passes through every point of the unit square $[0,1] \times [0,1]$. A space-filling curve can be thought of as a map from one-dimensional space onto a higher-dimensional space. There are different types of space filling curve which holds the various properties. Peano curve was the first type of space filling curve and following that other curves evolved. [3][4]

A. Properties of Space-Filling Curve

The important properties of space-filling curves are as follows. These properties are not shared by all space-filling curves, in particular the properties do not hold for the Lebesgue curve. [5-7]

1) *Holder Continuity:* A map $f: I \subset R \rightarrow R^d$ is called Holder continuous of order $1/k$ (or short Holder-$1/k$) with Holder constant c_f ifor all $s, t \in I$

$$||f(s) - f(t)|| \leq c_f |s - t|^{1/k}$$

This property is also referred to as Lipschitz continuity. Space-filling curves in dimension d are typically Holder-1/d. [8]

2) *Nowhere Differentiability:* The Hilbert curve, the Moore curve, the Peano curve, and the Sierpinski curve are nowhere differentiable. But, the Lebesgue curve is differentiable almost everywhere, since the Cantor set has measure 0.
3) *Bi-Measure-Preserving Property:* By its recursive construction the Hilbert curve maps an interval to a region with an area equal to the length of the interval. In general we have for d-dimensional Hilbert curves that for any Borel set $A \subset [0; 1]$

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Volume 5 Issue IV, April 2017
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$$\lambda_1(A) = \lambda_d(\Psi_d(A))$$

where λ_1 and λ_d denote the one- and d-dimensional measure, respectively.[14]

4) Dilation and Translation Property: If we consider the second step of the recursive construction of the Hilbert curve, we see that the Hilbert curve starts with a scaled copy of itself, followed by several translated and rotated copies. In general, a space-filling curve Ψ has the dilation property and the translation property if there is a $p \geq 2$ such that for all s; $t \in [0; 1]$

$$||\Psi(s) - \Psi(t)|| = \sqrt{p}\,||\Psi(s/p) - \Psi(t/p)\ ||$$

And for all $1 \leq t \leq p$ and $s, t \in [(i-1)/p, i/p]$

$$||\Psi(s) - \Psi(t)|| = ||\Psi(s + {}^{1}/_{p}) - \Psi(t + {}^{1}/_{p})||$$

B. Reverse-S Space-Filling Curve

The reverse S space-filling curve is the improved version of the left-to-right-top- to-bottom space-filling curve. The most important characteristic is that the path goes through neighbouring pixels only. This path offers the ideal conditions for the histogram modification data hiding algorithm based on the adjacent pixel difference. [10]

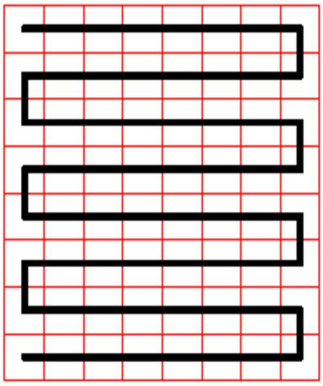

Fig1: Reverse-S-SFC

Assuming that the curves fill a square area with size equal to n. Furthermore, the length of a path ***P*** is the sum of the Euclidean distance between the neighbouring pixels, i.e., the total distance a cursor would travel, if they were following the iteration through the image pixels. The path length in pixels is measured through the following formula is

$$P = (n-1)(n+1)$$

III. PROPOSED ALGORITHM

In this section, an algorithm has been presented. The development of an algorithm is based on Reverse-S-SFC. The decoding is difficult for the third party.

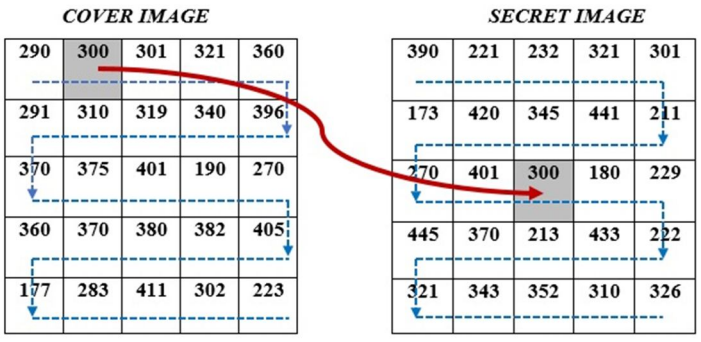

Fig: 2 Multi-dimensional Surface Fitting

A. Encoding Process

In this approach, we take two images for the purpose of steganography using Reverse-S-SFC. Flower image is an original image

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which refers to as cover or carrier image. Baby image is a secret image to embed within cover image and Fig: 1 is an image of Reverse-S-SFC which is used to identify location on the image. Using Multi-dimensional Surface Fitting (MSF) technique (Fig: 2) helps to embed the secret image within cover image. The process of encoding is explained in pseudo code.

1) Pseudo Code for Encoding:

STEP 1: Get the cover image and secret image.
STEP 2: Generating the Reverse-S-Space filling curve to identify the targeted region.
STEP 3: Using the Multi-dimensional surface fitting technique, pixel of cover image is embedded over secret image which having the same pixel value.
STEP 4: Encoded image was obtained.

B. Decoding Process

In the extraction process, the encoded image has taken and recognize targeted region by generating Reverse-S-SFC and extracting the image by using again the MSF technique. Pseudo code of decoding process is shown below. Thus the image is decoded. All this process is done using image processing tool of MATLAB.

1) Pseudo Code for Decoding:

STEP 1: Get the encoded image.
STEP 2: Generate the Reverse-S-Space filling curve to identify the embedded pixel.
STEP 3: By using the Multi-dimensional surface fitting technique, it will replace the embedded pixel to the appropriate place.
STEP 4: Decoded image 1 and decoded image 2 were obtained.

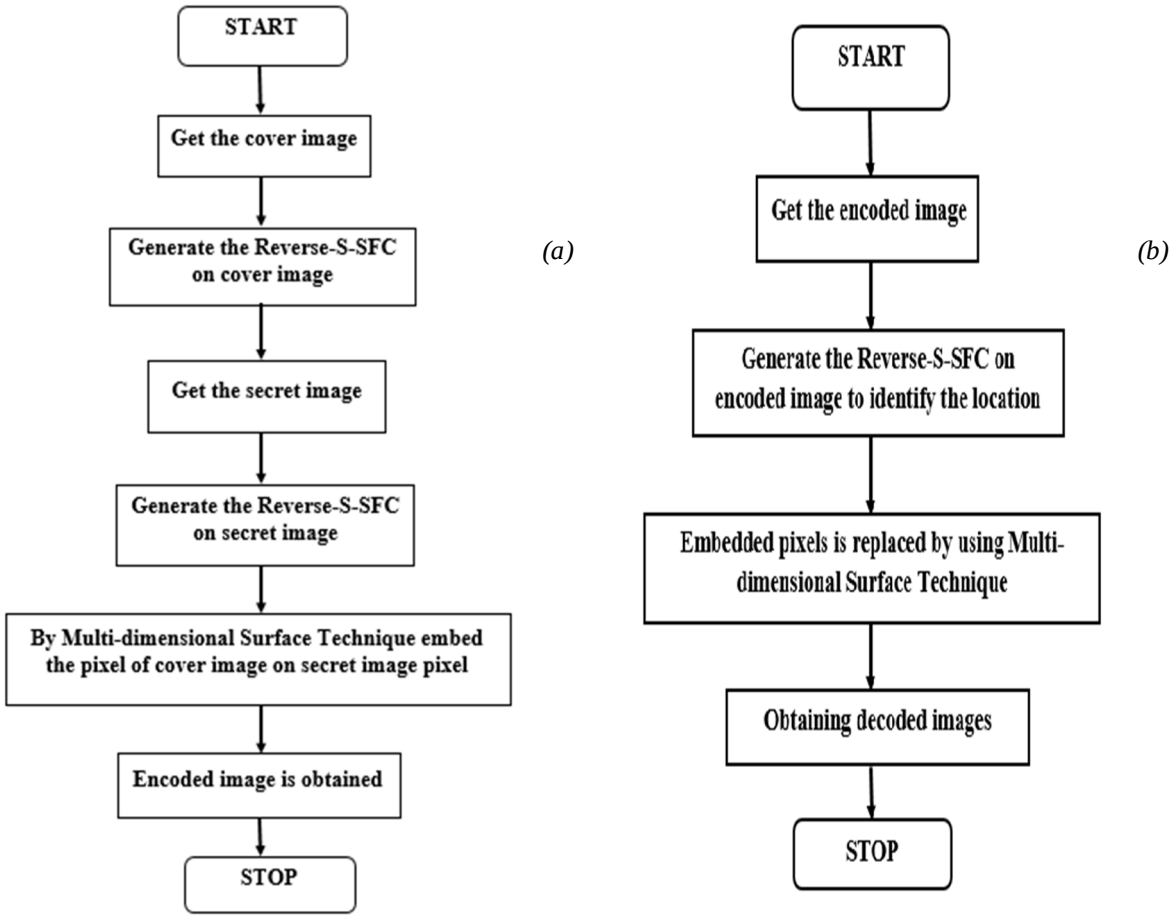

Fig: 3(a) Flow chart for encoding process, 3(b) Flow chart for decoding process

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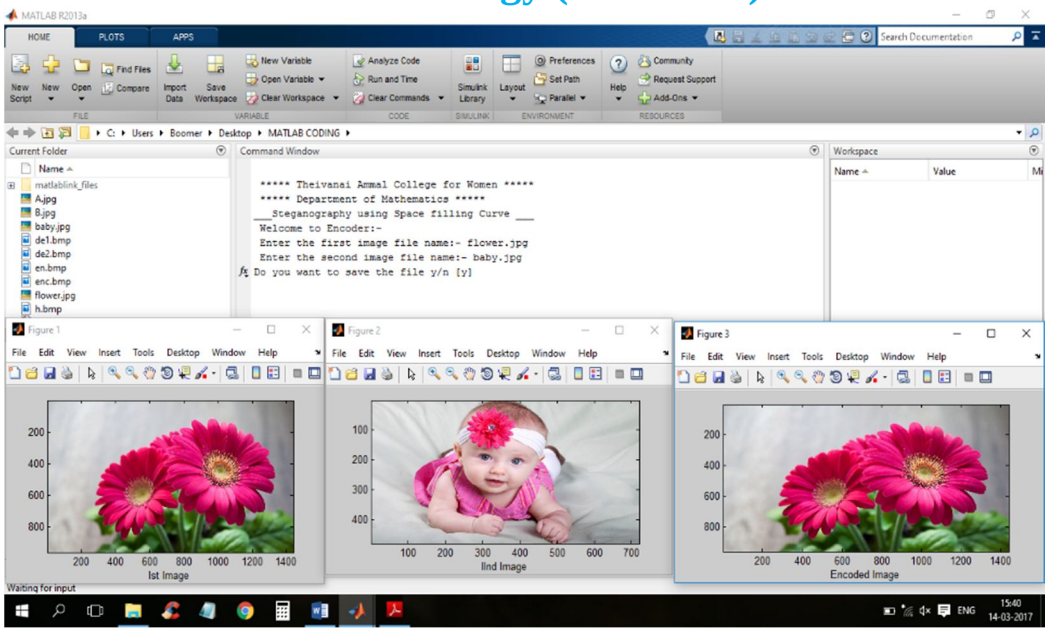
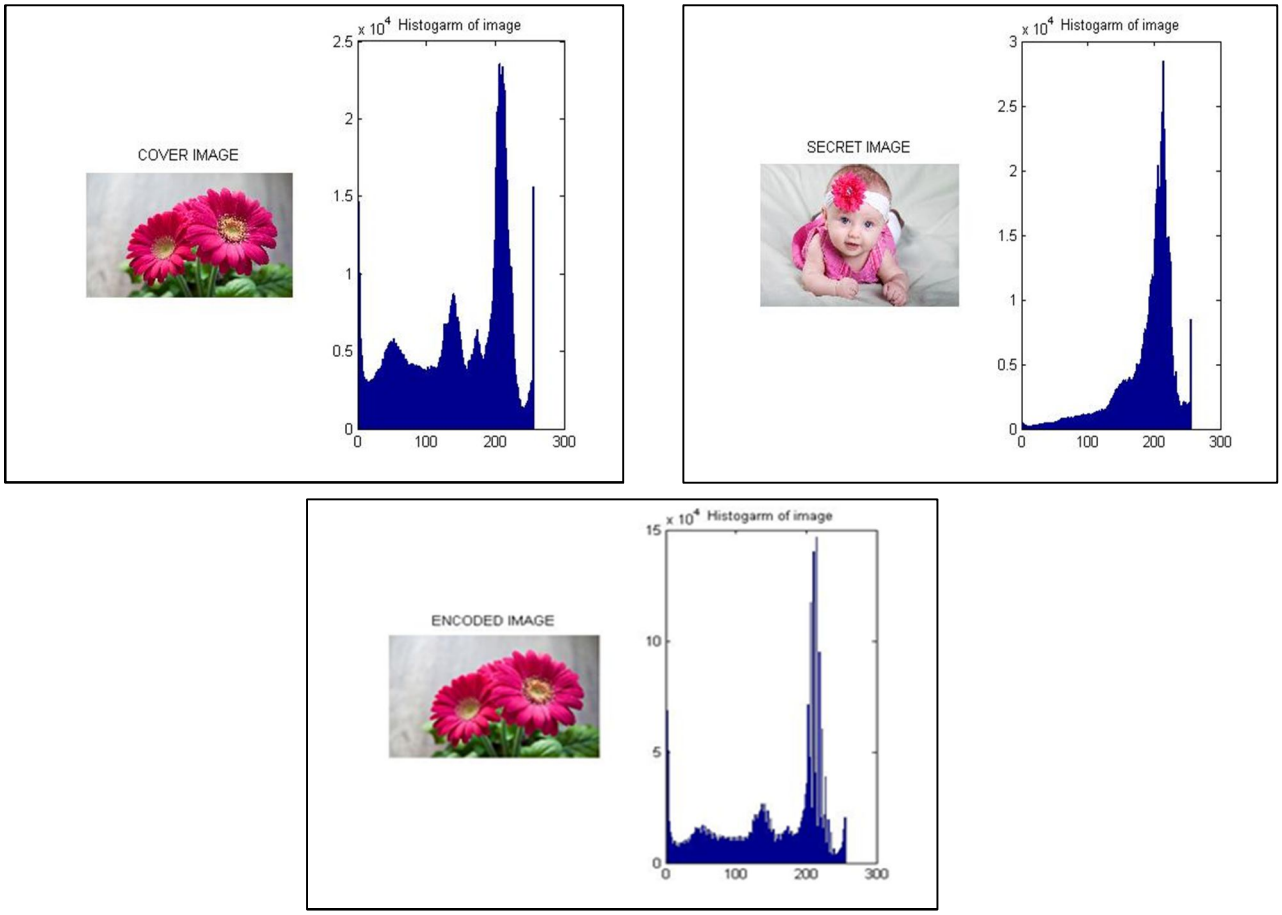


Fig: 4 Encoded image

(a) (b)



(c)

Fig: 5 Histogram of image: 5(a) Flower image as cover image, 5(b) Baby image as secret image, 5(c) Encoded image

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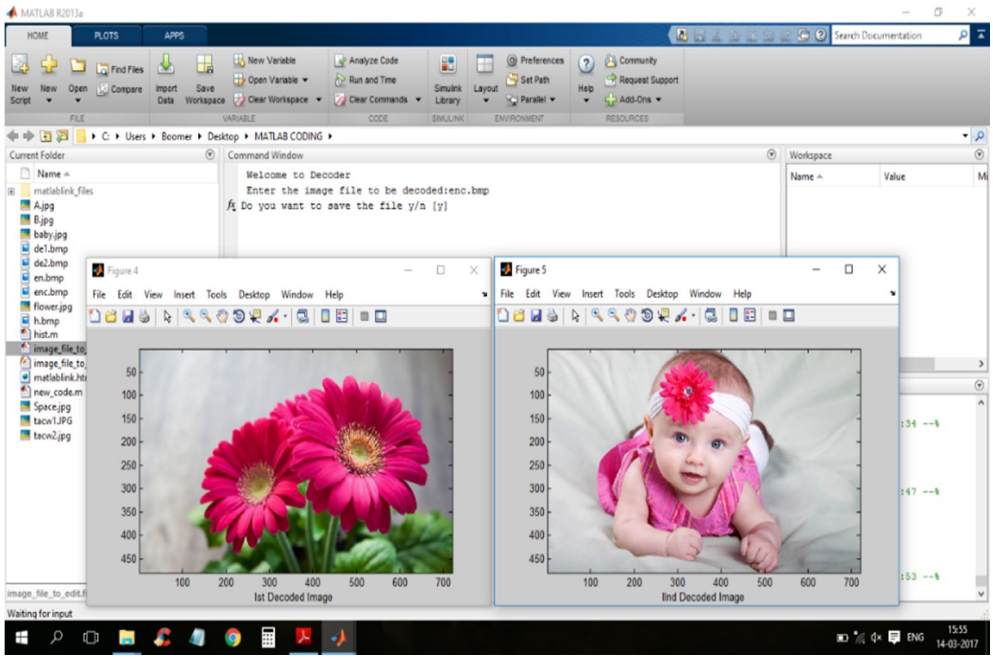
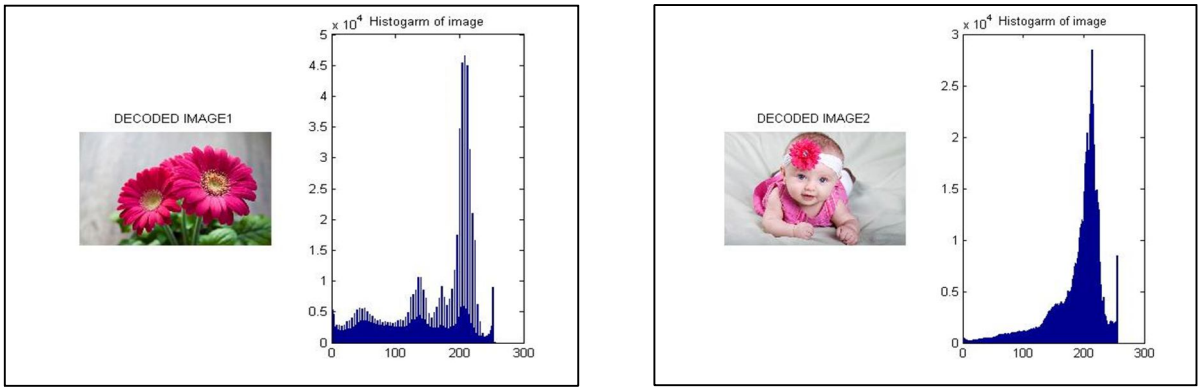


Fig: 6 Decoded image



(a) (b)

Fig: 7 Histogram of image: 7(a) Decoded image1, 7(b) Decoded image2

IV. CONCLUSION

Steganography is a very useful technique for providing information security. In the above article, potential space filling curve has been adopted along with steganography to hide an image behind another image. It is difficult for third party to go for brute force attack and differential attack. In our future work, we are planning to provide information security using various types of space filling curve with multiple orders.

V. ACKNOWLEGMENT

The authors are thankful to the referees for their valuable comments and suggestions for improving this paper.

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Volume 5 Issue IV, April 2017
ISSN: 2321-9653

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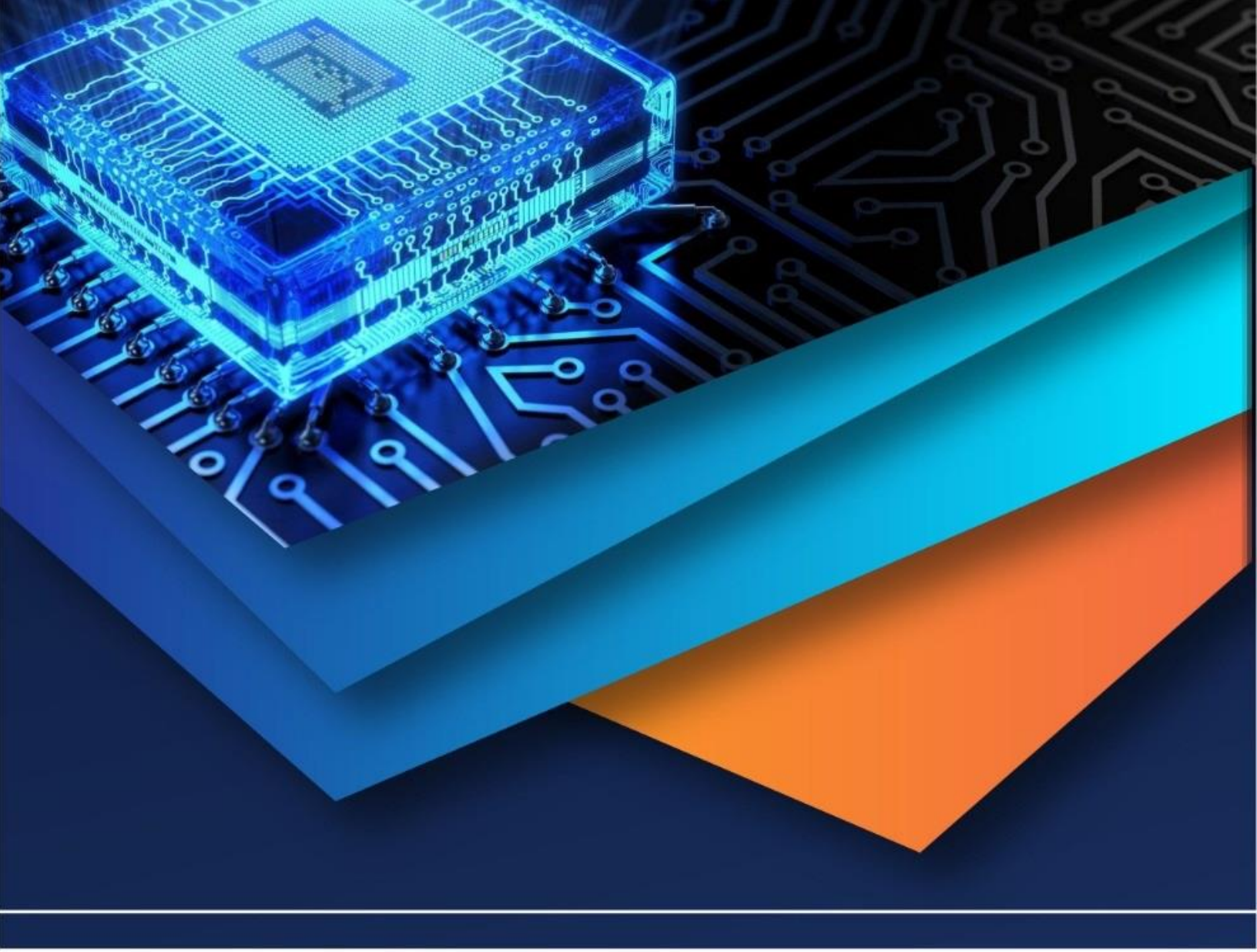

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