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# Estimation of Mango Tree Count and Crown Cover Delineation using Template Matching Algorithm

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***Abstract: Light detection and Ranging (LiDAR) nowadays is becoming a widely used tool in forest inventory management. LiDAR data has three dimensional structure information that can be used to estimate tree height and crown diameter, the use of this available LiDAR information, availability of image processing software and well developed algorithm allow us to estimate and detect individual tree counts. Several algorithms were developed for different types of remote sensing images, and were tested in different forest areas. However, there were very few studies testing an algorithm in tree crop plantations due to the problems in detecting individual trees affected by varying conditions such as different size of canopy of young and old trees, clumped or clustered trees which sometimes lead to underestimation. This paper aims to estimate the number of trees using LiDAR data and high resolution imagery using a single detection method. The study was conducted in Mangifera indica plantation. The study area is composed of young and matured mango trees having different tree crown size, the planting orientation of mango in the area also vary from isolated and clustered mango tree crown which is a challenge in detecting individual trees. Template matching method in eCognition Developer 9 was applied to different layers derived from point cloud data and high resolution image. Canopy Height Model (CHM) was found to be the optimal layer in creating template sample based on the correlation value of 0.94. The results demonstrated that template matching algorithm can detect the mango tree crowns with 88 % accuracy based on the reference data which is manually delineated. This study suggests that template matching algorithm can be used to estimate mango tree counts. Further study is needed to further improve the algorithm to increase the percent detection. The study also suggested that the method be tested in other types of plantation.***

***Keywords: Canopy Height Model (CHM), Light Detection and Ranging (LiDAR), Mangifera indica, Orchard, Template Matching Method***

## I. INTRODUCTION

Tree crown detection is an important field in remote sensing research because it provides a means in vegetation distribution mapping, vegetation density estimation, vegetation change monitoring and species classification [1]. Modern forest management requires that forest resources are efficiently managed, not only for timber production, but also for maintaining biodiversity and meeting wildlife, environmental, and recreational needs [2]. In addition to forest inventory, it is also used in flight obstacle mapping, power line mapping, real state visualization and mapping, and telecommunication planning [3]. An orchard is a plantation of trees of the same species and often of the same age. Consequently, trees in orchards usually have similar sizes and shapes and are regularly spaced. The task of estimating fruit production generally implies counting trees, a time consuming task that could benefit from the use of the very high resolution (VHR) satellite images, but also the near-global high resolution image coverage such as in Google-Earth and other internet-based image services [4]. The tree inventory in orchards is of great interest for orchard management and for government insurance plans. However, the conventional inventory is time-consuming and expensive [5]. The use of Remote Sensing such as Lidar technology and development of efficient algorithm can be adapted to estimate and detect individual tree counts of orchards. This paper aims to estimate the number and delineate trees crowns using LiDAR data and high resolution imagery using a single detection method.

## II. OBJECTIVES

The objective of the study is to estimate the number and delineate tree crowns of mango plantation using Template Matching Algorithm.

## III.MATERIALS AND METHODS

### *A. Location of the Study*

The selected study area was a mango plantation which is composed of young and matured, isolated and clustered mango trees. The area is mostly a flat terrain, the distribution of mango trees were somewhat diverse in terms of crown size, spacing, growth stages

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and planting orientation. The main tree crop is mango; however a number of non-agricultural trees are also present and sporadically distributed in the area. The area is located in Brgy. Salagusog Cuyapo, Nueva Ecjia (15$^o$ 14' 13.09" N, 120$^o$ 14' 13.81") with an area of 1.16 km$^2$ (Figure 1).

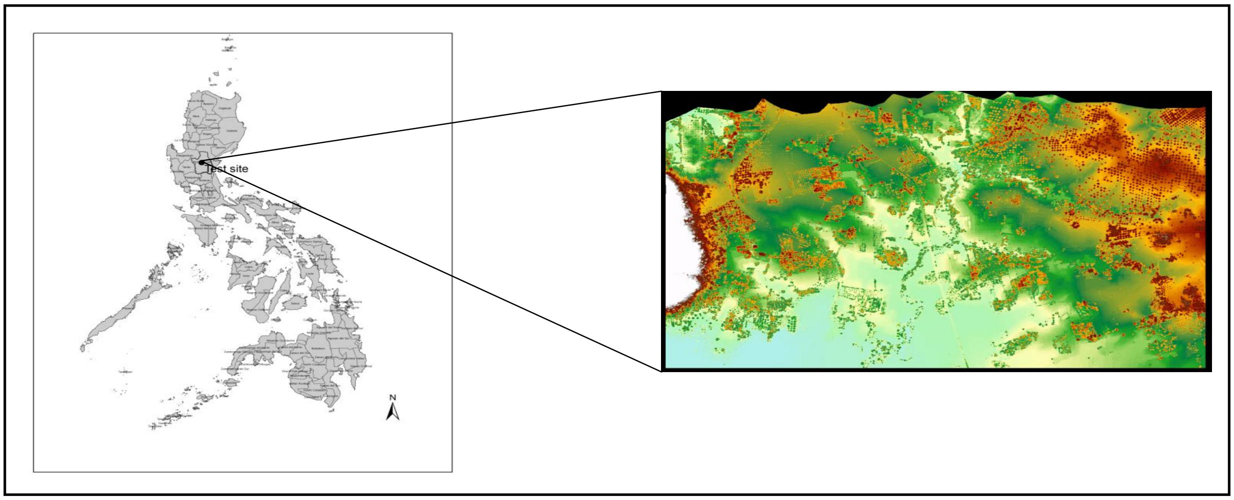


Fig. 1. Location of the test site and color coded digital surface model used in the study

*B. Data Sets and Processing of LiDAR Data*

1) *Data Sets:* LiDAR data and aerial images were acquired from Phil-LiDAR1 Data Acquisition Component.
2) *Processing of LiDAR data:* LiDAR point cloud derivatives were derived using LasTools, average intensity and number of returns were obtained using LasGrid, while, height information such as Digital Surface Model (DSM) and Digital Elevation Model (DEM) were derived using Blast2DEM, curvature was derive using 3D analysts tool in arcGIS while Canopy Height Model (CHM) was derived using LasTools pipeline toolbox in arcGIS. High resolution image with RGB bands were processed in Envi. GRVI (Green Red Vegetation Index) was also derived using the Ortho-image using band math equation as follows. The list of derivatives used and their corresponding descriptions were shown in Table 1.

$$GRVI = \frac{Green - Red}{Green + Red}$$

TABLE I

LIST OF DERIVATIVES USED FOR TREE CROWN EXTRACTION

| Data Sources | Derivatives | Description |
|---|---|---|
| LiDAR | Intensity | Created from the whole intensity spectrum of LiDAR point cloud. Generally, Objects with high reflectivity, have higher intensity than dark |
| LiDAR | Number of Returns | Created from number of return of LiDAR point clouds, useful in separating buildings and trees |
| LiDAR | Curvature | Second derivative of a surface or slope of the slope |
| LiDAR | nDSM | DTM subtracted from DSM to obtain the height of the objects above the |
| LiDAR | CHM | Canopy Height Model |
| LiDAR | Slope | Generated from LiDAR point clouds |
| Orthophoto | RGB | Original bands of the Orthophoto, show spectral properties of features |
| Orthophoto | HSV | Transformation applied to the original Orthophoto image in the HSV color |
| Orthophoto | GRVI | Useful for identifying vegetation and non-vegetation features |

*C. Image Processing and Analysis*

Every word in a heading must be capitalized except for short minor words as listed in Section III-B. Image analysis was carried out mainly in eCognition Developer 9 following the framework shown in Figure 4. LiDAR point cloud and aerial image derivatives

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were loaded in the software. Template samples were generated in different layers used. To build the models, various samples of mangoes were collected considering the different sizes, appearance and location within the test area (Figure 2). Two sets of group size were generated in creating the template and each correlation values were obtained to identify the optimal layer template to be used in detection and creating points of individual tree crowns (Figure 3), only one image derivative was used having the highest correlation value, after which, tall features were extracted using multi-threshold algorithm and segmented using multi-resolution segmentation to delineate individual tree crowns, then, classified using assigned class algorithm based on the points generated in template matching. To support the evaluation of the algorithm, reference data were generated using manual delineation using the high resolution image to count the actual number of trees followed by calculation of percent detected trees.

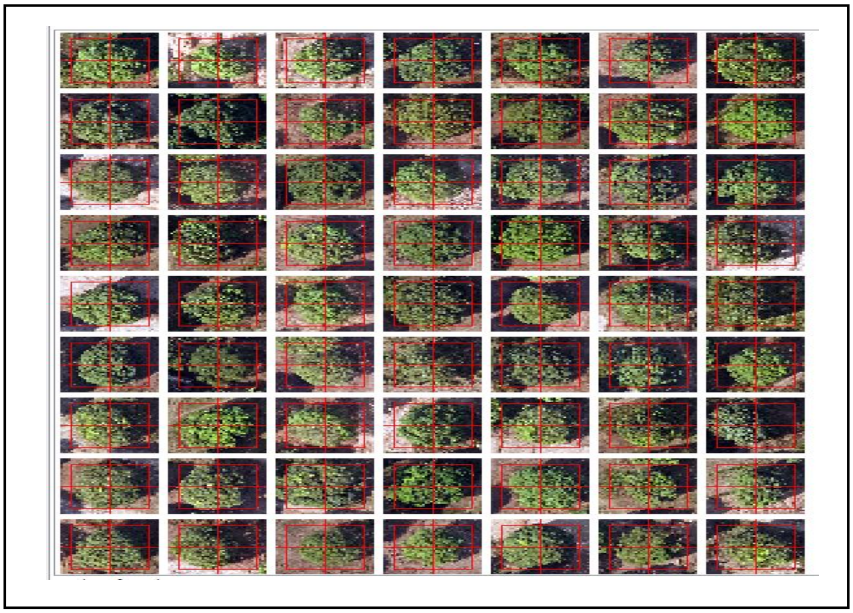

Fig. 2. Samples used to generate template

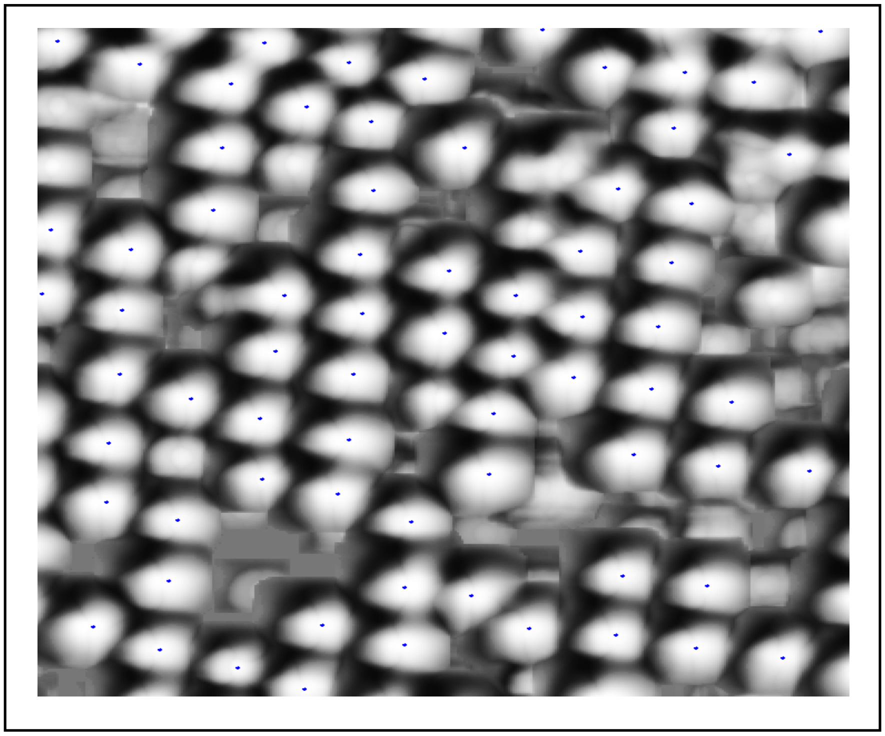

Fig. 3. Points generated per crown using CHM template

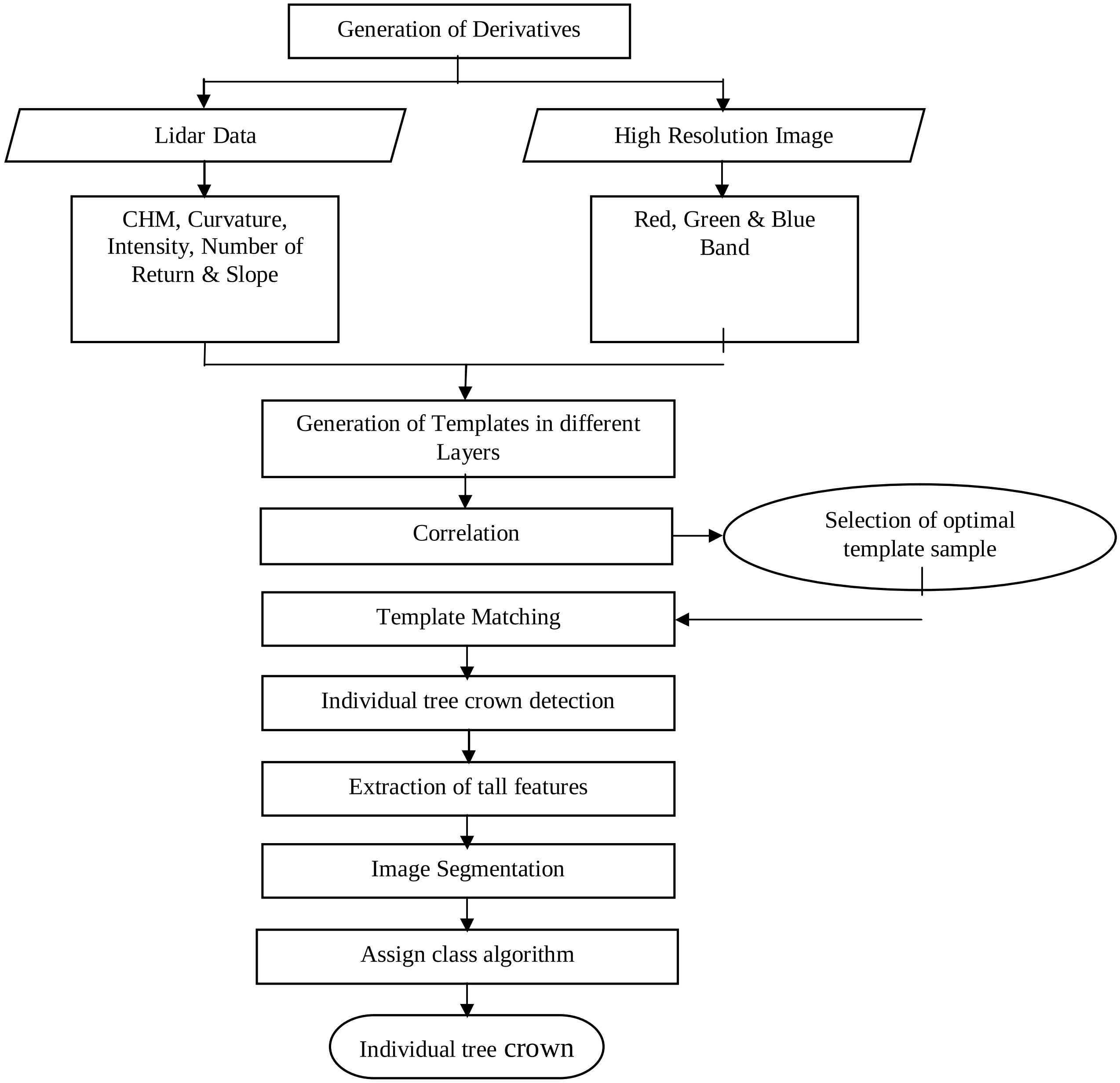


Fig. 4. The conceptual framework of the study

## IV. RESULTS AND DISCUSSION

The study was conducted in mango plantation, the study area is composed of young and matured mango trees having different tree crown size, the planting orientation of mango in the area also varies from isolated and clustered mango tree crowns which make detecting individual trees more challenging. To perform the main analysis, optimal layer derivatives was first identified by looking at the best correlation value. eCognition uses a correlation value ranging from 0 to 1 wherein the higher the value the higher the possibility of identifying the sample match. Correlation coefficient method computes global local position of the template in the scene image [6]. Correlation value of different template layers used was shown in Table 2. Two group size (0 and 3) were use in generating the templates, In terms of template groups, group size 3 was found to be efficient in generating the optimal template as all layer template in group size 3 were improved from 0.58 (slope) to 0.94 (CHM). While in terms of layers, CHM was found to be optimal wherein it has the highest correlation value in both group sizes. Reference [7] presented the individual-tree-based forest inventory using laser scanner tree finding maxima of the Canopy Height Model and segmentation for edge detection.

The Terrain Model (TM) method includes a model generation and a template matching procedure [8]. Intuitively, a series of models are built to characterize what a tree looks like at different locations in an image by taking into consideration both the trees geometric and radiometric properties [9]. Template matching algorithm was used in eCognition Developer 9 to different layers derived from point cloud data and high resolution image. Results of the automatic detection and delineation of individual mango tree crown was presented in Figure 4. Generated results were overlaid in CHM (a.) and Aerial Image (b.), it was clearly seen in the northeastern portion of the aerial image with significant number of mango trees that were missed by the algorithm, and this could be due to the clustering of mango trees while isolated mango were successfully classified. CHM with group size 3 was found to be the optimal layer in creating template sample based on the correlation value of 0.94. A total of 1,272 mango trees detected and delineated out of the total reference data of 1,431 mango trees (Table 3). The results demonstrated that template matching algorithm can detect the mango tree crowns with 88 % accuracy based on the reference data which is manually delineated.

TABLE 2
Correlation value of different template layer derivatives used in the study.

| Layers | Correlation Value | |
|---|---|---|
| | Group size 0 | Group size 3 |
| CHM | 0.89 | 0.94* |
| GRVI | 0.69 | 0.79 |
| Red | 0.59 | 0.65 |
| Green | 0.57 | 0.65 |
| Blue | 0.41 | 0.56 |
| Intensity | 0.39 | 0.53 |
| No. of Return | 0.17 | 0.56 |
| Curvature | 0.28 | 0.40 |
| Slope | 0.31 | 0.58 |

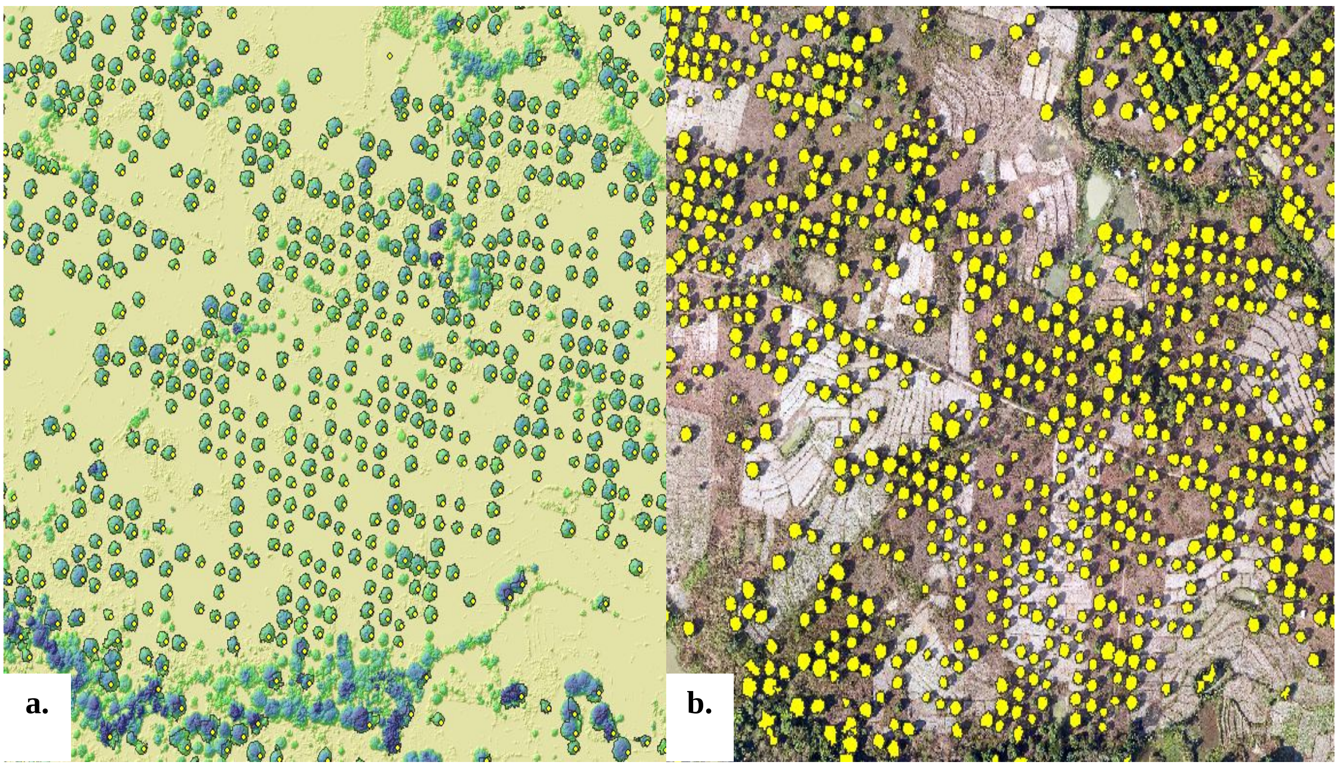


Fig. 4. Results of tree detection and delineation using template matching algorithm. a. shows the points generated in individual mango tree crowns overlaid in CHM; b. delineated mango tree crowns overlaid in Aerial Image.

TABLE 3.
No. of detected trees using template matching

| No. of Tree Crowns Detected | Reference Data | Percent Tree Detected |
|---|---|---|
| 1272 | 1431 | 88.89 |

## V. CONCLUSIONS AND RECOMMENDATION

This study shows that Template Matching Algorithm can be used to estimate mango tree counts. Further study is needed to further improve the algorithm to increase its accuracy. Also, it is suggested that the method be tested in other types of plantation crops. Furthermore, it also recommended to use negative templates to further complement the positive template used in the study.

## VI. ACKNOWLEDGMENT

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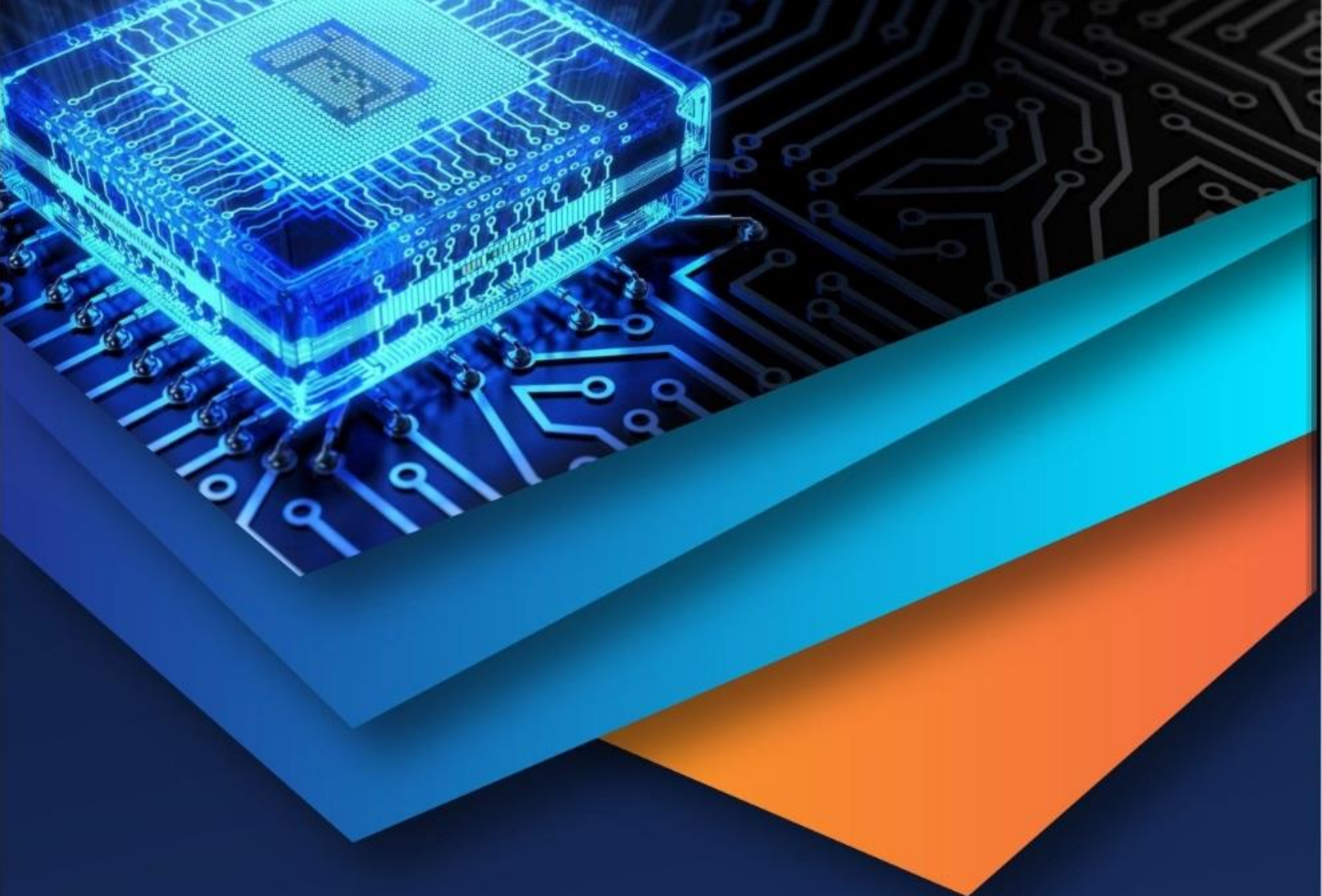


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