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A Comparison of Fuzzy C-Means and K-Means Clustering for Extraction of City Colours

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Abstract: ***The colour palette of each urban metropolis reflects its cultural identity and its unique flair. For urban development and urban renewal projects, incorporating a city's existing colour palette into a construction plan would ensure that the completed project would be in harmony with the existing colour schemes of a neighbourhood. An earlier investigation implemented Fuzzy C-Means (FCM) colour extraction to identify five dominant colours from the images of each of the twelve major cosmopolitan cities that are situated on six continents. These cities were Cairo, Cape Town, Singapore, Tokyo, Perth, Sydney, London, Madrid, Mexico City, New York City, Buenos Aires, and Lima. This current research is a follow-on investigation of the previous city colour extraction study. It applies K-Means clustering to acquire five dominant colours for each of these 12 cities. The goal of this current research is to determine if the type of clustering method implemented would impact the results of the extracted colours. This is accomplished by comparing the city colours obtained by executing the K-Means clustering technique on these 12 cities and comparing these colours with those that were obtained from the previous FCM study.***
Keywords: K-Means clustering, Fuzzy C-Means (FCM), colour extraction, hard clustering, soft clustering, urban metropolis, dominant colours, city colour palettes

I. INTRODUCTION

Colour extraction techniques are computer vision algorithms that identify dominant colours of a picture [1-2]. These techniques are employed in several applications, such as mobile phone app design, urban development and renewal, and colour quantization [3-7]. For mobile phone app design, colour extraction obtains dominant colours for user interfaces [3]. For urban development and urban renewal projects, incorporating extracted dominant colours of existing neighbourhoods in design plans would ensure that completed construction endeavours would be in harmony with a city's existing colour schemes so as to preserve its cultural identity [4]. Colour extraction is also employed for colour quantization to reduce the number of colours in an image thereby reducing its file size [5-7].
Dominant colours could be extracted from images by using clustering methods. These are unsupervised machine learning algorithms that group pixels into clusters of similar colours [8-9]. Each cluster is defined by a centroid that is one of the dominant colours of an image [10]. Clustering methods are divided into soft and hard clustering techniques [11]. Soft clustering techniques, such as Fuzzy C-Means (FCM) clustering, assign each pixel a probability of being in each cluster [12]. Hard clustering methods, such as K-Means clustering, classify each pixel as belonging to only one cluster. The relationship between these clustering techniques is shown in Fig. 1.

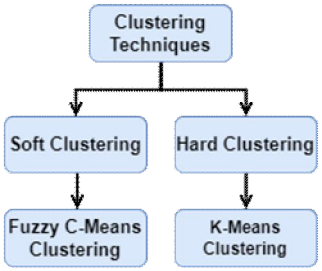

Fig. 1 Relationship Between Clustering Techniques

Previous research implemented FCM clustering to extract dominant colours from publicly available images of 12 cosmopolitan cities to determine if there were similarities in their colour palettes. These locations included Cairo, Cape Town, Singapore, Tokyo, Perth, Sydney, London, Madrid, Mexico City, New York City, Buenos Aires, and Lima. The hexadecimal (hex) codes and the colour names for the five dominant colours for each of these cities were determined [4].

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This current research is a follow-on study. It implements K-Means clustering to obtain five dominant colours from these 12 cities. It compares the colours that were obtained by implementing K-Means clustering with the colours that were previously obtained by implementing FCM clustering to determine if the type of clustering method would impact the extracted dominant colours.
The remainder of this paper is organized as follows: Section 2 reviews background information on colour extraction. Section 3 describes the experimental procedure. Section 4 discusses the experimental results, and Section 5 provides the conclusions and a brief discussion of future work.

II. BACKGROUND INFORMATION

This section provides background information on the Red Green Blue (RGB) colour space, FCM clustering, and K-Means clustering.

A. RGB Colour Space

The RGB colour space is a method for specifying the colour of each pixel of an image by using a red, a green, and a blue coordinate. Intensity for each colour coordinate varies from 0 to 255 [13]. The minimum value of zero indicates that a colour is not present in a pixel. The colour black, which has coordinates of (0,0,0), does not have any red, green, or blue colours. The maximum value of 255 indicates that a pixel has the highest amount of a colour [14]. The colour white, which has coordinates of (255, 255, 255), has the maximum amount of red, green, and blue colours. Other colours are represented by using various combinations of RGB coordinate values. Fig. 2 provides examples of the representation of RGB coordinates for six colours.

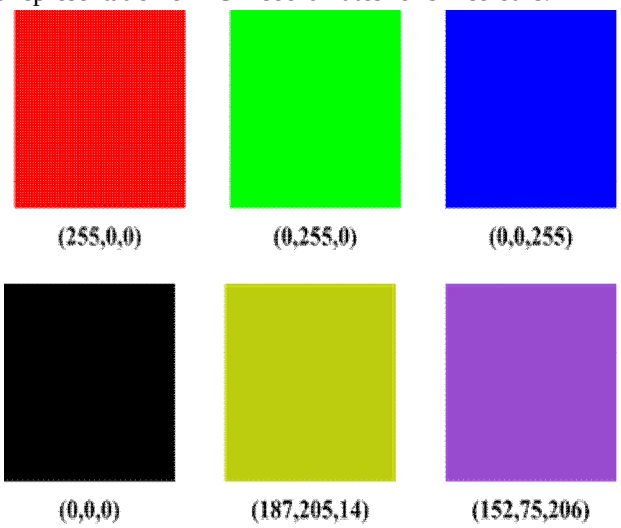

Fig. 2 RGB Coordinate Examples

The RGB colour difference formula compares two colours, and it calculates the Euclidian distance between the colour coordinates. This equation is provided as follows:

$$dE = \sqrt{((R_2 - R_1)^2 + (B_2 - B_1)^2 + (G_2 - G_1)^2)} \quad (1)$$

where dE is the colour difference value, R_1, B_1, and G_1 are the colour coordinate values for colour 1, and R_2, B_2, and G_2 are the colour coordinate values for colour 2 [15].
RGB colours could also be described by using hex colour codes, which consist of a "#" symbol followed by a string of six alphanumeric characters [16-17]. Furthermore, RGB coordinates could be converted to hex codes by converting each coordinate from base 10 to base 16 [18]. The first two hex code characters correspond to the red coordinate, the second two correspond to the green coordinate, and the last two correspond to the blue coordinate [19-20]. The relationship between each part of a hex code and each part of its corresponding RGB coordinates is provided in Fig. 3.

#RRGGBB

Fig. 3 Parts of a Hexadecimal Colour Code

The hex code for vivid purple, for example, is #6a0f8e, whereas the emerald colour has a hex code of #50c878 [21-22].

B. FCM Clustering

FCM clustering is a soft clustering technique that identifies dominant colours for a RGB picture. It begins by defining the input variables. They are the threshold value, fuzzifier, number of clusters, and maximum number of iterations [4]. Next, the centroids are initially set to random RGB colours, and each membership degree in the membership matrix is initialized with a random probability under the constraint that the membership degrees corresponding each pixel add up to one. Next, the cluster centroids, membership degrees, and the termination criterion value are calculated. This algorithm then determines if the termination criterion is smaller than the threshold. If not, it continues to calculate the centroids, membership degrees, and termination criterion until the termination criterion is less than the threshold. The FCM method ends, and the final centroids are outputted as the dominant colours. The FCM activity diagram is provided in Fig. 4.

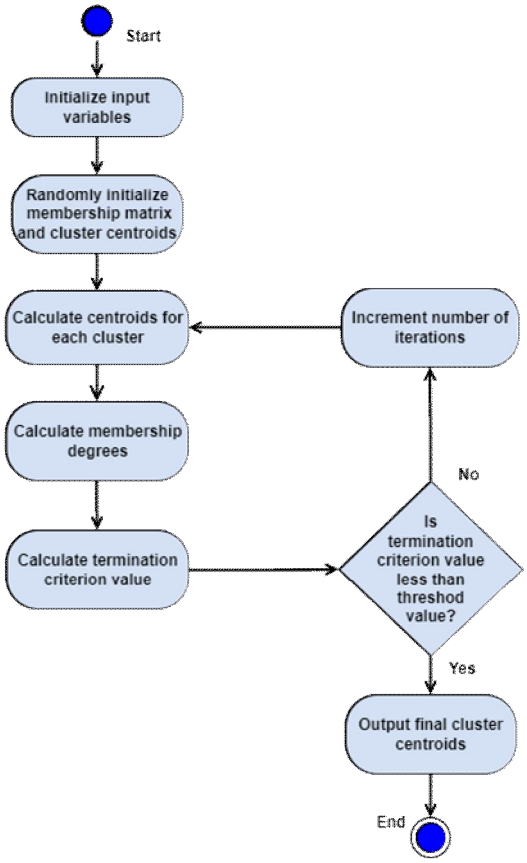

Fig. 4 FCM Activity Diagram [4]

C. K-Means Clustering

K-Means clustering is a hard clustering technique that identifies dominant colours for a RGB image. This procedure begins by defining the input variables to include the number of clusters and the maximum number of iterations. The cluster centroids are then initialized with random RGB colours. The colour difference between each pixel and centroid is then calculated [23]. Each pixel is assigned to the cluster that has the centroid with the smallest colour difference. The new centroids are then computed by using the colour coordinates of all the pixels that are assigned to each cluster. The equations for the red, green, and blue coordinates for the centroid of the first cluster are provided as follows:

$$\overline{R_1} = \frac{1}{n}\sum_{j=1}^{n} R_j \quad (2)$$

$$\overline{G_1} = \frac{1}{n}\sum_{j=1}^{n} G_j \quad (3)$$

$$\overline{B_1} = \frac{1}{n}\sum_{j=1}^{n} B_j \quad (4)$$

where n is the total number of pixels in the cluster, j is the current pixel, R_j is the red coordinate value for the current pixel, G_j is the green coordinate value for the current pixel, and B_j is the blue coordinate value of the current pixel. The procedure to calculate the centroid for the first cluster is then repeated to calculate the centroids for the other clusters.

The K-Means clustering algorithm then checks to see if the same pixels are placed in the identical clusters. If this is not the case, this technique repeatedly calculates the colour differences, assigns the pixels to clusters, and calculates the centroids until the same pixels are placed in the identical clusters. This algorithm then terminates, and the centroids are used as the dominant colours. The K-Means clustering activity diagram is given in Fig. 5.

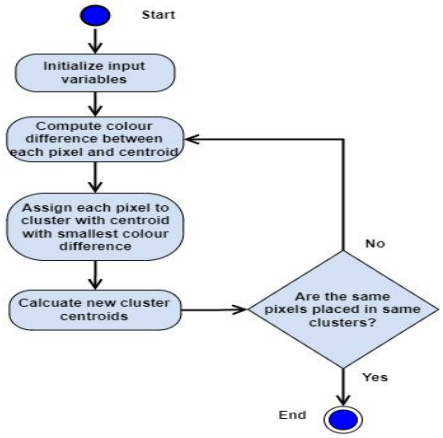

Fig. 5 K-Means Clustering Activity Diagram

III.EXPERIMENTAL PROCEDURE

A Python program to implement K-Means clustering was written to extract dominant colours for each of the 12 cities that were used in the earlier FCM colour extraction study. The results were displayed as hex codes and colour names. The K-Means clustering colour extraction results were then compared with the previous FCM colour extraction results for these cities to determine if the type of clustering method executed would impact the extracted dominant colours [4].

The K-Means clustering computer program began by loading each of the two RGB images for a city from their Joint Photographic Experts Group (JPG) files. The dimensions of all these JPGs were set to 1080x1080-pixel to ensure that the dimensions of the pictures were consistent. Next, K-Means clustering, with 5 clusters and a maximum number of iterations of 200, was applied to each picture to obtain the 5 dominant colours for each image. These input variables for this investigation were identical to the ones that were used in the earlier FCM colour extraction study so that the results for the colour extraction techniques could be compared [4]. The dominant colours for each picture were each saved to a list. A combined list was formed by appending together the dominant colour lists for each picture. K-Means clustering was then applied to this combined list to obtain the 5 overall dominant colours, outputted as hex codes, for a city. The workflow for the K-Means clustering program is provided in Fig. 6. The hex codes for the extracted colours were then entered into the color-name.com website to obtain the corresponding name for each colour [24]. The colour extraction results, displayed as hex codes along with their colour names, were then tabulated.

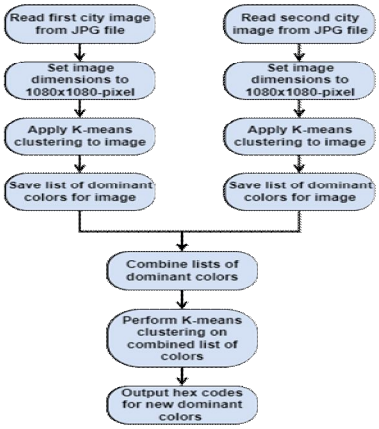

Fig. 6 K-Means Clustering Colour Extraction Program Workflow

IV. DISCUSSION OF EXPERIMENTAL RESULTS

The K-Means clustering results were compared with the FCM results from the previous study by comparing the colour names and the hexadecimal codes for the five dominant colours that were obtained by using each colour extraction method [4]. The results for the FCM and K-Means clustering colour extraction techniques are provided in Table I.

TABLE I
COLOUR EXTRACTION RESULTS TABLE

Continent	City	FCM [4]		K-Means Clustering		Number of Colours in Common
		Hex Codes	Colours	Hex Codes	Colours	
Africa	Cairo	#948971 #2a2418 #5f5038 #d6c0ac #52b9d3	Cinereous Raisin Black Olive Drab Camouflage Dark Vanilla Sea Serpent	#928872 #61523a #2d271a #d5c4b0 #51bad5	Cinereous Umber Pine Tree Dark Vanilla Sea Serpent	3
	Cape Town	#757674 #3b3d36 #c5cdd1 #86aed9 #0b83e4	Sonic Silver Black Olive Chinese Silver Light Cobalt Blue Blue Cola	#3f423a #c6cdd1 #7b7977 #8aaac7 #0f87e7	Black Olive Chinese Silver Sonic Silver Ceil Blue Cola	4
Asia	Singapore	#7e8d96 #52606a #262d2c #d5dee4 #8bb3d8	Roman Silver Black Coral Charleston Green Gainsboro Light Cobalt Blue	#262d2b #d4dee4 #74828b #4d5a63 #9aacbb	Charleston Green Gainsboro Slate Grey Independence Pewter Blue	2
	Tokyo	#6b6c6e #46474b #939394 #bdbdbb #1d1f23	Dim Grey Outer Space Spanish Grey Grey (X11) Dark Jungle Green	#1f2125 #bdbdbb #6c6d6e #48484b #939494	Raisin Black Grey (X11) Dark Silver Outer Space Spanish Grey	3
Australia	Perth	#323537 #787871 #cfd8e0 #86b2db	Jet Sonic Silver Columbia Blue Light Cobalt Blue	#353a3c #cfd8e0 #807f77 #8ab3d	Onyx Columbia Blue Grey (HTML/CSS	3

		#467bc5	Cyan-Blue Azure	9 #457cc7	Grey) Light Cobalt Blue Cyan-Blue Azure	
	Sydney	#a4c3db #727779 #24303d #727e95 #145174	Pale Cerulean Sonic Silver Gunmetal Slate Grey Dark Cerulean	#747e89 #32556e #8fb3d3 #bdcbd5 #25323d	Slate Grey Police Blue Dark Sky Blue Lavender Grey Gunmetal	2
Europe	London	#22201d #62615a #8e9391 #a7b7b8 #bfd2e8	Raisin Black Granite Grey Philippine Grey Cadet Blue (Crayola) Beau Blue	#65645c #b7c7d1 #171512 #3a3934 #8f9491	Granite Grey Pastel Blue Chinese Black Black Olive Philippine Grey	2
	Madrid	#403327 #8e796b #e4d6c6 #bca797 #5a93ed	Jacko Bean Shadow Bone Khaki (HTML/CSS) United Nations Blue	#a18d7f #e4d5c6 #685545 #372b21 #5b93ea	Cinereous Bone Quincy Bistre United Nations Blue	2
North America	Mexico City	#5b4840 #9f7965 #bca89e #201a18 #e6e3e1	Olive Drab Camouflage Blast-Off Bronze Tuscany Eerie Black Platinum	#322622 #715a50 #bd785a #b6a298 #dfdbd9	Temptress Boy Red Deer Tuscany Gainsboro	1
	New York City	#e0dde5 #484549 #a59fa4 #1c1b20 #746f71	Platinum Outer Space Quick Silver Eerie Black Dark Silver	#dedbe3 #1e1d22 #a59fa3 #49464a #747072	Gainsboro Raisin Black Quick Silver Outer Space Nickel	2
South America	Buenos Aires	#c8b39f #191513	Khaki (HTML/CSS)	#c5b19f #eaecee	Khaki (HTML/CSS)	5

		#86786d #4b433d #ebeef0	Black Chocolate Shadow Dark Puce Bright Grey	#4e443e #88786c #1b1815	Bright Grey Dark Puce Shadow Black Chocolate	
	Lima	#5b5555 #a2a1a6 #847874 #2c2c2d #dcdad8	Davy's Grey Quick Silver Grey (HTML/CSS Grey) Charleston Green Gainsboro	#80736d #dbd9d6 #474546 #a6a4a6 #212627	Sonic Silver Light Silver Outer Space Quick Silver Dark Gunmetal	1

For the images of Cairo, the colour extraction studies showed that there were three dominant colours in common. They were *cinerous*, *dark vanilla*, and *sea serpent*. Even though the colour names for the two other colours were different, the appearances of these colours were similar. The *olive drab camouflage* colour from the FCM results was similar to the *umber* colour from the K-Means clustering results, while the *raisin black* colour from the FCM results was similar to the *pine tree* colour from the K-Means clustering results.

For Cape Town, there were four dominant colours in common to include *sonic silver*, *black olive*, *Chinese silver*, and *blue cola*. Despite the colour name for the fifth colour being different, the *light cobalt blue* colour from the FCM results was comparable to the *ceil* colour from the K-Means clustering results.

For the images of Singapore, two dominant colours were the same. These colours were *Charleston green* and *Gainsboro*. Even though the colour names for the three other colours were different, they were similar in appearance. The *roman silver*, *black coral*, and *light cobalt blue* colours for the FCM results corresponded to the *slate grey*, *independence*, and *pewter blue* colours for the K-Means clustering experiments.

For Tokyo, three dominant colours were the same to include *outer space*, *Spanish grey*, and *grey (X11)*. Even though the colour names for the two other colours were dissimilar, their appearances were comparable. The *dim grey* colour for the FCM experiments resembled the *dark silver* colour for the K-Means clustering experiments, and the *dark jungle green* colour was similar to the *raisin black* colour.

For Perth, both clustering techniques resulted in three of the same dominant colours to include *Colombia blue*, *light cobalt blue*, and *cyan-blue azure*. For the two other sets of colours, the *Jet* colour for the FCM results was similar to the *onyx* colour for the K-Means clustering results, while *sonic silver* resembled *HTML/CSS grey*.

For the pictures of Sydney, there were two dominant colours in common. These colours were *gunmetal* and *slate grey*. Concerning the three other sets of colours, the *pale cerulean*, *sonic silver*, and *dark cerulean* colours for the FCM technique resembled the *dark sky blue*, *lavender grey*, and *police blue* colours for the K-Means clustering method.

For London, two dominant colours were the same: *granite grey* and *Philippine grey*. Although the names for the three other colours were different, the appearances of these colours were alike. The *raisin black*, *cadet blue*, and *beau blue* colours for the FCM algorithm were similar to the *Chinese black*, *black olive*, and *pastel blue* colours for the K-Means clustering technique.

For the Madrid images, two dominant colours were the same: *bone* and *United Nations blue*. Although the names for the three other colours were different, these colours were comparable. *Jacko bean*, *shadow*, and *khaki* from the FCM results corresponded to *bistre*, *Quincy*, and *cinereous* from the K-Means clustering results.

For Mexico City, both colour extraction techniques identified the *Tuscany* colour. Despite the names for the four other colours being different, these colours were similar. The *olive drab camouflage*, *blast-off bronze*, *eerie black*, and *platinum* colours for the FCM results corresponded to the *boy red*, *deer*, *temptress*, and *Gainsboro* colours for the K-Means clustering results.

For New York City images, the colour extraction studies showed that there were two of the same dominant colours to include *outer space* and *quick silver*. Even though the names of the other colours were different, the *platinum*, *eerie black*, and *dark silver* colours from the FCM method corresponded to the *Gainsboro*, *raisin black*, and *nickel* colours from the K-Means clustering algorithm.

For Buenos Aires, FCM and K-Means clustering resulted in the same five dominant colours. They were *khaki*, *black chocolate*, *shadow*, *dark puce*, and *bright grey*.

For the Lima results, both colour extraction methods identified the *quick silver* colour. Although the colour names for the four other colours were different, their appearances were similar. The *Davy's grey*, *grey (HTML/CSS grey)*, *Charleston green*, and *Gainsboro* colours for the FCM results corresponded the *outer space*, *sonic silver*, *dark gunmetal*, and *light silver* colours for the K-Means clustering results.

This colour extraction study also showed that each city had at least one colour in common when FCM and K-Means clustering were applied to the city images. Two cities had one colour in common, five cities had two colours in common, and three cities had three colours in common. One city had four colours that were the same, while one city had all five colours that were identical. This research showed that the dominant colours for these 12 cities obtained by implementing FCM and K-Means clustering were comparable to each other. Hence, this analysis showed that either of these colour extraction methods could be used to generate city colour palettes. The colour extraction frequency table is provided in Table II.

TABLE III
COLOUR EXTRACTION FREQUENCY TABLE

Number of Colours in Common	**Frequency**
1	2
2	5
3	3
4	1
5	1

V. CONCLUSIONS AND FUTURE WORK

This follow-on research implemented K-Means clustering to identify dominant colours for 12 international cities. These colours were compared with the dominant colours that were obtained in a previous study that implemented FCM clustering to extract dominant colours for these locations [4]. Mexico City and Lima had one colour that was the same for both the FCM and K-Means clustering results. They were the cities with the fewest number of colours that were the same for both techniques. Although the colour names for the four other colours were different, the appearances of these colours were similar. Buenos Aires, on the other hand, had all five dominant colours that were the same when FCM and K-Means clustering were applied to its cityscape images. It was the city with the highest number of colours that were the same. This study also showed that the FCM and K-Means clustering colour extraction techniques successfully extracted dominant colours from photographs of cities, and the extracted colours were consistent with each other. Because of this reason, either of these techniques could be employed to perform colour extraction successfully so as to obtain colour palettes for cities.

Future research could include applying other types of colour extraction techniques, such as hierarchical cluster analysis and gaussian mixture models, to extract colours from these cityscape images. The colours from this future study could be compared with the results of this current study.

VI. ACKNOWLEDGMENT

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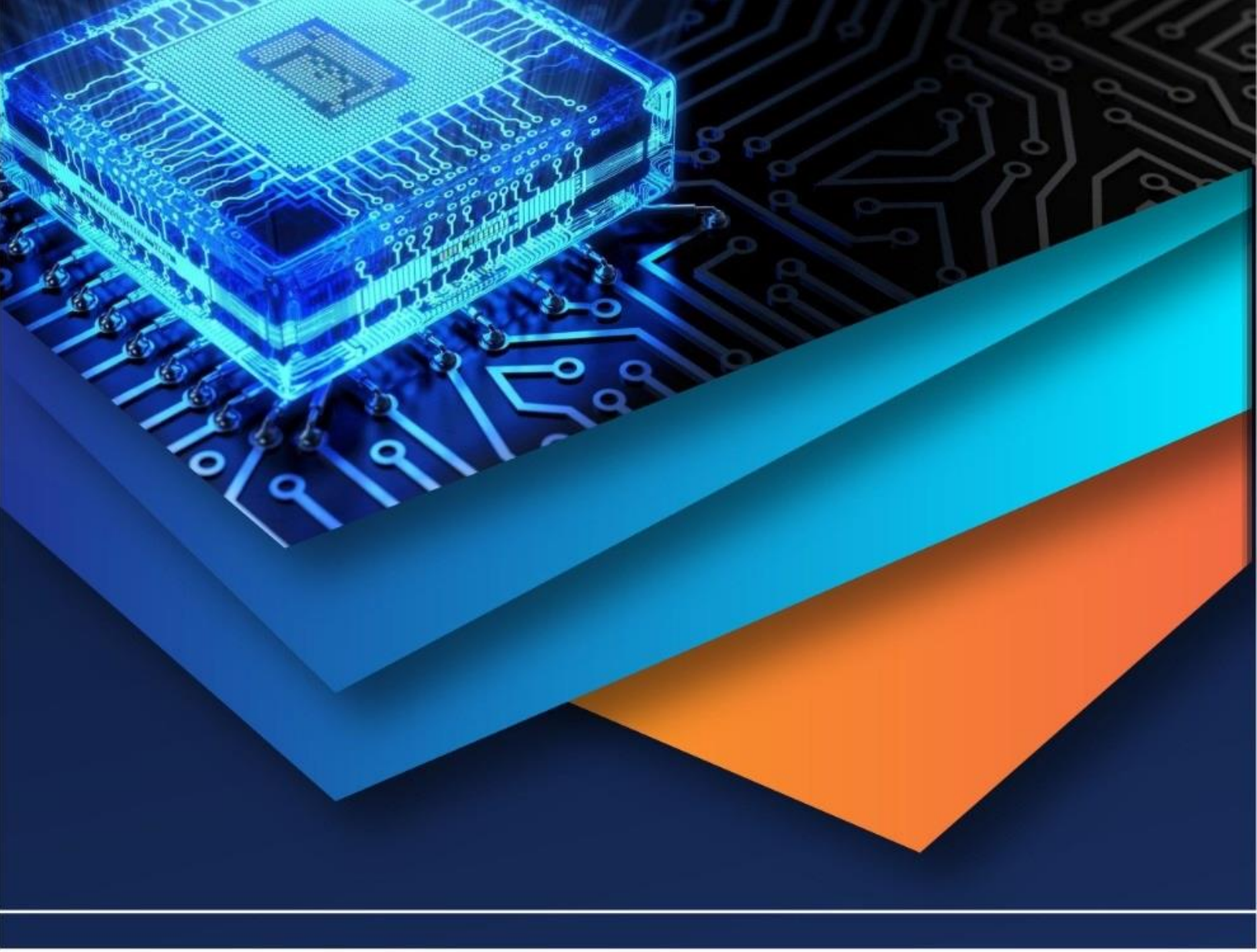

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