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An In-Depth Evaluation of AR-Based Interior Design and Decoration Applications

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Abstract: ***Interior Design is a vast and necessary field in today's day and age. People, these days, tend to look after the overall designing and planning of their own homes. They like to select colour themes, furniture items and decorative items of different varieties as per their liking. But most of the selection process is very tiring and time consuming as it involves visiting multiple different stores and showrooms. Also, with an increase in the variety in products and styles, it has become difficult for the consumer to make decisions. The existing models that try to deal with these problems are mainly AR based, exist only on IOS devices and their prime intent is e-commerce . The proposed model is a cross-platform mobile application that aims to become the one stop solution for all interior designing hurdles. The features will include replication of a room with accurate dimensions in the form of a 3D model. It will also give full creative freedom to the users to decorate the room as they see fit and bring forth an intelligent platform to purchase different items at their leisure.***
Keywords: Augmented Reality, Interior Design Applications, 3D Model, Object Detection, Unity.

I. INTRODUCTION

In the contemporary day and age, Augmented Reality(AR) is only heretofore a fiction. It has risen to become a fresh challenge for many researchers, scientists and technologists around the globe and has helped change the way users interact with the world sensationally. With the spiking rate of new smartphones, Augmented Reality is moving forward to bring creativity to life and help users interact with the organisations at a deeper level. Simply put, it is a formidable technology that enhances a user's real-world experience. It is a desire for many to build and design their house from the very start. Interior designing plays an important role here as it deals with the entirety of a room design that include home decor items such as furniture, lamps, wall paint, curtains and more. Interior Design is perplexing, from both the customer as well as a designers perspective because trying to replicate a room as per the description can be very complicated in the absence of any visualisations. Also, the routine method of selecting interior decoration items involves visiting various shops and showrooms which in itself is a very humdrum process. Here is where the concept of Augmented Reality emanates. The evolution of augmented reality helps make the other side of the story come into reality by playing with the existing surroundings and overlaying solid new features in it.

AR in interior design makes designing and decoration very easy for the customers. First and foremost, they have the ability to design their room with just a mobile phone or a tablet, from the comfort of their own homes. They are able to easily visualise the design before actually developing it. They can also make minute changes and guide the designer interactively using AR. All of this collectively can be achieved for free or at prices that are very minimal. The designers, too, benefit greatly from the use of AR. It is easier for them to present their innovative ideas to clients. They are also able to easily collaborate with both the architect and the client. Effective AR visualisation attracts new customers thus becoming very profitable for the designers. Designers gain a competitive edge by giving a complete view of their future products to their clients using AR. Thus, use of AR makes the job of the customer as well as that of the designer convenient and satisfactory at the same time. The technology of AR and VR is expected to grow exponentially in the interior design industry over the next 5-10 years. It is said that the technology will enable interior designers to quickly change colours, fabrics, patterns, textures, and even the overall style of the room, saving them a significant amount of time and effort when creating physical spaces. This could be advantageous to the customer as well. However, there is no system or application currently existing that incorporates all of these features. All existing applications in the market today are mainly for trying out furniture by styling them or placing them at different positions in a room.

Thus, proposed is a cross-platform AR based mobile application that will be able to replicate a room with accurate dimensions in AR where the user can then design the room as per their liking. It will help the users to place and drop various interior decor items and also help customise the products by changing its colours and other orientations. Other than this the application will focus on the entirety of a room design. It will not only help users select the required décor items and customise it, but also focus on other conventions of a room design such as the wall paint, frames and every other minute details.

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As a 3D room model will be created using the app, this model can be stored and reused again for changing the designs and the existing designs can be saved in the app. This will help the user navigate through the room like one would in reality. It will help enhance the user experience and give a clearer understanding as to how the room would look and also help the interior designers with their work by first visualising the designs before actually working on them.

The rest of the paper can be quoted as follows. Section II focuses on the studies carried out for the smooth implementation of the system. This section also mentions a comprehensive study of the various interior design applications that exist in the market today. Section III gives an overview about the objective behind our research followed by Section IV, which gives a fair idea about the suggested system, methodology and the dataset used to develop the system. Section IV helps understand the future scope of the application along with certain limitations. Section V concludes the research paper.

II. LITERATURE REVIEW

AR technology has not only gained popularity in the fields of science and medicine, but it has also begun to evolve in the fields of engineering and architecture, prompting various studies. Augmented Reality is gaining popularity due to significant improvements in computer vision algorithms and affordable technology. The retail sale of furniture accounts for more than $100 billion of the US economy. However, physical retailers account for the majority of sales. Furniture purchases as well as purchase of other décor items made in physical stores are time- and labour-intensive. Augmented Reality can play an important role in solving this problem by helping to create easy to use applications for interior designing. Thus, there have been a lot of companies and developers who have tried to develop applications that incorporate Augmented Reality for Interior Designing and Infrastructure Planning. Many of these systems prove to be successful but still consist of many drawbacks. One such major flaw is that their main focus has been only on a certain set of furniture and they only allow trying out items live using a mobile camera. The user does not have the full creative freedom to design the entire room as per their wish. This chunk provides an overview of the various approaches used for interior designing using Augmented Reality which have been presented in the literature.

In 2021, P. Kan et al. published a research paper[1] in which they discussed a new algorithm for automated interior design. This algorithm was based on the Hierarchical Tree of Procedural Rules. There were three user case studies that were conducted with the main goal being to use Augmented Reality for interactive and personalised furnishing. An algorithm based on Hierarchical Procedural Rules instead of Optimization algorithm was used because the computational cost was high. The results of the system developed thus, outperformed the existing one in terms of probability of sensible layout generation and provided personalised design recommendations of furniture in the generated interior design. However, the method is constrained by predefined generative rules leading to lower diversity of possible generated designs. Procedural Furniture arrangement can lead to limited adaptability of procedural methods to various standard and non-standard room shapes.

Rohan Moares et al. in [2] developed an interior décor application named “Inter AR” which is an interior décor app using Augmented Reality Technology. The main aim of the application was to cut the prototyping costs and help simulate a better experience for the customer. It was made using Unity Software and AR SDK and is compatible with all existing Android versions.The four major modules in the system were a camera, image processing, tracking and rendering. Some of the major drawbacks of this application is that the furniture objects which are seen in the option are imported from the backend and stored locally and hence it is not possible to convert the image into a 3D object. Also, the user is unable to place two or more instances of an object on a single surface due to limited features provided by the SDK tool.

The paper [3] describes a cross-platform interior design developed by AR Foundation Framework SDK AR techniques based on UNITY Platform. It displays the virtual models on the user’s real scene and also takes and shows the measurements of the Augmented Components. It allows the user to replace the object if needed and helps the user to move the object in a 360 degree view. Now, even if the object can be moved 360 degrees, the room is still static which can cause an error in deciding where the object has to be placed. As it has to be done in real-time, the design created cannot be saved or revisited and the user will have to try the object again.

In 2021, Kandil A and his colleagues proposed a solution to enhance the user experience of Interior Design Mobile AR Applications.

They developed an application called Furniture AR or FAR using Android Studio and Google’s ARCore. This paper [4] mainly focused on how the UI of such an AR app can be modified based on user feedback. This was done based on System Usability Scale (SUS), Handheld Augmented Reality Usability Scale (HARUS), task completion time, and the number of user errors Based on this, the UI of their application was modified.

In 2016, A. Adiyodi et al. published a paper[5] in which they proposed an Augmented Reality system that uses markers on the floors or walls to track the object and define the coordinate system of the room. The user can select a virtual furniture and then arrange it alongside a real furniture using the marked positions for reference. This interaction is called Tangible AR in real time and can help change the colour, style or covering of furniture in a real environment. The issue of this system was that the objects could only be manipulated based on the markers in the scene and the usage of this system is limited to placing the objects only and not actual designing. Thus, if the markers are not placed properly the user cannot place objects.

S. Sharma et al. proposed a markerless augmented reality based interior designing system in paper[6]. This technique helps enhance the user experience for better perception of things. It contains sensors in devices to accurately detect the real-world environment and allows the user to place virtual objects into the real world without reading the image. However, this model does not help modify the objects based on colour and other features. It can consume a lot of power and is prone to slow adoption.

S. Sridhar and S. Sanagavarapu made use of "The Visual Inertial Odometry (VIO)" Algorithm in paper[7] which helps track the in-place orientation of the real-world with the use of a phone camera. They came up with a method that not only uses images captured by the camera but also uses the orientation of the camera with respect to the ground plane. It gives a more realistic view for the consumer to judge their fit and dimensions efficiently. Their application does not support dynamic model updating. It consists of only furniture models that are limited in number as they are encoded in the app.

In 2018, S. Nasir et al. published a paper[8] that proposed a system exhibiting two types of AR, Markerless AR and Marker-based AR. It is a cost effective solution that does not require any sort of expensive gadgets and is very cost-effective. Their proposed system allows the users to add multiple objects to the screen in real-time. This paper basically promotes the use of AR for the purpose of interior design and architecture.

In paper[9], Y.J. Park and his colleagues proposed a user-oriented, pan-tilt projection based AR system for Interior Design (DesignAR). This system helped design the interiors of non-predefined spaces. It creates a 3D map of the space and objects in its surroundings. It makes use of a modified RANSAC Algorithm for finding the optimal planar space. However, the drawbacks were that the current DesignAR application focused only on the interior design of the walls. Even though the users can perform interior design in the actual space directly, one cannot create a replica of the room on the app and save it for further use. Another drawback of using a hardware based mobile AR application is that it may lack flexibility.

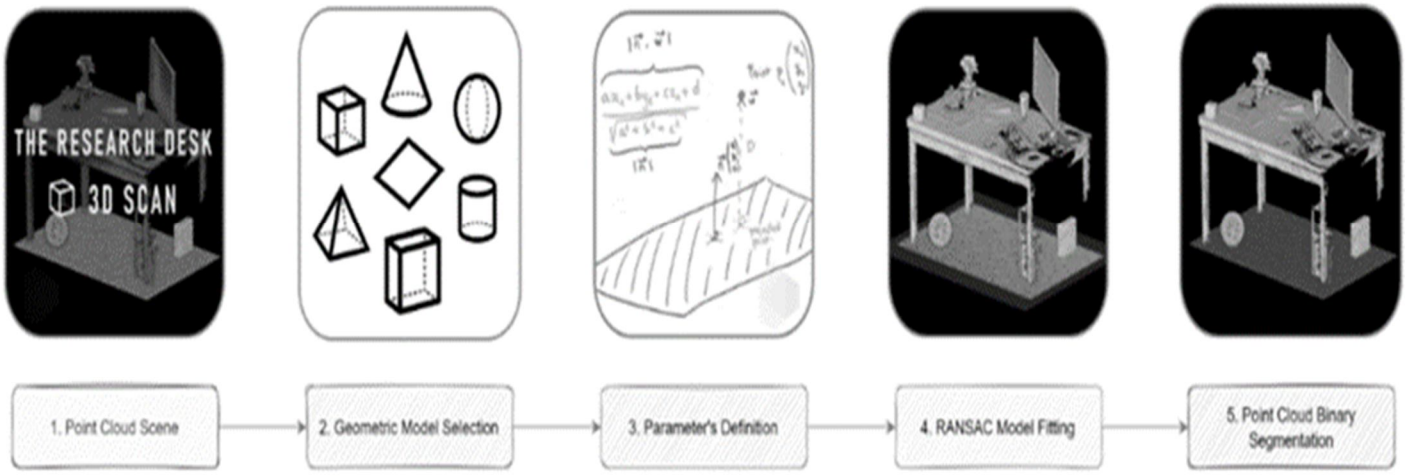


Fig. 1. Working of RANSAC

In paper[10], the authors made an AR based android application that uses ARCore and Android Studio in order to project furniture in a real world augmented environment. This is done in real time using marker-based AR and camera. This application only had a limited amount of furniture that the user could interact with. Happens in real-time and hence is not 3 Dimensional.

On conducting extensive research on some of the best existing interior design and decor applications in the market today, following are the features and gaps identified in each of them.

TABLE I.
Features and GAPS in Existing Apps

Sr. No.	Application Name	Features	Gaps
1	Houzz	An all-in one application that millions of professionals use to get ideas and shop for materials. It has a "View my Room" feature that helps the user to see decor furniture in their own rooms live.	Houzz's AR tool needs some manoeuvring to get all the elements right on the screen. One needs to keep the camera static as it is live or they may get the object placement wrong.
2	Dulux Visualizer	Dulux Visualizer helps find the perfect shade for the wall with the help of AR technology. It provides a huge variety of colours to choose from and also helps filter them based on the user requirement.	Based on user reviews on the play store, it was found that the colours on the app look unrealistic and often prove to be different from the one ordered. There are a lot of bugs in the UI that haven't been solved and thus makes it difficult for the users to navigate.
3	Decor Matters	Unlike other apps that focus only on the furniture, it allows you to visualize an entire design or layout in your room. You can either create your own design using templates, view other users' plans in your space or upload the photo of your own room.	It is not compatible with the android version and is tough to visualize how the actual item will fit in the space in reality.
4	MagicPlan	This is one of the best available applications for architectural planning as it helps create a 3D model of the room which is accurate according to the room dimensions. It gives the architecture full creative freedom to develop a house model.	The application is difficult to use for users with no experience of its understanding. It creates a 3D model of the room by taking the floorplan as an input but does not help with the designing of the room.
5	IKEA Place	IKEA Place is the best application developed in the field of AR for interior design that helps the user move and place objects in the real world through AR. It also supports purchasing of desired products but through another application of IKEA. It is available for ARCore supported phones.	This application is currently unavailable in India and is limited to IKEA products only. The live demo of objects is only feasible but in order to purchase any product, the user has to install another application which is time-consuming.

Table II reflects a comparison chart that differentiates the proposed system from all the existing applications. Most of these applications do not support the 3D model replication of the room whereas many of them allow 360 degree rotation of the objects but not the entire room. The proposed system supports creating a 3D model of the room and also incorporates features such as placement suggestion, in-app purchasing and provides the users with a one-stop platform that can help them with the entire infrastructure planning of their house. It will also support editing the designs if needed later on by changing its colour and material.

TABLE II
Comparison of Existing Apps

Features	Houzz	Dulux Visualizer	Decor Matters	MagicPlan	IKEA Place	Proposed System
Cross-Platform	✔	✔	-	✔	-	✔
Object Placement	(Only view the model)	-	✔	✔	✔	✔
Colour Change for items	-	-	-	-	-	✔
Placement Suggestion	✔	-	-	-	-	✔
Wall Paint	-	✔	-	-	-	✔
Complete Infrastructure planning	-	-	-	✔ (Architectural point of view)	-	✔
In-app Purchasing	✔	✔	✔	-	✔	✔
3D model replica of the entire house/room	-	-	-	✔	-	✔
360 degree rotation of the room	-	-	-	✔	-	✔

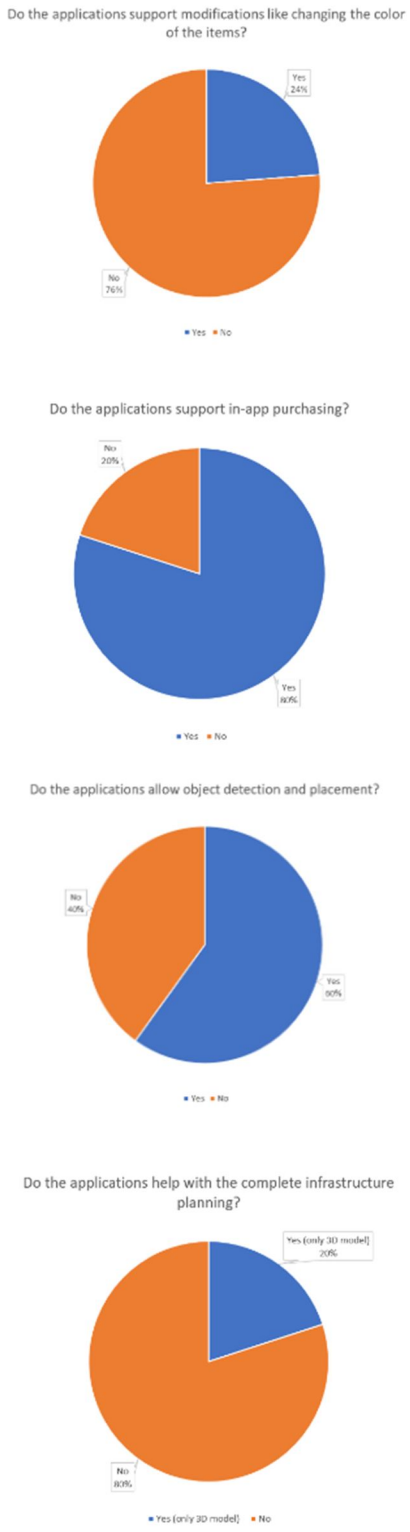


Fig. 2. Survey results of existing apps

We also conducted a survey to perform a comprehensiXe study of the existing interior design applications that are available in the market. The results obtained as a result of this survey are displayed in Figure II.

A comparative study was also conducted on the various deep learning algorithms available for Interior Design Object Detection. Three of the most popular algorithms are R-CNN, SSD and YOLO.

R-CNN – This model introduced deep learning and Convolutional Neural Network into the field of interior design. It improves the accuracy of the dataset greatly and hence is the gold standard in the field of interior design. There are also algorithms developed based on certain drawbacks found in R-CNN like Fast R-CNN and Mask R-CNN.
SSD – Single Shot MultiBox Detector ensures a good amount of speed and accuracy. Compared to the R-CNN Models, it has an obvious advantage because of its speed.
YOLO – It is an algorithm that uses convolutional neural networks for object detection. But it is much preferred than CNN as it has much better speed and accuracy. It requires only one CNN operation and hence its detection speed is better than that of the other two models. It is useful only when the target occupies a large part in the room environment. In order to Evaluate the models, Mean Average Precision(MAP) was used.

TABLE III.
COMPARISON OF DEEP LEARNING MODELS

Sr. No.	Algorithm Name	Accuracy Score
1.	R-CNN	0.83606
2.	SSD	0.688525
3.	YOLO	0.885

The primary objective of this paper is to achieve the goal of eliminating the gaps in the traditional systems and build an application that enables the creation of a 3D model of the room that can be reused again as well by the interior designers and customers. The existing applications that have been reviewed in this paper include some of the finest applications used by millions of users around the globe like IKEA Place, Houzz, Hutch and Measure. Measure makes use of low-level AR that consists of measuring and mapping of interior design spaces at the user's fingertips whereas applications like IKEA Place and Houzz extend the features of Measure by allowing the 3D furniture to be scaled to the dimensions of the room space, thereby allowing users to try out various furniture at their convenience. Hutch, on the other hand allows a user to take a picture of the room and try out various styles on it then using filters. After finalising the filter, users can save the design and use it for trying out furniture. On further research, it was also found that applications like Hutch had poor ratings on the play store and had a lot of small bugs in it. The proposed system's dataset too is not just limited to a few furniture items or interior decor items, instead it will consist of products from various brands in the market. Another major feature of the application is that it would allow in-app purchasing of all these products. Thus, the users won't have to visit the stores personally or go visit the respective sites in order to purchase any product which saves a lot of time.

III. SUGGESTED SYSTEM

The proposed system is an augmented reality based mobile application that is compatible on both android and iOS devices. "Interioriva – A one-stop solution for all your Interior Designing Hurdles" is a one of its kind mobile application. After the survey of the existing apps and papers, the drawbacks of each of them were reviewed, based on which, a proposed system has been formulated that not only solves all of these drawbacks but also makes the interior designing process much easier for the user. The following flowchart represents the proposed system of the project:

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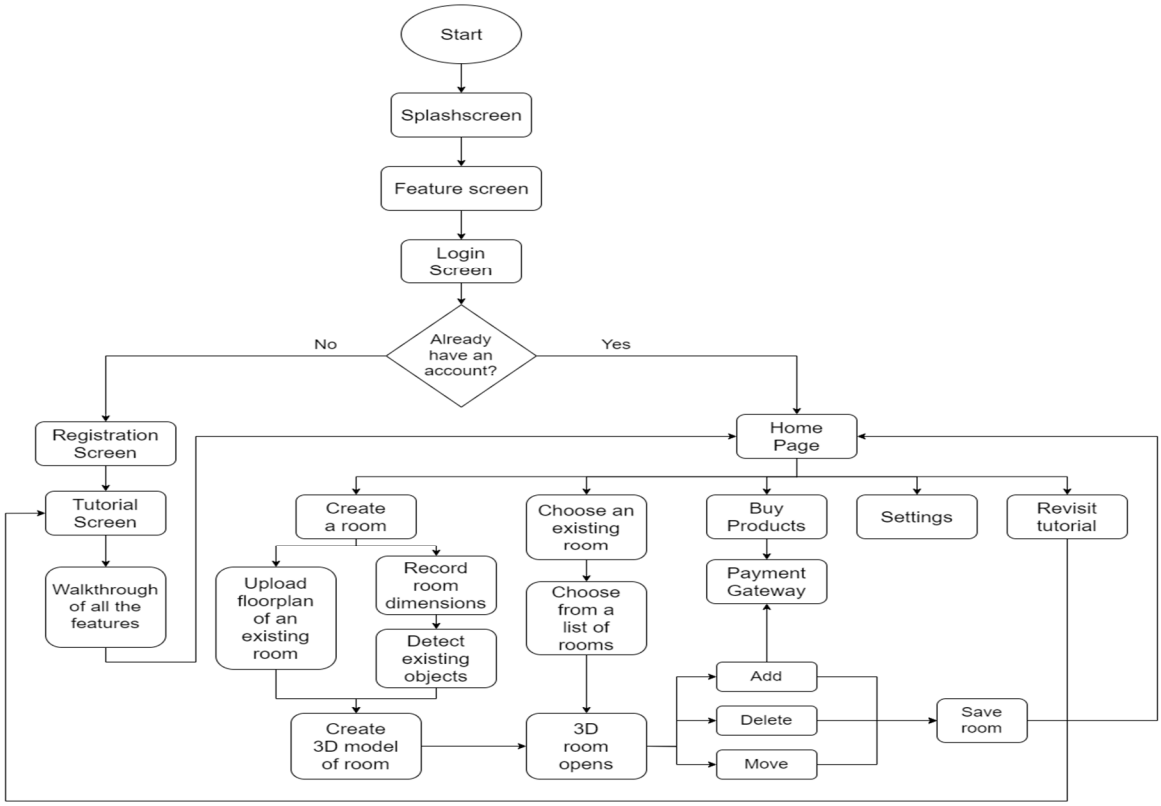


Fig. 3. Flowchart of proposed system

On Start, a Splash Screen appears followed by a Feature Screen which showcases the features of the application. Then, the user moves to the Login Screen which gives the choice of either logging into an existing account or moving to the Registration Screen. The user can create a new account on the Registration Screen and move to the Tutorial Screen where they will be given a walkthrough of all the features of the application. Existing users will be redirected to the Home Page where they will be presented with different options. The first option is to Create a Room. The user can either upload a copy of their floor plan or create their own floor plan using AR to create a 3D model of their room. There will also be an option to detect existing furniture items in the room using deep learning models. The user can also click on the Choose an Existing Room to directly move on to the designing phase of an existing room. The designing phase of the room gives 3 options to the user namely Add, Delete and Move. The user can add furniture items to the room, delete existing items in the room or move existing items to different places in the room using these options. The user can directly buy the added products through the app itself. Once the designing process is complete, the user can save the room and get back to editing it later on.

We are using Unity, AR Core and AR Foundation to implement the AR and 3D modelling components of the app including Add, Delete and Move operations. ReactNative is being used to develop the cross-platform mobile application. Firebase is being used for storage and authentication purposes.

IV. CONCLUSION & FUTURE SCOPE

AR technology opens up a plethora of new research opportunities in engineering and architecture. We have created a cross platform mobile application that is a one stop solution for all interior designing hurdles. 3D modelling of existing rooms and creative autonomy over the interior designing process are the highlights of this application. The use of a deep learning algorithm for object detection and automatic design generation enhance the quality of the designs created. This paper mainly focuses on the survey conducted about various existing interior decoration applications as well as the extensive research conducted in this domain. As a part of the future work, once the 3D model is created, the plan is to incorporate the concept of HCI (Human Computer Interaction) for moving and placing objects with our own hands. Also, collaboration with popular brands in the field would help with the purchasing of furniture and decor items.

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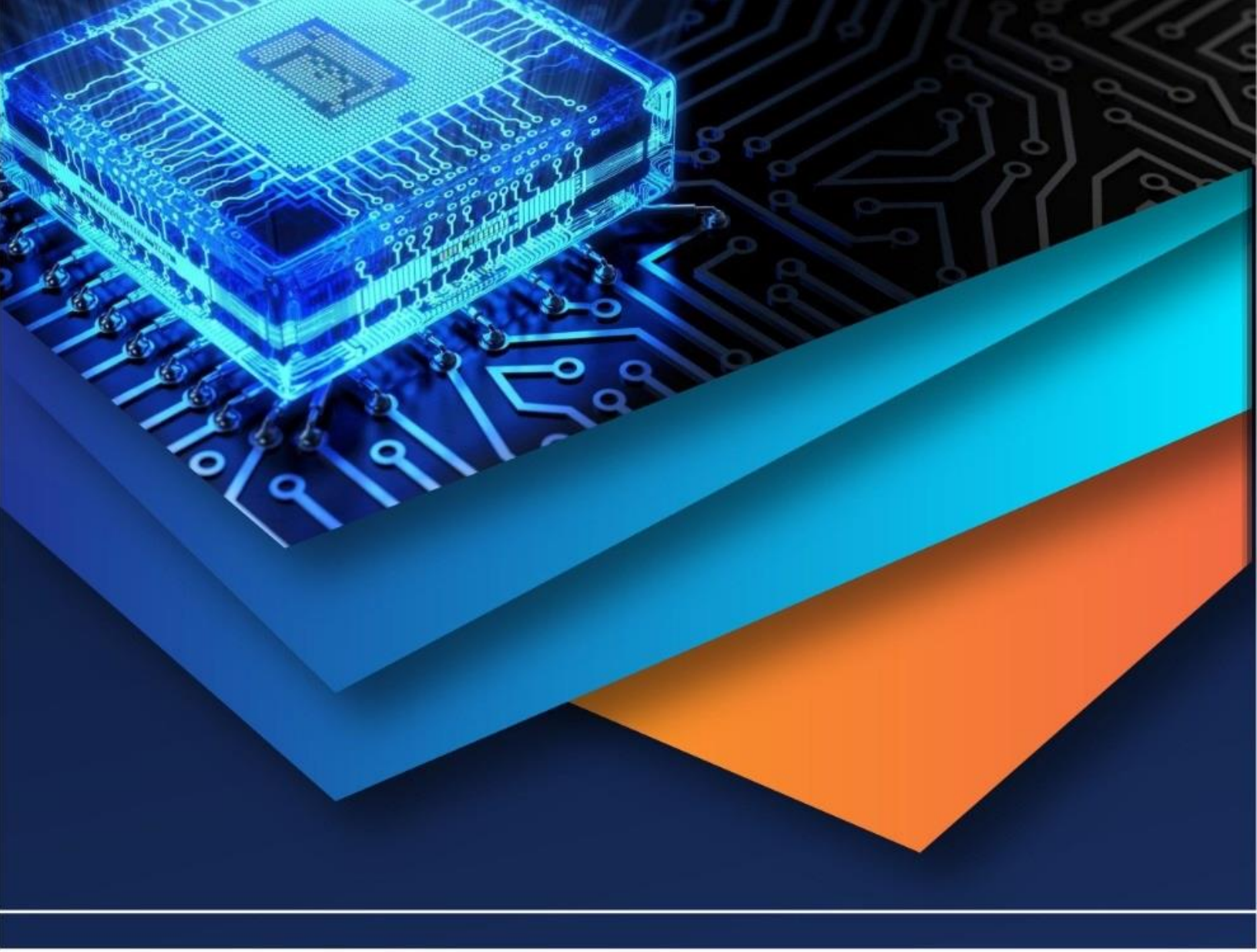
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