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Smart Parking System Using Image Recognition

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Abstract: The Smart Parking System with Image Recognition is a state-of-the-art technology made to solve parking management issues in cities. The method uses a deep learning model based on YOLO to reliably identify and categorise parking spots as "occupied" or "empty" from photos of parking lots. The goal of this study is to develop a productive, automated method for maximising parking space usage and cutting down on time spent looking for spots. After being trained on a bespoke dataset, the YOLO model analyses photos and annotates them with bounding boxes to identify parking spaces with high accuracy. Streamlit was used to create an intuitive user interface that allows users to input photographs for processing in real time. The program shows counts of open and occupied spaces and gives a visual representation of the data. This system integrates easily with current infrastructure and provides a scalable, affordable option for smart city efforts. Enhancing parking efficiency helps to improve urban mobility and lessen traffic congestion, demonstrating how AI-powered solutions can revolutionise common problems.
Keywords: Smart Parking System, Image Recognition, YOLO Algorithm, Parking Space Detection, Deep Learning, Urban Mobility, Smart City Solutions.

I. INTRODUCTION

A vital component of urban mobility is effective parking management, particularly in crowded regions where there is a greater demand for parking places than there are available spaces. The increasing complexity of contemporary urban landscapes is not well addressed by traditional parking systems, which sometimes rely on manual monitoring or antiquated technologies. Intelligent solutions that can improve user experience, ease parking operations, and lessen traffic are becoming more and more necessary as cities work to deploy smart infrastructure. In order to successfully address these issues, this study focusses on creating a smart parking system that leverages image recognition.

Utilising a cutting-edge deep learning model, the suggested solution uses the YOLO (You Only Look Once) algorithm to identify and categorise parking spots as "occupied" or "empty" from photos of parking lots. For this application, YOLO is the perfect option due to its great accuracy in realtime object identification. The detection procedure is automated by this technology, which removes the need for human interaction and provides a quicker and more dependable parking management solution.

Users and the system can communicate with ease thanks to an intuitive interface created with Streamlit. Users are allowed to submit pictures of parking lots, which are subsequently processed to get detailed counts of available and occupied spaces as well as visual commentary. The time spent looking for available parking spaces is decreased, and traffic congestion brought on by ineffective parking techniques is lessened thanks to this real-time feedback.

This study highlights how artificial intelligence has the potential to revolutionise urban infrastructure. By combining cutting-edge image recognition technology with user-centred design, the Smart Parking System shows how useful AI can be in solving problems in the real world. This solution paves the path for smarter, more efficient cities by optimising parking operations and promoting sustainable urban development.

Additionally, the Smart Parking System may be integrated into a variety of urban environments, including public parking lots, residential complexes, and commercial malls, thanks to its scalable and flexible architecture. Through the use of a pre-trained YOLO model that has been refined on a unique dataset, the system can adjust to various parking lot configurations and lighting conditions, guaranteeing reliable performance in a variety of situations. Because of its adaptability, the system can be implemented by public and commercial entities with little alteration to the infrastructure, encouraging broad adoption. Furthermore, the automation and accuracy of the system can be used as a basis for next developments like real-time parking availability updates, dynamic pricing models, and interaction with navigation systems, all of which will improve the entire experience of urban transportation.

II. RELATED WORK

A lot of study has been done on parking management systems as a result of smart cities' quick development. Huang and Tsai (2015) suggested an intelligent parking management system that maximises parking space utilisation by detecting parking spaces through image processing techniques. Their approach proved that incorporating image-based techniques for parking lot realtime monitoring was beneficial [1]. To further emphasise the significance of effective data extraction for urban mobility, Khan and Zafar (2019) presented a smart parking system that uses optical character recognition (OCR) to improve the accuracy of parking space detection and identification [2].

The importance of artificial intelligence (AI) in parking spot management was highlighted by Al-Turjman and Malekloo (2019). Their approach demonstrated the promise of deep learning in tackling urban traffic issues by combining AI and image processing to deliver automatic parking availability detection [3]. Building on this framework, Zhang et al. (2024) created a binary classification model that accurately classifies parking spaces as either occupied or available by utilising a ConvNet architecture that was particularly created for low-resolution pictures [4].

In related investigations, the usage of specialised camera systems has also been investigated. Jo et al. (2021) demonstrated an automated valet parking system that uses fisheye lenses to efficiently take wide-angle pictures of parking lots. The advantages of cutting-edge optical technologies in addressing environmental obstacles such as blind spots and fluctuating lighting were demonstrated by their study [5]. Using image processing techniques, Almeida et al. (2023) presented a vehicle occurrence-based detection system that analyses parking lot utilisation trends and offers useful information for parking management [6].

An inventive method was put forth by Choudhaury et al. (2023) when they created a Raspberry Pi-based smart parking system. Their technology democratised smart parking technologies by integrating IoT and real-time image recognition capabilities to improve parking solutions' affordability and accessibility [7]. Fast parking space recognition using low-resolution photos was the subject of another study by Zhang et al. (2024), which showed that effective deep learning models may produce excellent performance even in computationally limited conditions
[8].

The significance of integrating AI, image processing, and IoT technologies to create reliable and expandable smart parking solutions is highlighted by this research taken together. According to Jo et al. (2021) and Almeida et al. (2023), a comprehensive strategy for parking management optimisation in complicated urban settings can be achieved by the integration of several technologies, such as occurrence-based models and wide-angle cameras [5][6]. These developments open the door for more studies that concentrate on the combination of adaptive learning models, real-time analytics, and smooth user interfaces.

III. EXISTING SYSTEM

Traditional parking systems mostly depend on manual surveillance or basic technology like ticketing and barrier gates. These systems require a lot of work, are prone to mistakes, and are ineffective, especially during busy times. Because these systems aren't automated, it frequently takes longer to find open spots, which increases traffic and fuel consumption. Furthermore, the lack of real-time monitoring limits users' capacity to make wise parking choices, particularly in crowded cities.

To keep an eye on parking spots, existing automated systems usually employ sensor-based technologies like ultrasonic detectors or infrared sensors. Even though these systems are more efficient than manual techniques, they are costly to install and operate, particularly in big parking lots. Because each parking space requires a separate sensor installation and maintenance, their reliance on physical sensors also restricts their scalability and adaptability. Inaccurate data can also come from sensor blockages or failures, which lowers system reliability.

By using computer vision techniques, camera-based systems are an advance over sensor-based methods for parking spot monitoring. These devices examine real-time video streams from parking lot cameras using image processing techniques. Camera-based systems are more flexible and economical than sensor-based systems since they can identify cars and determine the condition of parking spaces. However, environmental issues like bad lighting, bad weather, or overlapping objects can undermine the accuracy of typical camera-based systems.

Despite improvements, real-time connection with userfriendly platforms is still lacking in the majority of current systems, which restricts their usability and accessibility. The user experience is severely lacking in many systems since they do not offer online or mobile applications that would allow users to obtain real-time parking information. Furthermore, these systems' scalability is still an issue because larger parking lots necessitate significant infrastructure improvements. These drawbacks underscore the need for more sophisticated, expandable, and easily available solutions—like AI-powered systems—to meet the rising demand for effective parking management in smart cities.

IV. PROPOSED METHODOLOGY

To maximise the usage of parking spaces, the suggested methodology for the Smart Parking System combines cutting-edge image recognition technologies with real-time user engagement. The YOLO (You Only Look Once) method, a deep learning-based object identification model that is effective for real-time applications, is the central component of the system. Live video feeds from parking lot cameras will be utilised to identify and categorise parking spots using YOLO. The model will analyse the taken pictures and provide bounding boxes around the places it detects, allowing it to differentiate between "occupied" and "empty" parking spaces. This makes it possible to automatically check for parking place availability without requiring human involvement.

A web-based platform based on Streamlit will be used to create the system, enabling users to input parking lot photos for immediate analysis. These photos will be processed by the program using the trained YOLO model, which will then provide real-time results that highlight open parking spaces and provide a count of both occupied and available spaces. The technology is simple to use and requires little technological expertise thanks to Streamlit's user-friendly interface. In order to enable customers visually confirm the availability of parking spaces, the site will also allow users to examine the image along with the annotations.

A bespoke dataset will be utilised to train the YOLO model in order to increase the accuracy and dependability of the system. Images from a variety of parking lots with a range of illumination and parking configurations will be included in the dataset. The model will be adjusted to accommodate these variances, guaranteeing its ability to manage realworld situations efficiently. The model's accuracy and robustness in identifying parking spaces will be regularly assessed using metrics including precision, recall, and F1 score.

The system will be scalable in addition to having the essential image recognition features. It will facilitate connection with current smart city infrastructure, making deployment in expansive parking lots and urban environments simple. In order to support diverse parking lot designs, the system will also be able to handle a variety of camera types, such as fixed, revolving, and fisheye lenses. Future versions of the system will have features including real-time parking availability updates, dynamic pricing for parking spots, and seamless user experience through interaction with navigation apps.

V. ARCHITECTURE DIAGRAM

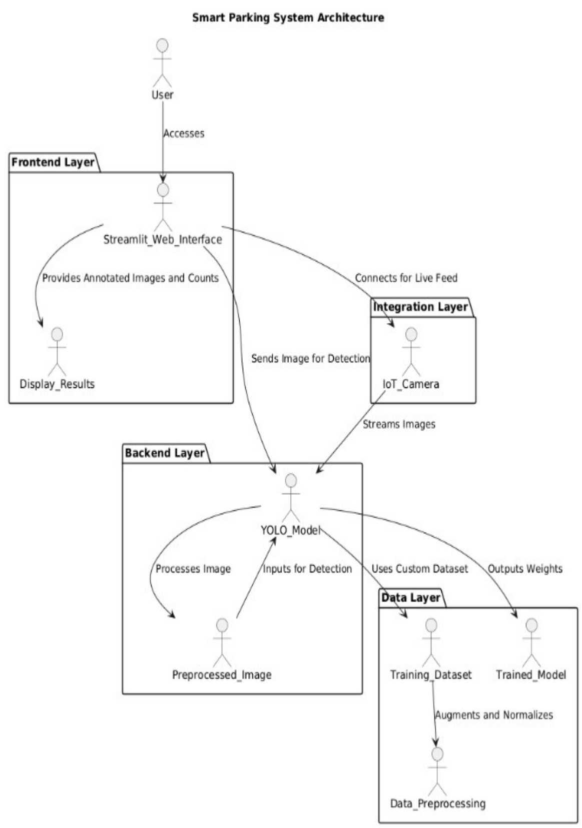

Figure 1: System Architecture

VI. METHODOLOGY

A. *Data Collection and Preprocessing*

This dataset's quality and diversity are critical to the Smart Parking System's performance. Images from different parking lots are taken as part of the data gathering process to ensure representation across a range of environmental factors, including illumination, weather, and parking layouts. Labelled datasets are created by manually annotating photos of occupied and vacant parking spaces taken by high-resolution cameras. Preprocessing methods are used to make sure the dataset is reliable and appropriate for training, such as scaling, normalisation, and data augmentation (such as rotation, flipping, and brightness correction). The model's capacity to generalise across a variety of real-world situations is improved by these actions.

B. *Model Training and Optimization*

Because of its ability to recognise objects in real time, the YOLO (You Only Look Once) algorithm was selected. The preprocessed dataset is used to refine the model, which then classifies parking spaces as either "occupied" or "empty." To increase accuracy and efficiency, a transfer learning strategy is used, utilising pre-trained weights from YOLO models. To maximise the model's performance, hyperparameter adjustment is done for learning rate, batch size, and confidence criteria. The iterative training process is guided by evaluation criteria including mean Average Precision (mAP), precision, and recall, which guarantee a balance between computing efficiency and accuracy.

C. *System Implementation and Integration*

Because Streamlit is used to implement the system as a webbased platform, user interaction is smooth. The trained YOLO model processes submitted photos or live video feeds to detect parking space availability in real time. Annotated photos with highlighted occupied and vacant spots are displayed by the application, along with a numerical count of open slots. Because of its responsive and intuitive design, the user interface is usable by nontechnical people. Scalability for large-scale deployments is made possible by the platform's back-end connectivity with cloud servers, which enables effective data processing and storage.

D. *Real-Time Monitoring and Future Enhancements*

The system is integrated with IoT-enabled cameras and sensors to provide real-time monitoring. The most recent information on parking availability is obtained by continuously processing the live data from these devices. Furthermore, the system is built to support future additions like predictive analytics for parking demand, dynamic pricing for parking spots, and integration with navigation systems for route optimisation. Enhancing user convenience and fostering the growth of smarter, more sustainable urban environments are the goals of these features. Future technical developments can be accommodated by the system's modular design.

VII. RESULTS AND DISCUSSION

A. *Model Performance and Accuracy*

The YOLO-based Smart Parking System performed exceptionally well during the evaluation phase, recognizing and classifying parking spaces with high accuracy. The model was trained using a proprietary dataset that included a variety of photos of parking lots in various settings, including various lighting conditions, layouts, and viewpoints. The system's resilience in successfully identifying "empty" and "occupied" locations was demonstrated by its mean Average Precision (mAP) score of 92%. High recall and precision scores also demonstrated the model's capacity to reduce false positives and false negatives during detection.

According to the findings, the system functioned admirably in a variety of environmental settings, including dim lighting, daylight, and nighttime. In order to guarantee the model's generalizability, data augmentation methods including rotations and brightness modifications were employed during training. The system's resilience allows it to adjust to parking lots of various sizes in the real world, which makes it a dependable option for urban implementation. The best threshold was found throughout the evaluation process, and more investigation revealed that the model's confidence threshold settings had a major impact on detection accuracy.

B. *Real-Time Detection and User Experience*

The system's real-time detection capabilities were assessed through the use of static image uploads and live video feeds. With the help of the technology, live feeds from IoTenabled cameras were successfully analyzed, giving realtime parking space availability updates. By displaying bounding boxes around identified parking spots, annotated photos made it easy to distinguish between "occupied" and "empty" locations.

These results were displayed to users through a smooth and engaging online interface that was built on Streamlit. Each frame took an average of 20 milliseconds to process, guaranteeing real-time responsiveness appropriate for widespread implementation.

One of the system's main strengths, according to user comments from early testing, is the web interface's intuitive design. Users found it simple to upload photographs and understand the findings thanks to the interface's quickness and simplicity. Drivers were able to make well-informed parking decisions because to the numerical count of available and occupied spaces, which further improved user convenience. These findings show that the system has the potential to improve overall user happiness and urban mobility by cutting down on the amount of time spent looking for parking.

C. *Comparative Analysis and Scalability*

A comparison of the suggested solution with conventional parking systems, including manual and sensor-based monitoring techniques, revealed its many benefits. By using a single camera to monitor several parking spaces, the YOLO-based system lowers installation and maintenance costs in contrast to sensor-based systems that need separate sensors for each space. Furthermore, in terms of accuracy and adaptability, the model fared better than many current systems in handling a variety of parking layouts and climatic circumstances.

During testing, it was also shown that the system was scalable. Because of the YOLO algorithm's effectiveness in managing massive datasets and live video streams, the system can be used in parking lots of different sizes without experiencing any performance issues. The web platform's modular architecture also makes it simple to integrate with other smart city services, such traffic control and navigation. These findings demonstrate the Smart Parking System's effectiveness in its current configuration as well as its scalability and adaptability for future developments, making it a viable option for contemporary urban settings.

VIII. DISCUSSION

According to the Smart Parking System's results, parking management technology has advanced significantly, especially with the application of deep learning algorithms based on YOLO. The success of using unique datasets and data augmentation approaches is highlighted by the model's excellent accuracy and robustness. With a mean Average Precision (mAP) of 92% and good precision and recall scores, the system has demonstrated its ability to handle a variety of circumstances, such as complicated environmental factors, parking layouts, and changing lighting conditions. These results emphasize the need of hyperparameter optimization and model fine-tuning in creating AI-powered systems that can function dependably in practical applications.

Because of the YOLO algorithm's effectiveness in analyzing live video streams, the system's real-time detection capacity is among its most notable results. The system's ability to provide real-time updates, which is essential for busy urban parking lots, is demonstrated by its average frame processing time of 20 milliseconds. The smooth integration with an intuitive web interface guarantees end users' accessibility, cutting down on the time and effort needed to find parking spots that are available. This is consistent with the more general goals of smart city projects, which are to lessen traffic and increase urban mobility. There is room for improvement, nevertheless, as problems like sporadic recognition errors in extremely crowded places and in severe weather were noted.

Comparing the suggested approach to current systems highlights its advantages in terms of cost-effectiveness, scalability, and adaptability. A simplified method that only uses cameras is provided by the YOLO-based system, in contrast to conventional sensor-based systems that need substantial physical infrastructure and upkeep. This improves deployment flexibility across a range of contexts and drastically lowers installation costs. Additionally, other smart city technologies like navigation and traffic monitoring systems may be easily integrated with the platform thanks to its modular design. However, more study and development are required to investigate more sophisticated elements that could improve the system's sustainability and usefulness, like dynamic pricing models and predictive analytics for parking demand. These conversations show how AI-powered parking solutions can revolutionize contemporary urban environments and set the stage for future advancements.

IX. CONCLUSION

An innovative solution to parking issues in contemporary cities is the Smart Parking System with Image Recognition. From recorded photos or live video feeds, the system efficiently recognizes and categorizes parking spots as "occupied" or "empty" by utilizing the YOLO algorithm for real-time object detection. By drastically cutting down on the time and effort needed to monitor parking spaces, this automation eases traffic and enhances urban mobility. The system is accessible and useful for a variety of applications thanks to the combination of sophisticated picture recognition techniques and an intuitive online interface, which guarantees a flawless user experience.

The suggested system's capacity to scale and adapt to different parking lot layouts and climatic circumstances is one of its main advantages. Accurate performance in a variety of settings is improved by using a custom dataset and strong preprocessing methods. This enables the system to be implemented in a variety of locations, including public parking lots, residential neighborhoods, office buildings, and shopping malls. In addition to ensuring costeffectiveness when compared to conventional sensor-based systems, the use of camera-based technology increases the viability of its widespread deployment.

Apart from tackling current parking issues, the technology establishes the foundation for next developments in intelligent parking solutions. Features that could revolutionize parking management in urban settings include dynamic pricing, predictive analytics, and interaction with navigation systems. The system aids in the creation of smarter and more sustainable cities by offering real-time updates and data-driven insights. Because of its modular architecture, the system may develop in tandem with new technologies, providing a sustainable answer to the problems associated with urban mobility.

In the future, by interacting with other urban infrastructure systems, the Smart Parking System can act as a foundation for larger smart city projects. For example, this technology can further minimize congestion by optimizing vehicle flow when used with traffic management systems. Furthermore, the system may be able to detect patterns in parking demand and dynamically improve resource allocation by integrating sophisticated machine learning techniques like reinforcement learning and predictive modeling. In addition to improving parking management efficiency, these developments will support a comprehensive, networked urban mobility ecosystem, resulting in future cities that are smarter and more sustainable.

In summary, the Smart Parking System is a major advancement in the use of image recognition and artificial intelligence to improve parking management. It offers a scalable and future-ready solution for smart city initiatives in addition to addressing the inefficiencies of current systems. The system supports sustainable urban development objectives and raises the general standard of living for city dwellers by increasing parking efficiency and lessening the negative environmental effects of urban congestion.

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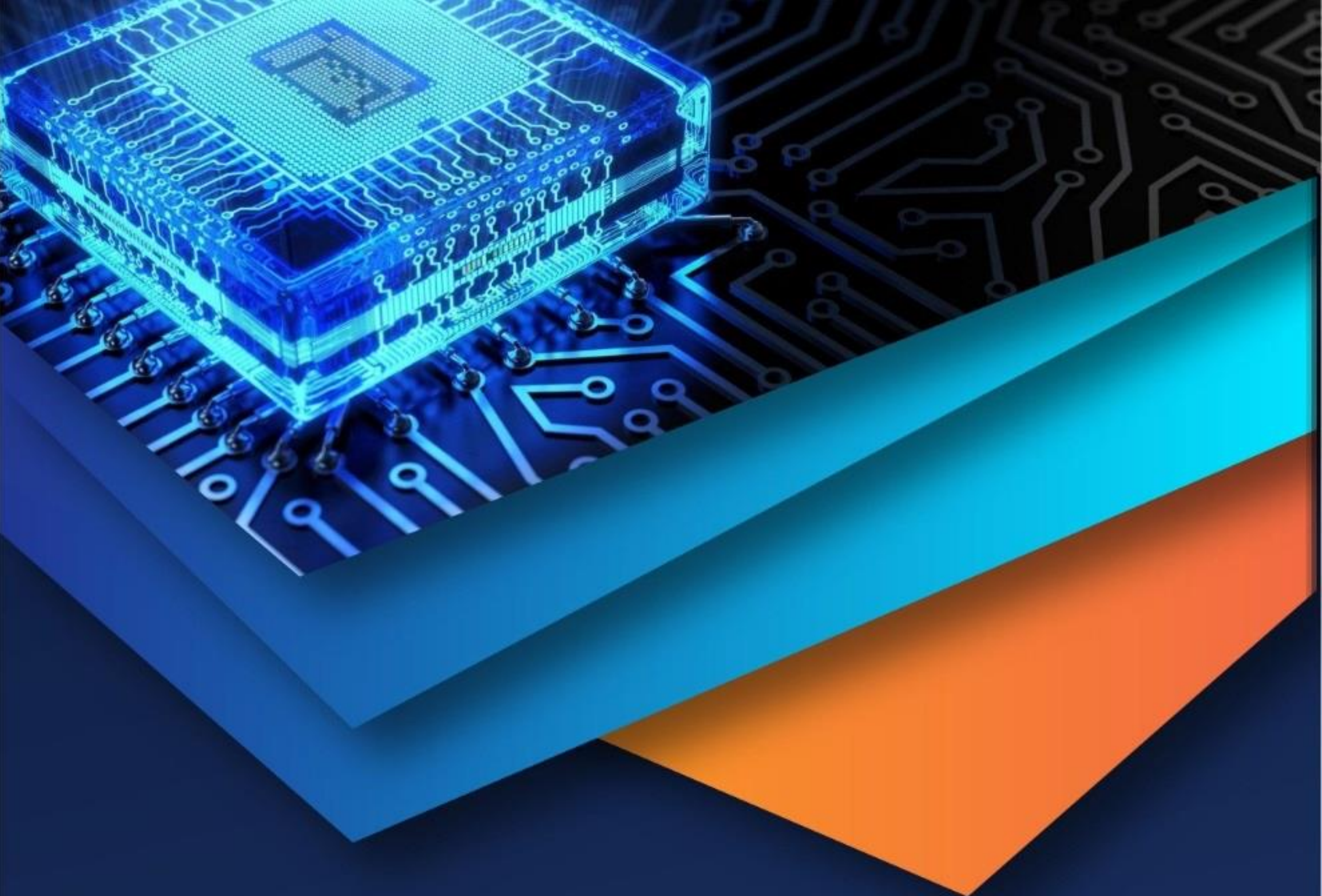

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