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VisionPark: Smart Parking System Using YOLO and OCR

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***Abstract*—Therapidincreaseinurbanvehicledensityhas led to significant challenges in parking management, including congestion, increased fuel consumption, and inefficient space utilization.ThispaperpresentsVisionPark,anintelligentparking system that leverages computer vision techniques for real-time parking space monitoring. The proposed approach utilizes the YOLO (You Only Look Once) algorithm for fast and accurate vehicle detection, combined with Optical Character Recognition (OCR) for automatic license plate identification.**

***The system processes live video streams to detect occupiedand vacant parking slots, enabling users to quickly locate availablespaces.Inadditiontoimprovingconvenience,thesystem maintains digital records of vehicles for enhanced security and monitoring. The proposed architecture is scalable and adaptable to various environments such as commercial complexes, office spaces, and public parking areas.**

***Experimental results demonstrate that the proposed system achieves 94.2% detection accuracy while maintaining efficient real-time performance. The integration of deep learning and automation makes VisionPark a practical solution for modern smart city applications.**

***IndexTerms*—SmartParking,ComputerVision,YOLO,OCR, Deep Learning, Intelligent Systems, Smart Cities**

I. INTRODUCTION

The increasing number of vehicles in urban areas has created significant challenges in managing parking spaces efficiently. Drivers often spend considerable time searchingfor available parking, which contributes to traffic congestion, increased fuel consumption, and environmental pollution [1],[3]. These issues highlight the need for intelligent parking solutions capable of providing real-time information.

Conventional parking systems rely on manual monitoringor static indicators, which fail to reflect real-time availability. With advancements in Internet of Things (IoT) and artificial intelligence, modern parking systems can provide dynamic monitoring and improved efficiency [2],[5]. However, many existing approaches require additional hardware such as sen-sors, increasing deployment cost and complexity.

Recentdevelopmentsindeeplearninghaveenabledthe use of computer vision techniques for automated parking management. Object detection models such as YOLO have demonstratedhighaccuracyandspeedinreal-timevehiclede-tection tasks [7]. Furthermore, Optical Character Recognition (OCR) techniques allow automatic extraction of license plate information, enabling efficient vehicle identification and record maintenance [8],[9].

This paper presents VisionPark, an intelligent parking sys-tem that integrates YOLO-based vehicle detection with OCR-basedlicenseplaterecognition.Thesystemanalyzesreal-time video feeds to identify occupied and vacant parking spaces while maintaining digital records of vehicles. The proposed approach aims to reduce parking search time, improve space utilization, and provide a scalable solution for modern urban environments.

The major contributions of the proposed VisionPark system are as follows:

- Real-time parking slot detection using YOLO-based ob-ject detection.
- Automated vehicle identification using OCR-based li-cense plate recognition.
- Integrationofedgecomputingtechniquesforreduced latency and faster response.
- Ascalableandcost-effectivesmartparkingframework suitable for smart city applications.

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II. LITERATURE REVIEW

Efficient parking management has been an active area of research due to the rapid growth of urban transportation systems. Early studies primarily focused on optimizing the allocation of parking spaces using algorithmic approaches. Arellano-Verdejo *et al.* [1] presented methods for optimal distributionofpublicparkingspotsinsmartcities,highlighting the importance of mathematical modeling in reducing conges-tion and improving resource utilization.

With the emergence of connected technologies, Internet of Things (IoT)-based parking systems have gained significant attention. Ke *et al.* [2] proposed an intelligent parking surveil-lance system that integrates edge artificial intelligence with IoTdevicestoprovidereliablereal-timemonitoring.Similarly, Al-Turjman and Malekloo[3] provided a comprehensive sur-vey on IoT-enabled smart parking systems, emphasizing their roleinimprovingurbanmobility.Liu*etal.*[5]furtherexplored IoT-based control mechanisms for parking guidance systems, demonstratingtheireffectivenessinmanagingtrafficflowand reducing search time for parking spaces.

InadditiontoIoT-basedapproaches,severalstudieshave focusedonreviewingtechnologicaladvancementsinsmart parking. Barriga *et al.* [4] conducted a detailed literature review highlighting the evolution of parking systems from traditional methods to intelligent solutions based on data-driventechnologies.Thesestudiesunderlinetheimportanceof integrating real-time data processing with intelligent decision-making to enhance system performance.

Recent advancements in deep learning have significantly improved the capabilities of smart parking systems. Canli and Toklu[6]demonstratedtheuseofdeeplearningtechniques in mobile-based parking applications, enabling efficient user interaction and real-time updates. Object detection models, particularly those belonging to the YOLO family, have been widely adopted due to their ability to perform fast and ac-curate detection. Praneeth *et al.* [7] discussed the scalabilityof YOLO-based models for edge deployment, making them suitable for real-time parking monitoring systems.

Another critical component of modern parking systems is automaticvehicleidentification.Wang*etal.*[8]proposed deep learning-based methods for license plate detection and recognition, achieving high accuracy in complex environ-ments.Similarly,DhyaniandKumar[9]developedareal- timesystemcombiningYOLO-baseddetectionwithOCR techniques for efficient license plate recognition. Sharma *etal.* [10] integrated number plate recognition with parking managementsystems,demonstratingimprovedautomationand reduced manual effort.

Overall, the reviewed literature indicates that while IoT-based systems provide effective monitoring, the integration of deeplearningtechniquessuchasYOLOandOCRsignificantly enhances automation and accuracy. However, many existing solutionseitherrelyheavilyonhardwareinfrastructureorlack a unified framework that combines real-time detection with vehicle identification. This gap motivates the development of the proposed VisionPark system, which integrates these tech-nologies into a scalable and efficient smart parking solution.

III. MAJOR ALGORITHMS USED IN THE PROPOSED SYSTEM

TheproposedVisionParksystemintegratescomputervision and deep learning techniques to enable automated and real-time parking management. The system focuses on accurate vehicle detection, parking space classification, and license platerecognition,therebyminimizingmanualinterventionand improving operational efficiency.

At the core of the system lies the YOLO (You Only Look Once) object detection algorithm, which performs real-time detection of vehicles within parking areas. YOLO divides an input image into a grid and predicts bounding boxes along with class probabilities for each cell [7].

The performance of the detection model is evaluated using Intersection over Union (IoU), which measures the overlap between predicted and ground truth bounding boxes:

$$IoU = \frac{Area of Overlap}{Area of Union} \quad (1)$$

To determine whether a parking space is occupied or va-cant, the system maps detected bounding boxes to predefined parking regions. A slot is classified as occupied if the IoU exceeds a defined threshold.

The system incorporates Optical Character Recognition (OCR) to extract license plate information from detected vehicles [8],[9].

The overall performance of the system is evaluated using standard classification metrics. Accuracy is computed as:

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (2)$$

where TP and TN represent correct predictions, while FP and FN denote incorrect classifications.
To further evaluate detection performance, precision and recall are defined as:

$$Precision = \frac{TP}{TP+FP} \quad (3)$$

$$Recall = \frac{TP}{TP+FN} \quad (4)$$

Precision indicates the correctness of detected vehicles, while recall measures the system's ability to detect all relevant vehicles.
By combining real-time object detection, spatial mapping, and text recognition, VisionPark provides a unified framework for intelligent parking management.

IV. ALGORITHMS FOR INTELLIGENT PARKING MANAGEMENT

The VisionPark system employs a combination of computer vision and deep learning techniques to automate parking space monitoring and vehicle identification. The architecture is designed to address challenges such as inefficient space utilization, lack of real-time visibility, and manual record management by integrating detection, classification, and recog-nition modules.
The vehicle detection component is based on the YOLO (You Only Look Once) algorithm, which enables real-time identification of vehicles within a parking area. The model processes input frames and predicts bounding boxes along with confidence scores in a single forward pass [7]. This approach ensures low latency and high detection accuracy, making it suitable for continuous video stream analysis. Figure 1 illustrates the overall workflow of the proposed system.

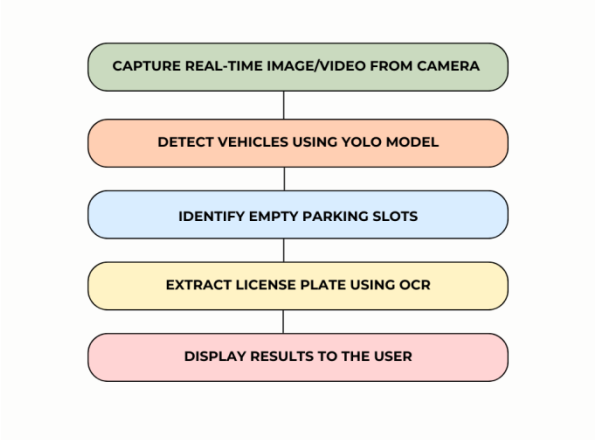


Fig.1: Workflow of VisionPark Intelligent Parking System

To determine parking occupancy, the system maps detected vehicles to predefined parking slots. Each slot is represented as a spatial region, and its status is evaluated based on over-lap with detected bounding boxes. The overlap is quantified using Intersection over Union (IoU), which ensures reliable classification of slots as occupied or vacant.
In addition to detection, the system integrates Optical Char-acter Recognition (OCR) for extracting license plate numbers from detected vehicles. The OCR module processes cropped vehicle regions and converts visual text into machine-readable form [8], [9]. This enables automatic vehicle identification and supports digital record keeping without human intervention.
The system further incorporates confidence thresholding to filter unreliable detections. Predictions with low confidence scores are discarded, reducing false positives and improving overall system robustness. This step is particularly important in dynamic environments with varying lighting and occlusion conditions.

To evaluate system performance, standard metrics such as accuracy,precision,andrecallareused.Thesemetricsprovide insightsintothereliabilityofvehicledetectionandparking

TABLEI:KeyAlgorithmsUsedinVisionPark

Algorithm/Module	Purpose
YOLOObjectDetection	Detectvehiclesinrealtime
IoU-BasedSlotMapping	Identifyoccupiedandvacantparkingspaces
OCRRecognition	Extractvehiclelicenseplateinformation
Confidence Thresholding	Reducefalsedetections
PerformanceMetrics	Evaluatedetectionandclassificationaccuracy

spaceclassification.Thecombinationoftheseevaluationmea-sures ensures that the system maintains a balance between detection sensitivity and correctness.

Overall, the integration of detection, spatial analysis, and textrecognitionallowsVisionParktooperateasacomprehen-sive parking management system. Unlike traditional sensor-basedapproaches,theproposedmethodreliessolelyoncamera input, making it more flexible and cost-effective for deploy-ment in diverse environments such as commercial complexes, office spaces, and public parking facilities.

V. RESEARCH CHALLENGES

Although smart parking systems have gained considerable attentioninrecentyears,severalpracticalchallengesstilllimit their effectiveness. One of the most common issues is unreli-able vehicle detection in real-world environments. Variations in lighting conditions, shadows, weather disturbances, and partialocclusionsoftendegradedetectionaccuracy,especially invision-basedsystems[2],[6].Theseinconsistenciesdirectly impact the reliability of parking occupancy estimation.

Anothercriticalconcernisachievingreal-timeperformance. Processing continuous video streams from multiple cameras requires significant computational resources. Many existing systemsexperiencedelayswhendeployedatscale,making itdifficulttoprovideinstantparkingupdatestousers[5],[7]. This limitation becomes more pronounced in large urban parking infrastructures.

Scalability is also a major challenge. While several ap-proaches perform efficiently in controlled or small-scale envi-ronments,theirperformancetendstodeclinewhenextendedto city-level deployments. Managing distributed parking spaces, integrating IoT devices, and maintaining synchronization across systems require robust and scalable architectures [1],[3].

Inaddition,theavailabilityofhigh-qualitydatasetsre-mains limited. Training deep learning models for parking applications requires well-annotated data, which is both time-consuming and labor-intensive to obtain. Inconsistent or in-sufficient data affects the generalization capability of models in diverse environments [4],[6].

Adaptability of models is another issue. Many systems are designed for specific layouts or camera positions, makingthem less effective when deployed in new settings. Changesin parking structure, vehicle types, or viewing angles often require retraining or fine-tuning of models [3],[4].

Furthermore, integrating additional functionalities such as license plate recognition introduces new complexities. These includehandlingdifferentplateformats,motionblur,and varying image quality, which can affect system accuracy [8]–[10].

Finally, cost and infrastructure constraints pose barriers to large-scale adoption. Systems relying on advanced sensors, multiple cameras, or edge devices may not be economically feasible for all environments, especially in developing regions [3],[5].

Addressing these challenges is essential for developing a reliableandscalablesolutionsuchasVisionPark,capable of delivering accurate and real-time parking insights across diverse conditions.

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VI. PROPOSED STRATEGIES

Toaddressthelimitationsobservedinexistingsmartparking solutions, several strategies are incorporated in the proposed VisionPark system. These strategies aim to improve detection accuracy, ensure real-time performance, and enhance system scalability.

To overcome inaccuracies caused by environmental varia-tions such as poor lighting, shadows, and occlusions, deep learning-based object detection models are utilized. These models are capable of learning complex visual patterns and provide more reliable detection compared to traditional meth-ods[2],[6]. Additionally, data augmentation techniques canbeappliedduringtrainingtoimprovemodelrobustnessacross diverse conditions.

Real-time performance is achieved by integrating edge computing techniques. Instead of relying solely on cloud processing, computation is partially performed on edge de-vices, reducing latency and enabling faster response times [5],[7]. This ensures that users receive timely updates regarding parking availability.

To handle scalability challenges, the system is designed us-inganIoT-basedarchitecture.Distributedsensorsandcameras communicate efficiently to manage multiple parking zones simultaneously, allowing seamless expansion from small to large-scale deployments [1],[3]. This approach supports ef-ficient resource utilization and system coordination.

The issue of limited and inconsistent datasets is addressed by incorporating diverse training data and leveraging transfer learning. Pre-trained models can be fine-tuned for parking-specificscenarios,reducingthedependencyonlargeannotated datasets while maintaining good performance [4],[6].

To improve adaptability, the system is designed to handle variations in camera angles and parking layouts. Periodic model updates and retraining mechanisms help maintain ac-curacy even when environmental conditions change [3].

Furthermore,theintegrationofadvancedmodulessuch as license plate recognition enhances system functionality. Modern deep learning techniques enable accurate recognition even under challenging conditions, contributing to improved automation and security [8]–[10].

Finally, cost-effectiveness is considered by optimizing the use of hardware resources. By combining efficient algorithms withaffordableedgedevices,thesystemachievesabalance between performance and implementation cost, making it suitable for practical deployment [5].

ThesestrategiescollectivelyensurethatVisionParkprovides a reliable, scalable, and efficient solution for modern parking management systems.

VII. LIMITATIONS

Despite continuous advancements in smart parking tech-nologies, several limitations persist in existing techniques that affect their practical deployment and overall performance.

Oneofthemajorlimitationsisthedependenceoncontrolled environmentalconditions.Manyvision-basedsystemsperform well under ideal lighting and minimal occlusion, but their accuracysignificantlydecreasesinreal-worldscenariosinvolv-ing shadows, weather variations, and complex backgrounds [2],[6]. This reduces the reliability of parking occupancy detection.

Another important drawback is the high computational requirement of deep learning models. While these modelsofferimprovedaccuracy,theyoftenrequirepowerfulhardware for real-time processing. This makes it challenging to deploy such systems on low-cost devices or in resource-constrained environments [7]. As a result, achieving a balance between performance and efficiency remains difficult.

Scalability is also a concern in many existing approaches. Systemsdesignedforsmallparkingareasoftenfailtomaintain efficiency when expanded to larger infrastructures. Managing multipledatasources,ensuringsynchronization,andmaintain-ing consistent performance across locations introduce addi-tional complexity [1],[3].

In addition, many techniques rely heavily on large, well-annotateddatasets fortraining.However,collecting andlabel-ing such datasets is time-consuming and prone to inconsisten-cies. This limitation affects the model's ability to generalize effectively across different environments [4],[6].

Lack of adaptability is another significant issue. Existing systems are often tailored to specific camera setups or parking layouts. When deployed in new environments, their perfor-mance may degrade unless the models are retrained or fine-tuned, which increases maintenance effort [3],[4].

Furthermore, integration of advanced features such as li-censeplaterecognitionintroducesadditionalchallenges.Vari-ationsinplateformats,motionblur,andlow-resolutionimages can reduce recognition accuracy, limiting the effectiveness of such systems in real-world applications [8]–[10].

Lastly, cost and infrastructure requirements restrict widespread adoption. Many systems depend on multiple sensors,high-resolutioncameras,andcontinuousconnectivity, makingthemlessfeasibleforlarge-scaleorbudget-constrained deployments [5].
These limitations highlight the need for a more robust and adaptable solution, which motivates the development of the proposed VisionPark system.

VIII. PROPOSED FRAMEWORK

Toaddressthelimitationsofexistingparkingsystems, theproposedVisionParkframeworkintroducesanintelligent, vision-basedapproachthatcombinesdeeplearning,edgecom-puting,andIoTintegrationforefficientparkingmanagement.

A. SystemOverview

VisionPark utilizes camera-based monitoring to detect ve-hicles and classify parking slot occupancy in real time. The system processes video input using a deep learning model trained for object detection, enabling accurate identificationof vehicles in diverse environmental conditions. The detected information is then used to determine slot availability and provide timely updates to users.

B. ModelArchitecture

The proposed system employs a state-of-the-art object de-tection model based on deep learning techniques. The modelis trained to identify vehicles and generate bounding boxes around them. By leveraging advanced feature extraction and localization capabilities, the system achieves improved accu-racyevenincomplexscenariossuchasocclusionsandvarying lighting conditions.

C. ImplementationDetails

The proposed VisionPark system was implemented using PythonandOpenCVlibrariesforimageandvideoprocessing. YOLOv8 was utilized for real-time vehicle detection, while EasyOCR was integrated for automatic license plate recogni-tion.
The system was trained on a custom parking dataset con-sisting of vehicle images captured under different lighting and environmental conditions. Training was performed over 50 epochs using a confidence threshold of 0.5.
The implementation was executed on a system equipped with an Intel Core i5 processor, 8 GB RAM, and integrated GPU support.

D. ModelTrainingandPerformanceAnalysis

The model was trained over multiple epochs to optimize detection accuracy and confidence. Performance evaluation was carried out using key loss metrics, including boundingbox loss and confidence loss.
Fig.2illustratesthevariationinboxlossduringtraining. A consistent decrease in loss indicates improved accuracy in predicting bounding box coordinates for detected vehicles.
Fig. 3 shows the trend of confidence loss across training epochs. The gradual reduction in confidence loss reflects the model's enhanced ability to correctly identify and classify vehicles.

E. PerformanceEvaluation

The performance of the proposed VisionPark system was evaluated using standard object detection metrics. The exper-imental results demonstrated high accuracy and efficient real-time performance under varying environmental conditions.

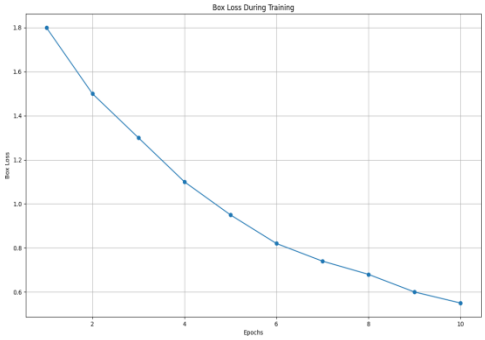


Fig.2:Variationofboxlossduringtraining.

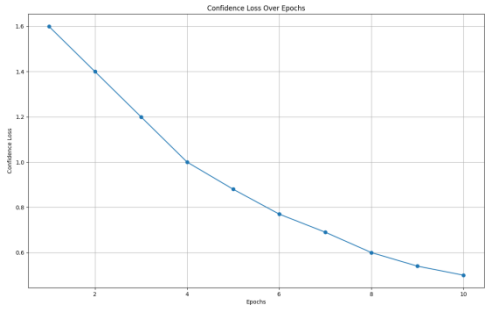


Fig. 3: Change in confidence loss over epochs. TABLE II: Performance Evaluation Metrics

Metric	Value
DetectionAccuracy	94.2%
Precision	92.1%
Recall	90.7%
FPSPerformance	24FPS
TrainingEpochs	50

F. UniquenessofVisionPark

Unlikemanyexistingparkingapplicationsthatrelyheav-ily on sensor-based detection or manual updates, VisionPark adopts a vision-based approach using deep learning for au-tomated and accurate vehicle detection. This reduces depen-dency on costly hardware sensors and minimizes maintenance requirements.

Another distinguishing feature of VisionPark is its abilitytooperateefficientlyundervaryingreal-worldconditions. By incorporating robust training techniques and adaptable models,thesystemmaintainsperformanceeveninchallenging environments such as low lighting or partial occlusions.

Additionally, VisionPark integrates edge computing to pro-cess data closer to the source, significantly reducing latency compared to cloud-dependent systems. This ensures faster updates and a better user experience.

The system is also designed with scalability in mind. Its IoT-based architecture allows seamless expansion across mul-tiple parking locations without compromising performance. Furthermore,themodulardesignenableseasyintegration of additional features such as license plate recognition and analytics.

Overall, VisionPark provides a cost-effective, scalable, and intelligent alternative to traditional parking solutions by com-biningaccuracy,efficiency,andadaptabilityinasingleframe-work.

G. SystemAdvantages

The proposed VisionPark system offers several advantages over traditional approaches. It provides real-time updates with reduced latency through edge processing, improves detection accuracy using deep learning, and ensures scalability through IoT-based communication. Additionally, the system is de-signed to be adaptable to different environments, making it suitable for practical deployment in smart cities.

Overall, the integration of these components enables Vi-sionPark to deliver a reliable, efficient, and scalable parking management solution.

IX. CONCLUSION

In this paper, an intelligent parking management system, VisionPark,hasbeenproposedtoaddressthelimitationsofex-isting parking solutions. The system leverages deep learning-based vehicle detection, edge computing, and IoT integration to provide accurate and real-time parking slot classification.

The experimental results demonstrate that the model achieves improved detection performance, as reflected by the consistent reduction in box loss and confidence loss during training.Thisindicatesthatthesystemiscapableofaccurately identifying vehicles and determining parking availability even under varying environmental conditions.

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Unlike traditional sensor-based or manual systems, Vision-Parkoffersacost-effectiveandscalablealternativebyutilizing vision-based techniques. The integration of edge processing furtherenhancessystemresponsiveness,makingitsuitablefor real-world deployment in smart city environments.

Although the proposed system shows promising results, there is scope for further improvement. Future work may include enhancing model efficiency for low-resource devices, incorporating advanced features such as predictive parking availability, and improving robustness under extreme condi-tions.

Overall, VisionPark presents a reliable, adaptable, and ef-ficient solution for modern parking management, contributing to the development of smarter and more sustainable urban infrastructure.

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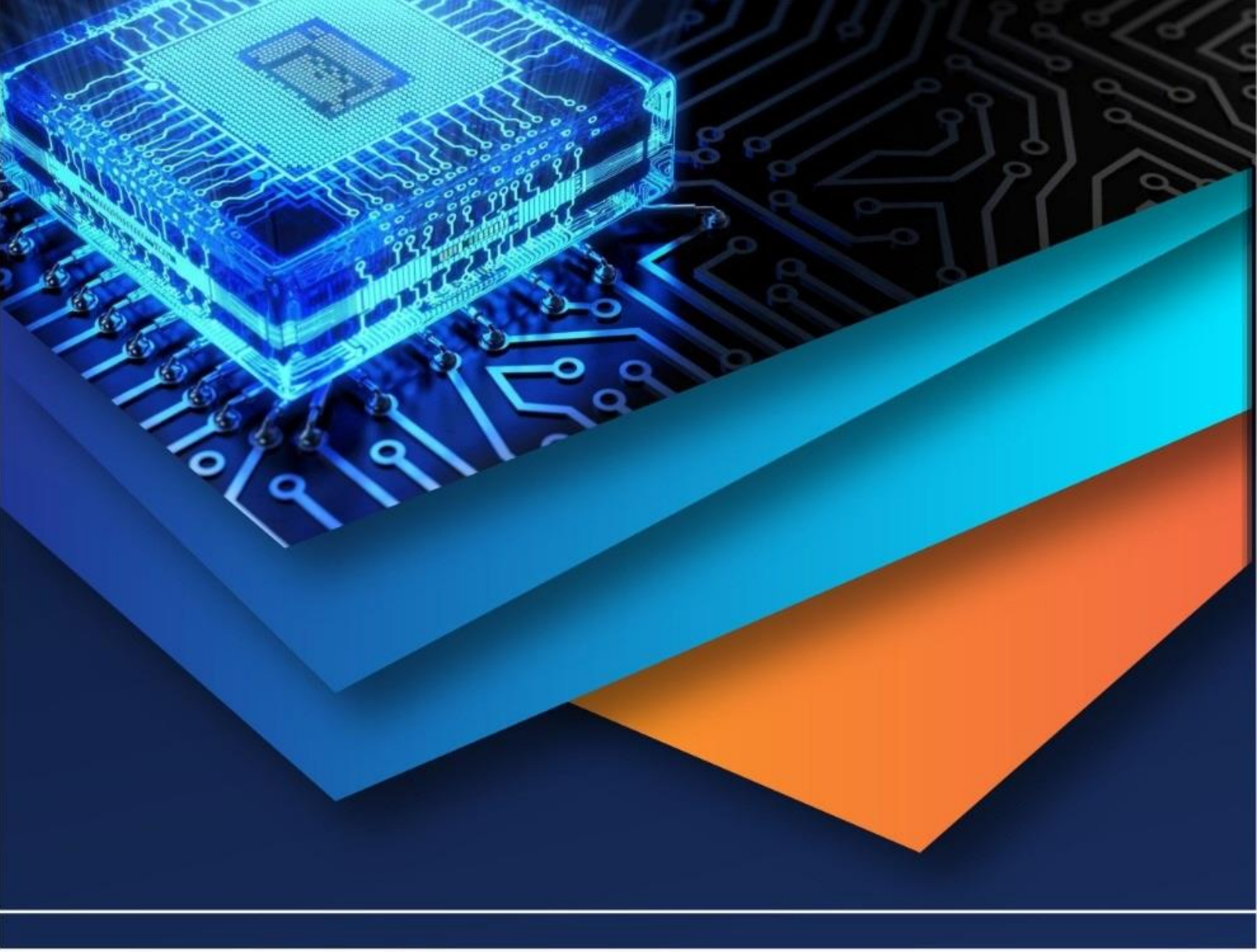
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