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A Study on Real-Time Traffic Detection using YOLO on Raspberry Pi with Case Study Analysis

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Abstract - **The increasing challenges of urban traffic congestion and road safety require efficient and cost-effective intelligent traffic monitoring systems. This paper presents the execution of a Raspberry Pi-based real-time traffic detection system using the You Only Look Once (YOLO) algorithm, along with a case study analysis based on existing research works. The proposed system leverages embedded computing and computer vision techniques to enable real-time identification of traffic signals and vehicles in resource-constrained environments. In contrast to conventional traffic control systems that depend on static control mechanisms and lack adaptability to dynamic traffic conditions, recent studies have demonstrated the effectiveness of YOLO-based object detection models for real-time traffic monitoring with high accuracy and speed. Furthermore, Raspberry Pi-based implementations have shown potential for low-cost and edge-based deployment in intelligent transportation systems. In addition to system implementation, this paper conducts a case study analysis of selected research works to evaluate different approaches in traffic detection and management, including deep learning-based detection models and IoT-enabled systems. The comparative analysis highlights the strengths and limitations of existing methods in terms of accuracy, computational efficiency, and scalability. The findings prove that hybrid approaches to lightweight hardware platforms and effective object detection algorithm are successful in solving traffic issues in the real life. The modern research might be called the continuation of the evolution of the efficient and effective intelligent traffic monitoring system depending on the analytical data of the existing literature.**

Keywords – Traffic management, YOLO, Reinforcement Learning, IOT, Raspberry Pi

1.Introduction

City with high population the traffic congestion, road safety became an important challenges due to urbanization and the rising car numbers. Weak measures to control traffic cause more time spent on the road, higher fuel use, air pollution, a higher crash rate. Conventional traffic technologies such as fixed-time and manually operated signals used in management cannot be adapted. effectively to rigorous traffic conditions, makes the poor movement in the traffic and congestion [1]. To overcome these problems, researchers have discovered some smart techniques which uses Artificial intelligence ,computer vision and IoT Among them methods which are used to detect objects deep learning based , algorithm called YOLO had an lot of attention because of its capability in real time. high accuracy and speed. Many of the research models shows that the algorithms are effective in detection of traffics and road signals in real scenarios, where the road safety and monitoring are being done. [2-4].

Besides of its capabilities of detections, the deployment of inexpensive embedded on intelligent systems it has turned into a significant line of research in platform. Raspberry Pi has become a trendy platform. to install real-time traffic monitoring due to its low cost, small size and capability assist vision applications. Prior research has demonstrated that integrating YOLO models with Raspberry Pi enables efficient and cost-effective traffic detection systems suitable for edge-based deployment [5].

Furthermore, advanced approaches such as reinforcement learning (RL) and IoT-based Systems for adaptive traffic control have been proposed to improve traffic efficiency. Reinforcement learning techniques enable dynamic optimization of traffic signals using real-time traffic conditions, while IoT-based systems facilitate real-time data collection and communication between traffic components. Although these approaches demonstrate improved adaptability and performance, they often require complex infrastructure and higher computational resources [6-8].

However, in spite of all these developments, it has been identified that there is a need to develop a simple, efficient, and cost-effective system for the purpose of traffic monitoring. In addition to this, it has also been identified that there is a need to develop a comprehensive analytical

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understanding of the existing research in order to determine their effectiveness. In this regard, this paper proposes a Raspberry Pi-based real-time traffic detection system using the YOLO algorithm. In addition to this, case study analysis has also been conducted in order to compare the existing research in the area of intelligent traffic management. Therefore, the objectives of this paper are to provide a practical solution in addition to a comprehensive analytical understanding of the development of efficient and cost-effective intelligent traffic management solutions.

In this paper, the following sections have been included: literature review and research background, system architecture, implementation and results, case study analysis based on existing research, and conclusion with future work.

2. Literature Review:

The development of intelligent traffic management systems has received significant scholarly attention in recent times due to the rise in urban traffic congestion and concerns regarding road safety. A variety of The literature has suggested strategies, including traditional traffic management strategies as well as cognitive results that comprising of IoT, deep and reinforcement learning. Conventional traffic Signal control strategies are strategies that have been traditionally used, including fixed-time and coordinated control strategies. employed in earlier systems.

Standard methods of managing traffic lights such as fixed time control and coordinated control. tactics, have been greatly resorted to in previous systems. Nevertheless, such strategies are not open. to real-time traffic state and can frequently end up with the inefficient management of traffic flow [1]. The inability of This has prompted the researchers to investigate intelligent such systems to be responsive to the different levels of traffic. and data-driven solutions.

Over the last several years, object detection algorithms based on deep learning, especially, the You Only Look Once (YOLO) algorithm, have become one of the most effective tools to use in real-time traffic monitoring. A number of studies have shown that The efficiency of YOLO models to detect road signs and traffic lights is high and in a fast manner. As an example, YOLO-based traffic signal Detection systems have been designed to enhance the safety of traffic by detecting the traffic signals and alerting the drivers in real-time [2]. On the same note, real-time traffic signal recognition and detection systems based on YOLO have demonstrated enhanced stability and performance under practical conditions [3]. More sophisticated implementations that apply YOLOv8 also enhance the accuracy of detection, precision, and recall, and can be used in real-time intelligent transportation systems [4].

Besides detection of signal, YOLO has been found of many applications in detection of traffic sign and driver. assistance systems. A Raspberry PI implementation shows that it is possible to deploy. On platforms like embedded , real-time detection and alerts to the users are being made by YOLO , thus its makes emphasizing, low-cost and edge-based suitability [5]. And addition to that the studies based on the comparison of YOLO variants show that more recent models results in higher performance with regard to speed and precision, allowing environmental resource-constrained [6]. Massive assessments with tailor-made. In Transportation applications the data regarding the object detection results provide that YOLO based models are efficient [7].

In addition to detection, there are a number of studies that involve adaptive traffic signal control based on object detection. techniques. An integrated systems with Combination of YOLO with the traffic control mechanisms alter the signal dynamically. vehicle density and queue length timings hence better traffic flows and lessening waiting time [8]. In the same manner, self-adaptive traffic light control systems make use of YOLO-based detection in order to do so. Optimize signal phases and reduce congestion, which proves the effectiveness of an integration of computer. traffic control strategies vision [9].

The introduction of the Internet of Things (IoT) technologies has also improved the traffic management system by allowing the real-time data collection and communication. Intelligent traffic systems based on IoT operate sensors and other linked devices that observe the state of the traffic and adapt signal cycles, which leads to better efficiency and the decreasing congestion rate [10]. Additionally, AIoT systems integrate YOLO object detection, cloud and edge computing to offer scalable and effective traffic management systems [11]. It has also been suggested that more sophisticated structures that use IoT, artificial intelligence, and energy optimization algorithms can be employed to facilitate sustainable infrastructures of smart cities [12].

Concurrently ,the adaptive traffic signal control has been universally studied with reinforcement learning (RL). The systems are able to learn optimal control strategies of traffic through interaction with the RL-based method. Simulation investigations with the aid of SUMO prove that RL can be used to solve the issue of congestion and enhance traffic efficiency by setting the signal timings dynamically [13]. The multi-agent ways of reinforcement learning also improve the performance of the systems by coordination of multiple intersections which result to less waiting time and better traffic flow [14]. The development of advanced hybrid models based on the reinforcement learning and optimization algorithm with communication infrastructure

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has also been suggested to manage intricate traffic conditions in an urban area, as well as urgent vehicle prioritization [15]. Also, reinforcement learning algorithms with IoT-based reinforcement learning networks based on graph neural networks permit coordinated and scalable traffic control within smart city settings [16].

More so, studies have addressed the hybrid deep learning architectures in traffic prediction and management. These approaches combine machine learning, deep learning, and reinforcement learning techniques to improve traffic flow prediction and decision-making, demonstrating improved accuracy and efficiency [17].

Nevertheless, there are still several challenges to be addressed. For instance, current intelligent traffic management systems are based on highly efficient algorithms, which are computationally intensive and resource-consuming. Reinforcement learning and IoT are effective, as they provide more accurate results; however, they are costly and complicated. YOLO is effective and efficient, as it provides accurate results; however, it is mainly based on detection and not comprehensive analytical studies. Therefore, there is a need to develop a simple and cost-effective system that is efficient in object detection, as well as carry out comprehensive analytical studies to assess the viability and effectiveness of current systems. Therefore, the motivation behind the current work is to consider the implementation of the YOLO algorithm and system analysis to ensure effective outcomes.

3. System Architecture

The current work presents a system architecture that is aimed at developing a simple and efficient real-time traffic detection system using the Raspberry Pi and YOLO algorithm. The system architecture is based on a modular structure consisting of three major parts: the input layer, the processing layer, and the output layer. The layered structure is aimed at providing a clear and efficient division of duties. The real-time traffic detection is carried out using a camera module, and the output is then fed to the Raspberry Pi and then to the YOLO algorithm to carry out object detection. The output is then fed to the user, allowing real-time monitoring.

3.1 Architecture Description

The architecture is organized into the following modules as shown in Figure 1

Input Layer:
The input layer consists of a camera module that continuously captures live video from the traffic environment. These video frames act as raw input data for the system.

Processing Layer:
The processing layer is the core of the system, implemented using Raspberry Pi. It performs:

- Frame acquisition from the camera
- Image preprocessing (resizing, normalization)
- Execution of the YOLO model for object detection

This layer is responsible for identifying traffic signals, vehicles, and other objects in real time.

Output Layer:

The output layer displays the processed results, including detected objects with labels and bounding boxes. The output can be shown on a monitor or terminal interface.

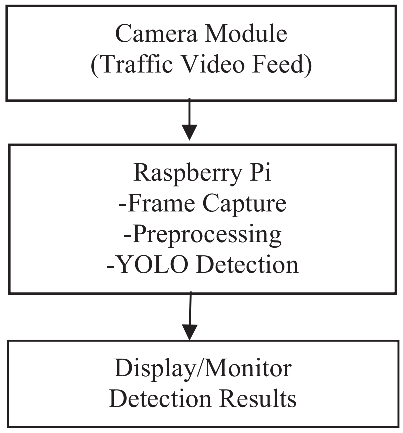

Figure 1. System Architecture Diagram (Block Representation)

3.2 Data Flow

The flow of data in the system follows a sequential pipeline as illustrated below:

Working Flow Description from the Figure 2

The video is divided into frames and then this data is sent to the Raspberry Pi for processing. Pre-processing of individual frames is carried out to improve image clarity and quality. The YOLO algorithm is applied to detect objects such as traffic signals, vehicles in the image. The output is further processed to get labeled output with bounding boxes.

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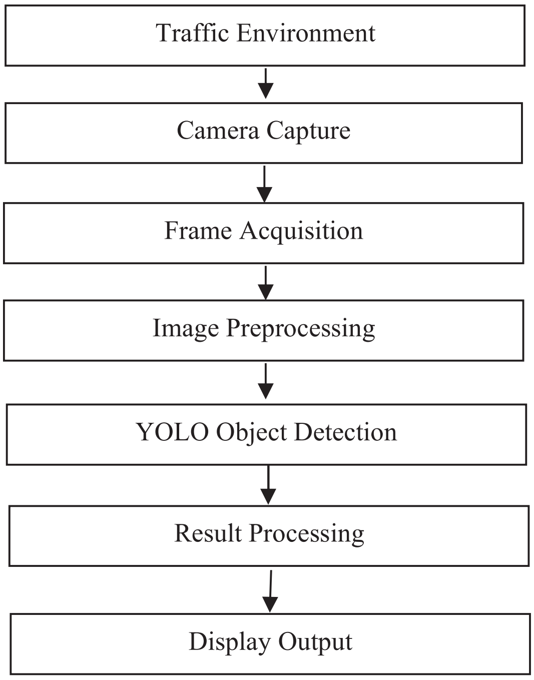

Figure 2. Data Flow

And in the last, the output is displayed to the user, providing the real-time monitoring of the scenario. Thus, this flow of operations is efficient in processing data and providing a real-time output to the user.

3.3 Advantages of the Proposed Architecture

- Simple and low-cost implementation using Raspberry Pi
- Real-time object detection using YOLO
- Modular design for easy scalability
- Suitable for edge computing applications

The proposed architecture provides a practical balance between performance and implementation simplicity. It can be extended with additional features such as IoT connectivity, cloud storage, and advanced analytics in future developments.

4. plementation and Results:

The results , The proposed system is implemented using a Raspberry Pi platform integrated with a camera module and a YOLO-based object detection model. The implementation focuses on developing a simple, cost-effective, and real-time traffic detection system suitable for edge-based applications.

4.1 Implementation Workflow

The overall implementation follows a sequential workflow: Below are the steps

```
Step 1: Capture real-time video using
camera
Step 2: Extract frames from video stream
Step 3: Preprocess frames (resize,
normalize)
Step 4: Apply YOLO object detection
Step 5: Identify traffic objects
(signals, vehicles)
Step 6: Display results with bounding
boxes
```

4.2 System Execution

During execution, the camera continuously captures video frames from the traffic environment. These frames are processed by the Raspberry Pi in real time. The YOLO model detects objects such as traffic signals and vehicles and marks them with bounding boxes and labels. The system operates efficiently under normal conditions, demonstrating the feasibility of deploying object detection models on low-cost embedded devices.

4.3 Results and Discussion

The result of the implementation is mainly qualitative and focuses on the real-time detection capability of the system. The evaluation was performed under normal lighting conditions and also in low-light and high-traffic conditions.

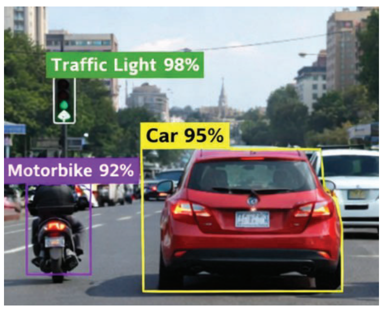

Figure 3: Real-time detection output under normal lighting conditions

Under normal illumination conditions, the system demonstrates an efficient detection process for traffic objects such as vehicles and traffic signals. The proposed

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YOLO model effectively detects multiple objects and provides bounding boxes with clear delineation and high confidence. The detection process remains consistent, and the Raspberry Pi processes the frames within an acceptable time.

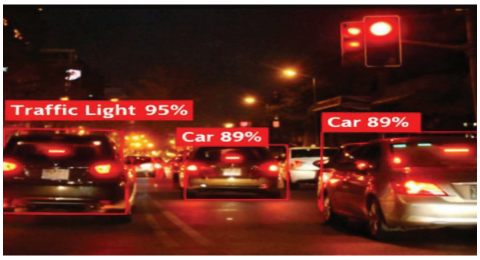

Figure 4: Detection output under low-light and high-traffic conditions

In low-light and high-traffic conditions, the system maintains the performance of real-time detection, although a slight drop in the accuracy of object detection is noticed. This drop in accuracy is mainly due to low visibility and the presence of overlapping objects in the scene. However, the system maintains a reasonable performance in object detection, thereby proving the robustness of the system.

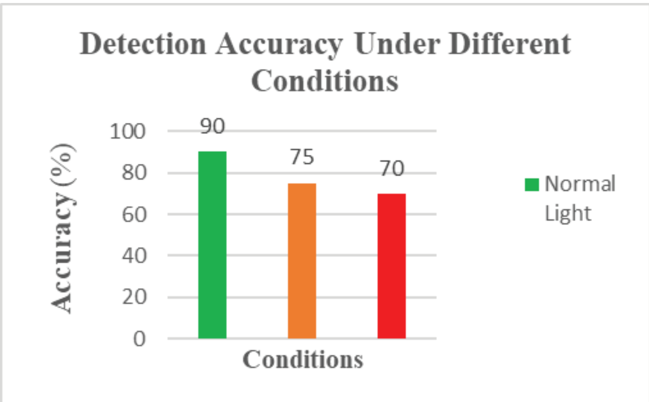

Figure 5: accuracy of different environmental conditions

The performance graph represents the different detection accuracy of the performance in the varied conditions. Accuracy is greater in the normal illumination conditions and moderate deterioration of the accuracy is observed in low illumination and high traffic density conditions. This is consistent with the existing literature that demonstrates that the environmental factors contribute greatly to the object detection systems. Regarding the outcomes of the implemented systems, it is evident that the proposed system, which is built on a Raspberry Pi, can be used to conduct real-time traffic detection using a deep learning algorithm like YOLO.

Nonetheless, different environmental aspects, including light and traffic, cause an effect on system accuracy. Differences in illumination conditions influence the quality of the image, whereas high density conditions will lead to the overlapping of objects in the scene making the object detection less accurate. These are common problems with vision-based object detection, and need to be taken into account in future research directions. With the help of the results, it is obvious that the proposed system, which is built on a deep learning algorithm and using Raspberry Pi, can be used to conduct real-time traffic detection.

4.6 Performance Discussion

Despite the fact that the system is deployed to a resource-constrained device, it shows the potential of the system to execute deep learning-based detectors at the edge. YOLO is very fast to detect and therefore can be applied to real-time use when compared to traditional applications.

Nonetheless, the performance lies on factors including:

- Lighting conditions
- Camera quality
- Model optimization

4.7 Summary

This implementation shows that the real time traffic detection can be carried out with Raspberry Pi-based system by the aid of YOLO. The findings indicate that there is a compromise on performance, cost and simplicity and as such, the system is applicable to practice and additional research.

5. Case Study Analysis.

The case study analysis in this section is instituted on a comparative analysis of the available research works with regards to the intelligent traffic management systems. The given analysis is aimed at studying different methodologies, their advantages and weaknesses, and their relevance in practice. Compared to experimental validation, the study is based on analytical information provided in the already existing literature.

5.1 Classification of Approaches

From the previous studies, the existing approaches can be categorized into four major types:

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1. YOLO-Based Detection Systems
2. IoT-Based Traffic Management Systems
3. System that are based on Reinforcement Learning
4. Hybrid and Predictive Models

YOLO-based solutions are also mainly concerned with real-time detection of objects in order to monitor traffic and identify signals. IoT systems make real-time communication and data gathering possible in an interconnected device. Reinforcement learning approach maximizes traffic lights on a dynamic basis by means of adaptive learning. The hybrid models are models combining several methods like machine learning, deep learning, and reinforcement learning to boost the accuracy of prediction and control.

5.2 Comparative Analysis of Techniques

Table 5.2.1 below presents the recent approaches and their summary.

Table 5.2.1: Comparison of Traffic Management Approaches

Approach Type	Key Feature	Advantages	Limitations
YOLO-Based	Real-time object detection	High speed, low cost	Limited decision-making capability
IoT-Based	Sensor-based monitoring	Scalable, real-time communication	Requires infrastructure
RL-Based	Adaptive learning	Dynamic optimization	High computational complexity
Hybrid Models	Combined techniques	High accuracy and prediction capability	Complex implementation

5.3 Graphical Comparative Analysis

In order to promote the clarity of analysis, the graphical presentation is taken to depict the connection between the various methods according to performance, complexity, and cost.

(1) Accuracy vs Complexity Analysis

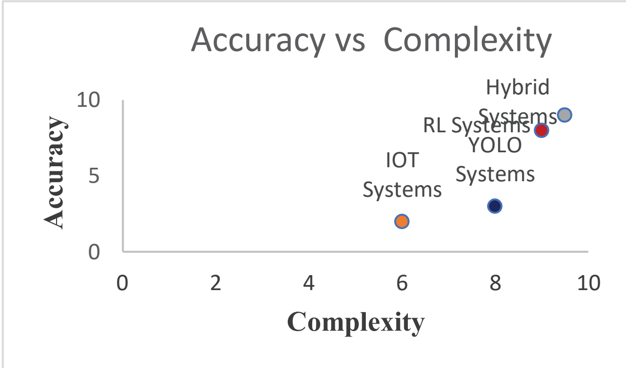

Figure 6 : Accuracy vs Complexity

This chart (Figure 6) shows that the systems based on the YOLO system have rather high accuracy and low computational complexity. Conversely, reinforcement learning and hybrid models are more accurate but far more complex as requiring more complicated algorithms and training.

(2) Cost vs Performance Analysis

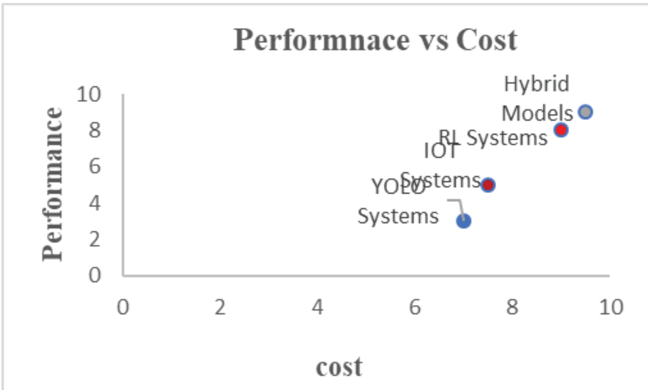

Figure 7: Cost vs Performance

As depicted in the graph (Figure 7), the YOLO-based systems have a proven cost-efficient solution with reasonable performance. IoT-based systems offer moderate performance at moderate costs, and reinforcement learning and hybrid models offer better performance at the cost of higher cost and more infrastructure.

(3) Overall Performance Comparison

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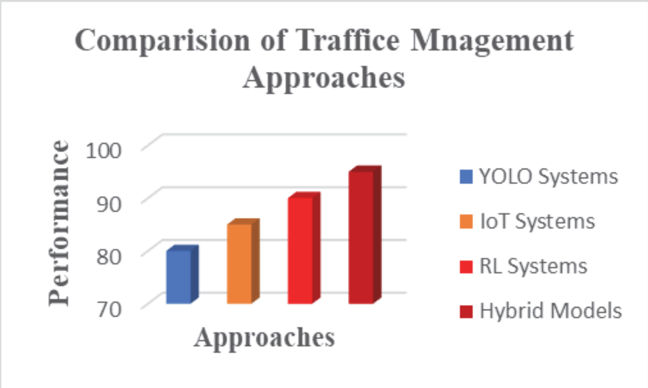

Figure 8: performance of different traffic management approaches

There is a comparative analysis of the performance levels of the various approaches using the bar chart (Figure 8). Reinforcement learning, Hybrid systems are most effective as a result of an adaptive capability and then hybrid models. IoT systems have a moderate performance, and YOLO-based systems have a balanced performance to be used in real-time applications.

(4) Application Suitability Analysis

In order to further determine the applicability in practice, a comparison of various approaches is performed in Table 5.3.1 on the basis of real-life deployment parameters.

Table 5.3.1: Application Suitability of Traffic Management Approaches

Approach	Real-Time Capability	Cost	Complexity	Practical Applicability
YOLO	High	Low	Low	High
IoT	High	Medium	Medium	High
RL	Medium	High	High	Limited
Hybrid	High	High	High	Moderate

According to the table, the systems based on YOLO are quite appropriate in the cases of real-time and low cost applications, especially when using embedded systems like the Raspberry Pi. Scalable deployments can also be done using IoT systems. But on the other hand, reinforcement learning and hybrid methods are more applicable in higher level applications because of its increased computational and infrastructural needs.

5.4 Key Observations

The following observations are derived from the comparative analysis:

- YOLO-based systems provide efficient real-time detection with low computational requirements
- IoT-based systems enhance scalability and enable real-time communication between devices
- Reinforcement learning approaches offer adaptive and dynamic traffic control but require high computational resources
- Hybrid models improve prediction accuracy and system performance but increase implementation complexity

5.5 Summary

According to the case study analysis, the best solution to suit all the needs of efficiency, cost, scalability, and performance does not exist. YOLO-based systems provide a medium scale solution to real time low cost and complexity application giving it a fit in embedded systems. On the contrary, reinforcement learning and hybrid models are more performance-enhancing, but they demand more advanced infrastructure and computing power.

This analysis supports the selection of a YOLO-based system in this study while identifying opportunities for integrating advanced techniques in future developments.

6. Conclusion and Future Work

In this, the implementation of the proposed system, which is based on the real-time traffic detection system using the Raspberry Pi platform and the YOLO algorithm, as well as the analysis of the existing traffic management techniques. The proposed system also shows the possibility of implementing an efficient object detection system in low-cost embedded systems, thereby validating the proposed system's practicality. The evaluation of existing methods also shows that the proposed system's choice of the YOLO algorithm provides a balanced approach to real-time object detection when the cost of implementation is considered. The evaluation also shows that the proposed IoT approach provides advantages in terms of system scalability and communication.

The results also show that no approach provides the best solution for all performance and implementation requirements, thereby validating the practical and cost-effective approach, especially for the short term. The results also show that the proposed system's choice of deep

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learning-based object detection models provides competent performance in embedded systems such as the Raspberry Pi. The proposed system provides real-time object detection with competent performance.

Future Work

The future work may be focused on improving the proposed system to include advanced techniques. Firstly, the system may be improved to include optimized deep learning models to enable efficient object detection. Moreover, data sharing and monitoring in real time might be enhanced by incorporating this system with IoT technology and integrated solutions. Adaptability to change over in traffic conditions might be achieved by incorporating various traffic management strategies, such as reinforcement learning and other learning strategies, The efficiency and ability of this system in processing and data management might be enhanced by incorporating various cloud, fog, and edge computing technologies. The system might be enhanced and improved to enable real-time testing in various critical and environmental conditions.

References

[1] Bao-Lin Ye, Weimin Wu, , Keyu Ruan, Lingxi Li, , Tehuan Chen, Huimin Gao, and Yaobin Chen , “A survey of model predictive control methods for traffic signal control” ,IEEE/CAA Journal of Automatica Sinica, vol. 6, Issue. 3, pp. 623–640, May 2019.

[2] J. Sharma, D. Kumar and A. Malhotra, "Advanced Traffic Signal Recognition Using Real-Time Detection Using YOLO v8," 2024 2nd World Conference on Communication & Computing (WCONF), RAIPUR, India, 2024, pp. 1-4

[3] S. Saklani, S. A. Dhondiyal and D. Singh, "Real-Time Traffic Management System Using YOLOv8: An analysis of various YOLO Models," 2025 4th OPJU International Technology Conference (OTCON) on Smart Computing for Innovation and Advancement in Industry 5.0, Raigarh, India, 2025, pp. 1-6,.

[4] K. Zaatouri and T. Ezzedine, "A Self-Adaptive Traffic Light Control System Based on YOLO," 2018 International Conference on Internet of Things, Embedded Systems and Communications (IINTEC), Hamammet, Tunisia, 2018, pp. 16-19.

[5] F. Köylü, "A Comparative Analysis of YOLO-Based Traffic Sign Detections With a Novel Turkish Traffic Sign Dataset," in *IEEE Access*, vol. 14, pp. 7744-7763, 2026

[6] I. Khan, M. Hasan, S. Islam, S. Reza, T. Reza and E. T. Efaz, "Adaptive Traffic Signal Control System Using Object Detection Based Approach," 2025 4th International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST), Dhaka, Bangladesh, 2025, pp. 86-91

[7] M. H. Kabir and M. S. Islam, "Enhancing Traffic Flow and Reducing Congestion: A Smart City Approach with an IoT-based Intelligent Traffic Management System," 2024 International Conference on Innovations in Science, Engineering and Technology (ICISET), Chittagong, Bangladesh, 2024, pp. 1-6

[8] K. M. Mhaidat, R. N. Abu Yosef and B. A. Sinno, "AIoT-Based Smart Traffic Light Management System using YOLO Object Detection and Transfer Learning," 2025 International Conference on Circuit, Systems and Communication (ICCSC), Fez, Morocco, 2025, pp. 1-6

[9] R. Sumathy and A. Rinu Rija, "IoT and AI-Driven Adaptive Traffic Signal Control Using Deep Reinforcement Learning and Graph Neural Networks," *2025* 10th International Conference on Smart Structures and Systems (ICSSS), Chennai, India, 2025, pp. 1-4.

[9] A. Janota *et al*., "Reinforcement Learning Approach to Adaptive Traffic Signal Control Using SUMO-RL," 2024 25th International Carpathian Control Conference (ICCC), Krynica Zdrój, Poland, 2024, pp. 01-06

[11] P. Zheng, Y. Chen and B. V. D. Kumar, "Regional Intelligent Traffic Signal Control System Based on Multi-agent Deep Reinforcement Learning," 2023 8th International Conference on Computer and Communication Systems (ICCCS), Guangzhou, China, 2023, pp. 362-367.

[12] R. T. Kumari, M.Bhavya, J. A. Reddy, T. T. Gopi and R. Lalitha, "Intelligent Traffic Flow Prediction Using Hybrid Deep Learning Models," 2025 International Conference on Sustainable Communication Networks and Application (ICSCN), Theni, India, 2025, pp. 639-644.

[13]S. Agrawal, R. Sharma, P. Srivastava and V. Patel, "Adaptive Traffic Signal Control System Using Deep Reinforcement Learning," 2024 IEEE International Conference on Intelligent Signal Processing and Effective Communication Technologies (INSPECT), Gwalior, India, 2024, pp. 1-6.

[14] A. Manonmani, R. Kumar K, S. Kumar M and S. Kumar G, "A Review on Smart Traffic Light Management and Energy Optimization with Artificial Intelligence(AI) enabled Programmable Logic Controller(PLC) using Internet of Things(IoT)," 2025 6th International Conference on IoT Based Control Networks and Intelligent Systems (ICICNIS), Bengaluru, India, 2025, pp. 495-501,

[15] J. Guo and I. Harmati, "Traffic Signal Control Based on Game Theoretical Framework," 2019 22nd International Conference on Process Control (PC19), Strbske Pleso, Slovakia, 2019, pp. 286-291

[16] Y. Setiawan, M. N. Puji and W. Astuti, "Traffic Signs Detection System Using YOLO (You Only Look Once) That Provides Notification," 2024 IEEE International Conference on Smart Mechatronics (ICSMech), Yogyakarta, Indonesia, 2024, pp. 95-100,.

[17] N. B. Bahadure, P. D. Patil, R. Birewar, P. Nayyar, A. Shrivastav and M. Oberoi, "Traffic Signal Detection and Recognition from Real-Scenes Using YOLO," 2023 IEEE Engineering Informatics, Melbourne, Australia, 2023, pp. 1-5

[18] S. Biswas, S. Acharjee, A. Ali and S. S. Chaudhari, "YOLOv8 based Traffic Signal Detection in Indian Road," 2023 7th International Conference on Electronics, Materials Engineering & Nano-Technology (IEMENTech), Kolkata, India, 2023, pp. 1-6

[19] Othman S. Al-Heety; Zahriladha Zakaria; Ahmed Abu-Khadrah; Mahamod Ismail; Mohammed Mudhafar Shakir; Sameer Alan, "Traffic Congestion Control With Emergency Awareness and Optimized Communication Infrastructure Using Reinforcement Learning and Non-Dominated Sorting Genetic Algorithm," in *IEEE Access*, vol. 14, pp. 33684-33704, 2026