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Automatic Traffic Signal by Using Artificial Intelligence

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Abstract- ***The rapid growth of urban populations and the increasing number of vehicles have led to congestion, traffic jams, and inefficiencies in road networks. Traditional traffic signal systems, which rely on fixed timing or manual control, often fail to address the dynamic and unpredictable flow of traffic. This paper outlines an automatic traffic signal system that enhances traffic management by using real -time data to adjust signal timings based on traffic density and flow. The proposed system employs sensors, cameras, or inductive loops to monitor vehicle movement and congestion levels at intersections. The signals are then controlled by an intelligent algorithm that dynamically adjusts the green, yellow, and red phases to optimize traffic flow, reduce waiting times, and minimize fuel consumption and emissions.***

Keywords: Automatic Traffic Signal, Artificial Intelligence, Real -time Data, Traffic Density, Optimize Traffic Flow.

I. INTRODUCTION

In many parts of the world, traffic congestion has been getting worse, and all signs point to this trend extending. This poses an undeniable negative impact on the quality of urban life. Its primary manifestation is a progressive slowing down of traffic, which increases travel time, fuel consumption, other operating costs, and environmental pollution when compared to a continuous flow of traffic. In addition, road capacity is one of the main reasons to cause traffic congestion. Problems with road development and maintenance in the cities, driving practices that show little consideration for other road users, inaccurate information on traffic conditions, and inadequate management by responsible authorities who are frequently dispersed among a variety of different bodies, all serve to exacerbate the situation in the region.The popularity of private vehicles in recent years has resulted in increasingly congested urban traffic. As a result, one of the major issues in major cities around the world is traffic. The harmful effects about congestion are suffered directly by vehicles that are trying to circulate. They affect not only drivers but also passengers of public transportation, who not only have to travel more slowly but also pay more for their tickets because of congestion. With the sharp increase in vehicle usage, the current traffic signal control only operates on a fixed time delay, which can be inefficient and result in significant losses.

Therefore, it is imperative to maintain congestion under control. Metal, power, and coloured plastic was used to construct the first electronic traffic signal. It was not automatic, and a policeman in a booth operated it. The fact that there were just red and green lights is more intriguing. The majority of modern traffic light systems employ a wire loop that is hidden beneath the road. When a car drives over this wire, which carries electric current, the magnetic field it generates causes it to activate by sending a signal to a roadside computer. Smart cities are being implemented in different parts of the world and to be more specific thanks to Artificial Intelligence. In doing so, these systems will reduce congestion, reduce pollution, decrease time speed on the road and even prevent accidents. We also believe that this will help pedestrian and cycle traffic in doing so which means a city working in sync and the benefits will be unimaginable considering the world's current use of the traffic systems. Considering these advantages, one can imagine the benefits to the city's economy, improvement in traffic safety and benefits to millions of people worldwide

II. LITERATURE REVIEW

Recent research has focused on using Machine Learning (ML), Deep Learning (DL), and Reinforcement Learning (RL) to create intelligent systems that can automatically adjust signal phases to minimize congestion, vehicle delay, and queue length. Among these, Deep Reinforcement Learning (DRL) and Multi-Agent Reinforcement Learning (MARL) approaches have shown remarkable performance in simulation-based traffic networks, demonstrating better adaptability and efficiency compared to traditional models.

AI Techniques in Traffic Signal Control

Fuzzy Logic Controllers (FLC):
Early intelligent systems used fuzzy logic to handle uncertainty in traffic data. FLCs are rule-based and computationally light but struggle with complex, dynamic traffic environments.

Machine Learning and Prediction Models:
Supervised ML models, such as Artificial Neural Networks (ANNs) and Long Short-Term Memory (LSTM) networks, predict vehicle flow and queue lengths, allowing proactive signal adjustments.

Reinforcement Learning (RL):
RL-based systems learn optimal control policies by interacting with simulated traffic environments. Each intersection is treated as an agent that maximizes a reward based on traffic performance (e.g., minimizing delay).
Deep Reinforcement Learning (DRL) and Multi-Agent Systems: Modern systems employ DRL for large-scale, complex traffic networks. Multi-agent coordination enables communication between intersections using Graph Neural Networks (GNNs) and Attention Mechanisms for improved efficiency and scalability.

Computer Vision and IoT-based Systems:
Vision-based detection uses AI to interpret live video feeds and estimate traffic density, integrating with fuzzy or RL-based controllers for real-time adaptive decision-making.

From the reviewed studies, it is evident that Reinforcement Learning—particularly Deep RL—has emerged as the dominant technique for automatic traffic control systems. The success of systems like IntelliLight, PressLight, and CoLight demonstrates the potential of AI in reducing average delay and improving throughput.

However, several limitations remain:

- Simulation vs. Reality Gap: Most models are tested only in simulators such as SUMO or CityFlow, making real-world deployment challenging.
- Coordination Complexity: Multi-agent systems face scalability and communication issues in large city networks.
- Safety and Interpretability: Deep models often act as "black boxes," raising concerns in safety-critical urban systems.

Recent research (2023–2025) is focusing on meta-learning, safe RL, and graph-based coordination to address these challenges and bring AI-based traffic control closer to real-world deployment.

Summary of Literature:

S.No	Author(s) / Year	AI Technique / Approach	Approach Simulator / Dataset Used	Performance Metrics	Key Findings / Limitations
1	2018	Deep Reinforcement Learning (DQN-based	CityFlow Simulato r	Avg. travel time, delay	Reduced average delay by 20–30% vs. fixed-time; limited generalization to new intersections.
2	2019	RL with Max-Pressure control	Queue length, throughput	Queue length, throughput	Achieved high scalability; depends on accurate pressure estimation.
3	2019	Multi-Agent RL + Graph Attention Network	CityFlow	Travel time, delay	Impro ved inter-intersection coordination; high computation cost
4	2020	Meta Reinforcement Learning	SUMO, CityFlow	Delay, throughput	Adapted faster to unseen traffic scenarios; heavy training requirement.
5	2024	Graph Neural Network + MARL	CityFlow	Travel time	Improved coordination; limited interpretability

III. METHODOLOGY

The proposed automatic traffic signal system uses infrared (IR) sensors to dynamically control the signal timing based on real-time vehicle detection and traffic density measurement.

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Components Required
Sensors: Infrared (IR) Emitters and receivers.

Control Unit: A microcontroller or Programmable Logic Controller (PLC) to process sensor data and execute the algorithm.

Traffic Lights: Red, yellow, and green LEDs or bulbs.
Power Supply: Required for both the sensors and the control unit.
Software: Algorithms necessary for dynamic signal timing based on sensor inputs.

Communication Module: Optional, for connection to a central traffic management system. Working Procedure

Vehicle Detection: An infrared sensor emits a beam. When a vehicle passes or stops within range, the reflected light is detected by the sensor receiver.

Data Processing: The Control Unit processes the sensor signals to determine vehicle presence and to calculate the traffic density in a specific area for advanced systems.

Traffic Light Control: Based on this real-time data, the Control Unit dynamically adjusts the timing of the traffic lights.

* If no vehicles are detected on a particular lane, its green signal is shortened.

* High traffic density may result in extending the green signal timing.

PROPOSED WORK
In this project, we provide an idea of making the traffic System intelligent using Artificial Intelligence. Images Captured by the digital camera can be examined to identify Vehicles and process lanes using computer vision software.The images are grouped and analyzed by Machine Learning Algorithms to obtain records. Using these records, the count Values are sent to the traffic signal to control the timing of The signal in each lane. With this, the duration of traffic Signal is managed by AI.Here, the vehicle identification is performed using a Convolutional neural network provided by Intel. Open CV Is a sizable open source library for image analysis, Machine learning, and computer vision, and it now plays an essential role in real-time operation, which is crucial in today's systems. It can be used to process photos and videos in order to recognize objects, people, or even cars. Here, Convolutional Neural Network is utilized to identify and detect vehicles. Detection and tracking of vehicles is very helpful in building a smart traffic system. YOLO algorithm is a machine learning algorithm in which the image is captured and processed. It uses convolutional neural networks to detect the vehicle in the region of interest. The individual frames for respective lanes are used and the vehicles are counted separately. As a result of this, in the lanes where there are more vehicles, will be cleared off at once without expanding the traffic further. Basically, smooth traffic clearance whether there are more or less vehicles.

Hardware used :
Raspberry Pi 3B+, Pi Camera, USB Web Camera, LED's and connecting wires
Software used :
Operating System: Raspbian OS, Compiler: Thonny python IDE, Software : Open CV, Algorithm: YOLO algorithm.

HARDWARE SPECIFICATIONS:
- Raspberry Pi 3B+

CPU type : 64-bit, quad-core Cortex-A53 processor About Clock speed – 1.4 GHz RAM size- 1GB SRAM Extended 40 Pin GPIO header Pi camera connection via HDMI and CSI Camera DC power input: 5v/2.5A Micro SD slot for storing data and loading your OS

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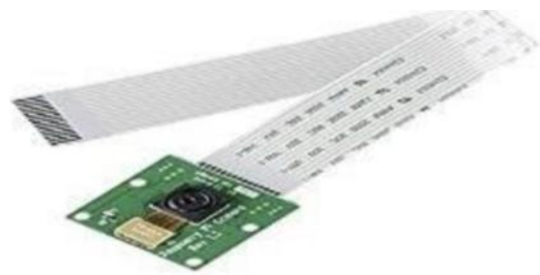
- PI Camera :



Omni Vision 5647 camera module
Resolution – 2592*1944
Supports – 1080p, 720p and 480p

USB Web Camera :

Full HD resolution of up to 1080
MAC OS, Windows, Linux, iOS, and Android are all Supported. Availability – USB 2.0

Overview of Computer Vision

A branch of artificial intelligence known as computer vision enables computers to extract relevant information from digital photos, video frames, and other visual sources and carry out intended tasks using the information recovered. If AI gives computers the ability to think, computer vision gives them the ability to see, observe, and comprehend. Nearly identical principles govern computer vision and human eyesight. Human vision has lifetime capability of understanding and learning from changes in the environment, but instead of employing optic nerves,the retina, and the visual cortex to complete these tasks,computers are trained to do so using data, cameras, and algorithms. Industries ranging from the energy sector to manufacturing and the automotive sector employ computer vision extensively. For picture recognition, a lot of data is required, and analytics are being used. If enough information is provided, the computer will examine it and continue to learn.

Tasks performed by Computer Vision

A. Image classification: It is a technique of seeing and classifying the image. That accurately predicts whether the given image belongs to a particular class.
B. Object detection: This technique identifies a class of image and tabulates its appearance.
C. Object tracking: It refers to following an object after it is detected. In this case it should not only classify and detect the object but also should continuously monitor it.
D. Content based image retrieval: Retrieving image from large database based on the content of the image and no tax associated with it.

Overview of YOLO Algorithm

You Only Look Once is known by the acronym YOLO. ItInstantly recognizes and detects different objects in a photo. The YOLO algorithm is significant due to its quickness, high accuracy, and capacity for learning. For real-time object detection, it makes use of convolutional neural networks. According to its name, the technique only needs one forward propagation through a neural network in order to detect objects.This indicates that a single algorithm run is used to anticipate the full image. Multiple class probabilities and bounding boxes are simultaneously predicted using the CNN. Three methods—residual blocks, bounding box regression, and intersection over union make up the foundation of the YOLO algorithm.

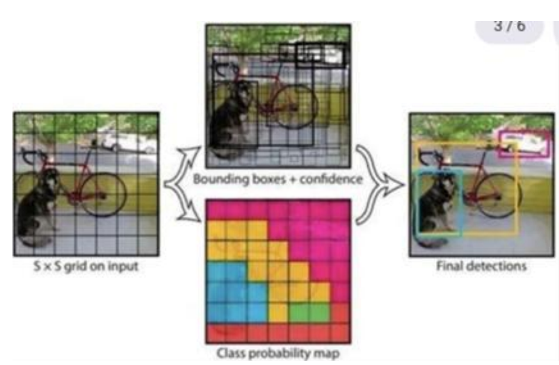


Fig. YOLO algorithm

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Convolutional Neural Network

A particular kind of neural network that analyses data used in image recognition is known as a convolutional neural network. Convolutional, pooling, and fully linked layers are the three primary layers that make up its series of layers. Each of this layers contain some nodes that looks at data given as an input and produce output.

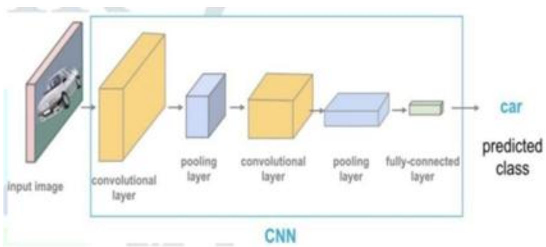
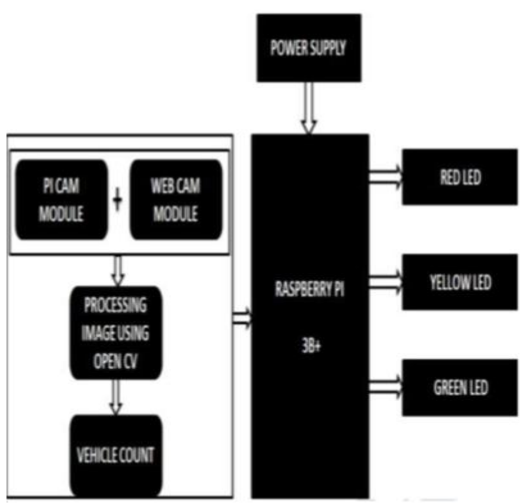


Fig. Convolutional neural network layers

Convolutional layers act as feature extractor, identifying particular features of an image. It consists of different filters, these filters are small grids of values to produce filtered output. Max pooling is one of the most popular types of pooling layer, which follows after the convolutional layer. In this layer the extracted features will be assigned with some weights. Different weights will be allocated for different features in an image.

DESIGN AND IMPLEMENTATION

Block Diagram



Working of proposed system

We are going to read images of vehicles through video frames such that the vehicles in the first lane are detected using a Raspberry pi camera and vehicles in the second lane are detected using a USB web camera. The Open CV software consists of in-built modules which support image cognition and detection. Hence necessary packages can be imported directly and the network is initialized. The YOLO algorithm will detect and count vehicles separately for both lanes. First the frames are pre-processed and we run the detection. Then the output data of vehicles is grouped into two categories for two different lanes.When there are more number of vehicles in the first lane than the second lane, the lane with higher number of vehicles will be cleared soon by giving green signal and increasing the time of the signal.Now if vehicles in the second lane start increasing beyond a certain count, then green signal will be now given to second lane and red signal to first lane. During this process there might be a case sometimes where there will be a large number of vehicles only in one particular lane and very few vehicles in the other lane then green signal will be given continuously for lane with more vehicles and the lane with less vehicles will never be given the green signal. In order to avoid such situations, in the proposed system we have a condition in the code that if any lane is not given green signal even after say three minutes the automatically the signal will be switched from current to the lane which was not given green signal for a longer duration. Hence this can be used for smooth traffic clearance in all the lanes without any problem.

ADVANTAGES AND DISADVANTAGES

Prototype

Detected output

Advantages
1) Reduced congestion and less emission
2) Improved road traffic discipline and safety
3) In addition to the need for increased convenience and safety, the deployment of this system and connected car technology is necessitated by the world's rapidly urbanizing cities.
4) Better planning and decision making
5) Time saving and operation efficiency
6) Improved customer service and reduced frustration
7) Improved health due to less environmental pollution
8) Reduce road accidents and enhanced productivity
9) Based on the detection, the system takes self-decisions and performs the operation. Hence human work is not required.
10) YOLO algorithm has self-learning capabilities from previous experience.
11) It leads to diverse transportation which is important for smart cities.

Real time implementation

Disadvantages
12) Requiring significant funds to adopt
13) It's hard to detect an error
14) AI needs human assistance

Applications
Artificial intelligence-based systems can be a smart investment for governments looking to get the most out of their restricted funds for streets and roads. The ability to manage more traffic and a growing population while lowering the capital expenses of creating new or rebuilt roadways is made feasible by them. Only 15% of the world's population was residing in metropolitan regions a century ago. More than fifty-five percent of people live in cities today, and sixty-eight percent are projected to do so in 2050. Hence urbanization needs smart traffic system implementation. With all the development comes an equal rise in traffic, necessitating the use of technology to help control the movement of people and commodities. The AI based system can also help the traffic agencies in penalizing the offenders and act as a deterrent. The cameras installed can detect and identify the vehicles which disobey traffic rules and fine them electronically. The AI based traffic system can cut- down the waiting time at traffic signals by almost half. Hence there is a scope and need for smart traffic implementation in the real world to ease clogged roads and cope up with the growing number of cars.

CONCLUSION

Results and Discussion
Implementation and working of proposed AI based traffic systems is successfully designed and tested. The output is analyzed and evaluated with Raspberry Pi hardware and computer Vision technology. In the proposed system the traffic signals are controlled based on the vehicle density and YOLO algorithm.the system detects the vehicles in video frames and based on the count of vehicles the signal is monitored. Upon receiving the message the LED lights are turned on and switch according our conditions given in the code.the performance of vehicles counting framework was satisfactory for both Convolutional Neural Network and YOLO version three combinations with vehicle tracking.We have used seven layers of

convolutional Neural network which gives high neural accuracy of 93.3% in detection.

Future Scope

In this paper the project AI based traffic control system is developed by integrating all the hardware components.Existence of every module has been examined and placed carefully, thus contributing to the best working of the unit hence in the future implementation of this project, we look forward to overcome all the disadvantages with the benefits of expanding technology using highly advanced components. The prototype can be developed further to make a wearable device and the design can be made more easier to access and user friendly.

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