Adaptive Traffic Signal Control using Real-Time Video Processing and Vehicle Detection

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Abstract. Vehicle traffic between cities has grown dramatically as a result of the fast rate of urbanization. As a result, a number of traffic-related issues have surfaced, including gridlock and an overabundance of different kinds of cars. It is crucial to collect road data in order to address traffic issues. Thus, the ultimate aim is to create a traffic control system that uses a convolutional neural network (CNN) and the maxim "you only look once" (YOLO) to find traffic volume and gather vehicle information from the road. This system uses YOLO to identify vehicles first, then combines it with a vehicle-counting technique to determine traffic flow. In order to regulate traffic light signals according to traffic density, adaptive traffic signals that can monitor in real time are therefore required. By capturing pictures of each lane at a junction, proposed solution suggested an adaptive traffic light management system that effectively controls traffic using image processing and image matching techniques.

Keywords: Adaptive Traffic Control, YOLOv4-tiny, Vehicle Detection, Real-Time Processing, Multi-Agent System, Smart Traffic Management.

1 Introduction

In practically all contemporary metropolitan areas which includes cities like Delhi, Mumbai, London, New York, and Singapore, the traffic congestion has grown to be a major concern for civil engineers due to rising traffic volumes and constrained road capacities. There are numerous social, economic, and environmental issues that can result from traffic congestion. First of all, drivers who are caught in traffic congestion have a greater danger of being late for their destination, which may be quite stressful. Stress in-turn leads to impatience and carelessness which may lead to accidents and traffic congestion. And, there is a huge financial penalty associated with traffic congestion.

1.1 Traffic Congestion

When utilization of transportation networks rises, a state known as traffic congestion develops. This condition will lead to reaching the destination slowly, increase in travel time and more number of vehicles waiting in queue. The most prevalent example is how cars physically use the roads. Congestion occurs when there is long queue of vehicles waiting in the queue which affects the normal traffic flow. The term "traffic jam" or "traffic snarl-up" refers to situations in which cars are completely stopped for extended periods of time. Road anger and frustration are

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two consequences of traffic congestion. When ambulances are used to save lives, time is of the essence. However, because of traffic, an ambulance's speed frequently has to be lowered when it must cross a crossroads. This makes it more difficult in cases where the patient in the ambulance need immediate medical attention that can only be given in a hospital. There is a chance that patients could die because an ambulance does not have the most up-to-date medical equipment. In Karnataka, India, the government has implemented the 108-ambulance service. Patients are admitted to the closest hospital via these 108 services. In Bangalore, India, for instance, this service is utilized, but anytime an ambulance gets caught in traffic, everything goes haywire. The patient's condition could deteriorate while the traffic is cleared, which could take hours. In Indian cities, as in many other parts of the world, traffic control is a difficult problem. Improper traffic management may lead to several other harmful effects and that need to be rectified efficiently.

1.2 Proliferation of Vehicles

A worldwide phenomenon, urbanization has a greater impact in emerging nations like India. The industrialization of these nations has drastically improved. Vehicle use has increased in industrialized nations as a result of increased industrialization, but fewer people have died as a result of improved infrastructure. Because of inadequate infrastructure, motor vehicle deaths are relatively greater in underdeveloped countries. Around the world, traffic accidents lead up to 50 million people get injuries and 1.24 million people get fatalities annually. Based on the statistics, this number of accidents varies by country. According to statistics, the number of accidents and fatalities in India has been rising.

2 Literature Review

Biologically inspired methods could help with many of the challenging networking issues that are still unresolved. One example of this effective strategy for resolving certain basic transportation issues is the recently suggested Virtual Traffic Lights (VTL)[1], [2].This paper demonstrates how to enable emergency vehicle priority management in a self-organized way at intersections by implementing a separate set of local regulations. According to the findings of extensive simulations, the suggested method has a minor effect on other cars' trip times, but it can reduce the travel time of the emergency vehicles.

Increasing desire for quicker transportation and rapid urbanization have caused severe traffic congestion in road traffic networks. With minimal environmental information, the existing signal control system must be able to identify the green time that reduces the trip time delay over the entire network. The traffic signal controller's inputs and rule base contain varying degrees of uncertainty, which GFMAS can handle. A virtual road network that replicated a portion of Singapore's central business district was used to evaluate simulation models of the agents created in PARAMICS. We conducted a thorough examination and comparison with the current traffic-control algorithms, the hierarchical multiagent system (HMS) and green link determining (GLIDE). When tested for realistic traffic-flow circumstances, the suggested GFMAS signal control performed better than both benchmarks. Additional testing demonstrates the proposed GFMAS's superior effectiveness in managing both planned and unforeseen problems and obstacles. The encouraging outcomes show the effectiveness of the suggested multiagent architecture and its potential for further advancement.

Conventional traffic signal timing techniques do not produce an effective control results in many metropolitan cities especially during the peak hours. Making the traffic control system to change signals based on traffic conditions is one option. However, this may lead to several issues as the system changes dynamically. This is also very difficult to manage and complexity increases when number of vehicles increase. Here we represent the large traffic network as the multi-agent system. It specifically uses Q-learning, that estimates the states based on the average length of approaching links.

Stochastic vehicle routing takes traffic uncertainties into account and is more optimized than normal vehicle routing. It may be roughly addressed by stating its two representative optimization models as MILP problems. Due to integer limitations, B&B approach, that is the conventional way for solving these two MILP problems, has exponential processing complexity. We suggest using a partial Lagrange multiplier approach to get around this computational inefficiency. Because it simply solves a linear programming (LP) issue, it takes advantage of the incidence matrix's complete unimodularity in the models. Therefore, the sub gradient approach may be used to further solve this problem, and the suggested approach can ensure polynomial computation complexity. Furthermore, we conduct experiments on three distinct graph scales such as small, medium, and large scales to evaluate the efficiency and convergence that we theoretically prove. Crucially, the deployment on a navigation system on the Singapore road network further validates that our approach can effectively address the stochastic vehicle routing problem in the actual world.

An agent-based methodology is well suited for this field of traffic and transportation since these systems are regionally distributed in continuously varying situations. Our review of the literature indicates that the strategies and tactics developed in the field of agent and multivalent systems have proven beneficial in domains such as intelligent traffic control, modeling and simulation, and more. This study investigates an agent-based strategy and its uses in air, rail, and road transportation. Additionally, this article discusses certain important topics related to the improvisation of traffic control and traffic management systems, including extendibility, flexibility, and interoperability. Lastly, a number of research avenues for the new optimization of the existing traffic system and proposed methodology proposed on this field are explored.

3 Existing System

The goal of agent-based vehicle rerouting techniques is to provide some vehicles with alternate routes in order to reduce overall traffic congestion. The ITS server just needs to compute partial pathways, such as the way from the origin nodes to the significant nodes, when a person requests an origin to destination service. Utilizing real-time traffic data presents another difficulty. Companies like Google, Microsoft, and TomTom have created commercial systems that leverage roadside infrastructures to gather real-time traffic data and give quickest routes that are considerate of traffic. Heavy traffic at a crossroads might cause traffic congestion. There are numerous traffic management strategies available to prevent congestion. However, as real-time scenarios are typically always changing and the system must adjust to the constantly shifting conditions, no technique is flawless on its own. In order to accommodate constantly shifting real-time traffic circumstances, we have attempted to offer some self-changing traffic management strategies. This method prioritizes ambulances and allots time to the traffic light of a certain lane based on the amount of traffic on the road. Additionally, we can signal a break in a certain lane. To prevent discomfort, the obstacle detection message is displayed on an LCD if there is one.

4 Proposed System

In order to lessen traffic congestion, we suggest a novel multi-agent dynamically adapting traffic management framework in this research. By introducing the concept of a computerized "pheromone," it connects traffic signal control and vehicle rerouting. In particular, every vehicle agent place two different kinds of pheromones along its path: the intention pheromone and the traffic pheromone, which stand for the present and future traffic volumes, respectively. In order to identify short-term traffic conditions without using the central ITS server, roadside infrastructure agents integrate the pheromones using a fusion or regression model, thereby obtaining the distributed property. We created an advanced traffic-monitoring system to capture data on vehicle types and traffic volume in real time. The goal of mYOLOv4-tiny was to increase detection efficiency and accomplish real-time object detection. The use of two efficient models (CNN and Vector-CNN) that use a novel network mapping fusion technique significantly reduced the number of model parameters while improving classification accuracy. Fig. 1 shows the Block Diagram.

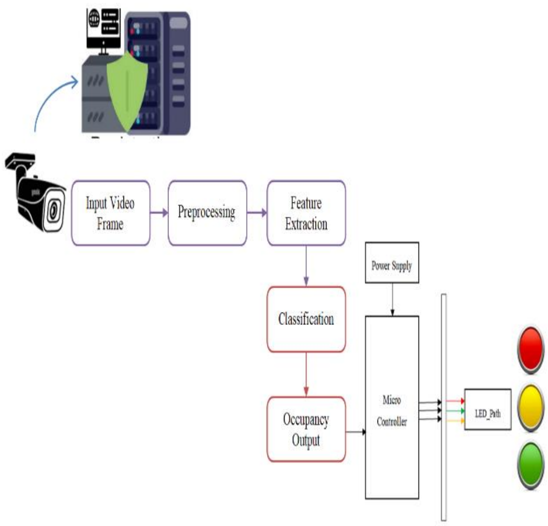

Fig. 1. Block Diagram.

5 Components

5.1 Power Supplies

A power supply, sometimes referred to as a power supply unit or PSU, is a system or apparatus that provides the electrical energy or other form energy to the desired system. The phrase is most frequently used to describe electrical energy sources, mechanical ones less frequently, and others infrequently. When working with digital circuits, this circuit is tiny +5V power supply is helpful. Any supermarket or electronics store will sell small, low-cost wall transformers with changeable output voltage. These transformers are easily available, but have very poor voltage regulation, making them unusable for digital circuit experimenters unless there is a way to improve the regulation. The solution to the issue is the circuit that follows. Fig. 2 shows the Power Supply for Microcontroller.

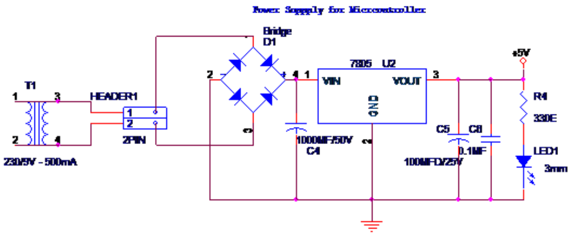

Fig. 2. Power Supply for Microcontroller.

5.1.1 Transformer

A transformer is a machine that uses inductively coupled wires to move electrical energy from one circuit to another. The primary circuit is fluctuating current generates a fluctuating magnetic field, which in turn causes the secondary circuit is voltage to fluctuate. This can cause current to flow in the transformer and move energy from one circuit to other by applying a load to the secondary circuit. An ideal factor that scales the secondary induced voltage from the main VP is the ratio of the wire turns in each winding:

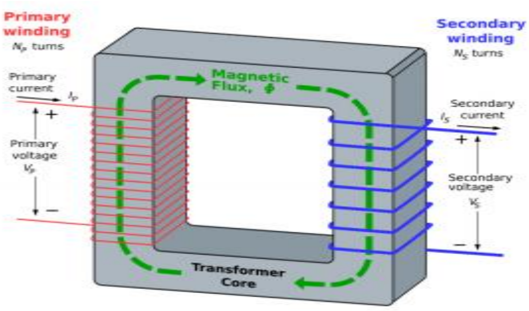

Fig. 3. Transformer Core.

The image above is a simplified version of an ideal step-down transformer design. In the primary coil, a current generates a magnetic field. The majority of the magnetic field lines produced by the primary current are contained within the iron and go through the primary coil and secondary coil, because these coils are wound around a core with high magnetic permeability, like iron. Fig. 3 shows the Transformer Core.

5.2 Arduino Nano

The Arduino Nano and the Arduino Duemilanove have many of the same features, but being packaged differently. The Nano features an inbuilt ATmega328P microcontroller. The main difference between them is that the UNO board is offered a 30-pin PDIP configuration, while the Nano board is available in a 32-pin plastic quad flat pack (TQFP). Compared to the UNO, which has six ADC ports, the Arduino Nano has eight, and its extra two pins are utilized for ADC operations. The Nano board has a mini-USB connector rather than a DC power jack like other Arduino boards do.

5.3 Arduino Nano Pinout

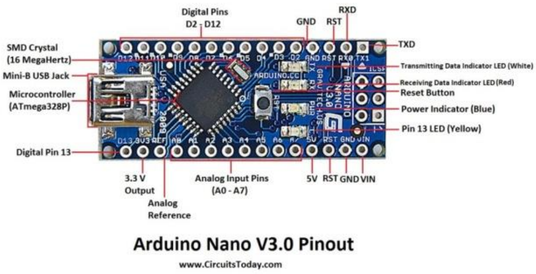

Fig. 4. Arduino Nano.

The picture suggests that the Arduino Nano has 36 pins overall. Finally, we will see a thorough format with all of the pins arranged by section. Fig. 4 shows the Arduino Nano. Fig. 5 shows the Arduino Nano Pin Description.

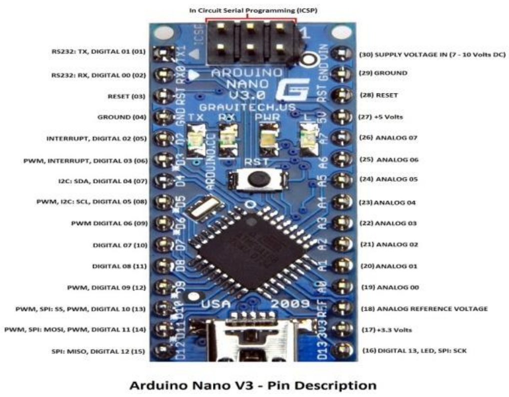

Fig. 5. Arduino Nano Pin Description.

5.4 Arduino Software

The Arduino Software IDE also referred to as Arduino Integrated Development Environment which provides an editor to write the code and which also provides a message box, and also a text console which is a toolbar that contains buttons for frequently used tasks. It helps us to interact with the Arduino hardware and dump the programs based on our needs. Fig. 6 shows the Arduino Software IDE.

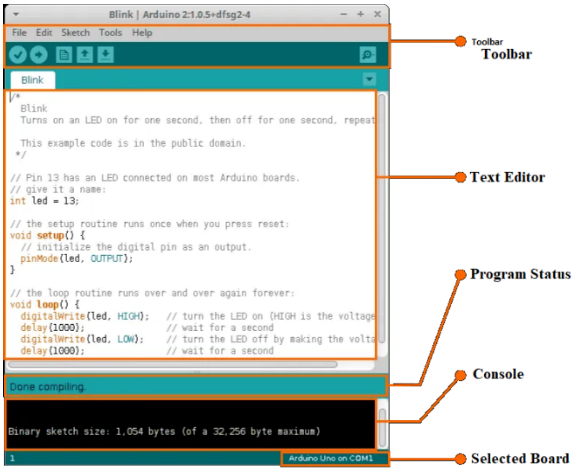

Fig. 6. Arduino Software IDE.

5.5 Writing Sketches

The programs which are created using the Arduino IDE are referred to as sketches. These sketches are edited using the text editor which is used to make changes whenever needed, and these will be saved with the. ino extension. This editor contains various tools which helps to make content changes and enable us the facility of copy and paste the desired replacement content. The issues available will be displayed by the message section and it also shows the feedback and recommended changes. Error messages and other information will be displayed on the console. In windows lower right corner, we can find the configured board and serial port. To create, save and open the sketches we can use the toolbar, and there we can find the options to check and upload the programs. Fig. 6 shows the Writing Sketches.

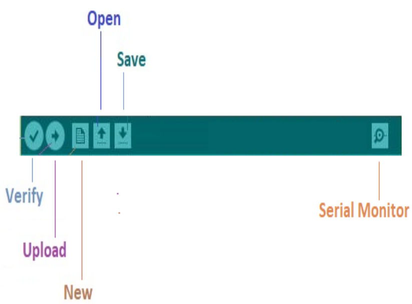

Fig. 6. Writing Sketches.

5.6 Arduino Nano

The Arduino Nano is a board with more features and it is a breadboard easy board and it is based on ATmega328P.It provides the exact features provide by the UNO board but in a smaller package. Arduino Nano is programmed with help of Arduino IDE, that is available both online and offline and is used by all of our boards. Fig. 7 shows the Arduino Nano.

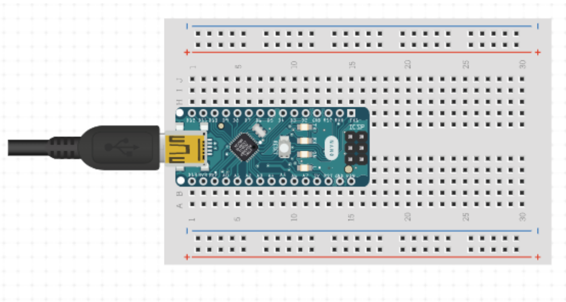

Fig. 7. Arduino Nano.

5.7 Arduino Nano And Arduino Desktop Ide

To write the programs on the Arduino Nano without the internet connection, the Arduino Desktop IDE need to be installed. Then to make the connection between PC and the Arduino Nano, Mini-B USB cable is needed. This cable will also provide the power to the board. Fig. 8 shows the USB.

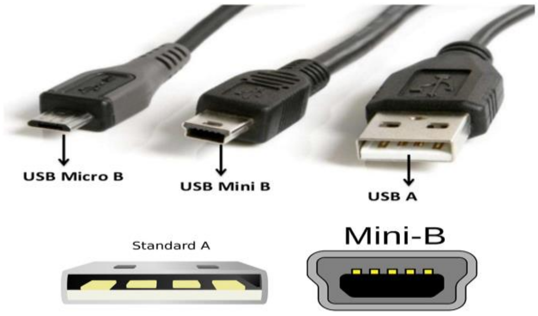

Fig. 8. USB.

6 Circuit Diagram

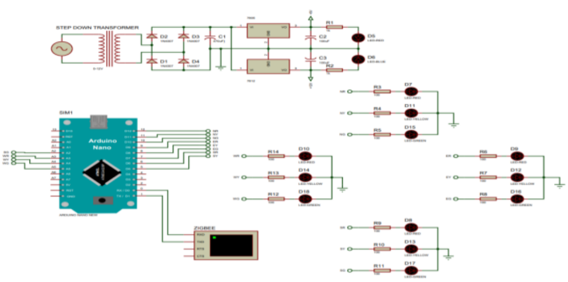

Fig. 9. Circuit Diagram.

If the system gets communicate with the local roadside infrastructure, they can get the intents of which road links vehicles should enter next. If a digital camera is unable to accurately count vehicles, the numbers may be extrapolated using prior traffic data. Furthermore, if we do not have full vehicle intentions, we can either approximate them using probabilistic inference or anticipate them with the help of machine-learning approaches. In this study, we rely on the k shortest path algorithm for our rerouting technique. In certain situations, two successive shortest pathways may differ significantly even though the difference in trip costs is minimal, and if the user is unfamiliar with the suggested path, he may not accept it. To enhance overall traffic performance, our rerouting method in this work, however, aims to lessen traffic congestion. Therefore, our main focus in this work is not the extent of deviation from the original path, i.e., user choice. However, in our future work, it is absolutely worth taking user choice and the difference between successive shortest pathways into account when designing a rerouting method. Fig. 9 shows the Circuit Diagram.

6.1 Traffic Light Control

Every traffic light, which comes in red, yellow, and green, uses low power LEDs. The green LED signifies "drive," the yellow LED signifies "listen," and the red LED signifies "stop." The steps involved in changing the LEDs' colour are as follows: Yellow-Green-Red-Green. There are twelve LEDs in total, three for each traffic signal. The driver clicks the path, and WiFi creates a signal to the matching path. The micro controller and TLC then compare this signal to the default traffic light path. The microcontroller modifies the signal's state by emitting a green signal along the ambulance's course if any of the sound signals match the received TLC. In order to alter the path, the microcontroller produces the value of the output data ranging to the receiver.

6.2 Power Supply

Power supply module performs the function of providing the voltage supply to the circuit. Fig 10 shows the power supply module. In this module diodes, step-down transformer, capacitors, voltage regulators will be a part of it.

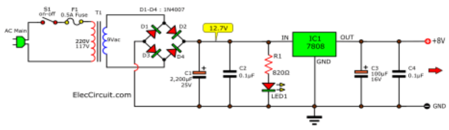

Fig. 10. Power Supply.

6.3 Microcontroller Module

Microcontroller is a small microcomputer which is used to control how embedded electronic systems operate in a range of applications. Its capabilities include using the sensor module to get the ambient temperature, with the help of display module to show characters, and with the help of the microcontroller software to switch on or off the necessary pins. Fig. 11 shows the Microcontroller Module.

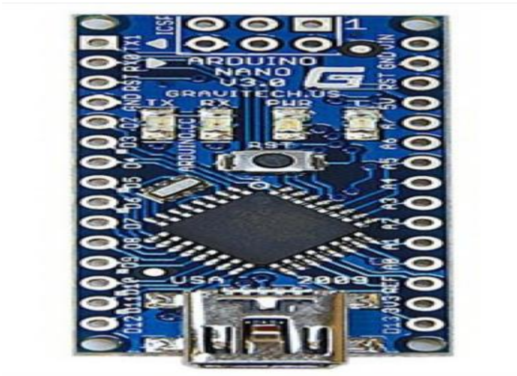

Fig. 11. Microcontroller Module.

7 Expected Output

Traffic control system that uses a convolutional neural network (CNN) and the maxim "you only look once" (YOLO) to find traffic volume and gather vehicle information from the road. This system uses YOLO to identify vehicles first, then combines it with a vehicle-counting technique to determine traffic flow. In order to regulate traffic light signals according to traffic density, adaptive traffic signals that can monitor in real time are therefore required. By capturing pictures of each lane at a junction, proposed solution suggested an adaptive traffic light management system that effectively controls traffic using image processing and image matching techniques.

7.1 Traffic Light Control

Traffic lights are the devices used at road crossings in transportation systems to regulate conflicting traffic flows. Colour phase and time length are the two main components of traffic light regulation in general. A series of common colors, such as red, yellow, and green, make up the colour phase. The time length denotes the durations during which the colour phases are visible. We suggest two online traffic light control solutions within the framework of unified traffic management. Based on the quantity of digital pheromone, both strategies automatically establish colour phases and determine how long they will last on competing highways. Fig. 12 shows the Output of the proposed solution.

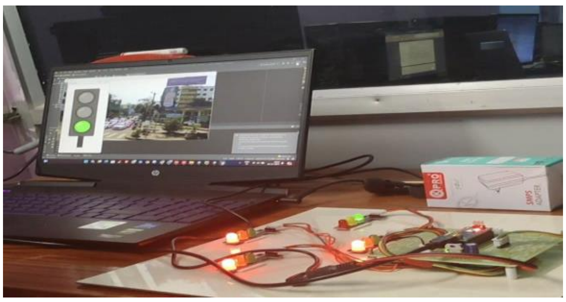

Fig. 12. Output of the proposed solution.

8 Conclusion

This proposed solution study suggested a new intelligent traffic-monitoring system for traffic volume data and vehicle type classification that combines a counting method with a YOLOv4-tiny model. After predicting congestion, we first choose which vehicles to reroute based on their driving intentions and the distance to the relevant road. We next employ a probabilistic technique based on local pheromone and global distance. In order to further reduce traffic congestion, we simultaneously create two pheromone-based ways to dynamically manage traffic signals, depending on whether they consider the downstream traffic status.

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