Intelligent Traffic Control System using YOLO Algorithm for Traffic Congested Cities

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Abstract-The number of vehicles on the road has increased in recent years, and many countries now require reliable and sophisticated control of the traffic signal system. By accurately calculating the traffic density based on the images captured by cameras installed on the traffic posts, this research aims to resolve this dilemma. The technique uses a simple algorithm that first processes a fuzzy controller to recognize vehicles using a Yolo classifier. It could be developed further for hardware implementation using specialized CPUs. Our method entails periodically capturing photos and processing them further with a cascade classifier. The classifier is retained for use in calibration. With the help of this method, the system can deduce the traffic density, which a fuzzy controller then evaluates to decide when to turn on the traffic signals. The output function of the fuzzy controller, which compares the vehicle density of the most recent photos, adjusts the output dynamically.

Keywords— object detection, yolo algorithm, fuzzy logic, traffic control.

1. INTRODUCTION

For many cities around the world, traffic congestion is a big challenge. Since there are more cars on the road and more people need transportation, city streets and highways regularly experience severe traffic congestion issues. When attempting to simulate the behavior of road traffic and develop an efficient means of control, many challenges appear. Using traffic lights to govern vehicle movements at junctions has proven to be one of the most reliable and adaptable ways to manage urban road traffic [1]. An efficient answer to this issue would be to create a sophisticated traffic monitoring and control system. In a typical traffic light controller, the cycle time between changes in the traffic lights is constant. As a result, it does not offer the best answer. The "time-of-the-day" method, which uses a small number of predetermined traffic light patterns and implements these patterns depending on the time of day, is the foundation for many traffic light controllers used in current practice. These automated solutions don't offer the best way to regulate changing traffic loads [2]. Real-time inputs should be collected by an intelligent traffic control system, which should then process them to produce a reference parameter that may be used to adjust the length of traffic signals to effectively relieve congestion [3]. A fuzzy logic controller is necessary because traffic flow is typically characterized by randomness and uncertainty [1].

Some of the attempts that have been previously made are as follows:

• Simple image processing procedures to control the traffic timers.

• Use of counters to count the number of cars passing for a period and suitably adjust the duration of the traffic signal to the count value.

• Edge detection technique which involves detection of number of vehicles present by detection of their edges.

In the above proposed techniques several disadvantages pose several limitations in the automation process. This algorithm is mainly aimed to overcome these disadvantages [3]. As the number of vehicles is constantly increasing but current infrastructures are limited, a reliable transportation system is important. An intelligent traffic control system can ensure a reliable transportation system.

According to edge detection, the number of vehicles on roadways at a junction has been tallied in [4]. This count has determined the density of the relevant side and has produced the related signal. But counting vehicles would be wrong if they were too near to one another. Another method for controlling traffic signals using image processing is suggested in [5][6], in which the reference image—an image with no vehicles—is first chosen and the real-time images are compared to it each time. The number of vehicles has been tallied after converting the binary image from the difference image. The issue is the same as in [4]. Techniques for morphological edge identification and fuzzy-based controllers are proposed in [7]. These methods rely on comparing a live traffic image to a reference image to calculate the traffic density. The traffic density is discovered to increase with difference.

Radar and supersonic techniques are already accessible in closed loop in [8]. To improve traffic flow and lessen congestion in smart cities, the fusion-based intelligent traffic congestion management system for vehicular networks (FITCCS-VN) uses machine learning techniques to gather and analyze traffic data. It gives drivers remote access to real-time traffic data so they can stay clear of backups. The system outperforms earlier methods, achieving a high accuracy of 95% and a low miss rate of 5% [20]. This study covers the current state of the art in network softwarization for effective and scalable traffic control using machine learning (ML) and deep learning (DL) methodologies. It provides background information on dimensionality reduction methods, traditional ML algorithms, and DL. In addition to addressing pertinent issues and obstacles, the study focuses on ML/DL applications in softwarized systems, such as traffic classification, prediction, and anomaly detection[21]. The system tested multiple settings based on current cycle measurements to minimize queued vehicles, demonstrating its adaptability. However, its reliance on single-cycle data and limited capability to handle traffic flow variations were noted. Chattarji et al. provide a

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Different methods are based on the idea of using RFID technology to track moving objects. The efficiency of the system lay in the fact that it operated traffic lights based on the current condition of the vehicular volume in various directions of a road crossingand not on pre-assigned timings [10]. This design can be employed in locations where RFID tagging of vehicles is required.

Because they could be adjusted to lengthen or shorten the signal cycle when the number of cars unexpectedly increased or decreased, Gi Young et al. thought that electrically sensitive traffic lights were more efficient than fixed preset traffic signal cycles. Their focus was employing fuzzy control to design the best traffic light possible. To estimate the unknown length of a vehicle, speed, and width of a road, fuzzy membership function values between 0 and 1 were utilized [11]. Various types of conditions, including automobile type, speed, starting time delay, and the volume of traffic, were also stored. Christe et al[14] .'s focus was on pixel-by-pixel image processing, pixel neighborhood change, and transformations that could be applied to either the entire image or only a portion of it. One of the two fundamental characteristics of intensity values—discontinuity or similarity—has been presented by Al-amry et al. as the basis for segmentation algorithms [15]. The first category is to divide an image based on sharp contrast changes, such as edges. The second category is based on segmenting an image into similar sections based on predetermined criteria.

The objectives of this research are:

1. To monitor the traffic density efficiently.

2. To control traffic to overcome the problem of traffic congestion in cities by fuzzy logic.

The remainder of the essay is structured as follows: Section 2 presents the technique; Section 3 elaborates on the experimental setup; Section 4 describes the experiments; Section 5 presents and discusses the results; Section 6 presents Acknowledgement; and Section 7 concludes the paper.

2. METHODOLOGY

The Yolo algorithm gives tremendous results for object detection. In figure 1, the overall flowchart of the system is shown.

2.1 Yolo Object Detector

YOLO (You Only Look Once) is a popular real time object detection algorithm that was first introduced by Joseph Redmon, Santosh Divvala, Ross Girshick, and Ali Farhadi in 2015. It revolutionized the field of object detection by achieving a good balance between accuracy and speed. Convolutional neural networks (CNN) and deep learning are used by YOLO (You Only Look Once) to recognize objects. Because it only needs to "see" each image once, as the name suggests, it differs from its "competitors." The YOLO algorithm approaches object detection as a regression problem, where it predicts the bounding boxes and class probabilities directly from the input image in a single pass. Unlike traditional approaches that use sliding windows or region proposal methods, YOLO divides the input image into a grid and assigns each grid cell the responsibility of detecting objects[22][23].

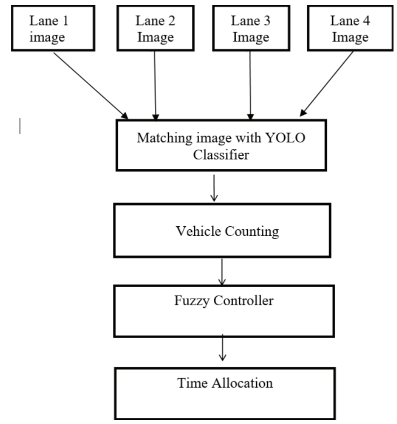

Figure 1: Flowchart of the system

The key idea behind YOLO is to divide the input image into a grid and have each grid cell responsible for predicting bounding boxes and class probabilities. This grid-based approach allows YOLO to process the entire image in a single pass, making it faster compared to methods that use sliding windows or region proposal techniques. By dividing the image into a grid, YOLO reduces the number of potential bounding box predictions compared to other methods. Each grid cell predicts multiple bounding boxes, along with their associated confidence scores. The confidence score indicates the probability of an object being present within the bounding box. Additionally, each grid cell predicts the class probabilities for the objects it detects. During training, YOLO uses labeled bounding boxes to calculate the loss and update the model's parameters. The loss function takes into account the bounding box predictions, their confidence scores, and the class probabilities, aiming to minimize the discrepancy between the predicted and ground truth values. By predicting bounding boxes and class probabilities directly, YOLO achieves real-time object detection, making it suitable for applications requiring fast and accurate detection, such as video analysis, real-time surveillance, and robotics [24],[25].

2.2 Fuzzy Logic System

As a type of many-valued logic, fuzzy logic allows any real integer between 0 and 1 to represent the truth value of a variable. It is used to handle the idea of partial truth, where the range of truth values lies between totally true and false. The truth values of variables in Boolean logic, however, are solely restricted to the integer values 0 or1.

The term "fuzzy control system" refers to a control system that is based on fuzzy logic, a mathematical system that analyzes analog input data in terms of logical variables that take on continuous values between 0 and 1, as opposed to classical or digital logic, which operates on discrete values of either 1 or 0 [16][17]. Fuzzy logic is often used in automation If logic is referred to as "fuzzy," it suggests that it could deal with concepts that are merely "largely true" as opposed to "true" or "false. Fuzzy logic, while not always the most superior option compared to evolutionary algorithms and neural networks, offers the advantage of providing solutions that can be described in human-understandable terms.

2.3 Elements of Fuzzy logic system

2.3.1 Membership Function

We can graphically display a fuzzy set and quantify linguistic terms using membership functions. A: X [0,1] is the definition of a membership function for a fuzzy set A on the universe of discourse X. Each component of X is assigned a value between 0 and 1 in this situation. It is also known as degree of membership or membership worth. It measures how much an element in X belongs to the fuzzy set A.

- The discourse universe is represented by the x axis.
- The [0, 1] interval's degrees of membership are shown on the y axis.

To fuzzify a numerical value, many membership functions may be relevant. The usage of complex functions does not increase output precision, thus simple membership functions are utilized instead. Among numerous different membership function forms, including trapezoidal, singleton, and Gaussian, the triangle membership function shape is the most prevalent [18].

2.3.2 Fuzzification

It changes crisp, traditional data into fuzzy, or membership functions (MFs). Deriving the membership functions for input and output variables and representing them with linguistic variables are the two steps involved. It is accomplished using several kinds of fuzzifiers. Fuzzifiers are often employed for the fuzzification process and come in eleven different varieties. They are bell-shaped, Sigmoidal, Trapezoidal, Triangular, Singleton, Gaussian, and S-curve fuzzifier. The specific type relies on the applications themselves. A triangle or trapezoidal waveform should be used for systems that require high dynamic fluctuation in a short amount of time. A Gaussian or S-curve waveform should be chosen for systems that require extremely high control accuracy. There are 11 built-in membership function kinds in the fuzzy logic.

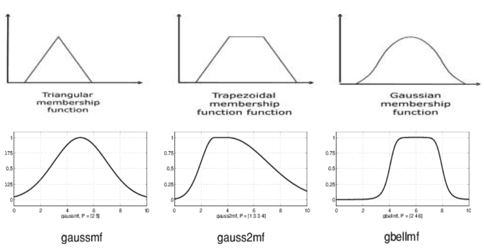

Figure 2: Graphical representation of different membership function [20]

2.3.3 Fuzzy Rule Base

The fuzzy sets and fuzzy operators are described in the rule matrix as conditional statements. One possible fuzzy if-then rule is the following

If x is A then y is Z

where Z represents a set of possible outcomes and A represents a set of requirements that must be met. The fuzzy logic control system rules are mapped using the rule matrix, a straightforward graphical tool. It accepts two or more input variables and expresses their logical combination (AND or OR) as one output response variable. The degree of membership for the rule matrix output might be either the highest or least of the degree of the rule's preceding application [16].

2.3.4 Inference and Defuzzification

Fuzzy logic can be used to map a given input to an output utilizing an inference technique. It makes use of the membership functions, logical operations, and if-then rules that were discussed in earlier parts. Mamdani and Sugeno inference systems represent the most prevalent varieties. Their methods for calculating results differ.

The inference engine's output is converted into clean output through the defuzzification procedure. A fuzzy set is used as the input to the defuzzification process, and one integer is produced as the result (crisp output). There are other defuzzification strategies that have been proposed, but four of them are frequently used: center-of-area (gravity), center-of-sums, and mean of maxima [19].

3. Experimental Setup

In this research, the amount of traffic on four roads that meet at a crossroad is calculated before a traffic signal light is turned on. The duration of the four separate traffic light signals on these four different roads will vary depending on the volume of traffic. The created yolo method is used to estimate the traffic density of each route in terms of the number of cars present at any given time.

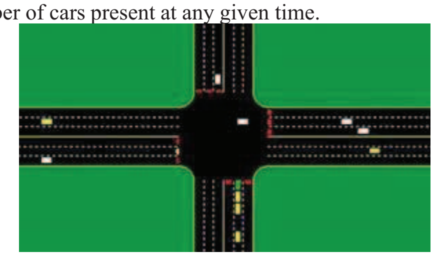

Figure 3: Four Lane Traffic Junction [22]

This technique mounts four cameras on a pole close to a traffic signal to provide a clear view of traffic on Lanes 1, 2, 3, and 4. in order for it to take the picture and examine the traffic on that specific side. By matching the image with the Yolo algorithm, this image is processed to identify how many vehicles are present. The density of that specific side will be calculated using the number of vehicles counted, and the fuzzy controller will be given the results. Finally, a fuzzy controller will produce the appropriate traffic signal. Thus, the entire system is split into three components: 1) Image acquisition; 2) image processing; and 3) fuzzy controller for controlling traffic signals

3.1 Real Time Image Acquisition

A camera that is tilted toward the road at a height H is mounted on a pole. The height is determined by the road area to be photographed and the camera's angle of view. Every road camera is positioned in the same manner. These cameras' output is connected to a computer.

3.2 Vehicle Detection

For the purpose of finding the automobiles, we used a yolo object detector. Deep learning and convolutional neural networks (CNN) are used by YOLO (You Only Look Once) for object detection. Because, as the name suggests, it only needs to "see" each image once, it differs from its "competitors." As a result, YOLO is one of the quickest detection methods. Our algorithm creates an SxS grid from the input image. An object will be detected by a particular grid cell if its center falls within that cell. B bounding boxes are predicted in each grid cell, together with confidence ratings for those boxes. The final stage, the reliability prediction, represents the IOU between both the projected unit as well as any regression coefficients boxes. The C conditional class probabilities, Pr(Classi |Object), are also predicted for each grid cell. These probabilities depend on the grid cell in which an object is located. We only predict one set of classification chances per grid cell, regardless of the number of boxes B. We calculate class-specific confidence scores for each box by multiplying the conditional class probabilities by the individual box confidence forecasts at test time. Both the likelihood that a class will appear in the box and how well the predicted box fits the object are encoded by these scores. The algorithm continues to eliminate the boxes that are below a specific threshold of lowest probability because the vast majority of these boxes will have extremely low probabilities. The remaining boxes are put through a process called "non-max suppression" to get rid of any potential duplicate items and only keep the most precise ones.

3.3 Traffic Light Control using Fuzzy Logic

The traffic light control unit receives information from the image processing unit about the number of vehicles on the road or the density of vehicles at each intersection. When used to control real-time traffic, fuzzy logic has the potential to approximate human intelligence. It facilitates the application of real-time rules that mimic human thought. Numerous traffic patterns at a junction can be managed using this application of fuzzy logic in the use of conventional traffic signals. The number of cars is counted using a yolo classifier and a live video feed that captures the image of the intersection of two roads. In order to feed the fuzzy controller, the input is thus made crisp. The fuzzy controller, upon which the interference is based, is enhanced by a fundamental set of principles. These interferences aid in determining the traffic light's timing, which restricts the volume of traffic based on its density.

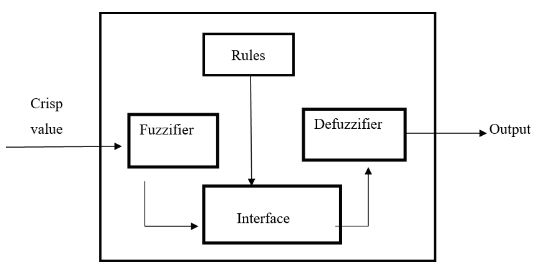

Figure 4: Basic Block Diagram of fuzzy logic

The fuzzy controller's output, which is decided based on the count value given to it, is used to manage the length of the traffic signals. The initial calibration is carried out to determine the average count value needed for low traffic and high traffic density. The traffic signal's time is extended if there is heavy traffic in order to relieve congestion in that area or on that section of the road. This is how fuzzy logic is designed to work. The fuzzy logic reduces the green lights on time to a minimum value chosen at calibration time if the count value of cars is less than or equal to a specific threshold.

The duration of the green lights on time is set to a moderate value, which is also based on initial calibration, if the count value is moderate or falls within the established value for medium traffic. If the count value is very high, there is a probability of congestion; as a result, the fuzzy controller lengthens the time the green light is on so that the region is free of congestion.

4. RESULT:

We proposed our project for four roads. At first, we took images of four lanes. Then we detected the number of vehicles on corresponding lanes and time duration of green traffic light signal is allocated for different number of vehicles. After detection the number of vehicles we found on each lane were 43, 37, 29 and 17.

For four roads simulation results are following:

Lane No.	Vehicles No.	Detected Vehicles No.	Time duration	Accuracy
LANE 1	46	43	5 minutes	93.4%
LANE 2	38	37	4 minutes	97.4%
LANE 3	31	29	4 minutes	93.5%
LANE 4	17	17	3 minutes	100%

Table 1. Number of Cars and duration of green light signal and accuracy

The result of the simulation is shown in figures 5,6,7, and 8.

Figure 5: Lane 1

Figure 6: Lane 2

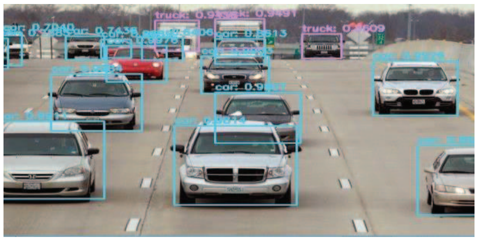

Figure 7: Lane 3

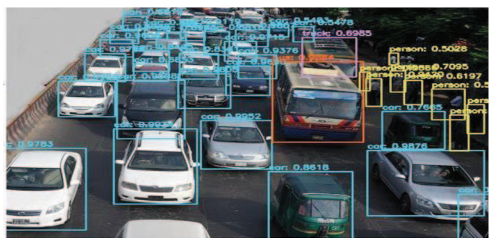

Figure 8: Lane 4

5. CONCLUSION

The image processing results are excellent for this research's goals. The procedure used to process the photos has successfully completed its duty. The precision of the code is significantly influenced by the camera parameters. The accuracy will improve as it becomes better. The cost of the traffic management system can be significantly reduced when compared to other systems now in use because it simply requires a computer and a high-end digital camera. The disadvantages of the earlier (now in use) traffic control approaches are mostly overcome by the method we suggest. The project shows that the suggested strategy is significantly more effective than conventional traffic control methods. The position of the camera when facing the road each time determines how accurately the time is calculated by a single moving camera. In conclusion, it is feasible to assess the level of traffic congestion using fuzzy logic with high accuracy and small error margins. However, users need to be aware of the following restrictions. The way rules are defined has a significant impact on fuzzy logic systems' accuracy. Variations in the time of day and day of the week will be crucial in determining how to define fuzzy logic. Additionally, manual membership function adjustment may be challenging, but it is essential for every new road segment to be assessed. Multiple actions can be performed in future to satisfy the following situations:

i. A system which can identify the presence of emergency vehicles like an ambulance or fire brigade and by giving preferences to those emergency vehicles.

ii. Captured images can be shared with law enforcement agencies and fire departments during an accident.

iii. Continuous monitoring to find the vehicle trajectories which can be used for expansion of roads or building new intersections or flyovers.

iv. The system can also be extended to highly efficient night surveillance.

6. ACKNOWLEDGMENT

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