DESIGN AND DEVELOPMENT OF REAL TIME AND INTELLIGENT TRAFFIC CONTROL SYSTEM

Rahul Vaghela[1]*, Dr Kamini Solanki[2], Dr Priya Swaminarayan[3],

[1] Research Scholar, Parul University, Vadodara, India
2 Assistant Professor, Gandhinagar Institute of Technology, Gandhinagar 382721, India
2Associate Professor, Parul computer application, Parul University, Vadodara, India
3Professor & Director, Parul computer application, Parul University, Vadodara, India

E-mail address:ravaghela83@gmail.com, kamini.solanki@paruluniversity.ac.in, priya.swaminarayan@paruluniversity.ac.in

Abstract: *Almost all part of Gujarat, India where signals are situated. The observations mainly done in the various urban areas of Ahmedabad and Baroda city. It seems, there is sufficient infrastructure but lack of identical way of handling traffics that result in many critical issues. The rapid growth of vehicles and the process of urbanization has increased many traffic related issues in cities. The traffic control and management are considering a hot topic due to its severe effects on environment, health of the people and fuel wastage due to long wait and congestions. The existing traffics signaling system follows fix timings in traffic signals and because of that sometime without traffic there may be long waiting time, however on other side, there may be short duration when long vehicle queues are present that will create long congestion chains in peak hours. It has observed that the people are facing many issues due to such fix timing of signal plan implemented at traffic signals without having input from existing traffic density. The main issues to be considered are that the people feel that their time is not respected which could result in disobey of traffic rules, ineffective way of handling traffic turn out be a big traffic congestion, Due to such long wait and hassle, there are heavy noise pollution, environment pollution and wasting of very important and limited natural resource in terms of fuels. Sometimes, It also create situations which require more police persons to defend and control such scenarios as it is consequences of ineffective or less prediction or rather no prediction for the timings of traffic lights. It has observed around 4, 80,652 road accidents in the year of 2016 and 4, 64,910 in 2017 in India. At the same time, the personal died in road crashes is 1, 47,913 in 2017 and 1, 50,785 in the year of 2016 in India [9]. It is indeed to have system that will understand the traffic that our country possess and do traffic classifications. Such classifications are used to generate intelligent system that will experimentally adjust traffic timings based on kind of heterogeneity exist in the traffic. It is also to experimentally tuning the perfect traffic timing plan which precisely fit to the traffic scenario and also help to solve problematic situation. There need to have strong requirements of understating our country traffic conditions and based on that design and develop a solution that will target many problematic issues for instance Noise pollution, environment pollution, health issues of victims, fuel saving as natural resource etc. This research paper describe the design of and development of intelligent system that will enhance the efficiency of single intersection by reducing excessive timing and increasing lower timings based on precise calculation of traffic density exist in each direction of single traffic intersection*

Keywords: **Image capturing, Image Segmentation, Convolutional Neural Network, Fuzzy rules, Membership Function, Fuzzy Control System, Object Detection, Object recognition, Object Classification, Arduino Atmega2560, Serial Transceiver FT2251 USB Cam, 5mm RGB LEDs Traffic module, Seven Segment Display[customized for 5 digits]**

1. Introduction

Almost all part of Gujarat where signals are situated. The observations mainly done in the various urban areas of Ahmedabad and Baroda. It seems, there is sufficient infrastructure but lack of identical way of handling traffics that result in many other critical issues. It has observed that the people are facing many issues due to such fix timing without having input from existing traffic density. It is indeed to consider the solution at state level as it has potentiality of eliminating many problems that may arise due to this. This solution will help to target many problematic issues for instance Noise pollution, environment pollution, health issues of victims, fuel saving as natural resource etc.

The existing traffics signaling system follows fix timings in traffic signals and because of that sometime without traffic there may be long waiting time, however on other side, there may be short duration when long vehicle queues are present that will create long congestion chains in peak hours . The main issues to be considered are that the people feel that their time is not respected which could result in disobey of traffic rules, ineffective way of handling traffic turn out be a big traffic congestion, The current traffic signal systems are based on magnetic loop detectors. It also collect very limited traffic information through infrared and radar sensors kept on the side of the road. Inductive looping techniques are cost effective however it also provides higher failures and not suitable when heavy traffic is concerned. [3]

At Present, The Traffic Light Control Responsibility Adhere To Ahmedabad Traffic Management And Information Control Center (ATMICC) Which Was Controlled By Ahmedabad Municipal Corporation (AMC) And Ahmedabad City Traffic Police. [7] Maintains An Inventory Of Signal Equipment Connected To It. It Also Purchases And Maintains Signaling Equipment And Infrastructure (Including The Mechanical, Electrical And Electronic Components That Make Up The System) So That It Is Designed And Deployed To Suit The Specific Ahmedabad Requirements In Terms Of Weather Conditions, Operating Environment, Security, Etc. [8]

1. Isolated Fixed Time Controller based Signaling:
2. Fixed Time Controller with Control Room Connectivity based Signaling
3. Adaptive Signaling System

There are around 227 signalized junctions under the purview of AMC. Out of 227, signals on 3 junctions are working on adaptive mode. Ahmedabad city is in the process of upgrading its traffic signaling system infrastructure [1].

2. Literature Review

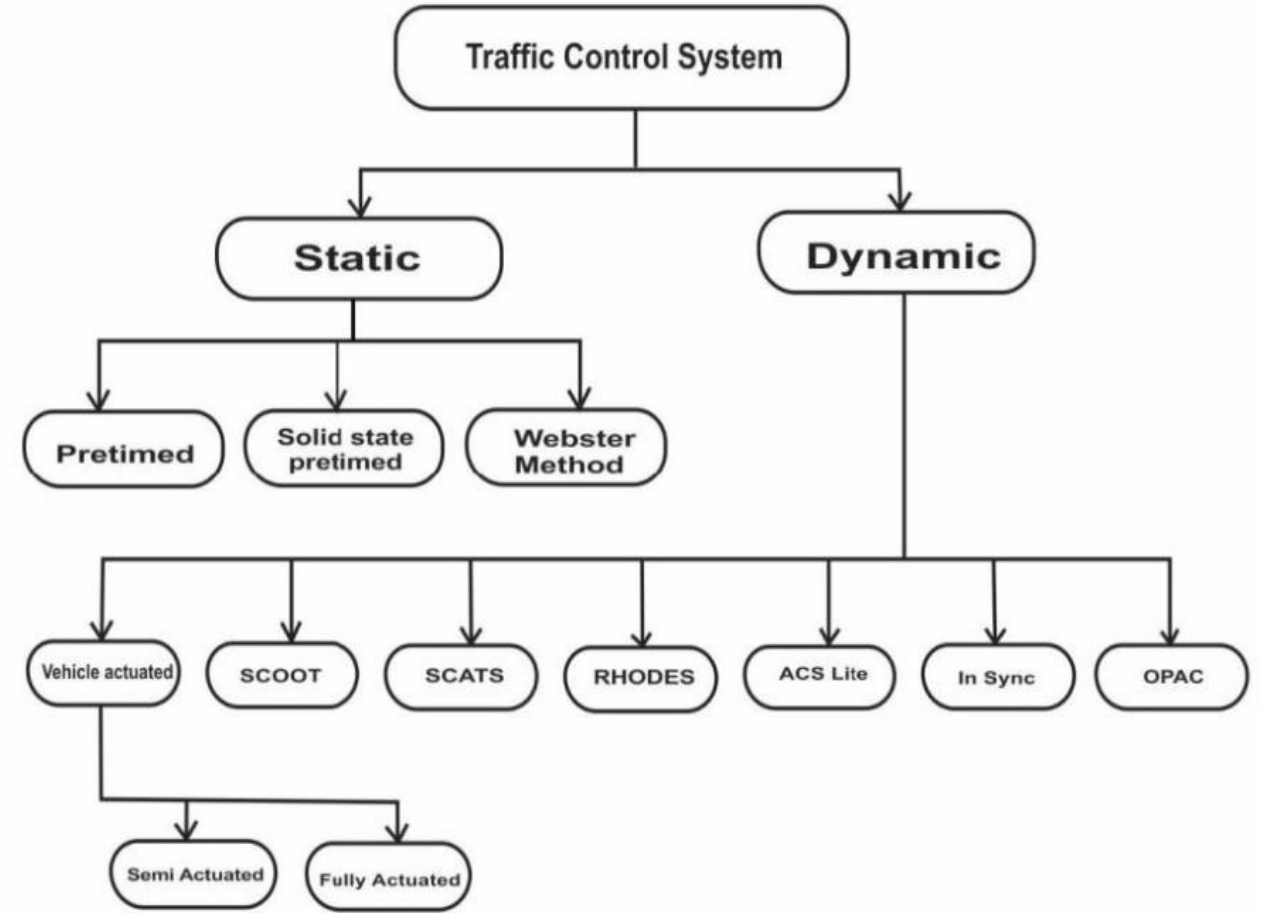


Figure. 1 Types of Traffic control [2]

2.1 Static

2.1.1 Pre-timed control*:* the cycle length, stages, and non-adaptive times and spaces are all in advance to modify. Updated with different timing plan and policy at different time intervals. [2]

2.1.2 Solid-state Pre-timed Control*:* Electromechanical timing devices are replaced with the software enabled prom chips. Signal plans detection and changes done digitally. [2]

2.1.3 Webster Method: It is an experimental pre-timed isolated control. There are two phases, one is signal phase and the other is split phase. The system should have critical phase timings and equal degree of saturation. [2]

2.1.4 TRANSYT: It is used to compile a series of fixed time signal plans for different times of day or for special recurring traffic conditions. Preparing such signal plans requires traffic data to be collected and analyzed. [2]

2.2 Dynamic: It tracks the rate of traffic every second, which makes the traffic rate easier to receive and changes traffic timing according to the traffic rate. Dynamic traffic signal control is also called positive traffic signal control.

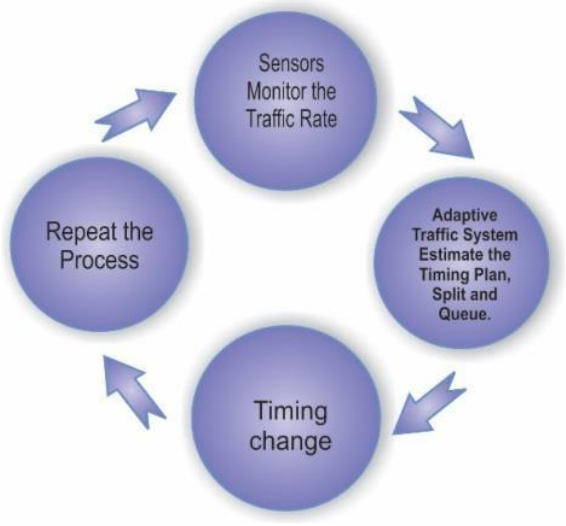


Figure. 2. Working of Adaptive Traffic Signal Control [2]

2.2.1 Vehicle Actuated Method: It utilizes information on present requests and operations, acquired from locators inside the crossing point, to change one or extra parts of the signal temporal arrangement on a cycle- by-cycle premise [2]

2.2.2 Semi-actuated control is suitable for confined convergences with a low-speed real street and lighter junction volume.

2.2.3 Fully-actuated control utilized at the crossing point of two arterials to improve green time distribution in a discriminating convergence control strategy

2.2.4 SCOOT (Split Cycle Offset Optimization Technique): It continuously monitored traffic flows over the whole network using inductive loop techniques and made a series of frequent small adjustments which are ranges from 1 to 4 seconds to signal timings to reduce delays. It is created in UK.

The use of inductive loops to detect wheels was put forward in the patents published in the late 1990s s by Stan´ czyk (1997) and Less (2000) [10]. Inductive loop sensors are frequently deployed as single sensors. Usually single-loop systems measure volume and line occupancy. Loop detectors are installed in the road surface and invisible for drivers. Vehicle magnetic acting on loop detector parameters allows to detect and

count axles. [9]. The Scoot System connects directly to central processing units and its success mostly depends on the data received through the vehicle detectors. Janusz Gajda; Piotr Piwowar et al (2012) [11] experimented and resulted that loop detectors can be used to detect wheels and count axles as well as to measure distances between axles in normal traffic conditions. The uncertainty of such measurements is higher

2.2.5 SCATS (Sydney Coordinated Adaptive Traffic signals): It was created by the Roads and Traffic Authority of New South Wales, Australia. It collects data through inductive loops and passes the data to local collector then regional and finally central processors where SCAT system installed. Control methods include: versatile operation, time of day and day of week coordination, and secluded sign operation [2]

2.2.6 RHODES (real-time traffic adaptive control system): RHODES will take information from varying sorts of locators or detectors and, bolstered what future traffic conditions are anticipated, create upgraded signal control plans. [2]

2.2.7 The ACS Light framework provides a low effort traffic control framework that works continuously with small and medium-sized groups, altering and facilitating signal timing to neglect to change the traffic model [2]

2.2.8 OPAC and INSYNC are the real time traffic optimization methodology used for distributed and neighborhood optimization

2.2.9 Research Gap

All Systems described ahead are using the inductive looping techniques to detect the vehicle platoons. No precise information of vehicles detection and also counts. Mostly consider the platoon of vehicles.

All methods are generating peak, off-peak and optimized signalling plan but real time traffic signalling plan is not approached yet. It studies traffic and its behaviour and prepare the traffic control plans.

A very small updates in the traffic signalling control was amended as per traffic analysis. Ranges from 1 to 4 seconds or so.

3. Review on Object detection and recognition techniques

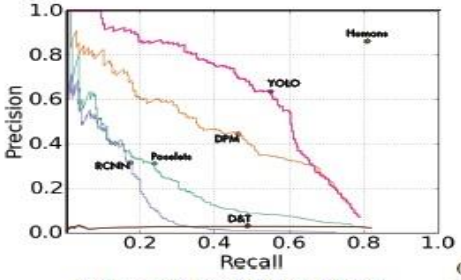
3.1 DPM (Deformable part model): It uses a sliding window approach where the classifier is run at evenly spaced locations over the entire image [3]. It uses a disjoint pipeline to extract static features, classify regions, and predict bounding boxes for high scoring regions. Due to static features and distributed approach, it become time consuming and less accurate.

3.2 R-CNN (Regional Convolution Neural Network): It is a method to first generate potential bounding boxes in an image and then run a classifier on these proposed boxes. [6]. Selective Search generates potential bounding boxes, a convolutional network extracts features, an SVM scores the boxes, a linear model adjusts the bounding boxes, and non-max suppression eliminates duplicate detections. Each stage required precise independent tuning. It produces around 2000 bounding boxes in selective search. [1]. It mistakes in background patches in an image for objects because it can't see the larger context.

3.3 YOLO (You only look Once, Unified real time object detections.): A frame object detection as a regression problem to spatially separated bounding boxes an associated class probabilities. [3] A single neural network predicts bounding boxes and class probabilities directly from full images in one evaluation. Since it uses the frame detection as regression model it will work with 150 fps which means it can process video streaming in real time with very less latency of 25 milliseconds. Also achieve double mean average precision (mAP) compared to other methods. [1]. Less or almost no error in background patches. Issues of localization in small objects. It divides the input image into an S *S grid. If the center of an object falls into a grid cell, that grid cell is responsible for detecting that object. [6]. each grid cell predicts B bounding boxes and confidence scores for those boxes. These confidence scores reflect how confident the model is that the box contains an object and also how accurate it thinks the box is that it predicts.The confidence as Pr(Object) * IOU If no object exists in that cell, the confidence scores should be zero. [6]

Each bounding box consists of 5 predictions: x, y, w, h, and confidence. The (x; y) coordinates represent the center of the box relative to the bounds of the grid cell. The width and height are predicted relative to the whole image. Finally the confidence prediction represents the IOU between the predicted box and any ground truth box. Each grid cell also predicts C conditional class probabilities, Pr(Class|Object). [6] By multiplying the conditional class probabilities and the individual box confidence predictions, which gives us class-specific confidence scores for each box. These scores encode both the probability of that class appearing in the box and how well the predicted box fits the object. Due to Spatial constraint, it reduces the no of generating multiple building boxes so mitigate multiple detections of the same object. YOLO=> 24 Convolution layers [extract features from the image] + 02 fully connected Neural layesr [predict the output probabilities and coordinates].Fast YOLO= 09 convolution layers + fewer filters> [3].It breaks through the CNN family's tradition and innovates a complete new way of solving the object detection with most simple and high efficient way. Its fastest speed has achieved the exciting unparalleled result with FPS 155, and its mAP can also reach up to 78.6, [5]

COCO [common objects in context] is a large-scale object detection, segmentation, and captioning dataset [16] Identified 5 classes in proposed Work: CAR, BUS, TRUCK, BICYCLE & MOTORCYCLE.



(a) Picasso Dataset precision-recall curves.

	VOC 2007	Picasso		People-Art
	AP	AP	Best F_1	AP
YOLO	**59.2**	**53.3**	**0.590**	**45**
R-CNN	54.2	10.4	0.226	26
DPM	43.2	37.8	0.458	32
Poselets [2]	36.5	17.8	0.271	
D&T [4]	-	1.9	0.051	

(b) Quantitative results on the VOC 2007, Picasso, and People-Art Datasets. The Picasso Dataset evaluates on both AP and best F_1 score.

Figure 5: Generalization results on Picasso and People-Art datasets.

Figure 6: Qualitative Results. YOLO running on sample artwork and natural images from the internet. It is mostly accurate although it does think one person is an airplane.

Figure. 3. Generalization results on Picasso and People-Art datasets [4]

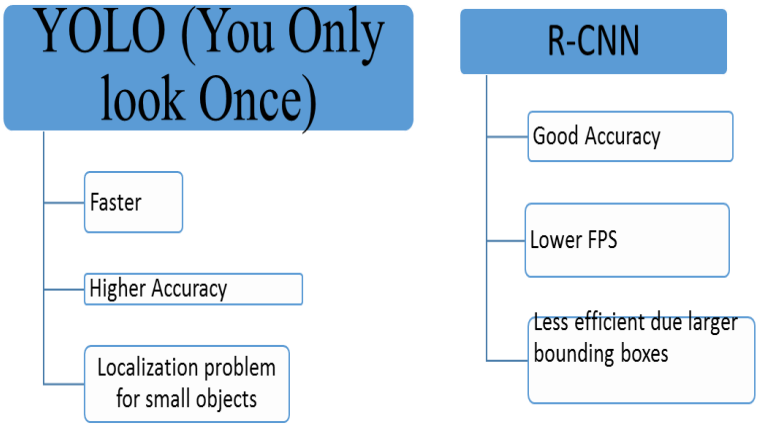


Figure. 4 Comparison of Object detection methods

4 Review on techniques use to generate dynamic traffic control plan based on measured density

Scheduling more than one intersection at once tends to increase runtime exponentially (McCluskey and Vallati 2017), that's why, A real-time, decentralized scheduling inference system is required to reduce traffic congestion at each intersections. [9]. the traffic should be modelled using "flows", and then analyzed through model-predictive controllers. Typical Strong requirements of dynamic traffic control due to adverse effects of bunching, overcrowding and schedule sliding. DOGS (dynamic optimization of greens co-ordination), for each cycle to shift between traffic-actuated control signal plans or to alternate to a lower or higher capacity program [fix timing plan]. [10]. Phase-by-Phase, reduces the delay utilizing tab search by controlling green time proportions allocated to phase. The decision making process in human can be imprecise or uncertain as compare to the algorithmic systems

The FL mainly comprises the set of rules in natural language. The given rules later converted into mathematical equivalent to form the part of a Fuzzy System for the real world. [14]
Fuzzy approach allows the mediate values and provide opportunities to think in multiple options like human. Fuzzy sets allow us to get accurate results by reducing the complications of the matter however mostly all real world problems are nonlinear and ambiguous. Fuzzy systems uses the knowledge from domain professionals to create rule base. It is best fitted to nonlinear input and output. FL system is mainly uses data measured through processes and because of that it works even better when model variables are not available precisely. Pappis and Mamdani et al. They offered to implement a fuzzy logic console at the intersection of one of two streets in one direction without diverting traffic. [13] Nakatsuyama et al. They applied a FL to control adjacent intersections with unidirectional movements to determine the extent or termination of the green signal of the downstream intersection based on traffic in the upstream direction. [12]

The FL mainly comprises the set of rules in natural language. The given rules later converted into mathematical equivalent to form the part of a Fuzzy System for the real world. [14] Fuzzy approach allows the mediate values and provide opportunities to think in multiple options like human. Fuzzy sets allow us to get accurate results by reducing the complications of the matter however mostly all real world problems are nonlinear and ambiguous. Fuzzy systems uses the knowledge from domain professionals to create rule base. It is best fitted to nonlinear input and output. FL system is mainly uses data measured through processes and because of that it works even better when model variables are not available precisely. Pappis and Mamdani et al. They offered to implement a fuzzy logic console at the intersection of one of two streets in one direction without diverting traffic. [13] Nakatsuyama et al. They applied a FL to control adjacent intersections with

unidirectional movements to determine the extent or termination of the green signal of the downstream intersection based on traffic in the upstream direction. [12]

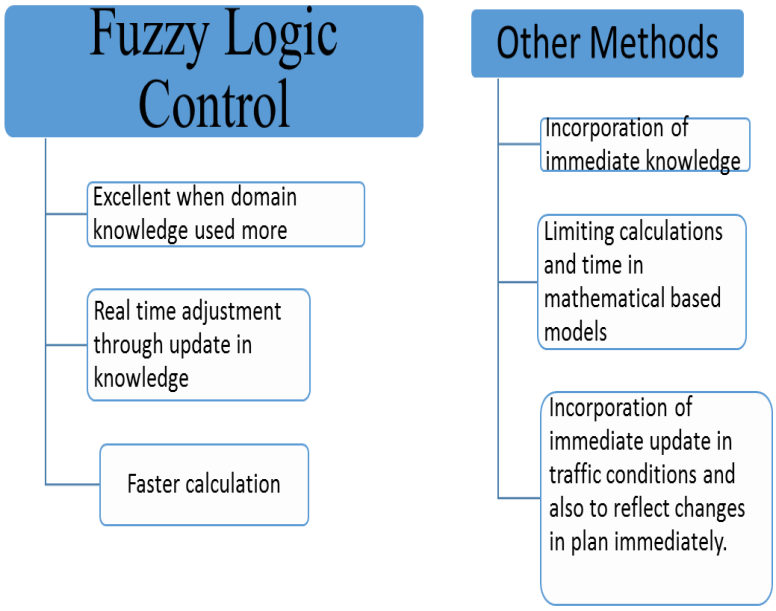


Figure. 5 Comparison of method used to predict saturation of time

The author also describe the model that will be used to trigger the next level notification if the user enters or leaves the marked geographic location area electronically which is popularly known as Geofencing. The concept will generate notification if users have any direct influence with marked area or it can also been trigger based on time duration. The concept of geofencing can be utilized to realize the traffic density in marked area and also to recognize any vehicle lies outside of the marked area.

5. Proposed Intelligent Traffic Control System

5.1 Key Objectives of Proposed System

- The proposed approach is a novel effort to target above mentioned issues.
- It is better way of identifying the traffic directions along with its time dimension.
- Measuring effective way of collecting the traffic density data and use it as a effective measure to create dynamic traffic signal controlling systems
- Real time traffic input to propose more accurate and real time system that handle traffic conditions and also avoid chaotic situations.
- To manage traffic by using dynamic or Adaptive traffic light system
- To reduce mental stress at the time of travelling
- To save fuel
- To save Environment by reducing pollution

5.2 The Intelligent Traffic control system is a product comprises of the below mentioned 3 main parts.

Part-1. Single Traffic signal for collecting traffic images for each four directions.
Part-2. Component for Applying Deep Learning technique to recognize vehicle objects from collected images

Part-3. Fuzzy Inference /rule base System to calculate Delta

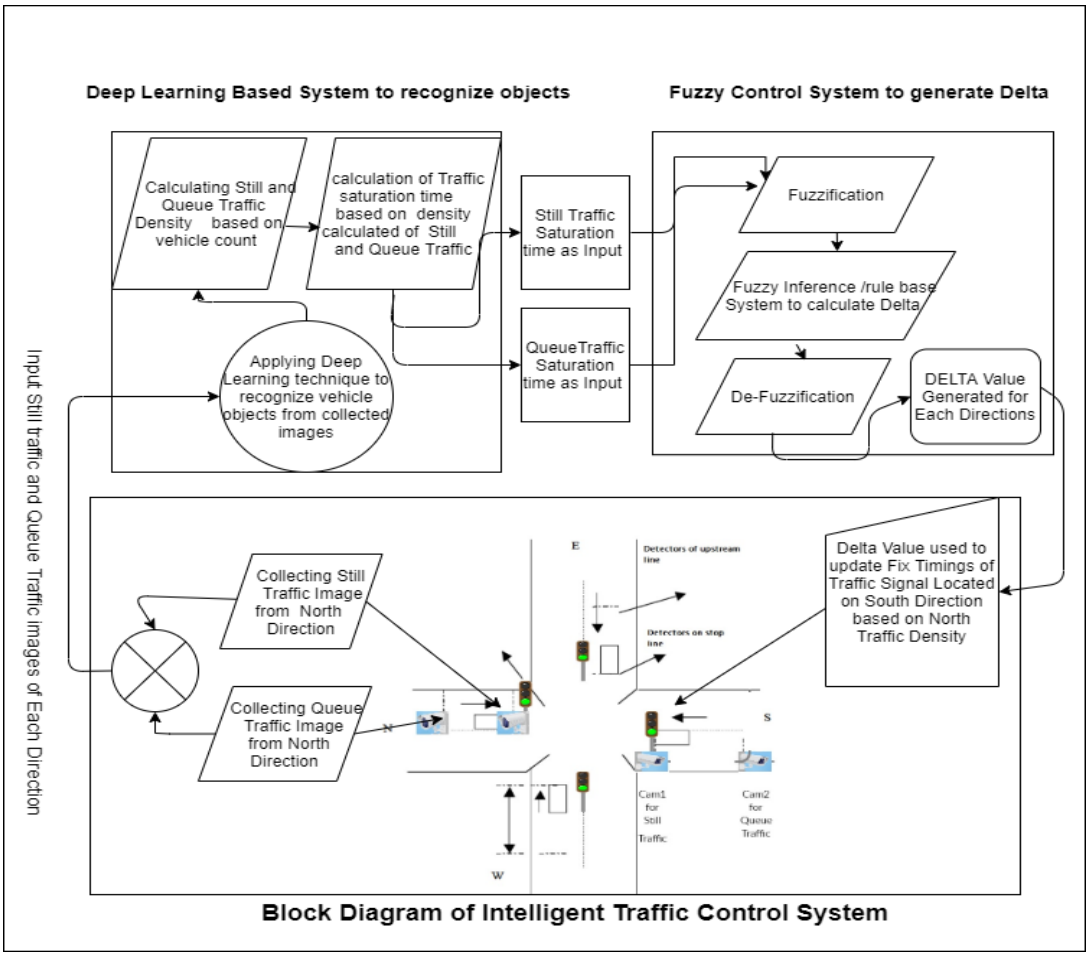


Figure.6. Block Diagram of proposed designed intelligent traffic control system

Three main sections in block diagram.
1. Density measure based in traffic detections
2. Generating intelligent control plan based on density data
3. Collecting traffic data and enforcing new dynamic plan on traffic signals.

6. Proposed Methodology for intelligent traffic control system

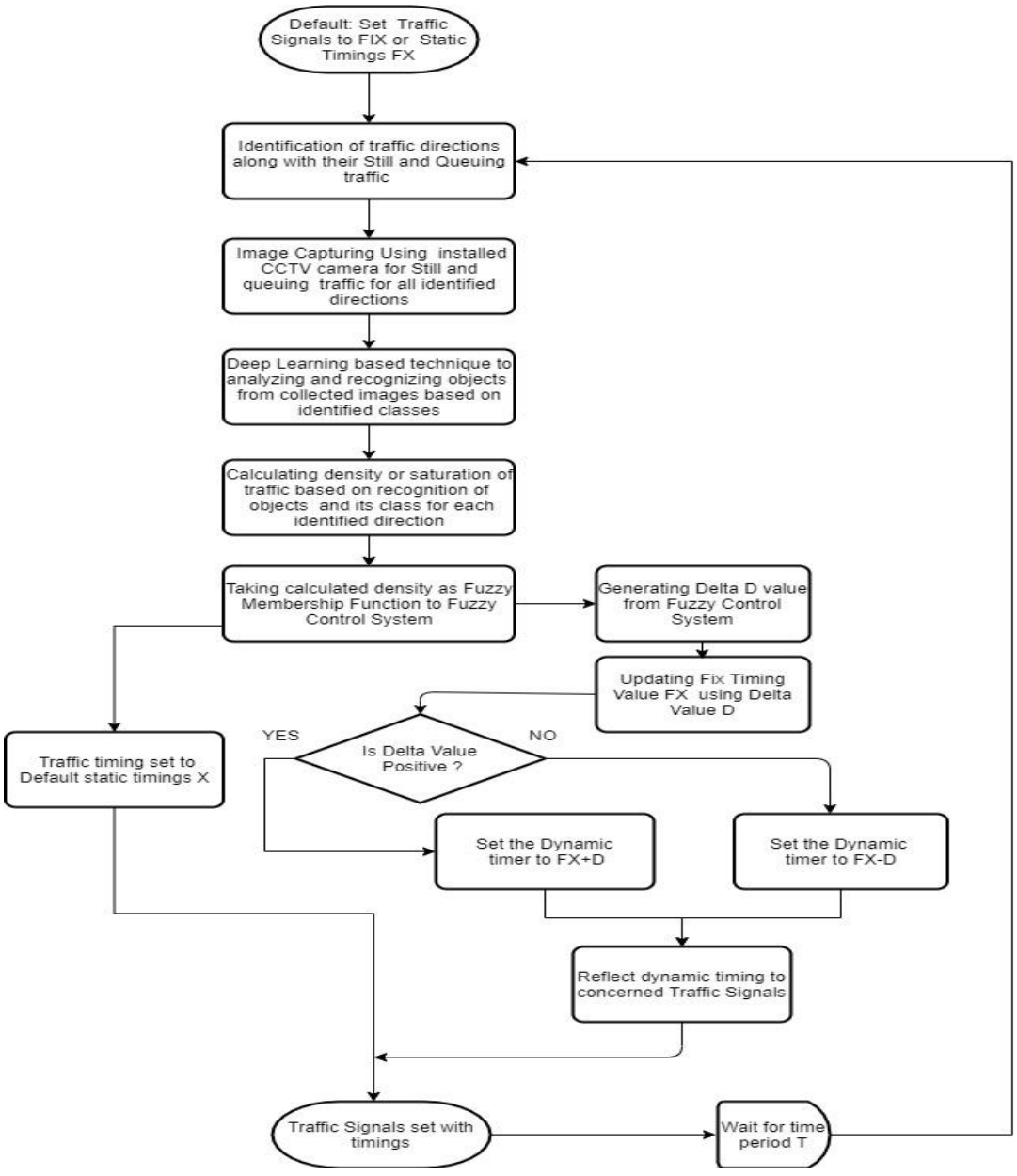


Figure 7. Methodology of Proposed Research Work

7. Results & Discussions

6.1 Tools and Technology

Used ANACONDA and TENSORFLOW based deep network to recognised objects

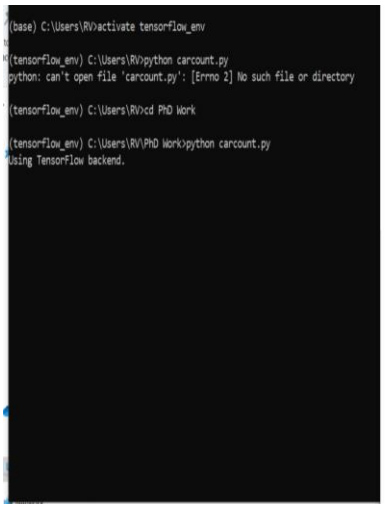
6.2 Training Set

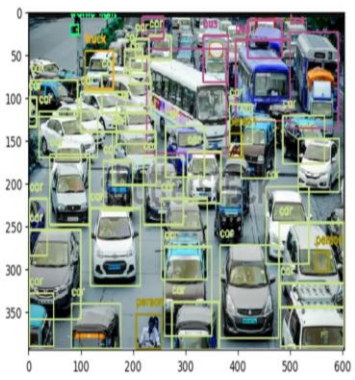
Demonstration of recognizing objects from the traffic scene using deep learning technique
It will identify various class objects of car, bus, truck, bicycle and motorcycle.
It uses YOLOv3 model trained on COCO dataset capable of detecting 80 common objects in context.

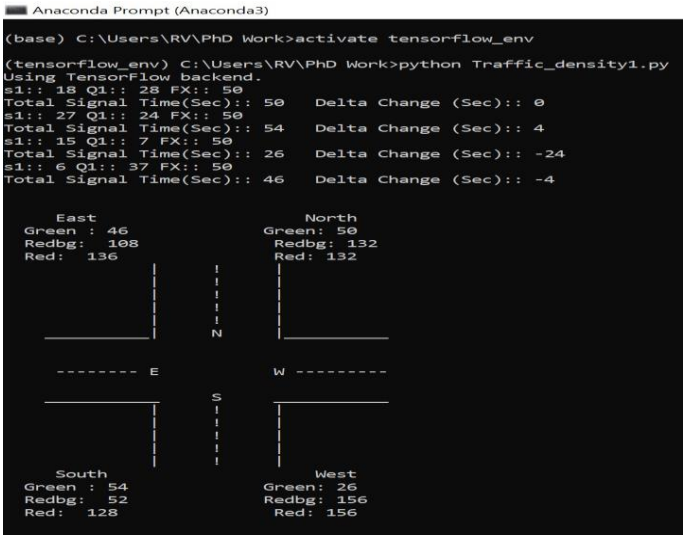
You Only Look Once v3 [YOLOv3] uses single neural network to the full image. This network divides the image into regions and predicts bounding boxes and probabilities for each region. These bounding boxes are weighted by the predicted probabilities. [6]

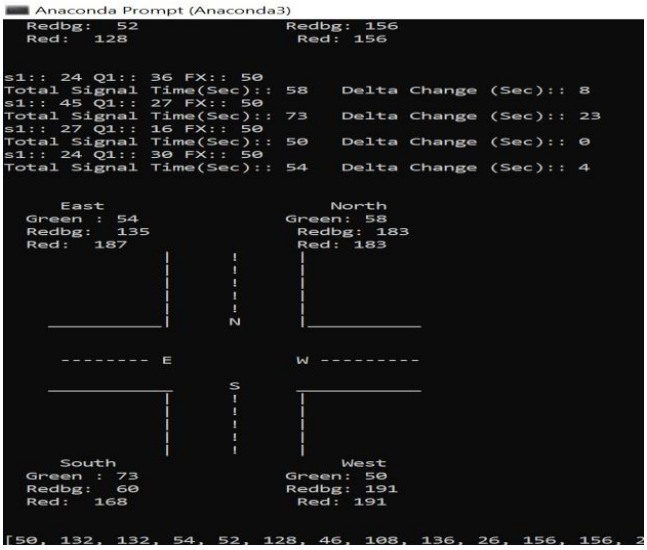
6.3 Results

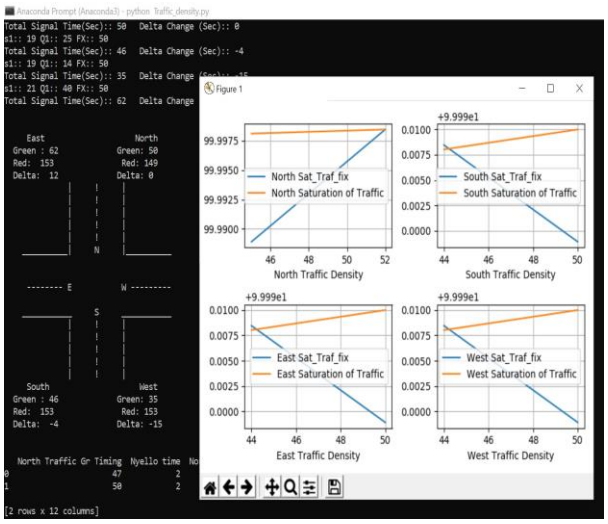
COCO [common objects in context] is a large-scale object detection, segmentation, and captioning dataset [1]
Identified 5 classes in proposed Work: CAR, BUS, TRUCK, and BICYCLE & MOTORCYCLE.
The below mentioned screenshot describes how the still traffic density denoted by s1 and queue density value denoted by q1 and based on that delta value are generated which decrement or increment S1 and Q1 value from fix value











6.4 Discussion

As we can observe from the above screenshot, the fix timing taken for default value is 50 seconds which is applied to all direction signals. There are four directions identified e.g. North, South, East and West. All direction traffic is collected in the form still traffic image

and queue traffic image. These images analysed for traffic density and used as input value for Fuzzy inference system. The intelligent fuzzy inference uses rules to generate delta value that will increase or decrease the fix value based on traffic density present at the signal in each direction. Accuracy level of each direction is denoted in above image where in you will find line that will depict the accuracy value of density and time required to clear that traffic in each direction which is also known as saturation of time.
The saturation of time for fix timing is depicted with orange color and the same for the developed intelligent system is shown with blue color. As you can see in the figure the value of fix timing ranges from 0 to 99 % for East, West and South and North direction while it ranges for 75% to 100% for the developed intelligent system which shows the greater efficiency of developed system. It can also concluded in a way that the developed system generate very precise timing plan based on the density present on each of the direction. It is indeed very good result which can be demonstrated though the said graph. The developed inference system can be modified or amended based on updating rules and also flexible in accommodating specific traffic conditions like there more two wheelers and slow moving vehicle like cycle, cart etc. in Indian traffic compared to western countries.

8. Conclusion

The paper has targeted the problem which exist due to inefficient way of using traffic signalling plan for single intersection. It also covers the severity of issues which can encounter due to the same like long wait and hassle, there are heavy noise pollution, environment pollution and wasting of very important and limited natural resource in terms of fuels. This paper has described all the existing methods of signalling plan exist and used. It has also described the research gap exist and how it can be targeted through the new designed and developed intelligent system. Till now, No one has used deep learning based technique to clearly classify the objects and calculating precise density to generate signalling plan based on that. The paper has also demonstrated the design of system in the form of block diagram and methodology used in system. It provides dedicated way to measure density of traffic and utilize in stringent way to design traffic signals. The three layer approach divide complexity in three part and take it in a way that will provide better way to handle single interaction. The video surveillance collect valuable input, in the form of traffic and process it to fetch traffic counts that will help to provide dynamicity to the signalling point. As mentioned above, there are various comparisons and work done in the area of actuated or adaptive signalling system but the researcher finds still the scope of intelligent method that help to optimize the cycle time, split time and offset optimizing based on local traffic conditions and also the kind traffic encountered. The searching also studies the strong requirement of dealing with countries having more two wheelers and other heterogeneity needs attention and proper dealing to provide safety and efficient management of traffic.

Acknowledgment

We would like to express our gratitude towards Parul University and Gandhinagar Institute of Technology for support.

References

[1] *Tsung-Yi Lin, Michael Maire, Serge Belongie, Lubomir Bourdev, Ross Girshick, James Hays, Pietro Perona, Deva Ramanan, C. Lawrence Zitnick, Piotr Dollár, Microsoft COCO: Common Objects in Context, 2020, https://arxiv.org/pdf/1405.0312.pdf*

[2] *Moganarangan N., Balaji N., Suresh Kumar R.G., Balaji S. and Palanivel N. Study on Static and Dynamic Traffic Control Systems. International Journal of Pure and Applied Mathematics 119(12), 2018, 565-579*

[3] *Redmon, Joseph and Farhadi, Ali, YOLOv3: An Incremental Improvement, 2018, https://pjreddie.com/darknet/yolo/ & https://pjreddie.com/media/files/papers/YOLOv3.pdf*

[4] *Xianglin W, Chaogang T, ,Jin L, Application of sensor-cloud systems: smart traffic control., Springer Nature Switzerland AG 2018 G. Wang et al. (Eds.): SpaCCS 2018, LNCS 11342, pp. 192–202, 2018.https://doi.org/10.1007/978-3-030-05345-1_16*

[5] *Huang, C., Lu, R., Choo, K.K.R.: Vehicular fog computing: architecture, use case, security and forensic challenges. IEEE Commun. Mag, 2017*

[6] *J. Redmon, S. Divvala, R. Girshick and A. Farhadi, "You Only Look Once: Unified, Real-Time Object Detection," 2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR), Las Vegas, NV, 2016, pp. 779-788, doi: 10.1109/CVPR.2016.91.*

[7] *Ahmedabad City Traffic Police (http://ahmedabadcitypolice.org/services/traffic-police/)*

[8] *Study on Traffic & Transport Policies and Strategies in Urban Areas in India (2008), MoUD Ahmedabad TMICC Operations Document GEF- Sustainable Urban Transport Project, India*

[9] *McCluskey, T., & Vallati, M. (2017). Embedding Automated Planning within Urban Traffic Management Operations. Proceedings of the International Conference on Automated Planning and Scheduling, 27(1). Retrieved from https://ojs.aaai.org/index.php/ICAPS/article/view/13842*

[10] *Vallati, M., Magazzeni, D., De Schutter, B., Chrpa, L., & McCluskey, T. (2016). Efficient Macroscopic Urban Traffic Models for Reducing Congestion: A PDDL+ Planning Approach. Proceedings of the AAAI Conference on Artificial Intelligence, 30(1). Retrieved from https://ojs.aaai.org/index.php/AAAI/article/view/10399*

[11] *Zhao, B., Zhang, C., Zhang, L.: Real-Time Traffic Light Scheduling Algorithm Based on Genetic Algorithm and Machine Learning (2015)*

[12] *Rahman Syed M, Ratrout Nedal, Review of the Fuzzy Logic based approach in Traffic signal control: Prospectus in Saudi Arabia, 2009*

[13] *Pappis , Mamdani, A fuzzy logic controller for a traffic junction. IEEE Trans. Systems, Man, and Cybernetics SMC-7, 1977*

[14] *Zhang, Li, Prevedouros, Signal control for oversaturated intersections using fuzzy logic, 1965*

[15] *Vaghela R., Solanki K. (2021) Fuzzy Logic based Light Control Systems for Heterogeneous Traffic and Prospectus in Ahmedabad (India). In: Kotecha K., Piuri V., Shah H., Patel R. (eds) Data Science and Intelligent Applications. Lecture Notes on Data Engineering and Communications Technologies, vol 52. Springer, Singapore. https://doi.org/10.1007/978-981-15-4474-3_28*