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Analysis of Dynamic Road Traffic Congestion Control (DRTCC) Techniques

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ABSTRACT : *Dynamic traffic light control at intersection has become one of the most active research areas to develop the Dynamic transportation systems (ITS). Due to the consistent growth in urbanization and traffic congestion, such a system was required which can control the timings of traffic lights dynamically with accurate measurement of traffic on the road. In this paper, analysis of all the techniques that has been developed to automate the traffic lights has been done.. The efficacy of all the techniques has been evaluated, using MATLAB software. After comparison of artificial intelligent techniques , it is found that image mosaicking technique is quite effective (in terms of improving moving time and reducing waiting time) for the control of the traffic signals to control congestion on the road.*

Keywords *- Static and dynamic feedback control, optimal control, Neural network, fuzzy expert system, PSO,GA, Image processing and mosaicking, traffic lights.*

I. INTRODUCTION

Traffic congestion is now considered to be one of the biggest problems in the urban environments. With increasing traffic on major roads controlled by traffic signals, many problems have become common. In most urbanized settings worldwide, drivers have become accustomed to undesirable congestion and excessive delay. Traffic congestion is considered to be one of the prominent issues that need attention. Traffic control and management experts and policy makers have come up with many possible solutions to solve the traffic congestion problem. Some of these solutions focused either on increasing the number of roads or lanes to cope with the demand or on limiting the traffic demand by levying tolls and raising taxes for using the system. Also, due to political concerns and feasibility constraints, both of these options did not offer a promising solution. Another solution is to use the current system in a more efficient way. This option offers high benefits and potential both on the short term and the long term. The increasing number of traffic jams, the rise in the health and environmental effects of the vehicular emissions, and the increasing fuel prices are other dimensions of the challenges of vehicular mobility in most developed countries. As a result, it has become apparent that multi-objective transportation control and management systems should be developed to address the multifaceted traffic problems. One of the well accepted and promising solutions is the use of Dynamic transportation systems. In this regard, this thesis contributes its share to improve the freeway traffic mobility by considering both environmental (emissions and dispersion of emissions) and economic concerns (travel time and energy consumption) of different stakeholders. In addition, many studies and statistics were generated in developing countries that proved that most of the road accidents are because of the very narrow roads and because of the destructive increase in the transportation means [1].

II. CONTROL DESIGN STRATEGIES

In the literature different control methodologies have been presented for controlling and managing a traffic network in which vehicles are driven by humans [2, 3]. In this section, we will discuss the control design methodologies for freeway traffic control that are currently most often used in practice such as :

2.1 FIXED CONTROL

Fixed Control is open loop control system which uses a preset cycle time to change the light. Based on the past data at that particular intersection, once the timings for RAG light has been set, controller makes On/Off the lights according to that. This type of control is easy to implement and cost is low. In an open loop control system the output is neither measured nor fed back for comparison with input. Faithfulness of an open loop control system depends on accuracy of input calibration. Fig. 2.1 shows the fixed control of traffic control.

Fig.2.1 Fixed Control System

2.2 STATIC FEEDBACK CONTROL

In static feedback control methods, the controller gets measurements from the system and determines control actions based on the current state of the system in such a way that the performance of the system is improved. The main examples of static feedback controllers are state feedback controllers (where the feedback gain can be computed using, e.g., pole placement) and PID controllers (for which several tuning rules exist,

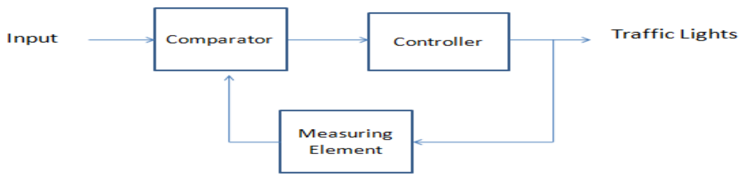


Fig. 2.2 Static feedback control

such as the Ziegler-Nichols rules) [4]. However, the static feedback strategy in general does not handle any external constraints. This is a major drawback of this control scheme. Here statics mean that the control parameters of the feedback controller are taken to be fixed.

2.3 OPTIMAL AND MODEL PREDECTIVE CONTROL

Two dynamic control methods that apply optimization algorithms to determine optimal control actions based on real-time measurements: optimal control and model predictive control. Dynamic traffic control methods continuously measure the state of the traffic network and respond accordingly. Dynamic traffic control methods can either be non-predictive or predictive [5,6]. Since traffic systems are highly non-linear and time-variant systems, model-based predictive traffic control approaches [7, 6] such as Model Predictive Control (MPC) are promising candidates. MPC is a model-based control approach that is based on the optimization of control inputs that improve a given performance criterion (objective function) over some prediction horizon. The performance criterion of MPC is formulated as a cost function of the predicted system states, outputs, or inputs. The MPC approach can be used for non-linear and time variant systems. In addition, it can incorporate constraints on the inputs, states, and outputs of the system. The MPC controller is demonstrated in two simulation-based case studies for a balanced reduction of travel time, emissions, fuel consumption, and dispersion of emissions.

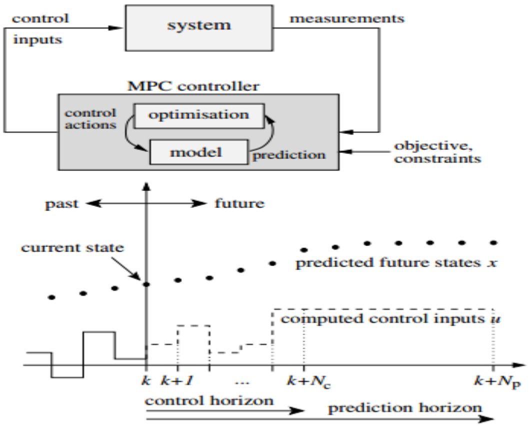


Fig. 2.3 Optimal and model predictive control

Table 2.1 Comparison between different Control strategies

Control method	Computational complexity	Constraints	Future inputs	Model based	scalability
Fixed Control	low	No	No	No	Localized
Static feedback control	Medium	No	Sometimes	Yes	Localized
MPC	High	yes	Yes	Yes	System-wide

Figure 2.3 shows the optimal and model predictive control strategy and Table 2.1 shows the comparison between different control strategies. The main advantages of MPC are that it takes the effect of the control inputs on the future system states, that it is able to take both equality and inequality non-linear constraints of the manipulated and controlled variables into account, and that it can be used for non-linear systems. Moreover, MPC can handle several process models as well as many performance criteria of significance to the system [7].MPC, and in particular, MPC for non-linear systems also has certain disadvantages. The main disadvantage of MPC for non-linear systems emanates from the non-linear and non-convex optimization problem involved. Such optimization problems do not only pose difficulty in computing optimal solutions, but also the computation time involved to get the optimal solutions may become very high. Usually, the computation time exponentially increases as the number of control inputs (optimization variables) or the prediction horizon increase.

III. TECHNIQUES FOR DRTCC

Artificial Intelligence (AI) techniques aim at enabling intelligence in machines to solve a problem using human intelligence and thinking. By human intelligence, we mean that the ability of computer programs to perceive a situation, to reason about the problem, and to act accordingly. AI techniques are mainly used in decision support systems, and one way to classify them is as follows:

3.1 ARTIFICIAL NEURAL NETWORK APPROACH

The adaptive traffic light problem was modeled using the ANN approach. The Researchers M.Patel and N. Ranganathan [8] created an ANN model which included predicting the traffic parameters for the next time frame and computing the cycle- time adjustment values. This model consisted of nine inputs (one of each past and present traffic parameters one hidden layers with 70 hidden nodes and three output nodes. The ANN model, if drawn a sketch, would like the figure shown below. The input given to the ANN models are the list of data collected by the sensors which are placed around the traffic lights. The sensors give the traffic light ANN model all the data

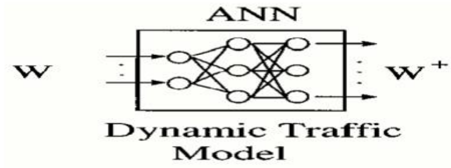


Fig. 3.1 Artificial neural network approach

The model after getting the input used the hidden layer to decide which nodes suites the current traffic situation. Each hidden nodes is given a membership function (i.e. between 0 and 1). After comparing the nodes and matching it with the current form of membership functions ranging from 0 to 1. Alternatives are selected as the output is then used by the traffic lights to set the timing for the red and green lights. The output of the ANN model will be in the form of membership functions ranging from 0 to 1.

3.2 GENETIC ALGORITHM APPROACH

Genetic algorithm [9] method proposes the use of technology to count the vehicle numbers by video image detection system. Then discusses the implementation of the genetic algorithm, and offers some suggestions intended to improve the efficiency of the system and to determine the vehicle numbers and the estimated number of people in the region by mobile cell location; where the system can makes changes in real time to avoid congestion wherever possible. The other application of the system can detect abnormal situations like car accidents, and the level of congestion. The system is based on a genetic algorithm that receives inputs from the video image detection system which will make a decision and determines the greens light time to minimize the congestions and flow of traffic jam. proposed system may compose of many technologies such as: Video Image Detection Systems, Vehicular Ad Hoc Networks and Mobile phone tracking, and Global Position System (GPS). Using these technologies with artificial intelligence could be creating an Dynamic traffic light that take a decision of green lights time by itself.

3.3 FUZZY EXPERT SYSTEM APPROACH

Fuzzy expert system [10] was used to control the traffic light in most cities. It was the most common system used in major areas. The fuzzy expert system composed of seven elements i.e. a radio frequency identification reader (RFID), an active RFID tag, a personal digital assistance (PDA), a wireless network, a database, a knowledge base and a backend server. In this system, the RFID reader detects a RF-ACTIVE code at 1024 MHz from the active tag pasted on the car. The active tag has a battery, which is inbuilt inside it, so that it can periodically and actively transmit messages stored in the tag. As soon as the data is received, the reader will save all information in the PDA. When the PDA accumulates the required amount of data, it will use its wireless card and connect to the backend server and store them in to the database in server.

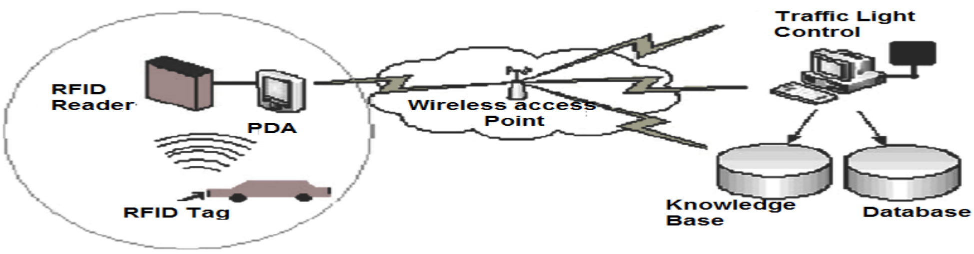


Fig. 3.2 Fuzzy Expert System

Now the server uses the data stored in the database to calculate maximum flow, interarrival time and average car speed. When all possible congestion roads and car speed are collected, then these data would be used as the input parameters of the traffic light control simulation model in the server. After getting the simulation results, the system is able to automatically give different alternatives in terms of varieties of traffic situations and then the red light or green light duration is being set via a traffic light control interface for improving the traffic congestion problems. All the rules and reasoning are used in the IF-THEN approach, starting from a basic idea and then tries to draw conclusions format. The system is using the forward chaining approach, which is a data driven approach, starting from a basic idea and then tries to draw conclusions.

3.4 SWARM INTELLIGENCE APPRAOCH (PSO)

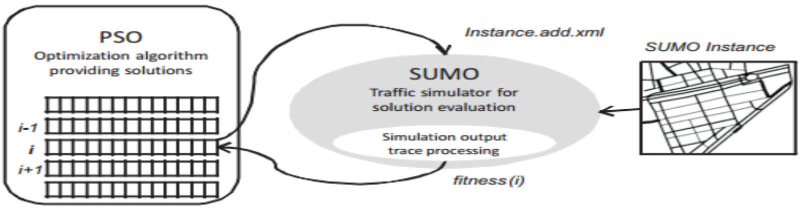


Fig. 3.3 Particle swarm optimization algorithm

When PSO [11] generates a new solution it is immediately used to update the cycle program. Then, SUMO is started, to simulate the scenario instance with streets, directions, obstacles, traffic lights, vehicles, speeds, routes, etc., under the new defined staging of the cycle programs. After the simulation, SUMO returns the global information necessary to compute the fitness function. Each solution evaluation requires only one simulation procedure since vehicle routes in SUMO are generated deterministically. In fact stochastic traffic simulators obtain similar results to deterministic ones, the latter allowing huge computing savings. In addition, we must note that each new cycle program is statically loaded for each simulation procedure. In his technique dynamically generate cycle programs during an isolated simulation as is done in agent-based algorithms has been presented which is used to obtain the optimized cycle programs for a given scenario and timetable. In fact real traffic light schedulers actually demand are constant cycle programs for specific areas and for pre-established time periods (rush hours, nocturne periods, etc.), which led them to take this approach.

3.5 HYBRID APPROACH OF FES AND ANN (IDUTC)

IDUTC [8] is a real time Dynamic decision making system that computes decisions within a dynamically changing application environment. The IDUTC model consists of seven elements. The names of the element are as follows.

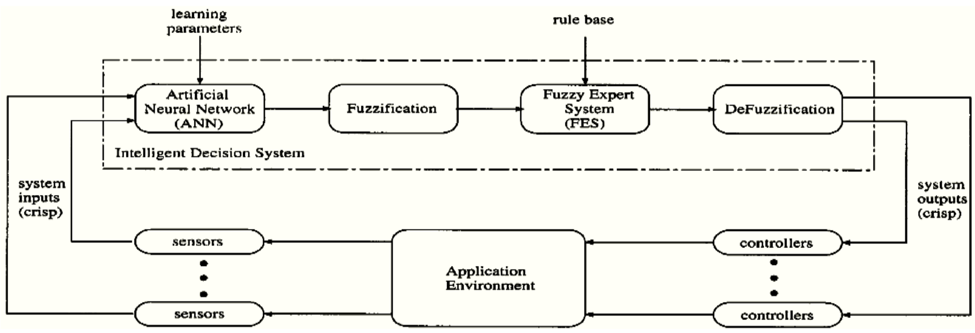


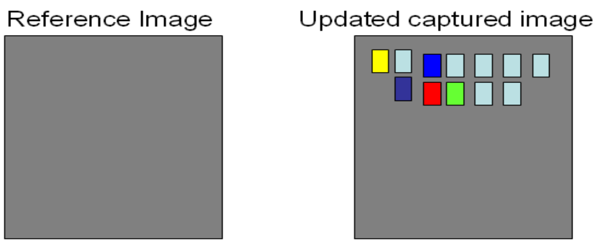
Figure 3.4 IDUTC system

- Artificial Neural Network (ANN).
- Fuzzification element
- Fuzzy expert systems (FES)
- Defuzzification Element.
- Application environment
- Controllers.
- Sensors

The architecture of the IDUTC is shown above. The system is placed at the road to sense the different parameters of the traffic conditions. The sensors are the actual input of the IDUTC model. Sensors collect the past data of the traffic conditions, which is all known as the application environments shown in the figure above. After the surrounding environmental The IDUTC is a self adjusting traffic light control system. The sensor of the ANN model collects all the data from the systems and processes it through the hidden layers and gives the desired output. Now the output of ANN model are is self-adjusting according to the situation of a domain. Then the fuzzy expert system fires the rules based on these fuzzy values. The De-fuzziification unit converts the computed decisions into crisp values that are used to control the environment through the controllers installed at the traffic lights. After running the simulation on the traffic light, past data are being collected along with the present data by the sensors.

3.6 IMAGE PROCESSING APPROACH

This approach [12] is based on the principle of matching area between reference image and updated image and this matching can be easily calculated by formula given below**.** The total area is the range of camera focused on the road. Reference image is black empty road image and updated image is capture when red light is on. In updated image the area covered by vehicles will reduce the area of empty road. After covering the area by vehicles rest of empty area will be compare with reference image which is already a empty road image. Thus after measuring the matching % between two images we can set the timing of RGY lights. Fig.3.5 shows the basic principle of the proposed scheme.



$$matched\_area(in\,percentage) = \frac{matched\_area}{total\_area} \times 100$$

Fig. 3.5 Image Matching Approach

In the image matching approach, one camera is installed alongside the traffic light, which will capture image sequences. An image of the road with no traffic is captured and converted into grey level, then this image is enhanced to signify signal to appear more than the noise and to also accentuate the image features. This enhancement was implemented using Gamma- correction [13,14]. After the enhancement is done, edges are detected in the enhanced image to remove irrelevant data with preserving the important structure of the image. This can be done using Perwitt edge detection operator [13] or using canny edge detection [14]. After edge detection procedure, both reference image and other different images are captured at different time intervals are matched. The traffic light is then to be controlled based on the percentage of matching. In image matching, all edges in one image are compared to all edges in the other image. Accuracy of this approach is highly affected by the changes in illumination and weather conditions. Furthermore, it does not take stationary vehicles into consideration. The vehicles may be moving fast on one side having matching percentage between 50% and 70% and at the other side of intersection, the matching percentage is also between 50% and 70%, but they are completely stationary.

3.7 IMAGE MOSAICKING APPROACH

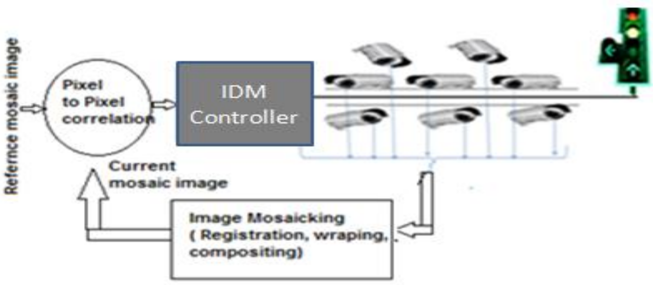


Fig.3.6 Functional block diagram of DRTCCS with MSVS

Figure 4.2 shows the components of DRTCC with multiple stable vision sensors (cameras). In this framework multiple cameras has been installed only for accurate measurement of density so that exact gap between the vehicles may by measured. One stable camera is not capable of measuring accurate density as it suffers from some installation problems (orientation adjustment). After processing the images taken from various angles, Image mosaic system gives the feedback to pixel to pixel correlation type error detector where it is compared with reference updated image. According the matching pattern of pixels, IDMC varies the timings or R-G lights.

IV. RESULT COMPARISON OF DRTCC TECHNIQUES

After closely reading the techniques for DRTCC, we could conclude that the IDUTC system provided decisions that relieve intersection congestion better than the ANN approach and was comparable to the FES approach. The ANN approach required more neural network nodes than the ANN in IDUTC, which led to slower training and higher implementation

Table 4.1 Comparative study on IDUTC, ANN and FES

System	Correct decision rate	Average wait time (m)	Number of nodes	Number of rules
IDUTC	95%	2.186	55	40
ANN	73%	2.958	83	-
FES	95%	2.975	-	40

cost. The FES system leads to correct decisions but didn’t reduce time for waiting as compared to IDUTC. The IDUTC uses the current and past values or data to compute decisions, but the FES uses only current traffic flows. As shown in Table 4.1 best correct decision rate, average wait time is taken by IDUTC system. In GAs, chromosomes share information with each other. So the whole population moves like a one group towards an optimal area. In PSO, only best gives out the information to others. It is a one -way information sharing mechanism. The evolution only looks for the best solution. Compared with GA, all the particles tend to converge to the best solution quickly even in the local version in most cases. The PSO and GA provides the better decision making for optimizing the timings of lights also it takes less time to take decision but hard to implement such a method in real life applications. In image processing/matching approach better decision may be achieved in short time and can be implemented in real life but problem is that a single camera cannot measure the accurate density on road as gap between two vehicles cannot be identified with single camera. After comparing these techniques we could conclude that image processing based automatic traffic light system is best decision making system for Dynamic transportation system among all the techniques.

To compare proposed technique with conventional techniques, an experiment has been performed on one vehicle. One of the vehicles is allowed to go to in W-E direction at 40Km/hr on AimSun test bed. Total time of 450 seconds has been given to vehicle to cover the distance. Randomly traffic density is applied on road in three difference situations (heavy traffic, moderate traffic and low traffic) to check the performance. The same conditions have been applied to IDUCT, FES, ANN techniques to check their performances. After simulate the experiment, it is found that vehicle when adopts dynamic road traffic management system (DRTMS) covers 4.6Km distance in specified time period whereas distance covered by vehicle using techniques IDUCT,FES and ANN is 4.3Km, 3.9Km and 3.6Km respectively when traffic is high as shown in figure 4.1. Here A is source and B is the destination whereas AO indicates the moving time of vehicle under test, OP indicates average waiting time with DRTCCS, OQ indicates average waiting time with IDUCT, OR indicates average waiting time with FES, OS indicates average waiting time with ANN and time taken by vehicle from P to B, Q to B, R to B and S to B indicates again average moving time. And OP is the time taken by DRTCCS to make the decision as plus waiting time after measuring the density.

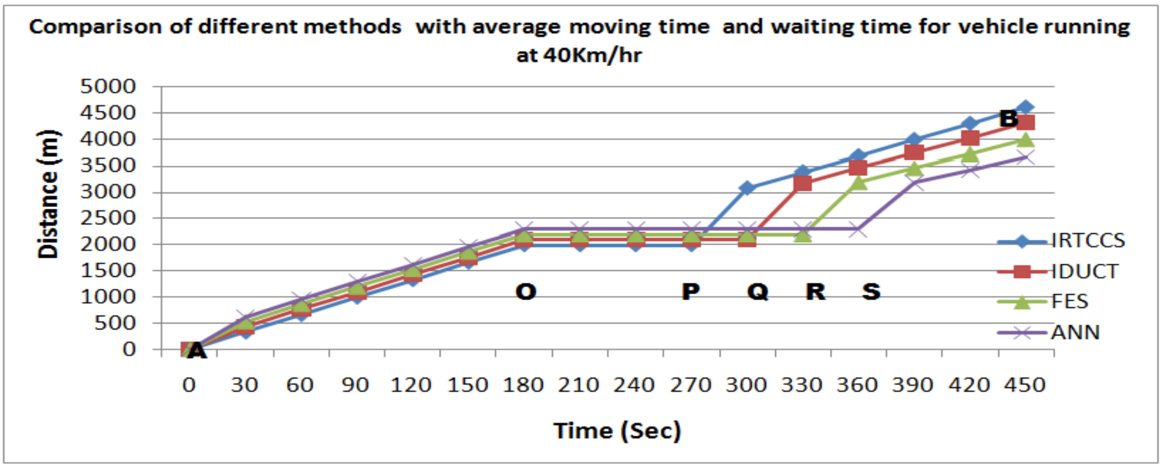


Fig.4.1 Comparison chart for DRTCC techniques

V. CONCLUSIONS AND FUTURE WORK

Problems were identified with current traffic control system. Beside, to analysis and design of new and effective system to solve the existing problems, an innovative algorithm is proposed in this research for arterial performance measurement by tracing the traffic density on road. An interesting property of the proposed model is that travel time estimation errors can be self-corrected with the signal status data, because the matching differences between a current image and updated image decides the timings of traffic lights. The efficacy of proposed method has been evaluated, using MATLAB, JAVA and LabVIEW software. The research study shows that the proposed algorithm can do better decision making to manipulate the timings of RAG lights. After comparison of proposed framework with conventional techniques, it is found that proposed method is quite effective (in terms of improving moving time and reducing waiting time) for the control of the traffic signals for controlling congestion on the road. We believe that this represents our initiative in development of low-cost, deployable strategies for alleviating congestion in developing regions. Based on the accurate dynamic traffic density measurement on road, Dynamic technique to manage the traffic lights has been developed for the purpose of maximizing traffic throughput and minimizing average waiting time at an intersection.

Some artificial Dynamic techniques like Fuzzy logic, FES, GA,PSO, ANN etc may be developed with image mosaicking for better decision making in short time on the basis of measurement of accurate density.

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