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Soft Computing Based Robust and Dynamic Road Traffic Control System-A Initiative to Development of Intelligent Transportation System (ITS)

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Abstract: This study describes the design of robust and dynamic intelligent road traffic control system based on Artificial Neural Network method. Learning system has been extensively adopted as approach for real time decision making system. As the conventional dynamic controller were used sensors which are having certain limitations so these limitations can be overcome by vision sensors, i.e., camera. Also, image and vision computing plays a important role in monitoring and measuring the traffic density on road. Problems were identified with the current traffic control system at the intersection on road and it required the development of a new system to solve the problems. The performance of the proposed method is evaluated with Aimsun, JAVA and MATLAB test bed. The results of extensive simulations using the proposed soft computing approach indicate that the system improves the average moving time and decrease the average waiting time.

Key words: Artificial neural network, traffic lights, image and vision computing, controller, traffic density measurement

INTRODUCTION

Traffic congestion is a major problem found in urban cities. Transportation systems are necessary to economic and the security of the human. The effectiveness of a transportation system depends on its ability to support the reliable movement of vehicles from one place to another. An urban traffic system is an important yet complex transportation system composed of pedestrians, vehicles, traffic lights and a traffic network model (Sheu, 2006). Problems related to urban traffic is serious matter and many researchers are trying hard to resolve them.

The huge number of vehicles causes serious problems like for example air and noise pollution, traffic jam, stress to drivers and fuel consumption (Chabrol *et al*., 2006). For a traveler, congestion means loss of time, missing of opportunities and getting frustration. It also, adversely impacts the industries due to productivity loss of the employees, loss of trade opportunities, delayed delivery. Common methods of conventional traffic light controls are time of day control; fix time control, area dynamic control. Artificial intelligence methods such as ANN (Dai *et al*., 2011), Fuzzy Expert system (Wen, 2008), extension neural network (Wang and Hung, 2003) and Intelligent Decision making system for Urban Traffic IDUTC (Patel and Ranganathan, 2001) are reported in literature. However, no such a system has developed which meets the adaptive characteristics like the minimum time to take the decision for on/off timings of RGY lights. Many studies and statistics were generated in developing countries which proved that most of the road accidents are because of the very narrow roads and because of the drastically increase in the transportation means. Traffic light is one of the most significant factors in the management of the traffic. Traffic light signs are that signs erected at the sides of the roads to provide information to road users. It has been proven that traffic signal timing and coordination of existing signals reduce significantly in traffic delay, energy, travel time and this consequently results in increased safety for the public. Due to poor strength of traffic police, it is impossible to control traffic manually in all area of city or town. For this reason, researchers take interest in developing dynamic efficient real-time traffic signal control.

This idea of controlling the traffic light dynamically (Papageorgiou *et al*., 2003) in real world has attracted many researchers to study in this field with the goal of creating automatic dynamic tool that can estimate the traffic congestion and based on this variable, the traffic sign time interval is forecasted. Analysis of traffic conditions showed that there are many fluctuations in the quantity of the vehicles approaching to a cross road for the same period of time. Therefore, the current automatic traffic light control using a timer which is commonly used in India at many cross roads is not realistic and such

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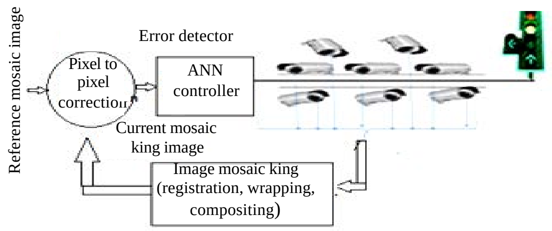

Fig. 1: Schematic diagram of proposed framework

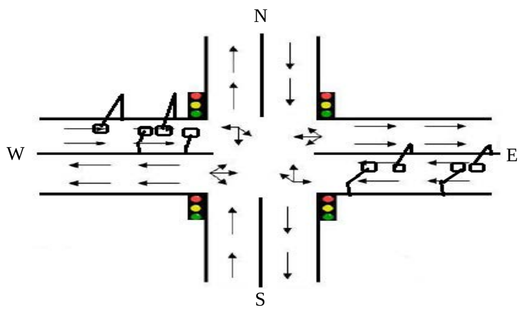

Fig. 2: Schematic diagram of'+'Junction type intersection

automatic tool is required to have more realistic, effective and efficient tool than the current one. The simulation result shows that proposed algorithm can achieve higher intersection throughput and lower vehicle's average waiting time. In addition, we implement the algorithm on our Aimsun and MATLAB test bed to test and evaluate the performance of our algorithm.

Traffic control framework: Figure 1 shows schematic diagram of proposed scheme in which error detector gives the counts of average pixel to pixel matching of reference mosaicked image and current mosaicked image. Here, multiple vision sensors have been used instead of conventional sensors like IR, ultraviolet sensor, inductive loop sensors that were used in conventional controllers. In addition, fuzzy controller have been used for better decision making to vary the timings of green/red lights as per density measured on road on the basis of layer structure of extension learning system manipulated by output of error detector. In feedback loop, vision sensors has been used for capture the images of traffic. The use of multiple vision sensors are only so that, it can measure the exact gap between vehicles to accurate measurement of traffic density. After capturing the images, the image passes though number of steps like saves the images, grey conversion, transformation, wrapping, compositing and finally, mosaicked image formed.

Figure 2 shows the schematic diagram of proposed framework on '+' shape road. The 4 web cameras of 12.0 mega pixels have been installed on each side of road. It has been assumed that in W-E and E-W direction, there are two lanes in each side as heavy traffic passes in these directions as compared to N-S and S-N which is having single lane due to low traffic on these directions.

The proposed algorithm works in such a way when normal traffic is detected, the timings remains same as set earlier. But, when algorithm detects traffic more than normal (normal traffic measurement range may be obtained from past data), timings of red/green lights varies accordingly. As macroscopic traffic flow model deals with average density, average velocity and average speed of traffic but in this proposed framework only traffic average density has been considered.

MATERIALS AND METHODS

Artificial neural network: The schematic structure of the ENN is depicted in Fig. 3. It includes both the input layer and the output layer. The nodes in the input layer receive the similar data of both images (reference mosaic image and current mosaic image) from error detector which gives feature pattern and use a set of weighted parameters to generate an image of the input pattern. In this network, there are two connection values (weights) between input nodes and output nodes, one connection represent the lower bound for this classical domain of the features and the other connection represents the upper bound. The connections between the jth input node and the kth output node are W_{kj}^{L} and W_{kj}^{U}. Only one output node in the output layer remains active to indicate a classification of the input pattern.

Learning algorithm for neural network: The learning of the NN can be seen as supervised learning and its purpose is to tune the weights of the NN to achieve good clustering performance or to minimize the clustering error. Before the learning, several variables have to be defined. Let training pattern set be $X=\{X_1,X_2,..., X_n\}$ where N_p is total number of training patterns. The ith pattern is $X_i^p= \{X_{i1}^p, X_{i2}^p, ..., X_{jn}^p\}$ where n is the total number of features of patterns and cluster of the ith pattern is p. To evaluate the clustering performance, the total error number is set as N_m and total error rate E_t is define below; learning algorithm can be described as.

$$E_t = \frac{N_m}{N_p} \quad (1)$$

Step 1: Set the connection weights between input nodes and output nodes. The range of classical domains can be either directly obtained from the previous requirement or determined from training data as follows:

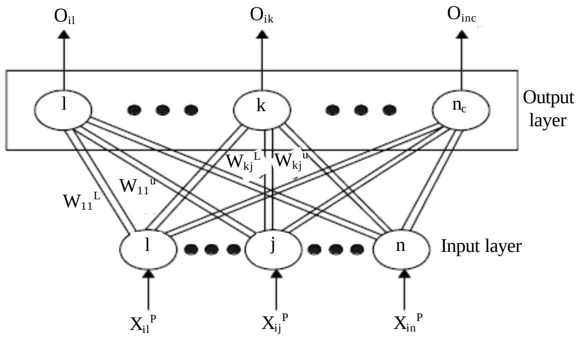

Fig. 3: Structure of neural network

$$W_{Kj}^{L} = \min W_{Kj}^{k} \tag{2}$$

$$W_{Kj}^{u} = \max W_{Kj}^{k} \tag{3}$$

Step 2: Calculate the initial cluster center of every cluster:

$$Z_k = \{Z_{k1}, Z_{k2}, ... Z_{kn}\} \tag{4}$$

$$Z_{kj} = (W_{kj}^{L} + W_{kj}^{u})/2,\ \text{for } K = 1,2,...,n; j = 1,2,...,n \tag{5}$$

Step 3: Read the i-th training pattern and its cluster number p:

$$X_i^p = \{X_{i1}^p, X_{i2}^p, ... X_{in}^p\}, p \in n_c \tag{6}$$

Step 4: Use the proposed Extension Distance (ED) to calculate the distance between the training pattern X_i^p and the kth cluster as follows:

$$ED_{ik} = \sum_{j=1}^{n} = 1\left[\frac{|X_{ij}^p - Z_{kj}|}{|W_{kj}^u - W_{kj}^L|/2} + 1\right], k = 1,2,....n \tag{7}$$

The proposed distance is a modification of extension distance and it can be graphically presented as in Fig. 3. It can describe the distance between the x and a range.

Step 5: Update the weights of the pth and the kth clusters as follows: Update, the centers of the pth and the kth clusters:

$$Z_{pj}^{L(new)} = Z_{pj}^{L(old)} + \eta\left(x_{ij}^{p} - z_{pj}^{old}\right) \tag{8}$$

$$Z_{kj}^{L(new)} = Z_{kj}^{L(old)} + \eta\left(x_{ij}^{p} - z_{kj}^{old}\right) \tag{9}$$

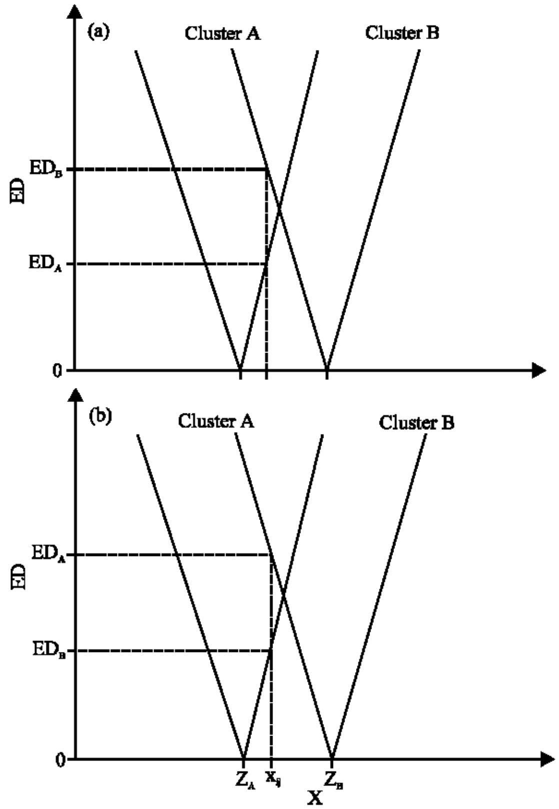

Fig. 4: Pattern of tuning cluster weights: a) before tuning and b) after tuning

Where is learning rate The result of tuning two clusters' weights shown in Fig. 4 which clearly indicates the change of c and ED_B.

Step 6: Repeat step 3-5 and if all patterns have been classified then learning is finished.

Step 8: Stop, if the clustering process has converged or the total error rate E_r has arrived at a preset value; otherwise, return to step 3.

It should be noted that the proposed NN can take input from human expertise before the learning and it can also produce meaningful output after the learning because the classified boundaries of the features are clearly determined.

Design criteria and constraints: In the development of the dynamic traffic lights control system the following assumptions are made:

- The junction is an isolated four-way junction with traffic coming from the North, West, South and East directions

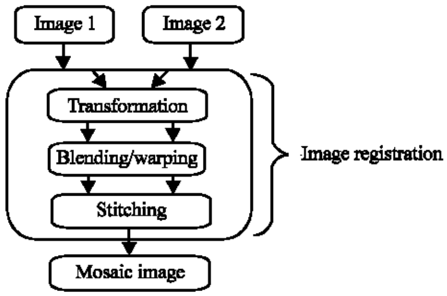

Fig. 5: Flow chart for image processing

- When traffic from the north and south moves, traffic from the West and East stops and vice-versa
- No right and left turns are considered
- The dynamic logic controller algorithm will observe the density of the north and South traffic as one side and the West and East traffic as another side
- East-West lane is assumed as the main approach

Vision computing: Image mosaicking is the process of smoothly piecing together overlapping images of a scene into a larger image. This operation is needed to increase the area of coverage of an image without sacrificing its resolution. Due to the limited size of digital images, it is sometimes not possible to include an area of interest in an image. In such a situation, overlapping images are obtained and the images are combined into a larger image through image mosaicking. An image mosaic is created from a set of overlapping images by registering and re-sampling all images to the coordinate space of one of the images. An image mosaicking system has to take into consideration the relation between the cameras, distances of the cameras to the scene, the scene content and the characteristics of the cameras. As shown in Fig. 5, image mosaic process consists of three steps: image transformation, image blending or warping and image compositing or stitching.

Algorithm for proposed framework: Algorithm has following steps:

- Acquire the images from individual cameras during red light and stores them automatically in data base
- RGB images are converted in to gray scale images
- Gray scales images are transformed in to different projections to meet the properties of pixel to pixel
- Projected images are warped or blended so that pixels of projected images perfectly match throughout the region
- Blended images are stitched or composited to make one image called mosaicked image which gives the information of images taken from different angles earlier
- Steps 1-5 repeated for reference image just after 2 sec when red becomes ON
- Algorithm waits until reference mosaicked image and current mosaicked image formed
- Pixel to pixel matching of both mosaicked images performed
- The average matching of both mosaicked images gives the command to learn based artificial neural network controller and timing of red/green lights varies according to that

Steps 1-9 executes during the red light so that timings of green light may be varied. For example, if total time is given to red light+green light is 60 sec and if traffic on N-S road is more than normal then timing of green light will be 50 sec and timing of red light will be 10 second. The set timings are arbitrary values.

Detection of traffic density: To perform traffic density estimation, we first use a simply polygon to manually mark the road segment area for image analysis. For a given camera feed on a road segment, this is a onetime operation that explicitly specifies the region of interest for the analysis. Then we convert the picture in to 8-bit gray scale and analyze the pixels within the marked segment area. For each value (0-255), we plot a histogram for number of pixels that each value of 256 different gray scale values.

It has verified that the gray of roads lies in the 135-165 range. Intuitively and backed by the analysis if an histogram is constructed for the varying levels of gray in the picture, depending on the level of congestion of the road, a histogram would be observed to have a smooth gray level area as compared to a high peak expected in an empty road. With increasing traffic, the peaks at 135-165 begin to reduce and the drop-off at either side is more gradual. By examining these histograms, we can easily estimate the traffic density on the roads. Figure 6a shows snapshots from a traffic feed (along with the corresponding histogram). The image on the left shows no congestion and we observe that the corresponding histogram shows peaks in the road gray areas. Similarly, Fig. 6b on the right shows a congested road and the corresponding histogram. Observe that the histogram is more evenly spread out and does not peak in the gray areas as much as the case with low congestion.

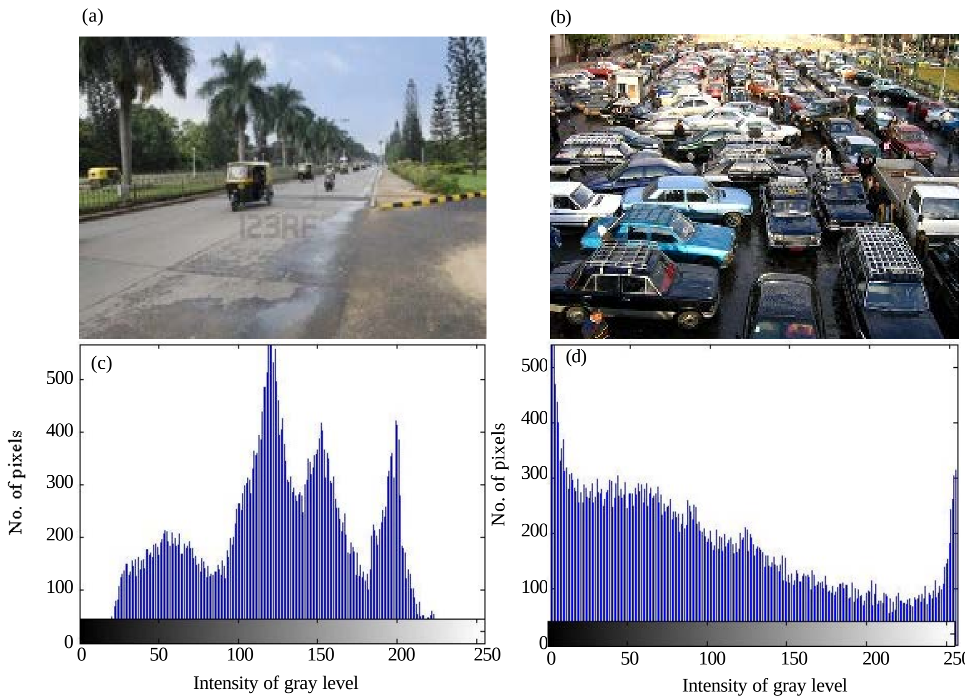

Fig. 6: a, c) No congestion image and histogram and b, d) Heavy congestion image and histogram

RESULTS AND DISCUSSION

Experimental results: Aimsun is the platform which has been developed to improve the transportation system. This platform has been used to evaluate the performance. It also gives the information about traffic present on road in percentage. To check the performance of proposed framework, Aimsun simulation test bed has been used as shown in Fig. 7. In GUI '+' type road has made with vision sensors to check the variations in timing of red/green lights. Figure 8 Shows the two images captured at different projections. After processing these images, final mosaicked image is shown in Fig. 9.

Fig. 7: Test bed with Aimsun

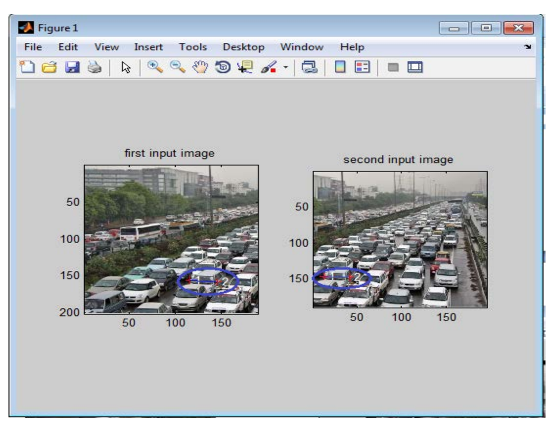

Fig. 8: Two images captured at different projections

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 20 km h^{-1} on Aimsun test bed. Total time of 300 seconds is given to vehicle to check the distance to be covered. Randomly, traffic density is applied on road to check the performance. The same conditions have been applied to ANN with conventional sensors technique to check their performances. After simulate the experiment, it is found that vehicle when adopt Neural Network controller with Vision Sensor (NNVS) computing, covers 600 m distance in specified time period whereas distance covered by vehicle using technique ANN with conventional sensor is 480 m. Simulation results shows average waiting time and moving times for vehicles.

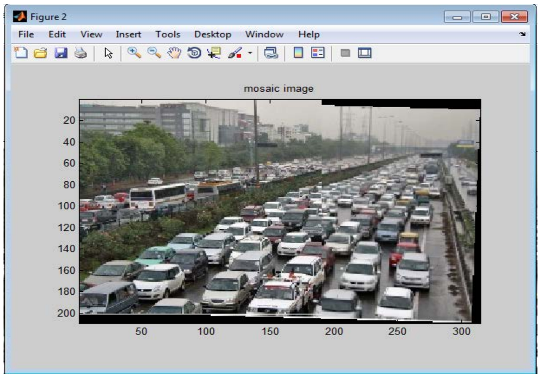

Fig. 9: Final mosaicked image

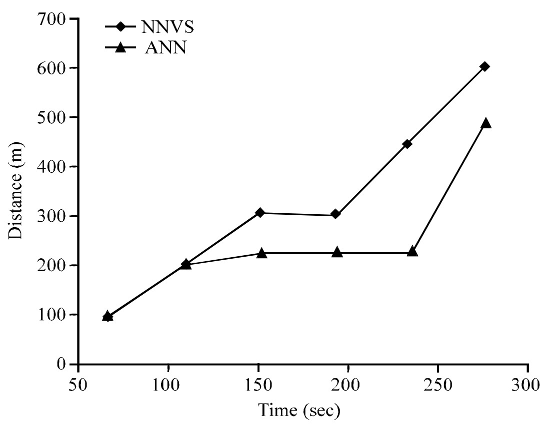

Fig. 10: Comparison chart of conventional techniques with proposed scheme

Whereas, the time taken by vehicles when no distance is covered is the time when red light becomes on and remains on for a time depends upon traffic present on road and execution of algorithm.

During this red light period, decision making algorithm decides the timing of green light for next cycle. As it can be seen in Fig. 10 that proposed framework increases the average moving time and decreases the average waiting time.

CONCLUSION

Road traffic congestion is a central problem in most developing regions. Most urban areas have poorly managed traffic networks with several traffic hot-spots or potential congestion areas. In this study, we study the problem of road traffic congestion in high congestion hot-spots in developing regions. We first present a simple image processing algorithm to estimate traffic density at a hot-spot using web-camera feeds. Based on analysis of traffic images from live traffic feeds, we show evidence of congestion collapse which last for elongated time periods. Our hope is that localized de congestion mechanisms are potentially easier to deploy in real-world settings and can enhance the traffic flow at critical hot- spots in road traffic networks. 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, intelligent neural network controller with vision computing to manage the traffic lights has been developed for the purpose of maximizing traffic throughput and minimizing average waiting time at an intersection.

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