"FPGA Implementation of Intelligent Traffic Signal Controller Based On Neuro-Fuzzy System"

A. R. ZADE[1], D. R. DANDEKAR[2]

PG Department of Electronics Engineering, Bapurao Deshmukh College of Engineering, Sevagram (Wardha), Maharashtra, India

[1]ashish.z@rediffmail.com, [2]d.dandekar@rediffmail.com

***Absract*-Fast transportation systems and rapid transit systems are nerves of economic development for any nation. All developed nations have well developed transportation system with efficient traffic control on road, rail, and air. The monitoring and control of city traffic is one of the key issues especially in metropolitan areas due to ever increasing number of vehicles and pedestrians. Numerous methods are available to reduce delays and environmental problems caused by road traffic in major cities. Present traffic controllers are based on microcontroller and microprocessor. These traffic light controllers have limitations because it uses the predefined hardware, which functioning according to program that does not have the flexibility of modification on real time basis.In traffic signal control system, detection of traffic variables at intersection is very important and is the basic input data to determine signal timing. The "Intelligent Traffic Signal Controller using FPGA controller based on Neuro-Fuzzy system" is capable of taking decision to reduce delays at intersection. To develop the system, algorithm need to be developed using VHDL. The designing part of this controller into VHDL program eliminates the shortcomings of the other custom facilities and conventional controller design available today.**

Keywords: *FPGA, Intelligent, Delays at Intersection, Neuro-Fuzzy, VHDL.*

I. INTRODUCTION

Traffic signal is an essential element to manage the transportation network. At present, a major research focus has been on application of artificial intelligent techniques, for example, expert systems, fuzzy logic, neural network for intersection signal control. To improve traffic flow and safety of the current transportation system is to apply automation and intelligent control methods to roadside infrastructure and Vehicles. The complexity of modern traffic control system makes their design & optimization a complex task. Nevertheless, well configured traffic systems are essential to avoid unnecessary congestion in traffic network and to reduce the negative economic and environment impact of traffic.

Various computational intelligence based approaches have been proposed for designing real time traffic signal controllers, such as fuzzy sets, genetic algorithm and reinforcement learning and neural networks (NN). Neural network based system can provide effective control of large scale traffic network even as the complexity of simulation increases.

The Fuzzy logic theory is introduced in the traffic controller to provide an intelligent green interval response based on dynamic traffic load inputs. A fuzzy logic control scheme is proposed to overcome the inefficiency of conventional traffic controllers that has a preset cycle time regardless of dynamic traffic load. Fuzzy logic is used to model expert's thinking in situations where development of a mathematical model is very difficult or impossible. Fuzzy logic technique based system reflects two fundamental aspects of traffic responsive signal control – the observation of the on-going traffic situation around the intersection, and the control of the traffic signals in a manner appropriate to the observed situation .The key to achieving a high degree of responsiveness to traffic is to monitor closely the traffic flow on the approaches to the junction, and to interpret the incoming data correctly.This system brings fuzzy logic into toolbox currently available to traffic planners and engineers, enhancing their ability to deal with urban congestion problems so prevalent.

The fuzzy controller can be used with the input variables of the weighted traffic flow at the current and neighbouring intersections. This can be helpful for reducing the complexity of controllers. i.e., the controller has less input variables. For satisfying performance, the weighting fuzzy module is used to substitute the communication amongintersections.

Modern approaches towards designing traffic signal controllers suggest way to convert loop detector data or video detector into no. of vehicles waiting for queue for a major arterial intersection under interrupted traffic flow conditions by means of fuzzy logic and neural networks.

II. OBJECTIVE

Intelligent traffic control system is generally designed for different traffic parameters. The important parameters which contributes most for all types of traffic like homogeneous and heterogeneous in urban, rural and metro cities are

a) Congestion at the intersection,
b) Delay in traffic and
c) Synchronization of signal at current intersection with the signal at neighboring intersection.

The main objective of this paper is to discuss methods used in work problems mentioned above.

a. Congestion at the intersection

In India, Congestion is defined using Volume/Capacityratio. However, Passenger Car Unit (PCU) used to estimate the volume as well as capacity is subjective in nature and these are not directly measurable units. Therefore, the actualcapacity of the road is not determined and thus the value of congestion becomes subjective in nature. The type and intensity of congestion depends on many quantifiable factors such as volume, speed, headway, ratio of slow moving and fast moving vehicles etc. In this context, the quantification and evaluation of congestion severity has been taken as an important research to give a modification to the generalized design procedures and also to suggest the remedial solutions for releasing congestion. With increasing number of vehicles on road, heavy traffic congestion has substantially increased in major cities. This happened usually at the main junctions commonly in the morning, before office hour and in the evening, after office hours. The main effect of this matter is increased time wasting of the people on the road. The solution for this problem is by developing the program which different setting delays for different junctions. The delay for junctions that have high volume of traffic should be setting longer than the delay for the junction that has low of traffic. The congestion control process generally attempts to maximize throughput by selecting the phase that will pass the most vehicles through the intersection.

b. Delays in Traffic

There are many metrics exist in order to evaluate the performance of a traffic light controller. One of the most important metric to optimize, as it impacts directly on drivers is called the delay. The delay is defined by the amount of additional time a vehicle takes to complete its journey through the network because of traffic lights. Another interesting metric is the throughput which gives the number of vehicles that cross the intersection in a specified amount of time. Clearly, the general optimization goal for traffic network designers is to lower the delay and to increase the throughput of vehicles.

One of the solutions to this problem would be to design controllers that use adaptive policies. Such adaptive systems could react to current perceptions of traffic conditions and select the best actions in order to optimize the traffic flow at the intersection. Moreover, these adaptive systems could even be equipped with communication networks that could enable adaptive coordination between different intersections in order to improve the traffic flow globally. Such coordination could help minimize the overall delay caused by traffic signals.

c. Synchronization of signal at current intersection with the signal at neighboring intersection

The traffic flow has the characters of continuity and fluidity. When vehicles run to an intersection, the vehicles flow meets with obstruction because of the running conflict coming from the traffic flow in several directions. The vehicles flow slackens and even stops. The shock wave will affect the movement of the following traffic flow, even the clearing of vehicles *at*the upstream intersection. Therefore we must consider the influence of the neighbouring traffic flow. So evaluation of affected current traffic flows will consider the influence of traffic flow at neighbouring intersections which is imposed on signal timing at current intersection.

With the parameter coordination of the fuzzy weighting module, the produced signal timing can control the traffic flow smoothly at the intersections, and response the movement of theflow perfectly. So achieve the aim of the harmony between signals among multi intersections. The weighting coefficient can be used to indicate the imposed influence. Therefore the signal timings can harmonize each other amongthe neighbouring intersections. So the signal controller considering the neighbouring flow can give the effective real-time signal timing, and improve the total performance index of the system because of the coordination of the signals between intersections.

For the synchronization between current intersection and neighbouring intersection it is important to understand 32 different conflicts at the intersection which is shown in figure below:

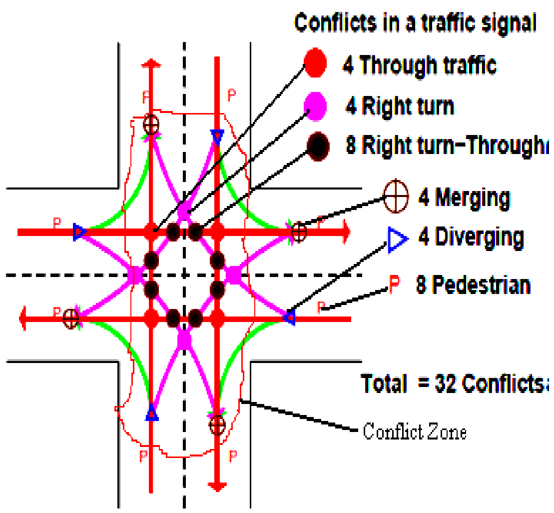

Fig. 1. Conflicts at the Intersection.

III. RELATED WORK

The problem of converting loop detector or video detector data into travel times and NVWQ(No. Of Vehicles Waiting for Queue)for signalized arterial intersection under interrupted traffic flow conditions is based model from Lu Conglin and Wei Wu [1] by the use offuzzy logic and neural networks.

An on-line supervised learning algorithm for building and tuning a neural fuzzy controller has been presented in this paper. The training data lets the learning scheme learn the network structure and parameters in real time. Based on the neural structure an off-line two-phasehybrid learning scheme tune theASC(adaptive subsethood controller) from the given input-output training data sets.Here more emphasise is given on urgency values which is defined as the values to determine the appropriate balance of distribution of the green light i.e., the urgency with which the stream requires green.

The multiobjective optimization of parameters for fuzzy logic controller is suggested for desired flexibility. For that the parameters of the signal controller is optimized with respect to different objectives or criteria. To solve this problem, effective multi-objective genetic algorithms (MOGA) is used. The simulation results show that the percentage of stops of algorithms is smaller 15.25% than the traditional extension principle, and using proposed algorithm, the average delay is also smaller 15-30% than the extension principle in the test area100-1500vph. So this controller produces lower vehicle delays and percentage of stopped vehicles than traditional actuated controller.

Traffic Light Controllers (TLC) problems based on microcontroller and microprocessor are solved using model proposed by Shilpa Chavan and R. Deshpande [2]. This technique uses sensors networks along with embedded system. The Infrared Sensors are applied to detect vehicles is mounted on road.

The signals from sensor assembly will be in the form of digital signals which corresponds to presence or absence of a vehicle. These digital signals from each lane will be given to the input port of microcontroller which determine the length of vehicle at each lane. This information is the input to microcontroller to determine various timing signals. These signals will be applied to two relay drivers which consist of ULN 2003. These relay drivers are level shifters and current amplifiers. The output of relay driver is applied to Red, Green and Orange LED at each junction. IC 24C61 is used for I2C interface.

The proposed Intelligent Traffic Light Controller can be more efficient than the conventional controller in respect of less waiting time, more distance travelled by average vehicles and efficient operation during emergency mode and GSM interface.

The signal controller at a single intersection that control its trafficbased on fuzzylogic and weighting coefficient [3] which gives the weights that the traffic flow at neighbour intersections imposes onthe signal timing at current intersection. The fuzzyrules of the signal controller and the weighting module are produced by the traffic information with the vehicles detectors. The average delay time of avehicle is used as aperformance index.The fuzzy controller shows the better performance with the simulation comparison of two signal controller at different traffic conditions which earns better realistic meaning and application value.

The multiagent system approach is used to develop distributed unsupervised traffic responsive signal control modelsproposed by by Dipti Shrinivasan [4], where each agent in the system is a local traffic signal controller for one intersection in the traffic network. The first multiagent system is developed using hybrid computational intelligent techniques.The second multiagent system is developed by integrating the simultaneous perturbation stochastic approximation theorem in fuzzy neural networks (NN).

The multiagent systems are implemented using Java and its multithreading technology. During the running of the simulation in PARAMICS Modeler, the multiple threads/processes in Java representing the agents are running concurrently. The model proposed shows the results which suggest that the hybrid NN-based multiagent system provides effective control of large scale traffic network even as the complexity of the simulation increases.

A developed adaptive neuro-fuzzy inference system can draw the membership functions and corresponding rules by its own from a given input data set [5], which makes the designing process easier and reliable compared to standard fuzzy logic controllers.

The Neuro-Fuzzy logic controller performs better than the fixed time controller due to its real time adaptability. The easiness of selecting the initial settings can be the advantage when real time signal controller is implemented.

A functional Fuzzy Traffic Controller (FTC) [6], which utilizes fuzzy logic algorithm. To develop the system, the behavior level of FTC algorithm has developed using VHDL under MAX+PLUS II CAD environment. The Finite State Machine (FSM) of the FTC has coded in VHDL programfor controlling the specific Traffic flow application. Later on, the FPGA Express (Synthesis tool) has used to get a fully gate level synthesis architecture for the whole Fuzzy based VLSI chip and then the optimization step has been applied for minimizing the VLSI chip's timing delay, clock speed, and area to get the correctness of FTC design.

The FTC chip can be also further interfaced withthe others control peripheral hardware modules to control amore complex traffic system. It overcomes the weakness of conventional traffic controllers with the capability of providing varying green cycle interval based on dynamic traffic load changes at every lane I a 4-way junction control.

An FPGA design implementation of a low cost 24-hour advancedtraffic light controller system is proposed by WM El-Medany and MR Hussain [7] as a term project of a VLSI design subject using VHDL. The system has been successfully tested and implemented in hardware using Xilinx Spartan 3 FPGA.

The division of traffic light system into three stages which includes the implementation of the state diagram, writing and simulating the VHDL code and programming the FPGA and development of the interface circuit.

A prototype is designed and implemented in Field Programmable Gate Arrays (FPGA)by N. Y. Hamisi, N. H. Mvungi and B. M. M. Mwinyiwiwa[8]. Using VHDL an algorithm has been developed for coordinating adjacent traffic signals along the arterial roads.

It is possible to use the developed algorithm to solve traffic congestion by increasing the number of junctions in the coordination system. Further more, having two or more junctions sharing the same controller may lead to reduction of controller cost which has been hampering efforts of traffic control for developing cities.

A hierarchical fuzzy logic traffic controller [9] is described for a real intersection of fourteen vehicle lanes and two pedestrian crossings controlled by signals with seven light phases. To evaluate the best fuzzy rule base, a fitness function is defined to characterize performance of the fuzzy controller The hierarchical fuzzy controller has seven inputs as queue lengths of the seven light phases, and oneoutput as green time of the selected phase. In the hierarchical fuzzy controller, there are six layers of fuzzy sub controllers with two inputs and one output. The sub-controllers in the first five layers have identical structure that has two inputs of queue lengths and one output of combined queue length employed as one input of next layer. The sub-controller in the last layer has two inputs, combined queue length obtained from the fifth layer and queue length of the selected phase, and one output as green time of the selected phase.

The developed fuzzy controller had better performance than the pre-cycle controller which is currently using in the intersection. It produces shorter average queue length than that of pre cycle controller, and shortens more than 38% of vehicle average waiting time of the pre-cycle controller.

A real-time adaptive signal control model decides optimal signal controlparameters commonly found in modern actuated controllers [10].The proposed control modelincorporates a traffic flow prediction process toestimate approach volumes based on the outflows fromupstream intersections, and to forecast turning movements at the target intersection according to the turning fractions in previous cycles.

Simulation results of proposed model shows performance of this model was best under traffic conditions of medium intensity, where the optimized parameters were expected to be valid.

The traffic light controlling system is proposed by Liu Yang and Chen Xian Feng in which the original relay wiring was replaced by the program, and the hardware and software resources of PLC [11] are used reasonably. The remote monitoring system of traffic lights at the crossroads was designed with configuration software MCGS, which monitored traffic lights in real-time and improved the reliability greatly.

The system simplified the communication between PLC and Host Computer by using industrial configuration software, which shortened the exploitation time greatly; especially, it is more fit for complex controlling system. The controlling of traffic lights is done by PLC and MCGS instead of the original relay control and increase life expectancy of this system.

The object segmentation, classify and tracking methodologiesare proposed to know well the real time measurements. According to the real time traffic measurement, the adaptive traffic signal control algorithm [12] is derived to settle the red–green switching of traffic lights.

Object segmentation is used to compute the difference between current image and background image to subtract object apart.The major goal of object classification is to determine the separated objects. These have several algorithm to handle problem of object tracking.

IV. PROPOSEDMETHOD

In case of traffic signal control, the resource in question is green time and the problem is made more complex by its temporal aspect and ever changing and stochastic nature of the demand. This means that the allocation of green time must be constantly reviewed as time passes & the situation changes in order to distribute it in the desired manner. An approach to this problem is to derive a value for each user, which reflects their claim on the limited resource & to use these values to determine the appropriate balance of distribution of the resource. This value for each user will be derived by using learning rule of neural network system.

The traffic conditions of the green phase are observed by the Extension Time Module. Green light extension time of the green phase is produced by this module according to the condition of observed traffic flows.Phase SequenceModule controls the phase sequence based on the vehicle's density and extension time of green light from Extension Time Module. The Output Module switches current phase to the appropriate next phase. Basically, this module switches the current phase to the next phase based on the outputs of Phase sequence Module.

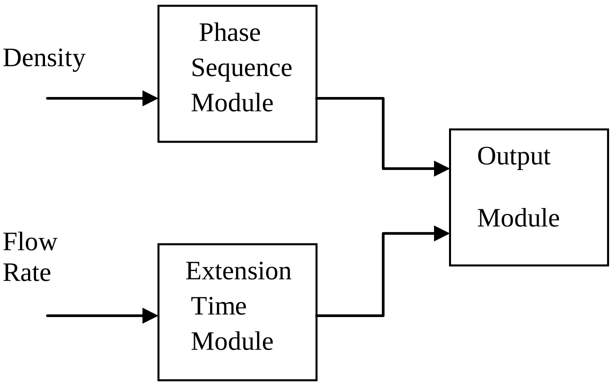

Fig. 2. Fuzzy Traffic Controller Design.

Fuzzy logic algorithm will be developed with available tools like MATLAB to achieve a smart and flexible knowledge based system in hardware design while achieving better efficiency in traffic control &minimizing traffic jam occurrences at interchange on road area.

The tested developed system, and the algorithm for traffic control will be then implementedin VHDL. Later on, by using synthesis tool like FPGA express, synthesis of the whole fuzzy based VLSI chip will be designed.

V. CONCLUSION

Designing the fuzzy neuro based controller implemented on FPGA will provide smart solution for Adaptive Traffic Control.Selection ofthe fuzzy logic rules and fuzzy inputs is very important to the results of the controller. Fuzzy logic is apowerfulandUser-friendly tool for dealing with the complex problems of traffic responsive signal control in a straight forward andintuitive way without losing any of the desired features of the problem solution.Adaptive neuro-fuzzy controller provides number of advantages starting from its implementation since it requires only a set of input values and modeled output values to decide the optimum membership functions and rules by it. In normal fuzzy logic controllers, the rules, and the membership functions should be provided after expert observations. It can overcome the weakness of conventional traffic controllers with the capability of providing varying green cycle interval based on dynamic traffic load changes at every lane in a 4-way junction control.

ACKNOWLEDGEMENT

Authors would like to thanks Prof. P. S. Bokare (Dean, BDCE, Sevagram (India)) and his project group for their support and providing necessary data useful in this project

REFFERENCES

[1] Lu Conglin, Wei Wu, IEEE Member, Tan Yuejin, *”Traffic Variable Estimation and Traffic Signal Control Based on Soft Computation”*, IEEE Intelligent Transportation Systems Conference, Washington, D. C., USA, October 3-6,2004.

[2] Shilpa S. Chavan (Walke), Dr. R. S. Deshpande, J. G. Rana, *“Design of Intelligent Traffic Light controller using Embedded System”*, International conference on Emerging Trends in Engg. & Tech., ICETET-09.

[3] Yan Li and Xiaoping FAN,*”Design of Signal Controllers for Urban Intersections Based on Fuzzy Logic and Weightings”* in proc. IEEE Conf. July 23-7,2003..

[4] Dipti Srinivasan, Min Chee Choy, and Ruey Long Cheu, *”Neural Networks for Real-Time Traffic Signal Control”*, *IEEE Transaction on Intelligent Transportation* Systems,Vol. 7, No. 3, September 2006.

[5] C. T. Wannige and D.U.J. Sonnadara, *“Traffic Signal Control Based on Adaptive Neuro-Fuzzy Inference”* 4th international conference on information and automation for sustainability, ICIAFS, 2008.

[6] Md. Shabiul Islam, Masuri Othman, Md. Anwarul Azim, M. S. Bhuyan, M. Saukat Jahan, H. R. Siddiquei, *“Design and Implementation of an Intelligent Fuzzy VLSI Chip for Traffic Control Application”*, IEEE region conference TENCON, 2006.

[7] WM El-Medany and MR Hussain,*“FPGA based advanced real traffic light controller system design”*,IEEE International Workshop on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, IDACS, 2007, Dortmund, Germany, 6-8 September 2007.

[8] N. Y. Hamisi, N. H. Mvungi, D. A. Mfinanga, B. M. M. Mwinyiwiwa, *“Prospects of Pre-timed Arterial Traffic Control Systems in City Roads of a typical Developing Country: A case Study of Dar es Salaam City”*, 2nd international conference on adaptive science and technology ICAST, December 2009,.

[9] Yi Hu, Andrew Chiou and Qinglong Han, *“Hierarchical Fuzzy Logic Control for Multiphase Traffic Intersection Using Evolutionary Algorithms”*, IEEE International Conference on Industrial Technology, ICIT, 2009.

[10] Xing Zheng and Lianyu Chu, *“Optimal Parameter Settings for Adaptive Traffic-Actuated Signal Control”*, 11th International IEEE Conference on International Transportation Systems, ITSC, 2008.

[11] Liu Yang and Chen Xian Feng, *“Design of Traffic Lights Controlling System Based on PLC andConfiguration Technology”*, International Conference on Multimedia Information Networking and security, MINES, 2009.

[12] Lawrence Y. Deng, Nick C. Tang, Dong-liang Lee, Chin Thin Wang and Ming Chih Lu, *“Vision Based Adaptive Traffic Signal Control System development”*, Proceedings 19th International Conference on Advanced Information Networking and Applications, AINA, Volume 2, 2005.

[13] Azura Che Soh/Lai Guan Rhung and Haslina Md. Sarkan, *“MATLAB Simulation of Fuzzy Traffic Controller for Multilane Isolated Intersection“*.

[14] P. Chakraborty and A. Das (2003), *“Principles of transportation engineering”*. Prentice Hall of India Private Limited New Delhi. EEE,

[15] Garber and Hoel ,*”Traffic and highway engineering”*.