AN APPLICATION OF ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM IN VEHICLE DELAY MODELING

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Abstract - An Adaptive Neuro-Fuzzy Inference System (ANFIS) approach is widely used to solve engineering problems. In this study, a model for estimating the average delay was developed by using ANFIS according to effective parameters, and the performance of the model was statistically evaluated. In this model, a hybrid method which is ANFIS was performed for training and test. The artificial network part of method used three input parameters representing cycle time of signalization (C), the green time (g) and the degree of saturation (x). The results of neuro-fuzzy network part of method were compared with the analytical models named HCM and Australian delay models. The performance of ANFIS was the better than other models and showed close agreement with simulated values.

Keywords – Vehicle Delay, Neuro-Fuzzy, Signalized Intersection

I. INTRODUCTION

Most traffic engineers and planners have focused on the design of optimum transportation plans which are cope with complex problems caused by urbanization as traffic junctions and delay etc. for years.One of the most important problems in transportation is delay and the accurately estimation of delay sinceitis a significant indicator to represent the performance of the signalized intersections and the level-of-service determination. The delay at an intersection generally occur because of waiting for other vehicles and pedestrians. It also depends on a lot of parameters such as road geometry, arriving type, traffic control system etc. The main aim of researchers is providing traffic flow without interrupt and minimizing the number of stops and delay at the each intersection. Therefore, a lot of basic and useful models have been proposed to calculate delay as accurately as possible. The most known of them in literature are Webster, Australian and Highway Capacity Manual (HCM) delay models, respectively. However, Webster model is not efficientfor over saturated flow since it gives high and meaningless values although it is known the oldest conventional approach. HCM is a time dependent model improved for years. It gives more reasonable values when compared to Webster model. Australian model depends on the coordinate transformation technique and is different from other analytical models with minimum degree saturation parameter x_0. Although they are still used for estimation of delay, there are some deficiencies in analytical models. Thus researchers try to overtake these deficiencies by using new approaches like intelligence techniques. Many researchers have tried to apply intelligent algorithms like Genetic Algorithm (GA), Particle Swarm Optimization (PSO) and Fuzzy-Logic (FL) etc. Muratet.al studied on applying Artificial Neural Network (ANN) to estimate vehicle delay. He used conventional delay formulas to determine uniform part of delay and ANN was used for the non-uniform part of delay. The results of model were compared with Webster, HCM and Australian models and observations. His study showed that ANN exposed encouraging results for over saturation and non-uniform conditions. In another study of Murat, Fuzzy Logic and Artificial Neural Network was compared for delay estimation. The results of models which were developed according to data obtained from ten signalized intersection were compared with each other and also HCM and Australian models. The delay estimations of FL and ANN were promising and also FL model results were the best fitted. Especially, it showed the %7 for under-saturated and %5 for over-saturated conditions in point of the average relative error. Atalay studied about comparison of vehicle delay models with artificial intelligence methods in his M.Sc dissertation and noticed that delay estimations of Neuro-Fuzzy method were quite compatible with observed delay values. Gokdaget aldeveloped delay model by using Adaptive neuro fuzzy inference system (ANFIS) and compared the results of model with other delay estimation models. They used three input variables which were simulation of time, the number of approaching vehicles in the green duration and the number of queuing vehicles in the red duration. The comparison of results showed that adaptive neuro fuzzy technique could be successfully applied to estimate vehicle delay. There are also numerous studies in which fuzzy logic and artificial neural network are employed to optimization of traffic signals and other traffic problems.

The purpose of this study is to examine whether ANFIS is effective and useful to accurately estimate the delay at a signalized intersection. It is applied by using data obtained from two-phase controlled intersection by using CORSIM simulation. The results of ANFIS are compared with conventional methods and the findings are shown in results and discussion section.

II. DETAILS EXPERIMENTAL

2.1. Adaptive Neuro-Fuzzy Inference System

ANFIS emerged as a practical application of artificial intelligent approaches for many fields. It was developed by Jang in the early 90's. Basically, it runs as a combination of Fuzzy Logic and Neural Network. In other words, it is a system, which incorporates Sugeno-type fuzzy into adaptive neuro network structure. ANFIS combines the advantages and benefits of fuzzy and neural network to reach optimum solution. To achieve this, the principles of Fuzzy Logic and Neural Network are used together in ANFIS. Rules, fuzzification, inference and neural network structure create the basic steps and structure of ANFIS. The schematic form of fuzzy system is shown in Fig.1.

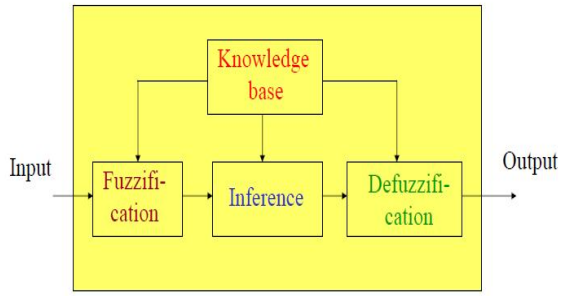

Fig.1. Fuzzy System

The output of neural network is determined according to fuzzy system or in other words, rules base. The neural network of fuzzy rule base is illustrated in Fig.2.

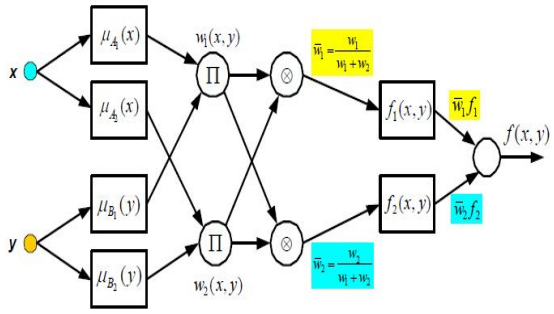

Fig.2. Neural Network Structure

2.2. Development of ANFIS model

In order to apply ANFIS model for estimation of delay, determination of properties of intersection is an important step. Thus, a four-leg intersection was created in CORSIM simulation program. The intersection is shown in Fig.3.

It was controlled by pre-timed controller and operated with two phases. Different traffic conditions could be created on simulation program while input variables of intersection such as cycle length, degree of saturation, volume and capacity etc.werevaried between ranges of parameters. Therefore, training and test data for development of ANFIS could be obtained by using CORSIM simulation program.

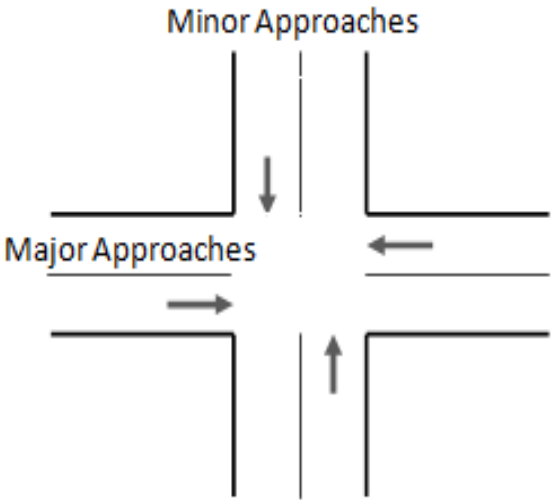

Fig.3. The Simulated Intersection

250 different traffic conditions were run on CORSIM simulations and obtained delay values with input variables for training and test. 200 data selected randomly were used for training and remaining 50 data were used for test of ANFIS. Three input variables which are cycle time of signalization (C), the green time (g) and the degree of saturation (x). The saturation flow varied between 1500 and 1800 vph. Degree of saturation for major approaches ranged from 0.7 to 1.4 and also is a constant value as 0.7 for minor approaches. Cycle length was 60, 90, 120 and 150 respectively. Green ratio ranged from 0.35 to 0.60. Therefore, displayed green times were set according with this green ratio.According to training data ANFIS structure were created and run to determine coefficients of network. The structure of ANFIS is illustrated in Fig.4.

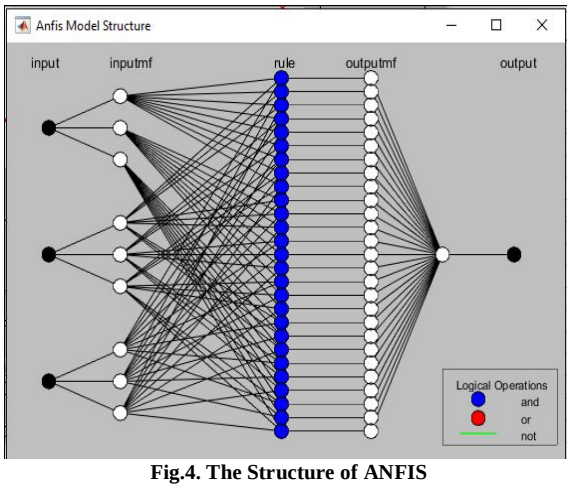

Fig.4. The Structure of ANFIS

27 rules base were generated by ANFIS according to input and output data. The rules base is showed in Fig.5

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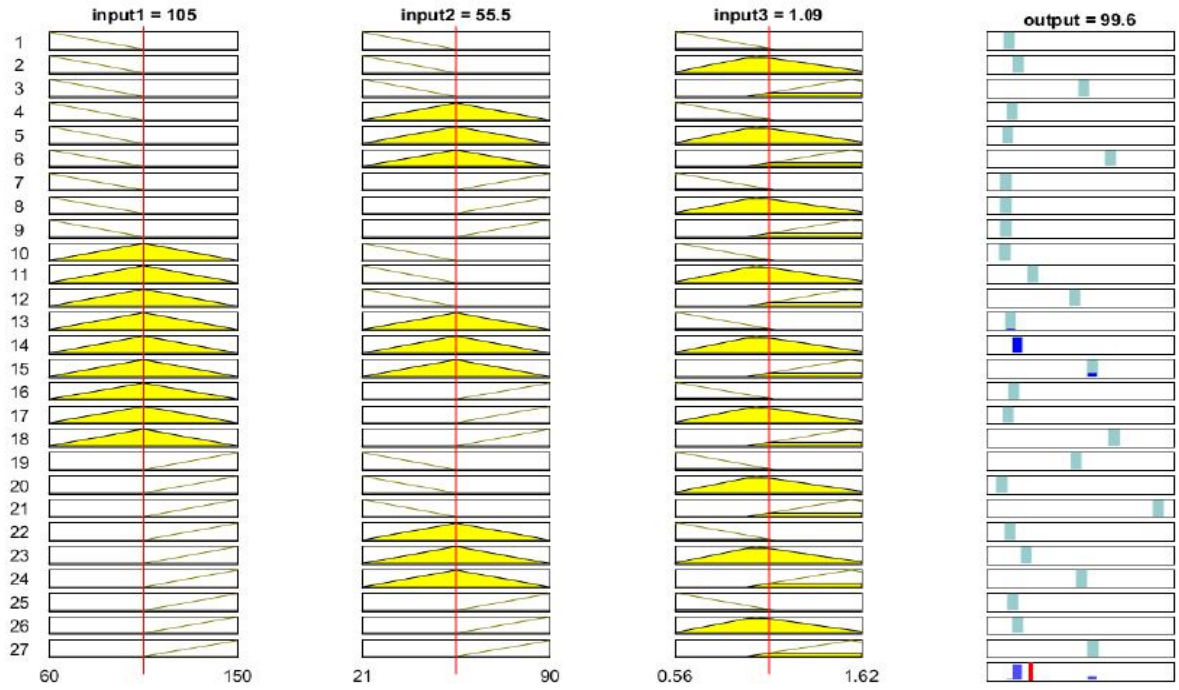
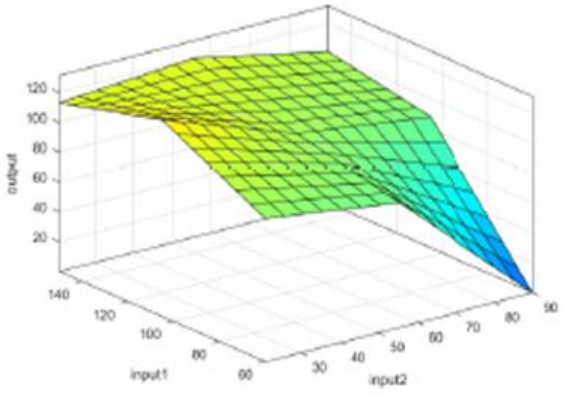
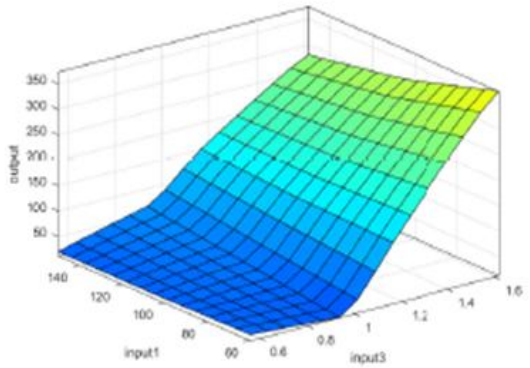


Fig.5. Rules Base

In Fig.4 and Fig.5, input 1 is cycle length, input 2 is green time and input 3 is degree of saturation respectively. The distributions of training data are shown in Fig.6.

After training of ANFIS, it was tested with test data and obtained delay values to compare results of it with other models.





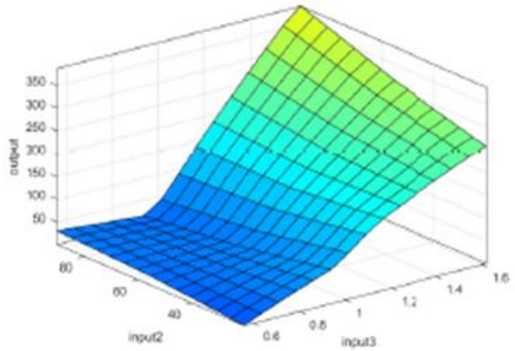


Fig.6. Distribution of Training Data

III. RESULTS AND DISCUSSION

The results of ANFIS and other analytical models named HCM and Australia delay models are compared using mean absolute percentage error (MAPE), root mean square error (RMSE) and R^2 defined by eqs. (1-3).

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(D_{Observed} - D_{estimated})^2} \quad (1)$$

$$\text{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{A_{Observed} - A_{estimated}}{A_{Observed}}\right| * 100 \quad (2)$$

$$R^2 = 1 - \left[\frac{\sum_{i=1}^{n}(A_{Observed} - A_{estimated})^2}{\sum_{i=1}^{n}(A_{Observed} - A_{mean})}\right] \quad (3)$$

The comparison results are illustrated in Table 1.

	HCM		AUSTRALIAN		ANFIS	
	Training	Test	Training	Test	Training	Test
RMSE	21,17	19,98	15,48	19,09	6,07	6,54
MAPE	29,83	20,21	16,53	11,90	4,66	3,28
R^2	96.60	95.64	97.9	96,53	99.52	99.37

Table 1: The Statistic of Training and Test Data for Comparison

Number	Cycle	Green Time	Degree of Saturation	Reference Delay	HCM	AUSTRALIAN	ANFIS
1	60	24	0,83	29,9	37,9	22,2	31,0
2	60	30	1,07	78,6	82,1	69,1	82,0
3	120	48	0,83	41,0	64,9	37,6	47,5
4	120	66	0,61	28,1	43,3	18,2	25,3
5	150	60	0,83	48,0	78,4	45,3	50,0
6	150	82,5	0,61	30,7	53,4	22,8	28,5
7	60	24	1,11	112,4	98,3	89,7	105,4
8	90	31,5	1,27	181,2	178,6	171,7	179,6
9	90	45	1,07	90,2	97,1	76,6	91,1
10	120	42	1,27	191,5	193,6	182,9	192,5
11	120	66	0,81	34,4	55,7	24,2	34,2
12	150	60	1,11	128,0	143,3	117,7	127,1
13	60	27	1,23	163,7	146,2	139,6	155,7
14	90	40,5	1,23	173,0	161,2	149,6	165,9
15	120	60	1,11	117,6	125,3	99,8	115,5
16	150	67,5	1,23	173,9	191,2	169,5	167,8
17	60	30	1,33	215,9	187,6	183,2	198,8
18	120	54	1,48	276,6	283,3	281,3	260,3
19	150	82,5	1,21	170,8	179,9	151,9	158,2
20	120	72	1,30	206,7	200,3	185,5	200,8

Table 2: The Delay Values of Test Data

As seen from Table 1, when the performance of existing and proposed model are compared to each other, test R^2 values obtained by means of test data are 95.64, 96.53, 99.37 for HCM, Australian and ANFIS, respectively. MAPE and RMSE values of ANFIS is better than other models and delay values of ANFIS is closer to references delay values. Some samples of test data are shown in Table 2.As understood from Table 2, ANFIS model is able to obtain more accurate delay values for under-saturated and over saturated conditions. Thus, ANFIS model may be used as an alternative model to estimate delay at a signalized intersection.

CONCLUSIONS

In this study, it was tried to propose a delay model by different approach named ANFIS. Proposed model was developed with three parameters which arecycle time of signalization (C), the green time (g) and the degree of saturation (x). That the results obtained were compared with error measurements such as RMSE, MAPE and the R^2 determines model's feasibility. The ANFIS model could better predict vehicle delay in terms of relative errors between referenced and estimated values. Additionally, a comparative study was performed between proposed and existing models. Results of statically comparison showed that ANFIS had the best performances in terms of measurements criteria.

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