Artificial Neural Network Model of Traffic Operations at Signalized Junction in Johor Bahru, Malaysia

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Abstract: - Driving behavior models are an important component of microscopic traffic simulation tools. Artificial Neural Networks (ANN) are systems that try to make use of some of the known or expected organizing principles of the human brain. Today neural networks can be trained to solve problems that are difficult for conventional computers or human beings. In this research four signalized junction in Johor Bahru have been considered and simulation of driver’s behavior in terms of delay and queue length have been implemented. The neural network approach seems to be more natural and reasonable than the conventional method. The neural network is also more effective and efficient in determining appropriate traffic terms of study.

Key-Words: - Artificial Neural Network; Delay; Flow; Queue Length; Simulation; Traffic Signal Setting

1 Introduction
Traffic congestion is a major problem in urban areas. The importance of better management of the road network to efficiently utilize existing capacity is increasing. In recent years, a large array of traffic management schemes have been proposed and implemented. Methods and algorithms proposed for traffic management need to be calibrated and tested. In most cases, only limited, if any, field tests are feasible because of prohibitively high costs and lack of public acceptance [1].

Furthermore, the usefulness of such field studies is deterred by the inability to fully control the conditions under which they are performed.

One of the most important issues in traffic regulation and control is how drivers behave when they are on the road and how they react to specific prescriptive signals. This behavior has a great impact on both traffic safety and on flow fluidity, and it may lead to a capacity reduction of the intersection [2].

Driving behavior models describe drivers’ decisions with respect to their vehicle movement under different traffic conditions.

Driving behavior models are an important component of microscopic traffic simulation tools. They are also important to several other fields of transportation science and engineering such as safety studies and capacity analysis, in which aggregate traffic flow characteristics may be deduced from the behaviors of individual drivers.

Analysis of driver behavior is a very complex problem and it is now under study by many researchers. Computer simulation, Neural Networks, also known as connectionist models is one of these methods.

Artificial Intelligence (AI) techniques are suitable for application to specific transportation problems that are amenable to treatment on the basis of rules and relationships [3].

Research on artificial neural networks started around 1940 and was inspired by interest in the neurophysiological fundamentals of the human brain. It was known that the brain consists of interconnected nerve cells –the neurons- that influence each other by electrical signals. A neuron conducts its signals via its axon that projects from its cell body (soma), and it receives signals from other neurons over the connections between their axons and its dendrites. These joints are called synapses, and the two connecting cells are separated by a tiny gap about 200nm wide [4].

Artificial Neural Networks (ANN) are systems that try to make use of some of the known or expected organizing principles of the human brain. Neurons communicate with each other via weighted connections – the synaptic weights. The modelling of single neurons and the so-called “learning rules” for modifying synaptic weights were the initial research topics [5].

Over the past few years, ANN has been applied successfully into many engineering as well as non-engineering applications.

Research in neural networks stems from the idea that simulating, on a computer, the way that the brain processes information may prove useful in understanding thought processes [6].
2 Research Contribution
Most urban areas have used traffic signal control systems along major arterial streets and highways for a number of years. These systems typically provide time-phased signal control to smooth traffic flow [7].

Today neural networks can be trained to solve problems that are difficult for conventional computers or human beings. Throughout the toolbox emphasis is placed on neural network paradigms that build up to or are themselves used in engineering, financial, and other practical applications.

The information processing principles of biological neural networks have been applied to building a computer system for solving difficult problems whose solutions normally require human intelligence [8].

3 Case Study Description
In this research four signalized junctions named “JLN TUN ABDUL RAZAK – JLN KEBUN TEH LAMA; JLN WONG AH FOK – JLN STATION; JLN TJpanion PUTERI – JLN STULANG; JLN BANDAR – JLN ABU BAKAR” with different geometric data, traffic signal setting and traffic flow in Johor Bahru, Malaysia have been considered.

Data was collected at all sites in June 2009 in the evening peak hours 5:00 p.m until 7:00 p.m.

Artificial neural network’ or ANN is the term used to describe a computer model assumption of the biological brain. It consists of a set of interconnected simple processing units which combine to output a signal to solve a certain problem based on the input signals it received.

The interconnected simple processing units have adjustable gains that are slowly adjusted through iterations influenced by the input-output patterns given to the ANN.

An ANN is an information-processing system that has certain performance characteristics in common with biological neural networks.

The development of ANNs has been largely inspired by the biological brain, and thus it is important for researchers in the field of ANNs to understand some aspects of the biological brain.

Commonly neural networks are adjusted, or trained, so that a particular input leads to a specific target output. Such a situation is shown in Fig. 2. There, the network will be adjusted, based on a comparison of the output and the target, until the network output matches the target. Typically many such input/target pairs are needed to train a network.

![Figure 2. Artificial Neural Network block diagram](image)

An ANN computer model in this study is a system that handles two inputs, which are traffic signal setting and traffic flow at each intersection, processes them and its output are delay and queue length separately. According to this fact that geometric data at each intersection are the same, they have not been considered as a variable input in the computer modeling. The outputs are achieved to solve a task that the model has been trained to solve.

![Figure 3. Neural Network Structure](image)
The feed-forward Backpropagation (B.P) is the network type and Least Mean Square (LMS) as a training method, have been implemented in this study. The addition of a hidden layer of neurons in the network allows the solution of nonlinear problems, and many practical applications.

Activation functions play an important role in many ANNs. In new neural network paradigms, the activation functions are more sophisticatedly used. One of the most popular activation functions used is the logistic activation function or more popularly referred to as the tan-sigmoid function. The mathematical expression of this sigmoid function which is used in this study is as follows:

\[ f(\text{net}_j) = \tanh(\text{net}_j) = \frac{2}{1+e^{-2\text{net}_j}} - 1 \]  

(1)

Because this function is differentiable, it enables the B.P. algorithm to adapt the lower layers of weights in a multilayer neural network.

If the last layer of a multilayer network has tan-sigmoid neurons, then the outputs of the network are limited to a small range. Hence linear output neurons are used in the network of this study for outputs can take on any value. Training patterns are obtained from the samples of the types of traffic signal settings and traffic flows to be given to the multilayer neural network.

The error is calculated at every iteration and is backpropagated through the layers of the ANN to adapt the weights. The weights are adapted such that the error is minimized. Once the error has reached a justified minimum value, the training is stopped, and the neural network is reconfigured in the recall mode to solve the task.

Fig. 4 and Fig. 5 show the actual/ANN modeling results at four signalized junction for delay and queue length respectively. The objective is to minimize the error between actual and model output. A comparison of the actual delay and ANN output results shows that the model has been implemented appropriately.

Fig. 5 shows a comparison of queue length at four signalized junctions. It should be noted that all flows have been sorted from lowest to highest values at all four junctions.

Since junction 1 that is the connection of JLN ABDUL RAZAK – JLN KEBUN TEH LAMA and located along the main connecting roadway of Skudai – Johor Bahru, and flow rates at this location are more than other junctions, the graphical simulation of delay and queue length have been shown only for this junction in Fig. 6 and Fig. 7.

To simulate the response of the neural network model for the entire range of inputs that the system is configured to work for, the Fig. 6 and Fig. 7 are shown for delay and queue length respectively. They help view the input-output surface of the system.

Fig. 7 indicates that with increasing the value of traffic signal setting by green period, the number of vehicles in queue come down which sounds very rational.
5 Artificial Neural Network Model Validation

The performance of trained ANN model can be evaluated by computing the error percentage of each output. The more training patterns leads to better adaption of the system to actual data.

Table 1 shows the percentage error of actual values and model outputs for each delay and queue length at each junction separately. The time interval is 15 minutes.

Fig. 8 and Fig. 9 represent the calibration of delay and queue length at each junction.

From Table 1 and Fig. 8 and Fig. 9 the acceptable ranges of error for each output at junctions is visible. But it has not been achieved an appropriate value for queue length simulation at junction 3.

As we have mentioned before more iterations leads to better results that could be considered and implemented for case without high accuracy in result.

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>5:00-5:15</th>
<th>5:15-5:30</th>
<th>5:30-5:45</th>
<th>5:45-6:00</th>
<th>6:00-6:15</th>
<th>6:15-6:30</th>
<th>6:30-6:45</th>
<th>6:45-7:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction 1: JLN TUN ABDUL RAZAK – JLN KEBUN THE LAMA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay Error (%)</td>
<td>-5.2549</td>
<td>1.2511</td>
<td>5.8841</td>
<td>-0.3093</td>
<td>-2.9223</td>
<td>-5.0205</td>
<td>2.9919</td>
<td>-0.3939</td>
</tr>
<tr>
<td>Queue Length Error (%)</td>
<td>8.4325</td>
<td>-24.9344</td>
<td>9.3975</td>
<td>-2.3057</td>
<td>-0.2143</td>
<td>-0.5856</td>
<td>0.8266</td>
<td>1.8948</td>
</tr>
</tbody>
</table>

Junction 2: JLN WONG AH FOK – JLN STATION

| Delay Error (%)     | -1.2241   | -7.9856   | 0.9720    | 0.0935    | 0.4504    | -2.2754   | 3.1037    | 1.9102    |
| Queue Length Error (%) | 8.0436   | -0.4790   | -12.6500  | -7.3739   | 6.6977    | -0.3764   | 8.9456    | -5.1158   |

Junction 3 : JLN TANJUNG PUTERI – JLN STULANG

| Delay Error (%)     | 1.2089    | 0.2413    | -1.2044   | -0.9482   | -0.1240   | 0.9621    | -4.6150   | 4.5752    |

Junction 4: JLN BANDAR – JLN ABU BAKAR

| Delay Error (%)     | 0.1899    | 2.0185    | -2.1273   | -0.0797   | -8.9370   | 4.3059    | -1.5617   | 5.5715    |
| Queue Length Error (%) | -0.0664  | -6.5439   | 4.1011    | 1.7839    | -3.2303   | 1.2883    | -0.7131   | 1.3110    |

Table 1. Summary of error percentage of delay and queue length between actual and ANN model outputs at each signalized junction.
6 Conclusion
In the case studies, a simulation of driver's behavior at signalized junctions is implemented. The feasibility of the neural network approach has been identified. The study treats the driver's decision mechanism as a neural network process.

ANNs are indeed computer/mathematical models of some crude assumptions of the biological brain. They are made up of many interconnections and nodes (neurons). They need to be trained before they can be used. Thus, they need enough/correct training patterns to be trained to perform the correct task. They can perform computational tasks such as prediction, decision making, pattern matching, etc. after training. They can be applied to many engineering applications as well as other areas.

The neural network approach seems to be more natural and reasonable than the conventional method. The neural network is also more effective and efficient in determining appropriate traffic terms of study.

Acknowledgment
The authors are thankful to MOSTI through RMC of Universiti Teknologi Malaysia (UTM) and UTM for providing financial aid to carry out this research.

References: