Traffic Estimation And Real Time Prediction Using Adhoc Networks

Fatima Batool
Centre For Advanced Studies in Engineering
fatima@carepvtltd.com

Shoab A Khan
Centre for Advanced Studies in Engineering
shoab@carepvtltd.com

Abstract

This paper presents the process of developing a multilayer feed forward neural network combined with a backpropagation algorithm for forecasting travel time and traffic congestion. Prediction of travel time and traffic congestion based on past and current traffic information is not straightforward due to among others, the high complexity and ill predictability of traffic process, incorrect observations and different data sources. However it appears that neural networks can be exhaustively used to solve these problems. The system is designed on top of a mesh based communication infrastructure for the mobile nodes to communicate. Communication network comprises of multiple networks i.e. VHF, UHF. The mesh based communication approach enables easy deployment of the system in real world. OLSR routing protocol is used for establishing an ad hoc network for peer-to-peer communication.

1. Introduction

Traffic estimation and travel time prediction in a road traffic network are critical for many intelligent transportation systems and traffic management systems. The common objective of these systems is to provide information necessary to help individual drivers identify optimal routes based on real time information and researches have shown that it has a positive effect on traffic load in congested areas. On the other hand it provides information to the passengers about the bus arrival with high accuracy; sitting at the base station user can view the picture of the whole traffic and congestion level of desired area. Paper presents the best-optimized solution for traffic estimation of whole city/country based on the real time data coming from the GPS installed at vehicles. System finds it application in many areas e.g. due to traffic congestion or unpredictable schedule passengers have to wait a long wasting time and energy on the stops. Completely revamping the bus system would take numerous years and wouldn’t improve the life of current. By studying many paradigms closely we have developed a plan that optimizes the proper approaches for this system. In order to best serve the community, our plan calls for the use of a GPS system for locating the device. This locating technology combines with the field of Artificial intelligence and makes use of state of the art artificial neural network model for traffic prediction. Paper gives an overview of how the neural network model is trained. In addition to weather conditions, time and temporal information (season, day of the week, hour of the day and special occasions, inflow/outflow links our method takes advantage of the speed coming from the GPS installed at each vehicle and using the neural network model it predicts traffic congestion level and from that
congestion level gives the estimation of travel
time which can be beneficial for the drivers to
take smart decisions and at the same time can
provide the passengers with the arrival time of
vehicle/bus on the next stop thus helping them in
alleviating from the burden of waiting and
improve the overall efficiency and reputation of
the system. In order to route the data from
multiple nodes to central server an ad hoc
network with a central backbone of gateway
nodes is established. GPS data from multiple
vehicles is collected at the base station where
neural network model runs and the estimated
travel time and arrival time is passed to vehicles
and by combining the congestion level of small
adhoc networks traffic congestion of whole city
is mapped on GIS. Communication network is
established using multiple networks to provide
redundancy and ensure reliability. VHF network
is used for the purpose.

This paper is organized as follows; Section 2
explains the proposed design, expands on the
problem statement by listing the limitations of
existing manual procedures for the task. In this
section we will describe the model used for
travel time prediction, focus on the inputs for
neural network model and how the data was
trained. Section 3 explains the proposed network,
the underlying protocols being used, portray how
the real time data is routed from the network and
the training data is used to predict travel time
estimation using neural networks. Section 4
describes the results and lists the conclusions and
additional features that can be added to improve
the system.

2. Neural network Training

This section explains in detail how the neural
network model is trained, what were the
algorithms that were used for this purpose, what
are the possible inputs for the neural network
model and the sources for these inputs.

Commercial GPS receivers installed at the
vehicles transmit latitude, longitude, time and
speed to the central station where information is
analyzed and mapped on GIS. GPS data are
point data available only at given intervals of
time intervals. The knowledge of the time that a
vehicle is say at point A on map is necessary but
not sufficient to determine when the vehicle will
reach point B. In addition to the bus location
data, information essential to estimate when the
bus would arrive at point B also requires other
parameters and some intelligence. Similarly
sitting at the base station one can only view his
own fleet having GPS receivers installed on
them. In order to best utilize this data we have
developed optimization-based vehicle routing
and traffic estimation system using computationally practical solution procedures for
finding optimal, or near-optimal, solutions to
portray a complete picture of the traffic of whole
city/country taking into account vehicle speed,
location and arrival time on target nodes using an
ad hoc network with a central backbone of
gateway nodes. Research has shown that people
have explored several techniques for forecasting
which can be classified as historical database
algorithms, time series and Kalman filtering
models simulation models and both in research
and in practical applications neural network
models have been proven to be the powerful
method for forecasting. Artificial neural network
models are mathematical models, which have the
ability to take into account spatial and temporal
travel time information simultaneously. After
selecting the model research was conducted on
the relevant factors that can influence travel
time. On a conceptual level route travel time is a
quantity that is a function of among other things
average speeds and congestions level along that
route. Relevant factors influencing the traffic
congestion level and speed are outlined as:
- Weather Conditions
- Time of Day, Day of the week
- Holidays, Events, Special Occasions
- Inflow/outflow Links.
- Maximum Speed Regulation Laws.

The influence of the factors on travel time
prediction was investigated in terms of
theoretical as well as empirical basis e.g. Study
revealed that heavy precipitation leads to
reduction in road capacity to 10% to 15%.
Similarly Figure 1 explains how the time of day
effect the travel time.

![Time vs travel Time](image)

**Time vs travel Time**

- Time 01 Day
- Series 1
Next step is to explore the sources of the input data and then train the neural network model with these inputs. As explained earlier GPS provides with speed and time in addition to the location. GIS is a powerful tool often used to enhance data analysis for a wide variety of applications depending upon how much information of layers you keep. We have developed a GIS application that represents all the possible layers required for prediction e.g. important sign boards, Max speed boards, roads etc.

These inputs were applied to neural network and using backpropagation algorithm, expected output is calculated. Equations used for backpropagation training are summarized as follows:

$$
\Delta w_{ji} = \eta \delta_{pj} O_{pi}
$$

where $\eta$ refers to the learning rate; $\delta_{pj}$ refers to the error signal at neuron $j$ in layer $L_i$; and $O_{pi}$ refers to the output of neuron $i$ in layer $L - 1$. With the error signal, $\delta_{pj}$, given by:

$$
\delta_{pj} = (t_{pj} - O_{pj})O_{pj}(1 - O_{pj}) \text{ for output neurons}
$$

$$
\delta_{pj} = O_{pj}(1 - O_{pj})\sum_k \delta_{pk} w_{kj} \text{ for hidden neurons}
$$

where $O_{pj}$ refers to layer $L_i$; $O_{pi}$ refers to layer $L - 1$; and $\delta_{pk}$ refers to layer $L + 1$. The network shown in the Figure 3 has three fields of neurons: one for input neurons, two for hidden processing elements, and one for the output neurons. There are connections from every neuron in field A to every one in field B, and, in turn, from every neuron in field B to every neuron in field C. Thus, there are two sets of weights, those figuring in the activations of hidden layer neurons, and those that help determine the output neuron activations.

In training, all of these weights were adjusted by considering what can be called a cost function in terms of the error in the computed output pattern and the desired output pattern. The feed forward Backpropagation network undergoes supervised training, with a finite number of pattern pairs consisting of an input pattern and a desired or target output pattern. An input pattern was presented at the input layer. The neurons passed the pattern activations to the next layer neurons, which were in a hidden layer. The outputs of the hidden layer neurons were obtained by using a bias, and also a threshold function with the activations determined by the weights and the inputs. These hidden layer outputs became inputs to the output neurons, which processed the inputs using an optional bias and a threshold function. The final output of the network was determined by the activations from the output layer. The computed pattern and the input pattern were compared, a function of this error for each component of the pattern was determined, and adjustment to weights of connections between the hidden layer and the output layer was computed. A similar computation, still based on the error in the output, was made for the
connection weights between the input and hidden layers. The procedure was repeated with each pattern pair assigned for training the network. The process was then repeated many times until the error was within a prescribed tolerance and convergence behavior was observed as shown in Figure 4.

Neural network model makes use of both real time data and historical data to predict the travel time. This requires a network capable of routing GPS data to the central server. Communication network is established using VHF network. The strategy used for the VHF network consists of several VHF Gateways laid in the form of mesh throughout the area of interest connected with each other by landlines. These fixed VHF transceivers serves as a strong network backbone and act as a gateway/router. Loop free transmission is achieved using Spanning tree algorithm for the VHF gateways. Slightly tailored version of OLSR (Optimized Link State Routing) [1] is used to route the packet from a vehicle to the nearest VHF receiver. These results in several smaller ad hoc networks connected to at least on gateway of the VHF mesh network. OLSR being a proactive routing protocol for ad hoc networks requires a large amount of memory, calculations and flow of control messages through out the network to couple up with a rapidly changing network configuration. Therefore to create multiple smaller size ad hoc networks provides a more feasible solution to the addressed problem. The nature of the problem makes it ideal for an ad hoc network that needs short-range wireless modems installed at each node. This makes the solution cost effective, robust and practically feasible. However the problem of long-range communication is solved by the strong backbone of VHF gateways that allows us to communicate at long distances. For the ad hoc network proactive routing algorithms like OLSR and location aware routing algorithms like DREAM (Distance Routing Effect Algorithm for Mobility) makes equally good candidates for selection. However OLSR is selected as it doesn’t use the location information and can work fine even if the location acquisition system fails. OLSR exploits the redundancy in conventional link state routing. The concept of active packet forwarding nodes namely MPRs (Multi point relays) in a network running on OLSR reduces the packet flow in the network manifold. Moreover the proactive nature of the algorithm maintains a path to the destination at all instances in time. All the packets are routed to the main monitoring center that maintains all the statistics. GPS data comprising of speed and location is collected at the base station where our
Neural network model and GIS application runs. Inputs from both the sources i.e. GPS and GIS are feed into the neural network, which predict the traffic congestion level and the time required to reach the next destination. Estimated travel time can be passed to drivers, and in order to make the predicted arrival time information to the passengers display boards need to be installed. These displays get their information directly from the monitoring devices chosen for the system. When the riders have this information they become less stressed.

![Figure 5 Mesh Based Adhoc Network](image)

### 4. Results

After establishment of this network we have tested and benchmarked the network by developing a platform for fleet management where real time data from multiple fleets were collected and feed into the neural network which predicted the congestion level and arrival time by making use of the weights files that were generated during the training process. Results obtained were quite satisfactory. Figure 6 shows the expected congestion level while the actual prediction made by the model is plotted in Figure 7 for speed only.

![Figure 6 Output of Neural Network model](image)

![Figure 7 Actual and Predicted Congestion level](image)

There are yet some other exciting features that can be added in future. Provided the travel time information on the Internet, this will be great for students and faculty in offices who need to catch a bus. The other aspect of the system will be the additional displays on the stops which will make record of important shops and displaying those shops so that instead of waiting on stop you can have a cup of coffee. Displays can also be used for displaying news and running commercials.

### References


