Estimate Traffic with Combined Neural Network Approach

Edmond Chin-Ping Chang, Ph.D., P.E
Oak Ridge National Laboratory,
Oak Ridge, TN 37831-6207 USA E-mail: ecc2005@ornl.gov

Abstract - Many operating agencies are currently developing computerized freeway traffic management systems to support traffic operations as part of the Intelligent Transportation System (ITS) user service improvements. This study illustrates the importance of using simplified data analysis and presents a promising approach for improving demand prediction and traffic data modeling to support pro-active traffic control. This study found that the proposed approach of combining advanced neural networks and conventional error correction is promising for improved ITS applications.

Keywords: Intelligent Transportation Systems, Numerical Data Analysis, Traffic Prediction, Neural Networks.

1. Introduction

Many operating agencies are currently developing Freeway Traffic Management Systems (FTMSs) and the Intelligent Transportation System (ITS) to improve traffic control and operations along major urban freeway corridors. Often, operating agencies must design and implement various traffic response plans to provide needed system control strategies during normal, congested, incident, dangerous conditions, and pre-scheduled special events. To improve the implementation of real-time control strategies, control centers must be able to identify traffic demand pattern changes quickly based on massive amount of real-time, up-to-date traffic measures [1][2][3]. Therefore, effective decision-making supports are essential to these Traffic Management Centers (TMC) in order to integrate traffic operations, environmental measures, roadway control, and motorist information in the shortest time possible. It is especially important since many traffic management centers have been significantly expanded operations as part of the Intelligent Transportation System (ITS) user service improvements.

Significant developments have been made in applying computer models and numerical analysis techniques for evaluating traffic control alternatives and assisting the traffic system improvement analyses. With proper data calibration, either macroscopic or microscopic traffic models can be used to assist traffic operational analysis of traffic control strategies. However, the macroscopic models cannot accurately represent system behavior, while microscopic models are often too computationally intensive and unsuitable for real-time applications due to the design complexity. With the increasing applications of ITS systems, developing pro-active control strategies, and designing accurate demand prediction capabilities quickly using real-time traffic data available are essential [3][4].

Simplified traffic prediction analyses not only are essential for detecting non-recurring incidents, but are also important for identifying daily traffic patterns for practical, day-to-day operations. New traffic control system software designs can take advantage of the increasing real-time surveillance capabilities currently being installed in most freeway traffic management systems. This paper examines a practical study approach of combining both advanced neural networks and conventional error correction techniques to improve freeway traffic operational behavior analysis based directly on real-world traffic measures. In this way, this system can minimize traffic demand calibration for improved system operations.

2. STUDY BACKGROUND

The traffic control industry is moving rapidly toward real-time, proactive traffic control. It is essential to develop a practical system software design that allows efficient traffic demand prediction algorithms that can be performed automatically in real-time. This section summarizes the theoretical background, the neural network formulation, and the general neural network training procedure being used. Several numerical analysis methods, often used for the time-series data prediction, are compared.

The automatic data reduction and analysis process should allow the user to identify traffic demand...
and flow pattern changes more accurately. This study will enhance traffic demand prediction functions, and examine the effectiveness of its usage in conjunction with an on-line error correction algorithm to provide improved adaptability for traffic demand prediction. Neural networks have become an emerging research area in engineering field. A neural network basically emulates the biological reasoning functions of a human brain in order to interpret and solve complicated, numerical, and pattern recognition problems. Neural network approach can especially organize massive information for improved pattern recognition. A neural network consists of three layers; each layer may contain several neurons with each neuron acts as function, such as using a sigmoid function [5].

2.1 Neural Network

A neural network training procedure includes data collection, paradigm selection, structure selection, parameter setup, and result testing. However, a large amount of relevant data should be collected in order to provide successful results. Most data are used in training, while reserving other data for later testing. Several paradigms are currently available, such as self-organizing map, backpropagation, adaptive resonance theory, and recurrent backpropagation [5]. Different paradigms have characteristics and strengths to represent specific numerical functions. For instance, self-organizing map is unsupervised and feedforward; backpropagation is supervised and feedforward; adaptive resonance theory is unsupervised and feedback; recurrent backpropagation is supervised and feedback. After training, the performance (prediction) of neural nets must be tested. Once the prediction results are satisfactory, the neural nets can then be used.

2.2 Numerical Analysis

Various numerical analysis methods have been used to analyze time series behaviors and perform prediction, including Exponential smoothing techniques, Kalman Filter, Box-Jenkins technique. These methods are limited to specific problems.

3. System Design

This study is to examine the effectiveness of the proposed neural network approach and the enhancements for the potential use of real-time traffic observations to improve traffic modeling based on real-world traffic observations. Several subtasks are designed to evaluate the promising approach as illustrated in Figure 1 “Overall Design Approach.”

The system development process includes the problem analysis, neural network training, error correction, system evaluation, and application subtasks.

To assist the real-time traffic demand prediction, a neural network and an error correction algorithm were devised to provide a needed heuristic adjustments to the neural network model. The design considerations for an accurate pattern identification and allows enhancements for future automatic heuristic adjustments after the neural network have been developed, that can take advantages of numerical analysis techniques, are very important. To support this system design, this study uses the neural network training, error correction, and practical system application.

3.1 Neural Network Training

After the freeway traffic volume model is established, the pre-processed real-world freeway data are used to train neural nets. After proper network training, different neural net configurations are tested against the traffic data for appropriateness. Only successfully trained neural nets can be accepted.

3.2 Error Correction Technique

R1, a heuristic, historical, numerical based error correction algorithm, developed at Texas Transportation Institute (TTI) in 1960s, can be used to improve the on-line data prediction results by smoothing the results obtained from the neural nets as developed from the historical data records collected previously.

As illustrated in Figure 2 “Error Correction Algorithm,” R1 algorithm is a heuristic-based error correction algorithm, based on the exponential smoothing concept, to improve the effectiveness of neural network traffic prediction and thereby increase its effectiveness of the proactive traffic control.

The R1 algorithm then adjusts the next prediction depending on the direction of error measured at the current observation. If the error is greater than 0, which represents an insufficient correction, the next prediction should be decreased by a certain amount. If the error is less than 0, which represents an
over-correction from the prediction, the next prediction correction amount should be increased. The amount of error correction, as developed, allows the users to adjust the sensitivity of the neural network as developed through the heuristic observation, according to the subjective measures, such as the quality of the detector data. Therefore, proper correction amount can be obtained to smooth sharp prediction. In this way, errors can be minimized to predict closer to real-world traffic observations.

3.3 Practical System Application

After satisfactory performance evaluation, the neural nets and error correction algorithms are used for prediction. Since most freeway traffic control software is implemented in conventional environment, the data interfaces between the neural nets and error correction algorithms are further designed and the program was implemented the conventional C program languages.

After training, the trained neural nets can be embedded into or integrated with these traffic control applications. In this way, the user can better interact with freeway systems and monitor system traffic responses for an entire freeway. Appropriate pro-active traffic control strategies, according to the users’ confidence on the quality of the detector data and the level of control strategies, can then be applied to improve freeway traffic control prediction capabilities based on real-time traffic measures.

4. Study Results

Several numerical analyses and neural net modeling experiments were performed at TTI, using I-35W freeway traffic data collected from the Fort Worth District of the Texas Department of Transportation (TxDOT).

Based on the real-time traffic volume data were obtained in the 5-minute intervals from each freeway lane and ramp, different types of data analyses were performed to examine the operational sensitivity of various data smoothing techniques, characteristics of different traffic lanes, weekday/weekend variations, and effects of seasonal variations.

As shown in Figure 3 “Traffic Flow, I-35W Study Site,” a section of the interstate freeway I-35W passes through Hattie, Rosedale, Allen, Morningside, Barry, Ripy, and Seminary streets in Fort Worth, Texas. In all cases, the system was able to predict reasonably well at these locations during April 27 and 28, 1993.

5. Conclusions and Recommendations

Many operating agencies are currently developing computerized systems to improve computerized traffic management as part of the Intelligent Transportation System (ITS) user service improvements. To facilitate the prediction, diagnosis, and control decisions from the uncertain information available in most ITS systems, it is important to develop automated decision-making support techniques that can provide improved automatic traffic prediction and support proactive traffic control through simplified but practical data analysis techniques. In addition, self-learning, automatic adjustment, and human interface functions, being designed, can later be integrated into the ITS system data warehouse to provide automatic system tuning and calibration based on the real-time traffic measures as these systems expand in the future.

This study found that the proposed combined approach of neural networks and error correction algorithm is promising for traffic prediction and proactive control. Once the neural net models are successfully trained, the system can quickly pick up demand trends for pro-active traffic demand management. The error correction algorithm can further smooth out errors that may be caused by sharp neural net prediction. The error correction algorithm can also provide human interactions after the neural network has been developed; therefore, can improve traffic system prediction.

Further study is also recommended to use traffic data from other more heavily loaded freeways for additional analysis using this technique. In addition, further traffic estimation algorithm evaluation is recommended to examine the prediction capability using traffic observations from freeways located at different areas.

6. References


Dr. Chang is a Registered Professional Engineer, Certified Civil Engineer in Texas and in Taiwan, R.O.C., the Senior Advisor of United Nations Development Program's (UNDP) STAR and TOKTEN program. Dr. Chang is also members of many active international ITS standards development professional organizations, including ITS America Standards & Protocol (S&P) Committee, ITS America System Architecture (SA) Committee, AASHTO NTCIP Ramp Metering (RMC) Working Group, U.S. Technical Advisory Group (USTAG) to ISO TC204 Committee. Dr. Change's professional research interests include: Computerized Freeway and Arterial Traffic Management Systems, Signal Timing Optimization, Urban Transportation Systems Analysis, Traffic Flow Theory, Real-Time Traffic Simulation, Microcomputer Applications, Expert Systems, Artificial Intelligence applications, and Intelligent Transportation Systems and NTCIP.

Author Biography - Edmond Chin-Ping Chang, Ph.D., P.E. is the ITS Program Manager, Energy Division, Oak Ridge National Laboratory after working as an Research Engineer of the Texas Transportation Institute at the Texas A&M University System. Dr. Chang has over 24 years of Transportation Engineering, Transportation Management, and System Engineering experience, and authored over 400 publications.
Figure 1. Overall Design Approach.

Figure 2. Error Correction Algorithm,
Figure 3. Traffic Flow, I-35W Study Site.