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Forecasting of short-term traffic-flow based on improved neurofuzzy models via emotional temporal difference learning algorithm

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ABSTRACT

Bounded rationally idea, rather that optimization idea, have result and better performance in decision making theory. Bounded rationality is the idea in decision making, rationality of individuals is limited by the information they have, the cognitive limitations of their minds, and the finite amount of time they have to make decisions. The emotional theory is an important topic presented in this field. The new methods in the direction of purposeful forecasting issues, which are based on cognitive limitations, are presented in this study. The presented algorithms in this study are emphasizes to rectify the learning the peak points, to increase the forecasting accuracy, to decrease the computational time and comply the multi-object forecasting in the algorithms. The structure of the proposed algorithms is based on approximation of its current estimate according to previously learned estimates. The short term traffic flow forecasting is a real benchmark that has been studied in this area. Traffic flow is a good measure of traffic activity. The time-series data used for fitting the proposed models are obtained from a two lane street I-494 in Minnesota City, USA. The research discuss the strong points of new method based on neurofuzzy and limbic system structure such as Locally Linear Neurofuzzy network (LLNF) and Brain Emotional Learning Based Intelligent Controller (BELBIC) models against classical and other intelligent methods such as Radial Basis Function (RBF), Takagi–Sugeno (T–S) neurofuzzy, and Multi-Layer Perceptron (MLP), and the effect of noise on the performance of the models is also considered. Finally, findings confirmed the significance of structural brain modeling beyond the classical artificial neural networks.

1. Introduction

The forecasting of traffic flows, traffic volumes and travel times is a very important part of traffic management, control and information system. The traffic simulation is correspondingly needed to make these forecasting in a reliable way. The results of the traffic circumstance forecastings can be used for different purposes such as to influence travel behavior, to reduce traffic congestion and generally to improve the performance of traffic management system.

As powerful computational tools for forecasting tasks, Artificial Neural Networks (ANNs) outperformed on early days of classical models. In real world issues, when there is no enough physical foundation and when data is mixed with colored noise, the neural and neurofuzzy models are still proficient of making good estimations (Elsner, 1992). The Emotional Learning (EL) algorithm has been presented for the first time to train the neurofuzzy models (Gholipour et al., 2003a). They can be regarded as RBF (Nelles, 1993, 2001). As the architecture of RBF presents, it is a locally linear model. Recently, MLP and RBF neural networks have produced appropriate results in various fields of forecasting. Their prominent features include limited forecasting errors, relatively low computational complexity, low computational time measurements and high generalization.

Temporal Difference Learning (TDL) algorithm has been presented for the first time to change the training procedures in ANNs in control multivariable systems by Abdi et al. (2004). They proved that by augmenting emotions to TDL algorithm the capability of the networks can be increased. The obtained results have shown that the proposed algorithm as a simple algorithm with a low-volume computations is capable of improving rise time and controlling complex system. In some engineering applications, a multi-step forecasting in a class of ANN is implemented by TDL

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algorithm (Hwang and Moon, 1991) and in some other applications, it is implemented by combining several approaches with neural network forecasting, such as multiple-neural-network, time-delay neural network and adaptive time-delay neural network (Xie et al., 2006). In both applications, it has provided satisfactory results.

Why the intelligent adaptive models are the aim of our study? Conventional statistical models or classical models usually suffer their strict mathematical assumptions when describing complex traffic circumstances. But, intelligent adaptive models are made for describing phenomenon under non-ideal physical environments such as traffic-flows. The intelligent adaptive models can adapt itself for a wide variety of traffic circumstances. The studies show reliable performance of these models.

The emotional algorithm inherently emphasizes the learning of the forecast critical factors, features and objectives in traffic-flow as short-time ones to perform remarkably accurate forecasting. Flows in traffic foreseeing as outstanding contributions of Emotional Temporal Difference (ETD) learning algorithm motivated the researchers in this study to introduce a multi-objective learning algorithm in a purposeful forecasting. The T–S neurofuzzy, BELBIC and LLNF models with Model Tree learning (LoLiMoT) algorithms are the three models that are updated by developing the emotional algorithms. In addition to these models, MLP and RBF neural networks are studied and their results are compared. According to the importance of studying noise in the real world applications, the LLNF model is just studied as a good forecaster in noise condition based on a hybrid learning algorithm (combination of wavenet and LoLiMoT algorithm which is called WLoLiMoT).

The main contributions of this paper are:

- Providing a new learning algorithm to enhance the performance of the neurofuzzy models.
- Applying the BELBIC and LLNF model in short-term traffic-flow forecasting applications for the first time.
- Providing a new hybrid algorithm to overcome the noise signal.
- Solving the curse of dimensionality issues in Daubechies wavelets and LoLiMoT algorithm by the aid of multi-step forecasting concept.
- Using different evaluation indices to specify the proper models.

In this study, after a review of the literature and stating the problem in Section 2, the EL and TD as new learning algorithms are introduced in Section 3, the combination of them is provided. And this hybrid learning algorithm is used to train a class of neurofuzzy models. The classical model and the proposed hybrid ARIMA and ANN models are described in Section 4. The T–S neurofuzzy models and some general issues on intelligent models such as neurofuzzy models, the limbic model of mammalian brain and original model of BELBIC algorithm are discussed in Sections 5 and 6, respectively. The LLNF model with LoLiMoT and with WLoLiMoT algorithms are presented in Section 7 in order to study noise. Finally in Section 8, the results of short-term traffic-flow forecasting performed by ETD learning algorithm to learning models are presented and a comparison is made between the results of forecaster, MLPNNs, RBF, neurofuzzy networks, Autoregressive Integrated Moving Average Neural Network (ARIMANN), BELBIC and LLNF models with EL. The conclusion included in Section 9 confirms the capability of the new model to improve the accuracy and the computational time over the neurofuzzy models.

2. Background

Flow, speed and density are important macroscopic traffic features to demonstrate the load of traffic on the transportation system. The topic of forecasting short term traffic-flow has been discussed for three decades, and many models have been generated. The general consideration in forecasting is shown in Fig. 1.

These models usually are classified as the following groups: Historical Average (Stephanedes et al., 1981), Kalman Filter (KF) (Okutani and Stephanedes, 1984; Abdi et al., 2010), ANNs (Smith and Demetsky, 1994; Chen et al., 2004; Tan et al., 2007; Zheng et al., 2006), ANN with parallel Back Propagation (BP) training (Tan et al., 2007), Self-Scaling Parallel Quasi-Newton neural network (Tan et al., 2009), Exponential Smoothing (Messer, 1993), Fuzzy Logic System (FLS) methodology (Zhang and Ye, 2008), K-Nearest Neighborhood (Davis and Nihan, 1991), ARIMA (Ahmed and Cook, 1980), Traffic-flow simulator method (Lam and Xu 1999), the Seasonal Autoregressive Integrated Moving Average (SARIMA) based on Bayesian estimator (Ghosh et al., 2007), Bayesian Network (Jung and Cho, 2008), Wavelet Transform (Xie and Zhang, 2006), Spectral Analysis (Nicholson and Swann, 1974), Neurofuzzy theory (Park, 2002; Yin et al., 2002), Wavelet Transform and neural network theory (Stephanedes et al., 1981), Chaotic Time Series Analysis (Xue and Shi, 2008), Neurogenetics theory (Abdulhai et al., 2002), and Adaptive Network based Fuzzy Inference System (ANFIS) (Dong et al., 2009).

The T–S neurofuzzy model with FIS, ELFIS and ANFIS learning algorithm is studied specially based on multilayer feedforward neural networks (Roger, 1993; Halgamuge and Glesner, 1994; Hou et al., 2003). The ANFIS networks have several structure varieties and functions of the basic ANFIS structural design which are similar to the RBF (Roger, 1993). Short-term traffic-flow forecasting on the dynamic traffic-flow data has been discussed with a technique based on ANFIS and random factors (Liu et al., 2008). Although many models are used to forecast traffic flow, but based on traffic circumstances complexity, traffic analysts can hardly select the proper model for a definite highway at a certain time. A forecasting model which acts better than the others in a certain traffic circumstance can completely fail or degrade in the other traffic circumstances. Furthermore, earlier models have their own disadvantages in forecasting, although the strengths are noticeable (Smith and Demetsky, 1997). Some models have a main disadvantage in replying to unexpected events such as the historical average model. The exponential smoothing model's weaknesses are indicated to lead in great states' variations and the difficulty of obtaining a proper smooth constant.

The main disadvantages of the ANN are that it is mainly dependent on the training of the network. The important training

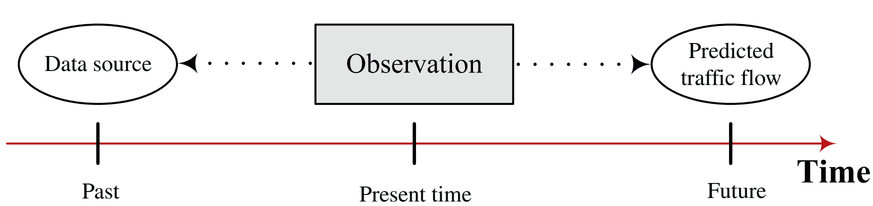

Fig. 1. General consideration in forecasting.