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Traffic flow forecasting by seasonal SVR with chaotic simulated annealing algorithm

Wei-Chiang Hong *

Department of Information Management, Oriental Institute of Technology, 58 Sec. 2, Sichuan Rd., Panchiao, Taipei 220, Taiwan, ROC

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ABSTRACT

Accurate forecasting of inter-urban traffic flow has been one of the most important issues globally in the research on road traffic congestion. However, the information of inter-urban traffic presents a challenging situation; the traffic flow forecasting involves a rather complex nonlinear data pattern, particularly during daily peak periods, traffic flow data reveals cyclic (seasonal) trend. In the recent years, the support vector regression model (SVR) has been widely used to solve nonlinear regression and time series problems. However, the applications of SVR models to deal with cyclic (seasonal) trend time series have not been widely explored. This investigation presents a traffic flow forecasting model that combines the seasonal support vector regression model with chaotic simulated annealing algorithm (SSVRCSA), to forecast inter-urban traffic flow. Additionally, a numerical example of traffic flow values from northern Taiwan is employed to elucidate the forecasting performance of the proposed SSVRCSA model. The forecasting results indicate that the proposed model yields more accurate forecasting results than the seasonal autoregressive integrated moving average (SARIMA), back-propagation neural network (BPNN) and seasonal Holt-Winters (SHW) models. Therefore, the SSVRCSA model is a promising alternative for forecasting traffic flow.

1. Introduction

The effective capacity of inter-urban motorway networks is an essential component of traffic control systems, particularly during daily peak periods. Since slightly inaccurate capacity predictions will lead to congestion with huge social costs in terms of travel time, fuel costs and environment pollution, accurate traffic flow forecasting during peak periods is a very topic attracted interests in the literature.

There has been a wide variety of forecasting approaches applied to forecast the traffic flow in an inter-urban motorway network. Those approaches could be classified according to the type of data, forecast horizon and potential end-use [1], such as Kalman state space filtering models [2–5] and system identification models [6]. However, traffic flow data are collected at specific locations at constant intervals of time, thus, they are in the form of spatial time series. The mentioned studies and their empirical results have indicated that the problem of traffic flow forecasting in an inter-urban motorway network is multi-dimensional, including relationships among measurements made at different times and geographical sites. In addition, these methods are difficult to cope with observation noise and missing values while modeling. Therefore, Danech-Pajouh and Aron [7] employ a layered statistical approach with a mathematical clustering technique to group the traffic flow data, then, a separately tuned linear regression model is applied to each grouped cluster. Their experimental results reveal that the proposed model is superior to the ARIMA model. Based on the multi-dimensional pattern recognition requests, such as intervals of time, geographical sites and the relationships between dependent variable and independent variables, non-parametric regression models [8–11] have also successfully been employed to forecast motorway traffic flow. For example, Guo et al. [8] recently restore multi-dimensional dynamics of the Beijing 2nd ring road system with chaos and fractal theory to forecast the traffic flow by employing multivariate time series of local prediction method. Their experimental results indicate that the proposed method has high prediction accuracy within 2 or 5 min level. These multivariate regression models are often faced with a dilemma that employed socio-economic factors are found to have insignificant coefficients, even though they may strongly affect traffic flow; conversely, eliminating these redundant variables may raise the explanation ability (denoted by R^2), but raises the co-linearity problem. This represents a major restriction of econometric models.

Furthermore, the ARIMA models, initially developed by Box and Jenkins [12], are one of the most popular alternatives in

* Tel.: +886 2 7738 0145x5316; fax: +886 2 7738 6310.
E-mail addresses: samuelsonhong@gmail.com, samuelhong@ieee.org

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traffic flow forecasting [11,13–16]. For example, Kamarianakis and Prastacos [14] successfully employ the ARIMA model with space and time factors to forecast space-time stationary traffic flow. However, the limitation of ARIMA models is that their natural tendency, concentrated on the mean values of the past series data, seems unable to capture the rapid variational process changes underlying of traffic flow [17]. Recently, as an extension of ARIMA model, Williams [18] applies seasonal ARIMA (SARIMA) model to traffic flow forecasting. The proposed model considers the peak/non-peak flow periods by seasonal differencing, and forecasting results report that it significantly outperforms the heuristic forecast generation methods in terms of forecasting accuracy. However, it is quite time consuming to detect the outlier required and to estimate the parameter of SARIMA model. These new findings are also encouraging the author to employ the SARIMA model as the benchmarking model in this study.

As mentioned above that rapid variational process changes underlying inter-urban traffic flow is complicated to be captured by a single linear statistical algorithm, the artificial neural networks (ANN) models, being able to approximate any degree of complexity and without prior knowledge of problem solving, have received attentions and have been considered as alternatives for traffic flow forecasting models [15,19–24]. ANN is based on a model of emulating the processes of the human neurological system to determine the numbers of vehicle and temporal characteristics from the historical traffic flow patterns, especially for nonlinear and dynamic evolutions. Therefore, ANN is widely applied in traffic flow forecasting. Recently, Vlahogianni et al. [23], successfully considering the proper representation of traffic flow data with temporal and spatial characteristics, employ a genetic algorithm with multilayered structural optimization strategy to determine the appropriate neural network structure. Their results show that the capabilities of a simple static neural network, with genetically optimized step size, momentum and number of hidden units, are very satisfactory when modeling both univariate and multivariate traffic data. Yin et al. [25] develop a fuzzy-neural model (FNM) to predict traffic flow in an urban street network. The empirical results show that the FNM model provides more accurate forecasting results than the BPNN model. Even though ANN-based forecasting models can approximate any function particularly for nonlinear function, their limitations are difficult to explain the operations of the so-called black-box (such as how to determine suitable network structure); in addition, the training errors of any ANN network are non-convex to difficultly find out the global optimum. To overcome the latter drawback, an up-to-date research tendency is to employ novel evolutionary algorithms or wavelet function with ANN to explore the global optimum in the non-convex solution ranges. Li et al. [26] combine simulated annealing (SA) algorithm to the processing of GA in a back-propagation neural network (BPNN) traffic flow forecasting model to get rid of local optimum (premature convergence of GA). The results show that the hybrid algorithm (SA with GA) can improve the traffic flow forecasting accuracy. Huang and Lu [27] apply multi-scale analysis to decompose the sequences of traffic flow parameters into the low and high frequency coefficients. ANN with GA is then used to optimize those multi-scale coefficients. The results indicate that the proposed approach can receive more accurate predictions than traditional ANN model. Yang et al. [28] propose wavelet neural network model by combining the advantages of wavelet transform and RBF network to forecast short-term traffic flow. The wavelet function firstly is used to decompose and reconstruct traffic flow data with similar periods and signal components, respectively, and then RBF network is employed to forecast. The results indicate that the forecasting performance is better than just applying neural network in prediction.

Support vector machines (SVM) are originally developed to solve pattern recognition and classification problems. With the introduction of Vapnik's ε-insensitive loss function, SVMs have been extended to solve nonlinear regression estimation problems, i.e., the so-called support vector regression (SVR), and have been successfully applied to solve forecasting problems in many fields, such as business demand (stocks index, exchange rate, 3G subscribers, tourist arrivals, etc.) forecasting [29–32] engineering and software field (production values and reliability) forecasting [33,34], atmospheric science forecasting [35–39], electric load forecasting [40–45], etc. The practical results indicate that poor forecasting accuracy is suffered from the lack of knowledge of the selection of the three parameters (σ, C and ε) in a SVR model. There are lots of existing practical approaches to the selection of C and ε, such as user-defined based on priori knowledge and experience, cross-validation and asymptotical optimization. However, structural methods for efficiently and simultaneously confirming the selection of those three parameters efficiently are lacking. Therefore, it is deserved to provide more alternative evolutionary algorithms to for each performance to improve the forecasting accuracy. The author has conducted a series of research by employing different evolutionary algorithms and hybrid evolutionary algorithms with chaotic sequences to test well the guideline which algorithm is suitable for which data pattern. The author finds that each algorithm has its superiorities and limitations; thus, employing hybrid different algorithms will be more powerful than using a single algorithm [46]. In this investigation, focussing on the drawbacks of simulated annealing (SA) algorithm, the author proposes the chaotic simulated annealing algorithm (CSA) to determine the values of three parameters in a SVR model. In addition, as mentioned the traffic flow data not only involves a complicated nonlinear data pattern, but also reveals cyclic (seasonal) trend during daily peak periods (morning/evening commute peak time). The applications of SVR models to deal with cyclic (seasonal) trend time series have not been widely explored. Therefore, this paper also attempts to apply the seasonal adjustment method [47,48] to deal with seasonal trend time series problem. The proposed SSVRCSA model is applied to forecast inter-urban motorway traffic flow in the Panchiao City of Taipei County, Taiwan. The rest of this paper is organized as follows. Section 2 presents the models for comparing forecast performance and SVR models. Section 3 introduces the proposed SSVRCSA forecasting model. Section 4 illustrates a numerical example that reveals the forecasting performance of the proposed models. Conclusions are finally made in Section 5.

2. Forecasting methodology

In this investigation, to reveal the superiority of the proposed SSVRCSA model in terms of determining well three parameters of a SVR model by CSA, and to address the novelty of the SSVRCSA model in terms of well-coping with seasonality of inter-urban traffic flow, simple back-propagation neural network (BPNN) model and two seasonal based models, the seasonal ARIMA (SARIMA) and seasonal Holt-Winters (SHW), are used to compare the forecasting performance of traffic flow.

2.1. Seasonal autoregressive integrated moving average (SARIMA) model

Proposed by Box and Jenkins [12], the seasonal ARIMA process has been one of the most popular approaches in time series forecasting, particularly for strong seasonal component. The SARIMA process is often referred to as the SARIMA$(p,d,q)\times(P,D,Q)_S$ model. Similar to the ARIMA model, the forecasting values are