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RESEARCH PAPER

OD Matrices Network Estimation from Link Counts by Neural Networks

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Abstract: This paper attempts to deal with traffic Origin Destination (OD) matrix estimation starting from the measurements of flow on road network links. It proposes a different approach from published articles to date, by applying multilayer feed-forward neural networks. Since the relationship between link flow and the related OD matrix is continuous, it is possible to use the well known approximation property of Neural Network models. The method is proposed for a real-time correction of the OD matrix. Two application scenarios were developed: a trial network and an actual rural network were both simulated by a micro-simulator that assigns known OD matrices. A Principal Component Analysis (PCA) technique was used to reduce the amount of variables and to achieve improved significance for input data. The estimated error was relatively low and, as opposed to analytical approaches, the processing time was almost in real time, making this approach suitable for applications in dynamic traffic management. Comparisons with results obtained by an OD estimation commercial program show better performance in the NN approach both as regards error and computing time.

Key Words: urban traffic; OD matrix estimation, neural networks, PCA, link flow, variance stabilization

1 Introduction

The analysis of urban networks has advanced significantly since the mid 1980s in order to solve problems relating to road circulation arising from two different research fields: spatial forecasting and time series prediction.

Spatial forecasting is usually solved by using assignment techniques with a known or partially known Origin Destination (OD) matrix which describes traffic demand arising between two places (called centroids) of origin and destination. The dimension of spatial forecasting is related to the number of centroids although many relationships are void and the matrix is generally sparse. Many planning and control methods with equilibrium and dynamic approaches are based on the use of an OD matrix. The in-the-field surveys necessary to build this matrix are expensive and often cannot be repeated. For this reason, methodological and operating alternatives have been under review for many years aiming to building the OD matrix by using link flows that are generally less expensive.

At the same time, techniques based on Auto Regressive (AR), Mobile Average (MA) and variants[1], and on neural networks[2] for forecasting a time series have been developed. In particular, as regards to urban networks, traffic forecasting deals with flow data on links or on their sections or turning percentage at intersections. The results achieved can be considered very satisfactory. Particularly for neural networks there is a slightly higher possibility of making predictions in respect to analytical models which regards sensitivity to noise or other unidentified data. Technical papers and application software on these subjects are numerous; a review of neural network applications in the field of transport is reported by Mussone[3].

Many efforts have been made to solve the problem of OD estimation. Some are based on entropy maximization. Gong[4] uses a Hopfield neural network as a tool for solving the related optimal problem. Other authors maximize trip distribution dispersion on all available paths; in other cases the model is based on an OD matrix objective and no references are made to the difference between the estimated matrix and the real

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one [5]. This model was later extended by Fisk[6] for use on congested networks. However, the bi-level approach poses certain difficulties in finding an optimal solution because of non-convex and non-differential formulations.

Florian and Chen[7] formulated a heuristic approach capable of leading to an optimal solution by limiting the objective to the correction of the OD matrix. Other approaches are based on models that use the statistical properties of the variables observed. For instance, Cascetta[8] used an estimation based on generalized least squares (GLS); Bell[9] applied a technique of generalized least constrained squares. Cascetta and Nguyen[10] proposed an overview of statistical methods for estimating the OD matrix, with regard to generalized and constrained least squares and also an estimation of likelihood of the Bayesian type.

Several approaches can be found in published articles to model dynamic components of OD matrices. They vary from time space trajectory[11], random walk models[12] and autoregressive formulations to model time series of ODs [13] or based on a deviation between actual and historical ODs[14]. The Kalman's filtering algorithm was proposed by many authors[12, 15]. The explicit modeling and estimation of the dynamic mapping was presented in reference [16]; different formulations of least squares approaches can be found in reference [15] and integrated models of a non-assignment-based model with a dynamic traffic assignment model in reference [17]. A comprehensive overview can be found also in reference [18].

Neural networks (both in recurrent or non-recurrent versions) are tools for solving function approximations both by using or not using time as an explicit variable. They are handy tools for solving OD estimation problem. In fact, it is important to note that there is a continuous relationship between link flow and OD values. Specific applications of neural networks (NN) to OD estimation are related to the works of Yang *et al* [19, 20]. The estimation of the OD matrix is based on the minimization of squared error between predicted and detected flow in two different scenarios. In the first case the feed-forward neural network is used to work out the desired minimization. The latter case concerns the Hanshin Highways which are characterized by many ramps located at different distances and therefore performance evaluation is more difficult because the actual dynamic OD matrix is unknown and comparison can be done only between a predicted and a static OD matrix. Kikuchi and Tanaka [21] applied NN for a freeway network continuously monitored at inflow and outflow ramps.

The aim of this paper is to try and solve the OD matrix estimation by using neural networks, starting from knowledge of flow measurements on road network links. Our paper wishes to contribute to the non-assignment-based approaches in OD estimation as proposed by Chang and Tao[17]. We propose an application of multilayer feed-forward neural networks in order to estimate the OD matrices by using the well-known approximation property of these models. The existence of a relationship that can be represented by a continuous function between flow measured on links and the OD matrix and produces them can be taken for granted. Because of the learning mechanism of feed-forward neural networks, however, the contemporary knowledge of the OD matrix and related link flows is required for the training set. This requirement is met thanks to the virtual laboratory of the transport group of the University of Naples[22], that produced all necessary information.

The proposed method assumes that the OD matrices to be estimated by using the new link flow values do not have a very different structure from those used in the learning phase of neural networks; in this case we can actually speak of correction of the OD matrix. This fact can be considered a limit of the approach, though it is bounded to special cases of unpredictable changes in supply (links are completely or partially closed to traffic) or in demand (social disorder or social phenomena). Exceptional but foreseeable changes can instead be included in an NN model as well especially if a simulation laboratory is used to prepare traffic scenarios.

One advantage of this approach concerns the processing time which, as in all neural network models, is very short in the recall mode. PCA (Principal Component Analysis) has been applied to reduce the size of input data which in this type of application can be very wide. Another advantage of this approach concerns the possibility of testing the robustness of an NN model when the flow of some links is not used (simulating what happens in the real world when some measures are not available).

The paper has another four sections. Section 2 concerns data analysis and pre-processing before using the neural network procedure and tackles the subject of the analytical description of the process to be modeled and the methodologies to apply, if possible, in order to improve the performance that can be achieved by the model. In the third section, the experimentation scenarios we refer to: the traffic network, OD matrices, and link flows are described and the techniques to extract the necessary data for training the neural network and the results of neural network learning are presented. The fourth section presents validation results obtained for the traffic networks analyzed. Finally, in the last section we propose our conclusions and suggest future developments of this research.

2 Data Pre-Processing

In the approach we adopted, neural networks were used to work out a non linear Maximum Likelihood estimate of OD matrices. The first step for a proper estimate entails a training that should be as easy as possible. In this respect, data (OD