Estimation of the Transport Demand for Real-Time Applications

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ABSTRACT

The starting point of this thesis is the proposal of an architecture for a Real-Time Advanced Traffic Management and Control Systems and Advanced Traffic Information Systems that use microscopic simulation models to support a sound decision-making process in traffic management and in the dissemination of information. This proposal is the first aim of a research work undertaken in this thesis and it has been evaluated in the scope of the European Projects PETRI and CAPITALS. The feasibility of the proposed architecture strongly depends on the capability of short-term prediction of the network conditions which becomes the key component of the proposed architecture. The short-term prediction is defined in terms of the dynamic prediction of OD matrices and the use of a microscopic simulation model, which receives as input the predicted OD matrices and generates as output the network state.

The requirement for short-term forecasting led to identify a second objective of the thesis: the estimation of OD matrices in real-time. The research done in the thesis investigates the dynamic estimation of OD matrices combining the real-time detector measurements on a subset of links of the road network combined with historical OD matrices. The proposed approach for the dynamic prediction of the network state in terms of the estimated OD matrix is based on Neural Networks, which are natural candidates for forecasting models in absence of clear patterns, and have an easily parallelisable structure to achieve the computational requirements of a real-time application.

The dynamic prediction of the network state by means of neural networks has one main drawback: the amount of data required for the proper training of the neural network, due to the size of the neural network and the corresponding amount of parameters, and, consequently the computational infeasibility of the training process. This thesis proposes to solve this handicap by identifying that the mobility patterns between OD pairs are determined by the paths connecting them, and then classifying the OD pairs by clusters in function of the structure of these paths. This technique allows an original neural network of a large size to be split into a set of smaller neural networks whose training is easier and feasible.

This approach leads to a complementary problem: the quality of the cluster classes, and consequently of the associated neural networks, depending on the quality of the path definition. The proposed solution consists in obtaining the paths from a microsimulation-based heuristic dynamic traffic assignment. The heuristic traffic assignment becomes then the key component of the proposed architecture because it solves the problem of partition the large neural network into independent or almost independent smaller neural networks and, besides, allows to determine the road network state using the microsimulation from the estimated OD matrices and at the same time generates the patterns in the training process for the neural networks.

The implementation of the proposed solution using microsimulation required a complementary development in the microsimulator AIMSUN to endow with a set of new functionalities: shortest path calculation using time dependant cost functions, route choice functions coherent with the dynamic traffic assignment principles, graphical tools to conduct the analysis of the used paths and other support tools required in the validation process of simulation models.

In consequence, the main contributions of this thesis are:

- The architecture designed to support the sound decision-making process in real-time applications of traffic management, using microsimulation.
- The implementation of a heuristic dynamic traffic assignment based, on microsimulation, which uses the two theoretical approaches: the preventive and the reactive traffic assignment; based on a new method to update the cost functions and compute the reactive assignment.
- A mobility patterns analysis process in terms of paths between OD pairs.
- An OD pairs classification process in terms of the mobility patterns, and the tool to analyse the OD paths.
- A neural network structure for mobility matrices prediction considering the OD pairs clusters
- An scheme to generate the required patterns to train the neural networks
- A new version of the traffic microscopic simulator AIMSUN, which includes all required functionalities to implement the methods proposed and developed in the thesis.