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An adaptive agent-based approach to traffic simulation

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Abstract

The aim of this work is to present the initial exploration of a behavioural Dynamic Traffic Assignment model, particularly suitable to be used and implemented in agent-based micro-simulations. The proposal relies on the assumption that travellers take routing policies rather than paths, leading us to introduce the possibility for each simulated agent to apply, in real time, a strategy allowing him to possibly re-route his path depending on the perceived local traffic conditions, jam and/or time spent.

The re-routing process allows the agents to directly react to any change in the road network. For the sake of simplicity, the agents' strategy is modelled with a simple neural network whose parameters are determined during a preliminary training stage. The inputs of such neural network read the local information about the route network and the output gives the action to undertake: stay on the same path or modify it. As the agents use only local information, the overall network topology does not really matter, thus the strategy is able to cope with large networks.

Numerical experiments are performed on various scenarios containing different proportions of trained strategic agents, agents with random strategies and non-strategic agents, to test the robustness and adaptability to new environments and varying network conditions. The methodology is also compared against MATSim and real world data. The outcome of the experiments suggest that this work-in-progress already produces encouraging results.

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Keywords: behavioural dynamic traffic assignment; agent-based model; strategic agents; neural networks; routing policy

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1. Introduction

Traffic flows simulation represents a central part of traffic micro-simulators such as MATSim Meister et al. (2010), DynaMIT Ben-Akiva et al. (1998) and AIMSUN Barceló and Casas (2005) as well as the traffic modelling part of UrbanSim Waddell (2002) and ILUTE Salvini and Miller (2005) integrated simulators. This module is in charge of executing the daily plans of simulated individuals in a physical environment, i.e. representing the traffic flows dynamics on a road network.

In recent decades, dynamics traffic assignment (for short DTA in the following) models emerged for solving this problem (see Chiu et al. (2011) for an extensive description of these techniques), which either aim at reaching a steady-state (user equilibrium) of the considered system or at simulating the agents route choice behaviours.

DTA techniques can also be distinguished by their analytical or simulation-based nature. Analytical methods formulate the traffic assignment as non-linear programming and optimisation problems or variational inequalities instead of focusing on the agents' behaviours. Examples of such works include Friesz et al. (1993), Merchant and Nemhauser (1978a) and Merchant and Nemhauser (1978b). Even though they have demonstrated their usefulness and are grounded on sound mathematical theories, their complexity and computational cost make their application to large-scale scenarios difficult Peeta and Ziliaskopoulos (2001).

Hence simulation-based methods, which explicitly model the individuals' mobility behaviours, have recently gained more attention in the literature (Nagel and Fltter ¨od (2009), Bazghandi (2012) and Ben-Akiva et al. (2012)). The underlying idea is to compute a user equilibrium by means of an iterative process. These successive steps generate traffic flows until the travel time of every agent becomes stationary, i.e. reaches a user equilibrium. This class of models is more suited to an agent-based approach than the analytical ones because of their very first assumption of focusing on agents' mobility behaviour rather than optimising a complex objective function. Nevertheless, due to their iterative nature they are also endowed with computational issues. Indeed if the road network and the number of agents involved are large, the DTA algorithms of this type may converge slowly to an equilibrium state Pan et al. (2012).

We can observe that both categories of DTA methods for steady-state solutions are not suited to temporal networks as the agents' lacks of real-time response to network modifications. For instance if an accident occurs at some point of an agent's trip, if the number of agents in the network changes, or if the network is modified by adding/removing streets, the whole optimisation/iterative stages must be repeated to compute a new equilibrium. Moreover these steady states approaches rely on strong assumptions and have several limitations now well identified. We refer the reader to Dehoux and Toint (1991) for a discussion of these limitations and why these models should be avoided in favour of purely behavioural models such as the ones proposed in PACSIM Cornélis and Toint (1998), FREESIM Rathi and Nemeth (1986) and CARSIM Benekohal and Treiterer (1988). The interested reader may find a recent review of these schemes in Pan et al. (2012).

The aim of this work is to present an original behavioural DTA model which is particularly appropriate in the context of agent-based micro-simulation. The proposal relies on the assumption that travellers take routing policies rather than paths Gao et al. (2010), leading us to introduce the possibility for each simulated agent to apply a strategy allowing it to possibly re-route his path depending on perceived local traffic conditions. This re-routing process allows the agents to directly react to any change in the road network, which removes the need of restarting the whole simulation process and consequently decreases the computational cost. For the sake of simplicity, we decide to model the agents strategy with a simple neural network whose parameters are determined during a preliminary learning stage. Of course more complex structures can be considered.

The paper is organised as follows. Section 2 formally details the design of the agents' strategies and their optimization process. The resulting mobility behaviour is then illustrated under various scenarios, testing the robustness of the strategies, in Section 3. Finally concluding remarks and perspectives are discussed in Section 4.