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A dynamic behavioural traffic assignment model with strategic agents ☆

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ABSTRACT

Foresee traffic conditions and demand is a major issue nowadays that is very often approached using simulation tools. The aim of this work is to propose an innovative strategy to tackle such problem, relying on the presentation and analysis of a behavioural dynamic traffic assignment.

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 already spent in his journey.

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 and not previously explored 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 existing approaches and real world data. The outcome of the experiments suggest that this work-in-progress already produces encouraging results in terms of accuracy and computational efficiency. This indicates that the proposed approach has the potential to provide better tools to investigate and forecast drivers' choice behaviours. Eventually these tools can improve the delivery and efficiency of traffic information to the drivers.

1. Introduction

In the recent decades researchers from socio-economical sciences have increasingly tighten the ties with colleagues from other disciplines such as physics, mathematics and computer science just to mention few of them. Hence methods and tools own to the latter have been successfully improved and then applied to understand some socio-economical phenomena.

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However differences are still present between such domains, in particular concerning the experimental method and its reproducibility. In social sciences experiments are highly time consuming as many repetitions are needed to cover the human heterogeneity and unravel possible "universal social laws" not yet determined or limited to describe aggregate data, quoting Asimov "In studying society, we place human beings in the place of subatomic particles, but now there is the added factor of the human mind. Particles move mindlessly; human beings do not. To take into account the various attitudes and impulses of mind adds so much complexity that there lacks time to take care of all of it" (Asimov, 1988). Moreover there is a clear difficulty to scale up results of experiments done on small group to larger sizes (cities, countries).

For all these reasons, scientists resort to numerical micro-simulations to tackle relevant societal research questions (Helbing, 2016), in particular individual based models, also called micro-simulations, are very appealing, once properly calibrated on real data, because they allow to fully take care of the heterogeneity of the involved agents. This approach has been already used and proved its validity in transportation problems.

Traffic flows simulation represents a central part of traffic micro-simulators such as POLARIS (Auld et al., 2016), MATSim (Meister et al., 2010), DynaMIT (Ben-Akiva et al., 1998), DynaSmart (Mahmassani et al., 1992), AIMSUN (Barceló and Casas, 2005), DynusT (Chiu et al., 2011b) and DTAlite (Zhou et al., 2014) as well as the traffic modelling part of UrbanSim (Waddell, 2002) and ILUTE (Salvini and Miller, 2005) integrated simulators. This component 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 (DTA) models have emerged for solving this problem (see Chiu et al. (2011a) for an extensive description of these techniques), which either aim at reaching a steady-state of the considered system or at simulating the agents route choice behaviours. A steady-state of the system is achieved when it reaches either one of the following.

User equilibrium
the journey times on all the routes actually used are equal, and less than those which would be experienced by a single vehicle (or user) on any unused route (Wardrop's first principle, Wardrop, 1952);

Stochastic user equilibrium
no user believes he/she can improve his/her travel time by unilaterally changing routes (Daganzo and Sheffi, 1977).

DTA techniques can also be distinguished by their analytical or simulation-based nature (Peeta and Ziliaskopoulos, 2001). 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,b). 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 and allow to account for the heterogeneity of the involved agents, have recently gained more attention in the literature (Nagel and Flötteröd, 2009; Bazghandi, 2012; Ben-Akiva et al., 2012). The underlying idea is to try reaching an (stochastic) user equilibrium by means of iterative simulations. These successive steps generate traffic flows until the travel time of every agent becomes stationary, i.e. reaches a (stochastic) user equilibrium. This class of models is more suited to an agent-based approach than the analytical ones by focusing on agents' mobility behaviour rather than optimising a complex objective function. Nevertheless, due to their iterative nature those methods can be endowed with computational issues. Indeed if the road network and the number of agents involved are large, the 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 suitable to dynamic networks as the agents lack 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 that have been long 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.

These behavioural models, focusing on the travellers decision (in terms of path and/or departure time choices) have been widely investigated since the seminal work of Mahmassani and Chang (1987). For instance behavioural models are proposed in the FREESIM (Rathi and Nemeth, 1986), CARSIM (Benekohal and Treiterer, 1988), PACSIM (Cornélis and Toint, 1998) and AgBM-DTALite (Xiong et al., 2017) simulation packages. Interested readers may find a review of these schemes in Pel et al. (2012). Investigating these models leads to the development of new tools able to better investigate and forecast drivers' behaviours, a necessary step for the design of efficient traffic information delivery systems.

The aim of this work is to present a first step development of a behavioural DTA. The proposal relies on the assumption that travellers can take routing policies rather than paths. This concept, originally used for transit (Nguyen and Pallotino, 1988; Spiess and Florian, 1989; Nguyen et al., 1998) has been adapted to model drivers' adaptive route behavior (Gao et al., 2010; Gao, 2012; Xiong et al., 2016). The existing works typically assume that a driver has access to real time information that can be provided via a proper device (e.g. a radio, a connected navigation system or dynamic message signs.