Systems Modelling & Simulation: The Sharing of Traffic Knowledge

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Abstract. Advanced traveller information systems (ATIS) have seen a recent surge in popularity among urban users. These systems have the ability to considerably increase traffic flow, but are limited by their penetration ratio among the city's population. In this work we simulate a road network where different levels of information percolation are tested. The analogy with real life is to assess the extend to which an ATIS can improve total travel time and road utilization, and quantify this usefulness by means of improvements of traffic flow on several metrics.

Keywords: Traffic Modelling · Simulation · Advanced Traveler Information Systems

1 Context

In large urban cities the problems generated by traffic can not be disregarded. The stress it causes and the time it steals are never welcomed by the people that get stuck in it, even more because people always seem to be in a hurry to get somewhere. Thus, virtual tools like *WAZE* will naturally succeed, as they attempt to help people avoid traffic situations, by suggesting possible secondary trajectories that despite being lengthier can be travelled in inferior time.

In this paper we explore how different rates of adherence to an Advanced Traveler Information Systems (ATIS), like *WAZE*, can impact the traffic situation of a certain urban area.

2 Problem Statement

In this paper, we make an anlysis of the possible impacts of having a large urban community that makes use of an (ATIS) and how the influencing variables affect its performance. Several influencing variables can be named, such as the topology of the network, traffic densities, and the most relevant one, the rate of adherence to the ATIS.

However, gathering traffic data from a large urban center network or even from several distinct urban centers can prove to be a very exhausting and resource-consuming task. Therefore, this problem will be approached using a modelling and simulation technique, while having real data to ground the agents' behaviours used in the model.

Even though the main focus of this paper is study how different rates of user adherence to an ATIS affect its prediction success rate, there is also the intention to study how the aforementioned remaining factors can also affect the same prediction success rate.

3 Domain Characterization

According to [Louf and Barthelemy, 2014], cities follow one of four topology patterns, depending on the amount of blocks with a given shape and on the existence of small or large areas. This study intends to cover cities belonging to the full range of identified patterns.

By the analysis of several cities belonging to one pattern, predictions can then be made regarding the impact of different adherence rates to the ATIS in cities with equal topology patterns.

For the characterization of the problem, an ATIS with inner workings similar to [Mobile, 2019] will be used. *WAZE*'s ability to give trustful information to its users is directly correlated to the number of Users connected to its Network. *WAZE* uses real-time information provided by it's users, such as their average speed and location, to predict the traffic's current state. Therefore, the more users are connected to *WAZE* in a given area, at a certain time, the more precise the information should be. By knowing your desired destination, *WAZE* can provide you with alternating routes predicted to be faster.

4 Simulation Purpose

Simulation is the imitation of some real world process or system over time. Simulations are of great use when applied to complex systems that can not be solved in a mathematical way. In such situations, by representing certain key characteristics or behaviours of the selected physical or abstract system, one can attempt to present a trustworthy model of a real system [**?**].

We opted to make a simulation of the problem aforementioned since we can gain insight regarding its functioning, as well as analysis of what-if situations that would be otherwise impossible to recreate. For instance, it is not possible to force the population living in a certain large urban area to use an ATIS following the adherence rates that are of interest to us. The problem becomes even more simulation adequate when we consider the impacts of different topologies, meaning we would have to force those same adherence rates on distinct urban areas. Thus, the problem at hand seems to fit and benefit from the purposes and circumstances of using a simulation.

5 Hypothesis

In this paper we test the hypothesis that increasing levels of information percolation have a positive impact on a traffic grid's flow. Additionally, we propose by intuition that this relation is non-linear, following a curve similar to a logistic function. We'll also assess whether the discovered relation holds for different grid topologies.

In order to test our hypotheses, we use different simulation scenarios and performance metrics. Initially, we use a simple *matrix-shaped* road network, and grid-search ratios of usage penetration of an ATIS, in the range [0, 1], by running complete simulations for each value and evaluating results on several performance metrics.

For measuring performance, we use several known traffic performance metrics [Kaparias et al., 2011]: average travel time to points of interest, average origin-destination travel time, average origin-destination travel distance, average travel speed, average fuel consumption, time spent in dense traffic, cost per vehicle miles of travel (related to fuel consumption).

6 Related Work

This is not a novelty work and as such we should briefly describe some other other advances that have been made with respect to information percolation in the context of traffic problems.

- [Capela et al., 2014] - A new type of optimization algorithm is introduced that is based on the Ant Colony Optimization (ACO) algorithm but with its logic inverted. Inverted Ant Colony Optimization (IACO) was used for traffic management and vehicle distribution. It was shown that this approach not only improved the local space but the global space as well. The algorithm centers around the thought that vehicles while passing through a given road, free pheromones that signal their passage. This in turn allows other vehicles to change their trajectory when considering that a road might suffer from congestion if it has a lot of said pheromones. This is somewhat parallel to what we are trying to test, with the idea that not choosing paths that a lot of others are already taking can be beneficial for the driver, even if the alternative path has less utility for him and thus a knowledge of other drivers can improve our decision-making abilities.
- [Guriau et al., 2016] - Cooperative Intelligent Transportation System (C-ITS), a new paradigm of ITS is discussed for efficient traffic state estimation and traffic control. This cooperation is made at three levels of action, (1) vehicles with Advanced Driver Assistance System (ADAS) adjust their behaviour to surrounding conditions, (2) information is exchanged with the infrastructure and (3) information is shared between vehicles. Cooperative models are introduced into a traffic simulator to assess the benefits of this

emerging strategy. Modeling the behaviour of cooperative vehicles is made resourcing to a three-layered approach, the physical layer with vehicle dynamics, the communication layer the manages the information exchange based on proximity and reliability and the trust layer, modeling an agent's trust in others. Simulation results give evidence of the benefits of the cooperative paradigm in terms of homogenization and safety.
- [Shang et al., 2017] - A two-layered model that captures the segregation of drivers in traffic networks due to information sharing and learning processes. This model does not assume perfect information, rather it starts from the principle that travellers form groups where information is shared among its members. Therefore, a decision is taken based not only on the user's experience but also on the decision of other group members. The two layers to this model are two interacting networks, a conceptual communication network (the cyber layer) and a day-to-day transport network capturing traffic information (the physical layer). The experiments made showed a strong positive correlation between the connectivity of the communication network and the convergence of the network. The proposed model can be used to study the influence of information sharing not only when it comes to convergence of the network but also to its stability, resilience and robustness.
- [Li et al., 2017] - An optimization model with different types of traveler knowledge is introduced. The model takes into account the capacity distribution across a large number of days (also referenced as scenarios) and categorizes travelers in two classes, those with access to perfect traffic information and those with information about expected traffic conditions and a confidence level. The objective of this work is to evaluate the impact of providing traffic information within a congested network. This non-linear optimization-based analysis method takes into account traveler routing behaviour with day-specific travel times across several representative random scenarios and develops on long-term steady state solutions with different types of traveler information users over multiple days.

7 User Stories

In this section we formulate User Stories for the simulation scenarios, in order to better define the simulation scenarios.

7.1 Citizen Perspective

- As a citizen, I want to choose whether or not I want to travel.
- As a citizen, I want to choose where I want to go.
- As a citizen, I want to choose my means of transportation.
- As a citizen, I want to choose the path I'll take to my destination.
- As a citizen, I want to learn to choose the path that maximizes my utility.

7.2 Simulation Owner perspective

- As the simulation owner, I want to evaluate performance indicators on different simulation scenarios, by varying the percentage of users who use an Advanced Traveler Information Systems (ATIS).
- As the simulation owner, I want to test simulation scenarios with different network topologies.
- As the simulation owner, I want to test simulation scenarios with different traffic densities.
- As the simulation owner, I want to re-engineer business processes associated with traffic flows.

8 Work Plan

- **1st - 2nd weeks** Project planning;
- **3rd - 4th weeks** Research state-of-the-art approaches and references;
- **5th - 10th weeks** Project development; Problem formalization; Evaluation of which performance metrics and indicators to use; Solution development; Experimentation; Analysis of results.
- **11th - 12th weeks** Writing of research paper.

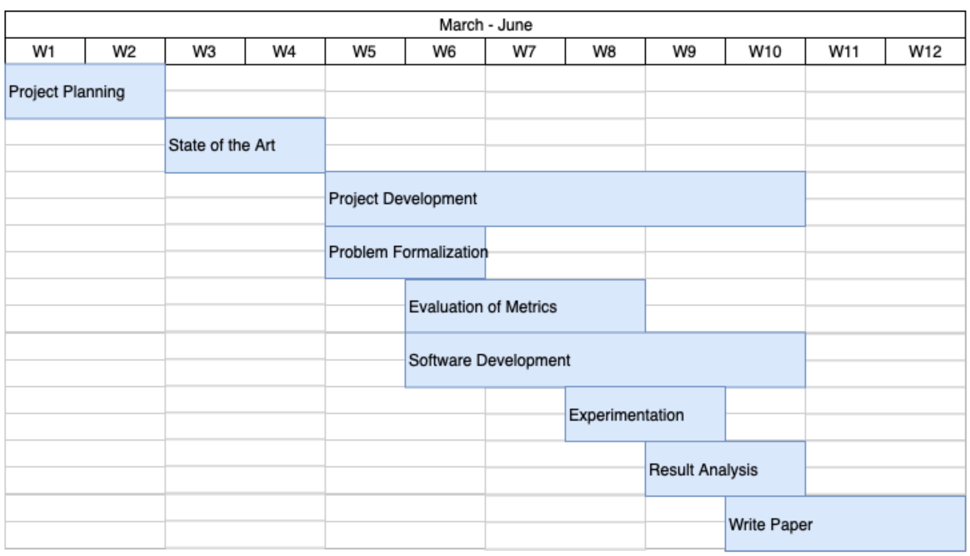

Fig. 1. Work plan represented as a Gantt chart

References

[Capela et al., 2014] Capela, J., Machado, P., Castro Silva, D., and Henriques Abreu, P. (2014). An inverted ant colony optimization approach to traffic. *Engineering Applications of Artificial Intelligence*, 36:122–133.

[Guriau et al., 2016] Guriau, M., Billot, R., Faouzi, N.-E. E., Monteil, J., Armetta, F., and Hassas, S. (2016). How to assess the benefits of connected vehicles? a simulation framework for the design of cooperative traffic management strategies. *Transportation Research Part C: Emerging Technologies*, 67:266 – 279.

[Kaparias et al., 2011] Kaparias, I., Bell, M., and Tomassini, M. (2011). Key performance indicators for traffic management and intelligent transport systems. *ISIS*, 14(06).

[Li et al., 2017] Li, M., Rouphail, N. M., Mahmoudi, M., Liu, J., and Zhou, X. (2017). Multi-scenario optimization approach for assessing the impacts of advanced traffic information under realistic stochastic capacity distributions. *Transportation Research Part C: Emerging Technologies*, 77:113 – 133.

[Louf and Barthelemy, 2014] Louf, R. and Barthelemy, M. (2014). A typology of street patterns. *Journal of The Royal Society Interface*, 11:20140924.

[Mobile, 2019] Mobile, W. (2009–2019). Waze. http://www.waze.com/.

[Shang et al., 2017] Shang, W., Han, K., Ochieng, W., and Angeloudis, P. (2017). Agent-based day-to-day traffic network model with information percolation. *Transportmetrica A: Transport Science*, 13(1):38–66.