Multi-Agent Dynamic Coupling for Cooperative Vehicles Modeling
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Abstract
Cooperative Intelligent Transportation Systems (C-ITS) are complex systems well-suited to a multi-agent modeling. We propose a multi-agent based modeling of a C-ITS, that couples 3 dynamics (physical, informational and control dynamics) in order to ensure a smooth cooperation between non cooperative and cooperative vehicles, that communicate with each other (V2V communication) and the infrastructure (I2V and V2I communication). We present our multi-agent model, tested through simulations using real traffic data and integrated into our extension of the Multi-model Open-source Vehicular-traffic SIMulator (MovSim).

Introduction
Traffic management relies on complex systems (i.e. Intelligent Transportation Systems) well suited to agent-based paradigms, as illustrated by several approaches (see (Chen and Cheng 2010) for a review). A way to improve traffic flow is to introduce cooperation between vehicles through their embedded communication and perception capabilities. Such cooperative vehicles can communicate with each other (Vehicle to Vehicle-V2V communication) and exchange information with the infrastructure part of Cooperative Systems (Infrastructure to Vehicle-I2V and Vehicle to Infrastructure-V2I). Infrastructure is composed of Road Side Units (RSU) spaced along the road network, able to collect information on their dedicated section and ensuring a decentralized control of cooperative vehicles.

In this paper, we present our three-layer multi-agent framework, which has been implemented for cooperative traffic modeling as an extension of an existing traffic simulator.

A three-layer framework

Overview
With respect to the governance of the system, the purpose is to make use of reliable information to influence the movements of vehicles while limiting traffic disturbances, and hence homogenize traffic flow.

Figure 1 presents the interaction between three layers:

- the physical layer concerns the vehicle dynamics rules and estimates on its dynamics,
- the communication layer governs the information exchanges through proximity and reliability rules,
- the trust layer models information reliability and enables an agent to evaluate trust in others.

Communication and trust layers influence the physical layer and hence vehicles behavior.

Extending a microscopic traffic simulator
The Multi-model Open-source Vehicular traffic SIMulator (MovSim) from (Treiber and Kesting 2013) has been selected to be extended for cooperative traffic modeling, because of its generic design pattern and the several already implemented models. Multi-agent concepts, the three-layer framework and cooperative vehicles interactions have been implemented in our extension of MovSim, illustrated in figure 2. We extend the simulator by adding new physical models (cooperative behavior) and new entities as the RSU. Both vehicles and infrastructure inherit from a generic agent framework which provides sensors, effectors, and a self-decision process to make them autonomous.
Introducing cooperation

A way to introduce cooperation at a microscopic level is to derive a multi-anticipative car following model able to describe vehicle to vehicle (V2V) communication and to improve traffic stability (Ge, Dai, and Dong 2006). We define the bilateral multi-anticipation law as a combination of weighted influences from surrounding vehicles (see (Monteil et al. 2014b) for more details). Cooperative vehicles can then take advantage of all the perceived data (from sensors, communication) to construct an extended perception by considering more than one vehicle ahead (anticipation) and behind (bilateral). All model parameters are randomly picked from a calibrated set (Monteil et al. 2014a) to reproduce drivers variability.

Conclusion and future work

We have proposed a multi-agent based extension of an existing simulator to model complex interactions between cooperative vehicles and, potentially, to and from the infrastructure. The implemented framework models both communications (information dynamics) and physical interactions. The additional control using the concept of trust improves the robustness of the model against perturbations introduced by sensors unreliability. The next step is to test different traffic management actions and we plan to develop learning strategies for both RSU and cooperative vehicles thanks to trust concepts.

References


