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:

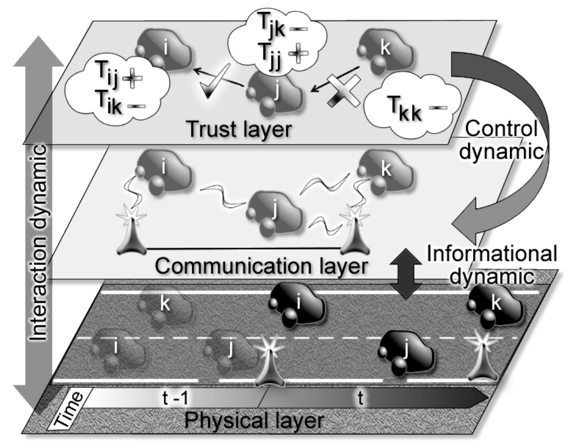

Figure 1: Interacting layers

- 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.

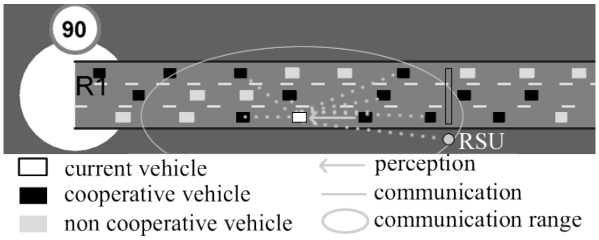

Figure 2: Screenshot of the cooperative traffic view in our extended version of MovSim simulator

Developing Sensor-oriented perception

Cooperative vehicles interact with their environment at the physical level. Each vehicle is designed as an autonomous system able to sense its surrounding environment thanks to embedded sensors, and then make a decision from this perception which is finally translated into a physical interaction (here, a longitudinal behavior *i.e.* an acceleration). Cooperative vehicles are equipped with a localization device (for instance GPS receiver) and a front laser infrared telemeter (which senses relative distance and speed to immediate leader); this information is completed by communication. Non-cooperative vehicles perception is limited to their immediate leader (relative distance/speed) and they do not have the ability to communicate.

Adding communication capabilities

As autonomous agents, cooperative vehicles can send and receive information. We define three types of exchanged information embedded in dedicated messages:

- Measurement message: holds all the sensors values shared by a vehicle to surrounding ones (broadcasting);
- Trust message: keeps the witness information concerning the trust an agent has in another one;
- Speed recommendation message: holds the speed recommendation broadcasted by RSU to the vehicles according to perceived aggregated traffic conditions.

All information embedded in messages helps the cooperative vehicles to extend their perception during their autonomous decision process. The communication layer design allows to implement other messages which are handled during the agents self-decision process.

Implementing self-decision

The notion of trust is related to the concept of delegation, which is critical in Multi-Agent Systems (Castelfranchi and Falcone 1998). Cooperative traffic is a perfect example of a delegation-based system since the action of a vehicle directly relies on the actions of other vehicles. According to the designed three layers, cooperative vehicles can evaluate sensor reliability by comparing redundant information. Then, a *TrustNet* (Schillo et al. 2000) local data structure enables the agents to keep trust information from direct and indirect sources in order to weight the information they received. Other computational trust models can be implemented within the trust layer.

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.

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