An Integrated Framework for Multi-Agent Traffic Simulation using SUMO and JADE

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Abstract. The rapid and ever-increasing population and urban activities have imposed a massive demand on Urban Transportation Systems (UTS). These systems were not prepared for such events, so traffic congestion and defective metropolitan systems were a direct consequence of this deficiency. The explosion of the computing technology brought together expertise from different scientific and technical disciplines giving birth to new computing and communication paradigms. Taking advantage of the modelling and simulation technologies we have devised a framework that combines the characteristics of the Multi-Agent System Development Framework, JADE, and the microscopic traffic simulator, SUMO, for the development and appraisal of multi-agent traffic solutions in contemporary traffic and transportation systems.

Keywords: SUMO, JADE, multi-agent systems, artificial societies, artificial transportation systems.

1 Introduction

The rapid and ever-increasing population and urban activities has imposed a massive demand on urban transportation systems [6]. Efficient transportation systems are crucial to an industrialized society and being its main communication infrastructure, rapid and effective solutions for traffic congestion are needed to prevent its negative impact on the city's social and economic welfare. A way to address this issue is resorting to the use of modelling and simulation as an imperative tool at decision maker's hands to effectively devise appropriate policies and management strategies.

The transportation domain is characterized by a high degree of uncertainty and dynamicity especially when considered in an urban context. Therefore, the use of simulation can result into improvements to the design and analysis of several management solutions for the optimization of the urban network throughput. Such an approach can provide us with the possibility of comparing studies between new infrastructure schemes or control algorithms without having to interfere with the real world directly, causing unnecessary and harmful disruptions.

Taking advantage of the simulation technologies a new generation of mobility systems, Intelligent Transportation Systems (ITS), arose allowing these algorithms to be implemented and polished before being deployed [4]. ITS is growing as the result of the synergy between Information and Communication Technologies and the Transportation Systems, which include vehicles and networks that move people and goods. Traditionally, mathematical equations have been used to describe the drivers and pedestrians movements taking into account several flow restraints, and used to tackle traffic related issues and to model them. According to this approach, traffic problems were handled as a whole, and the solution was a product of the fulfilment of all trips.

The formalization of the ITS concept is to be considered a great achievement by the transportation engineering community of practitioners and researchers. However, in the last few years the traffic and transportation domain has made a breakthrough in the way it is conceived, implemented and managed. The explosion of the computing technology in terms of applications we are experimenting in the last decade brought together expertise from different scientific and technical disciplines giving birth to new computing and communication paradigms. New type of socio-technical systems arose from such mutual conjunctions where people and technology live in mutual symbiosis. The transportation and, generally speaking urban domain could not be impermeable to such revolution. Indeed it proves to be a valid test-bed where such new social and technological paradigms can be applied.

Normally, in the development of traffic solutions the use of a simulator is very straightforward related to traffic flow and junctions management. Despite many attempts and published papers, the solutions presented to date do not make full use of the concept of intelligent agents. Additionally, the Multi-Agent Systems (MAS) approach has become recognized as a useful approach for modelling and simulating complex systems [5].

Keeping in mind the revolution in urban transportation mentioned above and guided by the need to design more human-centric economic and environmental solutions, a framework that generates an urban context, meaning a traffic network, respective infrastructure and its population, is necessary so that analysts and designers can study, develop and evaluate their policies and strategies.

In this paper, we present a framework that comprises all these requirements, providing community of researchers and practitioners with a tool that can instantiate an heterogeneous Artificial Society (AS) of drivers and Intelligent Traffic Light management solutions, immersed in a realistic traffic environment. The concept of AS can be used by traffic managers or government institutions as a test-bed for strategies and policies analysis towards the concept of social awareness for a sustainable use of resources.

Combining a powerful and standardized MAS development framework - JADE, with a large-scale microscopic traffic simulator - SUMO, our approach allows different types of studies, namely traffic control algorithms, service design, and also studies for the assessment of new policies and vehicle-to-vehicle communication applications.

The remainder of the paper is organized as follows. Section 2 discusses the methodological approach, proposing a general architecture underlying the characteristics of each component. Section 3 describes in detail the implementation procedure, whereas Section 4 presents a simple proof of concept scenario. Finally Section 5 draws some conclusion and points out future developments.

2 Methodology

Having to deal with atomic entities in the transportation domain the detail level comes down to the vehicle or better to the driver resolution. An Agent-Based Modelling approach seems to be the appropriate way to represent the road traffic environment, infrastructures and driver entities that live and interact in and with it. The microscopic traffic simulator chosen to provide the environment and traffic entities simulation is SUMO.

SUMO (**S**imulation of **U**rban **MO**bility) [1] is an open-source, highly portable, microscopic and multi-model traffic simulation package designed to handle large road networks and to establish a common test-bed for algorithms and models from traffic research.

SUMO is a microscopic traffic simulator, very popular in the research community, with a high number of scientific papers referring to it. Besides the mentioned features it also facilitates interoperability with external applications during run time using TraCI (**Tr**affic **C**ontrol **I**nterface) [8]. This interface uses a TCP based client/server architecture providing access to SUMO. It opens a port in SUMO's simulation process and awaits well-defined outbound commands.

On the other side of our approach is **JADE** (**J**ava **A**gent **DE**velopment Framework), a free software framework to develop agent-based applications. Its goal is to simplify the development while ensuring standard compliance through a comprehensive set of system services and agents. JADE is fully implemented in Java language and is compliant with the FIPA (Foundation for Intelligent Physical Agents) specifications.

This framework can be considered an agent middleware that implements an Agent Platform and a development framework. It deals with all those aspects that are not peculiar of the agent internals and that are independent of the applications, such as message transport, encoding and parsing, or agent life-cycle (AMS).

The agent platform can be dispersed on several computers, where each runs a single Java Virtual Machine (JVM). Each JVM is basically a container of agents that provides a complete run time environment for agent execution and allows several agents to concurrently execute on the same host.

TraSMAPI (**Tra**ffic **S**imulation **M**anager **A**pplication **P**rogramming **I**nterface) is another component in our approach, and can be seen as a generic microscopic traffic simulator API. TraSMAPI allows real-time communication between traffic-management agents and the environment created by various simulators.

Its API offers an abstraction level higher than the API of most common Microscopic Traffic Simulators so that, ideally, the solution should be independent of the microscopic simulator choice.

Taking into consideration all the general goal and software selection we have devised the following architecture depicted in Fig. 1.

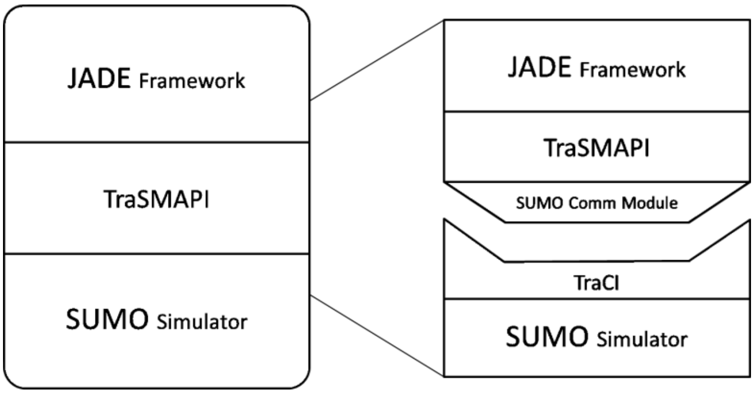

Fig. 1. Framework Architecture.

The SUMO Simulator offers an API allowing access to its simulation state - TraCI [8]. For an external application to communicate with this software it must obey TraCI's communication protocol and messages types. The Sumo Communication Module attached to TraSMAPI, converts this low-level simulator's API into a higher-level one, which will be then used by our artificial society of drivers and Traffic Lights infrastructure. These will be implemented in JADE's MAS development framework coupled with TraSMAPI, as illustrated in Fig. 1.

3 Implementation

Our goal is to have a heterogeneous artificial society of drivers in JADE's agent platform, each of its entities responsible for one vehicle in the SUMO's traffic environment.

However it would be very computationally expensive to simulate hundreds or thousands of vehicles and driver's decision-making in JADE. Hence, we have adopted the delegated-agent concept, which has been used in [7], to separate the tactical from the strategic layer of the agent, and execute them in parallel, thus improving performance, Fig. 2.

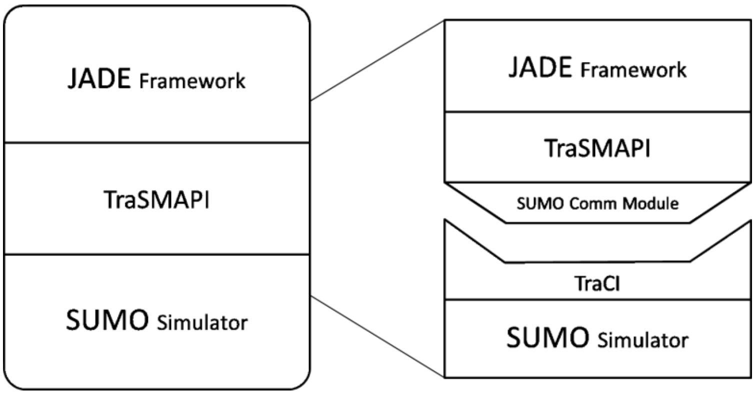

Fig. 2. Driver's reasoning layers: tactic-reactive layer in SUMO and strategic-cognitive layer in JADE.

The tactic-reactive layer is delegated to SUMO's microscopic traffic simulation model, such as car following [2], leaving the cognitive-strategic layer to the agent implemented in JADE's agent platform.

Aiming at this purpose we must make possible the association between a Driver Agent, instantiated in JADE's agent platform and a vehicle simulated by the microscopic traffic simulator SUMO.

In order to achieve these ideas, we need to extend the scope of TrasMAPI, enabling it to build an abstraction over a vehicle entity, as depicted in Fig. 3.

Thus, we have implemented the communication protocol concerning the vehicle's methods for variable retrieval or state change taking into account the compliance with the well-defined TraCI's instructions. For more detailed information, see TraCI's documentation and reference [8], where the protocol and message flow are presented and explained.

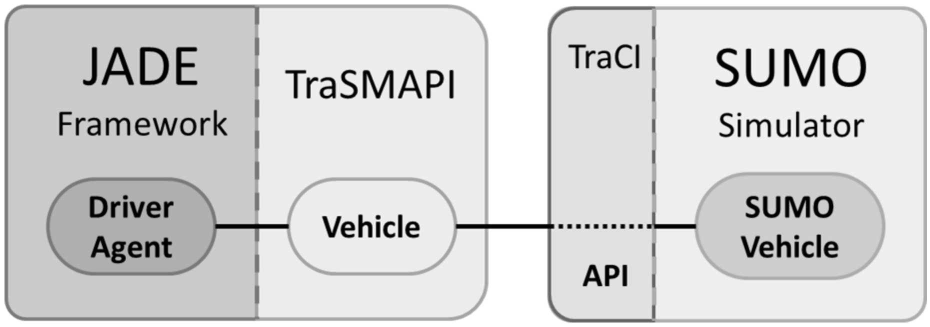

Fig. 3. Vehicle entity abstraction through the architectural design.

4 Experimentation Scenario

As a proof of concept for our test-bed, we have used and improved the German city of Eichstätt transportation network, using the JOSM application, correcting some intersections and lane cardinality, as seen in Fig. 4. Graphically we added the GoogleMaps decals to improve the user immersion during the visualization of the simulation process in run time.

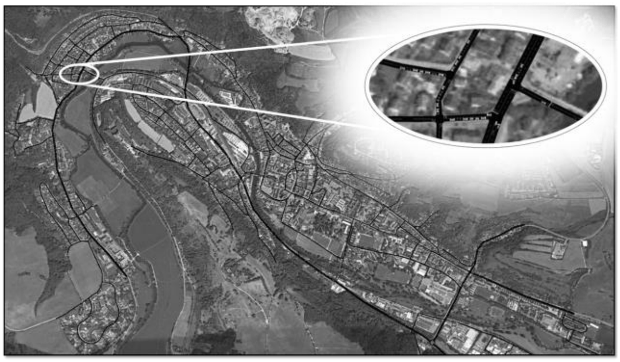

Fig. 4. Eichstätt transportation network.

The configuration files used to load SUMO simulation are only the network file and GUI settings. In this experimental set-up we intend to reproduce the drivers' decision-making process in route choice accounting for previous travel times.

With our framework we can instantiate a Driver to each vehicle simulated in SUMO. Therefore one may use all the methods that this simulated instance has, such as change destination, speed, route, among others.

In the beginning of the simulation it is given to each entity of the AS a random origin edge and orientation and a different random destination. With this, the agents' reactive layer in SUMO can make use of its shortest path algorithms and calculate the best route based on time travel to accomplish each driver's desire.

As a proof of concept, each Driver sets a value to its travel time table in SUMO, so that when the rerouting by travel-time algorithm is invoked, it will take into account the new table's values. This attitude argues in favour of the drivers' awareness and decision-making capabilities.

The instantiated traffic-light entities are an extension of a previous experience concerning the concept of advisory-based traffic control. The interested reader is referred to [3] for more details and further discussion.

4 Conclusions

Simulation proved to be an effective approach to analysing and designing novel traffic solutions in socio-technical systems. Traffic systems have been subjected to a lot of improvements in last decades and travellers have, in general, witnessed a revolution in the way a trip is planned and performed in urban networks. Hence, facing the current traffic situation in most developed countries it is now imperative to foster new transportation solutions using state-of-the-art technologies.

User is now a central figure in the new vision of urban systems, and most simulators follow a macro/microscopic approach as an attempt to improve the representation of traffic flow and management rather the traveller behaviour. Therefore we present a powerful framework for instantiating heterogeneous multi-agent systems representing different aspects of the traffic domain such as the socio-technical issues, embedded in intelligent artefacts, aiming to designing more human-centric and hence sustainable solutions. For this purpose two well-supported and popular platforms in the researcher and practitioner communities have been used, namely the JADE framework for developing agent-based systems and the SUMO microscopic traffic simulator.

The resulting tool also reveals a great flexibility and potential for multi-agent system development in terms of the socio-econometric aspects of the traffic domain, since one can easily develop his own Artificial Societies of drivers (synthetic population) immersed in a realistic representation of the urban traffic environment, where each agents is represented with its own preferences and beliefs. Such a society can be used thus to design solutions based on individual or collective intelligence and participation (social-aware attitudes) or as a test-bed for policy evaluation by governmental institutions. Experimentations with such an AS could provide the community of researchers and practitioners with better insights into the formation of emergent mobility patterns and how information or knowledge can affect the drivers' decision-making process.

In the present work we have shown how to instantiate a synthetic population of drivers on top of the SUMO traffic environment. This population resembles and can be considered as an artificial society, since it has all necessary characteristics, namely coordination, competition and collaboration. A demonstration of using the tool is described where driver agents decide to change their destination or to follow a different route according to their individual desires.

Moreover, we have also extended the ability of our framework to build artificial agents for traffic management through traffic light control. With this integrated tool, one can build and test with multi-domain test-beds. From vehicle-to-X (V2X, where X stands for vehicle/infrastructure/grid) scenarios to more complex driver/traffic-light interaction, practitioners and engineers may evaluate contemporary ITS solutions in their very essence, simulated entities can are now endowed with reasoning abilities in proposed artificial society of travellers and ITS-technologies.

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