A Cooperative Multi-agent System Simulation Model for Urban Traffic Intelligent Control

Xu JIN, Mhamed ITMI, Habib ABDULRAB
INSA-LITIS, BP 8, Place E. Blondel, 76131 Mt St-Aignan Cedex, FRANCE
(xujin948@yahoo.com, itmi@insa-rouen.fr, abdulrab@insa-rouen.fr)

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Abstract

Agent-based urban traffic simulation has been looked as an efficient tool for traffic planning. However, the main problem is how to build an agent-based model for traffic simulation. This research presents an urban traffic information intelligent control model, which adopts a multi-agents coordination approach for urban traffic information control to coordinate the traffic network. In this paper, we propose a new traffic information intelligent control hybrid model based on multi-agent system that performs the basic interface, planning and supports services for managing different types of demand responsive transportation. In this research, we expose the main features and the behaviors exhibited of the multi-agent system. Based on this model, a simplified multi-agent traffic information control system can be developed that is effective for reducing traffic congestion and air pollution.

1. INTRODUCTION

The current transportation situation, main objectives of demand responsive transport services and advantages of the multi-agent concept are described in this section:

1.1. Actual Situation

In recent years, urban traffic congestion and air pollution have become huge problems in many cities across many countries. In order to reduce congestion and air pollution, many governments have invested in improving their city infrastructures. However, infrastructure improvements are very costly to undertake; hence, existing infrastructure and vehicles have to be used more efficiently. Therefore, research on new traffic information control and traffic guidance strategies are particularly necessary and important. The application of new information technologies such as multi-agent technologies to urban traffic information control has made it possible to create and deploy more intelligent traffic management.

1.2. Objectives

To reduce traffic congestion and air pollution, it is necessary to conduct further research on the various characteristics of traffic flow patterns. In general, road traffic system consists of many autonomous, such as vehicle users, public transportation systems, traffic lights and traffic management centre, which distribute over a large area and interact with one another to achieve an individual goal. Our objective is to increase the efficient passages of every vehicle, while at the same time reduce the number of vehicles on the street. This could result in reduction in air pollution caused by the vehicle and traffic congestion.

1.3. Demand Responsive Transport (DRT) Services

Demand responsive transport services are planning computer systems in charge of the assignment and scheduling of client's traffic requests and using different vehicles available for these purposes. DRT services can provide rapid response transport services 'on demand' from the passengers, and offer greater flexibility in time and location for their clients. Moreover, it could also increase the number of passengers in every vehicle; thereby helping reduce environmental pollution and traffic congestion.

1.4. Advantages of the Multi-agents Concept

A multi-agent system is an autonomous intelligent computer system, in which every agent always has a certain level of intelligence. The level of an agent's intelligence could vary from having pre-determined roles and responsibilities to a learning entity. A multi-agent system is an aggregate of agents, with the objective of decomposing a larger system into several smaller agent systems in which they communicate and cooperate with one other. So agent-based model can produce high-quality simulations for complex and large-scale system behaviors, such as the urban traffic system, a large-scale complex system with multiple entities and complicated relationships among them. Hence, the application of multi-agent system to model and study urban traffic information systems is highly suitable and can be very efficient.

In this paper, we propose a set of new traffic information intelligent control hybrid model based on multi-agent

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systems that is able to automatically carry out traffic information control for DRT services. This paper is organized as follows: The next section describes related work on urban traffic simulation. Section 3 describes the problem to solve in greater detail. Section 4 describes the framework we have designed for the traffic information control based on MAS. In section 5 we define the agents for our problem domain. Section 6 introduces the agent planning sequence model. Finally, Section 7 concludes the paper.

2. RELATED WORK

The application of new multi-agent technologies to urban traffic information systems has made it possible to create intelligent systems for traffic control and management: the so-called Intelligent Traffic Systems (ITS) [1] or Advanced Traffic Management Systems (ATMS). The basic task of ITS is to support road managers in traffic management tasks [2].

Because urban traffic networks have interrupted traffic flow, they have to effectively manage a high quantity of vehicles in many small road sections. On the other side, they also have to deal with a non-interrupted flow and use traffic sensors for traffic data information integration. These features make it difficult for real time traffic management. The urban traffic simulators can be classified into two main kinds: macroscopic simulator and microscopic simulators. Macroscopic simulators use mathematical models that describe the flows of all vehicles. In microscopic simulator, each element is modeled separately, which allow it to interact with other elements.

Multi-agent systems are an efficient tool for the basis of urban traffic simulator. Many researchers have made studies on this subject. In [3], Patrick A. M. Ehlert and Leon J. M. Rothkrantz designed driving agents, which can exhibit human-like behaviors ranging from slow and careful to fast and aggressive driving behaviors. In [4], J. Miguel Leitao uses autonomous and controllable agent to model both the traffic environment and the controlled vehicles. And their scripting language is based in a well-known graphical language, Grafcet. In [5], Joacbim Wahle and Michael Schreckenberg present and review a framework for online simulations and predictions, which are based on the combination of real-world traffic data and a multi-agent traffic flow model.

3. PROBLEM TO SLOVE

3.1. Existing Solution for DRT

3.1.1. Telematics-based DRT

In order to alleviate the problems encountered in traditional transit service several flexible services were studied and offered. Telematics-based DRT systems based on traditional telecommunication technology has played a role in providing equitable transportation service to elderly and handicapped persons who have difficulty in accessing regular public transit systems. Telematics-based DRT systems are based upon organization via a Travel Dispatch Centre using booking and reservation systems which have the capability to dynamically assign passengers to vehicles and optimize the routes. A schematic representation of telematics-based DRT services is shown in Figure 1.

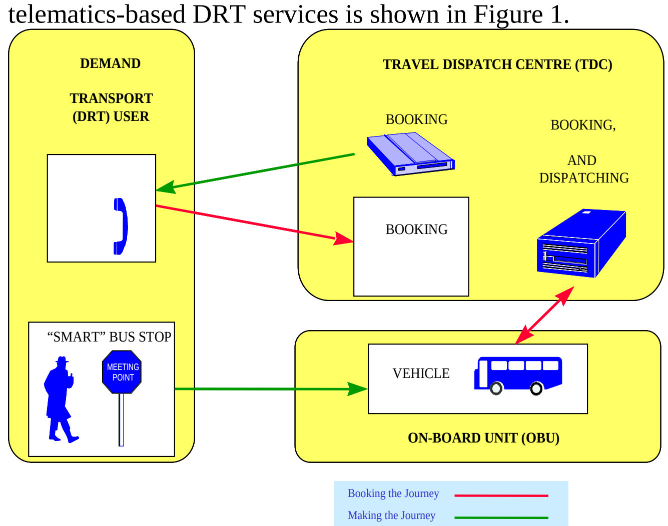

Fig. 1. Traditional Telematics Based DRT

Because it is based on traditional telecommunication technology, the telematics-based DRT services response to client is slow, and sometimes it is difficult to find the best solution for client, besides being unstable.

3.1.2. Intelligent Platform -based DRT

Intelligent Platform-based DRT systems are based upon an intelligent platform which has the capacity to dynamically assign passengers to vehicles and optimize the routes. These systems are used to provide real-time information on the status and location of the vehicle for the client. A schematic representation of Intelligent Platform-based DRT services is shown in Figure 2.

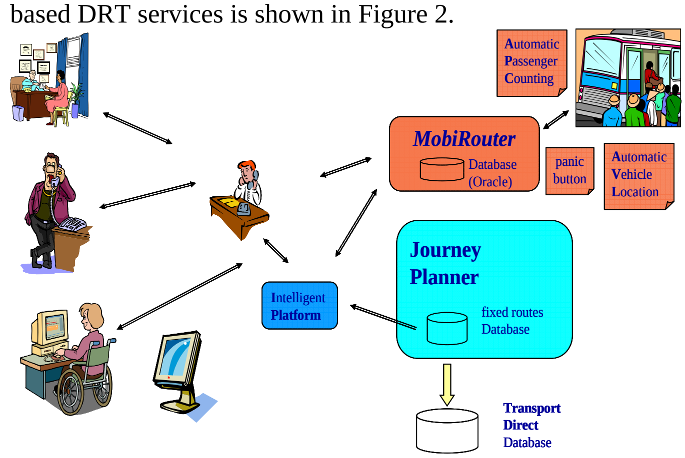

Fig. 2. Intelligent Platform Based DRT

The Intelligent Platform-based DRT services respond to clients more quickly, enhances mobility and is more reliable.

3.2. Approach for the Problem

We propose an approach based on multiple agents. Multi-agent systems can exhibit more complex behaviours such as: autonomy, learning, aggregation of agents: decompose the larger task to several small agents, and communicate and cooperate with each other.

Agent-based model has been used for simulation if complex large-scale system behaviours. So the application of multi-agent system to DRT system is suitable.

In short, the problem can be stated as follows: "How can we make agents to cooperate so as to give the client the best trip solution for his transportation request?" (See Fig.3)

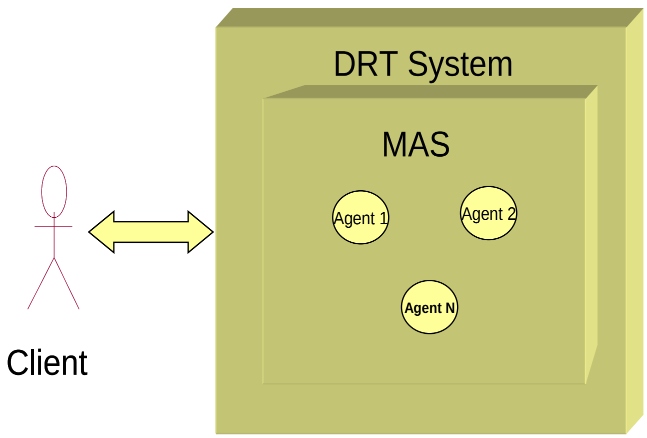

Fig.3. Agent Based DRT

In the following sections, we propose our agent-based hybrid model for traffic information intelligent control simulation that perform the basic interface, planning and support services for managing different types of DRT services.

4. FRAMEWORK OF SYSTEM

This section describes the agent framework used for urban traffic information intelligent control. The system agent framework is composed of three layers. The first layer is an agent platform (Jade platform), on top of it is the multi-agent architecture and finally there is the urban traffic information system. (See Fig. 4)

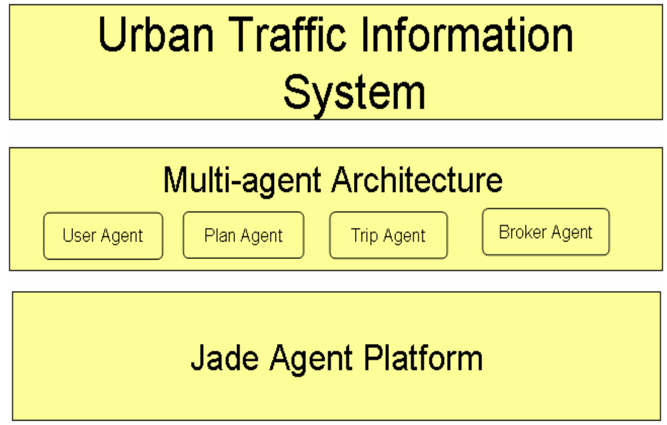

Fig. 4. System Agent Framework

In the lowest layer, the Jade agent platform [6] provides a distributed environment organized in containers where agents can reside and communicate. The JADE platform provides an agent management system (AMS) in charge of agent identification and localization, a directory facilitator (DF) for identifying agents by their offered services and a message transport system devoted to support the communication between agents and containers.

On top of the JADE agent platform resides the multi-agent architecture [7], providing the base agents, structures and semantics for implementing urban traffic information intelligent control system [8]. The agents are of four kinds as shown in Fig. 4: the user agent, which is in-charge of the communication with the different parties involved (vehicles, clients, other systems) by means of different devices [9]; the plan agents, which are in-charge of processing, assigning and scheduling the received trip requests encapsulate the assignment and scheduling of the transportation requests processed by the system; the trip agent, which is in-charge of modeling each real vehicle for the system [10]; and the broker agent, which is in-charge of the matching of transport requests with available vehicles [11].

Finally, over the first two layers an urban traffic information system layer is implemented. By extending and implementing the base agents system provided by the architecture, a concrete trips planning and traffic information control system can be developed.

5. THE DEFINITION OF AGENTS

This section describes the main agents in the multi-agent architecture used for urban traffic information intelligent control system.

5.1. User Agent

This agent represents a human user and their (allowed) interactions with system. It is responsible for capturing all the client's requirements. It provides communication and interoperability between the end user and the urban traffic information intelligent transportation system.

5.2. Plan Agent

This agent is in-charge of processing, assigning and scheduling the received trip requests. It is responsible for coordination with the other agents and the administration of the transportation service. It helps in the collaboration among agents that provide support to related functions, such as the matching of request to vehicles, the geographical data access, the accountability of the transactions and the service payment among others.

5.3. Trip Agent

This agent is in-charge of modeling each real vehicle in the system. It manages the trip plan of the vehicle and provides interoperability between the vehicle and the DRT system. It makes proposals for the actual plan, processes change information by the planner agent, updates the plan and reschedules the remaining requests.

5.4. Broker Agent

This agent is in-charge of matching transport requests with available vehicles. It manages service descriptions coming from vehicles side and client's side. The broker agent only provides a list of possible vehicle candidates, but it does not perform the assignment of transport requests to vehicles as the plan agent.

6. AGENT PLANNING SEQUENCE MODEL DESIGN

The agent planning sequence model design could be carried out by either a centralized model or a decentralized model. The differences among these two options are briefly described [12] and then we present our hybrid model for the solution.

The centralized model considers the optimization of the entire system as the most important thing. For this reason, it pursues the minimization of all disutility function that considers the agent operator (number of vehicles required, bus occupancy and slack times) [13] and the served users (effective waiting time, effective excess ride time).

The decentralized model is based on self-interested actors. This means that each agent seeks the maximization of its own utility. The hybrid model uses a third actor, the planner for applying filtering policies [14]. The agent behaves in a self-interested way as in the decentralized model approach [15]. The difference from the decentralized model is that the Planner filters the proposals by using different policies and hence is more stable. The characters and differences of them are briefly described below.

6.1. Centralized Model

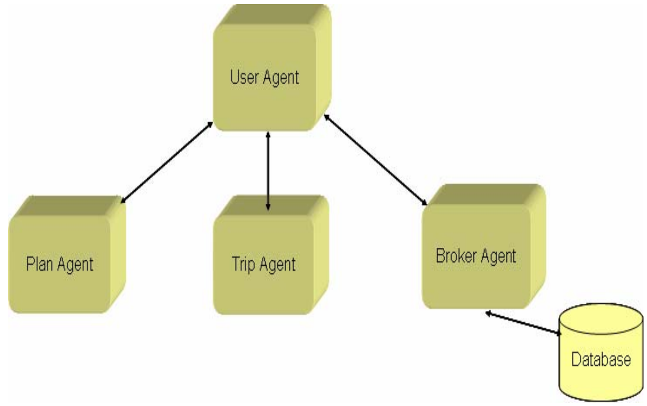

Fig. 5. Centralized Model

In the centralized model

1) The focus is on optimization of the global utility for the system.
2) Minimize the disutility operator. (number of vehicles required, fixed and variable traveling costs)
3) The served for users is more effective. Minimized total waiting time.

Since the urban traffic information system is not always linear, when something is amiss in the communication between the User agent and the Plan agent, the Trip agent and the Broker agent, the centralized system will be unstable. (See Fig. 5)

6.2. Decentralized Mode

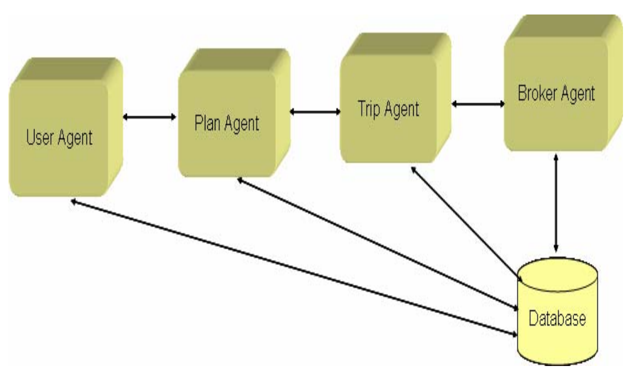

Fig. 6. Decentralized Model

In the decentralized model

1) Each agent is interested in maximizing its own utility.
2) Minimize total slack time.
3) Results in excess travel time and waiting time. (See Fig. 6)

6.3. Hybrid Model

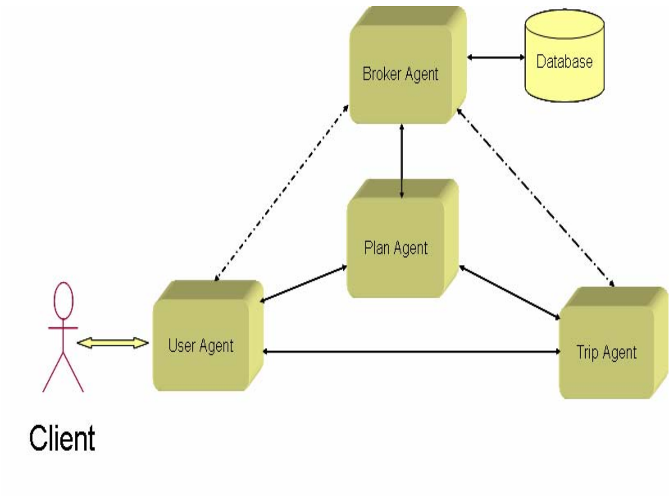

Fig. 7. Hybrid Model

In the hybrid model

1) A hybrid structure is used.
2) The plan agent applies filtering policies.
3) The Plan agent uses different policies to filter filter proposals received, whereby it can discard the worst proposal. So it can give the client the best solution. And the model has more stability. (See Fig. 7)

In this model the User agent's job is to represent the client and his decisions of the transportation request. So it also is responsible for the result. Since the real client do not directly communicate with the Plan agent, the User agent also constitutes a kind of client towards the transportation system, which is represented by the Plan agent. So when the clients change their requests in a dynamic scenario to deal with unexpected situations, the User agent also have responsibility for communicating the client about any subsequent changes to the original deal. These unexpected situations must also be communicated with the other agents. The User agent must communicate to the Plan agent about changes on the clients' desires (e.g. change the lieu, delays, and trip cancellations). The Plan agent will implement a negation with the Trip agent and the Broker agent about the changed request. After filtering a list of proposals, the User agent gives the client (through his User agent) the most suitable trip solution offered by the Plan agent. At the same time, the User agent holds a request profile containing the client's preferences concerning the trip. It also holds some negotiation capabilities with the Plan agent.

The Plan agent processes all the client's requests coming through the User agent. It is the agent that in charge of executing a negotiation role in the layer. In addition, the Plan agent is in charge of implementing the assignment through filtering policies and the negotiation process. It holds a list containing the trip requests being processed and a list of filtering policies to apply to the trip solutions. Before the Trip agent gives the proposals to the Plan agent, it will communicate with the Broker agent that manages the trip plan of the vehicle and other traffic information. When the Plan agent receives the trip-proposals from the trip agent, it can implement different filtering policies that include: minimize the number of used vehicles, the waiting time, the travel time, and the total traveled distance. This point is very important for the client that the system just like a "Black Box" [16]. The clients propose the request to the User agent and get the best solution.

To sum up, a comparison of three models has shown that the Hybrid model is able to provide resolution for the gaps in performance between the centralized and decentralized models. The hybrid model gives better results for the clients, in terms of excess travel time when compared with the centralized model. On the other hand, when compared with decentralized model, it gives better results for waiting time. And the most important thing is the hybrid model is more stable than the centralized and decentralized models.

7. CONCLUSION

In this paper we have described a multi-agent architecture for the urban traffic information intelligent control system, and proposed a new hybrid model.

Because in the real system, the stability is the most important, and the Hybrid model is more efficient. After we compare the three models, the multi-agent hybrid model is the best model for urban traffic information intelligent control system.

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References

[1] Cascetta E. Transportation Systems Engineering: Theory and Methods. Kluwer Academic Press, 2001 ISBN 0792367928

[2] McQueen B., Intelligent transportation systems architecture Artech House Books, 1999 ISBN 089006525X.

[3] Partich A.M.Ehlert, Leon J.M.Rotbkrantz, "Microscopic traffic simulation with reactive driving agents," *Proceedings of the IEEE Intelligent Transportation Systems Conferenc*e, pp. 860-865, Oakland, CA, USA, August 2001.

[4] J. Miguel Leitao, A. August SowF. Nunces Ferreira, "Graphical Control of Autonomous, Virtual Vehicles," *Proceedings of the IEEE Vehicular Technology Conference*, pp. 507-51 1, Tokyo, Japan, 2000.

[5] Joacbim Wahle, Michael Scbreckenberg, “A Multi-Agent System for On-lie Simulations based on Real-World Traffic Data,” *Proceedings of the International Conference on System Science*s, pp. 1125-1 133, Hawaii,USA, Jan. 2001.

[6] Bellifemine, F. et al, JADE - A FIPA Compliant Agent Framework. C SELT Internal Technical Report, 1999.

[7] Weiss, G., Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence, MIT Press, Massachusetts, USA. 1999.

[8] LIU Xiac-Ming, Wang Fei-Yue, ‘‘Study of City Area Traffic Coordination Control on The Basis of Agent,” *Proceedings of the IEEE Intelligent Transportation Systems Conference*, pp. 758-761, Singapore, September 2002.

[9] Ossowaki Sascha, Jose Cue Ana Garcia-Semo, “A Case of Multiagent Decision Support: Using Autonomous Agents for Urban Traffic Control,” *Lecture Notes in Artificial Intelligence*, pp. 100-111, Vo1.1484, 1998.

[10] Partich A.M.Ehlert, Leon J.M.Rotbkrantz, “Microscopic traffic simulation with reactive driving agents,” *Proceedings of the IEEE Intelligent Transportation Systems Conference*, pp. 860-865, Oakland, CA, USA, August 2001.

[11] Uchimura, K. et al. “Demand responsive services in hierarchical public transportation system”. *IEEE Trans. on Vehicular Technology*, Vol. 51, Issue 4, 2002, pp. 760 – 766.

[12] M. Zeller, R Mock-Hecker, “Modelling Autonomous gents in a nowledge Based Simulation Environment,” P*roceedings of the IEEE International Conference on Tools with AI*, pp, 412-415, Boston, Massachusetts, Nov. 1993.

[13] Transportation Research Board. *Highway Capacity Manual*. 2000

[14] Tomás, Vicente R. et al. *New technologies to work with traffic management plans*. Traffic Technology International-Annual review.2003

[15] Zhang Jin; Wang Hui; Li Ping. Towards the Applications of Multiagent Techniques in Intelligent Transportation Systems. In Proceedings of the *IEEE Int. Conf. on Intelligent Transportation Systems*, Oct. 2003, Vol. 2, pp. 1750 – 1754.

[16] Alan B. Tickle, Robert Andrews, Mostefa Golea, and Joachim Diederich. The truth will come to light: Directions and challenges in extracting the knowledge embedded within trained artificial neural networks. *IEEE Transactions on Neural Networks*, 9(6):1057.1068, 1998.

Biography

XU JIN was born in China, in 1975. In 2002, he received the M.A. degree in communication engineering from the HUST of China. He is currently pursuing the Ph.D. degree in compute science at INSA de Rouen, Rouen, France.

His research interests include intelligent transportation systems, multi-agent systems.