MULTI-AGENTS APPROACH FOR MODELLING TRAFFIC MANAGING SYSTEMS

An Architecture For A Decision-Making Aid Tool

Ahmad ALI, Michelle CHABROL, Michel GOURGAND
Université Blaise Pascal - Clermont-Ferrand II
LIMOS CNRS UMR 6158
Complexe des Cézeaux, 63173 AUBIERE Cedex France.
E-mail : ali@isima.fr, chabrol@isima.fr, gourgand@isima.fr

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ABSTRACT

This paper presents the use of a multi-agents approach to model and simulate the control system of the Urban Traffic Systems (UTS). The objective of the simulation is to bring a decision-making aid to the user in order to provide him the best way of controlling the studied system. Some criteria of performance should be optimized. The use of MadKit as platform of multi-agents systems is satisfying since it allows to implement the behavior of the agents independently. The application of ASDI-mi methodology to the system of control made it possible to specify the various entities of regulation (decision centers) which are the controller, the zone coordinator and the central unit. Each one of these entities manages four types of activities : signalized intersection, variable message signals, common transport vehicles and measures of traffic data. In what concerns the security, this system has a hierarchical structure, however, in most cases the decentralized structure prevails.

1 INTRODUCTION

Our study relates to Urban Traffic Systems (UTS). It focuses on the realization of a decision-making aid tool which aims to improve the quality of service for the users. The problem related to the design of UTS management is the control of decisions coherence in space and time, taking into account the characteristics of the studied systems (dynamic, disturbed) and their environment.

In general, the problem of traffic results in a demand where the users want to use the network to reach a "destination" starting from an "origin" in the best conditions and within a reasonable time. This demand is however higher than the limited capacity of the network.

In order to model, then to simulate the piloting of the UTS, we use a process of modeling requiring the construction of two models:

1. The generic knowledge model (analysis and specification).
2. The action model (design and implementation).

To reduce the complexity of this process we recommend a systemic decomposition in the form of three communicating subsystems: logical (noted LSS), physical (noted PSS) and decisional (noted DSS).

The decisional subsystem, or the control system, contains the operating rules of the UTS. This subsystem is most complex and most involved of the three.

2 STATE OF THE ART

Decision-making aid tools aim to manage a large amount of data and to assist the user to understand the meaning of this data. The distributed artificial intelligence (DAI) is an approach designed for controlling complex systems by distributing the decision-making. The complex systems are decomposed into interconnected subsystems. Each subsystem is responsible for the control of its domain and for the coordination of the activities with the other subsystems.

The hierarchical structures of piloting reveal their limits quickly when they are confronted with the existing needs: reactivity, adaptation and auto organization. The distributed approach of piloting can then contribute to the installation of agile organizations, combining logics of networks and hierarchy. However, the decentralized piloting of the UTS is essentially based on the interactions (decisional, informational and physical) of communicating entities; these entities are autonomous and capable of decision making. The difficulty is then how to control the spatial and temporal coherence decisions.

An approach based on the agents makes it possible to design models of decentralized piloting and auto organized making it possible to improve the reactivity of the systems of decision and to increase their autonomy.

The Multi-Agents Systems (MAS) are tools to conceptualize and describe the complex systems. This approach will contribute to the reduction of the complexity of traditional modeling. The technology of

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agents can help in the design and the analysis of a system if this system satisfies the three following conditions: the domain of the problem is geographically distributed so that the information and the control are also distributed, the subsystems exist in a dynamic environment and they must interact between them more effectively. These conditions are met in the domain of the UTS.

Several solutions for an adaptive management of the traffic network were suggested (Ossowski et al. 2005). Applications based on the multi-agents systems for the objectives of control and optimization were suggested by (Logi 1999).

(Li et al. 1996) suggest a cooperative system of control and of regulation based on the MAS, they proposed an architecture in three hierarchical levels: total, group and individual. (Finder and Strap 1992) have presented a distributed approach to optimize traffic signals. (Iftar 1997) has developed an intelligent approach of control to decentralize the regulation of the traffic.

(Adler and Blue 2002) propose a real time multi-agents approach of co-operation between the system of management and the system of guidance. This approach is based on a principle of negotiation between the agents which represent the entities of regulation, the driver and information providers.

(Cuena et al. 2000) propose TRYS as a knowledge representation environment supporting model to perform traffic management at a strategic level, its principle is to devise the studied system into areas, each one is controlled by a software component (an agent), this architecture allows us to understand the reasons and the evolutions of found problems.

(Ossowski et al. 2005) present a design method for the construction of agent-based decision support system for the management of urban traffic. The organizational model of this architecture allows the realization of dialogues between the decision maker and the decision support system to exchange four types of interactions: information, action performing, explication and advice.

Most of the applications based on MAS are vehicle–oriented which means that vehicles are considered as agents, other solutions are dedicated to solve one type of problems found in the system. In our study we are trying to build a global architecture able to solve the different types of problems. This architecture considers that the behaviour of studied system is depending on the management system and not on the behaviour of vehicles.

3 THE DECISIONAL SUBSYSTEM (DSS)

In reality, the urban traffic system is composed of several geographical zones, where each one is directed by a coordinator. Each coordinator manages at least two controllers of signalized junction. In fact, the controller has a composed environment: roadways, lanes, detectors, traffic lights and vehicles. The whole is related in a hierarchical way to a central unit. The entities of regulation (noted ER) are: the central unit, zone coordinators and the controllers (active objects).

Generally, the activities of the DSS are as follows:

- Reception of information of the other subsystems (by means of detecting sensors).
- Action on the LSS: developing a new signal plan.
- Action on the PSS: installation management rules for the breakdowns and for resources sharing.

The central unit has as the role of coordinating all the other entities of regulation so that the state of the system rests stable. It knows the system state using information provided by local decision centres (controllers) and by detectors. Its main function is to build phasing plans that are compatible with the current traffic situation, and then to apply them.

The zone coordinator coordinates a set of controllers. It ensures the management and the control of its zone. Within a completely decentralized system, the decision-making would be based on principles of cooperation and coordination. In order to reduce the delay at various intersections along an axis and in order to reduce the number of stops of the users, the coordinator is dedicated to the coordination of this axis. The improvement of such criteria of performance by the means of an adapted plan has a direct impact on delay, pollution…etc. These considerations support the passage of buses at the intersections by using adapted sensors and adapted plans.

The controller has very limited knowledge of the system because it manages only a limited number of signalized junctions. Its role is to ensure the local traffic flow. It must do it by respecting the signal plan provided by the central unit or the coordinator. It can however modify certain color phase length of this plan by carrying out retraction on the phases. It carries out only a local improvement in the total solution. In the major part of the existing systems, we can still find intersection not connected to the central unit.

According to the standard NF P99-071-1 of October 2001, relating to the specification of language DIASER (*DIAlogue Standard. pour les Équipements de Régulation*), a decision center can manage one or more applications as follows:

- Signalized junction application : a set of functions to control the operations of one or more (eight maximum) signal-controlled junctions (noted SJ);
- Application of Variable Message Signals: a set of functions to control the operation of the display systems (the panels with variable messages, noted VMS);

- Application of Common Transport Vehicle (CTV): a set of functions of identify and localize common transport vehicles to profit of the same type of priority;
- Traffic Measures (TM): a set of functions of local acquisition of the data of traffic intended for the regulation, and corresponding functions of control.

4 THE MULTI-AGENTS APPROACH IN THE CONTEXT OF THE DSS

The multi-agents approach enables us to specify the operation and the communication of the entities of regulation of the decisional subsystem. The specification of these agents means specifying the decision-making process.

The objective of our work is to build an architecture multi-agents that enables us to study the DSS, then to couple the MAS thus obtained with the model of simulation developed by (Sarramia 2002) by using the ASDI-mi methodology applied to the UTS.

In order to evaluate and to validate our multi-agents architecture, we defined the objective to detect any critical state going beyond of the threshold of concentration on the lanes of the studied system, then to apply some methods in order to improve the service, otherwise to inform the upper entity of regulation or the decision maker about the situation. In order to provide all information necessary to the entities of regulation, the MAS is fed by the PSS and LSS. These information must allow the entities of regulation to make a decision (to inform, calculate and take action, explain, advice, etc.). Thus, when a controller detects a critical state and cannot make a decision, it will inform the external system (coordinator or the central unit according to the studied system). This external system must be able, according to the data of the concerned intersection, to calculate and/or to propose a solution for the crossroads considered.

According to the suppliers of equipment of traffic management, the current orientation of traffic management is to make each entity of regulation (i.e agent) the most autonomous possible, especially at the decisional level. However, if this one is not able to solve its problem, it must cooperate with other entities of regulation. In fact, we equipped each agent with many methods of micro and macro regulation as specified by the CERTU (*Centre d'Etudes sur les Réseaux de Transport et l'Urbanisme*).

We chose the platform MadKit (www.madkit.org) like environment of MAS. It implements the paradigm AGR (Agent, Group, Role). It is an organization seen as a framework for the activities and the interactions of the agents by defining groups, roles and interconnections between these agents.

We will briefly define these three concepts:

Agent: Model AGR does not impose internal architecture of the agent. An agent is only indicated as active entity of communication which plays “roles” in “groups”. The designer can thus adopt the definition which is appropriate to him.

Group: the Groups are defined as atomic sets of aggregation of agents. Each agent belongs to one or more groups. In its more fundamental form, the group is only one manner of labeling a set of agents. The groups have the following characteristics:

- An agent can be a member of several groups at the same moment.
- The groups can overlap.
- A group can be created by any agent, and an agent can require its admission in any group.
- With the additional agents of the platform, a group can be local or be distributed on several machines.

Role: The role is an abstract representation of a function, of a service of the agent. Each agent can handle multiple roles, and each role handled by an agent is local with a group.

MadKit makes it possible to organize the decisional entities according to its architecture AGR as follows:

- The topology of the network of the studied UTS is made up of several geographical zones. Each zone directed by a zone coordinator or a controller corresponds to a group. A special group is that of the central unit: it makes it possible, initially, to describe the studied system (initialization of the data of the various agents), then to activate them.
- The three types of regulation entities (the entities where decisions must be made: the controller, the zone coordinator and the central unit) are represented by agent. All these agents play the common role of regulation and other roles which are dedicated for them. The common role makes it possible for the central unit to synchronize (via a dynamic management of the list of the agents) the other regulation entities, insofar as they have each one an asynchronous behavior.
- Each entity of regulation manages one or more applications among the four applications mentioned before, these application can be seen as agents, but for each level of control (local, zonal and global) the entity of regulation manages these application in a different way:

  - Local level (the controller agent):

- **The agent of traffic measures** provide the other agents (and the upper hierarchical level of agents) data concerning the current state of the system, these data are obtained by the detectors.
- **The agent of signalized junctions** analyze data obtained to detect any abnormal situation (saturation, accident,…etc.), if such situation has been found the agent tries to overtake it by making a decision, it has a set of possible actions

(like modifying traffic lights phasing plans, using variable message signals to announce the current situation or to suggest an alternative road, … etc.), each one of these actions is given a certain priority.
- **The agent of common transport vehicle** intend to track vehicles having fixed routings (buses, trams, …etc.) and to evaluate and calculate their trip time.
- **The agent of variable message signals**: its aim is to display messages on variable message signals panels installed on the road in order to 1) inform the drivers about traffic problems, and/or 2) recommend them to use alternative routes avoiding congestions.

▪ Zonal level (the zone coordinator agent):

The coordinator agent manages a set of controllers agents. The agent of signalized junctions try at this level to apply some specific policies at main roads and axis like applying a "green wave" or applying a strategy to give the priority to common transport vehicles in order to reduce their stop time. The agent of variable message signals aims to verify if messages proposed by the controllers are correct and to solve their conflicts (conflicts appear when two controllers use the same panel to display different messages).

▪ Global level (the central unit agent):

The central unit agent have a thorough knowledge of the infrastructure of the system, it aims to keep the system in a good steady situation by coordinating and cooperating with the others agents, and to calculate phasing plans which are compatible with the actual state of the system and then to apply them.

The structure of the agent ER is that of an active agent. A cognitive architecture (standard belief-desire-intentions) can be appropriated for the resolution of our problems. We implemented the knowledge of the domain of the UTS through active agents.

The intersections between the four applications in an entity of regulation and the decision-maker are outlined in Figure 1 :

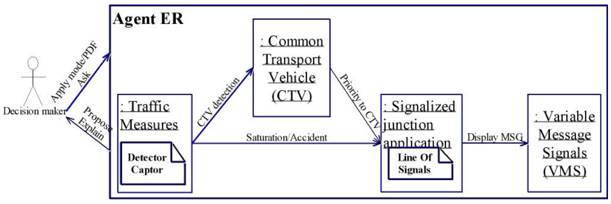

Figure 1 : interaction of application

The four applications interact with each other and try to take a correct action or to suggest a solution to the decision maker. (Ossowski et al. 2005) suggest that a decision making tool must be able to realize four types of communicative interactions:

- **Classification and information**: responding to the question: What is happening ? in order to know the actual state of the system.
- **Diagnosis and explanation**: knowing the reasons for what is happening, to explain the actual state.
- **Prediction and action**: a conversation about the realization of some actions: what happens if…?
- **Advice and configurations**: a dialogue about the benefits of some actions: what to do if…?

By definition, an agent reacts according to the events which it perceives of its environment, releases of its various processes. These events are either of the decisions coming from other agents of the DSS, or a change of state of an object of PSS (going beyond of a threshold of concentration, breakdown of a plan, etc). These external events involve internal events with the operation of the agent.

Each agent possess a knowledge about the physical infrastructure of the sections that it manages. An agent has two states:

▪ *Waiting (sleeping)*, when it is waiting of a starting event or for a message.
▪ *Active*, when a starting event occurs (alarm clock by the central unit) or a relating message is received. It begins the solving process.

It proceeds then to its various activities. In this case, it uses an algorithm to carry out one of the following activities:

▪ Collecting data relating to its environment, compared to the event which awoke it.
▪ The analysis of the data makes it possible to decide if its action is necessary or not according to fixed criteria's. This will make it possible to determine if it is about an action reflex or not.
▪ The activity of action decided following the analysis of the data, corresponds, for example with the calculation of a new plan. The results so obtained must be transmitted to other agents, and/or the entities controlled by this agent.
▪ The activity of communication makes it possible for the agent to inform or request the other agents of the MAS.

Figure 2 illustrates the internal structure and the various activities of each agent. This structure is composed of four modules :

knowledge module: containing knowledge about the infrastructure, and collected data from its environment, it also keeps a history of all events and actions.

analysis module: detecting the abnormal states and trying to know their reasons and their consequences.

decision module: making decisions from the results of analyze module and applying these decisions to the concerned entities.

communication module: realizing the interconnections between the agent and the other agents, the decision maker and the entities controlled by this agent.

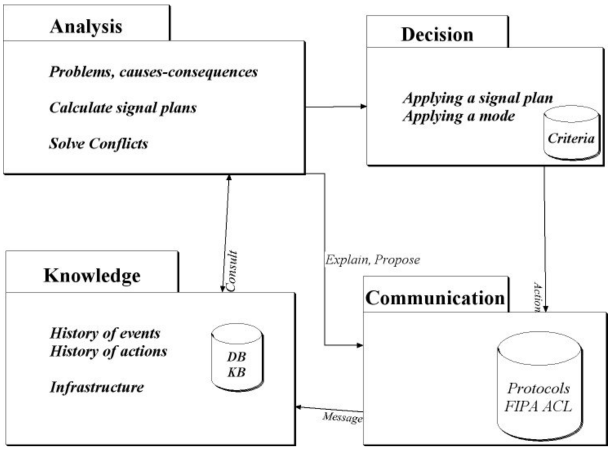

Figure 2 : Internal structure of the agent.

The central unit, playing the role of organizer, makes the passage of the agents from one time section to the following one, via a mechanism of synchronization.

When an agent detects a problem which it cannot solve, it requests an external help (co-operation). Then, the central unit (informed or solicited) pause the execution of the simulation and it devote itself for the resolution of the problem, and then finishes simulation.

CASE STUDY

This study case covers a zone in the south of the Riom city in France. This zone is composed of two axis: the national N9 and "Avenue de Clermont", each axis is managed by a controller contains two signaled intersections. This strategically important zone is one of the most congested zones in the city and is considered as the south entrance. Figure 3 illustrates the physical structure of this zone and the possible directions allowed by each intersection. Both controllers are linked to the zone coordinator.

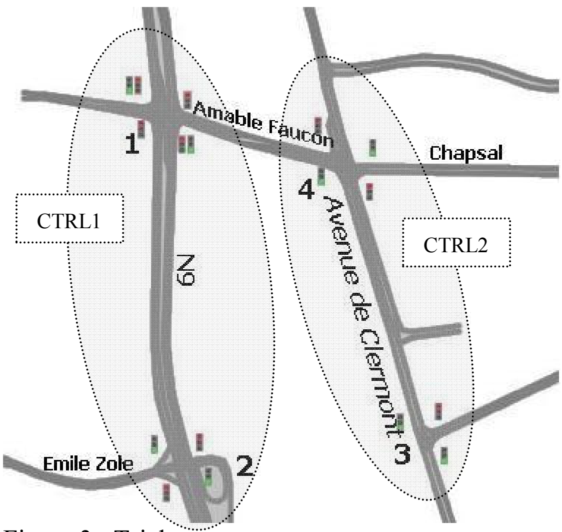

Figure 3 : Trial zone

The MAS takes its input data from the simulation model ASDI-mi applied to the studied system. These data are traces and indicators of individual vehicles (position, speed, direction,…), lanes (capacity, load,…) and signal plans. Each controller observes lanes ending up by a traffic signal in its section.

The objective of our multi-agents system is to solve problems linked to the decisional subsystem like the detection of congestion and the improvement of the corresponding signal plans. Each zone coordinator agent with its controller agents belong to a group. A group represents a geographical zone.

In the example, the intersections (1) and (2) are controlled by the first controller CTRL1, (3) and (4) by the second one CTRL2. Both controllers belong to one group (one zone) and are linked to the zone coordinator.

Implementation and results:
The role played by a controller on an intersection can be explained in more detail; we will take the intersection (1) as example:

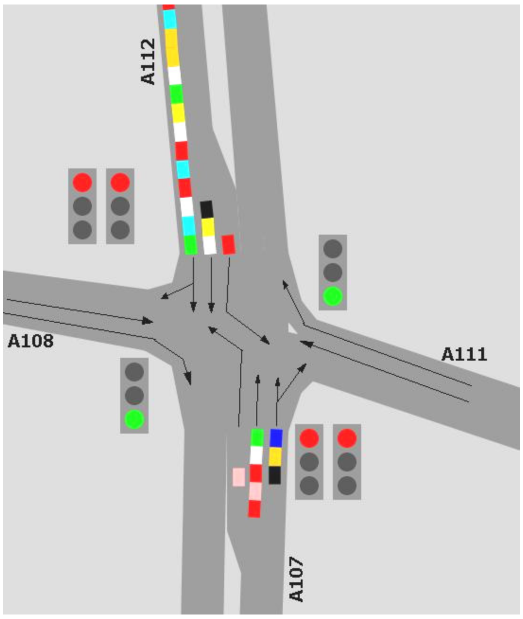

Figure 4 : Intersection (1)

A default signal plan with a cycle of 98 seconds is applied to the intersection (1). It has three lines of signals: the first is for the axis A112/A107 going towards or turning right, the second is for the axis A111 and A108 going towards or turning right, and the third is for vehicles coming from A107 or from A112 and turning to their left. The three lines share 80 seconds of green as follows: 30 for the axis A112 and A107, 20 seconds for vehicles turning left, and 30 seconds for the axis A111/A108,

The controller tries to detect any abnormal state (congestion, accident,…etc.). Once such situation is detected, the controller will inform the zone coordinator and the decision maker about this state, then it will start

calculating a new signal plan which corresponds to the situation.
For example, if a congestion is detected in A112, the controller agent will begin to analyse data in the last quarter hour which is a sufficient duration to understand the reason of the problem, and it will use these data to calculate a new signal plan, this signal plan will share the duration of green proportionally to the load of each line in a way to respect minimal duration of time to let pass the pedestrians.

We will compare the two following situations :

- For a duration of 2 hours, a static signal plan is applied at the intersection (1). In this situation the MAS will only detect the congestion states and will inform the zone coordinator and the decision maker about them.
- The same intersection is studied for the same duration, but in this situation, a dynamic signal plan calculated by the controller agent every quarter hour (in the worst case) will be applied.

In our example we will take a critical point of congestion of 15 vehicles/road and a duration of 40 seconds. We notice that the number of detected congestions and the duration of congestion is decreased to about 60% of the first situation.

Following the modifications applied at the intersection (1) the zone coordinator may take some actions of cooperation with other controllers on the same axis to produce a green wave on the axis N9.

CONCLUSION

In this article, we presented a step of modeling of the control system of urban traffic systems, based on a multi-agents approach, with an aim of proposing an architecture allowing testing various techniques of micro and macro regulation.
Comparing to a real traffic management system, our system allows the realization of the following functions:

- Collection of data from the studied system;
- Processing of these data and definition of actions;
- Implementation of these actions (i.e control of traffic signals).

The multi-agents paradigm appears to be adapted to specify the architecture and the behavior of the three levels of equipment of regulation (controller, zone coordinator and central unit). We associate an agent for each one of these three decisional entities.

According to the internal complexity of these decisional entities, four axis of activities have been identified: traffic measures, signalized junctions, common transport vehicle and variable message signals. An agent representing each axis makes it possible to specify and to design the functioning way of an urban traffic management system. The MAS obtained represents the real system in a way as clear and realistic as possible.

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AUTHOR BIOGRAPHIES

Ahmad ALI is Ph.D. student in the University of Blaise Pascal (Clermont-Ferrand, France) and belongs to the research team « Modelling and Decision Aid » of the LIMOS CNRS UMR 6158 (Laboratoire d’Informatique, de Modélisation et d’Optimisation des Systèmes). He is devoted to the study of urban traffic systems.

Michelle CHABROL is Associate Professor of Computer Sciences in the University of Blaise Pascal (Clermont-Ferrand, France) and belongs to the research team « Modelling and Decision Aid » of LIMOS. She is mainly interested in modeling methodology and discrete event simulation for urban traffic systems and hospitals.

Michel GOURGAND is Professor in the University of Blaise Pascal (Clermont-Ferrand, France) and manages the research team « Modelling and Decision Aid » of the LIMOS CNRS UMR 6158 (Laboratoire d’Informatique, de Modélisation et d’Optimisation des Systèmes). His research and teaching interests include manufacturing system modelling, scheduling problems and metaheuristics.