A Making-Decision System for an Urban Transportation Network

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ABSTRACT

This paper deals with the real time regulation of traffic within a disturbed transportation system. We show the necessity of a decision support system that detects, analyzes and resolves the unpredicted disturbances. Due to the disturbed aspect of transportation system, we present a multi-agent approach for the regulation process. This approach includes an anytime algorithm**,** which permits to access to solutions in real time. The quality of the results increases with allocated time. Our system is able to foresee all behaviors according to the environment with which it interacts. These aims offer real guarantees with respect to the temporal deadlines. The main objective is not to search an optimal solution for a disturbance, but to define a set of possible solutions.

Key Word: decision-making, anytime algorithm, network transportation, disturbed urban transportation network.

1. INTRODUCTION

The great difficulty related to traffic management of such systems is to follow the order of planned departure and arrival times of vehicles at different stops in the network. A making-decision system allows the human decision-maker who is designated as regulator to take the best decisions facing a given situation and in the shortest possible time. These regulators are overloaded with information that they have to treat immediately in order to find the relevant decisions that result in new vehicle schedules.

The distributed and opened character of the urban transportation network and complexity of executing tasks need a modular decomposition of the problem under consideration. The use of the multi-agent paradigm implies the integration of mechanisms, which take into account the temporal dimension. We shall introduce, through this paper, the prototype MASDAT (Multi-Agent System taking Decision in reAl Time**)** that permits to take into account the real time aspect while using an approach based on a multi-agents system. The use of MASDAT model has required that we develop an application on the regulation of a bimodal transportation network.

The results of our work will contribute at the end to illuminate the decision-making concerning the organizational evolution of the regulated network. Our contribution concerns the administrative agents of incidents, which aims to help the operators to choose a strategy. That occurs when there are knowledge accumulated on these incidents (context and resolution). It concerns also the agent vehicle which take into account the two modes of transportation (buses and trams) and the use of a specific agent of regulation, one for connection and the other for inter-station.

2. A REAL TIME SYSTEM AND MULTI-AGENT APPROACH

The system we propose is composed of agents which have evolutionary reasoning techniques. The agents adapt constantly the quality of collective solutions they propose to the resources. These agents are in a dynamic and uncertain environment, they have to share the resources and tasks to get an optimal realization. Our system can predict any behavior related to the environment with which it interacts to give real guaranties with respect to the temporal expiration dates.

Therefore, the recourse to the anytime technique seems a promising solution. The anytime algorithms appear at the end of the 80's [4][8]. The basic definition of an anytime algorithm is: "an anytime algorithm is an algorithm which allows, in exchange of a longer execution time, to give results of a better quality. This means: more the execution time left to carry out a task is longer, better the quality of the result provided in the end will be"[6].

The multi-agents system in our work must acquire an anytime behavior. The acquisition of this behavior must be done at two levels:

- the local level: it is the agent level, where the agent will have a behavior anytime
- the total level: it is the multi-agent level, where the system behaves an anytime comportment

3. A DISTRIBUTED DECISION-MAKING SYSTEM

In our multi-agent system, the agents which form the software system have at the same time anytime behaviors and the capacities of functioning in distributed mode. The characteristics presented by these agents are following:

- an anytime behavior,
- an automata (ATN) allows to model the stopping point of the anytime algorithm,
- a clock to measure the time between the states of the automata,
- communication functions allowing:
  - the communication between the anytime agents of the horizon H,

- the communication between agents of temporal coordination. This means between two horizons H and H,
- a temporal discretisation function,
- a time prediction function.

In the decision-making system, the anytime properties are used at the progressive extracting of information. At the beginning of the extracting process we have superficial, common and less precise information. The further we go in time more precise and important are the extracted information.

What is an anytime behavior?: an anytime agent is an agent with an anytime algorithm and which will be able to:

- give intermediate results of increasing quality at each execution step,
- predict the required time to obtain the next intermediate result.

Why an Augmented Transition Network (ATN)?: an ATN [5] is used to stabilize the behavior of an agent anytime, each crossing of state in the ATN corresponds to obtaining a result whose quality is better than that of the precedent. The ATN is used to store information concerning the temporal behavior of the agent anytime such as minimal, average, maximum time of execution of a task located between two states of the ATN

Temporal discretisation function: the aim of this function is to find the time unit, which could be used to measure the expired time between two states of ATN, it is greater than the base time unit. $d_{i,i+1}$ the transition between two states i and i+1, delta T is a variable which represents a subdivision of time and $n_{i,i+1}$ the number of delta T subdivided between two states i and i+1.
We have following relation:

$$d_{i,i+1} = \text{delta T} \times n_{i,i+1} \quad \text{where} \quad \text{delta T} = d_{i,i+1}/n_{i,i+1}$$

with i=1,2,3..

Time prediction function: this function allows to predict the running time needed to get over to the next state of ATN from the current state. This estimation is done with reference to the discrete running time needed usually to get over to the state to be reached.

Characteristics of temporal coordination agents: the agents of temporal coordination [6] are agents which get activated at a global level to flex the behavior of the multi-agents system, so it gives intermediary results of increasing quality in function of allocated running times. Agents of this type will intervene in little groups of agents to control their behavior (figure 1).

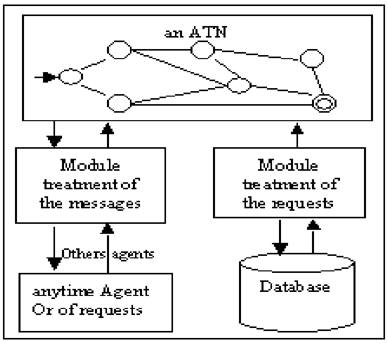

Figure 1: Temporal behavior of coordination Agent

The roles of these agents are:

- The capacity to treat the requests, i.e. the treatment of the messages received by the agent,
- the ability of locating physically the information systems available (module of requests treatment),
- the ability of sending the questions to others agents of requests.

4. APPLICATION OF THE MODEL ON THE URBAN TRANSPORTATION NETWORK

Our aim is to apply this approach to a bimodal urban transportation network to help the regulator to take a decision with regard to the disturbance in the normal functioning of the network.

Dynamic of the disturbance: taking into account the consequences of disturbance initiates the constitution of new sets of information in function of the expected vehicle by the concerned stops.
We are defining three subsets:

- the waiting stops of the delayed vehicle,
- the waiting stops of the vehicle following the vehicle which is late,
- the vehicle preceding the delayed vehicle.

The situation of the network changes in function of the evolution of state of the delayed vehicle, and this is following two axis:

- **time:** if initially the vehicle is delayed during one of its stops, the number of points changes in function of the evolution of this delay,
- **space:** the number of stops concerned by the problem changes also in function of the movements of the vehicle.

Space time horizon: the regulation process operates only in the disturbed mode. It is necessary to define through the diagnostic phase the set of the entities of network, which are related to the considered disturbances or which could be involved in the decision phase [3]. The definition of that kind of set depends on:

- the moment of detection of the incident,
- the nature of perturbation,
- the position of different vehicles in the network at the moment 't',
- the impact of the incidents,
- the nature of the involved vehicles,
- the period of the day etc…

During a disturbance, a set of entities of the network is implied in this one (vehicles, stops and connections). To take them into account, we establish a horizon of regulation corresponding to:
- a space axis: represented by the stops intervening in the disturbance or the regulation
- a temporal axis: represented by the participant in the disturbance or the regulation

We represent the set of the stop by S^H (stops of horizon H) and V^H (Vehicles of horizon H).

5. THE PROPOSED MODEL MASDAT

For the construction of our agents, we have been inspired from the work of [1][3][9]. Nevertheless, in our prototype we propose a vehicle agent which supports buses and trams.
We make a difference between the stop agent that treats the inter-station disturbances and we define a special agent for the management of connection [2].

The present proposed model consist of two modules:
- the surveillance module which is responsible for the management of static time of the network,
- the regulation module which is responsible for managing the disturbances and generation of the appropriate rescheduling measures.

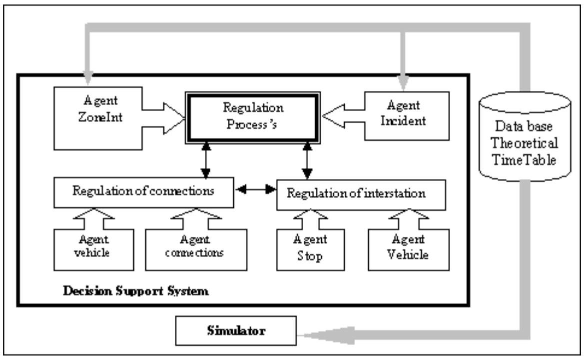

Figure 2: MASDAT Architecture

The surveillance module works under normal and disturbed conditions: it is composed of the following agents: VEHICLE, STOP and CONNECTION.
The regulation module treats the disturbances concerning buses and trams modes. The regulation module works only in disturbed mode. It is created when a disturbance appears. Its composing agents are INCIDENT and ZONEINT.
The agents of the two modules communicate with each other in other to cooperate in the real time treatment of different incidents.

6. BEHAVIOR OF THE DIFFERENT AGENTS

In totally, we have six agents, each one of this agents have its own roles.

Agent VEHICLE: the role of a vehicle agent is:
- applying the Theoretical TimeTable (TTT) which concerns the vehicle,
- applying the regulation measures assigned to it from the regulator.

The agents VEHICLE are asked about information concerning their position, an estimation of arrival times or possible delays. An estimated arriving time of a vehicle at a station is given by Automatic vehicle Monitoring (AVM) system but may be evaluated by:
- the distance between the stops,
- the average speed of the vehicle,
- the departure time of the previous stop,

Agent STOP: the STOP agent has the following roles:
- making sure that TT is respected,
- detecting the interval between the theoretical times of transition and the real times,
- creating an INCIDENT agent to manage the disturbance,
- signaling possible disturbances at stops,
- communicating with other STOP and VEHICLE agents to know about transition times.

In fact, STOP agents watch the transitions of vehicles to detect possible intervals between real times of transition and those of theoretical transitions. If the tolerated limit of the intervals is exceeded, these agents have to signal the appearance of a disturbance by creating an agent INCIDENT, which is responsible for its management.

Agent CONNECTION: the role of an agent CONNECTION is the same as the one of a STOP agent and its functions:
- management of connections,
- detection and determination of some decisions to avoid missed connections,
- communication with other CONNECTION agents.

The agent connection must considerate all information coming from the agent STOP and the agent VEHICLE before offering his own solutions.

Agent INCIDENT: an agent STOP creates an agent INCIDENT when a disturbance caused by a vehicle appears. Being responsible for the considered disturbance, this agent first identifies its characteristics (disturbed vehicle, delay, stop, cause,…). Then, it creates an agent ZONEINT that will generate several possible rescheduling solutions through an evolutionary approach.
The principal roles of the agent INCIDENT are:
- to create ZONEINT: for the diagnosis of incident and proposal for intermediate solutions,
- to await the primary diagnosis and solutions,
- to evaluate the diagnosis,
- to await solution regulation,
- to evaluate regulation,
- to await validation from regulator,
- to apply and follow regulation.

The agent INCIDENT must at any moment provide to the regulator one or more solutions. Thus, a limiting duration of processing data can be fixed in order to provide as fast as possible of the assistance to the regulator even by means of temporary but immediate solutions.

Agent ZONEINT: this agent is created by INCIDENT. It operates by an anytime evolutionary regulation approach that takes into account the several rescheduling criteria. This agent considers the present decision making problem as a dynamic vehicle-scheduling problem. Thus, the real time vehicle routing and scheduling problem is inadequate to solve with classical methods [7][11][12]. For this reason, we choose an evolutionary algorithm for the rescheduling of the traffic through a partial network reconfiguration.

The actions which are carried out by the agents ZONEINT are:

- localization of the horizon: the research of the concerned zone with disturbance according to a strategy defined to build the space-time horizon,
- collect information necessary to the assistance of agents VEHICLE and STOP to estimate the schedules of passage in the disturbed state of network (without regulation), forming the Disturbed timetable (DTT).
- control connection: to check the good course of the possible connections. If one or more connections are implied, it is necessary to rebuild the agents formed by ZONEINT in order to take account of the other concerned lines in the network,
- diagnose incident: evaluation of the importance of the disturbance according to the corresponding criteria of regulation,
- propose results: sending the various collected information to the agent INCIDENT.

Thus, we consider that the agents STOP and the agent VEHICLE are anytime agents and the agents ZONEINT and agent CONNECTION are temporal coordination agents.

7. SIMULATION RESULTS

We consider a partial network of Oran City (North of Algeria), it is the network of the university zone (characteristics of lines: table 1 and table 2). It is a zone where momentary flow is very significant and the network comprises different points of connections. The various components of the network are the vehicles (buses and future trams), lines and stops.

	Line B	Line 11	Line 34	Line 51	Line U (tram)
Number of Stops	20	20	10	12	13
Frequency (minutes)	15	10	20	10	8

Table 1: Characteristics of lines

Connections	Line B	Line 34	Line U (tram)
Line B		Cross road Boulanger	Cross road Boulanger
Line 11			Place Valéro
Line 51		Hayat City	Hayat City
Line U (tram)	Cross road Boulanger		

Table 2: Connections between lines

Example of scenario: we consider two lines of the network L1(line U of tram) and L2 (line 51), which crosses on the level of a node of connection (Hayat City: table 2). The vehicle V2 of the line L1, V_2^1 meets an unforeseen congestion in circulation and its driver estimates a delay of 7 min with the next stop. This disturbance can generate the following risks:

- miss the connections on the level of the node of connections,
- lose at least a revolution on the line.

Application of MASDAT to the scenario: this delay is captured via the AVM directly by the agent VEHICLE. The correspondent agent VEHICLE sends this estimate to nearest Agent STOP "S_2^1", which starts the creation of the agent INCIDENT.

As regards, the agent INCIDENT it creates the agent ZONEINT in order to form a group of agents (VEHICLE, STOP and CONNECTION) concerned with this disturbance, these agents can be group together according to their lines or routes, or according to the incidents which connect them.

The agent ZONEINT locates the zone by taking account of the vehicles of line L2, and communicates with all the concerned agents to extract all information (the positions, their load,. ..), it they gives to the agent INCIDENT a synthesis of the current situation. The agent INCIDENT seeks according to this information and that of the regulator, if this disturbance already arise.

If it is a case already present, the agent INCIDENT reference to the regulator the solution suggested directly

Else

- it compares the theoretical value with that observed,
- it calculates the new disturbed timetable as well as the loads disturbed for the vehicles on the whole of the network,
- it evaluates the disturbance,

Once this stage is carried out, we estimate for each action a satisfaction degree; it is calculated while being based on the duration to find the normal mode. The choice of the action to be used depends on the regulator. These actions can be: injection of vehicle, delay a vehicle, changing a course according to the position of the deposit compared to the position of the incident.

Analyze of the situation: the delay estimated by vehicle V2 is of 7 min. Thus, instead of arriving at 10:05, it will arrive at 10:12 in the stop S4 and the delay tolerated is of 2 min. This delay creates not only one irregularity in the intervals but also a risk of missed connection. The following figures (Table 3,4,5 and 6) present the table of theoretical and disturbed Timetable.

Line U (L1)				
	S_2^1	S_3^1	S_4^1	S_5^1
V_1^1	9:25	9:35	9:45	10:05
V_2^1	9:35	9:45	10:05	10:15
V_3^1	9:45	10:05	**10:15**	10:25

Table 3: Theoretical TimeTable of Line U

Line 51 (L2)				
	S_2^2	S_3^2	S_4^2	S_5^2
V_1^2	9:27	9:37	9:47	**10:07**
V_2^2	9:37	9:47	10:07	**10:17**
V_3^2	9:47	9:57	**10:17**	**10:27**

Table 4 Theoretical TimeTable of Line 51.

Line U (L1)				
	S_2^1	S_3^1	S_4^1	S_5^1
V_1^1	9:25	9:35	9:45	10:05
V_2^1	9:35	9:45	**10:12**	**10:22**
V_3^1	9:45	10:05	**10:22**	**10:32**

Table 5

Line 51 (L2)				
	S_2^2	S_3^2	S_4^2	S_5^2
V_1^2	9:27	9:37	9:47	10:07
V_2^2	9:37	9:47	**10:14**	**10:24**
V_3^2	9:47	9:57	**10:24**	**10:34**

Table 6

Table 5 and 6: Disturbed TimeTable reconfigured by the Agent INCIDENT (Rescheduling)

Evaluation of the consequence of disturbance: following a delay of 7 min, the passengers of vehicle V2 of line L1, V_2^1 who take a vehicle of line L2 will miss the connection of 10:07 and must wait, consequently, the connection of 10:17. This causes a total delay of 12 min in their course.
Following what is mentioned above, the vehicle, which follows the late vehicle, arrives at the stop at 10:15. In addition, the passengers of vehicle V_2^1 those from V_3^1 must also take the vehicle of line L2, which involves a very significant momentary flow and train of buses (successive vehicles with no consideration of intervals).

Operation of MASDAT: the system, according to TTT data and those of DTT evaluates the importance of disturbance. Given that the system functions in real time, the importance of disturbance therefore decreases according to the evolution of the network in time. The system proposes a first solution, which will be improved through time until achieving to a satisfactory one for the regulator. At this time the regulator stops research.

Solutions suggested by MASDAT: for this example, we interrupted the anytime algorithm three times with 10 seconds regular intervals. We obtain the following responses (Table 7).

Time before	N° Solution	Proposition
t1 10 sec	**Solution 1**	• change the schedules of passage of vehicles according to the delay • apply the new one TTT = DTT
t2 20 sec	**Solution 2**	• use the bus of the standard type (reserve) in the deposit • create a new course in line 2 for the passengers on standby in the connection • update TTT for the insertion of the new course.
t3 30 sec	**Solution 3**	• exploit the time of beat to the stops to reabsorb the delay caused by this disturbance • prevent the vehicle of the line L2 to increase its speed in order to arrive earlier • prevent the vehicles that follow the late vehicles of line L1 to slow down their speed in order to avoid a train of buses • create a new TTT

Table 7: Solutions suggested by MASDAT

Quality of the solutions: currently, the regulator does not have decision-making system, information which it receives from the AVM system are analyzed, then, it decides solution to adopt. On a purely comparative basis, the regulator can take the first solution obtained by MASDAT at least 10 seconds, only at the end of 1 minute, which gives a profit of 84% in response times. Moreover, the regulator has several possible solutions, which gives him an appreciable choice compared to the past.
These solutions are evaluated according to three essential criteria: punctuality, regularity and correspondence. This evaluation makes it possible the regulator to better choose according to the objectives whose he wants to achieve for the regulation of the disturbed line. This paper does not deal with the part of evaluation of the solutions suggested by MASDAT.
In a second part, considering the prevalence of supervision aspect in the role of regulator, we compared the actions of regulation proposed by MASDAT to those recommended by the regulator. The evaluation of simulation was about four variables: duration of the type of disturbance noticed (delay, advance, stopping), distance by report (next station, next deposit), temporary fluxes (aboard, next station), period of disturbance (the off-peak hour or the peak hour). In the majority of studied cases, simulation gives the same noticed result and particularly for the disturbances of type delay implicating either acceleration or simply a half-turn. Nevertheless, for the disturbances implicating correspondences, different scenarios are proposed in contradiction with the counted verbalisations.

8. DISCUSSION

The regulation process was defined as a process functioning in real time in order to supervise the urban transportation network, and to satisfy the request as well as possible. That consists in having a view of the situation and results in obtaining a maximum of relevant information, owing to the fact that certain decisions must be made in urgency. The information will be disposed to the regulator in a little time. However, the existing approaches, neglect considering the real time for the regulation of an urban transportation system. The work of [1] concerning the "ESCA" system, proposes a multi-agents architecture for the regulation in inter-station, it consists of the information management related to a disturbance in order to bring assistance to the regulator.

Laichour [9], for its system "SARC", proposes only a multi-agent architecture for the regulation of urban network system to the nodes of connections. His work consists in ensuring the correct operation of connection. It also proposes solutions to the regulator in case where there are some connection missed by means of an anticipated simulation. It is not thought that the regulator has time to make simulations before proposing a solution. The prototype SMAAD [3] proposes a cooperation between a multi-agent approach and genetic algorithm for regulating a multimodal urban transportation network. This approach enabled him to improve the solutions suggested for the regulator, and approach towards the optimal one, but in not exploitable times of the regulator.

However, within the framework of the computerized decision-making system, an incomplete or partial result obtained in times is often preferable to a precise and complete result obtained except time and thus not exploitable. The anytime approach seems very promising to consider such situations. It is the reason why we think that it would be relevant to employ this technique in the design of our system.

9. CONCLUSION

In our paper, we presented a multi-agent decision support system that provides the regulators with relevant decisions in case of disturbances. This system relies on the data supplied by Automatic Vehicle Monitoring system or manually entry by the regulator. The MASDAT under consideration includes an anytime algorithm that proposes partial solution to dysfunction that became precise in time. Moreover, in the suggested approach, a partial or incomplete results obtained in real time are often preferred, they are more useful for the decision-making than a complete and precise results obtained after.
Furthermore, this system can be also used for training and learning objectives. That is, the regulators can test, off-line, the impact of different combinations of decisions on several disturbance scenarios.

10. REFERENCES

[1] F. Balbo, ESAC : Un modèle d'interaction Multi-agent utilisant l'environnement comme support actif de communication : Application à la gestion des transports urbains, PARIS IX Dauphine University, Phd Thesis, January 2000.
[2] K. Bouamrane, N. Benyettou and B. Beldjilali, Urban Transport Bimodal Network Management using a Multi-Agents System Approach. Int Conference on Telecomputing and Information Technology/ ICTIT-IEEE 2004, 22-24 September, Amman-Jordan
[3] B. Fayech Chaar, Régulation des réseaux de transport multimodal: Systèmes Multi-agent et algorithmes évolutionnistes, University of Lille, Phd Thesis, 2003.
[4] T.Dean ., M. Boddy, Solving time-dependant planning problems. Proceedings of the 7th National Conference of Artificial Intelligence, Minneapolis, Minnesota, 1988, p. 419-454.
[5] A. Delhay, M. Dauchet, P.Taillibert, P. Vanheeghe. Optimization of the Average Quality of Anytime Algorithms. ECAI-98 Workshop on Monitoring and Control of Real-Time Intelligent Systems, Brighton, 245 august 1998.
[6] C. Duvallet, B. Sadeg. Des systèmes multiagents *anytime* pour la conception de systèmes d'aide à la décision. RSTI-TSI. Volume 23–N°8/2004, pp 997-1025.
[7] D. Huisman, R. Freling and A. PM Wagelmans. A Dynamic approach to Vehicle Scheduling. Econometric Institute, Erasmus University Rotterdam, Netherlands Report E12001-17.
[8] E. Horvitz E. Reasonning about beliefs and actions under computational resource constraints. Proceedings of the Workshop on Uncertainty in Artificial Intelligence, Seattle, Washington, 1987.
[9] H. Laichour, Modélisation Multi-agent et aide à la décision: Application à la régulation des correspondances dans les réseaux de transport urbain. University of Lille, Phd Thesis, december 2002.
[10] M. Tendjaoui. Supervision des réseaux multimodaux. Activity Report 2000.
[11] S.R. Thangiah. Vehicle Routing with time Windows using Genetic Algorithms. Artificial Intelligence and robotics Laboratory, Slippery Rock, University USA, applications Handbook of Genetic Algorithms: New Frontiers, Volume II, lance Chambers (Ed.) CRC Press, 1995 pp 253-277.
[12] K.Q. Zhu. A new Genetic Algorithm for VRPTW. Journal of combinatorial Optimization, April 2000, available: http:\\citeseer.nj.ncc.com/311264.html.

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