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Using intelligent agents for Transportation Regulation Support System design

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ABSTRACT

This paper presents an agent-based approach used to design a Transportation Regulation Support System (TRSS), that reports the network activity in real-time and thus assists the bus network regulators. The objective is to combine the functionalities of the existing information system with the functionalities of a decision support system in order to propose a generic model of a traffic regulation support system. Unlike the other approaches that only deal with a specific task, the original feature of our generic model is that it proposes a global approach to the regulation function under normal conditions (network monitoring, dynamic timetable management) and under disrupted conditions (disturbance assessment and action planning of feasible solutions). Following the introduction, the second section presents the notions of the domain and highlights the main regulation problems. The third section details and motivates our choice of the components of the generic model. Based on our generic model, in the fourth section, we present a TRSS prototype called SATIR (Système Automatique de Traitement des Incidents en Réseau – Automatic System for Network Incident Processing) that we have developed. SATIR has been tested on the Brussels transportation network (STIB). The results are presented in the fifth section. Lastly, we show how using the multi-agent paradigm opens perspectives regarding the development of new functionalities to improve the management of a bus network.

1. Introduction

The development of surface public transportation networks is a major issue in terms of ecology, economy and society. To improve its attractiveness, the urban networks must increase their quality in terms of punctuality and vehicle frequency while at the same time they must decrease management costs. A project like the Bus Rapid Transit shows the benefits of improving infrastructures; but better management of the available resources is less costly than improving network infrastructures. Intelligent Transportation Systems[1] (ITS), based on synergy between new information technologies for simulation, real-time control, and communications networks are an alternative to improve available resource management. Urban traffic control (UTC) systems are ITS enabling a better real-time management of available resources. The usability and the effectiveness of the UTC systems greatly depends on their ability to locate, assess and react to traffic disturbances.

In order to automate the transportation activity, the theoretical bus supply is computed. It gives the transportation plan which represents the optimum supply in a theoretical context. It may become obsolete as the urban traffic conditions evolve. Regulators (the staff in charge of monitoring the bus networks) have to ensure the success of the transportation plan, in the

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[1] http://www.ewh.ieee.org/tc/its/.

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sense of adapting theoretical supply to satisfy the passenger demand according to the urban traffic disturbances. Regulators use UTC systems known as Automatic Vehicle Monitoring (AVM) systems in order to collect and display data. The use of an AVM system is the first step to the computerization of the transportation network activity. However this system is limited to detecting disturbances linked to unanticipated demands and to traffic conditions but is not able to deal with difficulties related to the real-time management of the bus network: managing the inconsistencies of data coming from sensors that locate the vehicles, assessing a disturbance according to its context as well as proposing feasible solutions. These limits are due to the inadequacy of the data collecting, shaping and displaying processes. To cope with these limits, we propose to complete the AVM system with a Decision Support System (DSS) in order to analyze the data so as to give a dynamic and contextual assessment of the disturbances in real-time, as well as action planning and decision-making aid.

In this paper, we study the different ways to integrate an AVM system and a DSS into what we call a Transportation Regulation Support System (TRSS) that is to say how to build a TRSS with the functionalities of both the AVM system and the DSS. Then, we show that the best way to model efficiently these functionalities is to use a multi-agent paradigm. Agent-based DSS are particularly relevant in domains where human operators have to make operational decisions regarding the management of complex organizational processes that are inherently distributed (spatially, logically and/or physically) (Ossowski et al., 2004; Vahidov and Fazlollahi, 2004). The autonomy of a multi-agent system where distributed entities, called agents, interact with each other and its ability to adapt and react to the changes in the environment are essential in the field of transportation where the environment is dynamic, open and uncertain.

Section 2 describes real-time management of urban transportation networks and underlines their advantages and limits. Section 3 highlights different ways of integrating an AVM and a DSS to give a generic Transportation Regulation Support System. It motivates the different options that we have taken based on drawbacks of existing systems: the choice of an efficient architecture, the choice of a multi-agents model to support this architecture and the choice of a specific environment model to cope with the topological and temporal characteristics of the transportation domain. This generic model is then used in Section 4 to design a traffic regulation system in the case of the real-time management of the Belgium urban network (STIB network). Section 5 presents our experimentation and conclusions are drawn in Section 6.

2. Urban network regulation: notions of the domain

This section describes how information processing and task processing are performed in Urban Traffic Control systems. The first part describes the functionalities of the AVM system as well as the general data model based on it. The second part presents the regulation tasks and the drawbacks of existing regulation processes.

2.1. The Automatic Vehicle Monitoring system (AVM)

2.1.1. The AVM functionalities

In urban transportation control domain, human regulators are located in a control center. They have to manage the transportation network under normal operating conditions (where are the buses located?) and also under disturbed conditions (where are disturbances – bus delays, bus advances – located?). What action has to be taken to solve the problem?

In most networks, vehicles are located through sensors which provide real-time information. This information represents a huge amount of data (for example data arrives every 40 s in the STIB network). Furthermore it may be incomplete (a sensor may break down) or uncertain (the quality of the data may be poor). This data is collected through the Automatic Vehicle Monitoring system (AVM). The AVM system compares the actual positions of the vehicles (captured by the sensors) with their theoretical positions given by pre-registered timetables in order detect disturbances representing by alarms on the screen (color code in Fig. 1). In this way, the regulator can see whether the vehicles are running ahead of timetable or are running late.

Fig. 1 shows the AVM management of real-time information coming from sensors and the output of the system. Each line is represented two ways with its stops and its running buses. Each bus location is represented by (1) a number for its theoretical position coming from theoretical timetables and (2) a colored square for its real location detected by the system. This real location may be erroneous due to sensor break downs. Stops are represented by black dots. The gap between the theoretical position and the real position gives an information about the bus delays or advances. Colors give the importance of the delays or advances. Some AVM systems incorporate geographical criteria such as delay/advance alarms in a town-center, time criteria such as detecting a delay on the next scheduled departure. The role of the AVM system is to compute online basic information, organizes data collecting and displaying and computes alarms. Its screen interface facilitates the access to this data by allowing to click on a bus number to get more information on this bus or to click on a given stop to get more information on this stop (see Fig. 1). Given this information, the regulators have to rely on their own experience to decide upon the regulation actions to be taken. In this paper, we propose to automate the decision-making process to prevent it to rely on regulators' experience giving a generic model of urban Transportation Regulation Support Systems (TRSS).

2.1.2. The data model

A significant amount of work has been done to model data in automatic traffic regulation systems. The objectives were to represent both the physical network configuration and the bus timetables in a same model. The first project of a data model