A Supervisor Agent for Urban Traffic Monitoring

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Abstract— **This paper presents a supervisor system for urban traffic management, which aims to reduce cars' queues in large cities. To achieve such objective this system uses fuzzy sets to detect if a traffic-light is in trouble, case-based reasoning to match the current traffic situation with previous ones, and genetic algorithms to generate new programs for traffic-lights.**

***Keywords:** Real Time Systems, Adaptive Traffic Control, Inteligent Systems*

I. Introduction

The numbers of the cars' fleet in the streets have been increasing year after year in developing countries, creating a huge problem in big cities. Many streets and cities are not prepared to deal with the increasing traffic flow observed in recent years. The problem of controlling and coordinating decisions among traffic lights, observing several variables such as traffic flow (public and private), pedestrians, accidents, events and emergency vehicles is very complex yet crucial, for the impacts it produces in the citizens' and cities' lives.

Several initiatives have been taken, such as the Brazilian Intelligent Cities Project, proposed by the Brazilian Ministry of Science and Technology, involving many Brazilian universities and research centers to develop solutions for the current challenges. This paper presents a supervisor agent, which is part of the Intelligent Traffic Control System in the context of the Brazilian Intelligent Cities Project, described in [1].

A supervisor agent for such a complex and dynamic control system has to be traffic sensitive, to supervise the traffic control agents (which are disperse through the city and control each traffic light), detect abnormal traffic conditions, and change the traffic control programs in real-time. This situation awareness may allow better traffic strategies and management for the distributed system, in real-time. To achieve this, the supervisor agent includes three different techniques to take decisions and create new programs: a fuzzy algorithm to detect abnormal conditions, such as big queues and to identify similar controllers so they can share programs, a genetic algorithm to create new traffic programs, and case-based reasoning to search for older programs based on the current situation. Fuzzy sets are a well-known technique used to develop efficient systems to handle incomplete, inconsistent, and imprecise information. Case-based reasoning permits to reuse computational effort by reusing and adapting past experiences, whereas genetic algorithms permit to find novel solutions in very large search spaces. These problem characteristics are intrinsic to distributed real-time traffic control, and are not trivial to be solved.

This paper is organized as follows: section II presents some related works. The urban traffic control system is presented in section III. The supervisor agent is presented in section whereas section IV presents current results, and section V our concluding remarks.

II. Related Work

Several researchers have dealt with the problem of intelligent distributed traffic control, presenting different approaches.

Weiring et al. [2] proposes that the traffic lights be adjusted according to the vehicles' destinations, considering their routes. Chattraj et al. [3] uses a similar approach, but considers the next street cars are supposed to take. Fuzzy sets are used in [4], where traffic conditions are analyzed to find out the best moment to change the traffic program. Agents communicate wirelessly, self-organize and react to events by using a wireless sensor network infrastructure in [5,6]. An approach for agents and environment integration, composed by a real world, a virtual domain, and a control strategies subsystem, is presented in [7,8].

Traffic flow prediction is addressed by works such as [9], which obtains more accuracy in traffic flow prediction by using a fuzzy neural network model in chaotic traffic flow time series. [10] presents strategies to integrate different dynamic data in Intelligent Transportation Systems (ITS). Supervision environments also addressed in [11] where disturbances are identified to evaluate potential corrective actions.

These works present flexible, adaptive, distributed, and/or evolutive approaches, but not all of these characteristics.

III. URBAN TRAFFIC CONTROL SYSTEM

The Urban Traffic Control System, which is part of the Brazilian Intelligent Cities Project is composed by two types of agents: controller agents and supervisor agent. The controller agents will be installed in every intersection with traffic lights, and will be responsible for controlling the local traffic lights, and communicating with neighbor agents. The supervisor agent will be installed at the City Traffic Department, and will be responsible for monitoring, supervising and managing the traffic system.

The controller agents are cognitive and each one has two decision making mechanisms: the Local Problem Solver (LPS) and a hybrid Genetic Case-Based Mechanism (GCBM), that allow the agents to work independently; furthermore, its main goal is to be reactive and exchange information with other agents in order to improve traffic conditions. The LPS is responsible for collecting data from sensors located on the crossings and exchanging messages with the neighbor and the supervisor agents. This way, the agents are able to receive the information, process it, and share with the other agents. It is also responsible for calling the Fuzzy rules on system start and the GCBM functions.

The control strategy includes fuzzy sets and a hybrid genetic case-based mechanism. Usual traffic conditions are modeled as fuzzy production rules, which are used to train the agents as an initial process or after failures. The application of these rules generates an initial case-base, which will be used by the hybrid mechanism. More details about the controller agents mays be obtained in [1,12]. The focus of this paper is on the supervisor agent, which is described below.

IV. THE SUPERVISOR AGENT

The supervisor agent uses Sumo [13], a well-known traffic simulation system and TraCI, an API used to get information such as queue sizes, how many controller agents are present in the simulation, the controllers' programs, and to send new programs to the controllers.

Simulations are executed directly by the supervisor and the traffic data are collected on the fly so the supervisor can decide if that controller needs help. This happens when the number of cars in line increases continually and/or abruptly or when it exceeds the expected performance for that day and period. A traffic agent can monitor the traffic by viewing the traffic data that the Supervisor collects from Sumo in a user interface and on a map using Google Maps. It is also possible to change/create new programs for a controller using the user interface. To achieve this, the supervisor agent is composed by three main modules: Decisions, user interface and connection with Sumo. The user interface has two modules, one responsible for viewing the current traffic data and another where the user can create or send programs to a selected controller. The communication protocol with Sumo has two modules: one responsible for gathering information about the simulation and the other one to send commands to the controller agents. The third module (the Decision Module) is the heart of the supervisor agent. It is responsible for gathering the information about the simulation (queue size and cars flow) and passing them to the fuzzy observer so it can detect if a controller is in trouble. If so, the case-based module will use the current traffic situation to look for similar programs in the program's base and use them as the initial population for the genetic algorithm to create a better program. All the modules are illustrated by Figure 1.

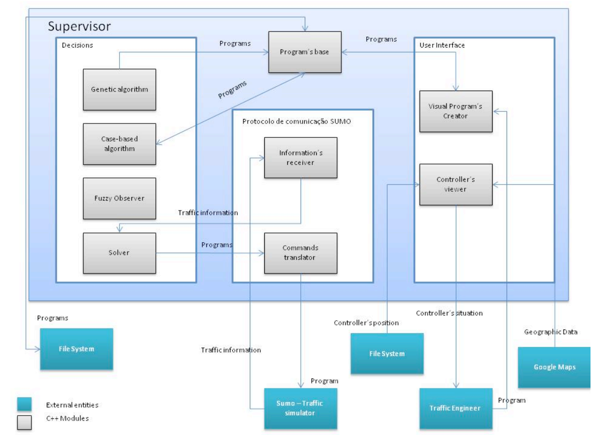


Figure 1. Supervisor Agent Architecture

The first step of the supervisor is to use identify if a controller agent is facing problems. It uses fuzzy linguistic variables, such as the queues sizes and traffic flows, illustrated by Figure 2 (illustration of queue size – traffic flow is similar) to detect if current queues are adequate for current traffic flows patterns or not. It calculates an adequation degree using conventional fuzzy production rules (such as if <local queue size is SMALL and next intersection queue size is NORMAL and … and local traffic flow is NORMAL and…> then adequation degree is BIG). The matched fuzzy rules are combined using the center of area method [1]. More details about fuzzy logic may be obtained in [14]. If the adequation degree (Figure 3) is from absent to small it is time to the supervisor to kick-off the process of creating new programs. The first step is to search if there is any controller that is similar to the problematic controller. To do this, the supervisor also uses a similar fuzzy algorithm to identify if other controllers are facing similar traffic flow patterns. Similar controllers will be used by the hybrid case-based genetic algorithm.

The programs of similar controllers (i.e. controllers facing similar situations) are represented as genes (Figure 4). Each traffic situation is formed by a list of attributes (genes) including the queue sizes and traffic flows from all the controlled streets in the neighborhood and in the tail of the gene there are information regarding the phases of the controller. Figure 5 illustrates this data structure.

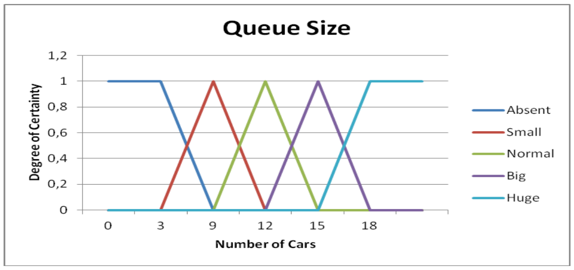


Figure 2. Fuzzy's input linguistic variable

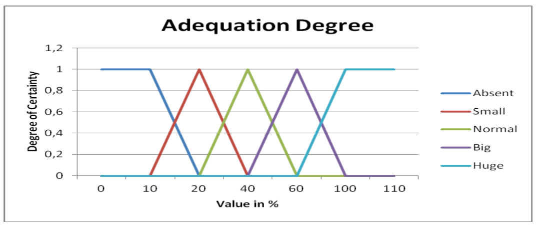


Figure 3. Fuzzy's ouput linguistic variable

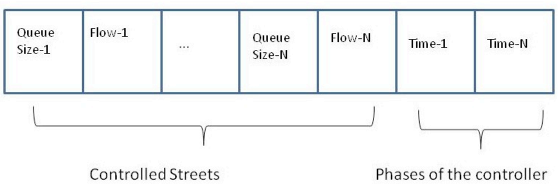


Figure 4. A gene

The genetic algorithm then combines the individuals (traffic situations) through conventional crossing-over and mutation processes. It generates 400 individuals each time using a mutation rate of 0.05. Other configurations of individuals per generation and mutation rates were tested, and this configuration showed the best results for this application. The fitness function is composed by N steps, where N is the number of phases (e.g. 3 for green-yellow-red) of the original controller. In each phase, the cars queue sizes and flow rates are analyzed to check if they correspond to the number of the original gene. If so, the next step is to analyze the phase's duration obtained during the crossing over operation. Depending on the cars queue sizes, the phase duration should to be in a pre-determined interval. The individuals are ranked and at the end of the process, the best individual is selected to be sent to the controller and the new program is saved in the program's base so it can be used in the future. We mean best individuals by those whose performance (e.g. average number of cars in line) are better (smaller) than those achieved by the other individuals in the simulations described. A similar genetic algorithm is described in more details in [1], and it is possible to find a more complete description about genetic mechanisms in [15].

Figures 5 and 6 exemplify the supervisor interfaces. Ass mentioned before, the supervisor has an interface where human traffic agents can see the current traffic situation of all available controllers, their programs, etc. It is also possible to send programs from the programs base or created on the fly to controllers. It is also possible to see the controllers in a Google Maps interface so the human agents may be more confident about the exact place where it is being conducted.

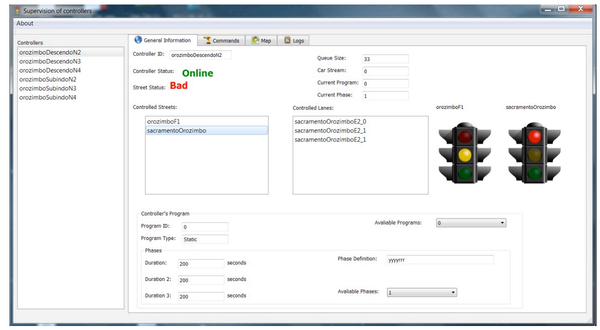
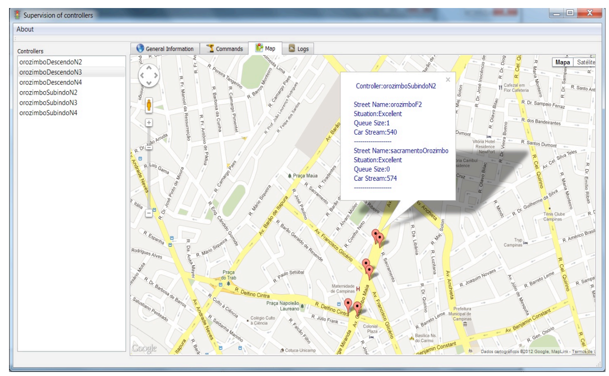


Figure 5. Controller overview



Figue 6. Google Maps interface

V. CURRENT RESULTS

To measure the effectiveness of the supervisor agent, two different simulations were conducted using the same scenario, shown in Figure 7. It depicts an area in downtown Campinas, a city of about 1 million people in the state of Sao Paulo, Brazil. The scenario includes 6 controllers and a cars flow of 1.500 cars/lane/hour at the main avenue and 1.000 cars/lane/hour at adjacent streets (very close to the measured ones). The numbers in the figure identify the controllers. The simulations were conducted for ten minutes each and repeated 5 times. The numbers shown reflect the average values measured for all the traffic lights in each intersection in the 5 repetitions.

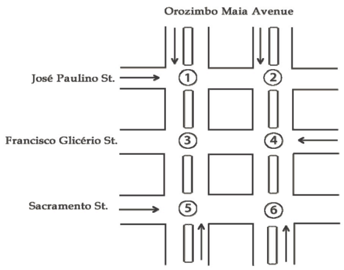


Figure 7. Simulation Scenario.

The first simulation, shown in Figure 8, shows the average number of vehicles (average queue lenghts) observed in the simulations without the action of the supervisor agent, where fixed time traffic strategies calibrated for the mentioned traffic flows, i.e., all the system simulations started with a real traffic cycle (green-yellow-red phases) adopted in the mentioned Campinas area, and then we observed how they managed the traffic lights. This figure shows the results obtained without including the supervisor agent in the simulation. Figure 9 shows the average results obtained at each controller using the supervisor agent.

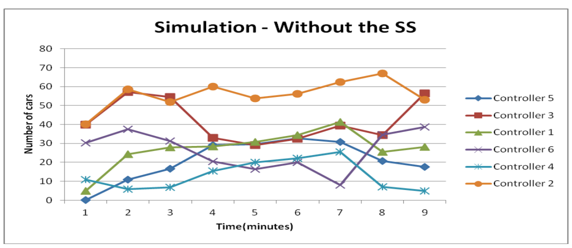


Figure 8. Simulations results I

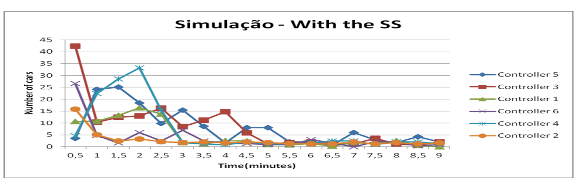


Figure 9. Simulations results II

VI. CONCLUDING REMARKS

In this paper were presented a supervisor agent for urban traffic control, which includes fuzzy sets, genetic algorithms and case-based reasoning to create new programs for traffic controllers. Our first results are encoraging since they showed that the strategy used may be adaptive and help improve traffic conditions by diminishing cars queues in cities' intersections. More tests will be conducted and new functionalities implemented so that it can be incorporated the traffic control system of the Brazilian Intelligent Cities Project. The project intends to implement the simulation strategies in a real neighborhood, and eventully in some major cities.

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