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Intelligent Traffic Light Management using Multi-Behavioral Agents

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***Abstract*—One of the biggest challenges in modern societies is to solve vehicular traffic problems. In this scenario, our proposal is to use a Multi-Agent Systems (MAS) composed of three types of agent: traffic light management agents, traffic jam detection agents, and agents that control the traffic lights at an intersection. This third type of agent is able to change its behaviour between what we have called a *selfish* mode (the agent will try to influence the other neighbour agents of its type to achieve its goal) or an *altruistic* mode (the agent will take into consideration the other neighbour *selfish* agents indications). To validate our solution, we have developed a MAS emulator which communicates with the *Simulation of Urban MObility* (SUMO) traffic simulator using the Traci tool to realize the experiments in a realistic environment. The obtained results show that our proposal is able to improve other existing solutions such as conventional traffic light management systems (static or dynamic) in terms of reduction of vehicle trip duration.**

***Keywords*—Multi-Agents System, Intelligent Transportation System, Smart Cities, Sensor Networks and Traffic Simulations**

I. INTRODUCTION

Intelligent Transportation Systems (ITS) have experimented a fast improvement over the last years thanks to the evolution in the technologies that they rely on. Specifically, subsystems such as Advanced Traffic Management Systems (ATMS) have benefited from the rise of technologies like those used in devices derived for the Internet of Things (IoT) paradigm. These technologies have allowed to increase the data volume used to make decisions.

A side effect of the evolution of the ATMS in the last years has become a great challenge in modern systems: how to process such a high information volume so that the decision-making process is correct and efficient.

Our proposal consists of defining a MAS for intersection management and coordination between intersections about traffic lights management. This kind of system has shown its utility to solve problems within distributed environments.

In section II we review existent systems that modify traffic light phases in order to solve traffic congestion problems, and we discuss why MAS have been proven as an effective tool in this topic. In our case, the main goal of the system will be to control the traffic lights scheduling in a road network, so they can adapt it to the environment. Three types of agent can be distinguished in the system. The first type will manage the variation of the duration of phases in a traffic light, guaranteeing its correct operation. The second type will be in some of the elements of the traffic scenario (i.e. vehicles or sensors in strategic points of the vial network), and will use the information of their environment to make decisions about whether there is a possible congestion situation. Finally, the third type of agent will be located at intersections and will make decisions about the variation of traffic lights phases using the information generated by the other agents. This agent will be responsible for notifying the changes on the duration of phases of all the traffic lights in a single intersection. This third type of agent will vary its own operation per the congestion degree of the intersection where it is located. For low traffic loads, it will work in what we call *altruistic* or *collaborative* mode, in which the agent will help other agents of the same type in different intersections to achieve their goal. However, when high traffic loads are detected, the agent will work in a *selfish* or *isolated* mode, in which the agent will only react to reports from the agents located in the same intersection.

We have modelled and developed the agents described before to validate the solution and emulate the MAS in a simulation environment. We have connected this development with the widely recognized traffic simulator SUMO [1]. Furthermore, we have selected a portion of the well-known traffic scenario "TAPAS Cologne" (Travel And Activity PAtterns Simulation Cologne) [2], [3] for the validation experiments. The portion we have selected reproduces the traffic in a portion of the map of the city of Cologne (Germany), as shown in Figure 1, for a whole

the duration of trips that are lower than the ones in the experiment 1, other for the duration of trips that are equal, and a third one for the trips that are higher in duration. Table I shows the percentage of vehicles obtained in each category for experiments 2 and 3.

Tabla I: Results summary (% of total vehicles)

Trip durations	Lower	Equal	Higher
Actuated Traffic Lights	58.70	28.41	12.89
MAS	60.52	27.08	12.41

Given that the system has been defined to prioritize some traffic flows over others, it is expected that not every vehicle in the simulation is able to reduce the duration of its trips. The obtained results show that the percentage of vehicles suffering an increase in the duration of its trip is low. The value is lower than the 13% in the experiment 2 and 3. It is also worth mentioning that half of those vehicles only experienced a 10% of increase in trip duration.

The improvement between using the "actuated traffic lights" system and our MAS may seem not too remarkable, but it must be contextualized. The simulation using the first method needs an induction loop in every edge of the network that ends in an intersection with traffic lights. Besides that, it must evaluate in every simulation step the registered values by each sensor so it can modify the duration of the traffic lights accordingly. Conversely, the MAS can perform the same task without using fixed sensors distributed along the network, as it is able to obtain information form the vehicles themselves (and incidentally from the possible induction loops installed in some roads), it also limits the amount of data needed to make decisions, as each agent decides if it is necessary to communicate its state or not.

On the other hand, it is important to highlight that, in very high traffic congestion situations, such as the ones simulated in our experiments, there are certain intersections that can reach blocking states where the variations in the actuated traffic lights are not enough to solve them. In that kind of situations, the proposed MAS has been able to "unlock" 1790 vehicles, that have been able to reduce the duration of their trip in Experiment 3.

Finally, the values shown in Figure 7b validate that the MAS is capable of reacting to situations of serious traffic jams, regardless of the number of active vehicles.

VI. CONCLUSIONS AND FUTURE WORK

In this paper we have addressed traffic congestion situations which is one of the most relevant challenges in the most of big cities around the world. More specifically, the main goal of our proposal was to reduce the traffic congestion situations by changing duration of traffic light phases. After analysing the results, and comparing them with other solutions like the static definition of traffic light scheduling or the actuated traffic lights, it is possible to say the use of a MAS is effective.

A secondary goal, but mandatory for the validation of the proposal, has been the implementation of the process that emulates the MAS and managing to communicate it with a widely-used traffic simulator such as SUMO. This goal has been accomplished, and has allowed us to perform experiments over a simulation scenario, which provides higher guarantees about the usefulness of the solution.

Although the conducted experiments yield satisfactory results, there are some avenues for further research in this topic. The decision-making rules of the agents used in this first proof of concept implementation have been very simple but effective, just defining some triggering values for the agents from which the TJamAgents report the situation, and a weighted value applied to the data received by each InteserctionAgent. Those values are used to decide if the traffic is prioritized in one way or another. Once the viability of the system has been proven, and the connection with the simulation platform has been developed, the future work will be related to make more complex decision-making algorithms, that allow better and more effective results. Finally, it would be important to study which is the minimum percentage of agents that should participate in the MAS without deteriorating the system effectiveness.

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