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# Multi-agent based traffic light management for privileged lane

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## Abstract

To optimize the travel time of priority vehicles (PV) and fluidize road traffic in Moroccan cities, we propose in this paper a control system to manage traffic at signalized intersections in urban areas, based on a multi-agent technology and fuzzy logic. the traffic system flow is divided into two types of vehicles; priority and non-priority vehicles, and a group of lanes assigned to each type, the ordinary vehicles can exploit only the ordinary lanes, while the PV may use both the priority and the ordinary lanes. This approach aims to favor emergency vehicles and promote collective modes of transport, it acts on the durations of the traffic light phases to control the different flows. We proposed a decentralized system of regulation based on the supervision of each lane which connects two intersections to build a local view of the crossroad, and intelligent cooperation between neighboring intersections to develop an overview of the environment. The regulation and prioritization decisions are made in real-time by fuzzy logic inference, communication, collaboration, and coordination between different agents. The performance of the proposed system is validated and designed in ANYLOGIC simulator, using a virtual road network that represents a section of the Marrakesh network.

**Keywords:** Coordination; fuzzy logic; multi-agent simulation; priority vehicles.

## 1. Introduction

The road network has an increasingly imbricated management because of the large number of contributed actors, and the unpredictability which characterizes the road flows. In Morocco between 2016 and 2017 traffic has increased by 3% (Ministry of Equipment Transport and Logistics-Morocco 2017). Thus, oftentimes the road infrastructure exceeds its capacity and traffic congestion occurs. The congestion in urban areas is a phenomenon that depends on the time lost at the crossroads stop lines and not on speed on the road.

Optimizing the management and exploitation of urban road networks requires the rationalization of light signals control and the improvement of the time allocated to each mode of urban transport. Optimal management of urban flow can only be guaranteed if priority vehicles are taken into account when crossroad management plans are being developed to create a reliable system that meets mobility needs and accessibility. Priority vehicles are the ensemble of modes that ensure mass mobility of people (bus, metro, tram, ...) or assigned and permitted to respond to emergencies (Ambulances, Fire service vehicles, Police vehicles, ...).

Prioritizing vehicles and regulation of urban road traffic at the signalized intersection are at the depth of research in the field of intelligent transport systems (ITS). Artificial intelligence (AI) is proposed as an efficient tool to implements ITS (Garcia-Nieto, Ferrer, and Alba 2014), in this contribution, we use agent technology and fuzzy logic to study the question of prioritizing vehicles and proposes a multi-agent system (MAS) to optimize traffic lights management.

Optimizing traffic control by reducing travel and delay time can have an important impact on the environment, such as reduce fuel consumption, traffic emissions, air and noise pollution.

In this paper, we propose a multi-agent traffic control system with priority lanes. This system regulates traffic streams at a signalized intersection in real-time, it uses fuzzy logic to deal with uncertainties characterized the traffic environment. The road network is divided into regions, each region contains one intersection and controlled by a group of agents, the control of the whole network is made by coordination and collaboration between neighboring agents' group.

Computer technologies, including agent technology, have been used extensively in traffic control and regulation (Balaji and Srinivasan 2011), and in various components of the transport system such as traffic lights (Bazzan 2005), vehicles and drivers (Xiao Xiong Weng, Shu Shen Yao, and Xue Feng Zhu 2005), highways (Teknomo 2006), and have demonstrated distinguished performance. Other researches study public transport priority (Tlig and Bhouri 2011).

Transport system regulation problems have been treated by agent technology to solve them in a distributed manner. Case-based reasoning was used in (Xiao Xiong Weng, Shu Shen Yao, and Xue Feng Zhu 2005) for the traffic lights management; the agents supervise the status of the road flow at a crossroads and select a solution to apply from its base of cases to fluidize the road traffic. Another approach offers intermodal regulation strategies to promote public transport (Bhouri et al. 2017).

The rest of the paper is organized as follows: Section 2 describes Road network modeling. Section 3 represents the proposed system structure and the agent organization. Section 4 explains the control decision process with fuzzy logic. Section 5 illustrates the simulation of the proposed system and the performance measures used to evaluate the system efficiency, as well as the discussion of the obtained results.

## 2. Road network modeling

In urban areas, vehicles use the road network which we modeled by a strongly connected oriented graph $N = (I, A)$, where $I$ the set of nodes which represent the intersection, and $A$ the set of the arcs which connect these intersections, we have two types of arcs; priority arcs which represent the priority lane PLij and regular arcs Aij which represent the ordinary lanes. We assume that to control an intersection we have to take into consideration upstream and downstream flows, therefore each arc has a set of successor arcs $succ(A_{ij}) = \{ A_{jk}, (i,j,k) \in I \}$ and a set of predecessor arcs $pred(A_{ij}) = \{ A_{ki}, (i,j,k) \in I \}$. Figure 1 represents a set of intersection $I = (\text{i1}, \text{i2}, \text{i3}, \text{i4}, \text{i5})$ with different arc successors and predecessors of i5 arcs.

Each junction is a signalized intersection, where all incoming and outgoing flows are controlled by a traffic light, and managed by a system that prioritizes emergency vehicles while ensuring the safety of road users and optimal management of the phase cycle. Table 1 shows a truth table of possible phases in intersection i5 for 5-phase cycle distribution C= {φ1, φ2, φ3, φ4, φP}, with priority phase (φP) called when needed, as well as the authorized and unauthorized arcs during each phase.

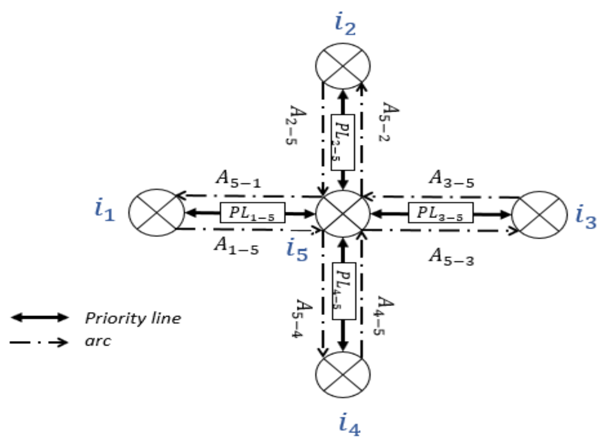


**Figure 1.** Model of 4 intersections with 8 regular arcs and 4 priority lanes.

**Table 1.** The truth table of possible phases in intersection *i5*.

| | Arcs / Phases | A1-5 | A5-1 | A2-5 | A5-2 | A3-5 | A5-3 | A4-5 | A5-4 | PL |
|---|---|---|---|---|---|---|---|---|---|---|
| Cycle | φ1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| | φ2 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 |
| | φ3 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| | φ4 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 |
| | φp | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

### 2.1. Description of urban transport model

The model presented was implemented on the AnyLogic platform. It is a model of road network management with a priority lane, it was built in the following way:

- The components have been recovered from the real-world road network; their deployment descriptors have been modified to take into account the multi-agent execution environment.
- The corresponding agents have been created;
- The components were deployed on our simulation environment;
- An intersection network with priority lanes and management light signals have been built,

simulating the road network.

- A set of normal and priority vehicles have been created with an origin-destination (OD) matrix to represent the different road flows.

An urban road traffic model is made up of:

- Lanes supervisors: represent the network of intersections connected by roads allow the movement and the course of different routes, they collect and process the supplied system situation data to transfer them to the management system.
- Vehicles: all of the entities (Priority and Non-priority vehicles) use the system to move around while respecting the operating rules and asking for priority if exists. The Priority vehicles are the emergency and public transport vehicles that use the priority Lanes (PL). The no priority vehicles are the set of all other modes of transport that use the no-priority lanes.
- Controller: implementation of management strategy and development of lights management plan.
- Coordinator: coordinates with the neighboring intersections and exchange local stat data to develop an overview of the environment

Figure 2 represents the fundamental components of the generic Urban Transport System (UTS).

## 3. Agent Modeling

The MAS consists of autonomous agents' collection who can define their own goals and actions, and they can interact and collaborate. To solve a problem in the MAS environment, agents work collectively (Dorri, Kanhere, and Jurdak 2018). It constitutes an effective platform for coordination and cooperation between several functional units within an organization.

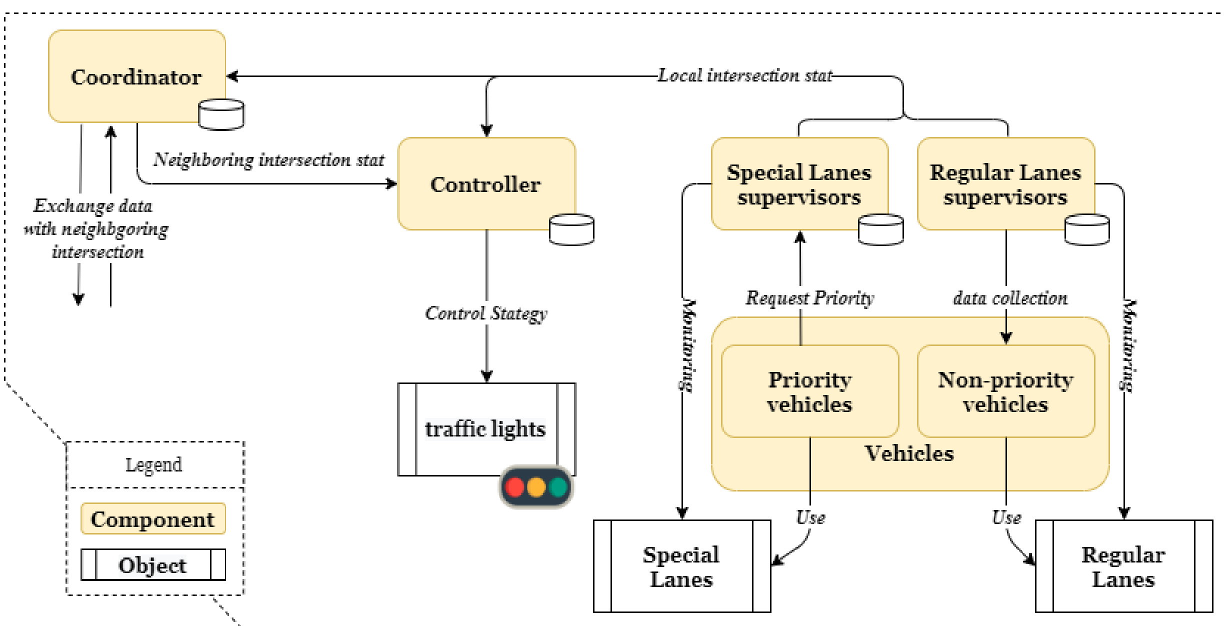


**Figure 2.** The fundamental components of an Urban Transport System (UTS).

### 3.1. The organizational structure of the MAS

The organizational structure we propose is described by a set of roles with their interactions. It can, therefore, be presented by a graph where each node corresponds to a role and a line describes the interactions between the associated roles (see Figure 3). This organizational model is inspired by the Aalaadin methodology and is based on three fundamental notions: agent, group, and role (Ferber and Gutknecht 1998).

To do this, we use a four-process approach:

1. Organizational structuring of a UTS.
2. UTS/MAS alignment.
3. Structuring a UTS into groups.
4. Structuring of groups into agents.

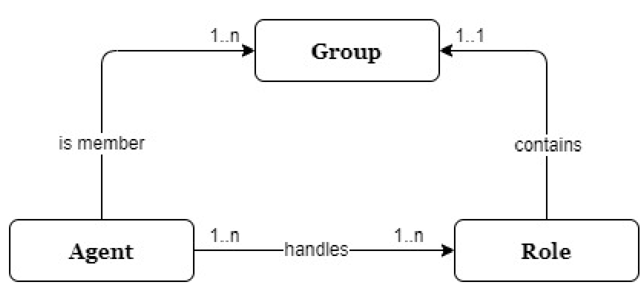


**Figure 3.** AALAADIN model architecture

## 3.2. Structuring a UTS into groups of agents

To structure the UTS system in the form of a multi-agent system, we will use a UTS/MAS alignment as shown in Table 2.

**Table 2.** UTS/MAS alignment.

| UTS component | MAS group |
|---|---|
| **Lanes supervisors** | NAG (Network Agent group) |
| **Vehicles** | |
| **Controller** | DAG (Decision Agent group) |
| **Coordinator** | |

Figure 4 shows the general architecture of the proposed MAS and the different interactions between agents.

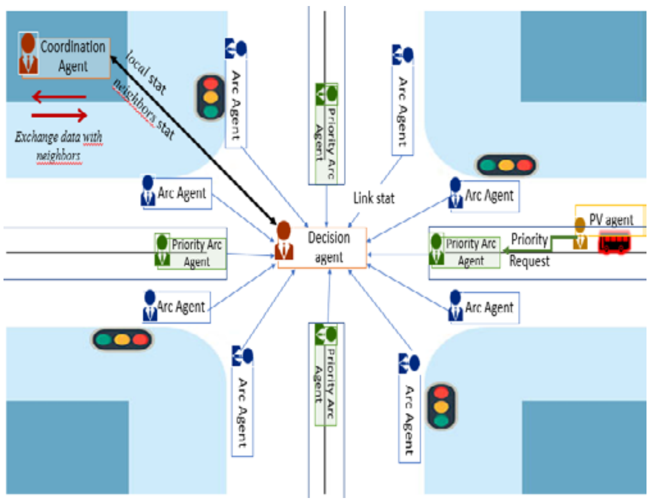


**Figure 4.** The proposed system architecture

## 4. Control Strategy

The Decision agent is responsible for deciding in collaboration with the other agents and the neighboring nodes. The data sent to the decision agent will go through a fuzzy logic system (Soetanto 2000) that consists of 3 steps: fuzzification, inference, and defuzzification as shown in Figure 5.

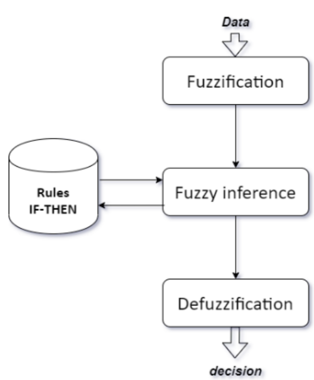


**Figure 1.** Fuzzy logic modules.

The fuzzification process determines the membership functions of linguistic variables.

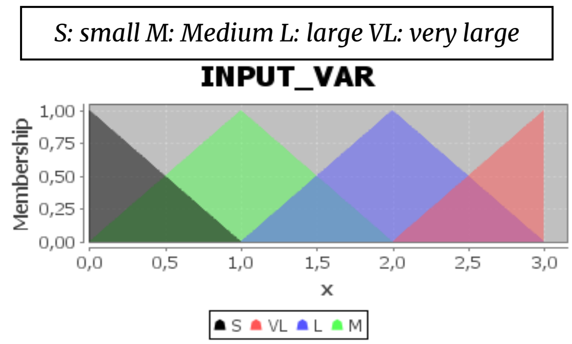


**Figure 5.** Membership function of the input/output linguistic variable.

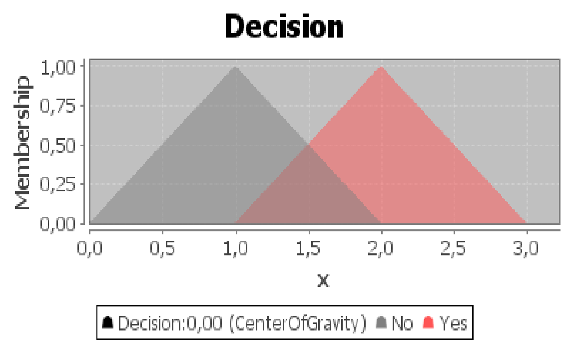


**Figure 6.** Membership function of the Decision linguistic variables.

To determine the decision from the membership functions we use the Center of Gravity (COG) method (Sautriau 1968).

## 5. Simulation results

To show the performance of the proposed system, we applied simulation to a virtual road network which represents a section of Marrakesh road network, and a set of priority and Non-priority vehicles with an origin-destination matrix to represent the different traffic flows.

### 5.1. Simulation environment

A simulation environment is created to evaluate the proposed model. This simulation is carried out with the AnyLogic simulator, which is a simulation environment for transportation systems (Abu-Taieh and El Sheikh 2007).

AnyLogic is a Java-based development environment that includes graphical model editor and code generator. We use the *jFuzzyLogic* library to implement the fuzzy inference system. Figure 9 describes the representation of different agents during the simulation model

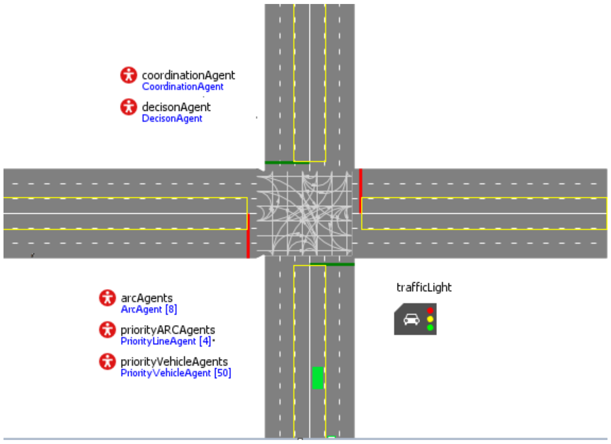


**Figure 7.** Agents during the simulation

The travel time was chosen to evaluate the performance of the system. The journey time (JT) of priority vehicles is the time between the start point and the arrival point.

The journey time obtained in our approach is compared with the journey time in perfectly stationary conditions (JTP) (Figure 8), with the priority vehicles evolved between the start and stop points at a fixed speed without stopping at the traffic lights signals, and with journey time in a regulation system without priority (Figure 9).

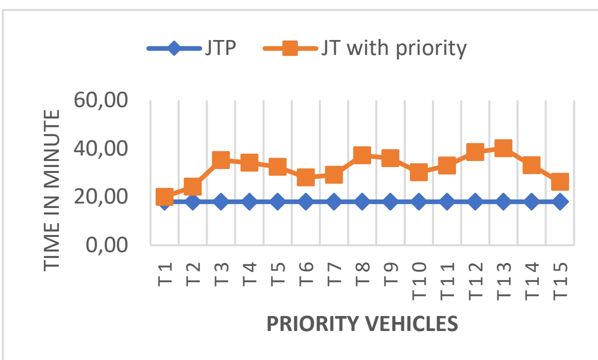


**Figure 8.** JT with priority lane compared to the JTP in perfect conditions.

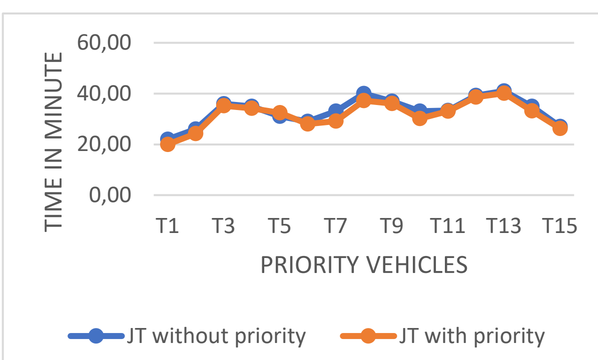


**Figure 9.** JT with priority lane compared to the JT without priority lane.

The results showed that the strategy based on the priority lane transport using multi-agent technology and fuzzy logic gives a reduced travel time and very close to the travel time in perfect conditions.

## 6. Conclusion

In this paper, we have presented and validate an approach based on the multi-agent system and fuzzy logic, where all agents communicate and cooperate to decide cooperatively. To have a more efficient system, the decisions and their conditions of taking must be recorded to create a knowledge base, which represents the expert's knowledge of the road traffic problem.

To allow our country to better manage urban road traffic and promote the use of public transport and favor the emergency vehicles, it is necessary to use a distributed decision system based on a multi-agent approach which gives more priority to modes common transport. As also recommended above, future research should study the trajectory planning generation.

## References

Abu-Taieh, Evon M.O., and Asim Abdel Rahman El Sheikh. 2007. "Commercial Simulation Packages: A Comparative Study." *International Journal of Simulation: Systems, Science and Technology* 8(2): 66–76.

Balaji, P. G., and D. Srinivasan. 2011. "Type-2 Fuzzy Logic Based Urban Traffic Management." *Engineering Applications of Artificial Intelligence* 24(1): 12–22. http://dx.doi.org/10.1016/j.engappai.2010.08.007.

Bazzan, Ana Lucia C. 2005. "A Distributed Approach for Coordination of Traffic Signal Agents." *International Conference on Autonomous Agents and Multi-Agent Systems* 10(1): 131–64. http://www.springerlink.com/index/10.1007/s10458-004-6975-9.

Bhouri, Neila, P Lotito, Neila Bhouri, and P Lotito Régulation. 2017. "Régulation Du Trafic Urbain Multimodal Avec Priorité Pour Les Transports En Commun."

Dorri, Ali, Salil S. Kanhere, and Raja Jurdak. 2018. "Multi-Agent Systems: A Survey." *IEEE Access* 6: 28573–93.

Ferber, Jacques, and Olivier Gutknecht. 1998. "A Meta-Model for the Analysis and Design of Organizations in Multi-Agent Systems." *Proceedings - International Conference on Multi Agent Systems, ICMAS 1998*: 128–35.

Garcia-Nieto, Jose, Javier Ferrer, and Enrique Alba. 2014. "Optimising Traffic Lights with Metaheuristics: Reduction of Car Emissions and Consumption." *Proceedings of the International Joint Conference on Neural Networks*: 48–54.

Ministry of Equipment Transport and Logistics-

Morocco, Morocco. 2017. “Recueil Du Trafic Routier 2017.”

Sautriau, F. 1968. “Cahier Technique 2.”

Soetanto, Danny Prabowo. 2000. “Implementing Fuzzy Logic in Determining Selling Price.” *Jurnal Teknik Industri* 2(1): 43–52.

Teknomo, Kardi. 2006. “Application of Microscopic Pedestrian Simulation Model.” *Transportation Research Part F: Traffic Psychology and Behaviour* 9(1): 15–27.

Tlig, Mohamed, and Neïla Bhouri. 2011. “A Multi-Agent System for Urban Traffic and Buses Regularity Control.” *Procedia - Social and Behavioral Sciences* 20: 896–905. http://dx.doi.org/10.1016/j.sbspro.2011.08.098.

Xiao Xiong Weng, Shu Shen Yao, and Xue Feng Zhu. 2005. “Architecture of Multi-Agent System for Traffic Signal Control.” (December): 2199–2204.