

A Methodology to Control Traffic Light Signals based on Rational Agents

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Abstract—This paper is devoted to develop and to evaluate a set of technologies with the objective of designing a methodology for the implementation of sophisticated traffic lights by means of rational agents. These devices would be capable of optimizing the behavior of a junction with multiple traffic signals, reaching a higher level of autonomy without losing reliability, accuracy and efficiency in the service. In particular, each traffic signal will be able to analyze the requirements and constraints of the road, in order to know its level of demand. With such information each agent will adapt its light cycle with the view of accomplishing a more fluid traffic and minimizing the environmental emissions while vehicles are stopped in a red light, using a case-based reasoning (CBR) adaptation. The paper also integrates a microscopic simulator and emission analyzer developed to run a set of tests in order to compare the presented methodology with traditional traffic control methods. For thus, two study cases are presented to demonstrate the efficiency of the introduced approach, offering significant mobility and environmental benefits. For example, for the first test and using observed traffic volumes, our approach increase mobility in 22% and reduce the emissions in 42%. Finally, when the roads are managed by sophisticated traffic lights, some conclusions draw advantages to achieve significant mobility and environmental advantages, demonstrating the utility of the presented approach.

Index Terms— Intelligent Transport Systems, Vehicular mobility, Neural Networks.

I. INTRODUCTION

IN recent years, road traffic has become an essential part of a modern city. Research in the field of the optimization traffic-volume arteries has been one of the most pursuit challenges [1]. As the number of road users constantly increases and resources provided by current infrastructures are limited, intelligent control of traffic has become a very important issue. In this sense, intelligent systems have proven to be computational tools that cover substantially diverse research areas due to their decision-making paradigm based on reasoning processes. For instance, avoiding traffic jams has been thought to be beneficial to both environment and economy, but improving traffic-flow may also lead to an expansion of the demand of the service [2]. Research has shown that such models yield realistic behavior [3], [4], [5], [6].

Manuscript received March 23, 2015; revised April 08, 2015.

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For example, cars in urban traffic can experience long travel times due to inefficient pre-programmed control of the traffic lights. The optimal control of traffic lights using sophisticated sensors and intelligent optimization algorithms might therefore be very beneficial. Optimization of traffic lights switching improves traffic flow and prevents traffic congestion. Traffic lights control is a complex problem of optimization and several intelligent algorithms, such as fuzzy logic, evolutionary algorithms and reinforcement learning (RL) have already been used in attempts to solve it. This paper describes a model-based rational multi-agent algorithm to control traffic lights. The presented approach introduces a formalization capable to take flexible and autonomous decisions for the calibration of the length of the cycles. This method proposes a cycle of three phases: environmental-oriented knowledge, decision-founded on information and execution-based on argumentation. In fact, each phase works using different engineering perspective. Environmental-oriented Knowledge, for example, uses different probabilistic distributions to simulate the vehicle arrivals at a particular lane of a junction. Decision-founded on Information is dedicated to think and to decide how to fix the behavior of the traffic lights using the principles of the CBR cycles adapted to the proposed methodology. Finally, execution-based on argumentation is the phase that allows agents to manage the physical changes of the signals performance. In particular, this phase is devoted to facilitate the interaction among agents by performing an adaptation of the KQML language [7]. Such communication therefore, is the process in which all the agents are ready to interact with the others so as to generate the commitment giving some extra time from their cycle. To evaluate the performance of our model-based on the CBR cycle, the paper presents two studied cases and their results using a simulated tool developed for the project. Trends, conclusions and future work are presented at the end in order to emphasize the advantages and usefulness of the promising approach.

II. RELATED WORK

Fast transportation systems and rapid transit systems are nerves of economic development for any nation. All developed nations have well developed transportation systems with efficient traffic control on road, rail, and air. The monitoring and control of city traffic is one of the key issues especially in metropolitan areas due to ever increasing number of vehicles and pedestrians. Numerous methods are available to reduce delays and environmental problems caused by road traffic in major cities. Current traffic controllers are based on microcontroller and microprocessor. These traffic light controllers have limitations because they do not have the flexibility of modification on real time basis. In traffic signal control systems, detection of traffic variables at intersections is very important and it is the basic input data to determine signal timing. According to this, in [3] an application of fuzzy logic for multi-agent based autonomous traffic lights control using wireless sensors to overcome problems like congestion, accidents, speed and traffic irregularities is presented. In fact, this approach provides a preferred solution by minimizing the vehicles waiting

time especially the emergency vehicles using fuzzy logic control under situations that normally occur during these situations. Likewise, in [5] a new infrastructure to vehicles communication and control system for intelligent speed control, which is based upon radio frequency identification (RFID) technology for identification of traffic signals on the road, and high accuracy vehicles speed measurement with Hall effect-based sensor is presented. To achieve an efficient adaptation of the speed of the vehicle, the approach introduces an adaptation of a fuzzy logic controller based on sensor fusion of the information provided by the infrastructure installed on the road. Finally, the results suggest unexpected traffic circumstances and improve the safety of the occupants of the vehicle. In this light, in [11] an Intelligent Traffic Signal Controller using FPGA controller based on Neuro-Fuzzy system is presented. Such approach is capable of taking decision to reduce delays in an intersection. In particular, the fuzzy logic theory in the controller provides an intelligent green interval response based on dynamic traffic using the input variables of the weighed traffic flow at the current and neighboring intersections. The paper argues that it is able to overcome the weakness of conventional traffic controllers by using its capability of providing a variety of green cycle intervals based on dynamic traffic load changes at every lane in a 4-way junction control. Besides the current trends to solve the gap between traditional traffic control and advanced computational methods, the field of the development of simulated environments to test the control and optimization of urban arterials is another interesting and promising area for further study. Nowadays there are computational tools that offer the opportunity of implementing and testing approaches in order to corroborate their ideas. Nonetheless these tools are not functional for all purposes. Because of this, some authors tend to develop their own tools while they are generating their methodological proposals. For instance, in [1] a reservation-bases approach to intersection control was designed and evaluated. This approach proposes the development of a novel simulator test bed for connected vehicle application. Indeed, the test bed integrates a microscopic traffic simulator with network simulator an emission analyzer. Some experiments are presented using the developed simulator in order to compare the mobility and environmental benefits of the introduced approach against traditional control methods. References [12], [13], [14], [15], [16], [17], [18], [19], [20], [21] are other examples of the aforementioned action. To the end, in [4] a complete review of literature about agent-based approaches well suited to the domain of traffic and transportation system, because transportation systems are often geographically distributed in dynamics changing environments is presented. In particular, the paper reviews agent-based traffic applications classified in five categories: 1) agent-based traffic control and management system architecture and platforms; 2) agent-based systems for roadway transportation; 3) agent-based systems for air-traffic control and management; 4) agent-based systems for railway transportation; and 5) multi-agent traffic modeling and simulation. However, software agents and artificial intelligence techniques in urban traffic systems arise as proper solutions in the last decade to provide high levels of efficiency in transport infrastructures. In despite of these efforts, the design, development and implementation of agent technology in traffic control systems are still immature and need to be further studied in order to achieve accuracy and trustworthy applications to build traffic control systems regarding to control the demand level and to minimize the emissions.

Limitations of Previous Works on ITS

- 1) Previous research has primarily focused on evaluating the mobility advantages and emission benefits of intelligent intersections systems ITS. However, the fact that intelligent intersections are devoted to reduce the time that cars are needlessly stopped in a red light and the acceleration and

deceleration maneuvers implies that they can also benefit the environment by reducing the fuel consumption, pollutant emissions and the generation of other class of contaminants (e.g., dust form the brake-pads, tires, spark-plugs, etc). For thus, the environmental benefits of intelligent intersections have not yet been clearly quantified in the literature.

- 2) Works devoted to ITS research are not able to use information about decisions taken previously when the junctions must be adjusted to offer a better level of mobility under overloaded traffic volumes.
- 3) Other models implemented to manage the control of the traffic-light signals are unable to use a communication protocol in the phase of synchronization of the lights-time in order to reach a successful interaction between intersections.
- 4) The current simulators in the state-of-the-art are not capable to work in real time and also they are not designed to auto-synchronize the time of the traffic signal lights while an experiment is performed.

III. OUR APPROACH

Long lines of vehicles, wide range of stop-time in intersections and environmental emissions are only some of the issues that traffic control is looking forward to avoiding. For thus, the paper introduces an approach where a rational agent is in-charge of the operations carried out for a traffic light signal. In particular, this agent is capable to analyze the behavior of an arterial before the green-light goes on. Indeed, such information is useful to evaluate the performance of the cycle-lights, allowing the system to establish a temporal situation to think what it should be done. After this, an agent acts modifying the time (length) of the lights to optimize the vehicles flow. Such process tries both to improve the level of the service in a particular lane, to reduce in a significant way the magnitude of the pollutants and to decrease as well as to decrease the fuel consumption. The general structure of traffic light control based on rational agents is showed in Fig. 1.

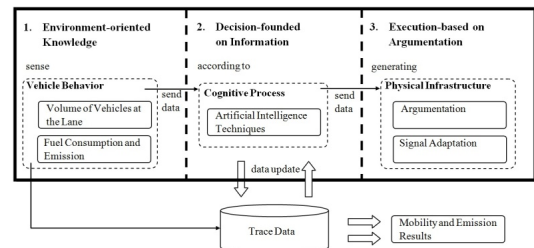


Fig. 1. General scheme of the presented approach.

A. Environmental-oriented knowledge

Let us define the ability of perception of the system such as the capability of a rational agent to sense information about the behavior of the vehicles in a particular lane at a determined junction. Formally, let us suppose that a junction J_α is part of a domain D , where each junction J_α has m arteries $A(J_\alpha) = \{a_1, a_2, a_3, \dots, a_{m-1}\}$. In particular, each J_i has associated a rational agent ra_i where $\forall J_i \exists ra_j \in RA = \{ra_1, ra_2, ra_3, \dots, ra_{n-1}\}$, where each ra_j is in-charge of controlling the phases of the traffic lights cycles in every convergent point between arteries.

In this sense, the environmental-oriented knowledge $E-ok$ is defined as the amount of data obtained from the road involving all the set of information related to the quantity Φ and the type Θ of vehicles that represent an arrive e in any artery of a particular junction $A(J_\alpha)$, such that:

$$\forall a_i \exists E-ok(a_i) \in E-ok(J_\alpha) \subseteq E-ok(D) \mid \\ E-ok(a_i) = [\Phi(e \in a_i) \wedge \Theta(e \in a_i)]$$

where:

$$\Phi(e \in a_i) = \sum_{e_i=1}^{\infty-1} e_i \therefore \Phi(e \in J_\alpha) = \sum_{a_i=1}^{m-1} \sum_{e_i=1}^{\infty-1} e_i$$

Besides, the type of vehicles that arrive to a particular artery are deinfed as a vector as follow:

$$\Theta(e \in a_i) = [\theta_1 \vee \theta_2 \vee \theta_3 \vee \theta_4 \vee \dots \vee \theta_{c-1}]$$

Particularly, the rational agent must control the fuel consumption FC and pollutant emissions (i.e., carbon monoxide CO, carbon dioxide CO₂, nitrogen oxides NO_x, hydrocarbons HC) according to:

$$\forall a_i \in J_{oc} \exists \begin{cases} a_i, a_j \in J_{oc} \mid a_i \neq a_j \\ FC_{a_i} \subseteq FC_{J_{oc}} \subseteq FC \\ CO_{a_i} \subseteq CO_{J_{oc}} \subseteq CO \\ CO2_{a_i} \subseteq CO2_{J_{oc}} \subseteq CO2 \\ NOx_{a_i} \subseteq NOx_{J_{oc}} \subseteq NOx \\ HC_{a_i} \subseteq HC_{J_{oc}} \subseteq HC \end{cases}$$

B. Decisions-founded on information

A decision is the process through which a rational agent ra_i must consider the information from a particular junction to decide what it must be done in order to improve the mobility of the vehicles in this specific lane and to reduce emissions in a representative way. To achieve this target, the approach proposes the use of some algorithms with the ability of mimicking human intelligence. In this sense, this technology permits the implementation of real-life rules similar to those people usually resort to. To emulate the behavior of a transit officer, the paper presents an adaptation of the CBR cycle as it follows:

The problem - While the amber light is flashing, the agent in turn must build a case of the situation over the lane using the following set of variables:

#Case_n

- V_L = the volume of vehicles in the lane
- T_{GL-TLI} = length of green light that the agent offered in the previous cycle.
- $V_{velocity}$ = standard velocity of the vehicles.
- d_{cross} = distance considered to the way out of the cars.
- #rails = quantity of rails at each lane.

In particular, for empirical reason proposed in this paper, the last three variables are constant parameters, which are different for each study case.

Retrieve - An agent must review the volume of vehicles in the lane using environment-oriented knowledge before the green light turns on. Using this information the agent looks inside the case-bases to extract the most similar situations to solve the problem. This search allows obtaining the possible length of green light in order to offer a good solution for the presented conditions of the lane. **Reuse** - A new solution is generated from the retrieved cases according to the problem conditions. At this stage the possible length to the green light is obtained in order to ensure a suitable level of service and to increase the performance of the entire intersection. **Revise** - A revision of the proposed solution (the volume of remaining vehicles on the lane) is done in order to evaluate the results and verify if the solution (in aspect of the vehicular mobility) has been satisfactory. To do this, the agent uses the eq. 1.

$$V_Q = \left(V_L - \text{abs} \left[\left(\frac{T_{GL-TLI} * V_{velocity}}{d_{cross}} \right) * \#rails \right] \right)_{t_0} \quad (1)$$

Retain - After the revision if the agent considers that the solution achieves a better performance than the offered by the common control, the studied problem and the proposed solution have to be indexed in the case-bases in order to use them in next occasions of the CBR cycle.

IV. IMPLEMENTATION

An advanced approach to optimize traffic control is proposed using a multi-agent system, in which the agents interact and communicate among themselves to make the level of the service better. Basically, a simulator and emission analyzer was developed in MatLab language to corroborate the methodology proposed in this approach and it is capable to simulate the behavior of different junctions with specific configurations (see Fig. 2). In particular, the simulator allows profiling two types of intersections with different distributions simulating the injection of vehicles at the lanes. Such

distributions have been adapted to generate the arrival of vehicles to the junction in a particular manner throughout the simulation. Then, the simulator manages three possible probabilistic distributions: normal, exponential and uniform. Also, it is possible to set three labeled functions: CBR, Cars Simulation and Data Acquisition. In particular, if the CBR option is not selected, the system uses a pre-programming scheduled length for the cycles of the traffic lights. Besides, the simulator is capable to measure the generation of environmental emission similar to the Comprehensive Modal Emission Model (CMEM) which is a microscopic emission model that predicts tailpipe emissions and fuel consumption based on a physical power-demand modeling approach second-by-second [10]. In this paper, CMEM is used only as a motivational model. The configuration allows fixing the time of the experiment and gives the clock-time of the simulation. Finally, by means of the simulation data section it is possible to appreciate the behavior of the traffic light cycles and the volume of vehicles in each traffic signal.

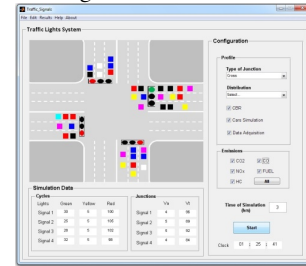


Fig. 2. Computational tool to simulate our approach.

In order to evaluate this approach, the paper presents a particular implementation of the proposed methodology as it follows:

Environmental-oriented Knowledge.

In order to generate the arrivals of the vehicles at a particular lane of the junction, the agents use a set of probabilistic distribution (normal, exponential and uniform) provided by the simulator. The agent then defines the moment of the vehicles arrival $time_{vehicle}$ using the selected distribution. Therefore, the volume of the vehicles V in a particular lane L_i is the sum of all arrived vehicles in a sampling time according with the length of the red light when this is on.

Decisions-founded on Information

To emulate the behavior of a transit officer, the paper presents an adaptation of the CBR cycle as it follows:

The problem - While the amber light is flashing, the agent in turn must build a case of the situation over the lane using the following set of variables:

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- V_L = the volume of vehicles in the lane
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In particular, for empirical reason proposed in this paper, the last three variables are constant parameters which are different for each study case.

Retrieve - An agent must review the volume of vehicles in the lane using environment-oriented knowledge before the green light turns on. Using this information the agent looks inside the case-bases to extract the most similar situations to solve the problem. This search allows obtaining the possible length of green light in order to offer a good solution for the presented conditions of the lane. **Reuse** - A new solution is generated from the retrieved cases according to the problem conditions. At this stage the possible length to the green light is obtained in order to ensure a suitable level of service and to increase the performance of the entire intersection. **Revise** - A revision of the proposed solution (the volume of remaining vehicles on the lane) is done in order to evaluate the results and verify if the solution (in aspect of the vehicular mobility) has been satisfactory. To do this, the agent uses the eq. 1.

$$V_Q = \left(V_L - \text{abs} \left[\left(\frac{T_{GL} - T_{L_i}}{d_{\text{cross}}} * V_{\text{velocity}} \right) * \# \text{rails} \right] \right)_{t_0} \quad (1)$$

Retain – After revision, if the agent considers that the solution achieves at least the 80% of performance (it means that the 80% of the vehicles have already left the lane) the studied problem and the proposed solution have to be indexed in the case-bases in order to use them in next occasions of the CBR cycle.

Execution-based on Argumentation.

At this stage, agents must interact with the other agents in order to argue a possible interchange of the length of their green lights. Such interaction is achieved by means of an adaptation of the KQML interaction protocol [7] as it follows:

$$\begin{aligned} \forall as_j \in AS [J_{\infty}(as_j) \rightarrow \text{time_green}(as_j)] \\ \exists as_j, as_k \in AS \mid as_j \neq as_k \therefore \end{aligned}$$

$$[J_{\infty}(as_j) \wedge \text{time_green_n}(as_j)] \rightarrow \text{request_time}(as_k)$$

When an agent receives the information of the requested green light, it decides the time that might offer, based on a revision of the previous presented green light on its lane. After such process, each agent is capable to operate its assigned interface (i.e., the traffic light) in order to update and to fix the length of the green light, modifying the length of the entire phase.

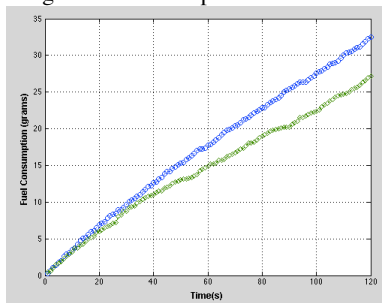


Fig. 3. Comparison between real data and simulated results.

V. CONCLUSIONS AND FUTURE WORK

One of the most intensive calculations in the overall application of the traffic flow is the part involving the simulation of the vehicular jams within junction areas. An advanced approach to optimize traffic control is proposed using a rational multi-agent system, in which the agents interact and communicate among themselves to make the level of the service better. Basically, a simulator and emission analyzer was developed in MatLab to corroborate the methodology proposed in this approach and it is capable to simulate the behavior of different junctions with specific configurations. In particular, the simulator allows profiling two types of intersections with a normal distribution simulating the injection of vehicles at the arteries. Such distribution has been adapted to generate the arrival of vehicles to the junction in a particular manner throughout the simulation. Basically, to provide a good level of vehicles mobility, the agent coordinator has to compute the volume of incoming vehicles V_L before each green light turns on. In this section, experiments are preformed to simulate the likely mobility and environmental benefits of the intelligent junction concept compared to traditional control approach. Two test cases are considered: 1) a connection between two four-way intersections and 2) a connection between two three-way junctions and a four-way intersection. The simulation settings are given as follows: 1) the length of the sampling times are fixed in 1, 4, 8, 12 simulated hours; 2) vehicles are injected into the simulations using a normal distribution taking into account the data showed in Table I and II respectively. From the data obtained in the performed simulations, some preliminary results have been obtained in order to evaluate the usefulness of the methodology proposed in this paper.

Test case 1. Two interconnected four-way junctions are simulated in the developed system with the requirements and constraints that are shown in Fig. 4 and Table I.

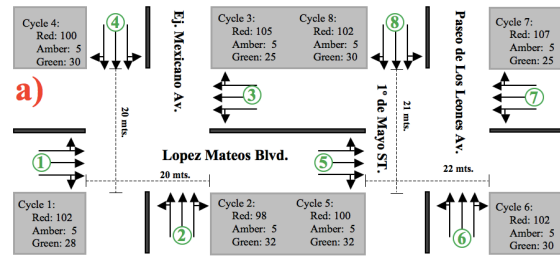


Fig. 4. General scheme of the case 1.

TABLE I.

The speed constant value is 50 Km/H. Performance is compared to demonstrate the benefits of the traffic lights based on intelligent control IC over traditional control methods TC. Fig. 5 shows the mobility performance of the IC based on communicative agents using the CBR filter over pre-programming TC. Specifically, such comparison is performed by taking into account the amount of vehicles that arrives versus the total of vehicles dispatched by the lane. First, focusing on increasing the average service, as shown in Fig. 6, the proposed methodology appears to be capable of improving substantially the service level of a particular intersection. For instance, the performance of the service of the IC is better than TC around 18% in the second sample time (i.e., the 4 hours case). Secondly, the environmental evaluation focused on the reductions in fuel consumption, as well as the reduction of the following four pollutants: 1) hydrocarbons HC; 2) carbon monoxide CO; 3) nitrogen oxides NOx; and 4) carbon dioxide CO2 as shown is Fig. 5.

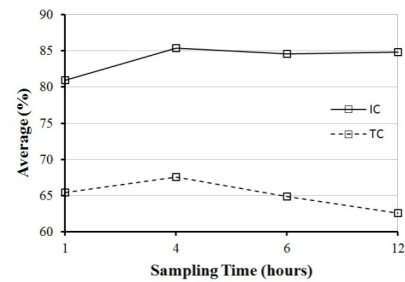
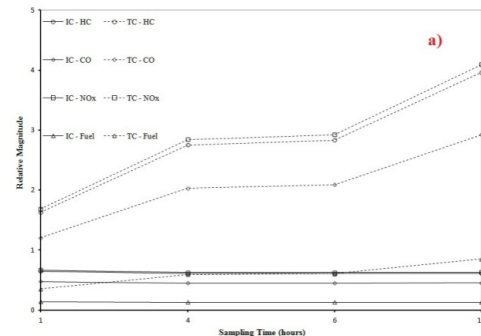


Fig. 5. Average of the Served Vehicles at a four-way junction.

Fig.6a compares the fuel consumption (in units of grams per second, generated by stopped cars while the red light is on) and the emission level of three of the pollutants (also in units of grams per second) under the IC and the TC for the different sampling times. The remaining pollutant is presented in Fig. 6b. For example, for the four hours of simulation (see Fig. 6b) the magnitude of CO2 emission under the control of intelligent agents shows a better performance than the one controlled by traditional methods, around 78%. In particular, the implementation of intelligent agents based on past decisions and under direct interactions with the purpose of coordinating length of the cycles in a particular junction, appears to have reduced the emission significantly. As the sampling time has increased, the IC manages to reduce both all the emissions, and the fuel consumption. The complete analyzing results are summarized in Table II.



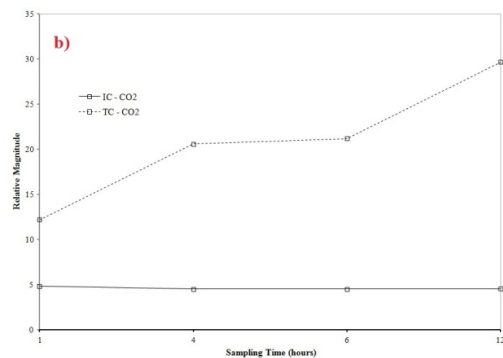


Fig. 6. Relative magnitude of emission and fuel consumption versus sample time: four-way test case.

TABLE II. EMISSION AND FUEL CONSUMPTION. CASE 1.

	Sample Time (hours)	Intelligent Control (IC)	Traditional Control (TC)	Improvement Rate (IC over TC)
HC (gram/sec)	1	0.6450	1.6321	60.48
	4	0.6044	2.7518	78.03
	6	0.6043	2.8317	78.65
	12	0.6091	3.9633	84.63
CO (gram/sec)	1	0.4757	1.2037	60.48
	4	0.4457	2.0294	78.03
	6	0.4456	2.0883	78.66
	12	0.4492	2.9229	84.63
CO2 (gram/sec)	1	4.8276	12.2147	60.47
	4	4.5234	20.5941	78.03
	6	4.5225	21.1900	78.65
	12	4.5589	29.6610	84.62
NOx (gram/sec)	1	0.6660	1.6851	60.47
	4	0.6240	2.8412	78.03
	6	0.6239	2.9237	78.66
	12	0.6289	4.0920	84.63
FUEL (gram/sec)	1	0.1383	0.3499	60.47
	4	0.1296	0.5900	78.03
	6	0.1295	0.6071	78.67
	12	0.1306	0.8498	84.63

Test Case II. The second test involves a real-world intersection, which includes a three-way junction in the City of Tampico, MX., which represents an important access to a main artery used by the inhabitants in this town (see the scheme of Fig. 3b). One of the lanes allows traffic in one direction (lane 1) and represents a road with a great amount of vehicle arrivals. The data used in the experiments has been obtained in real traffic study dated in Oct. – Dec. 2011 and Jan. – Mar. 2012 Just like in test case 1, the speed on all the lanes is a constant value fixed in 50 Km/H. For all the sampling times, the three traffic signals are configured as intelligent agents implementing the CBR filter as it is described in section 3. The obtained results are compared in order to emphasize the advantages of the traffic control based on intelligent agents over the pre-programming traditional control used in the synchronization phase of the studied intersection.

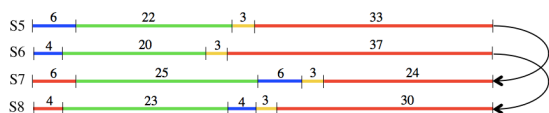


Fig. 7. Example of a traffic light signal phase.

Therefore, the Fig. 8 shows the mobility level confronting the volume of arrivals against the departures. Looking for ensuring high levels, the results report that IC assesses a better performance than TC in around 19%.

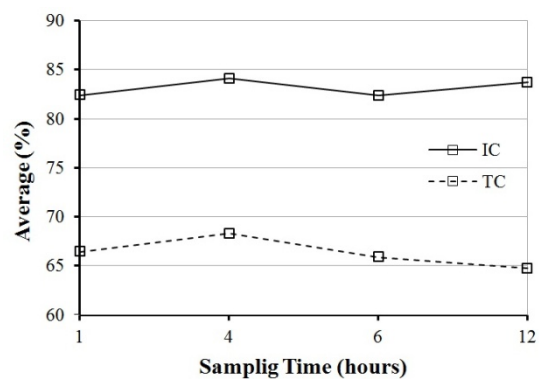


Fig. 8. Average of the Served Vehicles at a three-way junction.

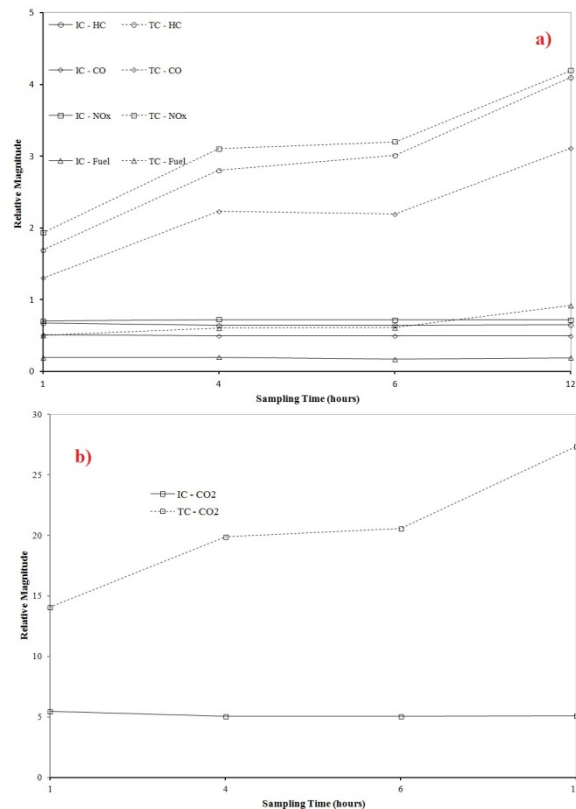


Fig. 9. Relative magnitude of emission and fuel consumption versus sample time: three-way test case.

Fig. 9a plots the gain obtained from the experiments regards to the emissions generated and fuel consumption along the sampling times. For experimental reasons, Fig. 9b shows the average achieved in the reduction on the volume of CO₂ while vehicles are stopped. For example, the magnitude of CO₂ emissions when the traffic lights are controlled by intelligent agents reaches a considerable improvement around of the 75% in comparison with the performance achieved by the traditional control observed in the real world infrastructure. The complete analyzing results are summarized in Table III.

TABLE III. EMISSION AND FUEL CONSUMPTION. CASE 2.

	Sample Time (hours)	Intelligent Control (IC)	Traditional Control (TC)	Improvement Rate (IC over TC)
HC (gram/sec)	1	0.6450	1.6321	60.48
	4	0.6044	2.7518	78.03
	6	0.6043	2.8317	78.65
	12	0.6091	3.9633	84.63
CO (gram/sec)	1	0.4757	1.2037	60.48
	4	0.4457	2.0294	78.03
	6	0.4456	2.0883	78.66
	12	0.4492	2.9229	84.63
CO2	1	4.8276	12.2147	60.47

(gram/sec)	4	4.5234	20.5941	78.03
	6	4.5225	21.1900	78.65
	12	4.5589	29.6610	84.62
NOx (gram/sec)	1	0.6660	1.6851	60.47
	4	0.6240	2.8412	78.03
	6	0.6239	2.9237	78.66
FUEL (gram/sec)	12	0.6289	4.0920	84.63
	1	0.1383	0.3499	60.47
	4	0.1296	0.5900	78.03
	6	0.1295	0.6071	78.67
	12	0.1306	0.8498	84.63

VI. CONCLUSIONS AND FUTURE WORK

The traffic congestion of the road is one of the main causes in the low productivity and decreasing of the standards of a modern city. In this sense, some recent trends in artificial intelligence suggest that in a close future, some vehicles and control systems will be operated by intelligent agents improving some challenges on the road. Based on the paradigm of ubiquitous computing, the control of the traffic based on intelligent agents offers an ideal path to operate the vitalities using internet or other ad-hoc interconnections based on information on real world time. In this case, the flexibility of the autonomous agents allows making decisions in similar ways as a human being does. In this sense, the paper introduces a novel methodology to manage traditional traffic control using intelligent agents. Specifically, agents are in-charge of assesses the conditions and requirements of the lanes in order to evaluate if the assigned length of green light offers a service with at least the **80%** of dispatched vehicles. To do this, the agents use an adaptation based on the CBR filter, which is also similar to that of a policeman handling the traffic flow at a typical junction. This cognitive process allows agents to be capable of evaluating past decision from a data base built over the time. In this light, an integrated simulator for the design and evaluation of intersection has been first developed. The simulator permits users to configure different aspects of a determined intersection in order to provide results that disclose the behavior of the traffic flow and other relevant information such as the emission and fuel consumption. The simulator also reports the changes of the length in each traffic light throughout the experiments. Finally, the studies performed in the integrated simulator were used to evaluate not only the likely mobility advantages but also the environmental benefits of the new strategy to control traffic lights based on intelligent agents. To do this, the results compared the volume of attended vehicles, the level of the service at the junction, the fuel consumption and emissions, under the traffic lights control based on intelligent agents, to those under traditional signal control methods. Different configurations have been considered in both experiments, with one involving an isolated intersection and a three-way intersection. The obtained results have clearly demonstrated the significant mobility benefits of the proposed approach in terms of the level of congestion after a green light by increasing traffic capacity in a particular lane as well as the significant reduction of stopping-time, fuel consumption and the emissions generated because of long-length of red lights. However, several future investigation aspects are suggested by the current research, including the following: Issues such as acceleration and des-acceleration, collision avoidance and vehicles with different velocities, must be included in the simulator by offering a set of more realistic situation in the virtual instrument proposed here.

In this paper, the focus has been basically on vehicular traffic and on assessing the mobility and environmental benefits using intelligent agents to control the length of the lights. Future research should attempt to evaluate the likely safety benefits of the approach and how pedestrians can be accommodated at such junctions. Intelligent traffic lights using sophisticated computational algorithms represent a novel futuristic approach to autonomous controlling the intersections. As such, future research should focus on assessing the reliability, robustness and safety of the approach under a wide range of expected operating conditions and likely failure modes.

In short, intelligent and communicative agents employed to control traditional pre-programming traffic lights are capable to ensure autonomy without losing security and effectiveness in the optimization of the vehicular flow at any particular junctions using the CBR methodology. Therefore, the paper promotes two main contributions for the state-of-the-art in the areas of the intelligent agents and in the field of computational tools to simulate and evaluate the behavior of vehicular traffic, such as:

Contribution 1. A novel and preliminarily methodology to optimize the traffic flow using intelligent agents. The paper reports a good and feasible structure to take advantages of using previous decisions in order to guarantee the major amount of vehicles served by the traffic light when the green light is on. In fact, the proposal outlines the way of including information about the requirements and constraint of the lane to identify the length of green light needed in order to communicate this information to other agents to reach a commitment of interchanging green time.

Contribution 2. A computational tool is an instrument to simulate the behavior of junctions in order to evaluate both the vehicular mobility as well as the fuel consumption and greenhouse emission. The paper argues the need to build new systems to satisfy the configuration requirements of vehicular traffic experts in a more friendly but reliable and effective way. The utility and feasibility of this system on several traffic scenarios have been demonstrated. Other future works is to generate a predictive incoming control to kwon the movement of the cars.

ACKNOWLEDGMENT

This paper was supported by the Programa para el Desarrollo Profesional Docente en oficio DSA/103.5/15/11.52.

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