An Autonomic System for Intelligent Truck Parking

Jose F. García[1], Vicente R. Tomás[2], Luis A. García[2] and Juan J. Martínez[1]
[1]*Institute of robotics and information and communication technologies (IRTIC), University of Valencia, Paterna, Spain*
[2]*Engineering and Computer Science Department, University Jaume I, Castellón de la Plana, Spain*

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Abstract: Traffic and road transport conditions are strongly influenced by the decisions of drivers. The more information they receive, the better decisions may be taken about their behavior. This is especially important in the transport of goods, since drivers are subject to traffic laws about maximum driving time and minimum time rest. In this paper a multi-agent system for negotiated management of parking spaces in road rest areas is presented. This system dynamically adapts itself to the preferences and needs of the drivers of goods about parking requests. The system is shown to be robust to incidents regarding the closure of road rest areas and an increased volume of freight traffic. The results also show that the number of illegal parkings is reduced resulting in greater road safety.

1 INTRODUCTION

The domain of road traffic and transport involves an inherently distributed environment. Several traffic organizations must act in a coordinated way to improve the traffic safety and status, for example by identifying traffic flow problems and by proposing actions to alleviate them. This coordination is fundamental in Long Distance Corridors (LCD). A LDC is a road network corridor that includes a common platform with a co-ordinated setup of different systems and services, contributing to improve traffic management and information for travelers and freight transport on long distances (Aumund, 2004). The main use of these corridors are the transport of goods. Therefore, route planning plays an important role in the goods road transport domain. However, route planing does not only include the itinerary but also the rest road areas to park and rest because journey time exceeds the maximum driving time required by law. Moreover, if drivers park in not allowed places, they can produce problems in traffic safety and be fined. The importance of the parking spaces in Europe is reflected in several institutional or research actions: ITS directive (Commission, 2010) , the EU ITS Action Plan (Commission, 2008) and the deployment guideline for Intelligent truck parking developed in the EasyWay project (EasyWay, 2012).

An Intelligent Truck Parking system (ITPs) is defined as an ITS service that support drivers in two ways: a) information and guidance (on truck parking areas) and b) reservation (of truck parking spaces). ITPs could be classified attending the level of Service (LoS). LoS defines the specific characteristics that the ITP offers to the drivers. In (EasyWay, 2012), 5 different levels are defined, from A (lower level) to E (high level). Currently, several organizations and projects have developed ITPs projects regarding level A to C. These systems are based on static information, based on books and journey routes periodically edited (ParkMyRig, 2014) (Project SETPOS, 2014). Regarding level of service D, systems with dynamic information, there are also different systems (Sndor and Csiszrr, 2013) (Vennekens, 2014). These booking systems are based on pre-trip systems, i.e. the driver has to book the place to rest before to begin the journey.

In (ParkYA, 2014), a new application for mobile devices has been developed to make easier to find car parking spaces in real-time. Despite it is a good approach, its main problem is that only drivers use it, the parking areas are not involved in the system. Thus, the parking availability is defined by drivers, that inform, in a qualitative and subjective way, the occupancy of areas.

So, current systems present several difficulties because drivers do not know the traffic behavior in advance, so they might even not reach the parking area booked, or when they reach it the area could not have free places. Therefore, an ITP system where drivers

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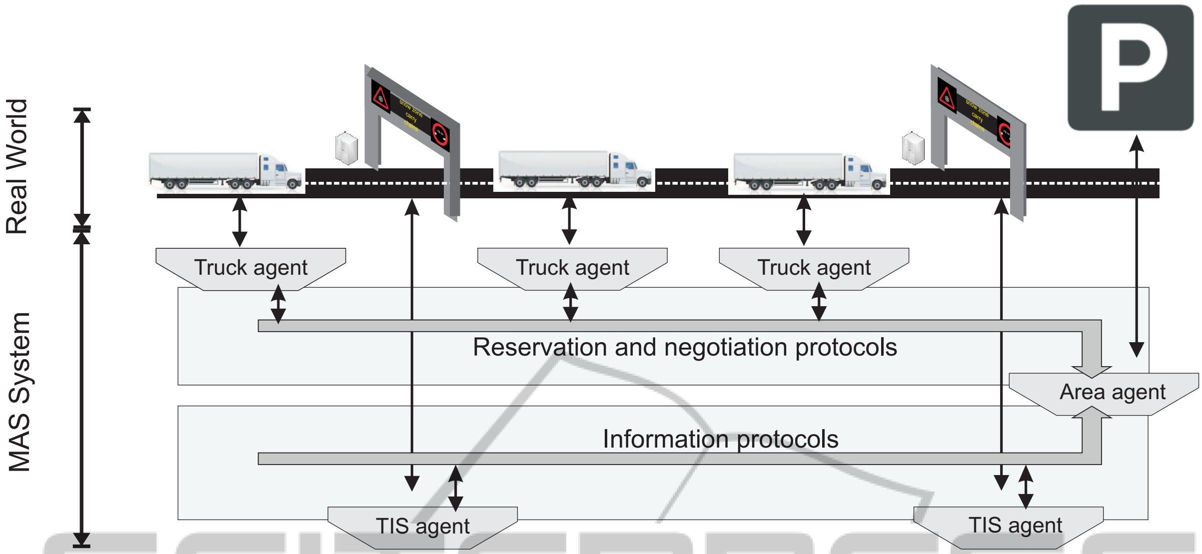

Figure 1: An example of the system architecture. At the top, a real world example is presented, including trucks, variable message signs and a rest area. On the bottom, the agents that compose the system are showed. Each truck has its own agent, there is also an agent for VMS and one agent for each area.

could modify their reservation on-trip, depending on the areas availability, are required. By this way, there is a demand for ITS services where the real-time communications between vehicles and infrastructure. In the last years, the advances of the communication technology have made possible the deployment of cooperative systems. A cooperative systems is a system where the different elements involved in the traffic domain can communicate with each other. These cooperative systems are usually addressed regarding the type of elements involved in the communications: V2V vehicle to vehicle, V2I vehicle to infrastructure, I2I infrastructure to infrastructure, etc. (Alexander Paier, 2013). But, not only cooperation is important, also the way this cooperation enables to run traffic objective functions, even in scenarios in which not central control is possible as it happens in the traffic domain. In (COST TU1102, 2015) new ways of designing Road Transportation Support (RTS) systems based on the ideas of autonomic systems are being analyzed. The concept of autonomic computing was defined at the end of the XX century (Kephart and Chess, 2003) and it defines an autonomic system as a system able to self-manage without the need of an external or central manager that identifies the action to be deployed in each situation or scenario.

In this paper, a new ITP system with self management properties is presented. It is defined as a multiagent architecture following a V2I approach. The system imposes the coordination between the traffic elements involved in the solution for an efficient occupation of the rest areas. It uses a new negotiation protocol suitable to adapt the dynamically required places by the trucks to the available places. Besides, the data exchanged for this negotiation uses the standard traffic data, DATEX.

The paper is structured as follows. Next section presents the proposed system for ITP. It describes the architecture, including the knowledge and information models and the communications and negotiation protocols. Then, in Section 3, the real network is modeled and the different experiments to test and evaluate the system are described. Finally, the conclusions are exposed.

2 A DISTRIBUTED SYSTEM FOR ITP

The objective of the system is to support truck drivers to find a place in the most preferable parking area according to their preferences. This system will also improve the parking management, because it can manage, in real time, the real occupancy of its parking places, avoiding bad parking nearby the area.

The system is based on the multiagent (MAS) paradigm. The definition of this proposed MAS contains: the architecture, the description of agents, the information and knowledge model, both public and private for each agent and the negotiation protocol to manage the reservation of free parking spaces.

2.1 System Architecture

The MAS is composed by several kinds of agents: area agent, truck agent, TIS agent, DF agent and interface agent. Figure 1 shows the software architecture of this MAS prototype.

2.1.1 Area Agent

Area agents are in charge of managing parking areas. Areas are located along the road network and have a limited number of parking spaces. The agent is responsible of several tasks:

- to attend the reservation process when places are available.
- to execute the negotiation protocol when there are more reservations than available places.
- to exchange information about space availability.

2.1.2 Truck Agent

Vehicles circulate along the road network. Truck agents are responsible of individual truck vehicles. Using the current truck location, the mean speed, and the driving times, it forecasts the possible next areas where the driver could park to rest. These areas are selected following the preferred order of the driver.

2.1.3 TIS Agent

The Traffic Information Service agent receives information from the different parking areas. It manages a set of Variable Message Signs and it diffuses information about the places availability in the parking spaces. This agent is an extension of the VMS agent described in (Tomas et al., 2012)

2.1.4 DF Agent

The DF agent provides a yellow pages service. Each agent can register, deregister and search for other agents or services available in the MAS platform or in other platforms. The directory facilitator used is the DF JADE agent (TILAB, 2014) specified by FIPA.

2.1.5 Interface Agent

The goal of this agent is to show how the system status evolves dynamically. This agent is based on a web application and it displays the road network and the reservation status via Google Maps. The map has the normal controls of a Google Maps plus a specific menu to show all the areas and trucks in the road, including their public information.

2.2 Information and Knowledge

The information and knowledge model is structured in two levels: a) the road network model describing the elements composing the road, including the parking areas and the truck based on DATEX II standard (DATEXII, 2014) and b) the reservation and negotiation process information.

2.2.1 Road Network Model

This domain is based on (Martinez et al., 2013). It has been extended and is composed by the following elements:

- Segments. They represent two way road sections and their characteristics (road name, number of lanes, length, free-flow speed, capacity, traffic restrictions, ...).
- Links: They represent the road network elements where two, or more, adjacent segments are connected. The link objects are subdivided in: bifurcations, unions, weavings and merges.
- Areas. They represent the rest areas where vehicles can park. The main characteristics are: segment, kilometer point (kp), facilities, truck capacity, current occupancy and list of reservations.
- Trucks. It models the trucks circulating by the road network. The main characteristics are: current location (segment and kp), origin, destination, maximum speed and current driving time.

2.2.2 Reservation and Negotiation Model

- Reservation. It represents an area choice from a specific truck. It includes the truck, the area, the expected arrival time according traffic conditions and the expected permanence time.
- Place_occupied. It represents a parking place occupied by a truck. It includes the truck, the area, the time the truck parked and the permanence time.
- Preference. It represents the truck's driver preference to a specific area.
- List of preferences. It is a ordered list identifying the preferences of a specific driver.
- Assignation. An assignation is a pair of elements $< truck_a, area_i >$ indicating that the truck a has been assigned to an area i.
- Feasible Solution. A feasible solution is a tuple of Assignations. It includes a possible assignation for the set of trucks and areas.

- Vote. It represents the score for a specific Feasible Solution.
- Final Solution. It represents the negotiation solution. It is the feasible solution that obtained the higher score.

2.3 Communication Protocols

The communication protocols define the way agents are related to each other in the platform to exchange information or to register other agent services. The communication protocol proposed follows the interaction protocols defined by FIPA (Foundation for Intelligent Physical Agents, 2000). Next, the main system protocols are described. The basic protocols like the registration to DF and similar are not defined.

- Reserve. Request protocol. The truck agent sends to an area a message to obtain a reservation. If the protocols ends successfully the area answers with a reservation. If not, a negotiation protocol between the area and the trucks begins.
- Ask_list_preferences. Query protocol. The area agent ask to the different trucks involved in the negotiation their preferences.
- Send_preferences. Inform protocol. List of preferences sent by trucks to the area agent managing the negotiation.
- Confirm_reservation. Inform protocol. Confirmation sent to trucks involved in the winning solution.
- Disconfirm_reservation. Inform protocol. The area agent informs to the truck about the cancellation of the requested reservation.
- Park_Status_register. Request protocol. The TIS agent sends a message to be registered in the area. The message contains the occupancy rate. When the area reaches this percentage, it informs the TIS agent registered.
- Park_Status_inform. Inform protocol. The area sends a message to the registered TIS agents when the occupancy rates have been reached.

2.4 Negotiation Protocol

The negotiation protocol is launched when an area has more reservations than available parking places. The area agent communicates with all involved trucks to begin the negotiation. The negotiation will be performed using a variation of Borda voting based protocol (Capdevila et al., 2013).

The negotiation begins and the area asks to all trucks their list of preferences. Each truck involved in the negotiation will assign a value to each of its preferences. In this approach, the truck preferences are generated taking into account only the time that the truck is on the network without stopping, and the distance to the areas. The preferences ordering is automatically calculated by means of an heuristic that is very close to a normal truck driver behavior: drivers try to maximize driving time without stop stabilized by law, i.e., the most remote area reachable for the truck will be the most preferred and the closest area will be the least preferred area.

Once the area has received all trucks preferences, it generates the set of feasible solutions which is composed by the set of possible assignations of trucks in the areas involved in the solution. These feasible solutions are sent to the trucks. Each truck calculates its votes and then, they are sent to the area. The area calculates the result and confirms the reservation to the trucks that have the reservation and disconfirms the reservation to the truck that is not in the winning solution. This truck will ask for a reservation in its following preferred area.

2.5 System Implementation

The system has been implemented in JAVA using a JADE (TILAB, 2014) platform. JADE is a software framework to develop agent applications in compliance with FIPA specifications for interoperable intelligent multiagent systems. Figure 2 shows a snapshot of the interface agent.

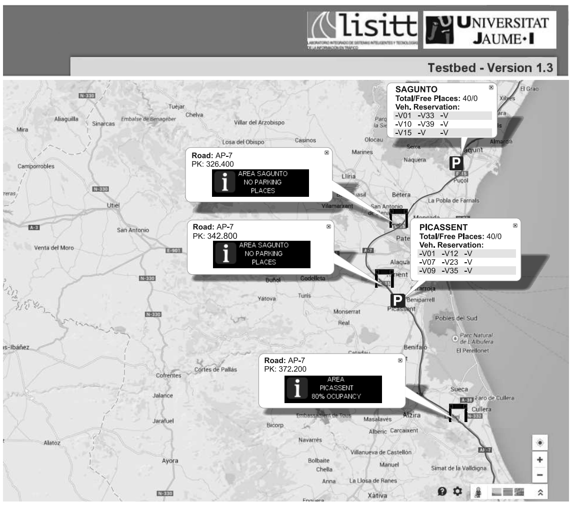

Figure 2: Interface agent snapshot. A section of the system is presented. Two parking areas, one without parking places are showed. The information provided via VMS is also presented.

3 THE MEDITERRANEAN CORRIDOR: E-15 MOTORWAY

To analyze and evaluate the proposed MAS, a real road network has been modeled. This road network is part of the Spanish Transeuropean Road Network (TERN) and belongs to one of the main european corridors, the E-15 Long distance corridor. It is used to transport goods not only from Spain but also from the North of Africa to Europe.

The modeled part covers the 400 km. of the Valencian Community. The elements modeled includes:

- 1 main road, E-15 (AP-7, A-7 & A-70 national motorways)
- 27 Segments.
- 25 Links.
- 24 VMS.
- 11 storage areas.

Three different scenarios have been developed to analyze the system: a) the system behavior in a real situation, b) the system robustness and c) the system scalability.

A set of 100 simulations have beed developed for each scenario. The areas and their availability are the same for all simulations. Truck positions have been created randomly. In all simulations, trucks drivers have been driving for some time, so, most of them will have to park in a rest area in the Valencian Community. The information of trucks and areas for the 100 simulations have been maintained for the three scenarios.

3.1 A Real Situation Test

In this scenario, the real traffic on heavy good vehicles have been simulated. The information is based on the Annual Average Daily Traffic (AADT) for the year 2012. (Fomento, 2012). The AADT varies little except in the ring-roads areas of the main cities. In the ring-roads, the intensity is too high because of the traffic of goods around cities. This intensity has not been taken into account because drivers do not drive long distances. In the E-15, the truck AADT is close to 1100 veh. The truck intensity in this scenario has been calculated using the traffic flow distribution in the E-15 during the day and the time used by drivers to cross the scenario. So, the intensity used in this scenario is defined to 400 trucks. The capacity of all areas has been harmonized to 40 places. This has been done to make easier the results analysis. The results are presented in figure 3.

Results show how without negotiation there are a lot of trucks parking in areas without places and they have to park on ramps, hard shoulders... This situation is specially difficult in *La Marina*. These situations happen because drivers want to reach the farthest area. However, applying the negotiation protocol, trucks are distributed in the upstreams areas (Sagunto, Picassent and La Safor). In these areas there are also truck parking without places, but this number is decreased a lot. This situation happens due to the random location of trucks and their driving times. There are no optimal solution where all vehicles have a parking area.

3.2 Testing the Robustness

To assess the system robustness, the baseline scenario has been compared with a new scenario where one of the areas (concretely *La Safor*) had a problem and it can not store trucks. This situation can be caused by different problems: an incident in the area that does not allow trucks to access it, or communication problems and the area could not negotiate its reservations.

Figure 4 presents the results of the same simulations but including the simulation without *La Safor* area. The results shows how applying the negotiation trucks are distributed in the area upstreams. However, without negotiation trucks park in the previous area, *Picassent*. This situation is strongly presented in simulation 14. It is worth to note from these results that the behavior of the areas far away to the area cancelled out is quite similar with respect to their behavior when all areas are available.

So, the system is robust since in spite of the failure in one of the areas, the system continues working and trucks start to negotiate with the following areas according to their preferences.

3.3 Testing the Scalability

To assess the system scalability, the number of trucks and the number of parking spaces in the areas have been increased up to 1000 vehicles and 100 parking places in each area.

The run-time and the number of messages exchanged increase linearly. So, there are no problems to execute the platform and agents in real time. However, before to conclude the system scalability results have to be analyzed.

Figure 5 presents the result of increasing the number of trucks. As in previous scenarios, when the negotiation protocol is used, trucks try to distribute the parking in their preferred areas, avoiding, if possible,

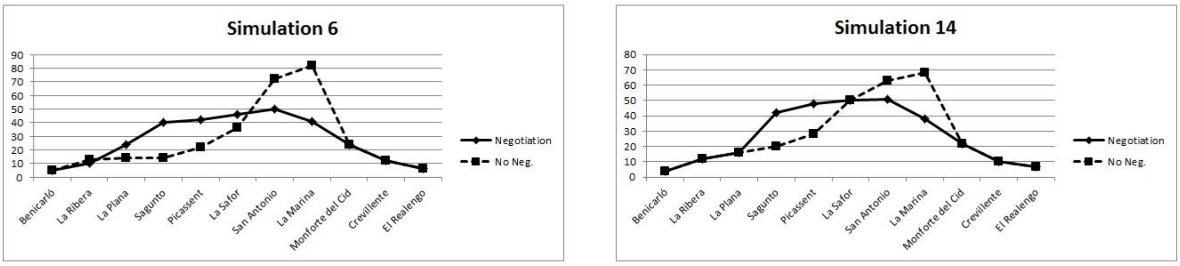

Figure 3: Results of simulation 6 and 14 are presented. The results of parking assignments with and without negotiation are presented.

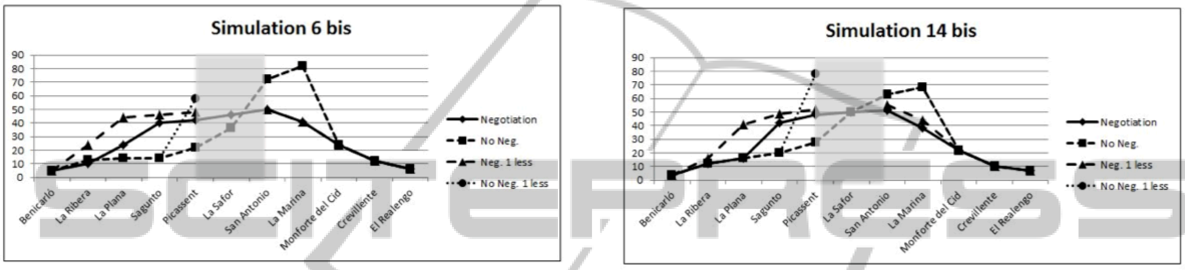

Figure 4: Results of simulation 6 and 14 comparing previous scenario and a new one dropping *La Safor*.

to exceed the areas capacity. This situation does not happen when the negotiation is not used.

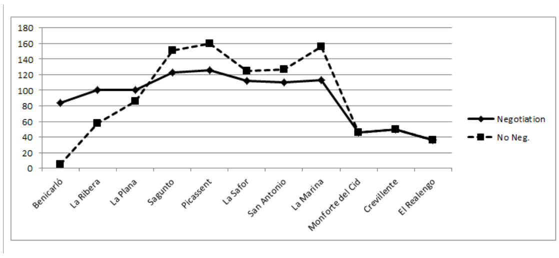

Figure 5: Simulation results increasing the number of trucks to 1.000.

4 CONCLUSIONS

In this paper, a multiagent system implementing a new ITP system is presented. The system uses a negotiation protocol to coordinate the parking of trucks in rest areas. The ITP protocol tries to guarantee that all vehicles have a parking space when they reach the rest area. In this way drivers comply laws about driving time and rest periods.

This new system improves the current ITP systems because it takes into account not only the current parking places but also the preferences of drivers. So, drivers can know in advance if they have a parking place reserved.

The negotiation protocol is adapted to the dynamic behavior of the traffic. When an area has no parking places, trucks trying to park in this area start a negotiation using votes. Each truck votes his best option from a possible set of solutions. The voting protocol is a modification of the Borda protocol adapted to this specific problem.

Negotiation processes and specifically voting systems always have the possibility of manipulation either by coalitions, previous knowledge... In this paper, it is assumed that drivers involved in the negotiation are benevolent. So, if some truck is assigned to an area that is not his first preference, it parks there. The system has not been designed from the scratch. Some agents and the traffic domain ontology have been extended from previous work. Furthermore, it uses the FIPA and DATEX II communication standards, so it is compatible with other existing traffic systems.

Results are very positives and promising. Three different scenarios were developed to analyze the system. In the first scenario, a real situation has been tested. In all 100 simulations, the results show that using the system and the negotiation the number of illegal parking places is reduced.

In the second scenario, the robustness of the system has been tested. To do it, an area was dropped from the scenario and the results, both using and not using the negotiation, were compared with the results of the first scenario. In this situation the illegal parking increases due to the absence of a parking area (40 places less than before). However, using the negotiation the solution improves the results, indicating the system has the capacity and the ability to deal with failures in any of its elements.

In the third scenario, the scalability has been tested. 1000 trucks were in the road. The system running behavior is not affected in a sensible way. The run-time and the increase of messages exchanged does not affect the system. Furthermore, the results using the negotiation were better again than the results without using it.

The self management autonomic property of the system has been demonstrated. This property has been reached in two levels: a) at individual level, areas manage their capacity and prevent the excess of parking and trucks are guaranteed to access to their preferred area; and b) at network level, although trucks deal on their preferred areas, the overall system performance is greatly improved, since trucks have information in real-time and illegal parking is reduced.

Despite the positive results, there are still work to do. Currently, an improvement of the negotiation protocol is being developed. This improvement consists in using the duration of the rest and the speed of trucks perform a small negotiation between pairs of trucks in the area, instead of begining a new negotiation among all trucks with a reservation.

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