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Research Paper

Modelling and Simulation for Smart Parking

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ABSTRACT: *Finding a parking space and avoiding traffic jams become a challenge in large cities, particularly at certain peak times of the day. This paper develops an approach based on multi-agent systems making it possible to model vehicle environments for their orientation towards the closest car park with free spaces while guiding them through the most fluid route. The architecture of the proposed system is based on the use of data collected in real time concerning the environment in which the vehicle is operating. A design of the approach is carried out using collaborative agents. Four cognitive agents guide drivers through the road network to the nearest car park with free spaces while showing them the most fluid route. For the simulation of the system, the Renew model has been used with success. The implementation of the application was designed using the JESS platform.*
KEYWORDS: *Smart parking, Multi-Agent Systems, Modelling and Simulation, Renew, Nets Within Nets, JESS.*

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I. INTRODUCTION

Today, parking system is a serious problem in the design of Smart Cities. Many studies proved that, when people are looking for a parking space they waste time, consume energy and they participate in the increase of the traffic congestion [1, 2]. When the search of a parking place is done manually, the driver randomly searches a free place in a parking near to his destination. During this search, several cases can occur such as multiple drivers searching a single parking place, and the driver cannot find the optimal itinerary. Smart parking is an interesting solution to this problem and many researches worked in this field to improve approaches and application to help drivers. Researches used emerging technologies and, mainly, wireless communication networks as well as the Internet of Things (IoT) and cloud computing [3].

To model smart parking situation, the multi agents system (MAS) approach is an efficient solution. In a multi-agent system, a set of agents that can be reactive, cognitive or hybrid collaborate and cooperate in order to solve a common problem in a parallel and distributed way. Each agent has only partial knowledge of the global environment and can perform a set of roles (functions, plans, services). The emergence of the behaviors of the different agents tends to resolve the overall problem posed. In the rest of this section, only the recent works concerning MAS applications in smart parking lots (2017-2021), are briefly presented.

In [4], authors propose a smart parking architecture based on MAS. A set of dedicated agents are proposed at three levels of the proposed architecture. At the interface level there are connected objects such as sensors (cameras), RFID terminals and others agents dedicated to capture the system environment. At the control level, other agents ensure the proper functioning of the system. This system uses a knowledge base for saving and consulting data. In [5], authors use an approach based on the MAS and Ant Colony Optimization (ACO) algorithm to find the optimal path be-tween the drivers and the closest free parking. [6] propose a system based on a distributed swarm intelligence strategy using the ant colony algorithm, cloud system, and multi-agent systems to guide the drivers toward the nearest free car park. In [7], authors propose a so-called Cooperative Automated Valet Parking (Co-AVP) system to search automatically vacant parking spaces for vehicles. Cooperative path finding has been extensively studied and considered as Multi-Agent Path Finding (MAPF). Authors in [8] present in their paper a system that uses an agent-based Cyber Physical System (CPS) smart parking. This system is composed of interconnected software agents using Internet of Things technologies. The proposed approach was implemented for bicycles and for cars. In [9], it is question of an agent-based model for a smart mobile parking booking system. This system considers the position of the car and

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its speed, and proposes available parking based on its destination place and arrival time. The system considers, also the parking fees. This work was studied for the Mauritian context.

The rest of this article is structured as follows: Section 2 presents a set of basic notions about smart parking management systems, sections 3,4 and 5 are devoted to the presentation of the simulation and the implementation of the model, and the last section concludes this work by suggesting future extensions.

II. BACKGROUNDS

Finding a parking space in a big city is becoming more and more of a big challenge. The driver must be familiar with this city as well as the various car parks located in the environment of his destination. He has to know the best way to get there, and when he does, chances are there are no free places.

The concept of intelligent parking combines several emerging technologies for optimal guidance and orientation of vehicle drivers to the parkings closest to their destination.

It is a set of advanced technologies such as : MAS, IoT, Sensors, Wireless communications, Fog and Cloud computing and other advanced hardware and software devices and applications.

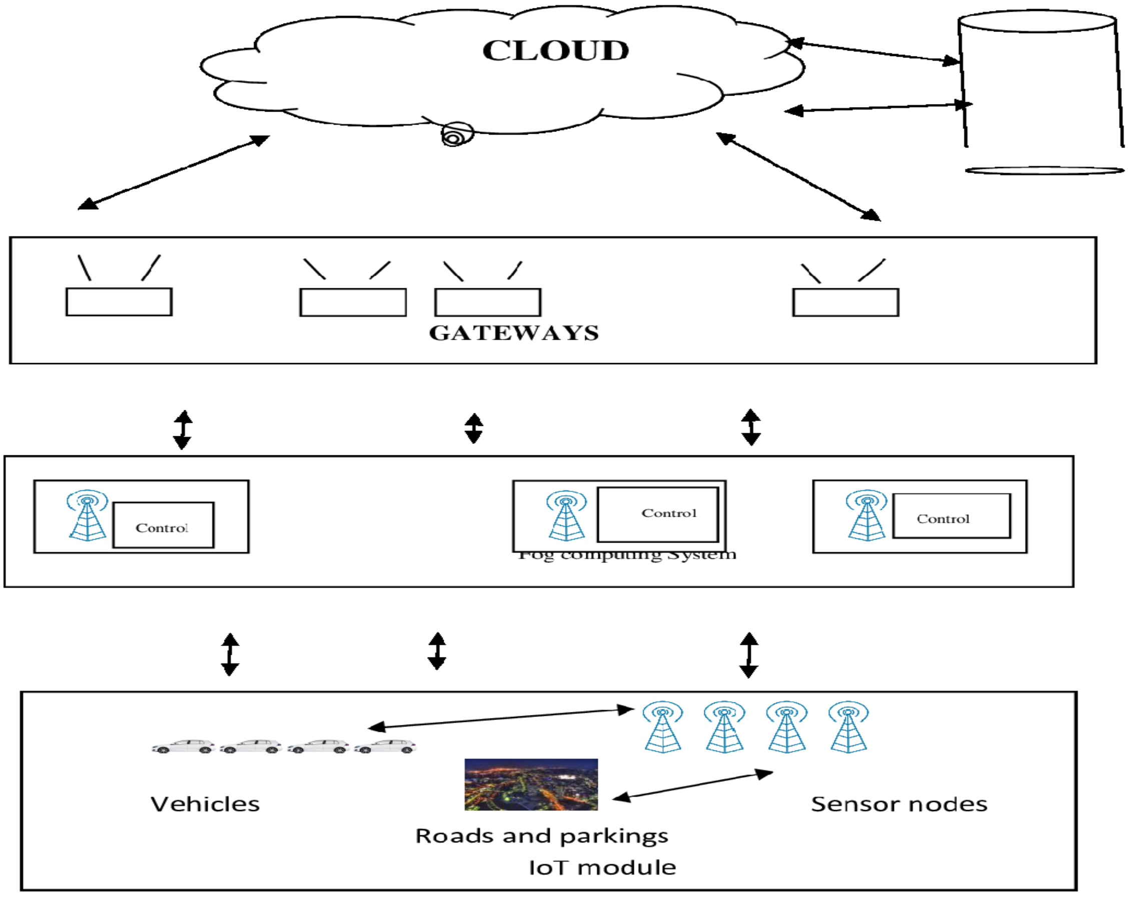


Figure1: The smart parking communication architecture.

Figure 1 depicts a schematic communication levels in a smart parking system:

- At the bottom of this architecture is the IoT module, which is responsible to establish wireless communication between the objects of the system. These objects are the parking, the road traffics and the vehicles (or the drivers). The IoT module establishes communication with the fog computing modules.
- In a second level is the fog computing system, which aims to decentralize the computing flow. Information issued from the IoT level is transmitted to this level. Note that there several fog computing

modules. In reality, each fog module comprises three elements: A control system, a beaconing interface and a communication interface.

- The data are routed towards a set of gateways to the cloud module. This latter provide a great and powerful processing and storage capacities.

III. THE SYSTEM MODEL

Four agents are proposed to manage the parking system and each agent have specifics rules tasks to realize as follows:

- The Driver Agent (DA): researches a parking space by requesting a manager then waits for the manager‘s answer (success or failure).

- The Manager Agent (MA): receives requests from DA with their preferences (prices and location) and works to find the appropriate parking space according to the agents‘preferences by sending request to the Sector Agents.

- The Sector Agent (SA): works to find the appropriate Parking agent‘s space according to the prices and preferences of the DA.

- The Parking Space Agent (PA): observes and validates the state of parking space and sends a result by message to Manager Agent. Fig.2. presents a modeling of Parking System modeled by the MAS formalism.

Where:

- DA, MA, SA1, SA2, SA3, PA1, PA2, PA3 are the set of agents that participate in the parking management,
- P1: Driver Agent is ready to request;
- P2: Driver Agent is waiting to interact with Manager Agent,
- P3: Driver Agent is waiting for Manager answer,
- P4: Manager Agent is ready to interact,
- P5: Manager Agent is preparing request to Sector agent,
- P6: Manager Agent is waiting for Sector Agent answer,
- P7: Sector Agents are ready to interact,
- P8: Sector Agents is preparing request to Parking Space Agent,
- P9: Sector Agents is waiting for Parking Space Agent answer,
- P10: Parking Space Agents are ready to interact;
- P11: Parking Space Agent is processing Sector Agent request (success message or fail message or choose another Parking Space Agent),
- P12: Parking Space Agent is waiting to interact with Manager Agent,
- P13: Manager Agent is preparing Driver Agent answer,
- P14: Manager Agent is waiting to interact with agent,
- P15: Driver agent gets an answer of his request,
- T1: Driver Agent sends request to Manager Agent with his preferences (place and price),
- T2: Manager Agent receives Driver Agent request,
- T3: Manager Agent sends requests to Sector Agent,
- T4: Sector Agent receives Manager Agent request,
- T5: Sector Agent sends request to Parking Space Agent,
- T6: Parking Space Agent receives Sector Agent request,
- T7: Parking Space Agent chooses other Parking Space Sector,
- T8: Parking Space Agent sends success message to Manager Agent,
- T9: Parking Space Agent sends failure message to Manager Agent,
- T10: Manager Agent receives Parking Space Agent message,
- T11: Manager Agent sends message to Driver Agent,
- T12: Driver Agent receives Manager Agent message,

IV. SIMULATION

For this system simulation, reference nets are used. Reference Nets Networks are object-oriented high-level Petri nets, in which tokens can be nets. It is question of Nets within Nets that assumes referential semantics. In this approach, tokens in one place can contain an object net. Nevertheless, object nets themselves can again contain tokens that represent nets, and thus a system of nested nets is obtained. Furthermore, transitions in nets can activate transitions in other nets, just like method calls of objects, by using synchronous channels [9]. Reference Nets Workshop (Renew: http://www.renew.de) is a Java-based high-level Petri net simulator that provides a flexible modeling approach based on reference nets.

Mulan (Multi agent system net within net) [10] is implemented in Renew. Mulan has the universal form as illustrated in Fig. 2. This formalism combines MAS and Petri Nets tools. Agents are able to be smart, so they gain access to a knowledge base; the behavior of the agent is expressed in forms of protocols. Protocol templates can be instantiated. The protocol is part of a conversation. In this study, the knowledge base is implemented in the Java Expert System Shell (JESS). The agent's knowledge base is filled with facts and rules.

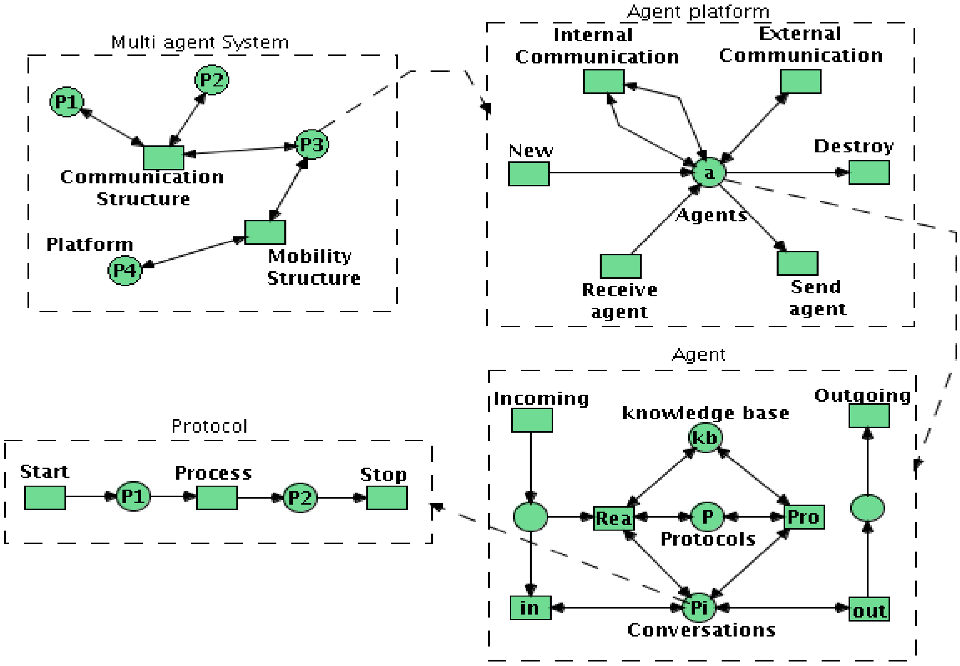
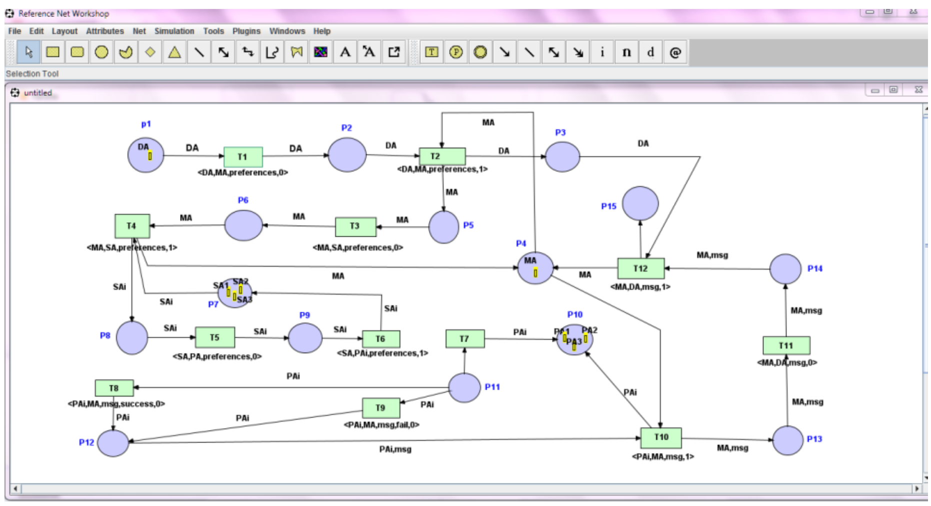


Figure2: Agent systems as nets within nets [10]

The obtained Renew model

The figure 3 illustrates the Renew simulation model of the smart parking. It should be noted, however, that this is part of the system. The different places and transitions are in accordance with the proposals set out at the beginning of this section.



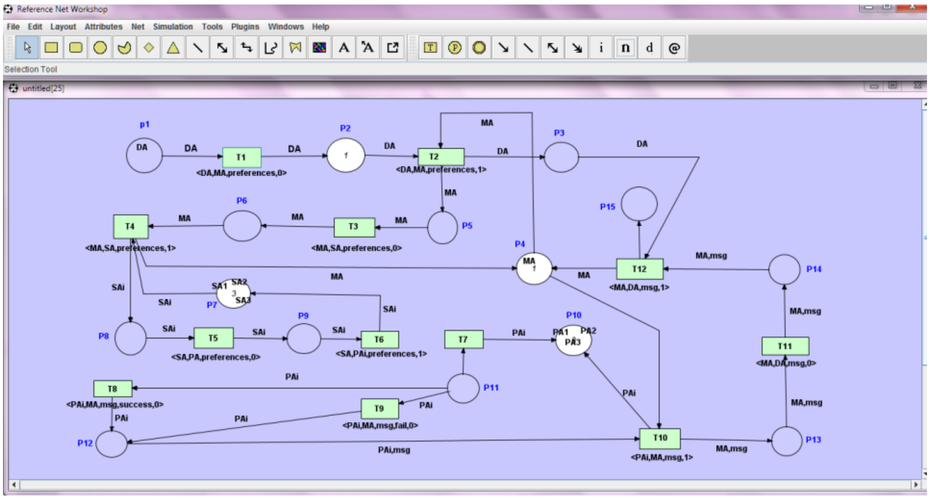


Figure 3: The renew model of the application.

V. THE JESS IMPLEMENTATION OF THE MODEL

The JESS expert system is used for modelling the smart parking agent knowledge base. Some examples of the implementation are given in the following. By example to establish the communication within agents, we define the ACL message template as follow:

(deftemplateACL Message (slot communicative-act) (slot sender) (slot receiver) (slot conversation-id) (slot protocol) (slot language) (slot content))

The context of a car driver agent's working memory depends on the road and the position on which it is. The following templates outline the context:

(deftemplate car (slot position) (slot action) (slot speed)(slot weather)(slot fuel)(slot engine)(slot state_ road)(slot content_ road)(slot offer _platform))

Now we illustrate some JESS rules, which exhibit the context changes. In the first one as soon as the car want to move toward village or center or high way it captures the context of these later, with the case when a kids or any object is found in these roads, at this moment the car brake is activated. Second when the level of the fuel is full the car refuge the offer provide by the platform.

(defrule A
(car {(position == zone)// (position == urban area)} && (content_ road == kid))
=>
(assert (ACLMessage (communicative-act INFORM) (sender platform) (receiver car) (content "kid") (conversation-id "information")))
(assert (car(braking)))

VI. CONCLUSION

The very rapid progress in the field of communication and information technologies has made it possible to design machines endowed with remarkable means of analysis and decision-making and which can provide appreciable benefits in all fields. In this paper, we have presented an attempt to model a smart car park that can help drivers find a place in a car park close to their destination. In future work, we will be interested in extending the reach of our system so that it encompasses the other aspects, particularly the Fog and Cloud layers.

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