A Modular Multi-agent Architecture for Smart Parking System

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Abstract. Cities noticed that their drivers had real problems to find a parking space easily, the difficulty roots from not knowing where the parking spaces are available at the given time. In this paper we will design an automatic smart parking architecture using multi-agent and expert systems which are the main domains of artificial intelligence. AI is accomplished by studying how human brain thinks and how humans learn, decide, and work while trying to solve a problem, and then using the outcomes of this study as a basis of developing intelligent software and systems. Implementing this scalable and low cost car parking framework will provides a lot of services for the driver: driver guidance, automatic payment, parking lot retrieval, Gate management, security and low cost of implementation.

Keywords: Smart parking system · Multi-Agent Systems · Expert systems

1 Introduction

Researchers are recently turned to applying technologies for management of parking area by designing and implementation of a prototype system of smart parking that allows vehicle drivers to effectively find the free parking places, making a reservation and payment. In the future the demand for the intelligent parking service will increase because the rapid growth in the automotive industries. The automatic management of parking lots by accurate monitoring and providing service to the customers and administrators is provided by such emerging services. An effective solution to this service can be provided by many new technologies.

This paper describes a dynamic architecture for management of a smart parking system based on multi-agent and expert systems. One of the most characteristics is the use of intelligent agents as the main components which focus on distributing the majority of the system's functionalities into processes. The paper is organized as follows: after a brief introduction we will discuss in the second section a state of the art of smart parking systems, and then in the third section we present the concepts of multi-agents and expert systems. Finally, we present a modular architecture for new smart parking management. The last section concludes our work and draws some perspectives.

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2 State of Art

Every day vehicle drivers have to find a vacant parking space especially during the rush hours. It is time-consuming and it is leading to more traffic, and air pollution.

The authors in [1–3] present the design and implementation of a smart parking system based on wireless sensor networks that allow vehicle drivers to find the free parking places. Also in [4] the author presents a wireless system for locating parking spots remotely via smartphone. This system automates the process of locating an available parking spot and paying for it.

Authors in [5] have proposed a scalable and low cost car parking framework (CFP) based on the integration of networked sensors and RFID technologies. These include driver guidance, automatic payment, parking lot retrieval, security and vandalism detection.

In others studies the authors have choose to design an automatic smart parking using internet of things which enables the user to find the nearest parking area and the available slot in that area [6–8].

From the previous state of art we remark that Researchers have promoted some services to the detriment of others. For that reason we will propose a new architecture that is based on multi-agent and expert systems. We should integrate the two different technologies together in order to achieve a system which is the most efficient, reliable, secure and inexpensive.

The proposed model is a modular multi-agent architecture where all processes are managed and controlled by different types of agents which are able to propose solutions, cooperate, on very dynamic environments and face real problems.

There are different kinds of agents in the architecture, each one with specific roles, capabilities and characteristics. This fact facilitates the flexibility of the architecture in incorporating new agents.

Our system will be divided in two architectures:

- Multi-agent architecture.
- Hardware architecture.

3 Overview of the Global Multi-agent Architecture

Many drivers had real problems to find a parking space easily especially during peak hours, the difficulty roots from not knowing where the parking spaces are available. Even if this is known, many vehicles may pursue a small number of parking spaces which in turn leads to traffic congestion. The traffic in parking space has been an area of concern in majority of cities. So, parking monitoring is an important solution.

From the previous state of the art it is noted that most authors have divided their architectures in different modules but no one of them have taken the preferences of the driver into consideration. For that reason we will propose a multi-agent system that is capable of providing parking services to the driver based on their personal preferences.

In this section, we give an overview of the multi-agent architecture which provides a high level model for smart parking management (Fig. 1).

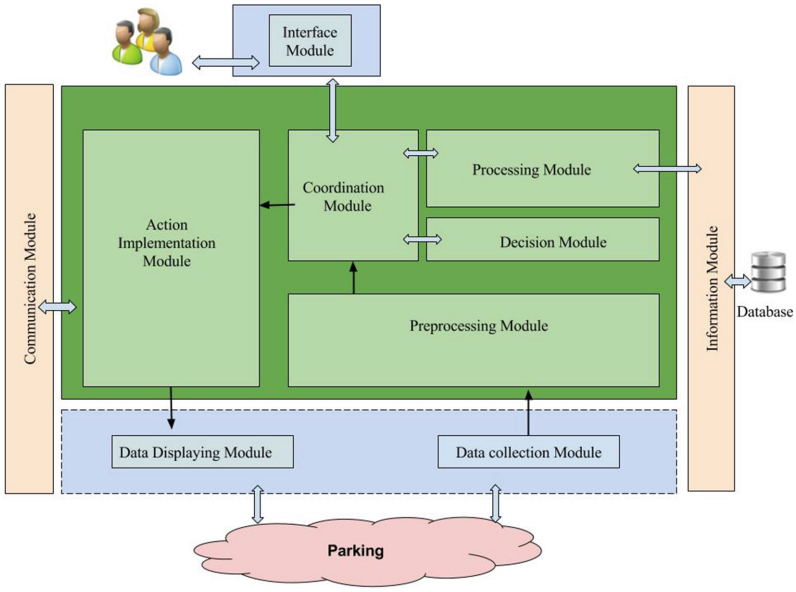

Fig. 1. Global smart parking architecture.

In order to understand deeply the common architecture, we describe below each layer of it.

- Decision Module: provide knowledge related to the regulations for agents. It is an expert system and its knowledge base mainly contains information related to the environmental performance and legislations.
- Communication Module: This layer ensures communications between all the layers of the architecture.
- Processing Module: This layer contains different agents, which can be implemented, responding to communication layer's alert and users requests.
- Preprocessing Module: Is responsible for the pre-processing of data captured from the environment (Sensors, Cameras, RFID).
- Coordination Module: It has the role of displaying information to the user in a suitable manner taking into account the constraints of his device. And it is responsible for the transmission of the user request to a specific agent of processing Module.
- Interface Module: It is responsible for capturing the user's query, as well as displaying the results.
- Action Implementation Module: Represents the set of behaviors necessary for the Parking control.
- Database: This part of the system includes all the data and tables used by all components of the platform, including static data, indicators related to agents, and appropriate decisions to the various scenarios of behavior to be submitted to Query Agent depending on the state of the collaboration between process agents.

- Information Module: manages interaction between the platform agent's and database of the system. It retrieves adequate data and sends it to the concerned agent.

3.1 Proposed Architecture

The traffic on roads and parking space has been an area of concern in majority of cities. So, parking monitoring is an important solution. To avoid these problems, recently many new researches have been developed that help in solving the parking problems to a great extent but no system had taken the preferences of the driver into considerations. For that reason our major objective is to design and implement architecture of a smart parking.

Implementing this scalable and low cost car parking framework will provides a lot of services for the driver: driver guidance, automatic payment, parking lot retrieval, Gate management, security and low cost of implementation.

Our work is based on the multi-agent and expert systems approaches because of their benefits.

The combination of these two approaches will encompasses cooperation, resolution of complex problems, modularity, efficiency, reliability, reusability and lies under the conjunctive use of knowledge as behavioral models of the experts.

Our proposed solution mainly focuses on analyzing user's queries to find a vacant slot based on their preferences.

Artificial Intelligence

Artificial Intelligence is a way of making a computer, a computer-controlled robot, or a software think intelligently, in the similar manner the intelligent humans think.

AI is accomplished by studying how human brain thinks and how humans learn, decide, and work while trying to solve a problem, and then using the outcomes of this study as a basis of developing intelligent software and systems.

The goals of AI are:

- To Create Expert Systems: The systems which exhibit intelligent behavior, learn, demonstrate, explain, and advice its users.
- To Implement Human Intelligence in Machines: Creating systems that understand, think, learn, and behave like humans.

An AI system is composed of an agent and its environment. The agents act in their environment. The environment may contain other agents.

Agent and Multi Agent Systems (MAS)

Agents are sophisticated computer programs that act autonomously on behalf of their users, across open and distributed environments, to solve a growing number of complex problems. Increasingly, however, applications require multiple agents that can work together. A multi-agent system is a set of software agents that interact to solve problems that are beyond the individual capacities or knowledge of each individual agent. We call a ''platform'' whatever allows those agents to interact not taking into consideration the shape that such a platform can take (centralized or not, embedded into the agents or not, …). This platform usually provides agents with a set of services depending on the system

needs and is considered as a tool for the agents, it does not exhibit an autonomous or pro-active behavior.

Agents, according to MAS community have the following properties:

- Autonomy: An agent possesses individual goals, resources and competences; as such it operates without direct human or other intervention, and has some degree of control over its actions and its internal state. One of the foremost consequences of agent autonomy is agent adaptability as an agent has the control over its own state and so can regulate its own functioning without outside assistance or supervision.
- Sociability: An agent can interact with other agents, and possibly humans, via some kind of agent communication language. Through this means, an agent is able to provide and ask for services.
- Reactivity: An agent perceives and acts, to some degree, on its close environment; it can respond in a timely fashion to changes that occur around it.
- Pro-activeness: Although some agents, called reactive agents, will simply act in response to stimulations from their environment, an agent may be able to exhibit goal-directed behavior by taking the initiative.

Expert System

One of the largest areas of applications of artificial intelligence is expert systems (ESs), or knowledge based systems as they are sometimes known. [9] Provides us with the following definition: An expert system is a computer program that represents and reasons with knowledge of some specialist subject with a view to solving problems or giving advice.

To solve expert-level problems, expert systems will need efficient access to a substantial domain knowledge base, and a reasoning mechanism to apply the knowledge to the problems they are given. Usually they will also need to be able to explain, to the users who rely on them, how they have reached their decisions. They will generally build upon the ideas of knowledge representation, production rules, search, and so on, that we have already covered.

Contribution of MAS and Expert Systems

The Multi-agent approach is justified by:

- Adaptation to reality
- Cooperation,
- The resolution of complex problems,
- Integration of incomplete expertise,
- Efficiency,
- Reliability,
- Reuse.

Expert systems have a lot of attractive features:

- Increased availability,
- Reduced cost,
- Reduced danger,

- Permanence,
- Increased reliability,
- Explanation,
- Fast and complete response at all times,
- Intelligent Database,
- Multiple expertise.

3.2 Description of the Proposed Architecture

The proposed architecture is able to connect the parking database where the parking information is stored and also connects to the knowledge base related to the environment (the environmental knowledge base). The environmental knowledge base will be shared between the agents in all stages of parking process.

The purpose of the system is to manage the parking places in a way to reduce the traffic congestion and time looking for free places. Agents require a knowledge representation in which to analyze and find solutions for helping users to find parking places.

The proposed architecture uses a rule-based reasoning to examine the proper solution for drivers. One of the most popular techniques used in the artificial intelligence is Rule-based reasoning. The rule-based architecture [10] has two major components: Knowledge based that contains the general knowledge about the problem which is a set of the production rules identified as "IF…THEN…" and inference engine is a mechanism to process the rules.

In our work, the environmental regulations such parking Entrance, Parking Exit and Mobile application have been modeled in form of IF-THEN rules.

In our multi-agent system, we apply a rule-based reasoning technique on the environmental regulations in order to make the right decision. Figure 2 shows the IF-THEN rules of parking entrance.

Now we will give an overview of the IF-THEN rules of Mobile application.

- Case1: Registered driver (Category = Normal). This means that the driver can make reservation on mobile application.

Rule1: IF driver is registered and category is normal
THEN check status of the payment

Rule2: IF driver is registered and category is normal and the status of payment is valid
THEN Check availability of parking spots

Rule3: IF driver is registered and category is normal and the status of payment is Invalid
THEN Recharge subscription card

Rule4: IF driver is registered and category is normal and the status of payment is valid and parking spots available
THEN the driver can make a reservation

Rule5: IF driver is registered and category is normal and the status of payment is valid and parking available spots and a place is reserved
THEN the driver can make guidance

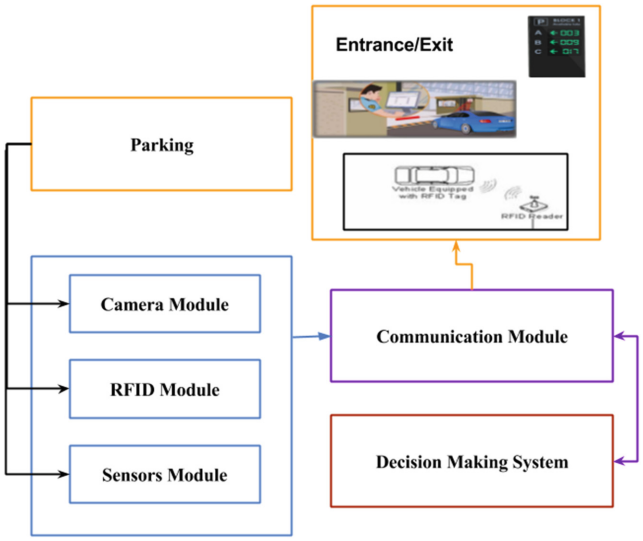

Fig. 2. Hardware architecture of smart parking system

- Case2: Registered driver (Category = VIP). The driver can't reserve on the application since a place has been allocated to him.

Rule1: IF driver is registered and category is VIP
THEN check status of the payment
Rule2: IF driver is registered and category is VIP and the status of payment is valid
THEN Check availability of parking spots
Rule3: IF driver is registered and category is VIP and the status of payment is valid
THEN the driver can check his number place
Rule4: IF driver is registered and category is VIP and the status of payment is valid
THEN the driver can check his number place
Rule5: IF driver is registered and category is VIP and the status of payment is valid
THEN the driver can make guidance

- Case3: Simple user. The user must register and choose his/her category to have benefits.

Rule1: IF driver is new user
THEN the user must register
Rule2: IF driver is new user and have chosen the category
THEN make payment

4 Hardware Architecture

The physical (or Hardware) architecture of the system is made up of different systems interacting with each other to better carry out the different services requested by the driver.

Our Physical architecture is divided in two modules:

- **Data Collection Module:** It concerns the sensors, cameras and RFID Tag which capture the information from the environment.
- **Data Displaying Module:** acts directly on the LCD installed in the entrance of the parking, LED installed in every parking spots, and the gate management.
- **Communication Module:** This Module ensures communication between all the modules of physical architecture.
- **Decision making System:** is implemented to well lead the management of the parking.

5 Future Work

As a future work we will detail each module of our architecture, we will discuss the system architecture mainly agents characteristics and their behaviors. Also, we will describe the implementation of the proposed system including the interaction of agents and the connection between agents and knowledge bases.

Our objective is to validate the architecture that we propose in this paper by developing a distributed platform that provides a lot of services for the driver.

6 Conclusion

In this paper, we give an overview of different parking systems which was implemented by many researches to resolve the growing problem of traffic congestion, wasted time, wasting money, and help provide better public service, reduce car emissions and pollution. And we propose a multi-agent architecture which provides a high level model for smart parking management. For that reason we used different modern techniques such as Expert Systems and SMA. We have integrated the two different technologies together in order to achieve a system which is the most efficient, reliable, secure and inexpensive.

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