

IoT-Enabled Smart Parking: Enhancing Efficiency and Sustainability in Smart Cities

Imrane OUHAMMOU ^{1*}, Tarik CHAFIQ ¹, and Mohamed HMAMOU ¹

¹ LGAGE, Faculty of Sciences Ben M'Sik, University Hassan II of Casablanca, B.P. 7955 Casablanca, Morocco

Abstract. The field of smart parking is growing rapidly and has many potential applications in densely populated urban areas. Internet of Things (IoT) and Arduino-based smart parking systems offer an innovative solution to solve parking problems in real time. Among other things, these systems reduce traffic congestion, improve road safety, reduce greenhouse gas emissions, and improve user experience.

In this paper, we present a smart parking system that uses an innovative architecture and algorithm to optimize vehicle parking. The system also tracks cars, their location, entry and exit details, and account management. An infrared sensor is integrated into the system to monitor the entry and exit of vehicles. This sensor uses beams of light to detect the presence of vehicles in a specific parking area, allowing for efficient use of available parking space.

This project has many benefits, such as optimized space utilization, reduced congestion and pollution, and an improved user experience. The system can be deployed in a variety of environments, including underground parking garages, shopping malls, airports, and train stations.

1 Introduction

Urban parking management has become a major issue in cities around the world due to rapid population growth and the increase of vehicles on the road [1]. This has led to increased congestion [2], a lack of parking spaces [3], and extended wait times to find an available space [4]. In response to these challenges, many municipalities have begun to explore IoT-based smart parking solutions to help drivers find available parking spaces faster and more efficiently [4]. Smart parking systems can reduce wait times [5], minimize congestion, improve vehicle safety, and provide significant benefits to citizens and municipalities [6].

The Internet of Things (IoT) has significantly improved urban parking management by enabling real-time monitoring of parking locations [7]. Parking sensors can be installed in parking spaces to provide real-time data on slot availability [8]. Drivers can then use mobile apps or signage to quickly find available parking spaces [9]. This can significantly reduce the time spent searching for a parking space, improving mobility, and reducing congestion on the roads [10]. In addition to managing parking spaces, smart parking systems can also help improve road safety by providing real-time information about road conditions [11].

Parking sensors can detect hazardous conditions such as ice on the road or unexpected obstacles [12], and drivers can be alerted to these conditions to avoid accidents. This can improve road safety for all road users, reducing the risk of traffic accidents and improving the quality of life for citizens [13].

This paper represents a proposal Arduino-based parking system that will facilitate the life of drivers by offering them a fast and efficient solution to find a parking space. The proposed system will be based on infrared sensors (**Fig.1.b**) that will control access to the parking lot.

The infrared sensor system used to detect vehicles offers several advantages. First, it allows an accurate and reliable detection of vehicles, which guarantees the reliability of the information displayed on a screen. In addition, these sensors do not require physical contact with the vehicles, which limits the risk of damage or malfunction, and they are inexpensive and easily accessible, which reduces installation and maintenance costs.

The display installed at the entrance of the parking lot plays a key role in the operation of the system. It allows drivers to quickly get accurate information about

* Corresponding author: imraneouhammou17@gmail.com

available parking spaces. The use of a display also helps to optimize space and minimize installation costs.

Lastly, the access control system ensures the safety of vehicles and limits fraud. Access to the parking lot is controlled by sensor-equipped barriers, which ensure that only authorized vehicles can enter.

2 Materials and methods

2.1 Materials

2.1.1 Arduino UNO card

The Arduino UNO card [14] (**Fig.1.a**) is the brain of the smart parking project. It is used to control the whole system, collecting data from the sensors, and sending signals to the entrance gate to open or close the access. The Arduino UNO board is also used to display the parking information in real time on the LCD screen.

2.1.2 Infrared sensor

Infrared sensors are one of the key components of the smart parking project. They are installed at the entrance and exit of the parking lot to detect vehicles and indicate whether a parking space is available or not. The infrared sensors (**Fig.1.b**) send a signal to the Arduino UNO board every time a vehicle passes by. The Arduino UNO board then uses these signals to update the display on the LCD screen and to control the entrance gate.

2.1.3 Micro servo motor

The micro servo motor (**Fig.1.c**) is used to control the entrance barrier. It is connected to the Arduino UNO board and opens or closes according to the signals sent by the board. The micro servo motor is an ideal choice for this project because it is small, easy to use and can be controlled precisely.

2.1.4 LCD display

The LCD screen (**Fig.1.d**) is used to display real-time parking information to drivers. It is connected to the Arduino UNO board and can display the number of available spaces, the number of occupied spaces and other important information. The LCD display is a key part of the project as it allows drivers to quickly know whether it is possible to park or not, which improves traffic flow and reduces congestion.

2.1.5 Breadboard

The breadboard is used to connect the various components of the smart parking project. It allows the electronic components to be easily connected to each other without the need to solder or make permanent connections. The breadboard (**Fig.1.e**) is an important part of the project because it facilitates the implementation and maintenance of the system.

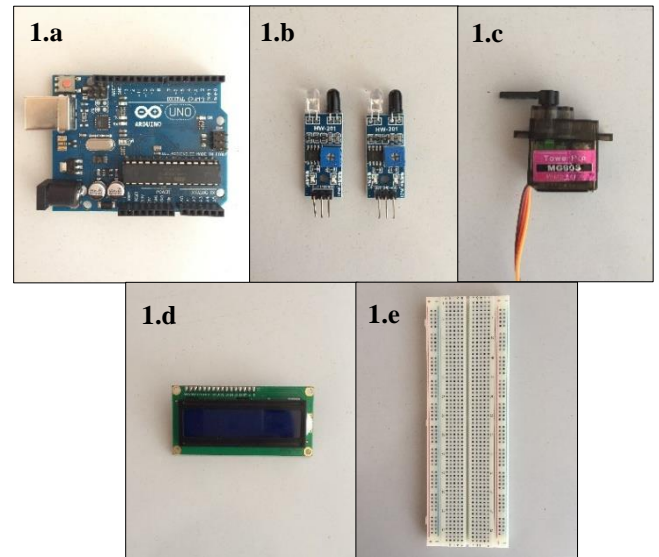


Fig. 1. Project components (**1.a** Arduino UNO card, **1.b** Infrared (IR) sensors, **1.c** Micro servo motor, **1.d** LCD display, **1.e** Breadboard)

2.2 Modeling and operation

The smart parking system project is based on a hardware architecture (**Fig.2**) that includes several components. The heart of the system is the Arduino card (**Fig.1.a**), which is responsible for the management and control of the entire system. Two infrared sensors (**Fig.1.b**) are placed at the entrance and exit doors of the parking lot to detect the presence of vehicles. A servo motor (**Fig.1.c**) is also placed at each door and is used to open and close the doors. In addition, an LCD display (**Fig.1.d**) is installed at the entrance of the parking lot to inform users of the availability of parking spaces. With this hardware configuration, the intelligent parking system can detect the entry and exit of vehicles, control access to the parking spaces and communicate real-time information to users.

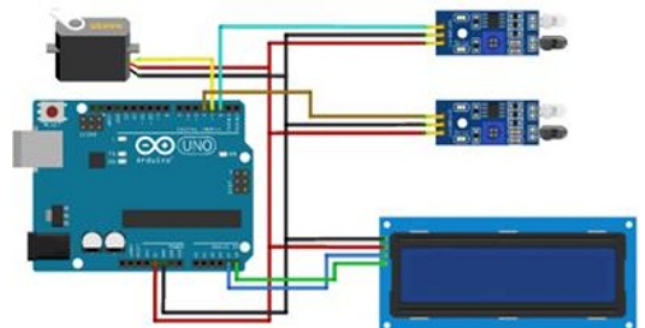


Fig. 2. Architecture of the proposed smart parking model

Once the components (**Fig.1**) were assembled according to the circuit diagram and the code was uploaded to the Arduino board, the IR sensors and servo motor were installed to the required specifications. The first IR sensor is installed at the entrance to the parking lot, while the second is placed at the exit. The servo motor controls the entrance and exit gate, allowing detection of incoming and outgoing vehicles. When all spaces are available, the LCD display shows that the parking lot is empty. When a vehicle arrives, the IR-1 sensor detects its presence and opens the servo gate to allow entry. Once the vehicle is parked, the LCD screen will indicate that a slot is occupied. If all spaces are occupied, the system blocks the entrance gate by closing the slave gate and displays a message on the LCD screen indicating that the parking lot is full. When a vehicle leaves a bay and arrives at the exit, the IR-2 sensor detects its presence, and the system opens the guardrail. The LCD screen then indicates that the space is available again, the system can then allow another vehicle to enter.

3 Examination and interpretation

For the examination of the Smart Parking project, it is important to look at the simulation of the actions to evaluate its operation. The results of these simulations are satisfactory, as shown in the figures below. When the parking lot is empty and there are three spaces available, the LCD correctly displays this information (**Fig.3.a**). If one car parks, the number of available spaces decreases to two, as expected (**Fig.3.b**). Then, if two cars park, the number of available spaces drops to one (**Fig.3.c**), which is also as expected. If a third car tries to park, the LCD displays that there are no more spaces available, which is consistent with the total occupancy of the parking lot (**Fig.3.d**).

Lastly, when the parking lot is occupied by three cars and a fourth car tries to park, the LCD displays the message "Sorry, the parking is full" (**Fig.4**). These results show that the Smart Parking project simulation works consistently and accurately, which is a good indicator of the quality of this project.

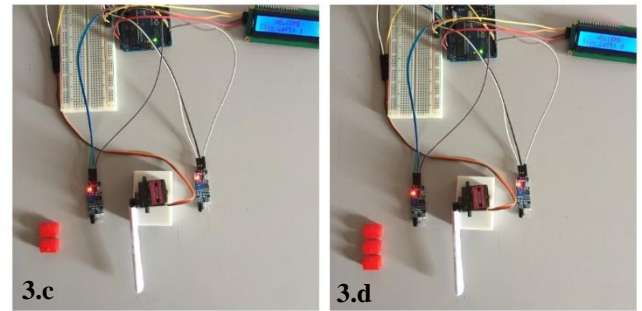
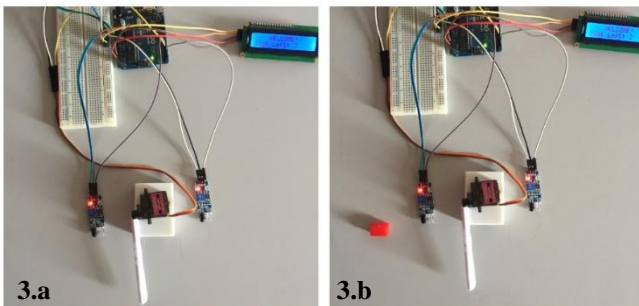


Fig. 3. Simulation of the actions to evaluate the smart parking project.

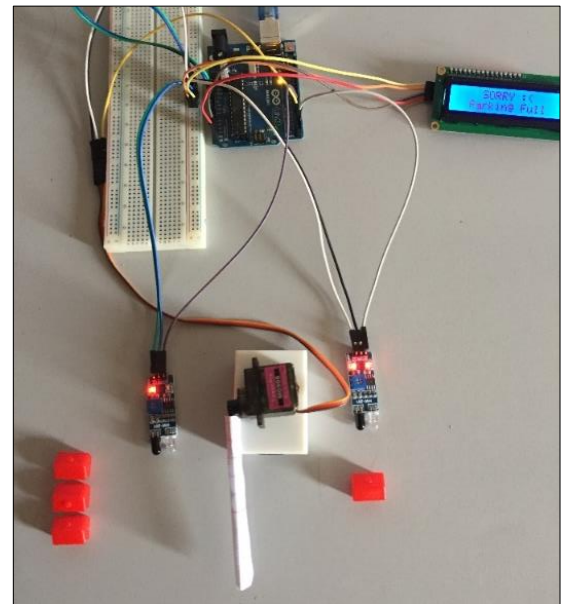


Fig. 4. Parking simulation in saturation situation

The simulation results presented in the figures (**Fig.3,4**) show that the Smart Parking project works consistently and accurately. This is a testament to the effectiveness of the project design (**Fig.2**) and implementation. However, it is important to emphasize that these results represent only a small-scale prototype, and further efforts are needed to improve the system in larger, complex projects. The simulation presented here shows that the project is promising and can be used as a basis for the design of more sophisticated and larger scale parking systems.

4 Conclusion

In conclusion, the use of an Arduino-based parking system has enabled the design of a cost-effective and easily adaptable system that can be deployed in different urban environments with different levels of complexity. The results obtained have shown that this system is able to effectively manage high demand parking situations, providing accurate information about the availability of spaces, and helping drivers to quickly find a parking space.

However, it is important to note that this project is still in development and requires improvements and adaptations for use in larger, complex environments. Additional efforts are needed to improve the accuracy, reliability, and usability of the system, as well as to explore opportunities for scaling and deployment in other settings. The Smart Parking project using Arduino sensors is a significant advance in smart parking management and offers promising prospects for the future of smart cities. With continued improvements, this project can help reduce congestion and greenhouse gas emissions, improve the driver experience, and make cities more pleasant and efficient.

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