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PARKING SPACE MANAGEMENT USING INTERNET OF THINGS

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ABSTRACT

This paper proposes the use of an IoT system as a tool to reduce the time spent searching for parking spaces. The developed system consists of a monitoring prototype, a real- time database and a smartphone application. The monitoring prototype consists of a development board, based on ESP8266 microcontroller and wireless network modules, connected to ultrasonic sensors for monitoring parking spaces. The microcontroller uploads all data to a cloud-hosted database, which lets you identify which parking spaces are available in real time through a smartphone app. By identifying parking spaces available directly from your mobile phone, you can significantly reduce the time wasted while searching for a parking space.

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INTRODUCTION

The growth rate of vehicles in circulation in Brazil has been gradually decreasing since 2011, according to re-ports by the Brazilian Institute of Planning and Taxation (IBPT, in Portuguese) (Amaral, 2018). In 2017, the growth of the vehicle fleet was 1.37%, while in 2015 the growth was 2.67% and in 2011 the growth rate was 8.32%. Even with this reduced growth rate in the number of vehicles, the country has reached a total of over 65 million vehicles currently in circulation in the country, of which 41 million are passenger cars.The growth in the number of vehicles in circulation, es-pecially passenger cars, is increasing the severity of various urban problems such as infrastructure and mobility such as congestion on public roads and the difficulty of finding a suitable parking spot. The number of parking spaces, whether public or private in Brazil, is often insufficient to accommodate the increasing number of vehicles, overloading public roads with cars parked on their side roads. However, the difficulty is often in locating available parking spaces in very large parking lots, wasting a lot of time in this search, and sometimes wasting available parking spaces that were not found by drivers.

The difficulty in finding parking places has caused more than half of Brazilian drivers not to shop in some shops, this data was obtained during the survey conducted in all state capitals, by the Credit Protection Service (SPC Brasil, in Portuguese) and by the National Confederation of Shopkeepers (CNDL, in Portuguese), which sought to analyze the impacts of urban mobility on local retail. From information like this, we can assume that the difficulty in finding a job has a significant and negative impact, not only on people's quality of life, but also on the country's economy. This justifies the search for solutions to avoid wasting time and resources when looking for a parking space, allowing them to be located more quickly and efficiently, thus improving the quality of life a little more and providing the most efficient use of parking lots.Technology has long become an important part of our daily lives, an example of our heavy reliance on technology today. It is related to the extensive use of smartphones, whether to communicate with friends and family through social networks, ordering a quick snack, or finding a place using GPS, the dependence on these devices is increasing, and we are getting used to new ways of interacting with these devices. The 29th Annual Survey on IT Use (Meirelles, 2018) conducted in 2018 by the Getúlio Vargas Foundation (FGV, in

Portuguese), reveals that the number of active smartphones in the country has reached more than 220 million units, the equivalent of more than one device. per inhabitant of the country. However, it is important to clarify that this does not mean that all Brazilians have such a device, since the same person may have more than one device. Similarly, or even because of the widespread use of smart- phones, the internet has become an almost ubiquitous tool in our daily lives, the current generation is almost always connected to the internet, a number that helps us visualize this scenario. released by the National Institute of Geography and Statistics (IBGE, in portuguese) as a result of the National Continuous Household Sample Survey (Continuous PNAD) , which reveals that 70.5% of Brazilian households have access to the Internet, of which 67% use their smartphones to connect to the network. Overall, figures such as those released by this research allow us to believe that the use of a car parking monitoring system based on IoT concepts could be a possible solution to minimize the difficulty of finding a space to park. It is important to highlight the existence of some systems proposals with similar objectives to the system developed in this work. A vacancy identification system was proposed in (Mahdi, 2018), which developed a prototype using pressure sensors, which at the moment a car is standing over them send a signal using Wi-Fi from a NodeMCU microcontroller. notifying the server, in this case Firebase, that the space has been taken.

The (Mahdi, 2018), approach was created by thinking about the traffic situation of Dhaka City in Bangladesh, which is suffering from major congestion caused mainly by cars parked in illegal places, such as in the middle of roads, sidewalks and other areas not allowed for traffic. parking. The application targets both the driver looking for a parking spot and the owners of a particular parking space who wish to rent it during business hours. This way, when a driver selects a vacancy in the application, the information and criteria defined by the vacancy owner are displayed. It is noteworthy that only one prototype was built, not really applied in a real situation, which raises doubts on the size of the sensors that should be used.
More complex systems using low-processing microcomputers, infrared sensors, NFC readers, or real-time camera image-based readers are also described in work done in (Kim, 2018; Baroffio, 2015; Abdulkader, 2018; Kodali, 2018). However, the implementation of some of these proposals does not fit the reality of this project, generally due to the high cost of some components or the need for major modifications to local infrastructure.Another system was devised in (da Silva, 2016). where ultrasonic sensors connected to Arduino Uno microcontrollers and Zigbee radios were used to monitor each parking space, sending the data to a central formed with a Zigbee receiver connected directly to a computer.Unlike the previously mentioned, the system developed in this work uses a monitoring prototype with multiple ultrasonic sensors, these sensors are connected to a microcontroller with integrated wireless modules and can identify the occupancy of two slots simultaneously for each prototype built. The microcontroller transmits the data, over the internet, in real time, to an online database, allowing applications for smartphones developed to access this database to obtain the status of each of the monitored parking spots.

Smart Parkings

The system developed in this work initially aimed to make it faster and more efficient to search for a parking space in a public parking environment. However, considering the possible use of the system to support private parking environments, an option to reserve an available parking space was developed.To ensure drivers have better access to this information, a real-time communication approach using a smartphone app is required.To check the situation of the parking space, after defining the possible states: available/free, unavailable/busy and reserved. An ultrasonic sensor was chosen for detection of the parked vehicle. The choice of sensor type was determined by the cost-benefit ratio, since this sensor type has good reading efficiency and a relatively more affordable price than the others, such as infrared presence and motion sensors. Noting that these according (Ernani Moura Amaral Filho, 2016), these sensors, despite the names they carry, do not really work due to movement, but with temperature variations, they are therefore calibrated with the temperature of the human body, so they are not suitable for identifying objects. that do not emit this temperature range, for this reason the ultrasonic sensors better fit the system proposal. An ultrasonic sensor will emit a sound wave that, when encountering an obstacle, will reflect back towards the receiver module, being possible to identify the distance between the object and the sensor. object near the sensor, in the case of the system developed in this project, the presence of this object characterizes the occupation of the monitored parking space by a particular vehicle.

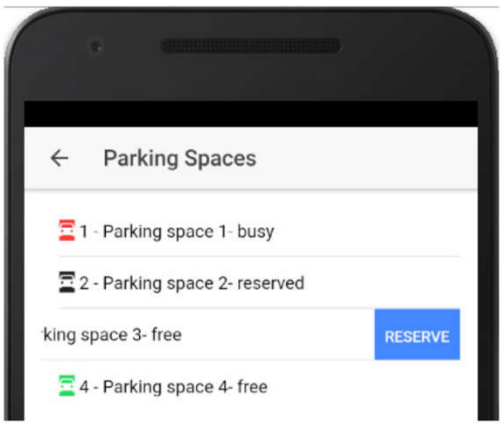
The information generated with the sensors is sent using a microcontroller with wireless internet module to an online database, that will record the status of parking spaces. This database can be consulted in real time to check the status of all spots in which sensors are being used.For the display of parking information, a mobile application was developed that receives data from monitored spaces, directly from the online database platform, providing real-time display of the status of each monitored space. This way, the driver can either go directly to the nearest available place or reserve one of them while heading straight for it. It is important to emphasize that once booked, the driver will have a certain time to occupy the reserved place, if the parking space is not occupied by the driver in time, the reservation will be automatically canceled, and the parking space will be available again.

System Architecture: The project was gradually developed in stages, first it was necessary to analyze each component individually, to ensure the correct functioning of the projected prototype, and then to test the necessary software for correct communication between all components of the system.

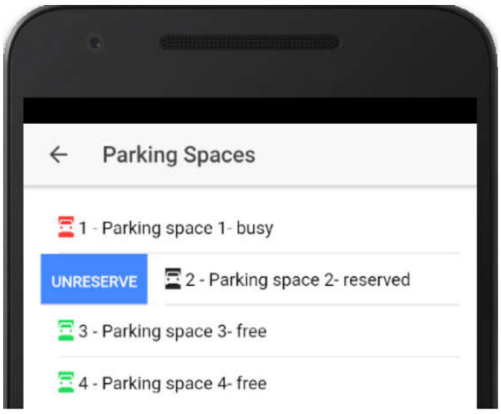
Development platform: The platform used for the development of this project was NodeMCU, which according to (de Oliveira, 2017) consists of an ESP8266 module - which is a 32-bit microprocessor with native support for wireless network connections, with a power and programming port, having 10 digital and one analog inputs. The choice of the ESP8266 was motivated by its low cost, coupled with the built-in wireless connection on the microcontroller board, which allows a more convenient way of communicating with a server to receive and send the data sent by the tests.

Software and Systems: For programming the chosen microcontroller, Arduino IDE was used, where the default programming language is C / C ++ and works on various platforms and operating systems such as Windows, Linux and macOS, Arduino IDE is ideal for creating various interactive environments and can be configured to use NodeMCU.The

mobile application developed in this project was built using Ionic which is a framework for mobile application development aimed at the development of hybrid applications and rapid development.After installing the application, it is required to login, if the user does not have a registered account yet, can create at this time. Once authenticated the user can select the option to display all monitored parking spaces, the status of each parking space is represented by colors, being green to indicate a available parking space, red for busy and gray for a reserved parking spot. A user can request the reservation of the parking spaces that are available at the moment, after the reservation, if the user who made the reservation no longer wants to use that parking space is possible to make the release, making it available to other users again, as shown in Figure 1. It is important to clarify that a reserved parking space remains unavailable to others until it is released by the driver who reserved it or exceeds the time limit for the user to park in the reserved parking space. The limit was initially set at 15 minutes after the reservation was confirmed.A great benefit of the mobile application is that the parking situation display is in real time, so when any car uses a parking space the application immediately changes the display of the parking space to busy for all users without reloading the page. This synchronization of information between the software and the microcontroller is performed by Firebase - a mobile and web application development platform, more specifically, the real-time database, which provides an API that enables application data is automatically synced across multiple clients. Firebase was chosen for its ability to store and synchronize data across all clients in real time and remain available when the app is offline.The schematic view of the project system can be observed in the Figure 2.



(a) Reserve parking space



(b) Unreserve parking space

Figure 1. Mobile Application Screens

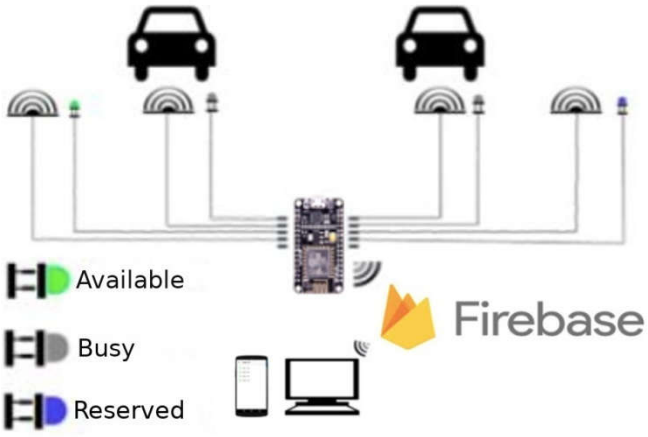


Figure 2. Proposed System

Components and Modules

After studying the basic concepts for the project development, it was necessary to organize the components, assemble the equipment and configure the projected prototype. Thus, the prototype works using a model structure constructed from the electronics and materials listed below:

Jumper wire;
1 Protoboard 810 points;
1 NodeMCU Esp8266;
2 Resistor 330 ohms;
4 Resistor 200 ohms
2 RGB LED Common Anode;
2 Ultrasonic Module HC-SR04.

The Table below shows the average values found in the market between January and February 2019. Of which, jumper wires and resistors, for being sold only in kits with a closed quantity of units can be reused for other projects or in the replication of new ones parking sensor prototypes.

Table 1. Initial Prototype Budget

Component	QTY	Price per item	Price(sum)
Jumper wire (Kit 40pcs/lot)	1	$2,0	$2,0
Protoboard 810 points	1	$ 4,0	$ 4,0
NodeMCU Esp8266	1	$ 7,6	$ 7,6
Resistors (100pcs Assorted)	1	$ 2,95	$ 2,95
RGB LED Common Anode	2	$ 0,20	$ 0,40
Ultrasonic Module HC-SR04	2	$2,30	$4,60
TOTAL	-	-	$21,55

The Circuit: The circuit is powered via USB cable by connecting a 5v output power supply to the microcontroller. On the digital pins of the development board are connected 2 LEDs and 2 ultrasonic sensors, these occupy the 10 available digital pins, all being interconnected using a protoboard. The LEDs are powered by 3.3v outputs, but the sensors used in the project need more power to function properly, so they are powered using the 5v output of the microcontroller.The circuit works as follows, according to the implemented algorithm, the ultrasonic sensors are in charge of calculating the distance from the end of the parking space to the car. The microcontroller reads the sensors and analyzes the situation of each monitored parking space. If an object is identified by the sensor within a distance of up to 100 centimeters over a period of 40 seconds, the microcontroller will consider the occupation of the monitored parking space. Consequently, the LED

indicating the status of that spot will go out signaling the unavailability of the parking space that is now busy. On the other hand, when the vehicle moves away from the sensors, the indicator LED will light green, indicating that that space is now available, in parallel with this procedure occurs the synchronization of parking lot status with the Firebase database, which sends this information automatically available to all connected devices.Finally, using a web application, we can also change the status of a parking space from available to reserved, once this process is done by recording the status of that parking space in the database, this information is automatically synchronized with the microcontroller, which changes the LED color to blue, indicating that the location in question is reserved. The following Figure 3 shows the circuit used in the prototype:

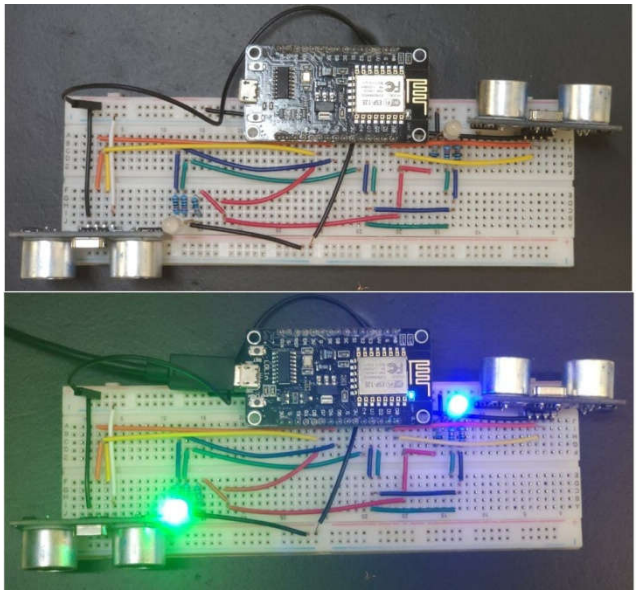


Figure 3. Initial prototype

For behavioral evaluation, the components and the designed system were submitted to the following tests:

Component Testing: The objective of this test is to evaluate the correct functioning of the monitoring device components. Initially, attempts were made to connect the microcontroller to wireless internet networks, seeking to receive and send data over the internet using the ESP8266 micro- controller. Subsequently, it was verified that the ultrasonic sensors used, performed the distance readings correctly, for this, objects of different sizes were placed in front of the sensors at different distances, comparing the sensor outputs with the actual distance measured in centimeters.

System Test: The purpose of this test was to evaluate if the system was working properly, behaving as expected by the project authors. To perform these tests, the monitoring prototype was placed at a height of 25 centimeters from the ground, under a support platform, the platform was arranged between two parking spaces in opposite directions at a distance of approximately 30 centimeters from the beginning of each In one of the spaces, as shown in the Figure 4, the sensors were configured to identify the presence of objects at a distance of up to 100 cm, for a minimum period of 40 seconds, these reference values were empirically defined by the authors for the realization. of the tests. The vehicles were positioned at four levels of distance in each parking space, observing the state identified by the sensors through the web monitoring system, as exemplified in the Figure 5.

Figure 4. Test with both parking spaces available

Figure 5. Test with a busy parking space

RESULTS AND DISCUSSIONS

Behaved as expected, the component test revealed a good accuracy of the sensors in the distance measurement, no differences were obtained greater than 1 millimeter between the distance identified by the sensor and the real distance. The microcontroller wireless module also worked as expected, being able to connect to many wireless networks without any problems, including networks routed through smartphones.

The system was able to correctly identify the status of monitored parking spaces, according to the parameters implemented in the identification algorithm, signaling as unavailable, a space in which a vehicle was at a distance of 100 cm or less from the sensors for a period of time. not less than 40 seconds. Communication between the device and the web system occurred almost instantaneously, even when the internet connection was made through low speed networks, providing real-time status of monitored places, this behavior was also verified when using the web system to mark a place as reserved, a process in which the status indication LED was immediately changed to blue by the microcontroller. The states of monitored parking spaces, observing four measuring distances, are described in Table , and the outputs shown by the application for each measured distance are displayed.

Table 2. Monitoring Test Results

Distance App	Output
120 cm	2 - Parking space 2- free
102 cm	2 - Parking space 2- free
100 cm	2 - Parking space 2- busy
50 cm	2 - Parking space 2- busy

Conclusion

In this work, an IoT-based system was designed to manage parking spaces in a parking lot. The system was developed using relatively low-cost components to build the necessary equipment. The project presented satisfactory results, reaching the objective of monitoring some parking spaces using ultra-sonic sensors, and the internet as a means of providing the information generated to users.Thus, the viability and efficiency in the use of internet of things to control parking spaces has been demonstrated. This is an efficient and relatively low-cost way to control parking spaces, both in terms of system development, maintenance and installation. It was also possible to observe benefits by using the internet, not being necessary to use other communication resources such as bluetooth or radio devices to send the generated information, being sufficient the use of a web system connected using only the internet.

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