



## **DESIGN AND STUDY OF A SMART PARK SYSTEM: UNIVERSITY OF KUFA AS A CASE STUDY**

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### **ABSTRACT**

Finding a vacant parking space nowadays is time and fuel consuming. This problem may cause drivers to get frustrated and eventually improper parking will appear. The universities, in particular, are one of these places, which needs more attention for providing parking services. Therefore, this study has focused on finding the parking required for such facilities and the benefit of applying smart parking services there. The main campus of the University of Kufa has been evaluated by collecting parking data for both on-street and off-street parking. The results of field data show a clear lack of parking space for most of the faculties in the main campus. The required additional parking spaces are 260. This study has suggested using the smart parks. The model of smart park system has been introduced by this study as a solution to the parking problem, especially in the university and generally in other places. Arduino and ultrasonic sensors were used to detect the empty places in a park and display this status to the screen. The model has been applied at the park of College of Engineering with encouraging results.

**KEYWORDS:** Parking facilities, university parking, Smart park, Arduino UNO, Ultrasonic Sensors.

## 1. INTRODUCTION

Finding a suitable park is one of the challenging problems nowadays generally in the urban areas, especially in the universities (Barata et al., 2010). Less attention has been paid for arranging parking in the universities even these universities from the major trip generators and distributors in any city in Iraq. University of Kufa is one of the major trips attracting in Al-Najaf (Al-Jameel and Kamel, 2016). This leads to high number of people coming to this center of activity and one could see clearly a huge amount of parking vehicles outside the campus (illegal parking) which represent the vehicles of students or the others coming for other purposes as shown in Fig. 1. This phenomenon shows how much the number of parking space is? Moreover, just the employees who are able to enter into the main campus. However, the lack of spacing is so clear through the evaluation done by this study even a lot of parks in the university are not included in the fundamental site plan of the university.



**Fig. 1. Illegal parks outside the main campus of the university.**

The existing suitable park for parking vehicle is an important impression for specific urban and suburban areas. Even is more designers know that the parking structures must be designed specifically for the types of visitors which structure will serve, based on the certain or specific facilities. These are supported and controlled on flow of daily traffic (Young et al., 1991).

Parking studies are therefore used to determine the demand for and the supply of parking facilities in an area (Garber and Hoel, 1997). Using low-cost sensors, real-time data collection, and mobile-phone-enabled automated payment systems that allow people to reserve parking in advance or very accurately predict where they will likely find a spot (Young et al., 1991). When deployed as a system, smart parking thus reduces car emissions in urban centers by reducing

the need for people to needlessly circle city blocks searching for parking. It also permits cities to carefully manage their parking supply. Smart parking helps one of the biggest problems on driving in urban areas; finding empty parking spaces and controlling illegal parking (Young et al., 1991).

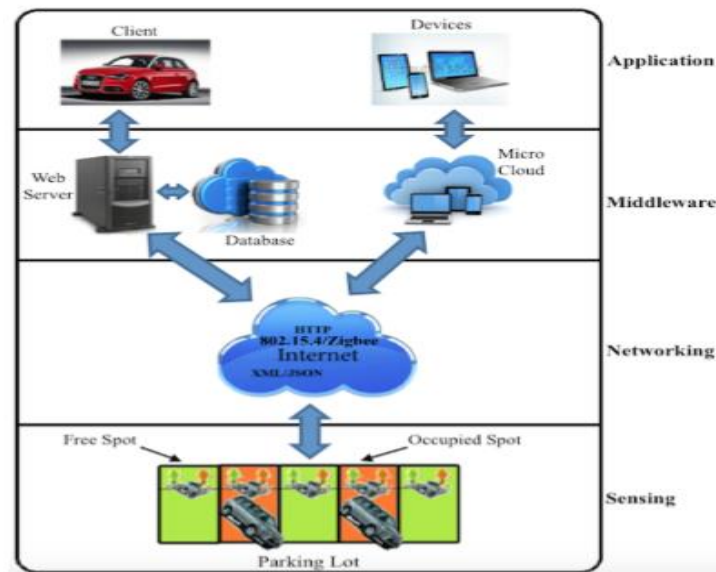
Different managements have been implemented to mitigate the parking problems in the campus of universities across the world such as the university of Coimbra and university of California (Dasila et al., 2015, Barata et al., 2010, Alshuwaikhat and Abubaker, 2008, Shang et al., 2007 and Balsas, 2003). Therefore, the university of Kufa has been studied to enrich the area of parking services and shedding the light for such problem.

Smart Parking System (SPS) plays a significant role nowadays, to improve the services of parking to motorists. There are many different systems can be used in the SPS to develop the parking services at organizations, malls, universities and cities by providing the parking data controlling and the car parks activities monitoring. The purpose of this paper is to investigate the issues of parking to fulfill the requirements of drivers. Therefore, using wireless smart parking system is to display the empty spaces in a park on an outside screen. Thus, ultrasonic sensors will be used to investigate whether the spaces are empty or full. In this paper, two Arduino Uno were used as a controller of the SPS.

According to the above paragraph, there are two parts will be discussed in the following sections: first part is to evaluate the parks in the university and the second part is how to design model for the SPS.

## **2. THE SMART PARKING**

Smart parking is a good component of a smart city application. A citizen of a smart city may use his mobile device, a tablet or the Internet to access from home the smart city applications to find a free parking spot in the city center. A smart parking system can provide efficient car parking management through remote parking spot localization and reservation fast car retrieval parking regulation using gate control and management car security and protection in the parking lot by associating car movement to a specific RFID tag parking gate management and many other services such as parking billing and payment by replacing the paper-based ticketing by RFID tags (Reza et al., 2012).



**Fig. 2. The smart parking system (Access2, 2017).**

The SPS could be detected the car park availability using several methods such as the ultrasonic sensor, short message service (SMS), and wireless sensor network. The ultrasonic sensor system also provides other facilities such as vacant car park detection, improper parking detection, display available parking lot and directional indicators toward the vacant car park space, payment facilities and different types of parking spaces by using LED indicator (Tee, 2014). Whereas, The SMS that sent by users will be processed by a wireless communication instrumentation device called micro-RTU (Remote Terminal Unit). This micro-RTU will eventually reply the confirmation of booking with the reservation details such as password and numbers. The password will be used to enter the parking area and valid for a certain amount of time (Tee, 2014). Finally, the third one allows drivers of vehicle to search for the free parking places effectively by using mobile application. The system consists of wireless sensor networks, embedded web server, central web server and mobile application (Tee, 2014).

### 3. DATA COLLECTION STAGE

The required data for parking evaluation are three types: origin and destination, accumulated vehicles, and average turnover (license plate method) (Al-Jameel, 2017). The origin and destination data are not required because only just the employees used the parks in the campus. Similarly, the average turnover index is about one because the time for parking is more than one hour. Therefore, this study is just focused on the specific duration to evaluate the parking vehicles by counting the number of spaces and the number of vehicles occupying these parks.



**Fig. 3. Ultrasonic sensor** (Access1, 2017).

#### 4. SELECTED SITES

The parking sites have been selected from the main campus are five parks as indicated in [Table 1](#). Moreover, this table also shows how many visits have been implemented there.

**Table 1. Observed parking sites.**

Site	No. of visits	Date
Engineering park	1	7-11-2016
The parks of the Science faculty	2	5-12-2016
Parks of the university presidency	3	5-12-2016
Park of the Art Faculty	4	5-3-2016
Park of the Fiqh Faculty	5	5-12-2016

Data have been collected by recording the entering and exiting vehicles. The survey includes counting the number of entering and leaving vehicles from each park. The observers conducted these surveys each 15 minute. Moreover, the geometric design for each park has been determined such as the width, length and the number of spaces.

##### 4.1. College of Engineering

The survey started at 9:30 A.M. The number of parked vehicles before starting our survey was 68. A lot of vehicles are illegally parked on-street as indicated in [Fig. 4](#). The park is oversaturated. Therefore, there is a lack of suitable spaces for parking vehicles. Thus, there is

a need for extending the no. of space in the park of faculty. This could be attributed to the average turnover which is approximately one. The occupancy over 100%, as indicated in Table 2, which means that vehicles are illegally parked in the lot causing an impedance for entering and leaving vehicles.



**Fig. 4. Parking outside the Faculty of Engineering position.**

In addition to this park, two small parks with 110 vehicles which their occupancy 100% are specified for employees and staff. However, in the day of the evaluation, the number of on-street parking illegally was 150 vehicles as shown in Fig. 4. Therefore, the required number of additional spaces are 150 for the staff and employees only.

**Table 2. Accumulated parked vehicles for Engineering park.**

Time	In	Out	Stop vehicles	Accumulated vehicles	Occupancy
09:30-09:45	0	0	68	68	100
09:45-10:00	1	0	68	69	101.47
10:00-10:15	1	1	67	69	101.47
10:15-10:30	1	0	68	70	102.09
10:30-10:45	1	0	68	71	104.4
10:45-11:00	0	2	67	69	101.47
11:00-11:15	2	3	64	68	100
11:15-11:30	0	4	60	64	94.11

#### **4.2. College of Science**

The survey started at 10:40AM as presented in Table 3. The number of spaces for this park is 48. Many vehicles parked outside position equal to five vehicles on either side of the road. The



already parked vehicles, were found before starting the survey, were 44. Even the occupancy is less than 100% but the park is oversaturated because some spaces have been specified for some persons. This could be noticed clearly by existing a lot of illegal on-street parking.

**Table 3. Accumulated parked vehicles for faculty of Science.**

Time	Stop vehicles	In	out	Accumulated Vehicles	Occupancy
10:40-10:55	44	0	0	44	91.67
11:55-10:10	42	0	0	44	91.67
11:10-11:25	44	2	1	45	93.75
11:25-11:40	42	0	3	42	87.50

However, other staffs park their vehicles illegally in the parking lot which is unpaved and not planned as a park. The number of these vehicles at the day of counting were 20 vehicles.

#### **4.3. The park of University of Kufa 's presidency building**

Table 4 indicates that the number of spaces for this park is 128. Moreover, the number of parked vehicles before counting was 113 vehicles. However, 60 vehicles were observed out of the park, i.e. on-street parking. In addition, this office is visited by several employees and staffs from other colleges and even other people out of the university for different purposes.

**Table 4. Presidency building park.**

Time	Stopped vehicles	In	out	Accumulated vehicles	Occupancy
12:15 -12:30	113	9	6	116	90.62
12:30 -12:45	116	5	8	113	88.12
12:45 -01:00	113	5	11	106	82.81
01:00 -01:15	106	5	2	109	85.21

#### **4.4. College of Fiqh**

The survey started at 10:00 AM as shown in [Table 5](#). The number of parked vehicles, before starting our survey, were 36 and the number of total spaces was 36. This park also suffers from lack in capacity as indicated in the previous parks. [Fig. 5](#) demonstrates the lot of this faculty.



**Fig. 5. The parking of The Faculty of Fiqh.**

At the time of survey, it was noticed that just six vehicles parked out of the park as on-street parking vehicles as shown in [Fig. 5](#).

**Table 5. Accumulated parked vehicles for Al-Fiqh faculty.**

Time	Stop vehicles	in	out	Accumulated Vehicles	Occupancy
10:00 - 10:15	36	0	2	34	94.44
15 -10:30:10	34	1	1	34	94.44
30 -10:45:10	34	1	2	33	91.67
00:11-10:45	33	3	2	34	94.44
11:00-11:15	34	3	1	36	100
11:15-11:30	36	1	2	35	97.22
11:30-11:45	35	2	1	36	100
11:45-12:00	36	1	3	34	94.44

#### **4.5. College of Art**

The survey started at 1:00 PM. The number of total spaces in this lot was 51. This only park which works under its capacity as indicated [Table 6](#).



**Table 6. Accumulated parked vehicles for Art faculty.**

Time	Stop vehicles	In	out	Accumulated vehicles	Occupancy
01:00-01:15	33	2	4	31	60.78
01:15-01:30	32	1	3	29	56.86
01:30-01:45	30	1	2	28	54.90
01:45-02:00	29	0	0	28	54.90

In the light of above surveys, it was found that the College of Medicine has no specific park but they use on-street parking. At the time of survey, the number of on-street parking was 30 vehicles.

In summary, the required number of parking spaces are 150 for College Engineering, 20 for College of Science, 50 for University of Kufa 's Presidency building, 30 for College of Medicine, and 10 for College of Faqih. The total number is 260 parking spaces for just employees and staffs. The solution for such parking problem is by constructing SPS for both lots and multi-story parks. This will benefit the university if the students are allowed to enter the campus and use such park by paying for parking.

## 5. BUILDING THE SPS MODEL

The parking in University of Kufa should be redesigned by this suggested design. This smart park system would assist drivers to find the empty spaces in the smart park easily. This SPS is implemented in such a way that be suitable to cover parks, gates, streets. The SPS contains ultrasonic sensors in each slot of the parking area to detect the cars. In addition, using two displays (LCD) which the first one placed in the front of parking gate to show the status of parking space and the second displays the installed in the main street to show for drivers the number of empty slots in the parking area. While Arduino UNO plays the important role in this SPS that it is processing the feedback signals from ultrasonic sensors and take the decision then send it to LCDs by the wireless systems. The system consists of two parts. The first part is installed in the park and contain Arduino UNO, ultrasonic sensors and RF 315/433 MHz transmitter. The second part is the receiver part which includes Arduino UNO, RF 315/433 MHz receiver and LCD. The next section will explain the parts of the system in details.

## 6. ARDUINO UNO PLATFORM

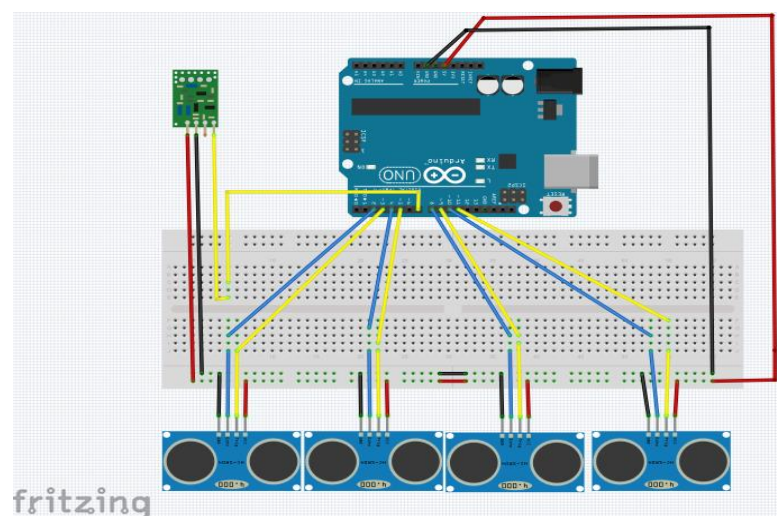
Generally, Arduino is a microcontroller platform which can be programmed easily. It is an electrical open source board used to connect the devices between them and control our environment. Sensors, lights, motors, can be wired as inputs and outputs via the Arduino pins to design a desirable project. There are many different Arduino boards in this study Arduino UNO was used. The main pins of Arduino are power pins, analog pins, and digital pins. Some of digital pins can work as a pulse width modulation (PWM) output pins. The properties of the Arduino UNO board are working at 16 MHz, cheap, easy to be wired, small size and suitable to our prototype ([Arduino, 2017](#)).

### 6.1. Software

To achieve the desirable results, the Arduino board has to be programmed in such a way to understand the devices that connected together. Thus, the Arduino software (IDE) is used to program Arduino board. It runs on different operation systems such as Windows, Linux, Macintosh OSX and recently on Android. It is flexible enough for both beginner and advanced users. Furthermore, it can be extended by the experienced programmers because it is an open source.

In this paper, some libraries were used to run the prototype of the project such as RCSSwitch and LiquidCrystal\_I2C libraries which was downloaded from GitHub website ([Kianpisheh et al., 2012](#)).

The first part of the SPS is indicated in Fig. 6. It was designed using Fritzing program which is an open source hardware used to simulate the circuit. It specially deals with Arduino.



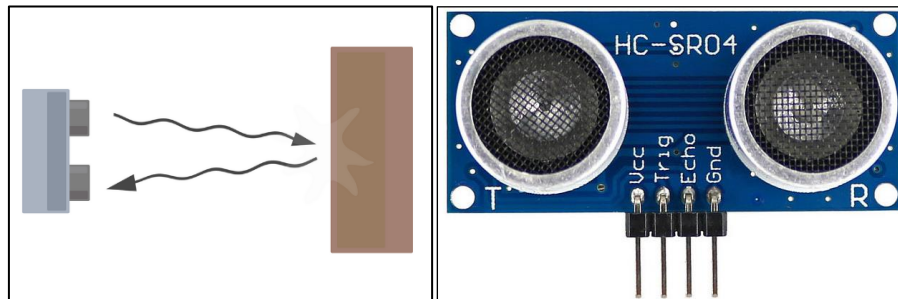
**Fig. 6. The detector and transmitter part of the SPS.**

## 6.2. Transmitter part of the SPS system:

It consists of the following parts as discussed in the next following sub-sections:

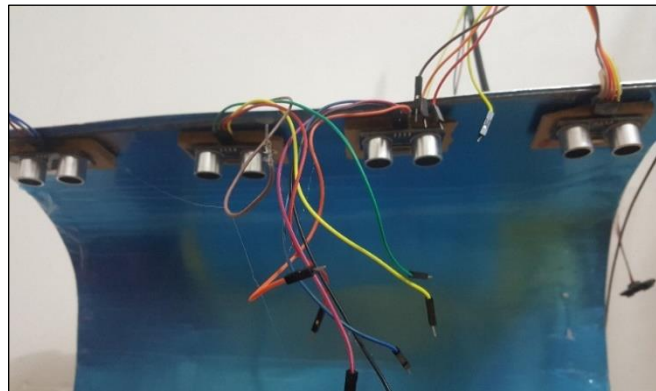
### 6.2.1. Ultrasonic sensors

The ultrasonic sensor is a device that uses the sound wave at a specific frequency. It sends out the sound wave by the trigger part then waiting to bounce back. The time between sending and receiving the wave sound, the sensor can estimate the distance between its position and the object (Idris et al., 2009). The ultrasonic Arduino module is designed with four pins, as indicated in Fig. 7, which are Vcc, Trig, Echo and GND, respectively.



**Fig. 7. Diagram of the basic ultrasonic sensor operation.**

In this paper, four ultrasonic sensors are used as a case study to design a small park for applying this idea. Fig. 8 shows the locations of the ultrasonic sensors. They located 30 cm above the ground, then the distance will be reduced to less than 30 cm when cars stopped under the sensors.



**Fig. 8. The locations of the ultrasonic sensors.**

### 6.2.2. RF 315/433 MHz transmitter module

The first part also contains the transmitter RF which sends a specific code for each case to the receiver part. The Rf transmitter contains mainly three pins, Vcc, GND and data. The specification of the RF is to work at 3-12V while the current work is between 9mA to 40mA.

It uses ASK modulation. It can transmit data over 90m in open area. Finally, it is a very cheap transmitter.

### 6.2.3. The hardware connection

The breadboard is used to connect the Ultrasonic sensors and RF transmitter antenna to Arduino UNO. The Vcc and GND of the ultrasonic sensors and RF antenna are connected to Arduino Vcc and GND. The data pin of the RF transmitter antenna is connected to digital pin 7 of the Arduino. While the four trig pins of the ultrasonic sensors are connected to 8, 10, 2, 4 digital pins of Arduino respectively. These pins are programmed as output pins. The echo pins were connected to 9, 11, 3, 4 of digital Arduino pins.

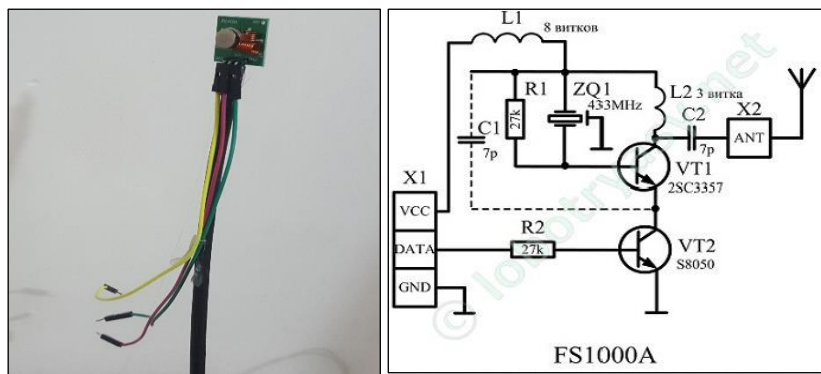


Fig. 9. RF 315/433 MHz transmitter module.

### 6.2.4. The program of the first part

Arduino was programmed to control the transmitted and received signals of the ultrasonic sensors. First of all, the Arduino board enables the trig pins of the ultrasonic sensors which sends the sound wave out. Then the signal will bounce back once it hits an object. The echo part of the ultrasonic sensors will sense the return signal. The duration between sending and receiving the signal will be stored in a variable called "duration". Next, the Arduino will estimate the distance between the ultrasonic sensor and ground or a car as indicated in Eq. 1.

$$\text{Distance} = \text{duration}/58.2$$

1

Then the programmed Arduino tests four ultrasonic sensors with four equations. Any equation gives distance less than 30 cm that means there is an object under the sensors which is a car. The following step of the program is to give a unique code for each status. The RC switch library is used to encode and send the data over the RF transmitter.

### 6.3. The received part

The second part of the SPS contains three components which are Arduino UNO, Rf receiver and 2\*16 LCD. Fig. 10 is designed by fritzing software shows the received part. Arduino UNO was explained in the aforementioned section; therefore, the LCD and RF receiver will be explained in the next sub-sections.

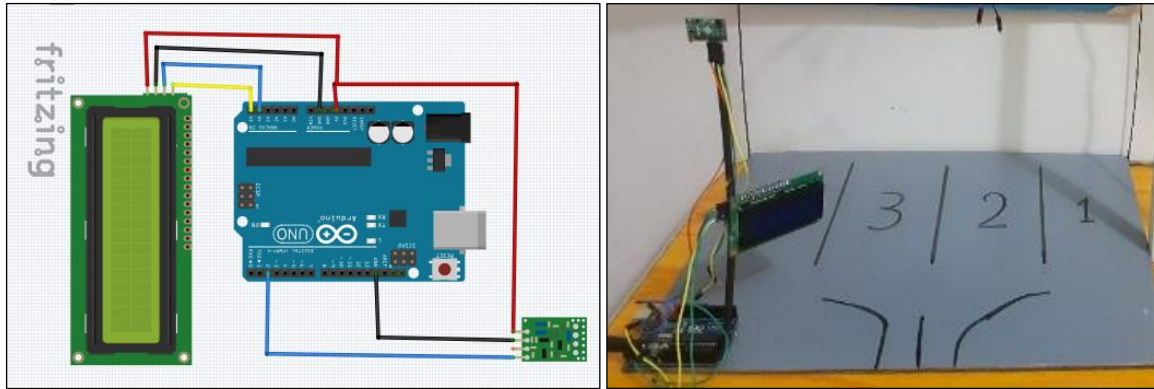


Fig. 10. The second part of the SPS.

#### 6.3.1 RF 315/433 MHz receiver module

The main characteristics of RF receiver are compatible with Arduino platform. It is used to receive the data from the first part of the SPS. The properties of this receiver are to work at 5VDC and 5mA and its sensitivity is -105 dBm. It has four pins Vcc, data, data and GND, respectively.

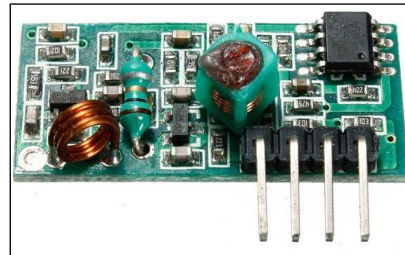
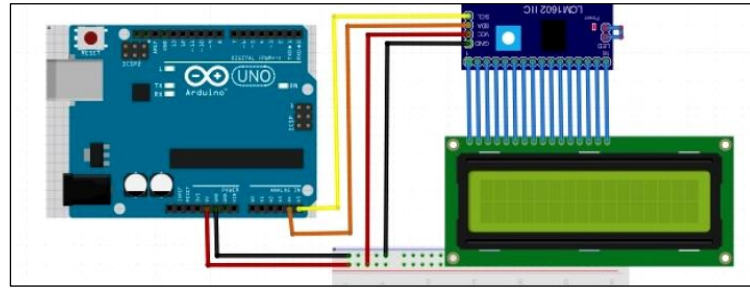


Fig. 11. Circuit module of the RF receiver.

#### 6.3.2 2\*16 LCD display

In the received part, there is a screen which was located in the gate of the park in order to show the status of the occupancy for spaces in the park. In this prototype a 2\*16 LCD was used for many reasons, such as it is cheap, compatible with Arduino platform and easy to be programmed using "LiquidCrystal\_I2C" library. However, it has 16 pins and it is difficult to connect with the Arduino board. Thus, using an I2C module which shrinks the pins of LCD from 16 to 4 pins only. Therefore, the LCD with I2C module was connected to the Arduino board via four pins only GND, Vcc, SDA and SCL.



**Fig. 12. LCD, I2C and Arduino connection.**

### **6.3.3 The hardware connection**

The Vcc and GND pins of Arduino board were connected to LCD and RF receiver module. The data pin of RF antenna was wired to the second digital pin of the Arduino board and work as an input. While the SDA and SCL pins of I2C were joined to A4 and A5 of analog pins of Arduino respectively.

### **6.3.4 The program of the second part**

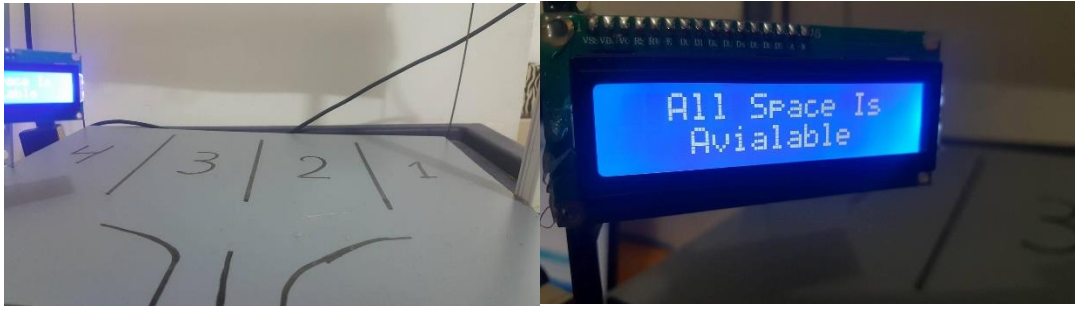
The use of the RC switch library is to make the Arduino platform compatible with the RF receiver. The RF Receiver module will receive data and decode it then send it to the Arduino board via second digital pins. The Arduino was programmed to store these data in a variable called "value". Then, this variable is compared with some prestored values where each value shows a case in the park. If the value of the variable is matched with one of the prestored values that leads to Arduino sending a suitable sentence to the LCD.

## **6.4. The experiment**

As mentioned above, the Arduino of the first part was programmed to discover the distance of four locations in the park (as a case study) via ultrasonic sensors. There are many cases may be happened, consequently, each case should have a unique code to be sent. For example, the code "6" is for empty park that means when four ultrasonic sensors measure over 30 cm. The RC switch library will encode "6" in such a way then it transmits to the second part via a transmit module. The RF receiver antenna will collect the data then decode it into "6" again and send it to the Arduino which compares it with some values. Then, the Arduino will send a sentence "All spaces are available" to LCD display as shown in [Fig. 13](#).

As the sound wave hits the car instead of the ground causing the less than 30 cm. This means the spaces are not empty. To find the empty space, the drivers should look at the LCD board which is placed in the front of the park gate before entering the park. The LCD shows the vacant spot number as demonstrated in [Fig. 14](#).





**Fig. 13. The empty park.**



**Fig. 14. The LCD displays the available spot.**

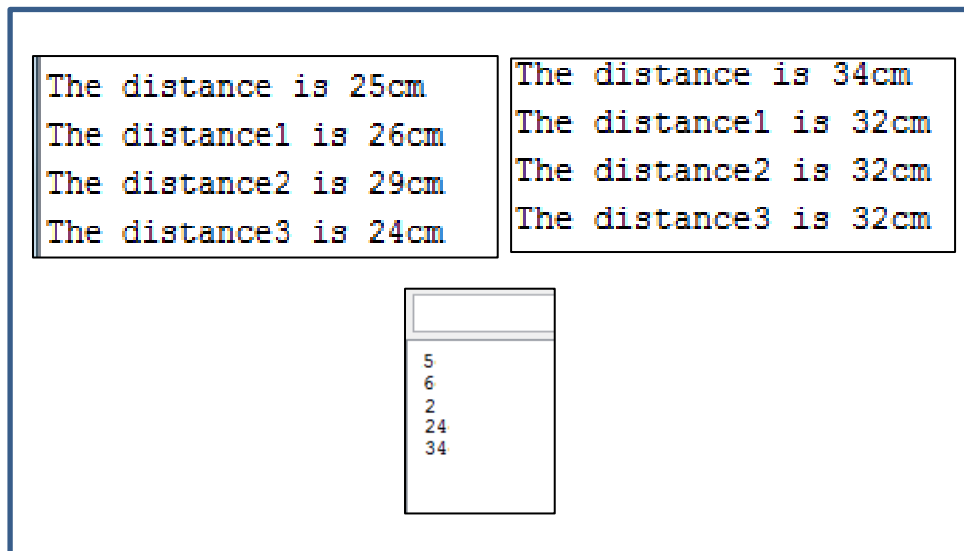
Generally, the system detects the status of the park each 5 sec. The time detection can be changed. In addition, the first part can write the distance that measured by the ultrasonic sensors when connecting the Arduino to a Laptop. Similarly, the second part will appear the received code as shown in [Fig. 15](#).

Table 7 illustrates some cases that may happen with each its code and sentence.

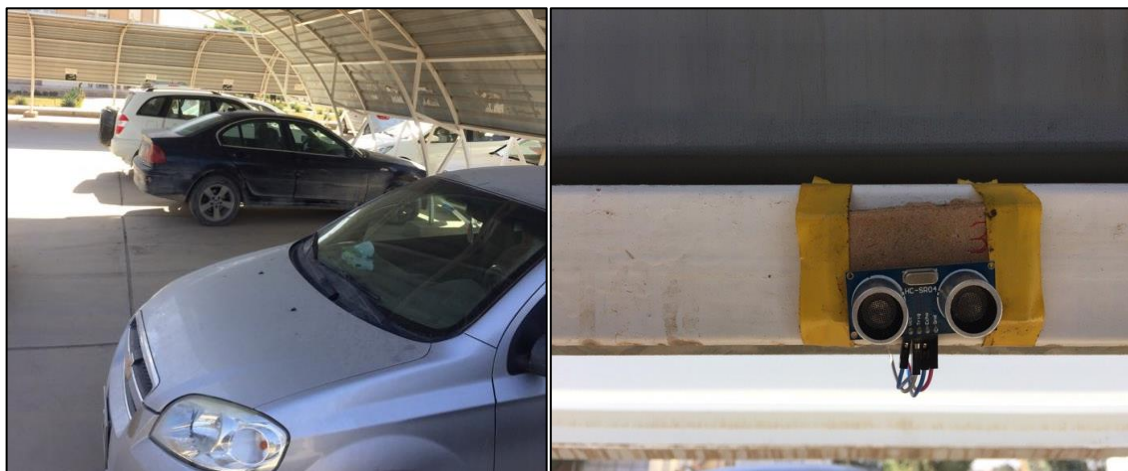
**Table 7. shows some statues of the park and code of each case**

Position 1	Position 2	Position 3	Position 4	Code	sentence
Empty	Empty	Empty	Empty	6	All spaces are available
Full	Full	Full	Full	5	Not Available spaces
Empty	Full	Full	Full	1	First space is available
Empty	Full	Full	Empty	14	1 <sup>st</sup> & 4 <sup>th</sup> spaces are available

Finally, four spots in the park of the College of Engineering were chosen to apply the suggested model as shown in [Fig. 16](#). The left image illustrates that there are three cars at first, third and fourth spaces in the park.

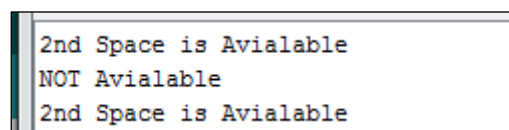


**Fig. 15. The Serial Monitor of the two parts of the SPS.**



**Fig. 16. shows the actual park at engineering college.**

Therefore, the receiver park will show the results on the screen as shown in Fig. 17.



**Fig. 17. The results of two different cases in the park.**

The first sentence is "the second space is free to use", this assists the drivers to know before coming to the park if any there is a free space. Consequently, drivers gain the time to find the empty spaces. While the second sentence in Fig. 17 is "there is no available space in the park", so the driver must look for another park. This model reduces the traffic jam.

In summary, the developed model has been tested with field data as discussed above and it shows encouraging results in terms of indicating the status of space whether it is available or taken. In addition, this developed model will assist in reducing the time of getting right space

because there is a variable message (screen) indicates where is the available space. Furthermore, this model could be used in the multistory park where the drivers could not see all spaces. Thus, the screen in the front of gate of the garage will indicate the status of each story and where the empty space is.

## **7. CONCLUSIONS AND RECOMMENDATIONS**

The main points come up with this study could be summarized as following:

1. Generally, there is an obvious lack of parking spaces (up to 260 parking spaces) for whole the university due to illegally parking vehicles in front of the most the faculties and even outside the university. One could see illegally parked vehicles everywhere.
2. Using Arduino UNO as a microcontroller of SPS which is very cheap and easy to be programmed and Ultrasonic sensors were used because they are compatible with Arduino and they can detect the distance between 5cm to 7m.
3. Arduino has been programmed to enable ultrasonic sensors to measure the distance between them and ground, then the feedback signals will be processed by Arduino to send a suitable code to the receiver part of SPS. The receive part of SPS received a code and translate it into a sentence, finally, the sentence will appear on the display.
4. The model has been applied in the park of engineering and connecting the model to a screen which indicates the status of parking space either available or busy displaying on screen. The model exactly mimics the reality.

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