UPark Real-Time Parking Garage Information System

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***Abstract* — The U-Park system aims to solve a problem rampant at the University of Central Florida and all across the world: the lack of information about parking garage availability. U-Park uses an array of sensors to monitor all of the spots in a particular garage. Spot occupancy information is then relayed wirelessly to central access points across the parking garage. The information is passed across the Internet to update a database containing the parking availability information of the garage in question. This information can then be viewed in real-time on a web interface, which is optimized for any size of device accessing it. The U-Park system reduces the amount of time it will take for users to get to where they need to get to on campus by minimizing the amount of time it takes to find a parking spot. Instead of users having to drive around aimlessly in a full garage waiting for someone to leave, wasting gas in the process, users will know exactly where spots are available in a particular garage before they even leave the house.**

***Index Terms* — ATMega328P-PU microcontroller, database system, parking garage, ultrasonic sensors, web interface, wireless communication.**

I. Introduction

What exactly is U-Park, and how does it work? U-Park makes use of various sensing and communication devices to determine and transmit the occupancy of parking garages maintained by the system. With over sixty thousand students, the University of Central Florida is one of the largest schools in the United States by enrollment. The demand for parking spots has been increasing as the number of enrolled students keeps growing. Unfortunately, the current number of parking spots is not enough for all students, leading to the problem that many students are wasting their time driving around looking for a place to park.

Students have no knowledge about which parking garage is open or which garage has unoccupied spots. Many students arrive at classes late just because they spend over thirty minutes searching for parking or waiting for other students to get out of class. Even though a possible solution would be to build more parking garages in order to make a more efficient supply to demand ratio, this solution has not solved the problem thus far, and the cost of constant new construction is huge. If students were informed of the location of open spots, the problem could be mitigated at a much lower cost, and would allow for a more efficient use of already available resources.

The U-Park system works by using ultrasonic sensors to detect the occupancy of each spot in a garage. Multiple sensors will be connected to a single sensor module, which processes the data from the sensors and relays the information wirelessly to an access point in the garage. This sensor data is sent over the Internet to populate a SQL database, which is then queried by a web interface. The web interface is built in a way that resizes dynamically based on the screen size used to access the interface. Therefore, regardless of whether someone wants to find which garage to drive to before they leave the house, or check garage information on their phone at a stop light, the web interface will allow users to see the same interface regardless of the device with which they use to access it.

II. Requirement Specifications

The U-Park system's primary mission is to be a cost effective and reliable solution for parking management, while allowing the application's users clear parking availability information. The below requirements reflect this mission and delineate the specific criterion for making this mission a reality.

- The unit cost per sensor module will cost no more than $50.
- Each sensor module will contain sensors to monitor three adjacent parking spots.
- Each sensor module will contain a wireless transceiver to communicate parking availability data to a central hub.
- Data on the user interface will be no more than 3 minutes out of sync with actual parking availability.
- The sensor modules will be able to monitor parking 24 hours a day, 7 days a week and 365 days a year, however will likely only be used for around 16 hours to increase the lifespan of the components.
- Each module will pull no more than 0.5 watts of power.
- The U-Park system will rely solely on the use of standard 110V AC power and will convert to the required DC voltages used in the system.
- The U-Park system will be able to operate in the Florida climate.
- The user interface to check parking availability will allow users to see current parking availability and will have a mobile-friendly interface.

III. U-Park System

The U-Park system consists of four major development areas: hardware/PCB design, the microcontroller's embedded processing, the SQL database and the dynamic web application.

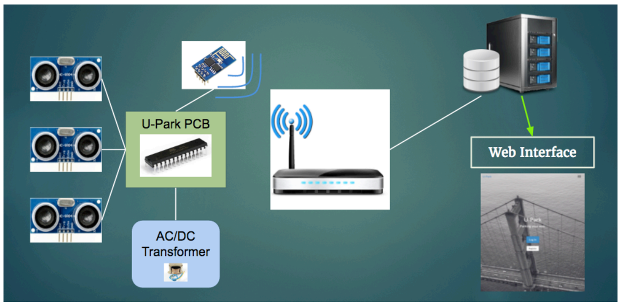

Fig. 1. This figure shows a high-level system schematic, which the U-Park design team will be aiming to replicate in the final product.

The system schematic clearly shows the different components, which make up the system. On the left of the picture, the ultrasonic sensors are shown connected to a custom PCB, which is connected to a Wi-Fi module. The PCB is powered by regular AC power from the wiring already in the garage. This alleviates the frustration of having to replace batteries in sensors, and cuts down on maintenance costs. The AC power must be converted to DC, and regulated to voltages the microcontroller and other modules require, which is done by the system's AC/DC transformer PCB. The Wi-Fi module communicates to the router, which then connects to the database. The web interface uses the database to provide users with up-to-date data from a particular garage.

IV. Design

A. Sensors

The section provides information about the ultrasonic sensor, which the parking system uses to detect whether or not there is a car parked in a given parking space. While other options such as Hall effect sensors were considered, the ultrasonic sensor was chosen due to its accuracy and simplicity. Also, the ultrasonic sensor can be mounted in any orientation as long as it can detect whether there is an object (i.e. a car) that has entered its detection path, and has crossed the distance threshold set by the distance parameters in the source code. The specifications for this sensor are shown in the tables that follow.

5V DC - 15mA power supply
Trigger Pulse Input
Echo Pulse Input
0V DC Ground (connected to the power supply)

Fig. 2. Ultrasonic sensor pin functions

The Above table shows the function of each of the pins on the ultrasonic sensor. The sensors will be powered in parallel with the microcontroller to ensure the input power is high enough to power the sensors, and reliable enough to maintain consistent operation of the system.

Working Voltage	5V (DC)
Working Current	15mA
Working Frequency	40 kHz
Maximum Detection Range	~ 4 - 5 meters
Minimum Detection Range	~ 2 centimeters
Measuring Angle	15 degrees
Trigger Input Signal	10uS TTL pulse
Echo Output Signal	Input TTL lever signal and range in proportion
Product Dimensions	(.45 x .20 x .15) centimeters
Operating Temperature	-40˚C to 120˚C
Overall Accuracy	(95%)$^{+}$
Life Span	2 years (minimum)
Weight	8.5 grams

Fig. 3. Ultrasonic sensor specifications

B. Wi-Fi Transceiver Module

Wireless communication is a primary requirement of the U-Park System. To this end, the group has chosen to use a transceiver that works on the 2.4 GHz WIFI band. This will allow the modules to communicate directly with the access point without the need for extra intermediary communication hardware/software. The modules are arranged in a star network configuration; therefore each module must have a way to communicate with a central access point. To accomplish this the team has chosen to use the ESP8266 WIFI Transceiver

This transceiver has a built-in antenna, and an eight-pin header pin connector for power and data-transfer. A problem, encountered during preliminary research, was that the team ordered a set of transceivers, which required external antennas (not included). This became an issue as it proved difficult to find external antennas which would fit the connector on the receiver, and which would be properly matched for this particular transceiver. This mistake, however, did help the team better justify the slightly higher costs associated with transceivers with built-in antennas.

The module contains the necessary Tx (transmitter) and Rx (Receiver) pins and three GPIO pins, which will connect to analog pins on the ATMega328p-pu microcontroller. To supply the module with power the unit needs two power wires and a ground wire. These are built right in to the custom PCB, which makes wiring a breeze.

One benefit of this transceiver is that it is a very common module for hobbyists, and therefore has ample amounts of available documentation, and tutorials are available to help in the development process. Helpful programming libraries are also common for the module. Because there would be hundreds of modules per garage when outfitted with the U-Park system, the code and libraries need to have reliable and tested files to ensure reliability of the system. If for instance the system had an unknown bug that caused errors to occur in the WIFI transmission, resulting in the sensors not being able to transmit any data, the entire system would effectively be useless.

While other communication systems such as Bluetooth were considered, the ESP8266 WIFI module was chosen due to its size, power, available development resources and its ability to communicate directly with the U-Park server.

C. Microcontroller

The U-Park system features an ATMega328P CPU, and an Ethernet WIFI module. The inexpensive 8 bit CPU allow the builders to connect up to three sensors, the WIFI module, and LED that will identify the different statuses (on/off, connected/not connected, etc.) that may prevail during operation. Some of the features of this microcontroller include:

- 23 Programmable I/O lines
- Operating voltage: 1.8 to 5.5V
- Temperature Range: -40 Celsius to 85 Celsius
- Speed grade: 0-4MHZ at 1.8-5.5V, 0-10 MHz at 2.7-5.5V, and 0-20 MHz at 4.5-5.5V
- Special microcontroller features: Power-on reset and programmable brown-out detection, internally calibrated oscillator, external and internal interrupt sources, and six sleep modes
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- Three flexible Timer/Counters with compare modes
- In Power-save mode, the asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping.

The 5V DC required to power both the microcontroller and the sensor is supplied an AC/DC converter, designed and built by the team. The function of the microcontroller consists in querying the three sensors connected to it, and determining if a vehicle is located in one of the three parking spots being monitored. Every thirty seconds the microcontroller will query for information. Once the microcontroller has acquired the data it will transmit it to the server through a Telnet session, using the Internet or a dedicated network.

D. Power System

The U-PARK system operates on an external power supply of 5V DC. Since using batteries is not an efficiency method for the system, the team designed AC to DC converter using transformer. In this design, the transformer step down the voltage from 120V AC to 6V AC, and the maximum current is 1A. The full-wave rectifier will convert AC to DC. The adjustable switching voltage regulator (LM2575) will regulate the output voltage to 5V. The reason the switching regulator was chosen instead of the linear regulator (LM7805) is because the linear regulators are only great for powering very low powered devices. Even though they are cheap, easy to use and very popular; the way they operate, makes them inefficient. The switching regulator is better choice because it works by taking small chunk of energy, bit by bit, from the input voltage source, and moving them to the output. This is accomplished with the help of an electrical switch and a controller, which generates the rate at which energy is transferred to the output. The energy loss due to moving chunks of energy around is relatively small, and the result is that switching regulators typically have 85% efficiency. The input capacitor (electrolytic, Cin>47uF) needs to be located as close as possible to the regulator for the purpose of stability. For operating temperature below -25 Celsius, Cin need to be larger in value. For both loop stability, and filtering of ripple voltage, an output capacitor is required. Also, the diode is placed close to the output to minimize unwanted noise. Schottky diodes have a fast switching speeds and low forward voltage drops, and thus offer the best performance, especially for switching regulators with low output voltages. Proper inductor selection is the main factor to the performance-switching power-supply design. The type of inductor chosen can have advantages and disadvantages. If high performance is a concern then the more expensive core inductors are the best choice. The inductor never should carry more than its rated current. Doing so may cause the inductor to saturate, in which case the inductance quickly drops, and the inductor looks like a low value resistor. To select the right programming resistor R1 and R2 value, use the following formula:

Vout= Vref (1 + R2/R1) where Vref= 1.23 V. Resistor R1 can be between 1KΩ and 5 KΩ (For best temperature coefficient and stability with time, use 1% metal film resistors).

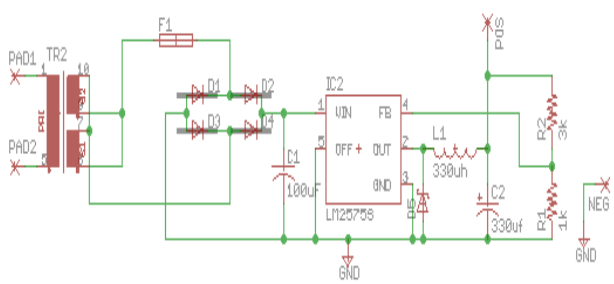

Fig.4. AC to DC schematic

E. U-Park Network

The network model that will be utilized for the U-Park sensor network will be a combination of a wireless star network and a mesh network. Each of the sensor modules will use a star network to wirelessly connect to a hub. Since the modules do not need to receive data and only need to send it, it makes sense to use this type of configuration. Each module will continuously update the data to the hub and the hub will relay the information to the surrounding hubs.

The hub network will use a mesh network topology. The hubs will pass the data received from their sensors to each other, and they will then pass that information out to the server. In order to create this network and avoid collisions, the hubs and sensors will have to be placed in a designated order. Each hub will read a distinct signal from each sensor. The signals from each sensor ring network will use the same frequencies. In order to avoid collisions, each of these star networks must be placed so that sensors using the same frequency will not overlap with each other. This will allow the signals to be broadcasted and connect to the correct hub.

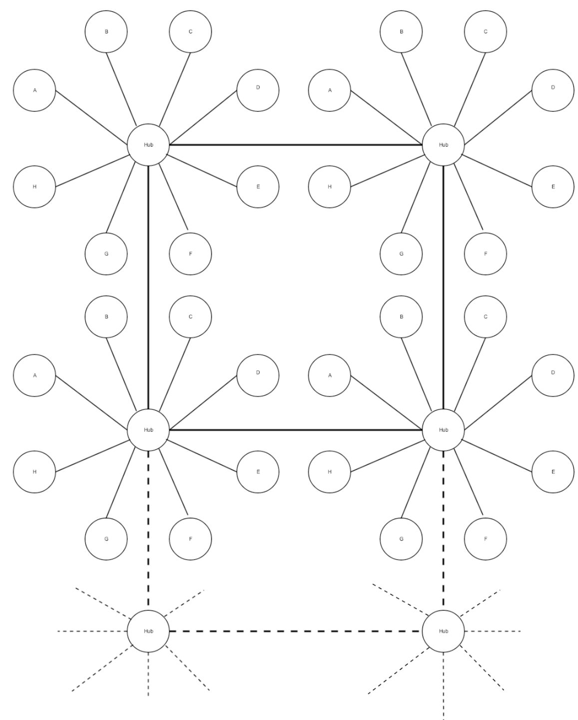

Fig. 5. The U-Park network topology. The network in the diagram above shows six nodes (routers) connected to multiple modules in a star configuration. The nodes are networked together into a mesh configuration.

Team nine believes that this is the best network to be utilized because it allows each module to only send data in one direction. The modules will use a Wi-Fi connection with the hub to send the state of each of the sensors. The hubs will be more robust FPGAs with a Wi-Fi and Ethernet connection. This will allow it to accommodate the data that is coming in and route it to the servers and other hubs via either an outside Wi-Fi network or wired network.

F. Database

After evaluating pros and cons of both MySQL and MS SQL Server, the team opted to use MySQL as the DBMS for the project. Immediately, the design phase of the database began. The project is pretty simple: To obtain the status of a parking spot at any time, record it, and make it available to three different user types: Admin, monitors (operators who routinely checks the system looking for errors), and standard users (people looking for a place to park)-.

In order to obtain parking information, team nine has designed a microcontroller capable of monitoring three parking spots at a time, and transmit the acquired data via Wi-Fi to a router; which in turn will transmit the data to a server. The problem consists in how to organize the microcontrollers' modules in a way that they can be associated to a particular client, in this case UCF, and within the client; where the parking is located. Additionally, (and for security reasons) access to data must be controlled, and a log file for transactions (for statistical purposes) is required. The resulting schema for the database is presented in the schema below.

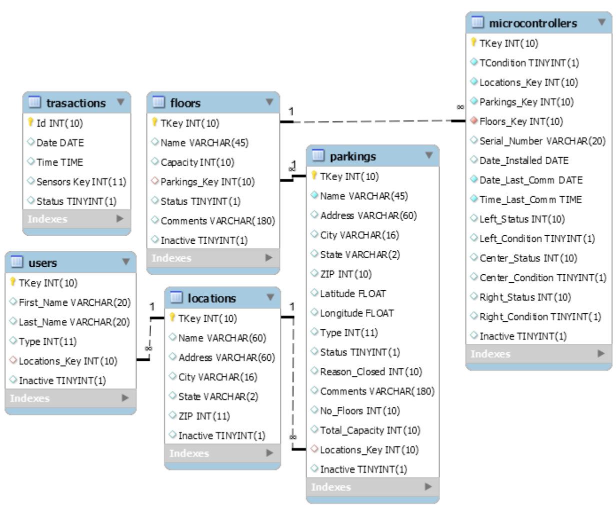

Fig.6. U-Park database's relational data model

G. Web Application

The application interface is where the user will have direct contact with the system. This is where users will be able to view the parking levels in the garages that are monitored by the U-Park sensors. The application will pull data from the database in order to display the parking levels of each garage.

When users first log in to the application, they will be prompted to select which garages they would like to "follow" using their account. They will then be able to choose from a list of garage owners, i.e. "UCF" or "Downtown Parking," and once they have chosen the owner, they will be able to select which of the owner's garages they would like to have on their "follow" list. On subsequent log-ins, the system will remember these "followed" garages and display a table with the status of each one.

The main page of each user will consist of a table with information about each garage the user has chosen to follow. This table will display the name of each garage, if the garage is open or closed, how many open spots are left, and a colored icon of how busy the garage is. This busy indicator will change color based on the amount of available spots left in the garage. It will also be red if the garage is marked as closed. This will allow users to determine at a glance how likely they are to find a parking spot.

Each row in the table with also contains two clickable icons that will take the user to the floor view page and the map view page. When the floor view icon is clicked on, the application will display the amount of parking left on each floor of the chosen garage. This will allow the user to know exactly which floor they need to go to in their chosen garage in order to find parking. The map view will pull up a Google map that will show the location of the chosen garage. An example of the usefulness of this would be if a person is new at UCF and did not know where each garage was located. If they wanted to park in Garage A because it was not busy, they could then pull up the map view to get directions to the exact location of the garage. This will be done by using Goggle's map API with the longitude and latitude of the garage supplied by the administrator. In the even the administrator does not provide this information, the user will be told that no map data exists.

The application is built using Bootstrap CSS. This is a library that allows for a large amount of portability for the website. It allows the data in the website to be sized to fit almost any size screen. This allows users to view the application on their computers, tablets, cell phones, and almost any size device that has an Internet connection. This means that a user can check the status of the garages on their computer before leaving their house, and then they will be able to check on their cell phones using the same application once they have gotten close to their destination. The web application is designed to quickly give users all the up to date information they need to make an informed parking decision.

G. Housing and Assembly

The housing for the U-Park module is an important part of the design, since the positioning of the sensor hardware has a great effect on the validity of the sensor output. The Housing contains two compartments inside. One compartment is for the supply circuitry, and the other is for all of the logic circuitry and processing. Separating the components out not only gives the team more flexibility when testing the different parts of the system, but also allows issues to be isolated quickly should they arise. One added benefit of having separate sections for the different PCBs inside of the housing is that in case there is an issue with interference between the sections, the two areas can be isolated.

The housing will have an aluminum arm extending out to the sides, which will hold the ultrasonic sensors. The arm must be long enough to ensure that the angle of the sensor looking down onto the car being detected is not too large since having a steep angle between the sensor and car could result in missed or incorrect readings.

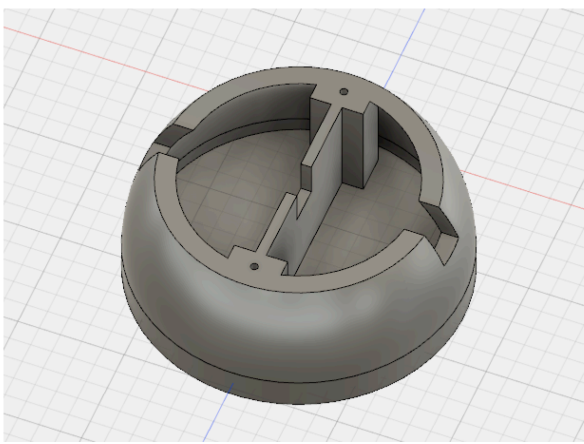

Fig.7. CAD design of the main housing unit's base

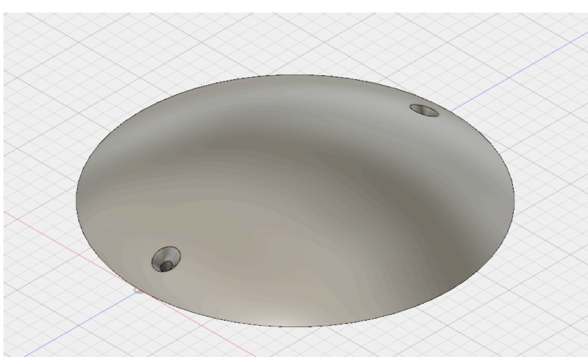

Fig.8. CAD design of the main housing unit's lid

The sensor modules will be mounted to the ceilings of the garage on all of the floors except the top floor. This way, the center sensor can detect the center spot, and the lateral sensors will detect the two adjacent spot occupancies. This keeps the sensor modules safe from being accidentally hit by a car or being tampered with, and ensures that obstructions do not come between the sensor modules and the parking spot being sensed.

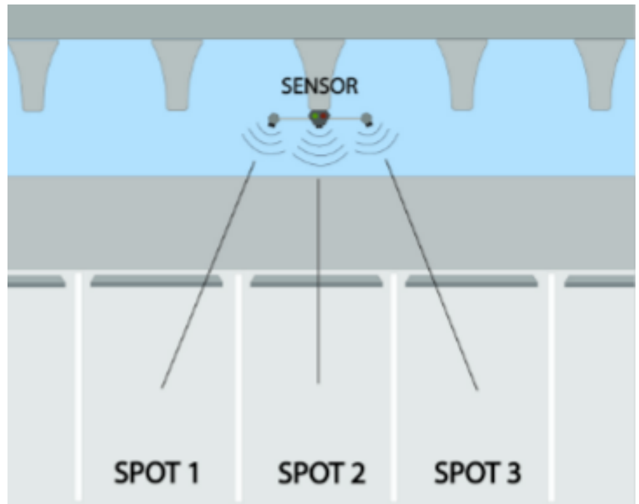

Fig.9. Layout of where the sensors will be mounted inside the main floors of the garage

Due to the top floor of a garage usually being open to the air, mounting to a ceiling above the cars is impossible. On the top floor of the garages, mounting needs to be done slightly differently. Instead of three spots, he top floor sensor modules will only detect the occupancy of two spots.

The sensor modules are placed in between two parking spots. This reduces the risk of someone pulling in a spot too far and damaging the sensor module, and also will give a more accurate reading since there will be less issues surrounding obstructions. While this solution does require the price to detect each spot slightly higher on the top floor of the garage, the benefit of lower repair and maintenance costs will offset the price difference.

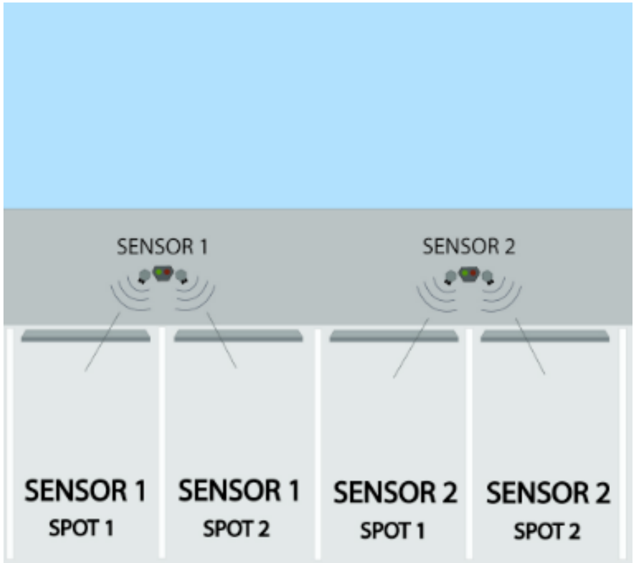

Fig.10. Layout of where the sensors will be mounted on the top floor of the garage

V. TESTING

Throughout both Senior Design I and Senior Design II, the U-Park team tested various aspects of the proposed hardware and software solutions to ensure that the most effective solution would triumph. By the beginning of senior design II, the grand majority of the initial design issues had been solved. The team was able to just focus on ordering parts and integrating all of the components instead of having to figure out slews of unforeseen issues.

It was the goal of the U-Park team to create a system that was both simple and robust due to the nature of the solution required to fix the parking situation at UCF. Much of the early testing was done to ensure all of the individual components were working as expected. The first prototypes of the system were made only a couple of weeks into the Senior Design I semester. These tests showed a valid proof of concept, and comparison between the different types of sensors, and what limitations befell each of the proposed solutions. Through this extensive preliminary testing, the U-Park team was able to discover issues with some of the Wi-Fi modules, and was able to decide on new sensor modules, which would not have the same issues.

Final testing and integration was performed during the Senior Design II semester. This testing focused on real-world deployment of the system. A full-scale version of the U-Park sensor modules was carried to parking garage on UCF's campus, and was tested for accuracy and responsiveness. The team also used the full-scale tests to verify that the angle of the ultrasonic sensors was not too steep, and that the signal was reflected back to the sensors without read errors.

During the final testing a mock-up interface was used. This GUI is similar in function to the web application, but allowed the U-Park team to test all of the sensors and Wi-Fi modules locally without having to worry about the full web interface to be completed.

Fig.11. Test user interface used to verify the accuracy of the sensors and Wi-Fi modules on the PCB

VI. CONCLUSION AND REFLECTIONS

The U-Park system is the type of system, which performs one basic function, which means there are not too many extraneous features that are not included. The system requires a basic set of functionality to work, and adding too many extra features could actually get in the way of users using the parking management interface efficiently. However, there is one aspect of the system, which is currently being overlooked due to time constraints. Currently the design team has decided to leave out the feature to be able to see how much traffic is driving through a particular garage. This information would help users not only know how many spots are available, but also if those spots are likely to be available in the near future, or if there already are a significant number of drivers in the garage that by the time the user would arrive the spots would be gone.

The U-Park system aims to be a product similar in usefulness to a fork. For instance a fork does a very helpful daily task, and no-one would want to live without a fork. But, adding too much functionality to the fork could detract from the actual usefulness and optimization for the specific task of eating. In the same way, if the design team tries to add too much functionality to the U-Park system, the added features could actually detract from the system's primary functionality of helping users to park faster and avoid driving around aimlessly.

VII. Future Improvements

There are two main improvements that the U-Park system could benefit from. The first, already mentioned in the above paragraph is the addition of sensors to detect users driving through the garage. This would likely require sensors at all of the entrances and exits of the garage that would be able to keep a rough estimate of how many cars are moving in and out of the garage. This would be extremely inaccurate, however, since the sensors would not be able to tell the difference between a person and a car and would therefore falsely estimate the number of cars driving through the garage. The fix to this problem would be to have cameras set up that using image processing software, would be able to detect the difference between cars, motorcycles and humans, which would allow it to keep a better count on the number of vehicles inside the garage.

The other improvement, which would be of use to the U-Park system, would be the inclusion of user studies. These user studies would examine the users opinions about the web application interface, and would ask users for input on what features, if any, to add the U-Park system which would help it better accomplish its goal of making the search for parking quicker and less cumbersome.

The primary reason these improvements are left to the future is due to the strict timeline required in the senior design process. If these improvements were to be accomplished in the time for senior design two, less time would be able to be spent perfecting the primary features of the U-Park system. Also, as the project develops in maturity, other important missing features may arise that could take precedent of the aforementioned ones.

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VIII. U-Park Team

Fig.12. From left to right: Carlos Pereda, Danny Russell, Them Le and Roddey Smith

The U-Park design team is made up of three CpE students (Carlos, Danny and Roddey) and one EE student (Them). This was a great balance and allowed for a great division of labor between the different group members. Them was primarily responsible for the PCB in Eagle CAD. Roddey was responsible for the hardware, and soldering and was the project manager for the U-Park team. Carlos was mainly responsible for the Microcontroller/sensors and the database, and Danny was responsible for the web interface and working with Carlos to create the database. The team constantly worked together on all aspects of the U-Park design, as each other's skill sets were required interchangeably throughout the project.