VACANT PARKING DETECTOR 2.0

Senior Design Project Proposal

ECE 445 Team #21

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1. Introduction

1.1 Objective:

Finding a parking space is a time-consuming process during rush hours. A research from USAToday states that “motorists spend an average of 17 hours a year searching for spots on streets, in lots, or in garages.” [1] INRIX Research, a renowned company specializes in transportation, combined the world's largest parking database with a survey, declaring that searching a parking space costs $345 per driver in wasted time, fuel and emissions [2]. With the development of societies, the number of personal automobiles keeps increasing. On the other hand, cities become more and more crowded and people need even more time to find a parking lot. This headache problem not only affects mood negatively since time is wasted, but also exacerbates the growing air pollution problem in big cities.

To save time and energy wasted, we plan to design and implement a parking space monitor, which detects parking spaces available, locates the available parking space for users, and helps users to find a parking space efficiently. Using an ultrasonic sensor, we can determine if there is a car in the parking space. The real-time information could be updated to the microcontroller with WLAN, which processes data and uploads them to the online database. Then users could access the real-time parking space data from an online database via the mobile APP and be fully prepared for the trip.

1.2 Background:

No matter in big cities such as Los Angeles, Chicago, or in small towns such as Champaign, the parking space monitor system is still not available. In this case, finding a parking space need some luck since drivers never know if they can find one nearby. As we stated above, our system helps to save time and energy for the parking space. Furthermore, this system is affordable but reliable. The total cost of one parking lot is around $20. We also plan to sell the system to UIUC Parking department, so we can even make some profits from the system.

1.3 High-level Requirements List:

- The detection system must be able to determine whether a vehicle presents in its monitoring space
- The communication between different parts of the system must be reliable to ensure accurate data transmission.
- The system must be able to notify incoming driver about local parking space status information.

2. Design

The detection system can be separated into five different modules: Power Module, Sensor Module, Control Module, Notification Module, and Mobile Application Module. The Power Module is responsible for keeping Control and Notification Modules running; while Sensor Module would be powered by itself using solar energy, and Mobile Application Module would acquire power from its host battery. The Sensor Module takes charge of detecting vehicle inside its duty range and transmitting the space occupancy status back to central control via WLAN. The Control Module would gather status information from individual Sensor Modules, and send the organized data out to an online server. The Notification Module is generally an online storage for local parking status information coming from the central control, and it opens an API for the mobile terminal to fetch data. The Mobile Application Module would be an iOS-based or Android-based application that can display live parking information on user's mobile device.

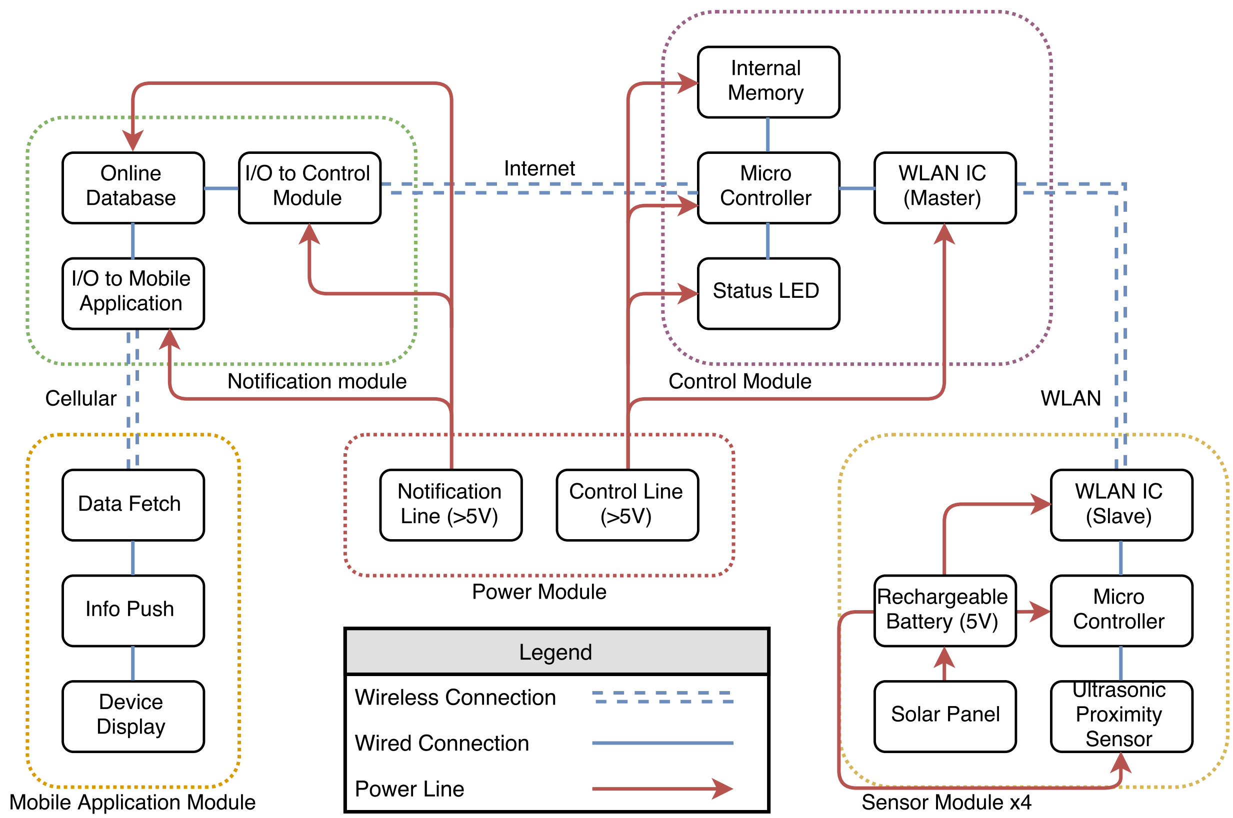

Figure 1: Design Block Diagram

2.1 Power Module:

There are two individual lines in Power Module: one is for Control Module, and the other is for Notification Module. Such separation is due to the consideration that these two modules may not be placed together in practice. We plan to use power from US standard 110V outlet, reduce the voltage to 6-9V using a transformer, and supply it to each these two lines respectively. We do not want to take the system online 24/7, because the solar-charged Li-ion battery may not be able to sustain Sensor Module operating all day long. There will be some algorithms that control shutdown and reboot of the system. The active operation hours would be selected to overlap part of the day when parking needs are high (morning to evening).

Requirement 1: Must supply >=5V and >=1A to support normal operation of each module.

Requirement 2: Must be able to control the shutdown and reboot of each module.

2.2 Sensor Module:

This module contains an ultrasonic proximity sensor, a microcontroller, a slave WLAN IC, and a pair of solar panel and Li-ion battery. The power supply of the module relies on the solar-charged Li-ion battery. Sensor Module would operate only in the day time (morning to evening). We plan to deploy 4 sets of the individual sensor module for demonstration purpose, with each of them monitoring a single parking space.

Requirement 1: Must be protected from weather, i.e. have some covers for electronics and IC.

2.2.1 Ultrasonic Proximity Sensor:

Each sensor has its emitter and receiver. When the emitted wave hits an object nearby, its reflection would be recorded. With certain reflection intensity threshold selected, the sensor would report if a car presents. Signal above threshold means the spot has a vehicle, otherwise, it is empty.

Requirement 1: Must be able to detect vehicle 0.3-0.6m away based on echo intensity.

Requirement 2: Must be mounted with angle and height to cover exactly one parking space but to recognize different vehicles from sedan to pickup truck.

2.2.2 Microcontroller:

The microcontroller is the bridge between the sensor and slave WLAN IC. It also controls the active operating hour of the Sensor module.

Requirement 1: Must be able to fetch occupancy status (1 bit) from sensor, index it with parking space info (2 bits) and pass it to slave WLAN IC with a >=5Hz refresh rate.

Requirement 2: Must be able to control the shutdown and reboot of each module.

2.2.3 Slave WLAN IC:

The IC would pair with master WLAN IC in Control Module to transmit data under standard 802.11 b/g/n protocol.

Requirement 1: Must send detection result (space index and occupancy status) to master WLAN IC with >=5Hz refresh rate.

2.2.4 Solar Panel:

The panel would absorb solar energy during daytime and charge the Li-ion battery.

Requirement 1: Must provide >=6V and >=1A output to pair solar charger.

2.2.5 Rechargeable Battery:

The Li-ion battery is responsible for powering the sensor module.

Requirement 1: Must provide >=5V and >=200mA to power the sensor module.

2.3 Control Module:

This module contains a microcontroller, status LEDs, an internal memory, and a master WLAN IC. It receives data from Sensor Module through WLAN, displays it for local verification, and sends it to Notification Module through Internet. Its power supply depends on control line in Power Module. As mentioned above, this module would not run all day long, instead, there would be some algorithms control its active operations.

Requirement 1: Must be placed within WLAN range to connect Sensor Module and near power outlets. And Must have access to the Internet, either wired or wireless.

2.3.1 Microcontroller:

The microcontroller is a bridge between the sensor and online database. It also shares data received from Sensor Module with internal memory and status LEDs for verification purpose.

Requirement 1: Must be able to identify detection data source, i.e. decode the space index.

Requirement 2: Must share data with other components with >=5Hz refresh rate.

2.3.2 Master WLAN IC:

This IC would pair with slave WLAN IC in Sensor Module to receive data under IEEE 802.11 b/g/n standards.

Requirement 1: Must receive data from different slave WLAN ICs and pass it to the onboard microcontroller with >=5Hz refresh rate.

2.3.3 Status LED:

There would be four individual LEDs representing four parking spaces under system coverage. The microcontroller would send a signal to each LED based on the index. A high signal means space is occupied and corresponding LED lights up; while a low signal means space is vacant and LED turns off.

Requirement 1: Must display occupancy status correctly and timely.

2.3.4 Internal Memory:

The memory would keep records of occupancy data for local verification purpose.

Requirement 1: Must have >=1MB capacity to store data from the past hour.

2.4 Notification Module:

This is a software module that contains an online database and two I/O to Control Module and Mobile Application. It is responsible for storing data from local detection system and sharing it with the paired application on every mobile terminal.

2.4.1 Online Database:

It receives data from the control module, stores it, and allows 24/7 access. During inactive hours, data would be stored but not updated.

Requirement 1: Must have >=10MB storage and operate reliably with a >=5Hz refresh rate.

2.4.2 I/O to Control:

It is the access port for Control Module to send detection data to the online database.

Requirement 1: Must acquire detection data from control with >=5Hz refresh rate.

2.4.3 I/O to App:

It is the access port for the mobile terminal to acquire detection data in the online database.

Requirement 1: Must provide updated data to the mobile application during active hours.

2.5 Mobile Application Module:

This is another software module that contains algorithms for data fetch and notification push. It would acquire data from the online database, decrypts the information, and displays the parking status in graphic style. The application may be based on iOS or Android platform.

Requirement 1: The mobile device must be self-powered and must have access to the Internet.

2.5.1 Data Fetch:

It would be an algorithm to communicate with the online database in Notification Module and to fetch parking status data back to the mobile terminal.

Requirement 1: Must have allocated on device memory to store data for decryption.

Requirement 2: Must acquire data precisely and timely during active hours.

2.5.2 Info Push:

It would be another algorithm to decrypt and organize fetched data, and to prepare the data ready for display.

Requirement 1: Must be able to process data in time with >=5Hz refresh rate.

Requirement 2: Must transform data into graphics that are easily comprehensible to the user, i.e. draw rectangles as parking spaces and color them with green as available and red as occupied.

2.5.3 Device Display:

This part is provided to us but has variations in scale and resolution.

Requirement 1: The application must be able to scale to fit different display parameters.

2.6 Risk Analysis:

The WLAN communication system between Sensor Module and Control Module would be the riskiest component in our design. None of us has a solid background in wireless communication, and we would have to work with prefabricated WLAN IC. We plan to use ESP8266 Wi-Fi Module in both ends, hence we need to configure it to support master/slave model. Given configuration successful, we still need to test its maximum connection range, and modify its antenna if necessary. The actual data transmission would be challenging in practice. The microcontroller in Sensor Module needs to send data and transmission command to slave WLAN IC; similarly, in Control Module, its microcontroller needs to work with master WLAN IC to receive data. Correct I/O between the microcontroller and WLAN IC also plays a crucial role successful wireless data transmission.

3. Ethics and Safety

3.1 Ethics:

When users use our vacant parking detector system, certain ethical issues could arise. Because of the limited number of parking slots, more than one drivers may look for places to park. At this point, the information about which slot is empty is very important for a driver to quickly occupy the place. According to IEEE Code of Ethics, #2: "To circumvent conflicts of interest among people related to the engineering design and tell them the whole story related to them when the conflicts exist," [3] our users should be able to get the updated information at the same time in order to realize the limitation of parking slots and to take appropriate actions regarding the situation. In our implementation, we use communication network devices that provide real-time data transmission to display the parking slots occupancy information to our users. Therefore, they can easily take the control of the situation and make more informed decisions.

To comply with IEEE Code of Ethics, #8: "To treat everyone in the same way regardless of their gender, sexual orientation, religion, disability, age, nationality, or other identity," [3] and avoid any discrimination in parking lot, it's important to design and create a fair environment for parking. Because of the choices of our hardware devices, there is no way to get information about our drivers' personal information such as gender and nationality. This makes the discrimination of any kind impossible.

By developing the vacant parking detector system, we believe this design of the system would benefit all the drivers by improving the efficiency of looking for a parking slot and letting them make more informed choices regarding the correct places to park. This is also a step following IEEE Code of Ethics, #1: “To regard public safety and wellbeing as the most important thing, to keep developing ethical practices, and to show all the possible hazards behind the implementation.” [3]

3.2 Safety:

Besides ethical issues, there are also some issues related to safety as we work on our project. Since most of the parts of our system are done via a communication network and phone devices, the safety of energy source, especially the devices providing solar power, becomes a paramount concern. In order to avoid any electrical shock, it’s crucial to understand the voltage of each solar panel that we are going to use. In reality, although a PV table's integrated power output is huge, the output voltage of each small panel is only 3 volts. [4] In our design, we choose small solar panels that provide a voltage of fewer than or equal to 5 volts to avoid any possible electrical shock.

Reference

[1] usatoday.com, "Drivers spend an average of 17 hours a year searching for parking spots", 2017. [Online]. Available: https://www.usatoday.com/story/money/2017/07/12/parking-pain-causes-financial-and-personal-strain/467637001/. [Accessed: 08-Feb-2018].

[2] inrix.com, "Searching for Parking Costs Americans $73 Billion a Year", 2017. [Online]. Available: http://inrix.com/press-releases/parking-pain-us/. [Accessed: 08-Feb-2018].

[3] ieee.org, "IEEE Code of Ethics", 2016. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 08-Feb-2018].

[4] James R. White and Mike Doherty, "Hazards in the Installation and Maintenance of Solar Panels", IEEE IAS Electrical Safety Workshop (ESW), Jan 2017.