Enhanced Parking Space Monitoring System

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Abstract

This paper delves into a potential solution for the problem of easily finding a spot in a parking garage. Specifically, it elaborates on how a series of cameras, a neural network, and a website can accomplish this in an efficient and cost effective manner. We compare this solution with the previous method of placing an IR sensor at the end of every parking spot. Both solutions include the use of an LED at every spot for quick identification, but the new solution removes the need for a large number of sensors. The addition of a website conveniently allows users to make travel and parking decisions before they ever arrive at the parking garage.

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1. Introduction

There are many times when it can be difficult for people to find parking, especially in cities or parking garages. It can be extremely frustrating to circle a parking garage multiple times without finding a spot for several minutes. Extra time spent searching for a spot creates unnecessary traffic and wastes fuel. In addition, drivers searching for open parking spaces often are not paying full attention to the road ahead of them. This creates a hazardous environment for both drivers and nearby pedestrians. Due to this, a product that aids drivers in locating a parking spot would be beneficial.

1.1 Background

According to INRIX, a parking and driving data analytics company, Americans spend an average of 17 hours per year searching for parking. This extra time costs about $345 per driver in wasted time and fuel. INRIX also found that 40% of drivers report avoiding going to shops due to the hassle of finding parking [5]. Burdensome parking experiences not only annoy drivers but also hurt the economy and local businesses as a whole. As well as being economically disruptive, poorly operated parking lots can also be dangerous. The National Safety Council reports that there are more than 50,000 car accidents per year in parking lots and garages. These accidents result in an average of 60,000 injuries and 500 deaths every year. With our design drivers will be able to be less distracted while getting to a parking spot.

1.2 Solution

Our solution is to monitor the parking spaces within a parking garage with a camera, and provide an easy to use web interface that would show where available parking spots are located. This way, a person could easily go to the website, find where a parking spot is located, and immediately go there, cutting the search time down drastically. In addition, colored LEDs will indicate the status of a spot to nearby drivers to further reduce their need to search for open spots. Mounting the device on the ceiling of the parking garage as seen in *Figure 1* allows for a better angle of sight and provides a degree of protection from vandalism or theft.

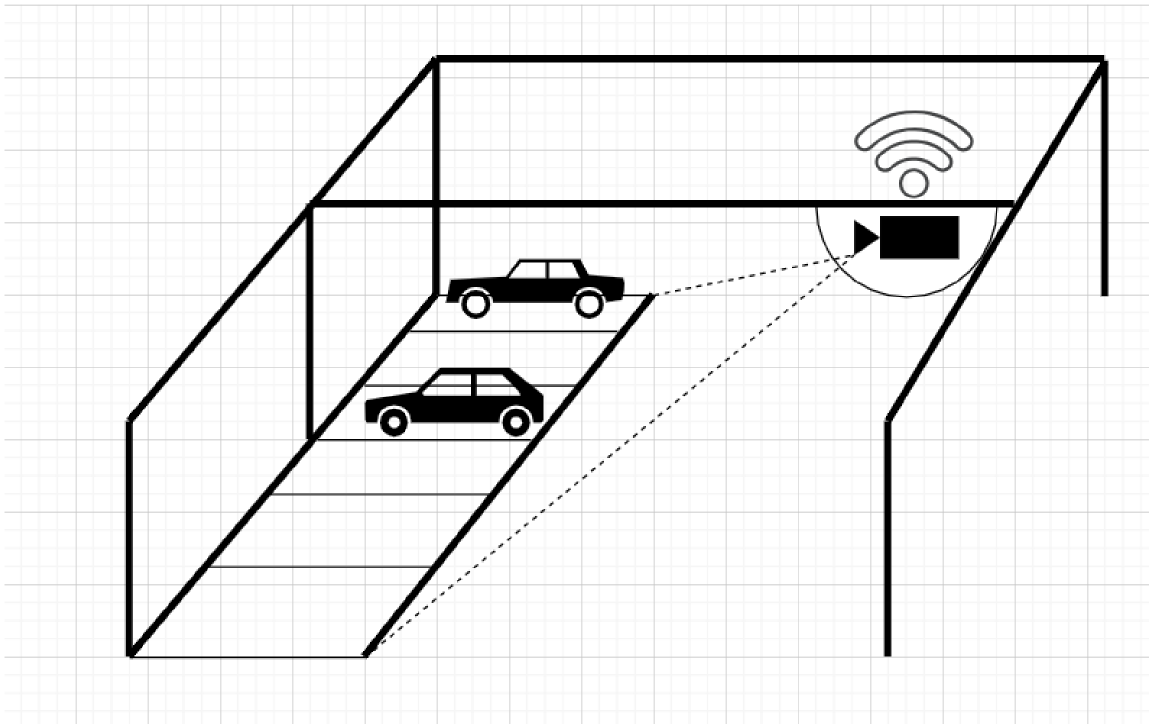

Fig. 1. Enhanced Parking Space Monitoring System Visual Aid

1.3 Design Differences

Currently implemented solutions to this problem do not provide the same level of accuracy or convenience as our design. Occasionally one can find signs outside of a parking garage that indicates the number of available parking spaces. These counters are prone to inaccuracy when a garage is busy and cars are tightly packed [7]. Newer parking garages will display colored LEDs above each spot to show availability, but lack the accuracy and online display of our design.

When compared to the previous group's project in *Fig. 3*, our solution differs in several key areas. Instead of using an IR sensor, our design utilizes a camera and video processing software to detect the presence of a vehicle. This allows for greater scalability in design because one camera can cover detection for several parking spaces. Additionally, the previous design used 2 colored LEDs to display the status of an individual parking space. Our design, however, only uses one green LED per space to reduce energy waste and production costs. In a parking garage our design is more practical due to the large number of parking spaces that need to be analyzed.

The previous solution required the bumper of the vehicle to be unrealistically close to the sensor in order to be counted. As seen in *Fig. 2*, The previous solution's sensor module is only accurate at a range less than 80cm. Due to the positioning of our new solution, the system can detect a vehicle as long as it is within the bounds of the parking space. Our design would allow for more accurate detection and more variation in vehicle sizes. The previous design could also send a false positive in the case of a pedestrian standing in front of the IR sensor. The video processing approach of our design would eliminate such errors.

In addition, we would provide a web interface so that a person could view the availability of various spots. This would function as a website where one could view available spots on a map, and easily see where the nearest available spot is. The previous solution offered an LCD display at the entrance of the parking structure. We feel that our web-based design is both more convenient and more practical. While the LCD display presents the same data as our website, our website is available from anywhere with internet connection. This is more convenient if a driver wishes to check availability before arriving or from inside the garage.

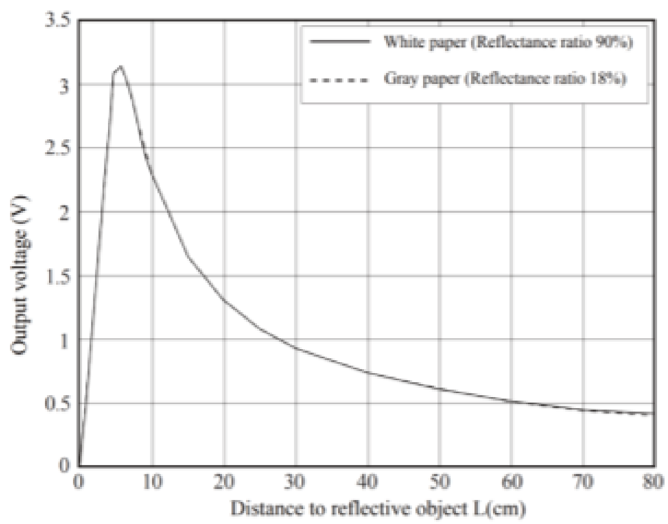

Fig. 2. Fall 2017 IR Sensor Output Voltage

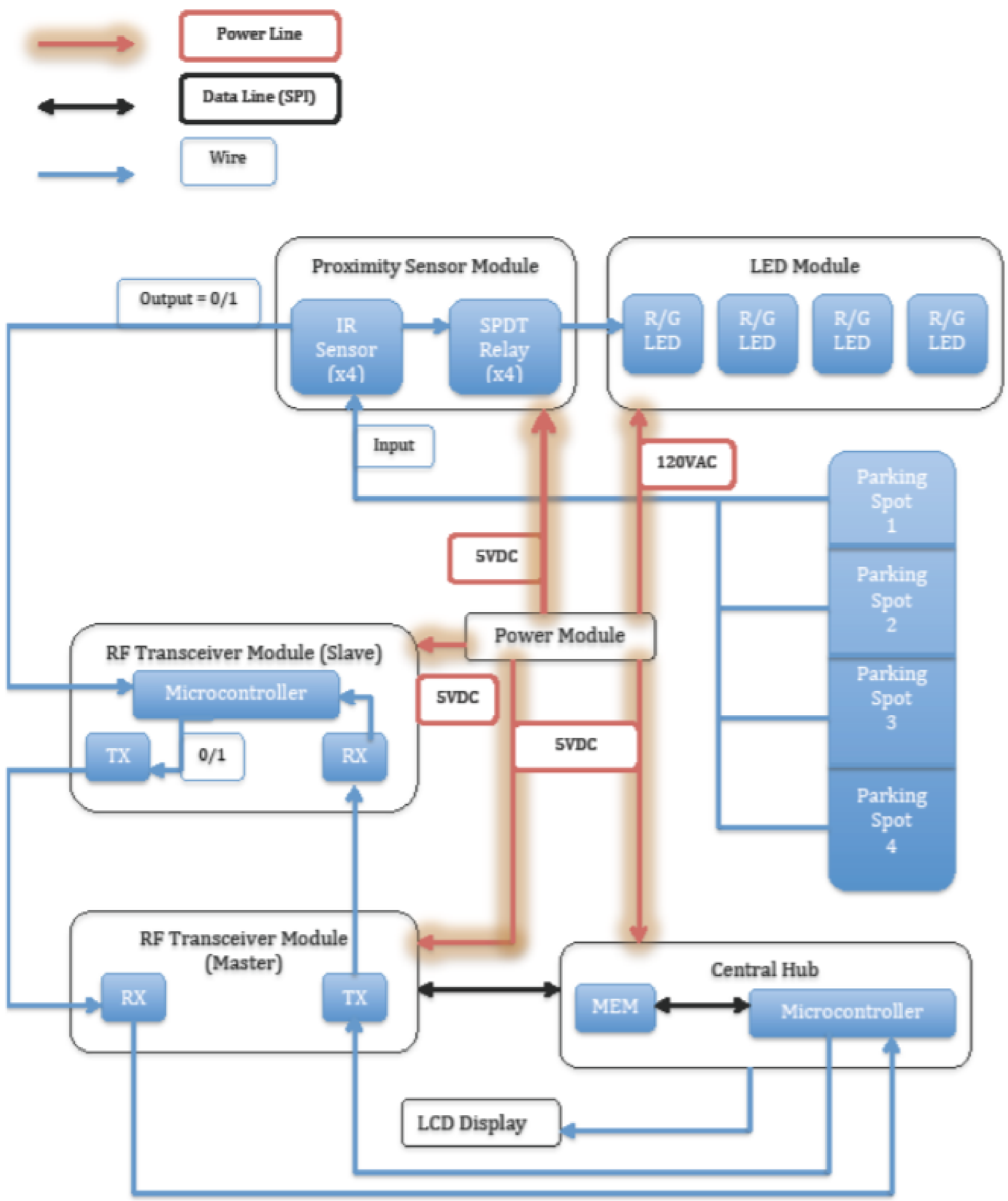

Fig. 3. Fall 2017 Parking Space Monitoring System Block Diagram

1.4 High Level Requirements

The following are the most important qualities our project must exhibit in order to be successful:

- Be able to differentiate a vehicle from other objects.
- Detect the presence of a vehicle in a parking space with 90% accuracy.
- Notify users of available parking spots through LEDs near the spots and a website containing an up-to-date map.

1.5 Block Diagram

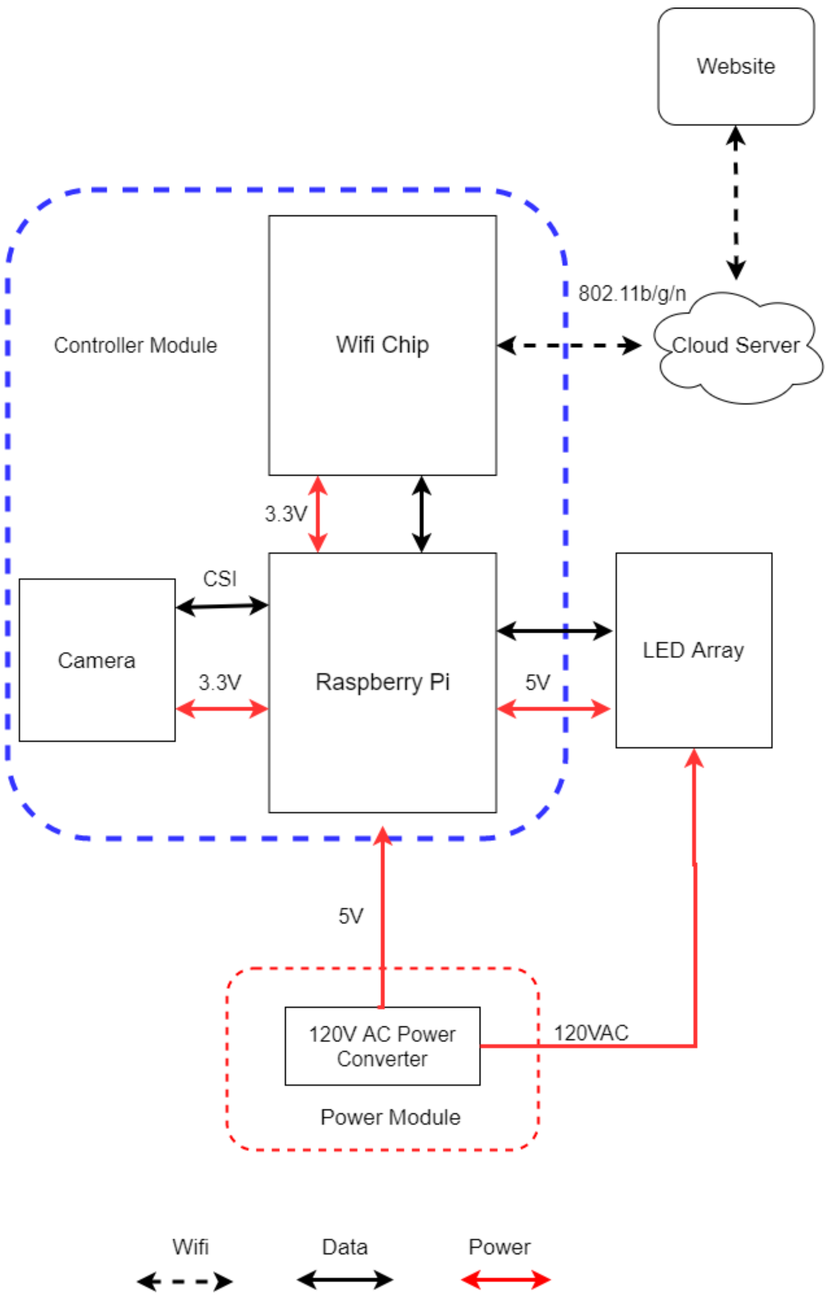

Fig. 4. Enhanced Parking Space Monitoring System Block Diagram

2. Implementation Details and Analysis

2.1 Physical Design

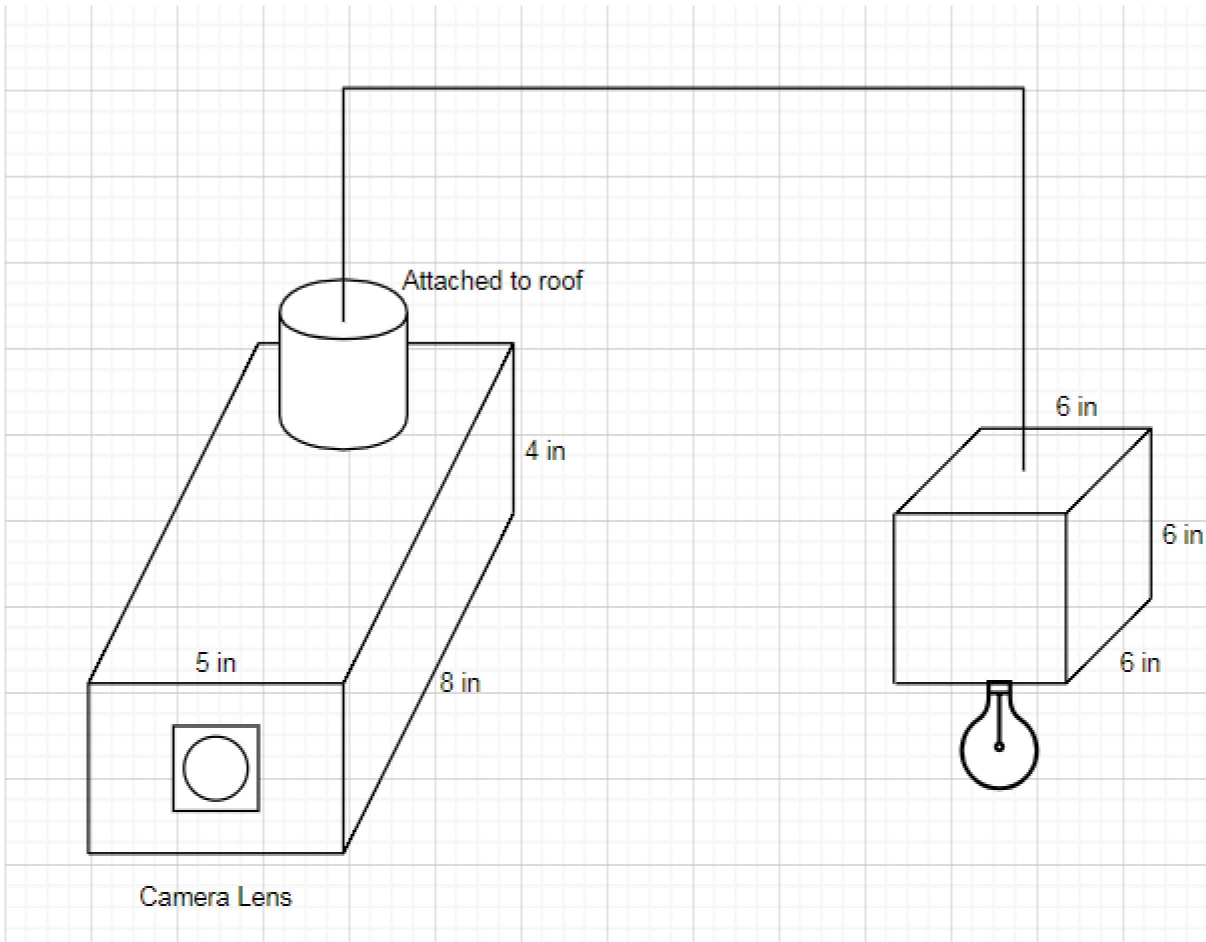

Fig. 5. Enhanced Parking Space Monitoring System Physical Design. Measurements are in inches

2.2 Subsystems

2.2.1 Camera

The Camera contributes primarily to the second high level requirement since it is responsible for generating the images that allow software detection of vehicles to occur. We will use the Raspberry Pi Camera Module V2-8, which connects directly to the CSI port on the Raspberry Pi. It is 8-megapixels and capable of 1080p video and still images. It has a vertical view angle of 48.8° and a horizontal angle of 62.2°. The Camera will be responsible for sensing a parking area and sending a stream of image data to the Raspberry Pi every second. In order for the system to function properly, all parking spots will be visible by at least one camera.

2.2.2 Raspberry Pi

The Raspberry Pi contributes to the first and second high level requirements. It will be implemented with a Raspberry Pi 4 Model B 4GB. Not only is it responsible for deciding what is and is not a vehicle in an image, it must detect whether or not that vehicle is in a parking spot and report the status of every spot it is responsible for to the Wifi Chip. The data pins on the Raspberry Pi output at 3.3V, which is the necessary input for the Wifi Chip, so they can be directly connected. The Raspberry Pi will receive a constant stream of data from the camera module. It will analyze the images it receives using a pre-trained neural network, identifying all vehicles in the image and deciding whether or not they fall within the bounds of a parking spot. It has a bare-board current draw of 500mA and a recommended PSU current capacity of 1.2A. It's operable voltage ranges are 4.75-5.25V.

For image processing, we will be forking a github project [8]. This project currently allows a user to specify the number of parking spots viewable by a camera feed. It then subtracts the number of cars from the number of spots to get the available parking space number. Our fork would allow a user to specify what area of the image is used for each spot only count a spot as 'in use' if the car overlaps the defined parking space. The goal is to correctly decide whether or not a car is in each of its parking spots 90% of the time and process at least one frame every second at least 99% of the time. It will transfer the status of the parking spots to the Wifi Chip exactly once every 10 seconds +/- 0.01 seconds.

2.2.3 LED Array

The LED Array contributes to the third high level requirement, as it makes identifying open spots when at the parking area much easier. Every parking spot will have a green LED light bulb. Each LED will connect to its local demultiplexer, which is connected to Raspberry Pi to determine if the LED is active for that spot. When the LED is on, it will signify the spot as being available.

2.2.4 Wifi Chip

We will use the ESP8266 ESP-12E NodeMCU development module to handle all input processing and communication with the server. This will take data input from the Raspberry Pi and communicate the parking spot occupancy to the server. This module requires 3.3V to function, but there is an onboard regulator that tolerates up to 10V. Thus, we can safely use the 5V output from the Power Module. While transmitting, the ESP8266 WiFi chip uses between 120mA and 170mA, depending on transmission power. Receiving will use between 50mA and 56mA. Thus, there is relatively minimal power draw compared to the other components. It will be required to communicate with the Cloud Server over IEEE 802.11b/g/n at >1 Kbps.

2.2.5 Power Module

The Power Module contributes to all three high level components because it is responsible for powering the hardware components by converting 120V AC to a form usable by the Camera, Raspberry Pi, and Wifi Chip. Specifically, it is required to accept 120V (+/- 30V) AC from a wall socket and output 5V (+/- 0.25V) AC.

2.2.6 Cloud Server

The Cloud Server contributes to the third high level requirement. It collects and sorts data gathered by the hardware devices. The Cloud Server will accumulate the processed image data from the Raspberry Pi, transferred through the Wifi Chip. From there, it will update the website with up-to-date information on where available parking spaces are located.

2.2.7 Website

The Website contributes to the third high level requirement. It takes parking space data from the Cloud Server and displays it in a readable map format to consumers. The Website will host a map showing the latest information on which parking spaces are available. It will receive this data from the Cloud Server.

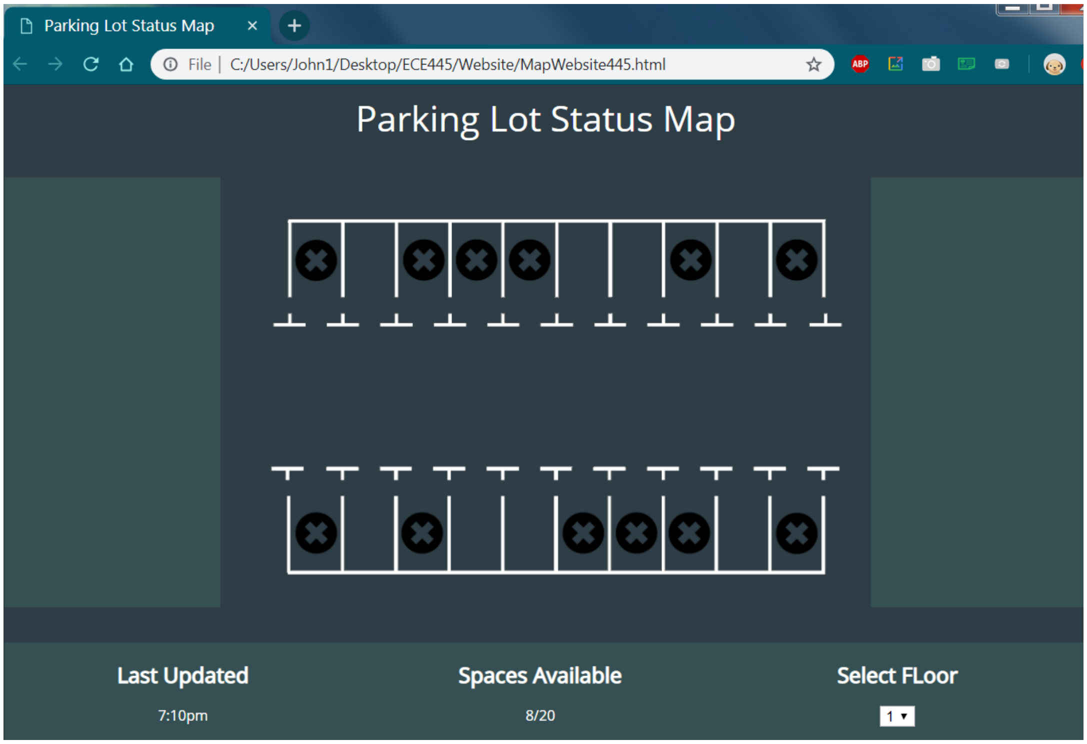

Fig. 6. Enhanced Parking Space Monitoring System Website Prototype

```
<html>
<head>
    <title>Parking Lot Status Map</title>
    <link rel="stylesheet" type="text/css" href="css/style.css" />

</head>

<body>
    <center>
    <header>Parking Lot Status Map</header>
    <p>
        <img src="images/Diagram.png">
    </p>
    <div class="sidebar_container">

    <div class="sidebar">
          <div class="sidebar_item">
            <h2>Last Updated</h2>
            <p>7:10pm</p>
          </div><!--close sidebar_item-->
        </div><!--close sidebar-->
    <div class="sidebar">
          <div class="sidebar_item">
            <h2>Spaces Available</h2>
            <p>8/20</p>
          </div><!--close sidebar_item-->
        </div><!--close sidebar-->
        <div class="sidebar">
          <div class="sidebar_item">
            <h2>Select FLoor</h2>
            <p>
                <form>
                    <select name = "dropdown">
                        <option value = "1" selected>1</option>
                        <option value = "2">2</option>
                        <option value = "3">3</option>
                    </select>
                </form>
            </p>
          </div><!--close sidebar_item-->
        </div><!--close sidebar-->
    </div>
</body>
</html>
```

Fig. 7. Enhanced Parking Space Monitoring System Website html

2.2.8 Circuit Schematic

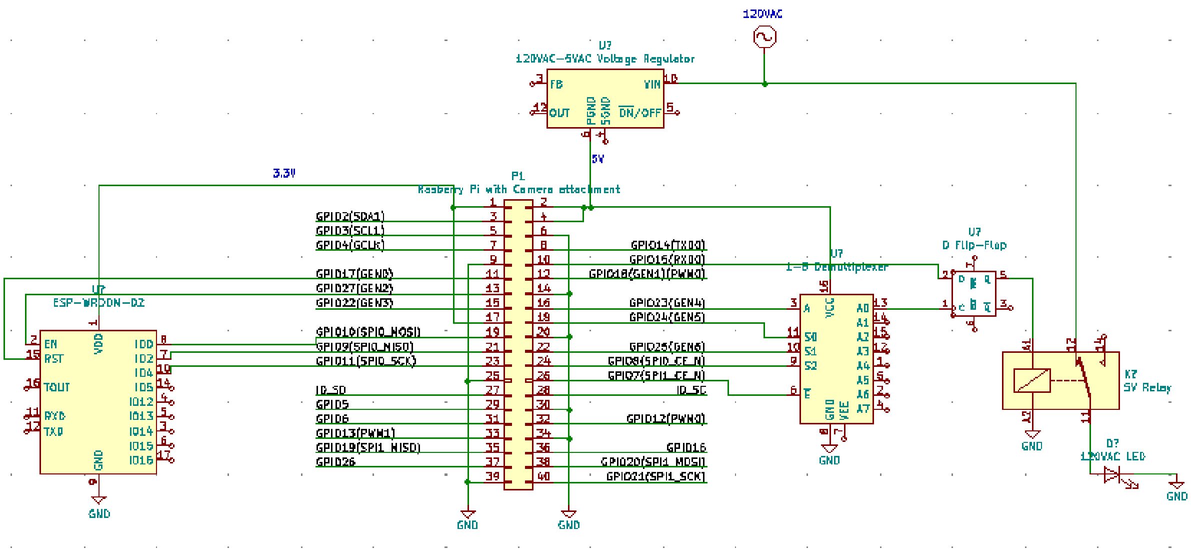

Fig. 8. Enhanced Parking Space Monitoring System Circuit Schematic

2.3 Tolerance Analysis

2.3.2 Component Tolerances

Modeling the Camera View-space:
Parking garage regulations can differ between cities, but we can do the following case-study calculations based on the rules found for Temecula, CA [16]. We are given that for a parking garage, one floor is 60 ft wide and 11 ft tall [17]. The parking spaces are 18 ft long and 10 ft wide. Our camera has a 48.8° vertical view angle and will be placed against the opposite wall (see *Fig. 9*). We assume average car dimensions of 16 x 6 x 6 feet (about the size of a large crossover vehicle).

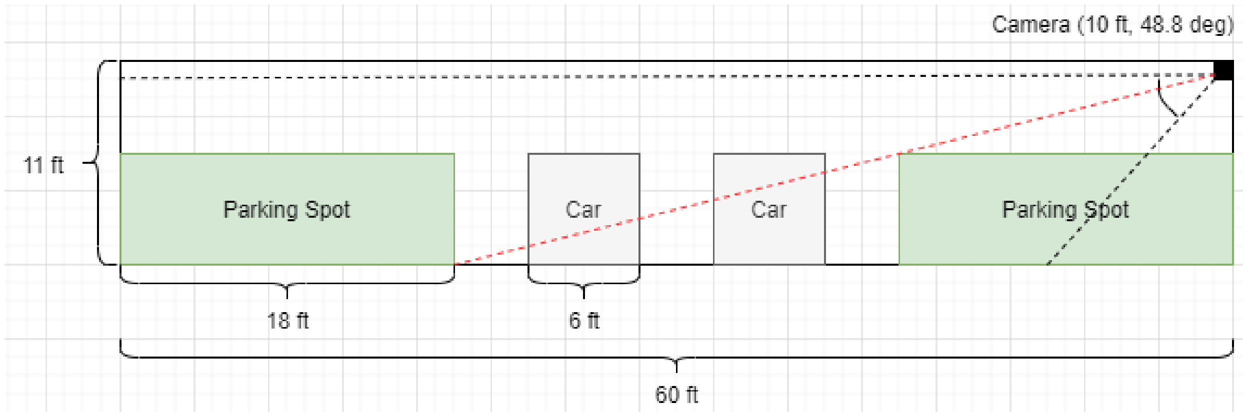

Fig. 9. Side View of Camera in Parking Garage (scale 1 ft²/cell)

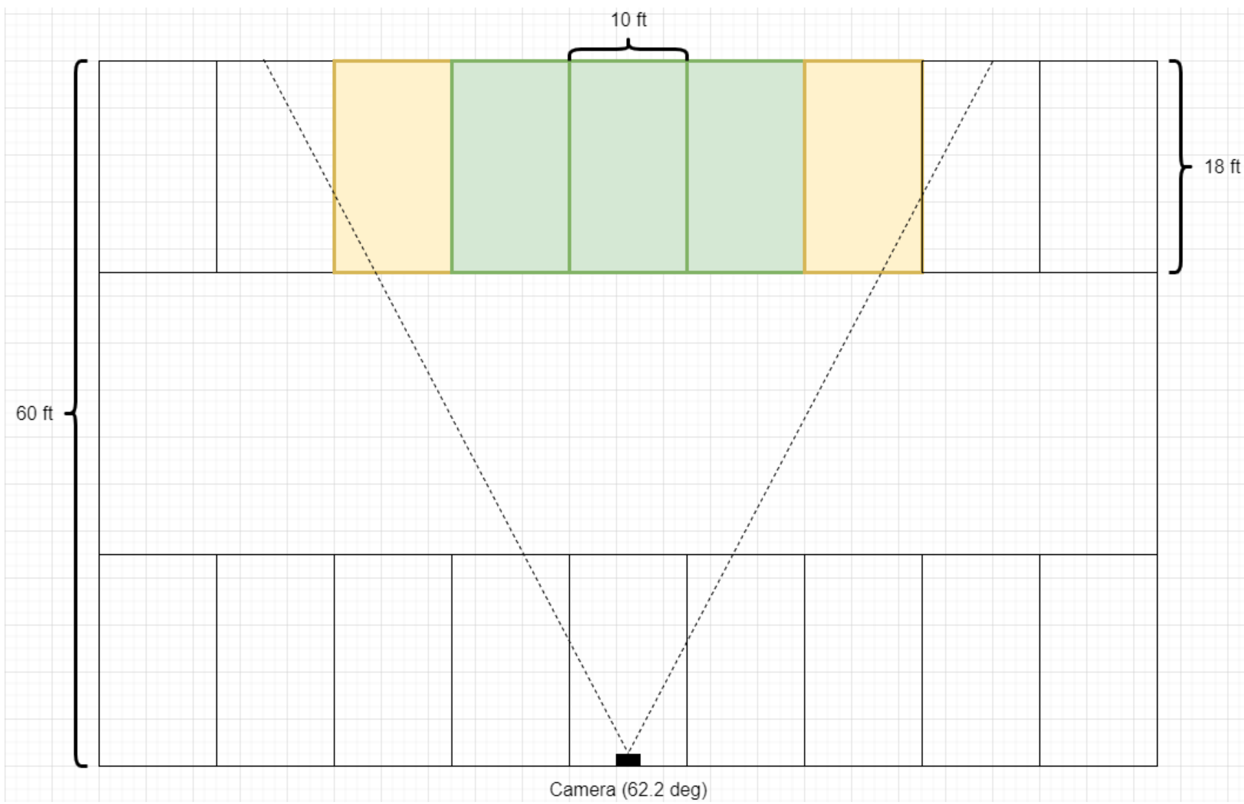

Fig. 10. Top View of Camera in Parking Garage (scale 1 ft²/cell)

Based on the layout in *Fig. 9*, the opposite parking spots and center lanes fall directly within the camera's field of view. Unfortunately, capturing the entire parking space is not possible when a car drives through the center lanes, as shown by the red lines. We counter this by averaging the camera's analysis over the course of 10 seconds. If we assume a car moves an average of 5 mph (about 7 ft/s) in a parking garage, a spot will be obscured for about 3 seconds. Thus, it is unlikely a spot will be mislabeled (which requires a car to be present in a spot for 5 seconds or more).

In *Fig. 9*, we show a top-down view to count the maximum number of cars in view of the camera at one time. We see that the camera fits the entirety of the center 3 spots within view, as well as the vast majority of the outer 2 spots. If we assume the final software is robust enough to identify the outer 2 spots, there will be a total of 5 spots in the camera's view (or 4 if shifted non-optimally to either side).

2.4 Cost Analysis

We estimated the cost of our development assuming a 10 hour per week of a 16 week schedule. Considering the average starting salary of a BE in ECE, we calculated our hourly wage to be $45 per hour [4].

$$\frac{\$45}{hr} \cdot \frac{10hr}{wk} \cdot 16wk \cdot 3 \cdot 2.5 = \$54,000$$

Description	Part Number	Manufacturer	Module	Price
Raspberry Pi 4 Model B (4GB)	B07TC2BK1X	Raspberry Pi	Control	$61.70
Raspberry Pi Camera Module V2-8	B01ER2SKFS	Raspberry Pi	Control	$27.50
Wifi Chip	ESP8266 ESP-12E NodeMCU	MakerFocus	Control	$9.39
Green LED x4	A19 Christmas Led Light Bulbs	NOVELUX	LED Array	$25.94
Voltage Regulator	296-20778-2-ND	Texas Instruments	Power	$2.39
E26 Light Bulb Socket x4	99770033	BROAN	LED Array	$23.60

Total Part Cost: $155.48

Total Development Cost: $54,155.48

3. Conclusions

3.1 Implementation Summary

For the second project, we were able to design a viable solution for monitoring parking garage space availability. Specifically, we made progress on analyzing what changes would need to be made to publicly available neural networks (Patrick), and we created an early build of the public-facing parking garage website (Benjamin and John). As such, the primary advancements thus far were in designing the necessary software for our project.

3.2 Unknowns and Testing Needs

Regarding the project components we were unable to work on, we were not able to make progress with the hardware components for the project. Specifically, we lack the funding and opportunity for obtaining the Camera, LED, Raspberry PI, and other circuit components, as well as the lab facilities needed to integrate and test them properly. To complete the parts of the project relating to these components, we would need safe access to a lab facility as well as a way to obtain university funded parts in a reasonable time frame. Once this was accomplished, we could load a feature complete version of the neural network onto the Raspberry Pi, as well as connect the Camera and Wifi Chip to the Raspberry Pi. Finally, we could perform end-to-end testing with the Raspberry Pi software and the Website.

3.3 Ethics and Safety

As the developers of this project, we believe it is important that we produce a safe, reliable, and efficient product to our user. We commit ourselves to holding a high degree of professional conduct in accordance with both the IEEE and ACM Code of Ethics. We will avoid ethical breaches by following all device specifications, working in our respective areas of competence, and clearly stating proper operating procedure (ACM 2.6). At the same time, we acknowledge that our device could be misused; therefore, we will take all necessary precautions to prevent any harmful modes of operation.

In accordance with the ACM Code of Ethics, this project will pose no risk to the user or community under standard operations. We will ensure that all wireless protocols are followed, and communications will be secure. The data gathered by our sensor will be the sole property of the intended user of the device (ACM 2.9). All software will follow accepted community standards.

Our module will have a camera attachment. Since a parking lot or parking garage is a public place where one does not have a reasonable expectation of privacy, cameras are allowed to record without any posted signage by law [3]. It may be nice, however, for consumers of the parking lot or garage to have a notice that cameras are active posted via sign.

It is both illegal and unsafe to use one's phone while driving [4]. As such, on the sign that gives the URL to the parking map website, we will post notices to either pull off to the side and stop while accessing the website or have a passenger navigate the website.

In addition, we will ensure there is no exposed wiring or electrical components in our design to minimize the risk of electrical shock, especially due to the fact that our project uses 120V from a wall outlet. Similarly we will ensure all components are operating within their respective operating regions to reduce the risk of a short or fire hazard. We will also be mounting the hardware components with screws, mitigating any risk of the hardware falling and causing damage to vehicles or people in the area.

3.4 Project Improvements

There are several improvements that could be made in the future. The first is that we limited our scope to parking garages so that all the hardware, such as LEDs, could be directly wired to the microcontroller. A future improvement would be to make this wireless, which would give more flexibility in camera placement and use cases. A second improvement would be to include a monitor that could be placed near the entrance of the parking garage or lot. This monitor would cycle through the various spot maps on the website to provide the user with a very easy way to see where parking is when they first enter without needing to access the internet on their personal device. This would increase safety due to less phone usage. Finally, we could figure out a way to have spots be reserved by a consumer in a way that they cannot be taken by a person that did not reserve the spot.

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