

University of Central Florida

Department of Electrical & Computer
Engineering

EEL 4914
Senior Design I

Divide & Conquer Parking Garage Management System Group 11

Author:

Chris Najem, CPE
Mark Rehn, EE
Tony Mai, CPE

Mentor:

Dr. Lei Wei

Reviewers:

Dr. Suboh Suboh	ECE	Associate Professor
Dr. Saleem Sahawneh	ECE	Associate Professor
Dr. Sun Wei	ECE	Associate Professor
Dr. Mark Maddox	ECE	Associate Professor



Chapter 2 - Project Description

2.1 Project Background and Motivation

Parking. It sounds like a simple task. Just pull in, find a spot and go on with your day. But in places like urban areas, college campuses, shopping and entertainment centers, finding a parking spot is anything but simple. You keep driving in circles scanning rows of cars while feeling your frustration rise with every pass. Parking has long been a challenging aspect of urban life. The process of searching for an empty parking spot often leads to frustration, wasted time and unnecessary fuel consumption.

With urbanization, traditional parking solutions have been proven inadequate in addressing these challenges. According to a study done by INRIX, a transportation analytics company, searching for parking costs the United States economy \$73 billion per year. On average American drivers spend 17 hours per year searching for a parking spot resulting in a \$350 cost per driver in wasted time, fuel, and emissions. These numbers only get larger in big cities, for instance in NYC drivers spend on average 107 hours per year searching for parking, costing \$2,243 per driver. Los Angeles trails NYC with 85 hours and \$1785 respectively.

The impact of not being able to find a parking spot isn't limited to financial consequences. Almost two-thirds of Americans reported that they feel stressed trying to find a parking spot, with 23 percent experiencing road rage after abandoning the trip due difficulty finding parking. According to Bob Pishue, senior economist at INRIX, "The search for parking, overpayments and fines is a \$96 billion problem in the U.S. To lessen the burden parking pain has on our economy and quality of life, drivers, parking operators and cities must adopt smart parking solutions."

Enter the Parking Garage Management System. It takes this everyday headache and turns it into an effortless experience. Imagine pulling into the parking garage and immediately knowing where to go to find an available spot. No guessing or moving around in circles scanning every row, just a straightforward path towards your destination. A smart parking system would provide real-time availability and directions for parking spots which can help alleviate the issue of driving in unnecessary circles trying to find parking. It's a small change with an enormous impact—not just on your day but on the environment and the flow of the city itself.

2.2 Goals and Objectives/Design Requirements

The Parking Garage Management System is designed to enhance efficiency, security, and user experience in parking facilities. Below is an outline of the goals and objectives:

Basic Goals (Must-Haves):

1. **Real-Time Monitoring:**
 - Ultrasonic sensors detect parking spot availability and update LED indicators (green for available, red for occupied).
2. **Navigation Assistance:**
 - Digital signage at the entrance displays available spaces, and a website/mobile app provides real-time updates.
3. **Security Enhancements:**
 - License plate recognition (LPR) cameras verify permits and generate alerts for unauthorized or overstaying vehicles.

4. **Automated Payments:**

- Users can purchase permits via a mobile app or website, with real-time database updates.

5. **Admin Dashboard:**

- Provides tools for monitoring occupancy, managing permits, and addressing alerts.

Advanced Goals (Desirable Features):

1. **Energy Efficiency:**

- Use solar panels and a battery management system for sustainable power.

2. **User Notifications:**

- SMS or app notifications for permit status and alerts.

3. **Data Analytics:**

- Track vehicle patterns for optimizing operations.

Stretch Goals:

1. **Dynamic Pricing:**

- Adjust prices based on demand.

2. **Advanced Security:**

- Include vehicle attribute recognition and law enforcement integration.

3. **Outdoor Parking Support:**

- Expand to outdoor lots with weather-resistant sensors

2.3 Description of Features/Functionalities

The Parking Garage Management System is designed to streamline the parking experience by integrating advanced hardware and software technologies. The system focuses on improving efficiency, security, and user convenience through the following features:

2.3.1. Real-Time Parking Availability

The system employs ultrasonic sensors installed in each parking spot to detect occupancy. These sensors provide real-time data to a central server, which updates the availability status on digital signage and the mobile application. LED indicators are installed at each parking spot, displaying:

- Green: Spot is available.
- Red: Spot is occupied.

This functionality minimizes the time users spend searching for parking spaces, improving overall user satisfaction and reducing traffic congestion in the parking garage.

2.3.2. Guided Parking Navigation

The system provides users with real-time navigation assistance through digital signage and an integrated website or mobile app. This feature is designed to optimize user experience and reduce the time spent searching for available parking. Key functionalities include:

- Digital Signage at Garage Entrance:
 - A large digital panel at the entrance displays the number of available spaces on each floor of the garage.
 - The panel updates in real time based on sensor data, ensuring accurate and up-to-date information for drivers.
- Website or Mobile Application:
 - A user-friendly platform (web or mobile app) shows the general number of available spaces across all garages connected to the system.

- Real-time updates ensure users can plan their parking before arriving at the location.

This dual-layered navigation system ensures that users can make informed parking decisions even before entering the garage, improving convenience and efficiency.

2.3.3. Security Monitoring

The system leverages license plate recognition (LPR) technology to enhance security by monitoring vehicle activity and permit compliance at the entrance and exit of the parking garage.

Key functionalities include:

- License Plate Recognition Cameras:
 - Cameras installed at the entrance and exit capture and identify vehicle license plates in real time.
 - The system cross-references the license plate with a parking permit database to verify authorization.
- Alerts for Unauthorized Vehicles:
 - If a vehicle does not have a valid parking permit, the system generates an immediate alert to local security personnel for prompt action.
 - Unauthorized vehicles are flagged in the system for monitoring and potential follow-up.
- Real-Time User Notifications:
 - For users who have previously registered their license plate, the system sends an SMS reminder immediately after the entrance camera recognizes a vehicle without a valid parking permit.
 - The reminder includes steps to quickly obtain a parking permit to avoid further issues.
- Extended Stay Monitoring:
 - The system tracks vehicles that overstay their allotted parking duration and sends alerts to local security, providing details about the vehicle and its extended stay.

By combining real-time monitoring, user notifications, and automated security alerts, this system ensures that only authorized vehicles can access the garage, enhances user compliance, and maintains a secure and efficient environment for all.

2.3.4. Admin Dashboard

The Admin Dashboard provides administrators with real-time control and monitoring capabilities to ensure smooth garage operations and efficient system management. This centralized interface is designed for ease of use and offers the following key functionalities:

- Real-Time Occupancy Monitoring:
 - Displays the current number of available and occupied spaces on each floor of the garage.
 - Includes a summary of overall occupancy across all connected garages.
- Vehicle Authorization Management:
 - Enables administrators to view, add, or update parking permits for registered users.
 - Provides a log of vehicles flagged for unauthorized access or extended stays, along with timestamps and incident details.

- System Alerts and Notifications:
 - Consolidates all alerts, such as unauthorized access, extended stays, or vehicles attempting to leave after operational hours.
 - Allows administrators to resolve alerts or escalate them to local security personnel.

The Admin Dashboard serves as the command center for the Parking Garage Management System, enabling seamless management, enhanced security, and data-driven decision-making for administrators.

2.3.5. Automated Payment System

The Automated Payment System simplifies the process of obtaining a parking permit through a user-friendly and efficient workflow, particularly benefiting users who do not have a parking permit when using the garage. This system eliminates the need for physical tickets and manual transactions. Key functionalities include:

- QR Code Access:
 - QR codes are strategically placed inside the garage for users to scan using their smartphones.
 - Scanning the QR code directs users to the system's website or mobile app, where they can quickly register their vehicle's license plate and purchase a parking permit.
- Flexible Parking Permit Options:
 - To accommodate a variety of user needs, the system offers multiple parking permit plans:
 - Daily: Ideal for one-time or short-term parking.
 - Weekly: A convenient option for users needing access for a few consecutive days.
 - Monthly: Cost-effective for regular users.
 - 6-Month: Mid-term option for frequent parkers.
 - Annual: Best value for long-term users.
 - Each option is clearly displayed with pricing and details, making it easier for users to select the plan that suits them best.
- Secure Payment Integration:
 - The system supports multiple payment methods, including credit cards, digital wallets, and other secure gateways.
 - Payment receipts are automatically sent via email or SMS for user convenience.
- Real-Time Parking Permit Updates:
 - Once payment is completed, the system immediately updates the vehicle's status in the parking database.
 - This ensures seamless entry and exit for users, monitored by the license plate recognition cameras.

This automated payment system enhances accessibility for users without prior parking permits, streamlining their experience while ensuring efficient and secure parking management.

2.4 Existing Products/Past Projects/Prior Related Work

Thankfully, certain parts of our project have been done previously, and a few small companies offer specific features that our product has, but we are focused on putting these features into one product. These offerings have helped us with brainstorming what products users like and what could help with ease of use for both the user and the admin/security.

2.4.1 Disney Springs

One of the main inspirations for our system is from Disney, where their Disney Springs shopping location has multiple garages that make it extremely easy to find open parking spots. They utilize LEDs to indicate whether a parking spot is open or not, where the LED being green means that the parking spot is free while the LED being red indicates an occupied parking spot. They also have a sign that shows the number of open spots on each floor and once you are on that floor, they have signs on each row that show the number of open spots for that row. This allows users to save time since they do not have to go through each row to find an open spot, while also allowing security to check if there could be anyone staying past the closing time of that garage. Many customers who had to park in their garages are usually amazed at the system and how easy it makes parking, especially at a busy shopping center like Disney Springs. Systems like the ones in the Disney Springs Garages are quite common outside of the US, so many Americans would like to see more of this technology to make their life a little easier. We are borrowing the LED system to indicate open or taken parking spots and the signs for the number of open spots, whether per row or floor.

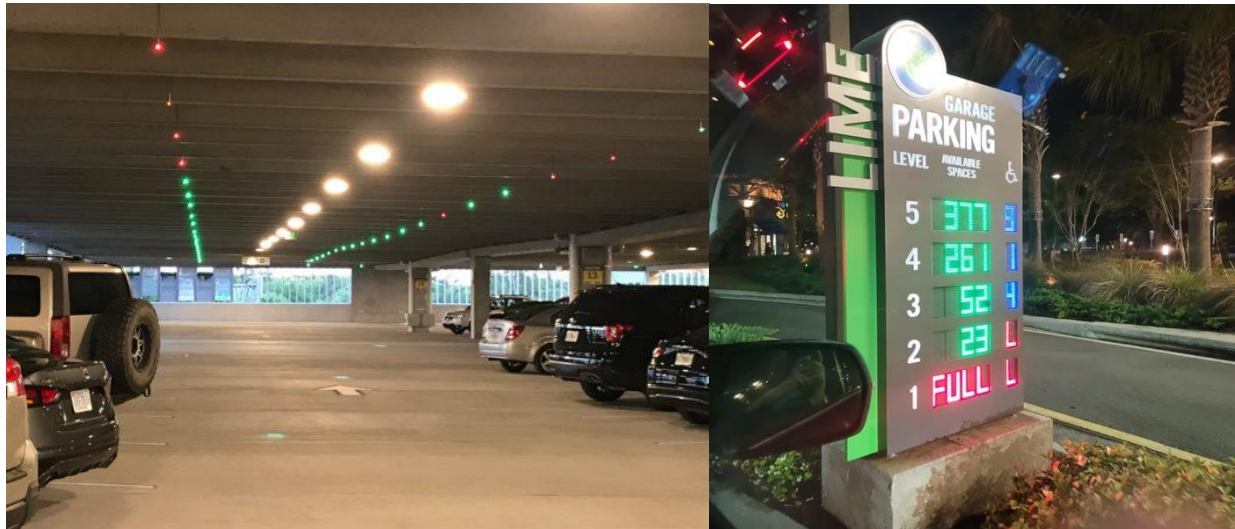


Figure 2.1: Disney Springs Garage LEDs and Signage

2.4.2 Parking Guidance System

While researching prior works, we stumbled upon a company called Parking Guidance Systems LLC, where their product resembles what we wanted to do. They are a company that specializes in teaming up with businesses that want their parking garages to have custom parking guidance solutions and seem to be based in the US. They use LEDs to also indicate free parking spaces for indoor parking and can create signs to show available parking, but one difference is that they also offer outdoor parking solutions, using sensors to show how many spaces are free in that parking lot. They also offer custom mobile apps for these parking garages for users to see real time information about the parking garage. A few locations in Texas and Oklahoma use their systems, where customers have stated that they do not have trouble finding parking due to these systems. We wanted to make an app and website before finding this company, but we will use their app features as a reference for our app and website features.

2.4.3 OpenALPR

Implementing AI to detect license plates is one of the conveniences we are striving to provide, whether it is to help the driver avoid a ticket or to help the security officer with notifying which cars do not have a permit. OpenALPR was one of the license plate detection software that we first stumbled upon and has many of the features we are looking for. Some of their features that interested us was the contactless payment system where the user's car is put into the database from the license plate and the user can pay for that car using the website. They also have a feature that can flag cars that have not paid for the permit and easy notification to security so they can ticket that car. Their database of vehicles includes not only their license plate, but also attributes of the vehicle like color, brand, etc. Numerous police departments in the country use their detection software to help with either traffic incidents or to help find specific vehicles that could be dangerous. We are focusing on just the license plate so our product will not focus on the vehicle attributes, but we will try and implement a system similar to how they flag cars that did not pay for a permit.

2.5 Engineering Specifications

The Parking Garage Management System integrates hardware and software to create a seamless parking solution. The hardware focuses on real-time data collection and system operation, while the software processes and presents this data for user interaction and administrative management. Together, these components provide an efficient and scalable solution to enhance parking convenience, security, and operational control.

2.5.1. Hardware Description

The hardware of the system is designed to ensure reliable and efficient operation through accurate data collection and communication. It incorporates components for detecting parking availability, monitoring vehicles, and managing power sustainably. These elements will work together to provide real-time updates and enable smooth integration with the software platform.

Key Hardware Features:

1. Edge Processing with the Microcontroller
 - Instead of sending raw data to the backend, the microcontroller will process sensor inputs locally to reduce network traffic.
 - A predefined threshold algorithm will determine if a parking spot is occupied before sending updates to the server.
2. Backup Power System for Critical Components
 - To prevent failures in case of power loss, a backup battery system will be implemented for:
 - License Plate Recognition (LPR) cameras.
 - Wireless communication modules.
 - This ensures security monitoring continues functioning even if the main power system fails.

Preliminary hardware components include:

- Ultrasonic Sensors - Detects parking spot occupancy and updates availability.
- License Plate Recognition (LPR) Cameras - Captures vehicle entry/exit data for security monitoring.

- Digital Signage & LED Displays - Guides drivers to available spaces in real-time.
- Wireless Communication Modules - Ensures seamless data transmission.
- Raspberry Pi - Handles image processing.
- Microcontrollers - Manages sensors, LED indicators, and real-time processing.
- Battery Management System (BMS) - Regulates solar panel power and backup power supply.
- Backup Power Units - Ensures continued operation of critical components in case of power failure.
- Voltage Regulators - Provides stable power to all electronic components.

2.5.2. Software Description

The software provides the framework for integrating hardware data into an intuitive platform for users and administrators. It will manage real-time updates on parking availability, permit handling, and secure payments, while enabling administrators to monitor and control system operations. Whether deployed as a mobile app, a website, or both, the software will be designed with scalability and user convenience in mind.

Key Software Features:

1. Machine Learning for License Plate Recognition
 - The LPR system will use a pre-trained deep learning model to improve accuracy.
2. Predictive Analytics for Parking Demand
 - The system will use historical parking data to estimate future demand trends.
3. Automated Ticketing for Violations
 - If a vehicle parks without a permit, the system will:
 - Capture the plate number.
 - Generate a violation report.
 - Send an alert to the admin dashboard.
 - This feature enhances security and compliance.

Preliminary software components include:

- Backend Server - Handles real-time data processing and database management.
- User Interface - Displays parking availability and handles permit purchases.
- Admin Dashboard - Provides monitoring, alerts, and analytics.
- Payment Gateway Integration - Ensures secure transactions and real-time permit updates.

2.6 Required Specifications

The table below outlines the key specifications for the Parking Garage Management System, detailing measurable criteria and highlighting specifications that will be demonstrable during the project.

Table 2.6.1 *Specification*

Specification	Value/Range	Description
Ultrasonic Sensor Accuracy	± 3 mm	Accuracy of ultrasonic sensors in detecting parking spot occupancy.
License Plate Recognition	$\geq 95\%$ (daytime) $\geq 85\%$ (nighttime)	Accuracy of LPR cameras in identifying license plates under varying lighting conditions.
System Uptime	$\geq 99.9\%$	The system's operational availability over a given time period.
Real-Time Updates	<5 second	Time for parking availability updates to propagate through the system.
Battery Life	≥ 12 hours	Minimum operational time using battery power without solar recharging.
Payment Processing Time	<10 seconds	Time required for completing parking permit transactions.
LED Indicator Visibility	≥ 20 meters	Distance from which LED indicators for parking spots can be clearly seen.
Power Efficiency	$\geq 85\%$	Efficiency of the battery management system in converting and using stored energy.
Backend Server Processing Speed	<500 ms	Maximum time for the backend server to process sensor and camera data.
Dashboard Alert Time	<2 seconds	Time for the admin dashboard to reflect alerts from the system.

2.6.2 Hardware Diagrams:

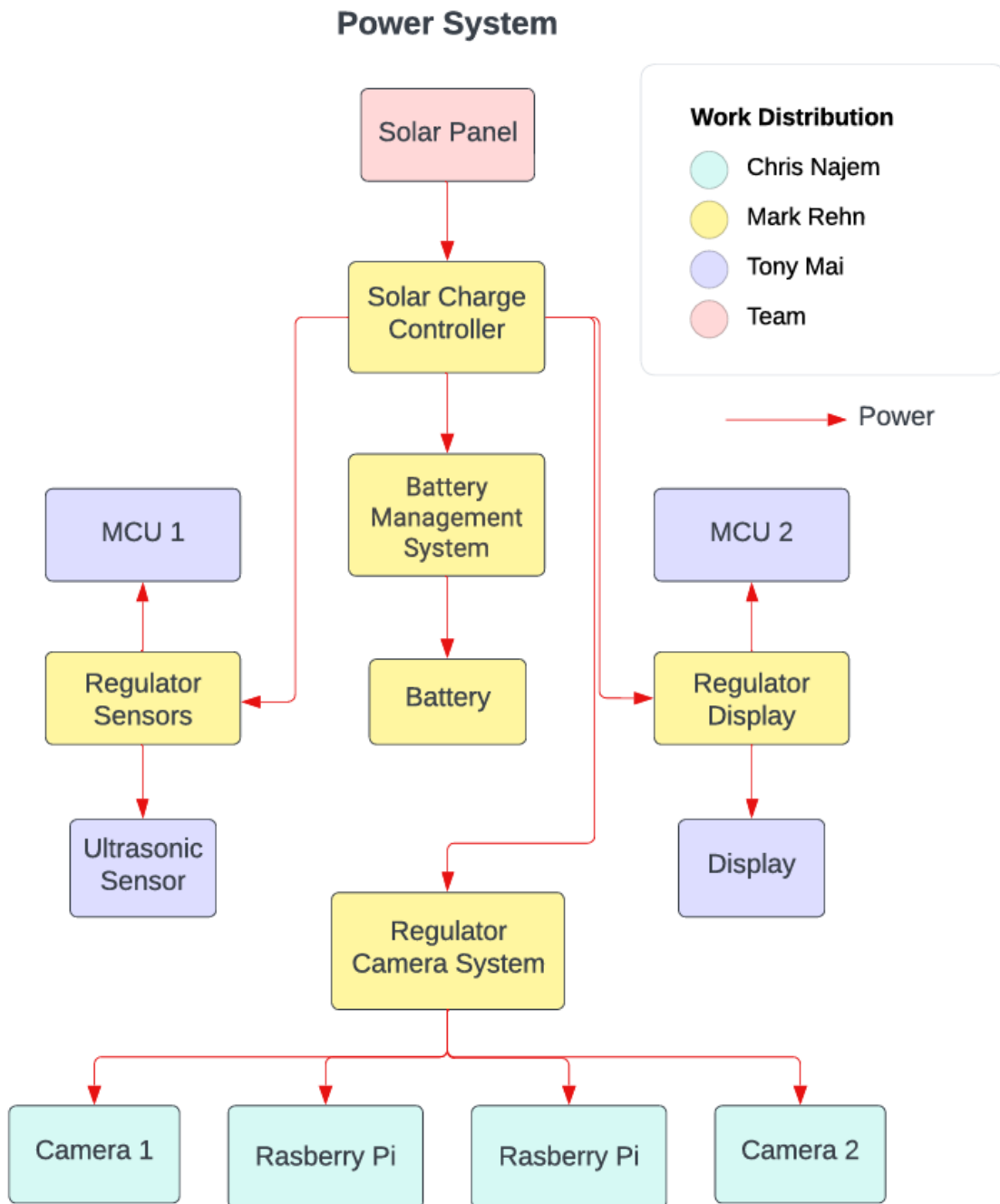


Figure 2.2: Power System Hardware Diagram
by Authors

Data Communication

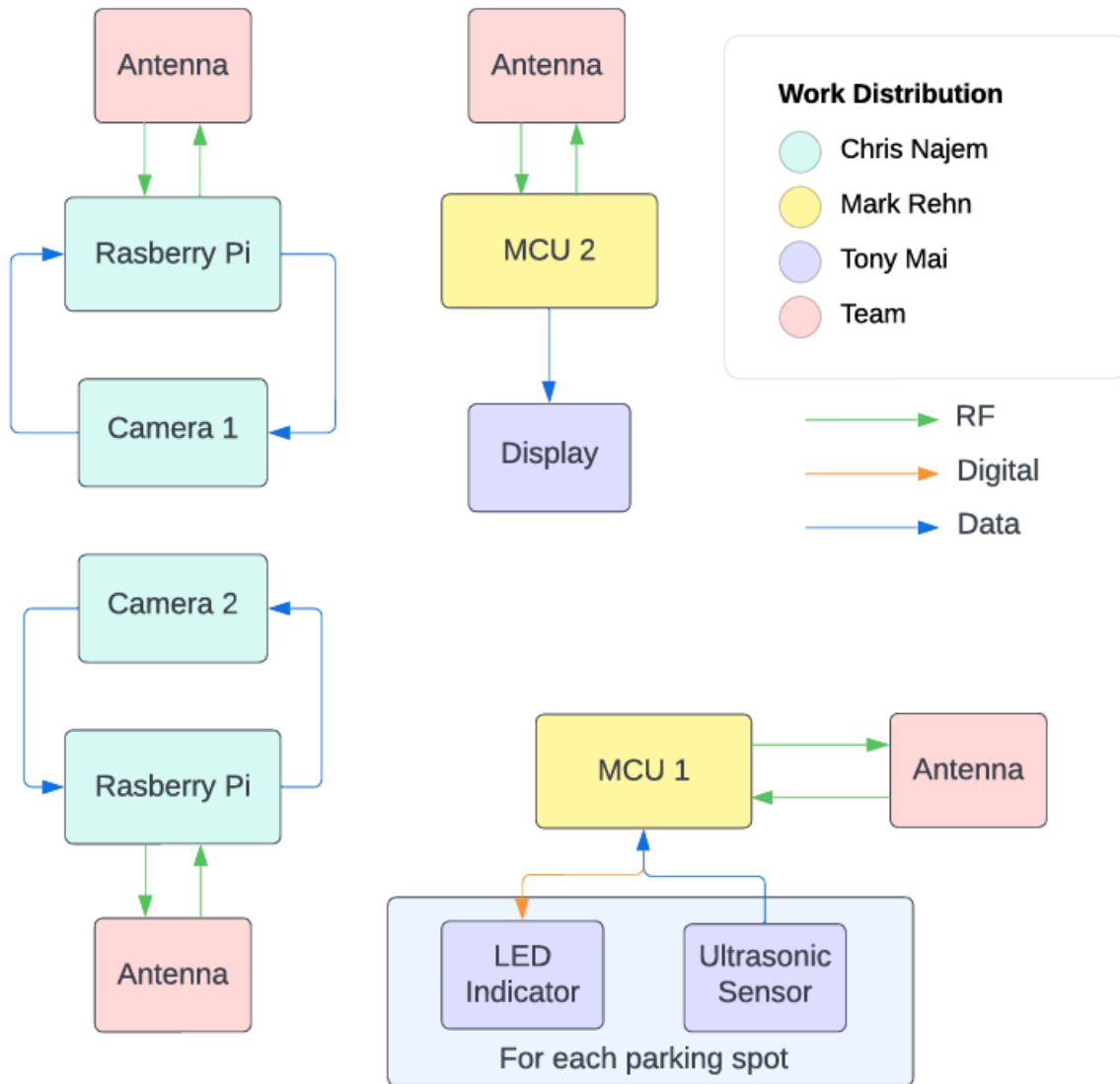


Figure 2.3: Data Communication Hardware Diagram
by Authors

2.6.3 Software Diagrams:

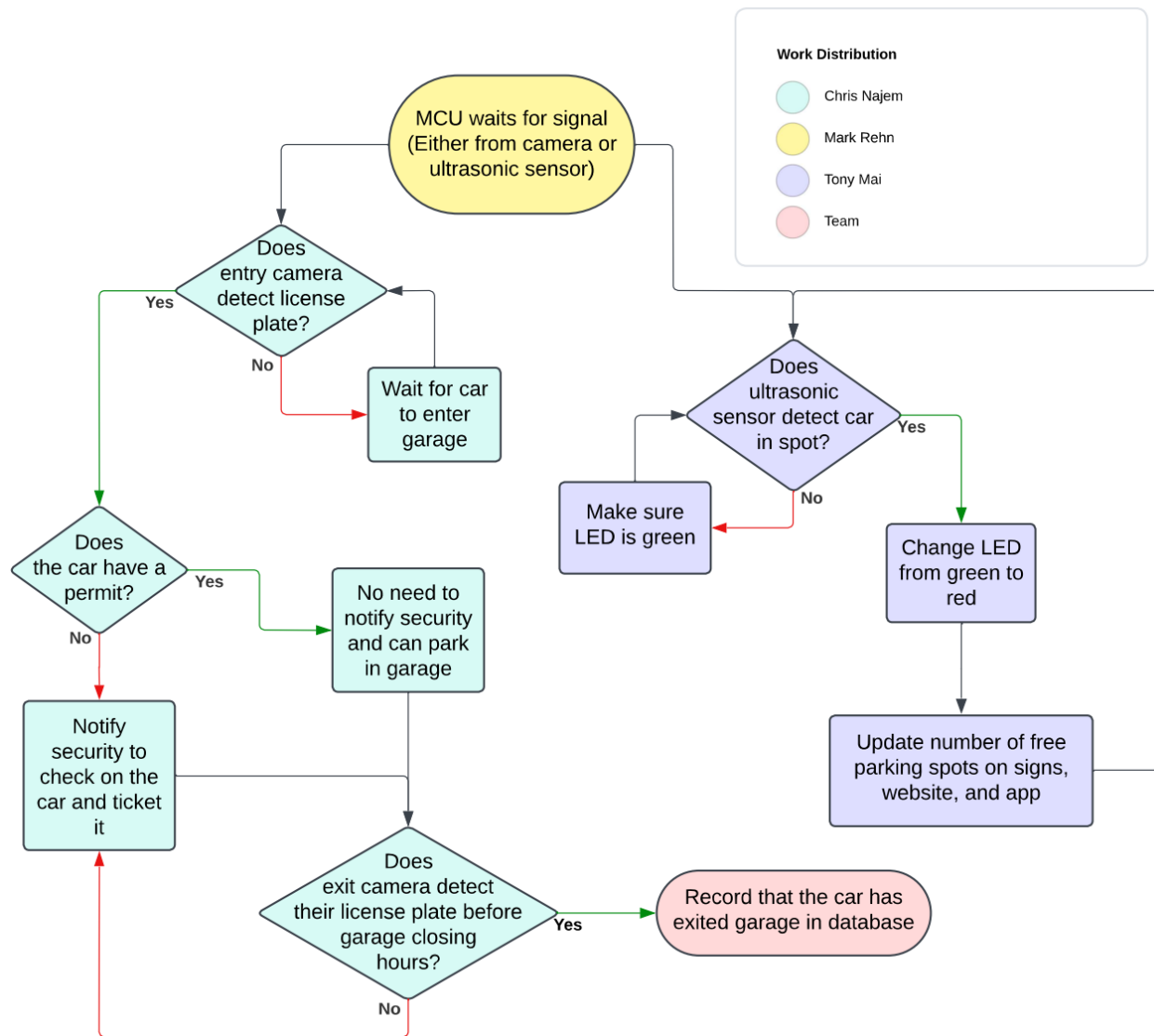


Figure 2.4: Software Diagram
by Authors

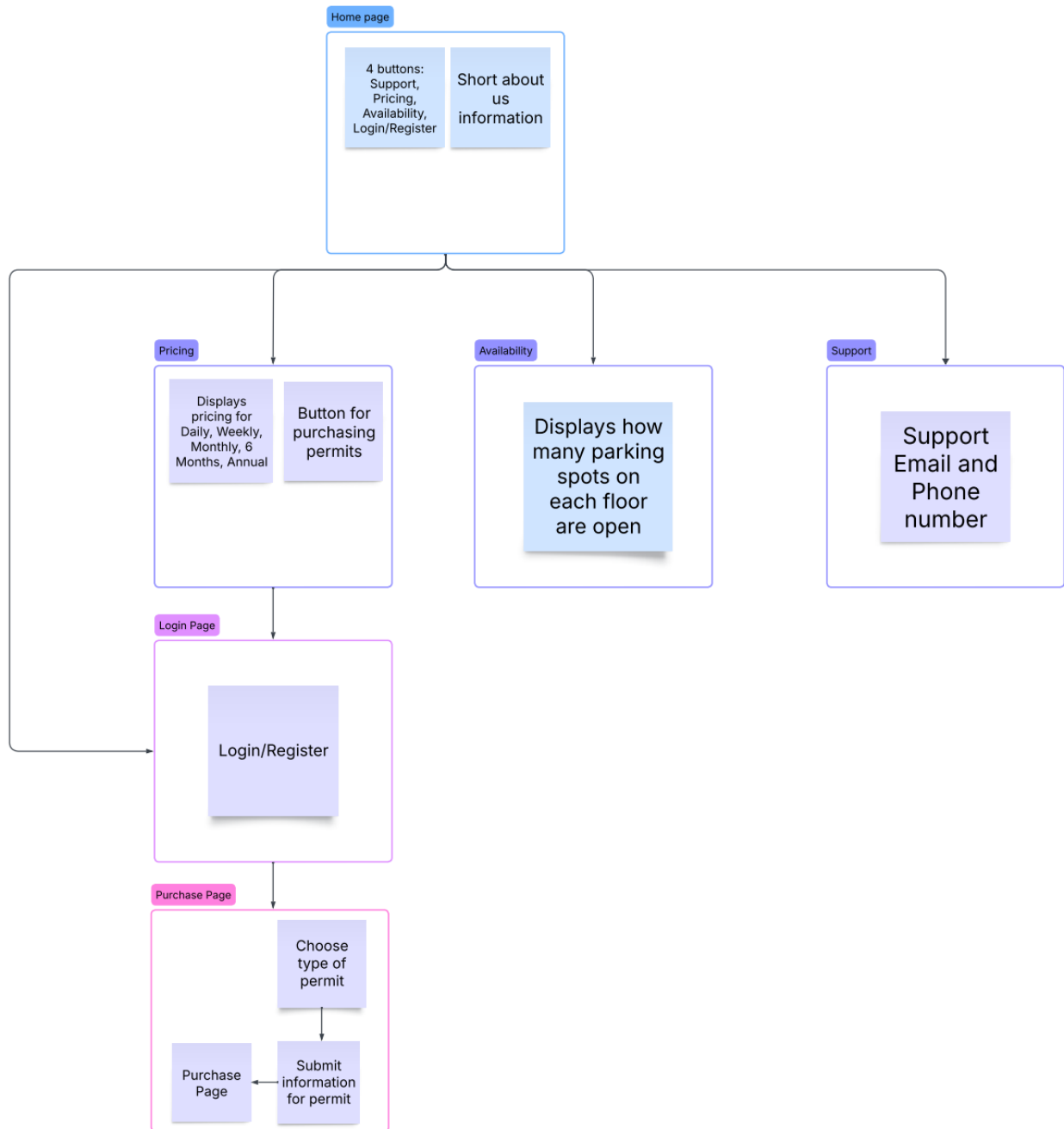


Figure 2.5: Website Diagram
by Authors

2.7 House of Quality

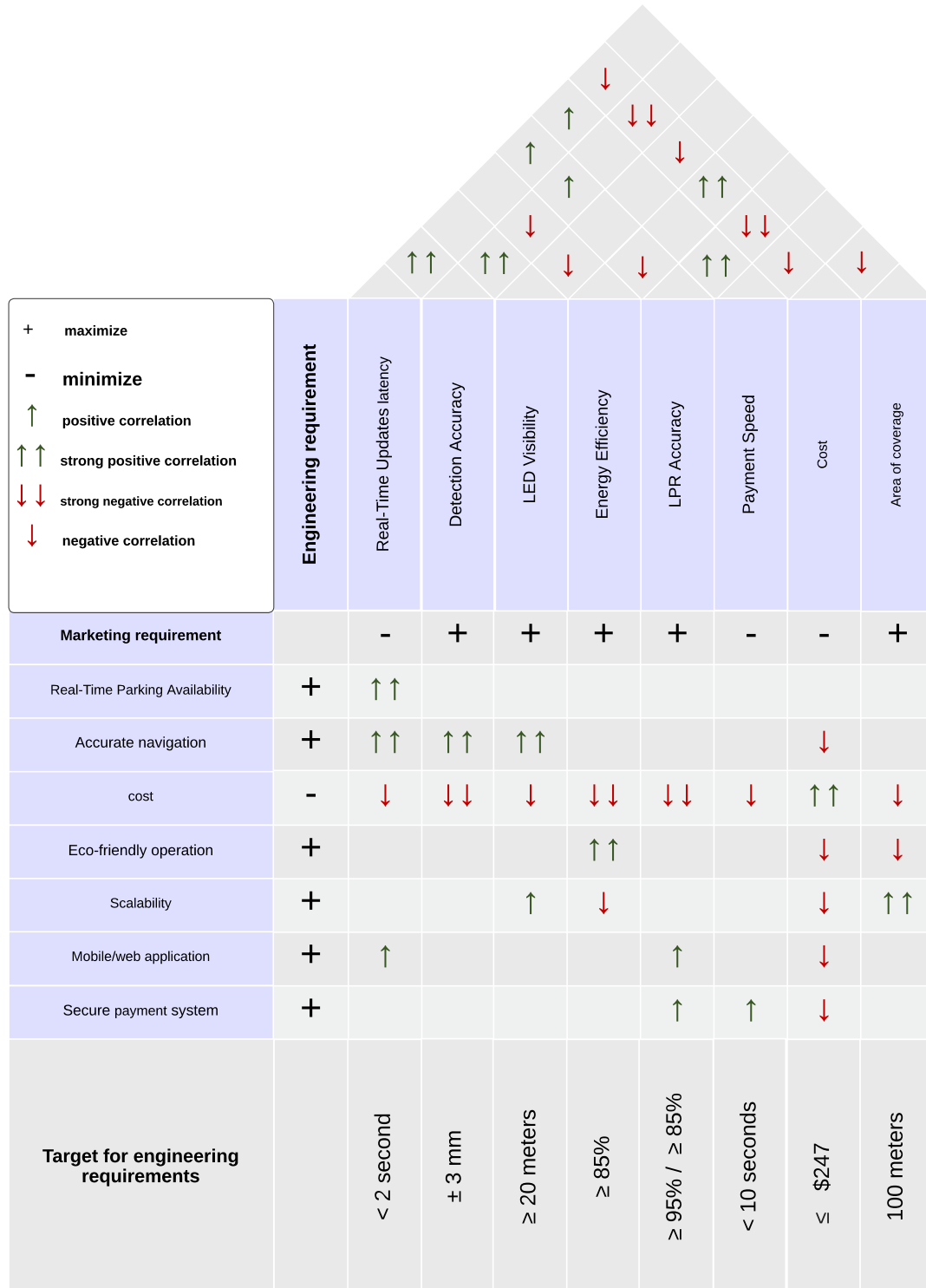


Figure 2.6: House of Quality
by Authors

Chapter 10 - Administrative Content

10.1 Budget and Financing

For our budget, we have given estimates that should be relatively close to how much we will be spending on our project. Since it is our own project and not sponsored, the team will be the ones using their money to buy the items, so it will be split up accordingly.

Table 10.1.1: Budget Allocation

Sub-System	Budget (USD)
Power (Batteries, Solar)	\$ 50.00
Sensors and Processing	\$ 200.00
PCBs and Electrical	\$ 100.00
Miscellaneous	\$ 50.00
Total	\$ 400

Table 10.1.2: Estimated Bill of Materials

Component	Subsystem	Quantity	Unit Cost (USD)	Total (USD)
Ultrasonic Sensors	Sensors and Processing	10	\$1.91	\$19.10
Cameras	Sensors and Processing	2	\$14.49	\$28.98
LED Indicators	Sensors and Processing	20	\$0.15	\$3.00
Microcontroller	Sensors and Processing	3	\$3.50	\$10.50
Raspberry Pi	Sensors and Processing	2	\$61.99	\$123.98
Singnage Displays	Sensors and Processing	2	\$1.59	\$3.18
Solar Panels	Power (Batteries, Solar)	2	\$14.99	\$29.98
Batteries	Power (Batteries, Solar)	8	\$1.95	\$15.60
Voltage Regulators	PCBs and Electrical	4	\$3.99	\$15.96
PCB for Sensors, Singnage Display	PCBs and Electrical	2	\$1.59	\$3.18
PCB for BMS	PCBs and Electrical	1	\$4.99	\$4.99
Miscellaneous Components	Miscellaneous	1	\$50	\$50.00
Total				\$308.45

10.2 Work Distribution

From our hardware and software diagrams, we will split the workloads between each member. Since Mark is the only EE in our group, he will focus on the PCB with most components while Chris and Tony will work on the software portion as well as helping with the cameras.

Table 10.2.1: Members' Responsibilities

Electrical Engineering	Responsibilities
Mark Rehn	PCB design
	PSU design
	MCU communications
Computer Engineering	Responsibilities
Chris Najem	Software for cameras
	Raspberry Pi communication with camera
	Software to help antenna communication
Computer Engineering	Responsibilities
Tony Mai	MCU connection with Display
	MCU connection with ultrasonic sensor/LED
	Software for ultrasonic sensor and LED

10.3 Project Milestones

During the formation of our group, we gave an estimate as to how often we will meet and work on our project. We then went based off our estimates and created the tables below for our expected timelines:

Table 10.3.1: Project Documentation

Project Documentation				
Item	Start Date	End Date	Duration	Description
Group Formation	01/07/2025	01/14/2025	1 week	Chris Najem, Mark Rehn, and Tony Mai
Brainstorming	01/14/2025	01/17/2025	0.5 week	Discuss and select the best idea
Initial Document	01/17/2025	01/24/2025	1 week	Divide and Conquer (10 pages)
Group Website	01/24/2025	02/07/2025	2 weeks	Update and upload D&C report
Midterm Document	02/10/2025	03/24/2025	6 weeks	Midterm Document (60 pages)
Update Group Website	03/28/2025	04/04/2025	1 week	Update and upload midterm report
Final Document	03/24/2025	04/22/2025	4 weeks	Final Document (90 pages)

Table 10.3.2: Project Fabrication

Project Fabrication				
Item	Start Date	End Date	Duration	Description
Components Selection	01/17/2025	02/07/2025	3 weeks	Choose project components
System Design	02/07/2025	02/28/2025	3 weeks	Create system schematics
Breadboard Prototype	02/21/2025	03/21/2025	4 weeks	Build and test initial prototype
System Testing	02/28/2025	03/21/2025	3 weeks	Verify system functionality
PCB Design	03/21/2025	04/11/2025	3 weeks	Design PCB layout
PCB Testing	TBD	TBD	TBD	Test manufactured PCB
Final Prototype	TBD	TBD	TBD	Assemble and finalize system