Conceptual Design for Parking Lot Monitoring System

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I. Introduction

This document aims to provide a high-level look at the design of the parking lot monitoring system. The fully formulated problem will be restated and explained in detail to make clear what problem the system will attempt to solve. The conceptual design of the system is detailed in a block diagram. The block diagram consists of the various subsystems that make up the parking lot monitoring system. An overview of each subsystem's components and overall function is given to help explain how the system's various parts will work individually and with each other. The information being passed from each subsystem to the next is shown in the block diagram to give a better idea of how the subsystems work together. This document will also dispel ambiguity in the specifications and constraints the system will be designed for. The timeline for the project is included in this document as well.

A. Fully Formulated Problem

Finding a parking spot on campus can be stressful for many students. It is a common belief that this problem stems from a simple lack of adequate parking for students who commute to campus. However, a few lots often have spots available. Due to human nature, students want to park as close as possible to where their classes are. This results in students wasting time looking for spots in the most high-demand lots instead of parking where spots are readily available and walking the rest of the way or taking the shuttle. If students had a way of knowing ahead of time whether it would be worth looking for a spot in a given parking lot, then that could save them a lot of time and stress.

This is the problem that the past capstone team who worked on the parking lot monitoring system also set out to solve. However, the current team believes their solution to be flawed. The cameras the previous team relied on to detect cars entering and exiting lots are vulnerable to any condition affecting visibility. This could mean rain, snow, a bad glare, or even just the darkness of night would reduce the system's accuracy, for example. Therefore, the current team has proposed a new solution to avoid these potential weaknesses. Ground sensors such as inductive loops would remain accurate in these limited visibility situations. This would result in the system having considerably lower downtime and remaining accurate around the clock. Combine this with a backup power system; you have virtually no downtime in most scenarios.

The system will be subject to certain specifications and constraints. These specifications and constraints, as well as their origin, are:

1) The existing solutions inherited from the previous project, the camera, sign, and server, shall be maintained at their current capability.
   - (Origin of constraint)
2) The system shall have a backup power system for the sensor in case the main power supply fails.
   - (Origin of constraint)
3) The system shall detect vehicles entering and exiting a parking lot.
   - (Origin of constraint)
4) The data collected by the sensor shall be communicated to the server wirelessly.
   - (Origin of constraint)
5) The system shall keep a local count of vehicles that enter or exit a parking lot if communication to the server is severed.
   - (Origin of constraint)
6) The system shall function at all times of the day.
   - (Origin of constraint)

II. Ethical, Professional, and Standards Considerations

TODO: brady / khalifa

A. Ethical and Broader Impacts

The ethical consideration for this system is to prevent any damage to sidewalks or roads during experimentation or sensor testing. Furthermore, seeking approval from the campus facility management before conducting any experiments is essential to ensure that the system's testing does not interfere with the campus environment. Another ethical consideration involves not utilizing the campus Wi-Fi network to connect the wireless sensor system to the server created by the previous capstone team [1]. This decision prevents any potential disruption or burden on the campus network. Instead, alternative wireless connectivity will ensure the system's data transmission to the server without impeding the campus's network resources.

B. Standards

The National Fire Protection Associated (NFPA) 70 and 70E Electrical Codes and Standards - These standards are intended to safeguard persons and property from hazards arising from the use of electricity. These standards will be strictly adhered to as the team works through each subsystem to ensure the electrical safety of the system, the working environment, and of any persons who come into contact with the system.

The International Electrotechnical Commission (IEC) 61000-6-4 - This standard sets requirements applied to electrical and electronics equipment to provide an adequate level of protection to radio services[9]. This standard would set limits on any inductive loops that are to be used.

C. Constraints Derived from Broader Considerations

Brady: I need the project proposal broader impacts to be revised

III. Block Diagram

The system has been broken down into **six (TODO:)** subsystems which are designed to be as modular as possible. These **six** systems are the sensor, signal processing, data interpretation and transmission, power, backup power, and upkeep of the former system that was previously used. The sensor subsection is responsible for acquiring data for the MCU. The signal processing is in charge of removing noise from the sensor signal before converting it to a digital signal for the MCU. **todo: talk about the rest of the systems as a mini intro**

A. Subsystem 1: Ground Based Sensor

This subsystem will be how vehicles are detected and the direction of the vehicle. Through the use of inductive loop(s), it will detect the presence of a vehicle when it passes over the top of the loop and affect the magnetic field that is generated from the power supply. When a vehicle passes over the loop, it will induce a change in the inductance, affecting the current flow. Once the change has occurred, it will then move into a Wheatstone Bridge circuit that will detect any change in voltage. If there is a voltage change, the output will be sent to the Signal Processing Subsystem as an analog signal to alert that a change has been detected in the sensor.

B. Subsystem 2: Signal Processing

The signal processing system receives an analog signal from the ground-based sensor and turns it into a noiseless digital signal for the MCU. This subsystem will be constructed onto a printed circuit board and will be attached to the MCU used for the data interpretation, transmission, and storage subsystem. The order of operations for processing the signal goes as follows: 1) Push the signal through a filter to remove any noise 2) Amplify the signal as needed so that it is at a high enough voltage to be read by the MCU 3) Use an analog-to-digital converter to convert the analog signal into a digital signal for an easily read signal for the MCU

Brady: Is there anything more to be added to this section?

C. Subsystem 3: Data Interpretation, Transmission, and Storage

The Data Interpretation, Transmission, and Storage subsystem is responsible for understanding the data sent from the Signal Processing subsystem, making decisions based on this data, transmitting data over a wireless network, and storing the data in a database. The data interpretation takes place in software loaded to a microcontroller contained in a housing next to the ground sensors. The transmission part of the subsystem consists of a wireless connection between the microcontroller and the central computer. The storage portion of the subsystem takes place in the central computer.

In greater detail and in order of operation, the Data Interpretation, Transmission, and Storage subsystem...

1) Receives digital signals from the signal processing subsystem which will contain information pertaining to the direction of traffic that was detected by the ground-based sensor subsystem.
2) Decides based on the data received whether a vehicle is entering or exiting the lot.
3) Increments the number of parking spots available in the lot if the car is exiting, or decrements the number of parking spots available in the lot if the car is entering.
4) Stores the updated number of parking spots available in the lot locally.
5) Checks to see if the microcontroller can reach the central computer over the wireless network.
6) Sends data to the central computer if the microcontroller can reach the central computer over the wireless network.
7) Receives the data sent over the wireless network from the microcontroller to the central computer.
8) Stores the data in a database on the central computer. This data is available for the computer science team to make use of.

D. Subsystem 4: Backup Battery

This subsystem powers other needed subsystems while the primary power source is off or the server is offline. The subsystem includes a battery, which can charge while the primary power source and the server are online. Also, it will have a battery management system that will allow the user to know the battery's state. That battery will have a kill switch to shut down the backup battery in emergencies. Moreover, to distribute the needed voltages for the three subsystems, a voltage regulator DC to DC will be used. Lastly, a protection circuit will be used to prevent any damage that might affect the three subsystems connected to the backup power.

E. Subsystem 5: Power

An AC/DC converter with a voltage regulator is crucial to electrical systems. It converts from alternating current (AC) to

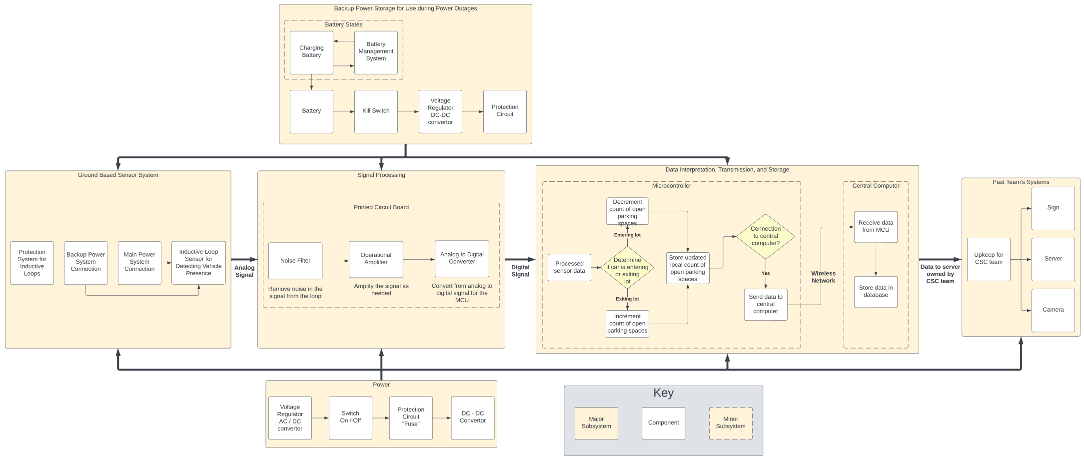


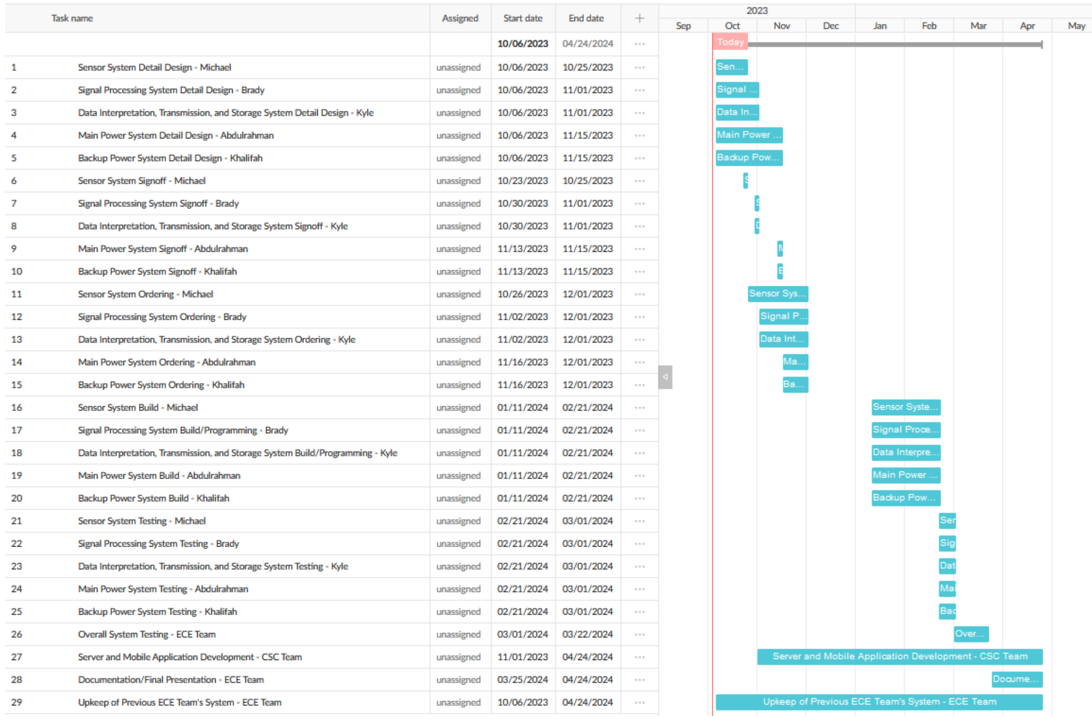
Fig. 1. Block Diagram for Conceptual Design

direct current (DC) or vice versa. This conversion is essential to power various electrical equipment that need a particular voltage type. To control the power supply, the subsystem also has a switch for turning the converter on and off. A protection circuit, frequently done using a fuse, is included in the subsystem to guarantee the system's safety. The fuse serves as a safety measure, protecting the converter and connected equipment from being harmed by an excessive current. A DC-DC converter may also be incorporated into this subsystem, allowing for additional voltage management and modification to match the needs of particular devices. This component is essential for giving electronic devices secure and consistent electricity.

IV. Timeline

When viewing Fig. 1. Block Diagram for Conceptual Design, it is worth noting that there are six subsystems for a team with five members. The subsystem labeled "Past Team's Systems" will be a minor subsystem as the team plans to upkeep the electrical aspect of the subsystem. Hence, the CSC team that will be working on artificial intelligence (AI) software has cameras that will work for them. The sign will also be maintained as displaying the number of available parking spots within a given parking lot will be necessary.

When viewing Fig. 2. Timeline for Conceptual Design, each team member is responsible for a specific subsystem based on their knowledge, skills, and interests in electrical and computer engineering. Michael Sisk will be accountable for the Ground-Based Sensor Subsystem. This subsystem has been deemed the highest priority subsystem, as with it, the team will be able to detect the presence of a vehicle, and the entire project will be complete with it. Brady Beecham will be responsible for the Signal Processing Subsystem. This subsystem is necessary as the signal that comes from the output of the Ground-Based Sensor System will need to be edited to an extent without losing essential parts of the signal so the signal can be transmitted to the next subsystem. Kyle Plant will be responsible for the Data Interpretation, Transmission, and Storage Subsystem. This subsystem will have high importance as it will take the edited signal from the Signal Processing System and process it so it can be determined if a vehicle is entering or leaving a parking lot and update the count. The count will be sent to the server to update the sign. This system will also be able to store the data locally in the case of a power outage and the server is down, but the system is still working correctly due to the backup power system. Abdulrahman Alrudayan will be responsible for the Main Power Subsystem. This subsystem will be needed to convert a standard 120 VAC wall outlet plug input source into the necessary DC values to correctly operate the previously mentioned systems' components. Suppose the output values from the voltage regulator are not correct. In that case, the system will not function properly, and it also introduces the possible risk of damaging the system and its components. Khalifah Altamimi will be responsible for the Backup Power Storage Subsystem. This subsystem will be very useful to the entire system as the system will have the ability to keep a local count during power outages. When a power outage occurs, the Backup Power Storage Subsystem will energize and provide short-term power for the system to continue functioning until the main power is restarted. This will allow students to continue knowing which parking lots are available while power is out on campus. When the main power is on, the backup power will be charged and stay charged until it is again needed. The CSC team mentioned will be responsible for implementing AI software into the camera system that was built by the previous ECE team. Implementing AI software into the camera system while creating a ground-based system to monitor parking availability in parking lots will allow the system to be used across all campus parking lots. With the two different methods being implemented on campus, parking lots that do not have the capabilities to install cameras can be monitored accordingly through the ground-based system, and the cameras can cover the lots that cannot implement the ground-based solution due to constraints.



	Task name	Assigned	Start date	End date
			10/06/2023	04/24/2024
1	Sensor System Detail Design - Michael	unassigned	10/06/2023	10/25/2023
2	Signal Processing System Detail Design - Brady	unassigned	10/06/2023	11/01/2023
3	Data Interpretation, Transmission, and Storage System Detail Design - Kyle	unassigned	10/06/2023	11/01/2023
4	Main Power System Detail Design - Abdulrahman	unassigned	10/06/2023	11/15/2023
5	Backup Power System Detail Design - Khalifah	unassigned	10/06/2023	11/15/2023
6	Sensor System Signoff - Michael	unassigned	10/23/2023	10/25/2023
7	Signal Processing System Signoff - Brady	unassigned	10/30/2023	11/01/2023
8	Data Interpretation, Transmission, and Storage System Signoff - Kyle	unassigned	10/30/2023	11/01/2023
9	Main Power System Signoff - Abdulrahman	unassigned	11/13/2023	11/15/2023
10	Backup Power System Signoff - Khalifah	unassigned	11/13/2023	11/15/2023
11	Sensor System Ordering - Michael	unassigned	10/26/2023	12/01/2023
12	Signal Processing System Ordering - Brady	unassigned	11/02/2023	12/01/2023
13	Data Interpretation, Transmission, and Storage System Ordering - Kyle	unassigned	11/02/2023	12/01/2023
14	Main Power System Ordering - Abdulrahman	unassigned	11/16/2023	12/01/2023
15	Backup Power System Ordering - Khalifah	unassigned	11/16/2023	12/01/2023
16	Sensor System Build - Michael	unassigned	01/11/2024	02/21/2024
17	Signal Processing System Build/Programming - Brady	unassigned	01/11/2024	02/21/2024
18	Data Interpretation, Transmission, and Storage System Build/Programming - Kyle	unassigned	01/11/2024	02/21/2024
19	Main Power System Build - Abdulrahman	unassigned	01/11/2024	02/21/2024
20	Backup Power System Build - Khalifah	unassigned	01/11/2024	02/21/2024
21	Sensor System Testing - Michael	unassigned	02/21/2024	03/01/2024
22	Signal Processing System Testing - Brady	unassigned	02/21/2024	03/01/2024
23	Data Interpretation, Transmission, and Storage System Testing - Kyle	unassigned	02/21/2024	03/01/2024
24	Main Power System Testing - Abdulrahman	unassigned	02/21/2024	03/01/2024
25	Backup Power System Testing - Khalifah	unassigned	02/21/2024	03/01/2024
26	Overall System Testing - ECE Team	unassigned	03/01/2024	03/22/2024
27	Server and Mobile Application Development - CSC Team	unassigned	11/01/2023	04/24/2024
28	Documentation/Final Presentation - ECE Team	unassigned	03/25/2024	04/24/2024
29	Upkeep of Previous ECE Team's System - ECE Team	unassigned	10/06/2023	04/24/2024

Fig. 2. Timeline for Conceptual Design

V. Conclusion

The parking lot monitoring system's design has been outlined in this document, along with a breakdown of its key elements and features. Finding a parking spot on campus could be more efficient and manageable, which is the main issue that our method tries to solve. To guarantee accuracy and minimize time off, the current team has suggested a novel strategy using ground-based sensors. The system is broken down into six modular subsystems in the document: Ground Sensor, Signal Processing, Data Interpretation, Transmission, Power, Backup Power, and Maintenance of the Previous System. The accurate and continuous operation of the parking lot monitoring system depends on each subsystem. To sum up, by giving students access to real-time information on parking availability and improving overall campus parking management, the parking lot monitoring system is intended to ease parking woes. This project wants to develop a trustworthy and effective solution for college students focusing on ethics, standards, and modular subsystems.

References

[1] Kesternucum, "KESTERNUCUM/ECE-capstone-team3: Parking lot monitoring system," GitHub, https://github.com/kesternucum/ECE-Capstone-Team3/tree/main (accessed Sep. 13, 2023).