Camera Inventory System

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Design Document

Team 10

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1. Introduction

1.1 Problem

In ECE 445, there is currently a very manual process for borrowing and returning components which puts a lot of stress and pressure on the TA's. As of right now, students come to pick up certain inventory that they need and the TA's have to manually log in what the student took. The same process is then repeated when students come to return their borrowed items and there are also cases when students don't return what they borrowed, resulting in more time and effort on the TA's end to find those students and retrieve the parts or charge them as needed. This process as a whole can be streamlined and automated in a safe manner to enable the course logistics to flow in a smoother manner without putting any pressure on the TA's.

1.2.1 Solution

Our solution is an automated camera-inventory system which essentially begins with components tagged with QR codes stored in a locked container. Students will then arrive and scan their iCard to unlock the container. At this point, we now know who scanned to open the box. Students will pick out the parts that they require and then hold them up to a camera. The camera will recognize the QR codes on the components and then begin logging which student took what component in a backend. The camera is a peripheral of a microcontroller which stores this data. We also have another camera peripheral which essentially acts as a security camera to prevent any theft of parts and clear identification of individuals if any such event occurs. The same process applies for returning components. Students will scan their iCard to unlock the box and rescan the components to indicate that they are returning the components.

1.2.2 Visual Aid

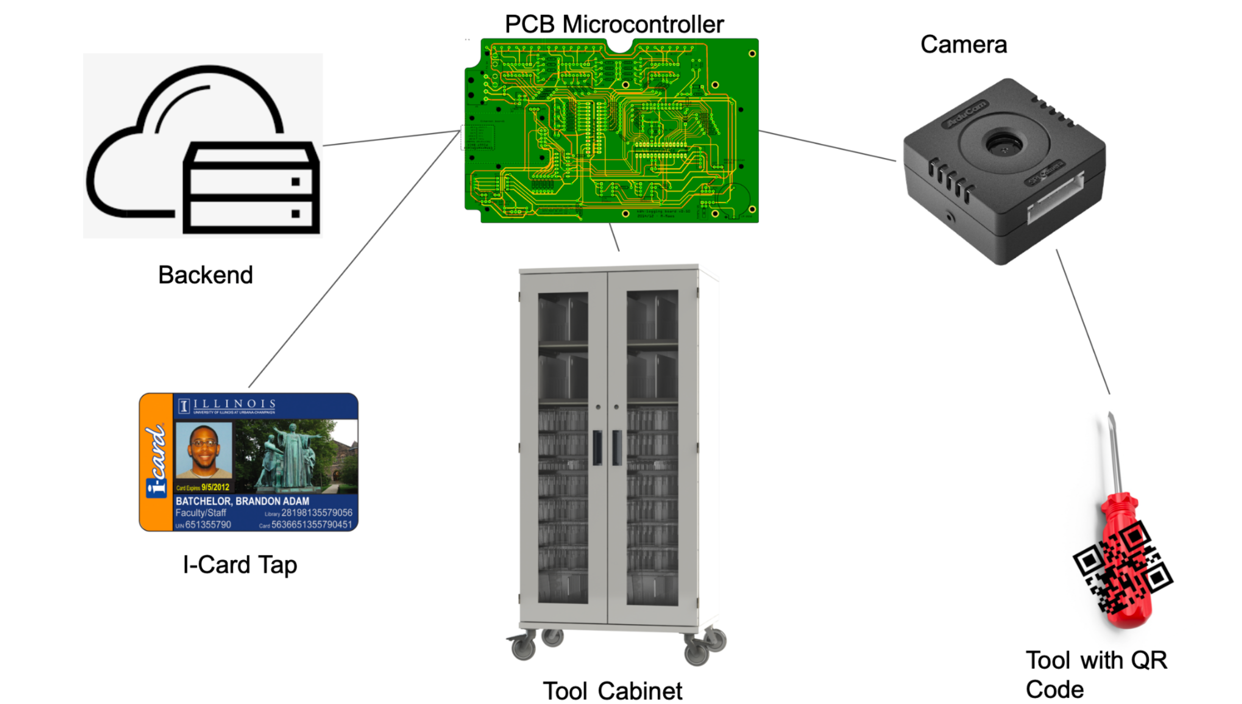

Figure 1: Block Diagram Overview for Camera Inventory System

1.3 High Level Requirements List

- The system should unlock the tool cabinet in less than 7 seconds from when a student first taps their iCard on the RFID reader.
- The system should be able to scan and recognize each component's QR code in less than 6 seconds of first appearing in the frame.
- The system should correctly update the database in less than 4 seconds when a student borrows or returns a tool after receiving its unique identifier from the QR code.

2. Design

2.1 Block Diagram

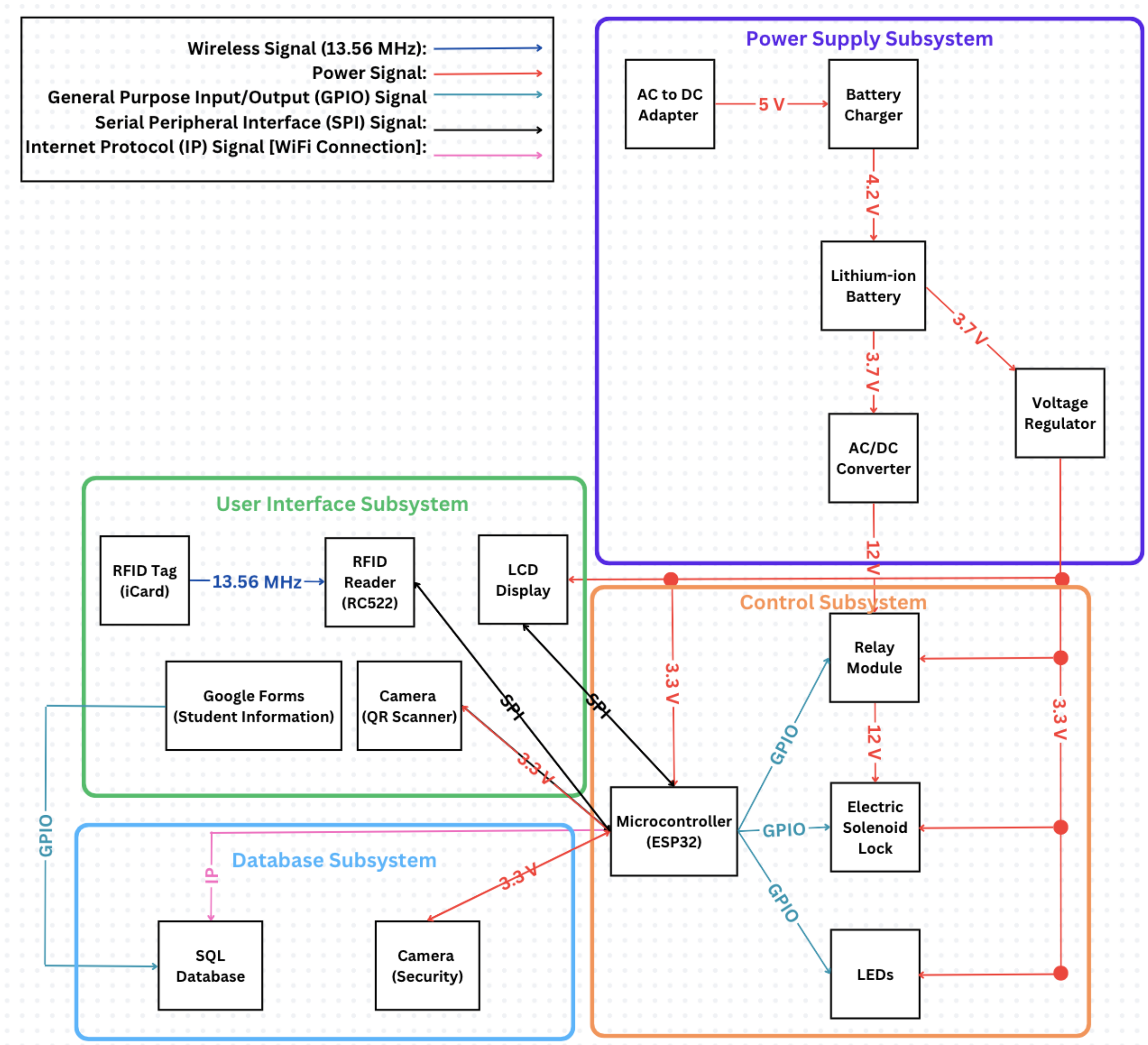

Figure 2: Block Diagram Overview for Camera Inventory System

2.2 Subsystem Overview & Requirements

User Interface Subsystem:

This subsystem comprises several key components, including a display unit (LCD) that provides real-time information about the system's status, a RFID reader for students to input their iCard, and a camera which acts as a barcode scanner for QR codes affixed to the components they wish to borrow or return. Before students can scan their iCards which contain RFID tags, they must first complete a Google Form. This form collects essential personal information, such as their name and University Identification Number (UIN), which is then stored into the SQL database. This information is vital for verification purposes and ensures that the student's identity matches the database records. Now, when a student approaches the container, they begin by scanning their iCard. This initiates a communication process with the control subsystem.

If the student is indeed authorized, the control subsystem, specifically the ESP32, sends a signal to the relay board, effectively unlocking the container. A visible indicator, the green LED on the LED subsystem, illuminates to signal that the container is now accessible. With the container unlocked, the student can enter and select the necessary components. Once their selection is complete, they employ the barcode scanner to register the borrowed components. The user interface subsystem transmits the barcode data to the control subsystem, and the control subsystem logs this transaction within the database, ensuring a record is maintained. Finally, a signal is sent to the relay board to lock the container securely. The red LED on the LED subsystem activates, visually indicating that the container is now locked.

The components of this subsystem have specific requirements. The display unit, responsible for providing real-time system status information, is expected to have a screen resolution of at least 1280x720 pixels and a refresh rate of at least 60 Hz, ensuring a clear and responsive user interface [4]. The RFID reader, used to scan student iCards, should operate at a frequency of 13.56 MHz, possess a reading range of at least 1 inches (with a tolerance of ±1 inch), and offer precise card detection [2]. The camera acting as a barcode scanner, employed for reading QR codes on components, should exhibit a scanning speed of a scan per 4 seconds (with a tolerance of ±1 seconds) and a scanning angle tolerance of ±5 degrees, enabling swift and accurate component identification. In addition, students are required to complete a Google Form with their name and University Identification Number (UIN) before accessing the system, ensuring proper identification.

Control Subsystem:

This subsystem is made up of an ESP32 microcontroller, a relay board, electric solenoid lock, and LEDs. The control subsystem communicates to other parts of our system, such as the user interface, power supply, and database subsystems. When a student wants to access the container, they scan their iCard on the user interface, and consequently, the control subsystem checks with the SQL database whether the student is allowed to open the container. If they are, it sends a signal to the relay board to unlock the container. At the same time, it keeps a record of this transaction in the SQL database, like a digital logbook. The ESP32 has WiFi connection capabilities which allows us to produce bare-metal code to interface with the SQL database. When a student wants to borrow a component, they scan it with a barcode scanner, and the control subsystem records this in the database and then tells the relay board to lock the container securely until the next time it's needed. To make things even easier for users, the control subsystem controls two LEDs. When the container is open and ready for use, a green LED lights up, signaling that it's unlocked. When the container is locked, a red LED turns on, giving a clear visual indication that it is secured.

The ESP32 microcontroller should operate at a clock speed of at least 160 MHz, providing the computational power needed for system control. The relay board must be capable of handling high-current loads, up to 5A (with a tolerance of ±0.5A), to effectively manage container access [3]. The electric solenoid lock should exhibit an unlocking time of less than 3 seconds and demonstrate durability through a minimum of 200 unlocking and locking cycles, ensuring secure and reliable container access. LED indicators, including a green LED to signal an unlocked container and a red LED to indicate a locked container, facilitate clear user feedback and enhance the visibility of system status.

Power Supply Subsystem:

This subsystem comprises four integral components, which are an AC/DC adapter, a battery charger, a lithium-ion battery, and a voltage regulator, and plays a crucial role in maintaining system operation. The AC/DC adapter is responsible for converting the alternating current (AC) received from a standard wall outlet into direct current (DC), which is the type of electricity electronic devices require. Specifically, the AC/DC adapter employed in our automated camera-inventory system is rated for 12 volts (V) and 2 amperes (A), equating to a power output capability of 24 watts (W). This provides the necessary electrical foundation to drive the system's various functions. Adjacent to this, the battery charger is designed to replenish the energy stores of the lithium-ion battery when the system is connected to an electrical outlet. This charger, optimized for lithium-ion batteries, operates at a rating of 12.6V and 3A, delivering a charging capacity of up to 37.8 watts (W). This ensures that the lithium-ion battery is consistently prepared to power the system. The lithium-ion battery itself is a high-performance rechargeable energy source, and in our automated camera-inventory system, it boasts a capacity of 4400 milliampere-hours (mAh). This capacity translates to the ability to deliver up to 4.4 amperes (A) of current for one hour, demonstrating its ability to sustain system operation [6]. Lastly, the voltage regulator is tasked with maintaining a stable output voltage, specifically set at 12 volts (V) in the system. Regardless of fluctuations in the input voltage, the voltage regulator ensures that the supplied voltage remains unwavering, contributing to the system's reliability and consistency. Evidently, the power supply subsystem facilitates the operation of all other subsystems by providing them with the necessary electrical power.

The AC/DC adapter should efficiently convert AC power to 12V and 2A of DC power, maintaining voltage and current within tolerances of ±0.5V and ±0.2A, respectively, ensuring a stable power supply foundation [5]. The battery charger must effectively replenish the lithium-ion battery at 12.6V and 3A (with voltage and current tolerances of ±0.2V and ±0.3A), guaranteeing the readiness of the power source [1]. The lithium-ion battery should boast a capacity of 4400mAh, delivering a continuous current of at least 4.4A for 1 hour in order to indicate its capacity to sustain system operation during power interruptions. The voltage regulator is tasked with maintaining a steady 12V output voltage, with a tight tolerance of ±0.1V, regardless of input voltage fluctuations.

3. Tolerance Analysis

We need to make sure that students are able to properly scan their QR codes using the camera connected to the ESP32. This interface is the essence of the project as a whole because it represents the system which replaces the manual process performed by the TA's currently. While it is the essence of the project, it is also the most challenging requirement as there are many factors that play a role when it comes to properly scanning the QR code. These factors are light intensity of the room, resolution of the camera, size of the QR code, distance between the camera and the QR code, and the density of the QR code.

However, due to the project, we can hold these following factors as constant and eliminate them from our tolerance analysis: light intensity of the room, resolution of the camera, and the density of the QR code. Therefore, the primary components that we need to pay attention to are the sizes of the QR codes and the distance between the camera and the QR code.

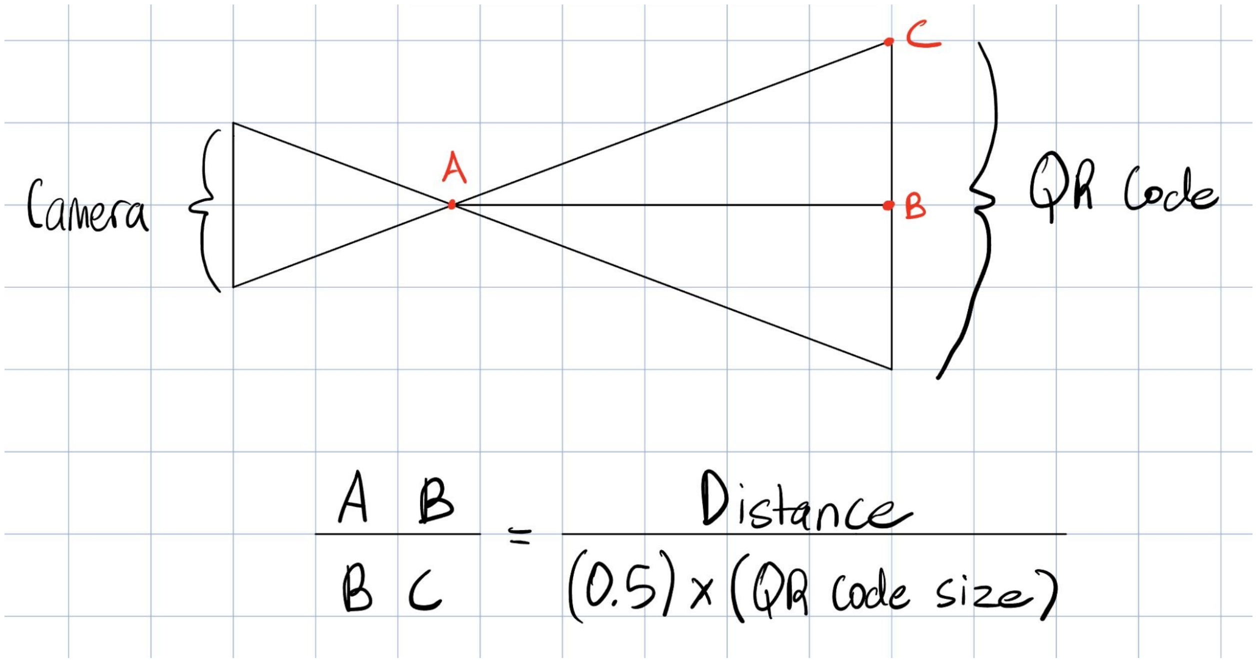

Figure 3: Camera and QR Code Diagram with formula including relative lengths

Using this derived formula and diagram, we can determine appropriate QR code sizes and corresponding distances that are ideal for the student without having to adjust too much. The units of measurements for both QR codes and distances would be in centimeters.

On the other hand, in terms of a tolerance analysis for the voltage regulator, we need to make sure that the voltage regulator is getting at least 3.3 V as an input and therefore we need to look at how the battery may be impacted in terms of providing that 3.3 V. This battery performance is dependent on where we are giving power to in the circuit and can look at the individual components and their current draws to determine the maximum time the battery can run before it drops below the required 3.3 V input for the voltage regulator.

Component	**Maximum Current Drawn (mA)**
Electric Solenoid Lock	430 mA [10]
Relay Module	2000 mA [9]
Microcontroller (ESP32)	80 mA [11]

Red LED	30 mA [12]
Green LED	20 mA [12]
LCD Display	2 mA [13]
2 Cameras	180 mA [14]
Total	**2742 mA (2.742 A)**

Figure 4: Maximum Current Drawn for Each Component from Power Supply

Total Battery Life (T) = (Capacity of Battery) / (Total Current Drawn)
T = (4400 mAh) / (2742 mA) = 1.605 hours

Given that our battery has a capacity 4400 mAh and the total current drawn from all the components which use the battery is 2.742 A, the total battery life would be around 1.6 hours or 96 minutes. To make sure that our battery can supply at least 3.3 V to the voltage regulator, it can only operate for up to 72 minutes without the battery voltage going lower than 3.3 V. Therefore, we need to ensure that this time constraint is met to validate that the components get the required power and can operate as needed.

4. Ethics & Safety

One relevant ethical concern for this system would be regarding user privacy. Since users are expected to stand in front of a camera to scan their item, there may be concerns about storing their biometric/facial information in our system as well, which users may understandably be uncomfortable with. The ACM Code of Ethics specifically raises this concern in their principle to respect the privacy of users, making it all the more important to heed. To mitigate this concern, we could make it clear to users that no visual information is stored - the camera is only used to read the QR code.

Another ethical concern is to avoid discrimination. As detailed in the ACM Code of Ethics, this is especially important given that our project may lead to technology-driven discrimination in terms of monitoring the supply cabinet. This project should not be used to prejudice or discriminate against any groups. To mitigate this, any violations found using our system should be thoroughly investigated by a user as well, to avoid any wrongful accusations.

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