# ECE 445 Senior Design Lab Proposal: Automatic Bookshelf Item Retrieval

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## 1 Introduction

### 1.1 Problem

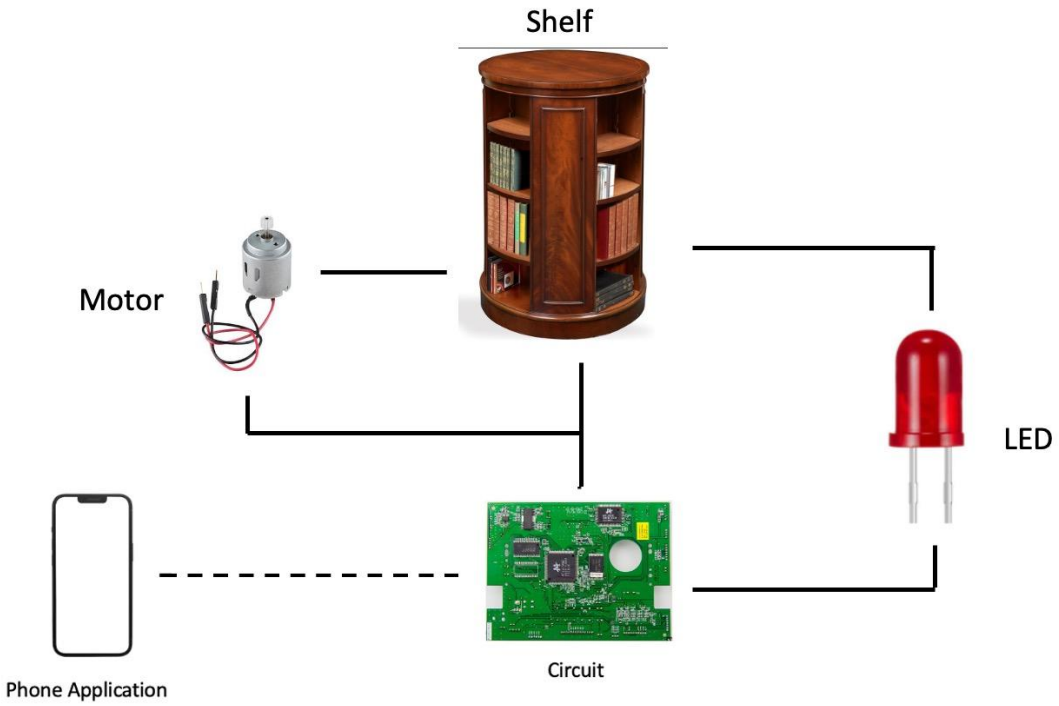
Oftentimes, when one has a lot of small electrical items, it can be very hard to keep track of everything. Components such as resistors and capacitors can be difficult to keep track of, especially when one has to keep track of many different components that look very similar. Things can get lost and disorganized very quickly. Something like a miniature bookshelf is what some use to organize their items, but they often can get very messy and it can be very tedious to find a specific item that one is looking for. It can also take a lot of time to find an item, and in general this is a bad user experience.

### 1.2 Solution

Our solution features a 4-sided miniature bookshelf, each side containing one section to place items, that rotates using a motor at the base of the bookshelf. This bookshelf will aid the user in finding their items easier by detecting when and where an item is inserted or removed from the bookshelf. On insertion, the user will enter the correct shelf ID into the app in order to mark that shelf with the current item. On retrieval, the user will be able to look up the item on the app, which will result in the bookshelf rotating to the correct side, and lighting up the shelf and specific location where that item is located.

The setup will be as follows. There will be shelf IDs placed on each side of the bookshelf labeled with a unique number. Each shelf ID will also be linked to an LED of that section and the combination of the two will be linked to the app. When the user looks to retrieve an item, the app will first figure out which section the item is located, then use the stepper motor to determine how much to rotate the bookshelf by in order to have the correct side face the user. Then, the LED will turn on to illuminate the object being retrieved. Insertion is much easier, as all the user has to type in the shelf ID of the section they put the item, which will be stored in the apps database.

## 1.3 Visual Aid



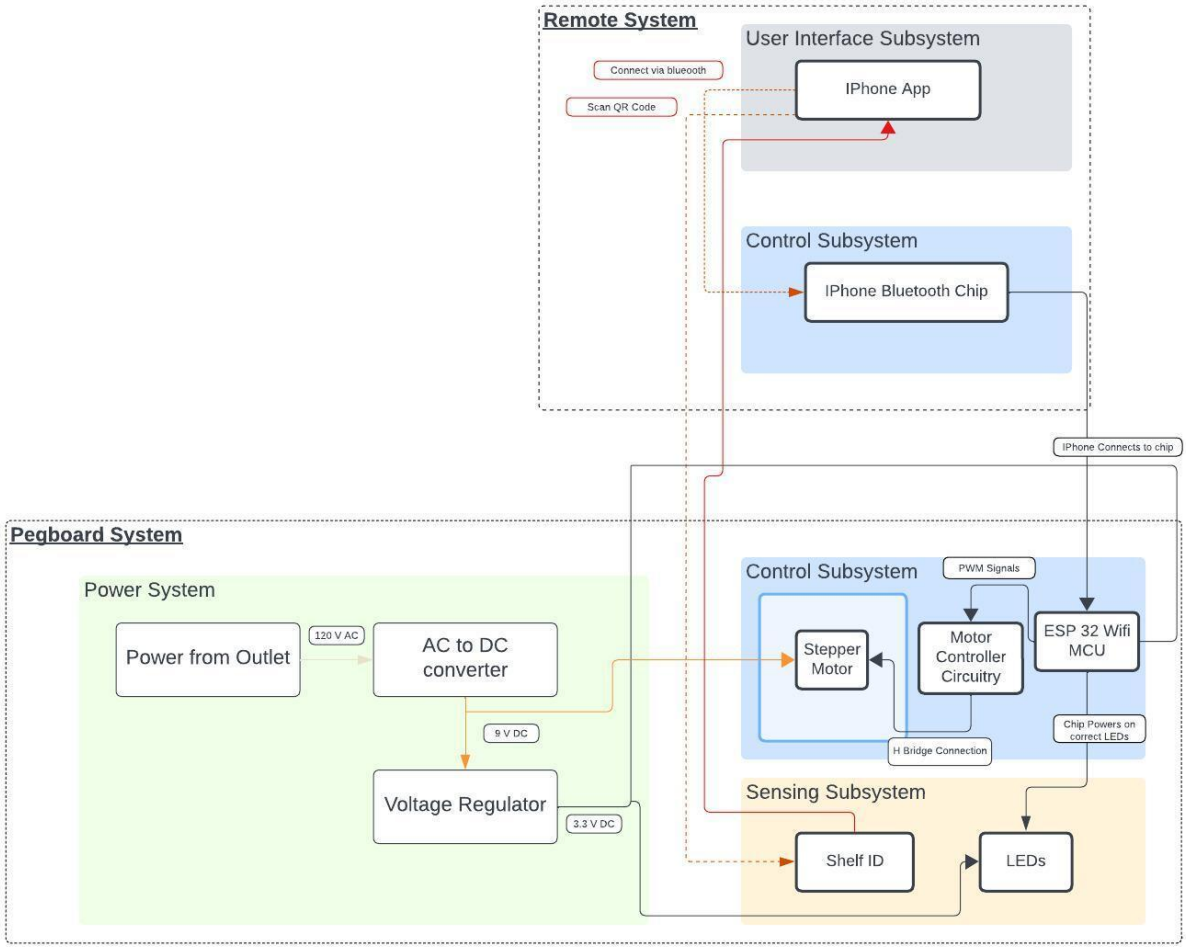

## 1.4 High Level Requirements

- Once prompted with the app, the bookshelf will turn to either angle 0, 90, 180, or 270 to face the user with the item that they requested to retrieve
- In the app, the user must be able to see 100% of the items they placed on the bookshelf (max of 16 items).
- Once the bookshelf has spun to the respective location based on what device the user is looking for, the LED will turn on within 15 seconds to show where the item is.

# 2 Design

## 2.1 Block Diagram

- Remote System - Contains the User Interface Subsystem and Control Subsystem on the phone. The User Interface Subsystem is connected to the rest of the system through bluetooth.
- Bookshelf System - Contains the Control Subsystem, Sensing Subsystem, and Power Subsystem that will be present on the bookshelf itself.



## 2.2 Subsystem Overview

- User Interface subsystem
    - This subsystem is what allows the user to interact with our device. On a mobile app, the user will be able to add more items to the bookshelf storage system, remove items from the system, and see what items are currently stored there.
- Control Subsystem (on Remote System)
    - This subsystem will allow the phone app to communicate with the PCB on the bookshelf system. It will use a bluetooth connection to send data between the the Phone System and the bookshelf System
- Control Subsystem (on bookshelf System)
    - This subsystem contains the microcontroller, potentiometer and motor. The microcontroller on the PCB will receive data from the remote system via a bluetooth connection. Based on this, the microcontroller will output the appropriate signals to the motor to turn it to the correct orientation. This subsystem also contains the potentiometer, which allows the microcontroller to determine the current orientation of the bookshelf system.
- Sensing Subsystem
    - This subsystem contains the LEDs and shelf IDs, and in a way also acts as the main way the user interacts with the bookshelf system. The LEDs alert the user to the exact position of their item, and the shelf ID allows them to input where they are placing the item to the system.
- Power Subsystem
    - This subsystem will contain the circuitry to convert the power to appropriate voltage levels. It will distribute the power to the motor, potentiometer, and all the components on the PCB such as the microcontroller.

## 2.3 Subsystem Requirements

- Sensing subsystem
    - This subsystem contains shelf IDs that will be read by the iPhone app of the user interface subsystem. There will be 4 unique shelf IDs. When the user is storing an item, the shelf ID allows them to select the location of the item being placed. This way, when an item is being retrieved, the control subsystem is aware of where the item is. For this component to be considered working, it should be able to be scanned and the correct code read. There will also be LEDs spread throughout the bookshelf, each belonging to one section of the bookshelf. When an item is being retrieved, the control subsystem will signal the appropriate LEDs to light up. This will allow the user to easily see where their stored item is. The correct LEDs should light up within ~15 seconds of an item in that section being selected for retrieval, otherwise this subsystem would not be working as intended.

| Requirements | Verification |
|---|---|
| ● The shelf ID should be assigned to a specific storage space in the app | ● Insert the shelf ID for 10 objects into the app<br>● Using the app, check the contents specific shelf ID<br>● Verify that only the items of that shelf are showing up under that shelf ID<br>● Repeat steps 2 and 3 for the other three shelves until all 10 objects have been verified in the correct location |
| ● The shelf ID should be connected to the LED that is placed in that section | ● Insert the shelf ID for 10 objects into the app<br>● Using the app, retrieve one item in one of the shelves.<br>● Ensure that the LED turns on for only the section in which the item was placed<br>● Repeat steps 2 and 3 for the other three shelves until all 4 LEDs have been turned on at least once |
| ● LED lights up within 15 seconds of retrieval | ● Insert the shelf ID for 10 objects into the app<br>● Using the app, retrieve an item of choice.<br>● After the bookshelf rotates and comes to a stop, start a timer<br>● Stop the timer when the LED turns on<br>● Ensure that the timer reads less than 15 seconds<br>● Repeat steps 2-4 until all 4 LEDs have been verified to turn on within 15 seconds |

- Power subsystem
    - This system will be responsible for distributing power throughout the entire bookshelf system. It will have 120V AC power as an input, and will output 3.3V DC power to the microcontroller. It will also output the required voltage to the motor. Since the specific motor has not been selected yet, this voltage is to be determined. To test this subsystem, a test load can be chosen that draws a large amount of power. This amount of power should be higher than the peak draw of

the bookshelf system. If the power subsystem can output this power continuously, then it can be verified to be working, otherwise this subsystem does not meet the necessary requirements.

| Requirements | Verification |
|---|---|
| • The system should be protected against overvoltage, overcurrent, undervoltage, and undercurrent. | • Connect to power and ensure all systems are attached to the bookshelf.<br>• Solder wires to the power rail and ground.<br>• Using a multimeter, measure voltage, current, and resistance and connect the probes to the power and ground wires to check that all their values are within their allowed range. |
| • The Power Subsystem must be able to supply at least 500mA to the rest of the system continuously at 9V ±0.1V and at 3.3V ±0.1V after the voltage step down. | • Connect to power and ensure all systems are attached to the bookshelf.<br>• Solder wires to the power rail and ground.<br>• Connect the multimeter to the probes to measure the voltage of the device of a multimeter to ensure it is 9V ±0.1V and 3.3V ±0.1V after the step down.<br>• Measure the current by connecting a resistor to the circuit and placing the probes of the multimeter on either side of the resistor<br>• Check to make sure that the current is greater than or equal to 500mA |

- Control subsystem (bookshelf System)
    - The control subsystem contains most of the logic of the bookshelf system. It contains the ESP32 microcontroller, as well as the motor and potentiometer. The ESP32 will receive data from the phone system through the inbuilt bluetooth capabilities of the microcontroller. It will also determine the current orientation of the bookshelf system with data from the potentiometer. Based on all this, the microcontroller will send signals to the motor to rotate it the correct amount and direction. Some ways of verifying this subsystem is working correctly include verifying that the bookshelf stops within +/- 10 degrees of the correct orientation. There are also end to end tests that can be conducted. This includes inputting a retrieval request on the app, and confirming that the bookshelf aligns itself correctly. While this test relies on another subsystem, it is the best way to test the overall capabilities of the control subsystem.

| Requirements | Verification |
|---|---|
| ● The system should allow users to choose an item to retrieve, and have the bookshelf turn towards the user with the requested item | ● Using the app, choose an item from the bookshelf you want to retrieve<br>● Once chosen, the bookshelf should spin to “angle 0,” which faces the user<br>● If the bookshelf stops within +/- 10 degrees of “angle 0,” it can be assumed that it works properly |

- User Interface Subsystem
    - This subsystem is how the user adds and retrieves items from the system. There will be a mobile app which allows the user to see all the current items in the system. They will also be able to insert the shelf ID of the item into the app in order to add an item. This is how the system will keep track of where each item is. When an item is being added, the user will be able to enter a name affiliated with each item. The app will also allow users to request items through the app. For this subsystem to work, it must be able to accurately keep track of each item and its location.

| Requirements | Verification |
|---|---|

| | |
|---|---|
| ● The system should allow users to accurately input bookshelf items onto the app interface | ● Choose an item from the bookshelf to add to the app<br>● Input a description of the item, and the shelf number of where the item has been placed<br>● Once added, verify if item is shown on app with the correct description and bookshelf location |
| ● The system should allow users to accurately choose an item from the bookshelf to retrieve | ● Choose an item from the app that you want to retrieve<br>● Once item has been chosen, observe bookshelf to see if it turns to and lights up at the correct location of the object you're looking for |

- Control Subsystem (Remote System)
    - This subsystem is responsible for sending data to the other control subsystem on the bookshelf System. The communication will occur using the phone's inbuilt bluetooth capability. This subsystem must accurately transmit all item additions and requests to the microcontroller for it to meet its requirements.

| Requirements | Verification |
|---|---|
| ● The system should be able to accurately transmit data from the mobile app to the bookshelf | ● Once app has been completely implemented, verify if all items on bookshelf are shown on the app interface<br>● Once all items on bookshelf are verified, choose one item that you |

| | |
|---|---|
| | would like to retrieve<br>● Once item has been selected, observe bookshelf to see if it turns to the correct location with the item you are looking for, and if the LED turns on<br>● Repeat for different items on the app to confirm if app and bookshelf has synced properly |

## 2.4 Tolerance Analysis

| Part | Worst Case Current Draw at 3.3V (mA) | Comments |
|---|---|---|
| ESP32-S3 | 340 | In active mode, the worst case current draw is quite high. In practice, it will likely be lower as the highest RF power will not be required. |
| Red LED | 15 | Red LED has a voltage drop of 1.8V and with a series resistor of 100 Ohms this results in a 15 mA draw |
| Current Sensors (4) | 9.6 | 2.4 mA draw from each current sensor, of which there are 4 |

| Variable | Value | Comment |
|---|---|---|
| Max Temperature | 150℃ | From LM317 Datasheet |
| Iout | 364.6 mA | |
| Vin | 5V | |
| Vout | 3.3V | |
| $\Theta_{ja}$ | 100 C/W | Junction to Ambient thermal resistance |
| $T_a$ | 40℃ | |

$$T = i_{out} * (V_{in} - V_{out}) * (\Theta_{ja}) + T_a = 0.3646A * (5.5V - 3.3V) * 100\,C/W$$

$$= 61.982℃ + 40℃ + 101.982℃$$

This temperature is significantly below the maximum operating range for the LM317. Based on this preliminary result, the LM317 will be able to output the required power while not overheating. It is important to note that a separate AC-DC converter will be required for the motor system. This is because if a single AC DC converter is used, the voltage drop across the

linear regulator will be higher. To account for this, a more complex regulator circuit would be required. Thus, we chose the tradeoff of having 2 AC-DC converters.

# 3 Ethics & Safety

There are a few ethical and safety concerns that we must consider when building our automatic item retrieving bookshelf.

## 3.1 Ethical Concerns

- **Privacy:** Privacy is a very prevalent ethical concern that many devices face. It is imperative that we consider the privacy of bookshelf users to ensure that we aren't collecting and storing any personal information that could be used negatively.
- **Data Security:** For data that we are collecting, it's important to protect the data effectively to ensure that no sensitive information is being stored in insecure locations. We must also not collect any more data than is necessary for our design to work.

## 3.2 Safety Concerns

- **Physical Safety:** When thinking about physical safety with the design of our bookshelf, it's important to consider that the mechanical and electrical components of the device are up to industry standards. With the mechanical components, we have to make sure that the motor and potentiometer are strategically placed in locations that won't be able to physically harm users of the bookshelf. With electrical components, it's important to ensure all wires are properly grounded and aren't exposed. Since this design contains 120V AC power, we must be sure to design a safe power distribution system that follows industry standards. We must also ensure that there are no pinch points in the mechanical design that could harm the user.
- **Fire Safety:** As we are using electrical components and various power sources, it's important to ensure that we don't input too much power at a given time to reduce overheating and potential fire hazards. We must also size all conductors correctly to reduce the risk of overheating, and will have to use appropriate overcurrent protection methods. This is an especially important point to consider because our design contains a motor which will have a high inrush current. So it will be important for us to design a safe system that takes this into account.

## References

1. https://www.piher.net/wp-content/uploads/PIHER_PC-16.pdf