ECE 445
Senior Design Laboratory
Project Proposal

Inventory Tracker

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Problem

Inventory tracking is an essential process in all types of applications ranging from small businesses to larger ones. It helps business owners keep track of their supplies and optimize their inventory levels based on demand. In addition, controlling the inventory could increase profitability when performed accurately. The process of tracking inventory is often done manually as it helps reduce cost, but this results in inaccurate results and discrepancies in the available supply due to human error. Moreover, it can be burdensome and time consuming as it often becomes repetitive which leads to inefficiency. As a result, automation has revolutionized the inventory tracking process. Although automating inventory tracking has been applied in several industries, small startups and business owners are still required to manually process their inventory due to the high cost of automation. Therefore, it is essential for them to shift to automating the process for a sustainable solution with less cost. Moreover, manual tracking is not only unreliable but it also poses a threat to the inventory as it remains unsecure at all times.

Solution

One proposed solution to the problem of asset tracking in small-owned businesses is a low-cost fully automated inventory management tracking system. This system would use an RFID scanner to scan an ID and unlock supply boxes to give users access. For additional security, it will allow users to only access inventory they are authorized to. The user would then be able to check the supplies available to them. The system would be connected to a web database that would display the stock of each item, what items have been checked out by which users and how many items have been checked out. Moreover, the system would allow a supervisor to access all supply boxes and restock products and update the total in the database. This would also help the user in visualizing the stock of inventory to see which items are in demand and thus increase efficiency and productivity.

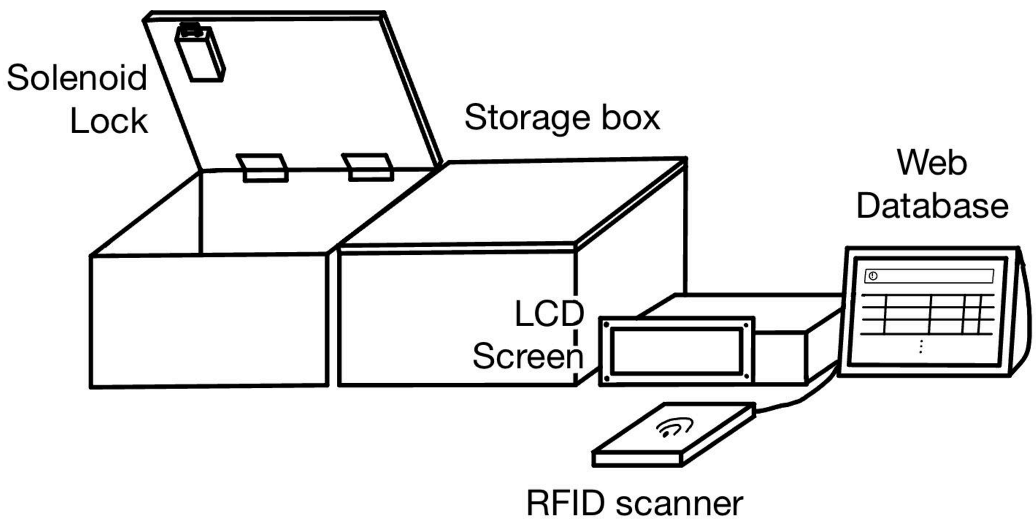
Moreover, the system would alarm the user if unauthorized access has been detected. This would be established through a locking mechanism for the boxes. The boxes would be locked with a magnet and current carrying wire to hold them shut. Once a user scans their RFID card, only the boxes they have access to will unlock and a message would appear in the display to mark which box has been unlocked. Finally, if a box is opened forcefully, this will alarm the user through the database that an unauthorized person has opened it.

High Level Requirements

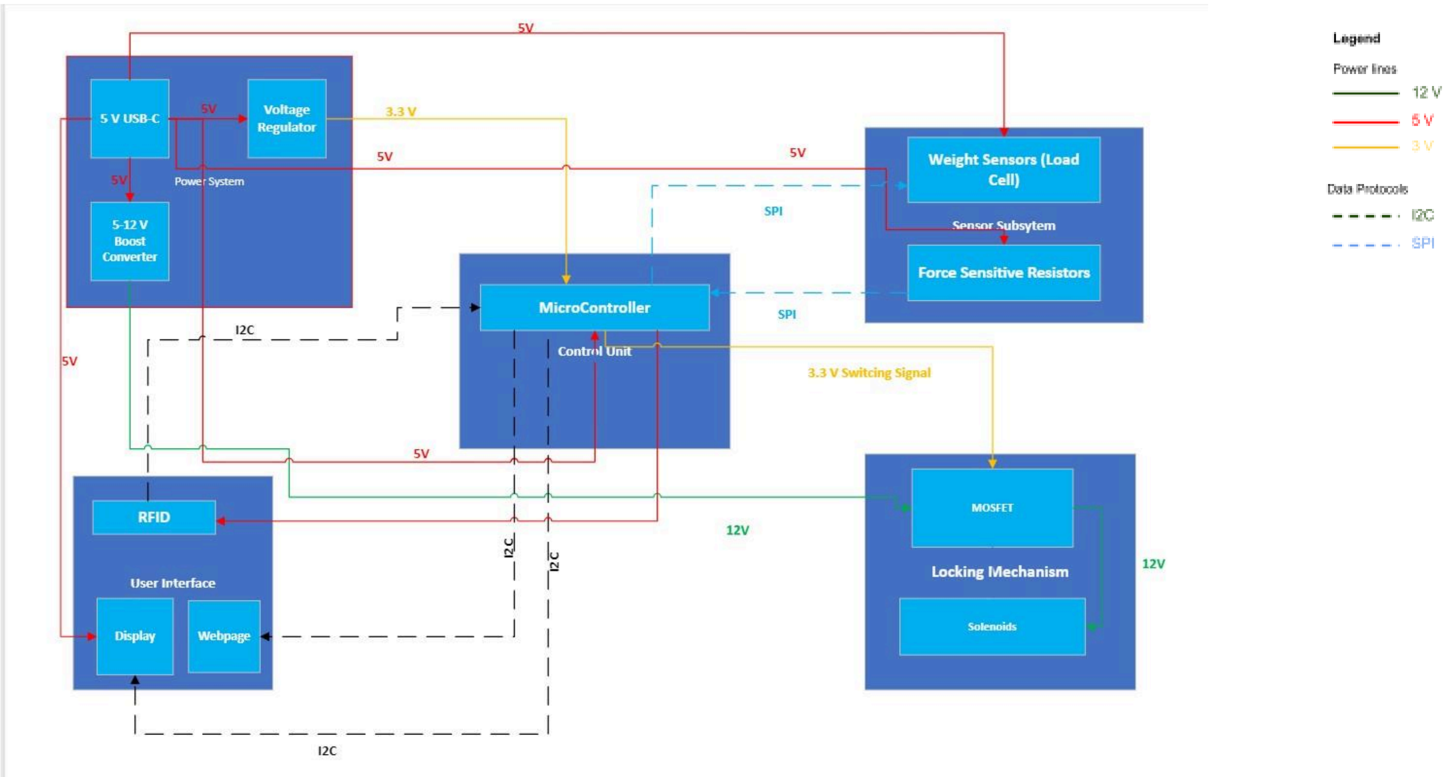
1. When the user scan's their RFID card, the solenoids on the boxes the user has access to should unlock within 5 seconds and the LCD display should display the boxes the user has access to in this same time.

2. When the user takes an item out of a box, the web database should display the item taken out and what user took it out within 5 seconds. The webpage should always display the number of items in stock and keep track of items checked out and who checked them out.
3. The alarm system should be triggered when force is applied to a locked box. Within 5 seconds of sufficient force being applied to the box door, both the LCD and web database should display that someone has tried to open a locked box.

Visual Aid



Block Diagram



Subsystem Overview

The system consists of 4 main subsystems: Power, Control Unit, Sensors, User interface, and Locking System.

1. **Power**
   The power subsystem should power the other units in the system. It includes a 120V AC to 5 V DC USB-C adapter, a 5V to 12V boost converter to power a solenoid lock which would be used in the Lock System, and a 5V to 3.3V voltage regulator to power the ESP32 microcontroller.

2. **Control Unit**
   The control unit will be the ESP32 microcontroller. It should receive data from the RFID module, weight sensor, and locking system. It will use this information to determine what should be shown on the display and which boxes to unlock.. It is powered by the 5V to 3.3V voltage regulator.

3. **Sensors**
   The sensors communicate information to the microcontroller and the locking system. The weight sensor will determine how many items are in each box and will use this information to determine if items have been checked out. The pressure sensor will monitor the door on

each box to determine if it is open forcefully or not, and communicate this to the locking system.

4. **User Interface**
The user interface consists of the RFID module and a display. The RFID module will allow users to access the selection of boxes they have been given access to through their RFID card. It will communicate with the microcontroller, which will communicate with the locking system for successful operation. Items checked out by the user, along with current stock of items, will be visible on a web page.

5. **Locking System**
The locking system consists of a solenoid lock, which uses a 12 V pulse to unlock when triggered by the RFID module. There is also an alarm system that will be triggered if a box is forcefully opened, but is supposed to be locked. This alarm will be present on the web database to warn the user.

Subsystem Requirements:

1. **Power**
    a. Power all the components of the system (around 3.3V-5V for sensors and microcontroller, 12 V for solenoid)
    b. Main power of supply would be a USB-C cable that would be plugged into the wall (about 120 V AC)

2. **Control Unit**
    a. Microcontroller successfully interfaces between the WIFI module (for the database) and the display to update stocked items and user checkout history.
    b. Microcontroller successfully determines the user-control features, while only unlocking the drawers that the user should have access to (it should determine that from the RFID Reader Module).
    c. Microcontroller successfully triggers the alarm system once unauthorized access has been noticed. It should differentiate between unauthorized access and authorized access successfully.
3. **Sensors**
    a. The weight sensor will monitor the amount of items in each box.
    b. The pressure sensor will monitor the doors of each box to determine if they are open. This will be part of the alarm system.

4. **User Interface**
    a. After the RFID, the microcontroller, and the locking system successfully unlocked the drawer to which the user has access to, the Display monitor should display the specific drawer to open.

b. The web database should display the supplies checked out and the user that checked them out with timestamps.
c. It should also track the items available and highlight those that are low in stock.

5. **Locking System**
   a. A solenoid door lock should hold the door locked at all times, except when the RFID module allows access.
   b. Once the RFID module sends data to unlock the box, a voltage will be applied to the solenoid to unlock the specified box.
   c. A pressure sensor in the drawer will detect if the drawer is open with force or not.
   d. The alarm will be triggered if the pressure sensor detects the drawer is open, and no voltage has been applied to the solenoid (which means it should remain shut and therefore uncertified access is encountered).
   e. The webpage will update to show that the alarm is triggered.

Tolerance Analysis

1. Consistent Power

One major aspect of this project that is critical to its success is ESP32 microcontroller. The microcontroller needs to have consistent power in order to work properly. To power the microcontroller, the LM317 voltage regulator will step down 5 V to about 3.3 V. The voltage regulator must be able to do this consistently and not overheat. According to the ESP32 datasheet [2], it can operate with an input voltage from 3.0 V to 3.6 V, so the voltage regulator must be able to stay within that range. According to the Wiki page on the ECE 445 website [1], the equation to determine the operating temperature of the voltage regulator is $T= i_{out}(v_{in}-v_{out})\theta_{ja}+T_a$ where θ_{ja} is the junction-to-ambient thermal resistance and T_a is the ambient temperature, assumed to be 25 °C.

According to the datasheet of the regulator [4], it can operate at temperatures up to 150 °C and is recommended to operate at less than 125 °C. It also has a junction-to-ambient thermal resistance of 66.8 °C/W. According to the ECE 445 Wiki page, the ESP32 should draw at maximum 355 mA. Using these parameters and the equation above, assuming in the worst case we operate at the minimum 3.0 V, the maximum calculated regulator temperature is 72.43 °C, which is within the recommended operating range.

2. Accurate Weight Sensing

To make sure the weight sensor we will be using can accurately sense the weights of all items we plan to put into the inventory, we have to find the appropriate range of weights that different kinds of weight sensors can support. Some weight sensors also need to be calibrated with known weights to function correctly, so deciding the range of weights/force and carefully choosing the right sensor are crucial for the system to work properly and accurately.

Force sensitive resistors (FSR) vary their resistance depending on how much pressure is being applied to the sensing area. Depending on the size of the resistor, FSR can sense applied force anywhere in the range of 100g - 10kg or as low as 2g. These sensors are simple to set up and great for sensing pressure, but they aren't incredibly accurate.

A strain gauge load cell is a type of electronic sensor used to measure force or strain. It comes in 1kg, 5kg, 10kg, and 20kg. For this load cell, we need to make sure to pick the one that has at least twice the max force/weight we intend to apply, the weights of items, so we get the most precision with the right range. So picking a 1kg strain gauge means the total weight of items for this section needs to be under 0.5kg for precision. Picking the 20kg strain gauge means we can have the weights of items to be up to 10kg.

Ethics and Safety

To ensure we work on this project in an ethical and safe manner we plan on following the IEEE Code of Ethics [3]. When issues arise between group members we will try to go through each person's point of view on the problem and try to find a good solution for everyone in a fair and efficient way. We understand the necessity of bringing up problems early before they can make working together a major difficulty. Along with that, we understand that this is a learning experience and we will focus on learning throughout this project.

Regarding privacy of data collected by the web database for user inventory tracking, we will ensure user data remains private and is only confined to the web database. The user's personal information will not be visible to the public and only necessary information will be kept. There will be no sensitive information stored in our database that can be easily used by the public to identify users (ex. names). We plan on only storing a form of identification number as user information. To further mitigate this concern, we plan to control access to the database with a PIN code so only authorized users can view the database of inventory tracking records.

Another concern is temperature regulation. The ESP32 can operate at up to 105 ^{o}C [3] and most other components can handle up to 125 . Using components above their rated temperature could cause components to burn and create safety hazards. In order to mitigate this, team members must determine the maximum temperature of components under the intended operating conditions and measure temperature of components during the testing procedure. Team members must disconnect power when it is determined that components are overheating, in order to mitigate damage to the system and avoid potential safety hazards.

References

[1] ECE 445. “Linear Regulators”. https://courses.engr.illinois.edu/ece445/wiki/#/regulators/index. (accessed Feb. 20, 2024).

[2] Espressif Systems. “ESP32-S3-WROOM-1 ESP32-S3-WROOM-1U Datasheet”. Espressif.com. https://www.espressif.com/sites/default/files/documentation/esp32-s3-wroom-1_wroom-1u_datasheet_en.pdf (accessed Feb. 8, 2024).

[3] IEEE. “IEEE Code of Ethics”. IEEE.org. https://www.ieee.org/about/corporate/governance/p7-8.html (accessed Feb. 8, 2024).

[4] Texas Instruments. “LM317 3-Terminal Adjustable Regulator”. https://www.ti.com/lit/ds/symlink/lm317.pdf?ts=1708370372081&ref_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252Fes-mx%252FLM317. (accessed Feb. 20, 2024).