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

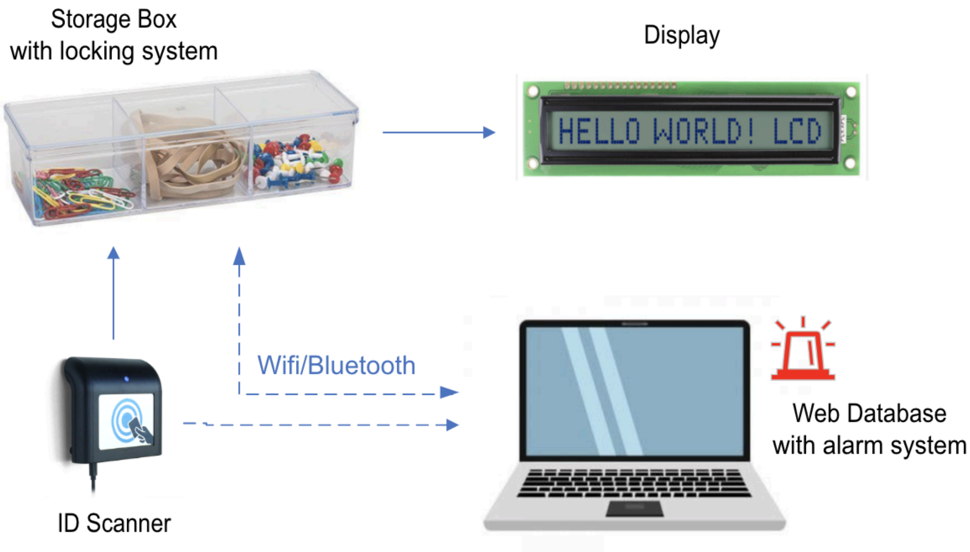
One proposed solution to the problem of asset tracking in small-owned businesses is a low-cost fully automated inventory management tracking system. This system would use an RFID scanner to scan an ID and unlock supply boxes to give users access. For additional security, it will allow users to only access 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.

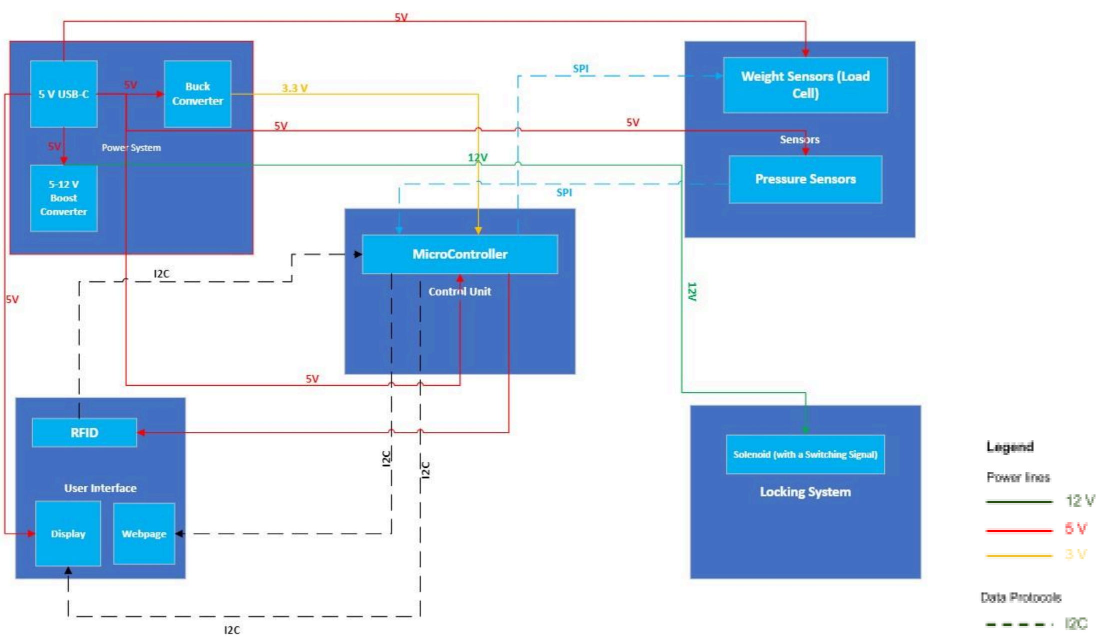
High Level Requirements

1. The user should be able to scan RFID to only unlock the drawers they have access to.
2. The user should be able to check out supplies and the web database should display the supplies checked out and the user that checked them out.
3. Alarm system should trigger when a drawer is opened by force.

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 buck converter 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 buck converter.

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**

   A portion of the project that is very important is the power system for the microcontroller. It will be a 120 V AC to 5V DC USB-C connector which will be stepped down to 3.3 V with a buck converter. The microcontroller will need a consistent voltage, so the filter of the converter needs to be properly designed.

   The ESP32 microcontroller needs an input voltage between 3.0 and 3.6 V [2].
   These are the equations for the output filter calculations.

   $L = (V_{in}-V_{out})D/(\Delta i_L f_s)$
   $C_{out} = \Delta i_L/(8 f_s \Delta V_{out})$,
   where D is the Duty Ratio, Δi_L is inductor ripple current, and f_s is switching frequency.

   A possible converter we found is the TPS563203, which has an input voltage range of 4.2 to 17 V and an output current maximum of 3 A [4]. It has a switching frequency, f_s, of 600 kHz [4]. A good rule of thumb for inductor current ripple is 30% of the total inductor current [1]. The ESP32 uses a minimum of 30 mA [2]. This would make the ripple current 9 mA based on the 30% rule. Given the required input voltage for the ESP32, the maximum output ripple voltage would be 0.6 V.

   The input-output relationship for a buck converter is $V_2=DV_1$. Since the voltage is being stepped down from 5 V to 3.3 V, the duty ratio would be 0.66.

   Using the output filter equations, the inductor value needs to be at least 208 uH and the output capacitor needs to be at least 3.125 nF.

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.

To ensure each team member is treating this project with the proper seriousness and care, we will hold weekly project update meetings outside of meetings with our TA and meetings to work on the project. We will also constantly evaluate how we are doing things to determine the most efficient and ethical ways to work on this project. This will also allow us to determine if there are any problems between team members that need to be addressed.

Regarding data collected by the web database for user access control, 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.

References

[1] Analog Devices. “Selecting the Right Inductor Current Ripple”. Analog.com. https://www.analog.com/en/resources/technical-articles/selecting-the-right-inductor-current-ripple.html (accessed Feb. 8, 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. “TPS56320x 4.2V to 17V Input, 3A, Synchronous Buck Converter in SOT563”. TI.com. https://www.ti.com/lit/gpn/tps563203 (accessed Feb. 7, 2024).