Bench Organizer

Senior Design Laboratory - Project Proposal

Team #12

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Table of Contents

1. Introduction

1.1 Problem Statement

In shared workspaces such as maker spaces, engineering labs, and mechanical workshops, tools are frequently misplaced or missed due to human error. Users often forget to return tools to their designated locations after use. This typically leads to inefficiencies, wasted time, and workflow disruptions. Existing solutions, such as manual sign-out sheets, RFID-based systems, and barcode scanning, require extra effort from users.

A more advanced and convenient solution is needed to track shared tools in real-time without requiring users to scan tags or log tool usage manually. The system should be capable of identifying tools, monitoring their movement, and ensuring they are returned to their proper storage locations. By minimizing loss and disorganization without adding additional inconvenience to the user experience, this solution can significantly improve efficiency and resource management in shared workspaces.

1.2 Solution

We propose a computer vision-based Bench Organizer that utilizes a camera to monitor a tool rack in real time, reduce tool misplacement, and improve efficiency in shared workspaces. The system employs OpenCV-based object detection models to detect and recognize tools and allow users to manually record a reference frame that captures the correct tool arrangement. By comparing the current frame with the recorded reference, users can quickly identify missing tools. Additionally, the system performs automatic checks at pre-set intervals to ensure tool availability and logs tool usage history, notifying users when a tool has been missing for an extended period.

To enhance user interaction and reliability, the system provides real-time alerts via LED indicators when tools are missing. It features a Bluetooth-connected camera module (Raspberry Pi Camera + Bluetooth Adapter) that operates separately from the processing unit, allowing flexible placement. Instead of a touchscreen, it uses a standard display screen with four physical buttons for control, ensuring simplicity and durability. This automated, low-maintenance solution improves organization and minimizes time wasted in shared work environments. In addition, cameras are also set in or near drawers to monitor the items inside drawers

1.3 Visual Aid

Figure 1: Visual Representation of the Bench Organizer

As shown above, each drawer contains a camera to monitor the activity of the item in it. The camera on the bench is used to monitor the user's activity on the bench. The microcontroller records the item information based on the camera information in the drawer. It also update the status (misplaced, using, lost) of items based on the camera on the bench. The OLED/LCD is used to display each item's status. The alert LED is used to inform when items are missing or misplaced.

1.4 High-Level Requirements

- **Accuracy and Responsiveness:** The most important success indicator of our project is the accuracy of recognition and system responsiveness. Using a pre-trained machine learning model, we expect the system to recognize 90% of the items within the model's category. Additionally, by utilizing the Bluetooth module, we anticipate that the recognition process will take less than two seconds.
- **Robustness:** In real-world scenarios, the system may be affected by varying lighting conditions. In this case, we must ensure that the system is robust enough to function reliably without being impacted by these variations. Additionally, the system should be able to differentiate whether a user is taking or placing an item based on the movement of their hands.
- **Extended Functionality:** We also expect that when an uncategorized item appears in the camera's view, users will receive a notification and be able to scan it into the system. The next time the item is detected, the system should be able to recognize it.

2. Design and Requirements

2.1 Block Diagram

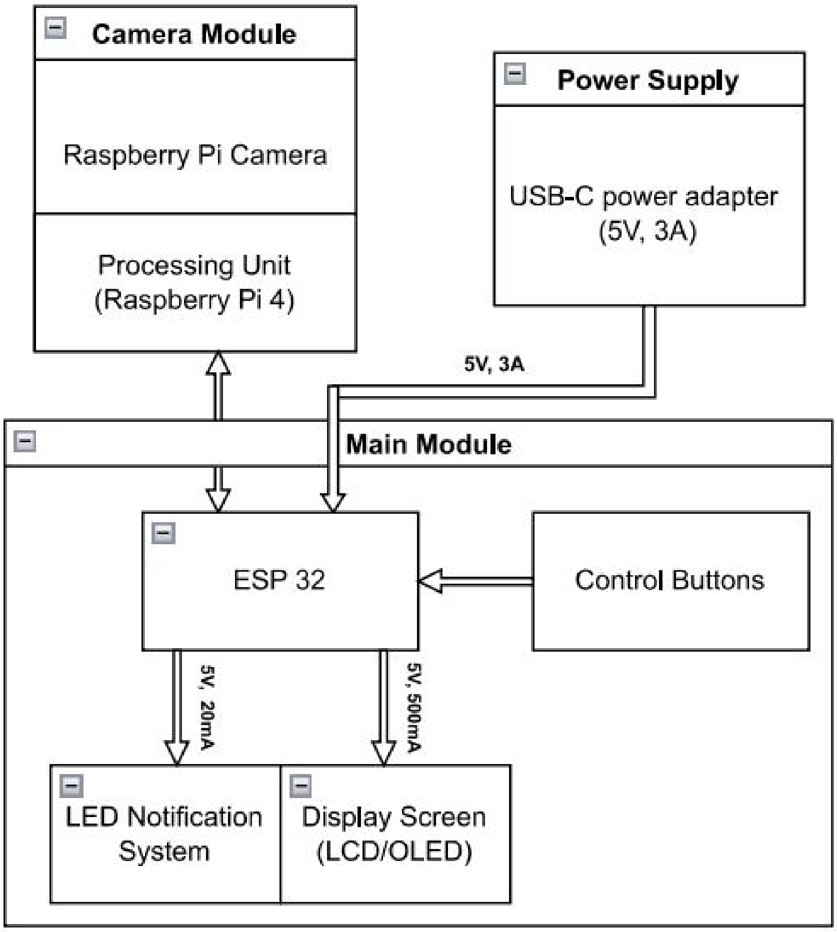


Figure 2 Block Diagram

2.2 Subsystem Description

Camera Subsystem

Raspberry Camera Module 3

Functionality:

The Camera Subsystem has one primary camera to monitor the user's activity on the tool rack to track the tool usage. Additionally, multiple cameras are integrated to monitor the changes in items stored within drawers to capture additions or removals in real time.

Contribution:

This subsystem captures the activity of the tool rack and drawer contents and transmits the images/videos to the processing unit via Bluetooth. By continuously monitoring tool interactions, it enables the system to detect missing or misplaced items. Furthermore, the camera subsystem also allows the system to recognize new tools added by users

Interface:

Inputs:

1. Visual Data (Images/Videos)
2. Command from the Processing Unit
3. Power source

Outputs:

1. Videos/Image Information transmitted to the processing unit via WIFI.

Requirement 1:
The Camera Subsystem must be able to accurately identify the same item under varying angles and lighting conditions.

Verification 1:
Test the subsystem by placing the same item in front of the camera at different angles and under different lighting conditions to confirm its ability to correctly identify the item.

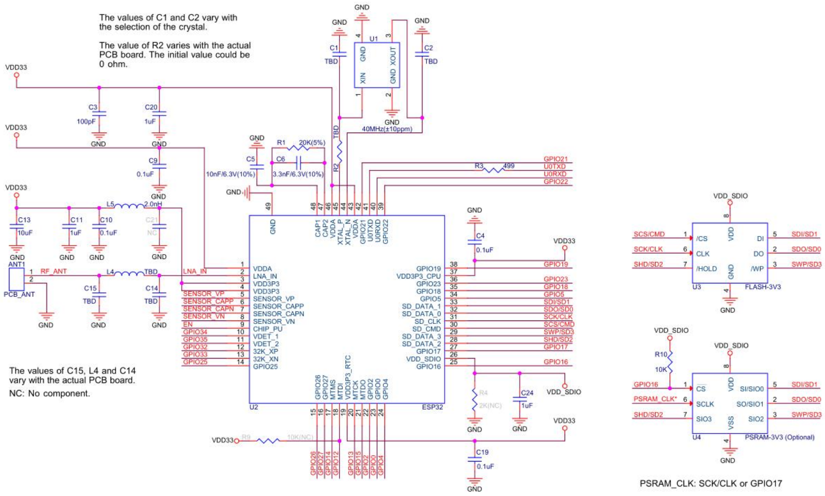
Requirement 2:

The Camera Subsystem must be able to accurately distinguish between different items to prevent confusion and errors.

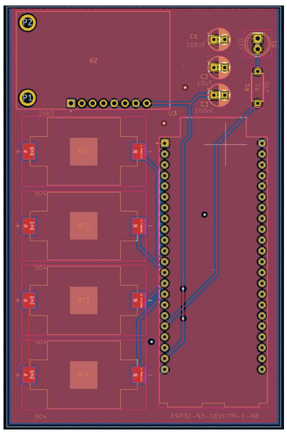
Verification 2:

Test the subsystem by placing similar items in front of the camera and verify whether it correctly identifies and differentiates each item.

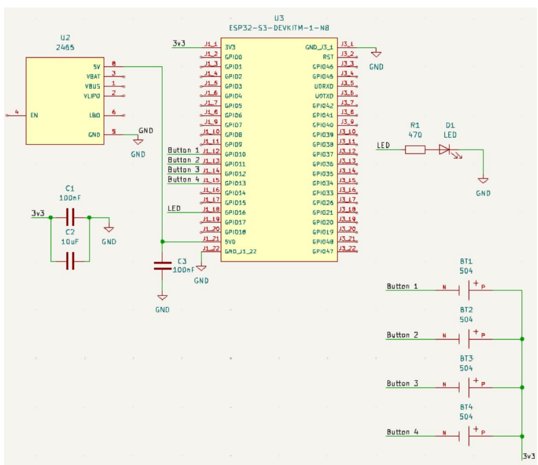
Processing Subsystem



ESP 32 Reference Schematic



Main Control Board



Main Control Board Schematic

Functionality:

The processing subsystem is powered by a microcontroller ESP 32, which serves as the central computing unit. It runs the pre-trained classification model using OpenCV which allows real-time recognition and tracking of tools. The model could recognize the items on the desk, detect missing tools or misplaced tools, and determine the appropriate drawer for storing newly introduced objects. In addition, it also manages the user interactions with the display and button inputs

Contribution:

This subsystem is responsible for analyzing visual data received from the Camera Subsystem, executing object detection algorithms, and making decisions based on tool presence and location. It also reduces tool misplacement and enhances workspace efficiency. Furthermore, it facilitates user feedback mechanisms, such as triggering LED indicators, updating the display, and logging tool usage history.

Interface:

Inputs:

1. Image and Video Data
2. Control Signal from the button
3. 5V/3A Power supply

Outputs:

1. Tool Status (missing, misplaced, newly added) updated to the Display
2. Control signal for LED indicators
3. Logged Data for usage history

Requirement 1:
The processing subsystem must be capable of receiving and transmitting data to and from other subsystems, including the Camera Subsystem and the User Interface Subsystem.

Verification 1:
Print the data or image received from the subsystems to verify that they match the expected results.

Requirement 2:
The processing subsystem must be able to update the status of each item when its status changes within the camera's view. The subsystem should be able to make the status change in 5 seconds.

Verification 2:

Manually change the status of specific items on the bench or in the drawer (e.g., remove an item from the bench or place an item in the drawer) and verify whether the system correctly updates the item's status.

Requirement 3:
The processing subsystem must be able to log information for any new item introduced to the system.

Verification 3:
Place an item that is not already in the system's database and register it. Verify that the item's information is accurately recorded in the system.

User Interface Subsystem

Functionality:

This subsystem provides a visual and interactive platform for users to monitor and manage tool organization. It includes an OLED display to present real-time item information, including tool status, missing or misplaced items, and storage guidance. Users can interact with the system through physical buttons to look for the items or log in a new item to the drawer. Additionally, an LED indicator serves as a visual alert to notify users when a tool is missing or misplaced.

Contribution:

This subsystem enhances user experience and accessibility by offering clear visual feedback and intuitive controls. By displaying real-time tool status and guiding proper organization, it helps reduce misplacement and ensures efficient workspace management. The LED indicator provides an immediate alert. The button interface ensures reliable operation without requiring a touchscreen.

Interface:

Inputs:

1. Tool Status Signal from the Processing Unit
2. Button Presses by User
3. Power Supply

Outputs:

1. OLED Display Updates
2. LED Indicator Alerts

Requirement:
The user must be able to locate an item by searching for it in the interface.

Verification:
Place an item in the drawer and verify that its status is correctly updated in the interface, indicating that it is in the drawer.

Power Subsystem

• The Raspberry Pi 4 is powered via a 5V, 3A USB-C power adapter or battery pack.

• The Bluetooth Camera Module is powered by a 3.7V Li-ion battery with a 5V Boost Converter.

• The Display and LED Notification System are powered through the Raspberry Pi GPIO (5V/3.3V).

2.3 Tolerance/Risk Analysis

During the detection process, several factors can impact accuracy, including camera resolution, lighting conditions, and the angle of view. Variations in these parameters may lead to detection failures. To achieve 90% accuracy, as specified in our high-level requirements, we must limit the angle of view tolerance to ±15° and restrict light variance to within ±20% to ensure consistent recognition performance.

Another critical factor to consider is processing time, as delays in response could affect usability. To meet the 2-second response time requirement, Bluetooth transmission delay must be kept below 500 ms, and button response time should not exceed 200 ms to ensure smooth and timely interactions. By maintaining these constraints, the system can provide reliable, real-time tool tracking and user feedback.

4. Cost and Schedule

4.1 Cost Analysis

Description	Part Number	Unit Price	Quantity	Total Price
Raspberry Pi Processor	PI4-4GB-STR32F-C4-BLK	119.95	1	119.95
Raspberry Pi Camera	RSP-CAM-V3-WIDE	35	1	35
Drawer Organizer	N/A	40	1	40
Camera	NexiGo N60	29.99	2	59.98

Microcontroller	ESP-32	15.95	1	15.95

4.2 Schedule

	Xiaohu Mu	Liangcheng Sun
Week of 3/10	PCB ordering	Check the PCB design
Week of 3/17	Train the Model for Item classification and recognition	Write the code for the Item Status system
Week of 3/24	Continue on train the Model for Item classification and recognition	Continue on write the code for the Item Status system
Week of 3/31	Test the power	Connect the PCB with other subsystems
Week of 4/7	Program the Bluetooth	Program on Raspberry processor
Week of 4/14	Test bugs and functionality for the software	Test bugs and functionality for the hardware and raspberry
Week of 4/21	Mock demo	Mock demo
Week of 4/28	Final demo	Final demo
Week of 5/5	Final Presentation	Final Presentation

5. Ethics and Safety

5.1 Ethics

The project aligns with the IEEE Code of Ethics and ensures that its development and usage promote fairness.

One key ethical consideration is user privacy. The system only captures and processes the images of tools and workspace interaction. It should avoid any forms of identification of the user's personal information. All captured data is strictly used and only used in the bench organizer system. Additionally, transparency is maintained by allowing users to update tool information manually.

Another key ethical consideration is theft prevention. If an item is taken from the bench without authorization, the system should be capable of detecting the removal and identifying the individual responsible. This can be achieved through real-time monitoring, facial recognition, or access logs, ensuring accountability and reducing the risk of theft. Additionally, the system should provide alerts or notifications to inform the user or relevant personnel of any unauthorized item removal.

5.2 Safety

In regards to safety, the system is designed to operate safely in a workshop or lab environment to minimize risks to users and workspace equipment. The system runs on low-voltage power sources to prevent electrical hazards. The battery pack will be a certified lithium-ion battery with proper overcharge and short-circuit protection to ensure safe and stable operation.

References

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