Wrench Monkey

GROUP 9

William Wandelt
Electrical Engineering

Rachael Sak
Electrical Engineering

Matthew Crespo
Electrical Engineering

Matthew Trump
Computer Engineering

Reviewers
Professor Maddox
Dr. Aman Behal

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Chapter 2: Project Description

Section 2.1: Background and Motivation

For decades, robots have been used in various industries to automate repetitive tasks and improve overall efficiency. The scope of robotic applications is vast, ranging from precision driven manufacturing of microchips, to the optimization of logistic processes in sorting centers and automated assembly lines streamlining production in various sectors. While the impact of robotic applications have been profound in manufacturing and assembly lines, the potential for robotics in addressing challenges within shared workspaces has yet to be fully explored.

In these specific environments, where seamless collaboration between workers is of utmost importance, the need for effective tool organization has become increasingly apparent. Shared workspaces in fields from manufacturing or repairs to research and development, often take on the issue of disorganization and tool misplacement. The traditional methods of tackling this issue such as manual tracking of tools through sign out sheets have proven inadequate in the evolving demands of modern work environments. This inadequacy becomes even more apparent as the number of workers within these shared spaces increases, necessitating a new dynamic solution.

Recognizing these challenges, our senior design project uses robotics and automation to address the persistent problem of tool organization in shared workspaces. The focus goes beyond increasing efficiency, extending to the broader challenges of accessibility within said environments. Our innovative solution takes the form of a toolbox robot, designed to seamlessly integrate into collaborative work environments, revolutionizing the way tools are managed.

Wrench Monkey, our envisioned toolbox robot, represents more than just a technical solution, but a leap forward in the evolution of collaborative workspaces. By redefining the dynamics of tool organization, our project aspires to contribute to the modern day workspaces that are not only efficient, but also adaptive, inclusive, and technologically advanced. As shared workspaces continue to evolve, our senior design project stands as a pioneering effort to shape the future through integration of robotics and intelligent automation.

Section 2.2: Past Work

Toolboxes are a staple in every workplace, as well as in many homes. They vary in size and look, however, for the most part they are all similar in that they have very basic features and are just a way to store tools. When deciding what toolbox to buy, there are many things to consider such as size, portability, durability, security in the form of a lockable product, and the inclusion or lack of drawers. While standard toolboxes are sufficient for most environments, there are cases where a more technologically advanced toolbox could be beneficial. There are a few companies that have created toolboxes that contain more technologically advanced features; however, these are often not easily accessible to the average consumer.

There are a few toolboxes on the market with varying levels of automation and inventory tracking. Most of these products seem to focus on checking out tools to hold employees accountable and prevent the loss of items. One such product is a smart toolbox created by Snap-On in 2012 called the Level 5 ATC Tool Control System. This product was developed for the utility industry and military type settings as a way to track and control access to tools. One benefit listed is that should a tool be left behind somewhere such as inside a jet engine, it could pose not only an extensive amount of damage but also a safety hazard. Features included in this toolbox are controlled access to the contents, item tracking and logging, and alert systems for errors.

To even unlock the toolbox, a card has to be scanned, such as an employee ID card. This allows the company to allow only certain people access to the tools. Once the toolbox is unlocked, the user can remove whichever tools they need, and the system has an optional feature where you can log which workspace you will be using the tools in. After closing the drawer, a camera mounted inside the drawer will compare the contents to the control image taken when the toolbox was first programmed and it will list on the touch screen how many tools were taken, where they were removed from, as well as the part numbers. The touch screen also has options to search for specific tools, as well as a way to see who has checked out each tool. When returning the tool, there is a way to notify the system if it is broken or lost, as well as if the tool is out for calibration or needs to be calibrated soon to ensure accuracy. Should a tool be returned to the wrong drawer or spot, the system will alert the user that there is an issue. This tracking and logging system can be very beneficial to users as it helps the users keep everything organized and keep track of tools that are checked out by other users.

Another toolbox on the market is the RFID Smart Toolbox. This device was created by Rovinj Technology, and it uses tools that have RFID tags on them in order to register if the tool is in the toolbox or not. This product has an inventory feature that will alert the individual taking inventory of what tools are missing within 3 seconds. It can also alert users if there is a tool that has not been returned in the allotted time, and will also then identify which person has said tool. A unique feature about this device is that it is smaller than the previously mentioned tool chest and is also rechargeable such that it can be physically taken to a workstation as opposed to being large and stationary, requiring the users to come to it to check out and return items.

The company Tool Raptors has also created a smart toolbox. Their product has four different operating modes, allowing the user to customize it to best suit their needs. The most basic mode is smart access only, which restricts who can unlock and access this toolbox. Another mode adds manual tool tracking where the user would tell the system which item they have taken. There is also the option to use RFID or sensors in order to automatically track which tools are taken and missing from the toolbox. This allows the user to customize the toolbox to best fit their needs. The toolbox is also equipped with a touchscreen and will send an alert when there is unauthorized access, as well as keep a log of who attempts to access the system.

Tramontina also has their own Smart Tool Cabinet, which is equipped with similar features to the others such as a touchscreen and restricted access, requiring a keycard to access the tools. It also uses a digital scanning system in order to track which tools are present in the toolbox. One thing that makes this product unique is the fact that it will automatically open and close the drawers the user needs.

Another such example comes from the Olpin Group's motorized toolbox product. This toolbox is specifically designed to transport tools through a workshop, a feature that aligns with our objective of semi-autonomously moving a toolbox through a workshop's space.

One of the safety features of the Olpin Group's toolbox is also relevant to our project. The built-in emergency stop feature ensures safety of users in the immediate serviceable area. This feature is similar to our project's implementation of obstacle collision avoidance, with an emphasis on user safety, and we aim to incorporate similar mechanisms in our design.

Another feature of the Olpin Group's toolbox is the "one drawer at a time" mechanism. This design allows only one drawer to be opened at a time, effectively preventing the toolbox from tipping over due to imbalance. This design element enhances user safety and efficiency, and we plan to integrate a similar feature in our toolbox.

Each of these projects serve as significant inspiration for our project. When combined in the Wrench Monkey Toolbox, they exemplify the blend of functionality, safety, and user-friendly design that we aspire to achieve with our project. By studying and learning from such past products, we aim to create a toolbox that not only meets but exceeds the standards set by these products, ultimately contributing to a safer and more efficient workspace.

Section 2.3: Goals and Objectives

Section 2.3.1: Main Goals/Objectives

The overarching goal of this project is to provide a product that increases shared workspace productivity and tool management. To tackle this central goal, a product will be designed and constructed that has the ability to indicate tool locations and transport desired tools.

For the goal of tool transportation, our first objective is to design and construct a frame on top of which a toolbox will be placed. More specifically, a drive system will be selected that allows Wrench Monkey to traverse a work environment autonomously. For example, if there are inclines in the workspace, Wrench Monkey should not need to be pushed to get over the incline. Since some work spaces can be in environments with gravel and other rough terrain, either treaded tires or tracked tread will be used.

To achieve autonomy, color sensors will be used to guide Wrench Monkey to the desired workstation by tracing the path to each of the workstations using different tape colors to identify the destination. Multiple color sensors will be used simultaneously in order to detect when Wrench Monkey is going off the path traced by the colored tape. To get to the various workbenches, the Wrench Monkey should be able to start from some central position that is set and then choose the path that will lead it to the desired location. Because there will be other obstacles in a workshop, sensors will also be attached to the frame to detect objects that could potentially obstruct the path of Wrench Monkey. When there is an object obstructing the path of Wrench Monkey, an audio system will alert users that its path has been blocked.

To fulfill the tool organization goal various objectives have been set to allow for new users to quickly find available tools for their tasks. Our first objective is to implement a pressure sensing system that will be able to detect whether a tool has been placed in one of the locations in Wrench Monkey. Wrench Monkey will have a WI-FI module so that the tool detection system can interface with a web application to keep track of the tools that are available–this functionality can then be used to prevent Wrench Monkey from moving to another workstation without the requested tool. Similarly, if a tool is needed, but is being used, Wrench Monkey will keep track of who is using it by requiring a user login for the web application. In addition, the web application will have the ability to request tools based on the task that is being completed by a user; for example, if some task A requires a hammer and a 10mm socket, the user will be able to select the task A request which will prompt Wrench Monkey to highlight the required tools. Wrench Monkey will also be equipped with a lighting system such that the requested tool(s) will be highlighted to make tool identification faster.

In terms of Wrench Monkey powering, it will be able to move to the designated outlet for charging when it is low on battery and/or at the end of the work day. Additionally, Wrench Monkey should be powered by off-the-shelf battery hardware that can be swapped when overall capacity has been sufficiently decreased.

Section 2.3.2: Stretch Goals/Objectives

For autonomy, a stretch objective would be to include voice recognition to call Wrench Monkey and/or to request specific tools. To accomplish this, would most likely require the use of artificial intelligence and signal processing, thus making this objective a stretch objective.

A stretch objective for the tool organization aspect of the project would be to determine whether a tool has been placed in the correct location. This would be done using either computer vision or an identification scheme such as barcodes; however, using barcodes could require a barcode scanner for each tool which would consume more power and require more space to be used for the sensor placement.

Finally, in regard to the Wrench Monkey powering, a stretch objective would be creating a charging dock so that users do not have to plug Monkey Wrench into a power outlet.

Section 2.4: Features/Functionalities

- Move between workspaces as requested by users
  - Alert user(s) when a required tool is being used
  - Users can change the paths to each of the work stations by rearranging the colored tape
  - Alert user(s) when object is obstructing path of Wrench Monkey
- Enhance tool organization
  - Highlight requested tools to make finding tools easier
  - Keep track of which are being used and who is using them
    - The users are tracked using pressure sensors and a toolbox login
  - Create “tasks” on the website
    - Keeps record of tools needed for tasks that are recurring
    - Makes requesting tools faster
- Powering
  - Will move to the designated outlet for charging when the battery is below 10%

Section 2.5: Engineering Specifications

The following requirements laid out were based on analysis of potential cost, feasibility, practicality, known size and weight, and intuition. Both software and hardware considerations were made when determining these desired parameters

Motorized Carrier	
Carrier Weight (exc. battery)	< 7 kg.
Carrier Weight Capacity	> 15 kg.
Power Consumption	< 10W idle
Speed	> 0.5 m/s
Battery Runtime	> 5 hours mixed use
Dimensions (LxWxH)	0.6m x 0.3m x 0.2m
Maximum Working Area	40 sq. m
Toolbox	
Weight (exc. battery)	< 20 kg.
Dimensions (LxWxH)	0.6m x 0.3m x 0.9m
Tool Capacity	> 20 tools

Overall Project	
Dimensions (LxWxH)	0.6m x 0.3m x 1.1m
Total Weight	< 40 kg.
Communication Frequency	2400 MHz
Voltage Input	12V
Obstacle Detection Range	> 1m
Color Detection Range	380-700nm
Cost	< $1000

Table 1: Engineering Specifications

Section 2.6 : Estimated Budget and Financing

The following table is an estimate for the costs of the components that are to be used for the project. From this budget and financing table, it can be seen that the total estimated cost will be less than $1000.

Item	Quantity	Unit Cost	Total
Toolbox	1	$20	$20
Color Sensor	2	$8	$16
Color Sensor Dev Board	2	$13	$26
Ultrasonic Sensor	3	$1.80	$5.40
Motors	2-4	$28	$56 - $112
Wheels (2-pack)	2	$14	$28
T-Slotted Aluminum Rails (12'')	≥2	$8	≥$16
T-Slotted Aluminum Rails (36'')	≥2	$16	≥$32
LED light strip	1	$30	$30
12V Battery	1	$30	$30

Item	Quantity	Unit Cost	Total
Tools (kit)	1	$20	$20
MCU Dev Boards	2	$10	$20
PCBs	1	$20	$20

Total Estimated Cost	$375.4

Table 2: Estimated Budget and Financing

Section 2.7: Hardware Block Diagram

The block diagram below outlines each of the modules and specific pieces of hardware we expect to require with our current design plans.

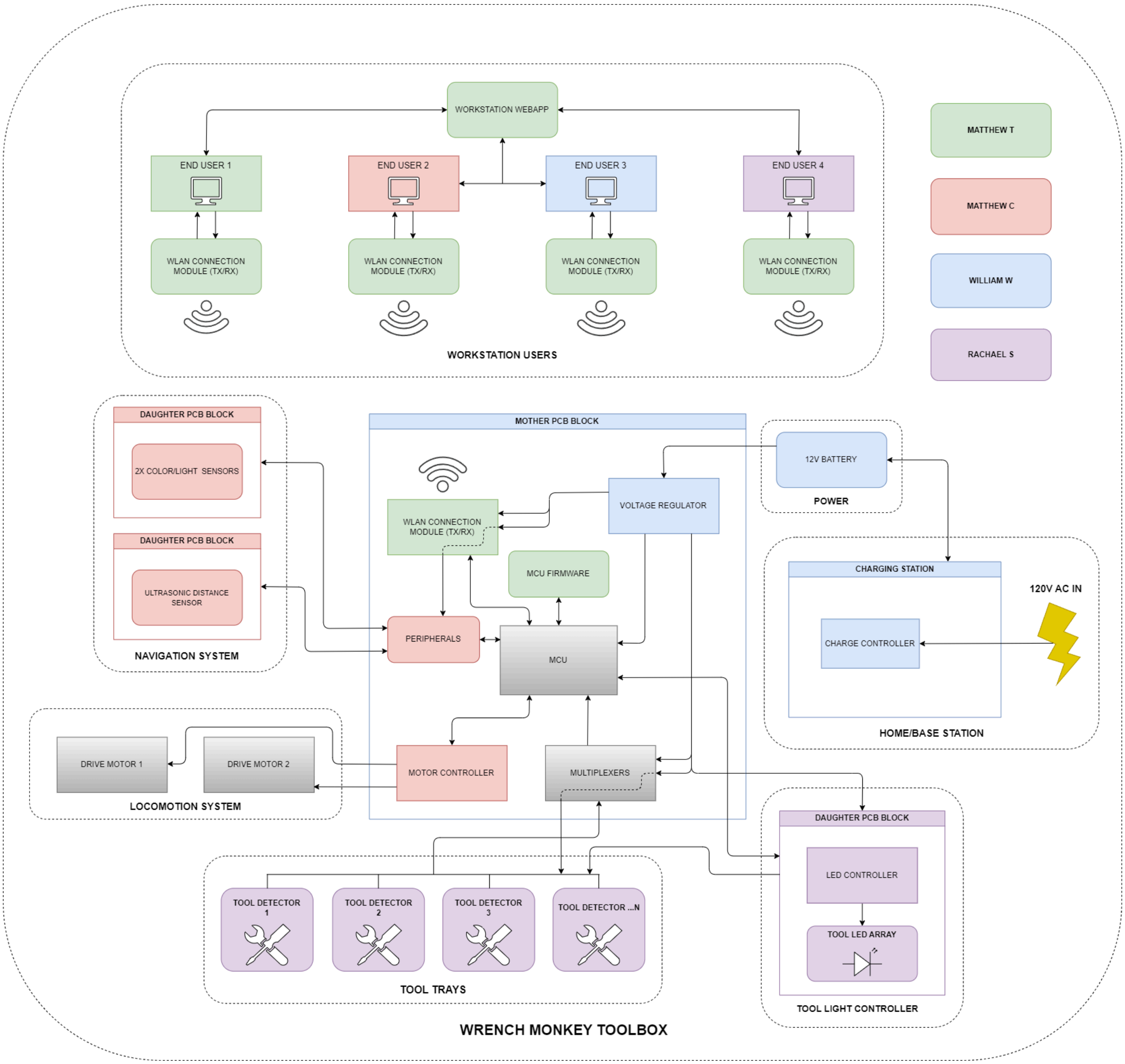


Figure 1: Hardware Block Diagram

Section 2.8: Software Flow Chart

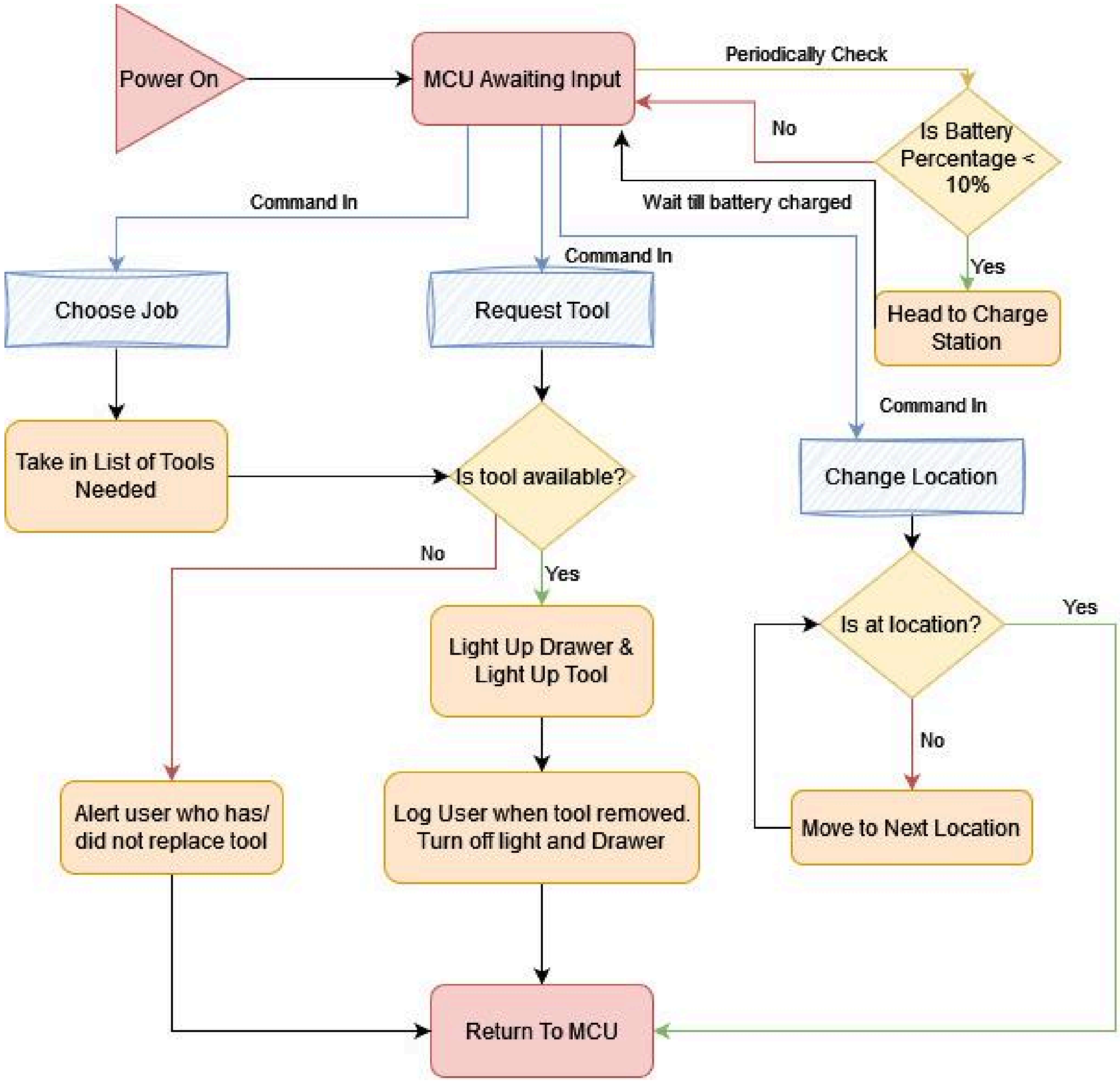


Figure 2: Software Block Diagram

Section 2.9: Prototype Illustration

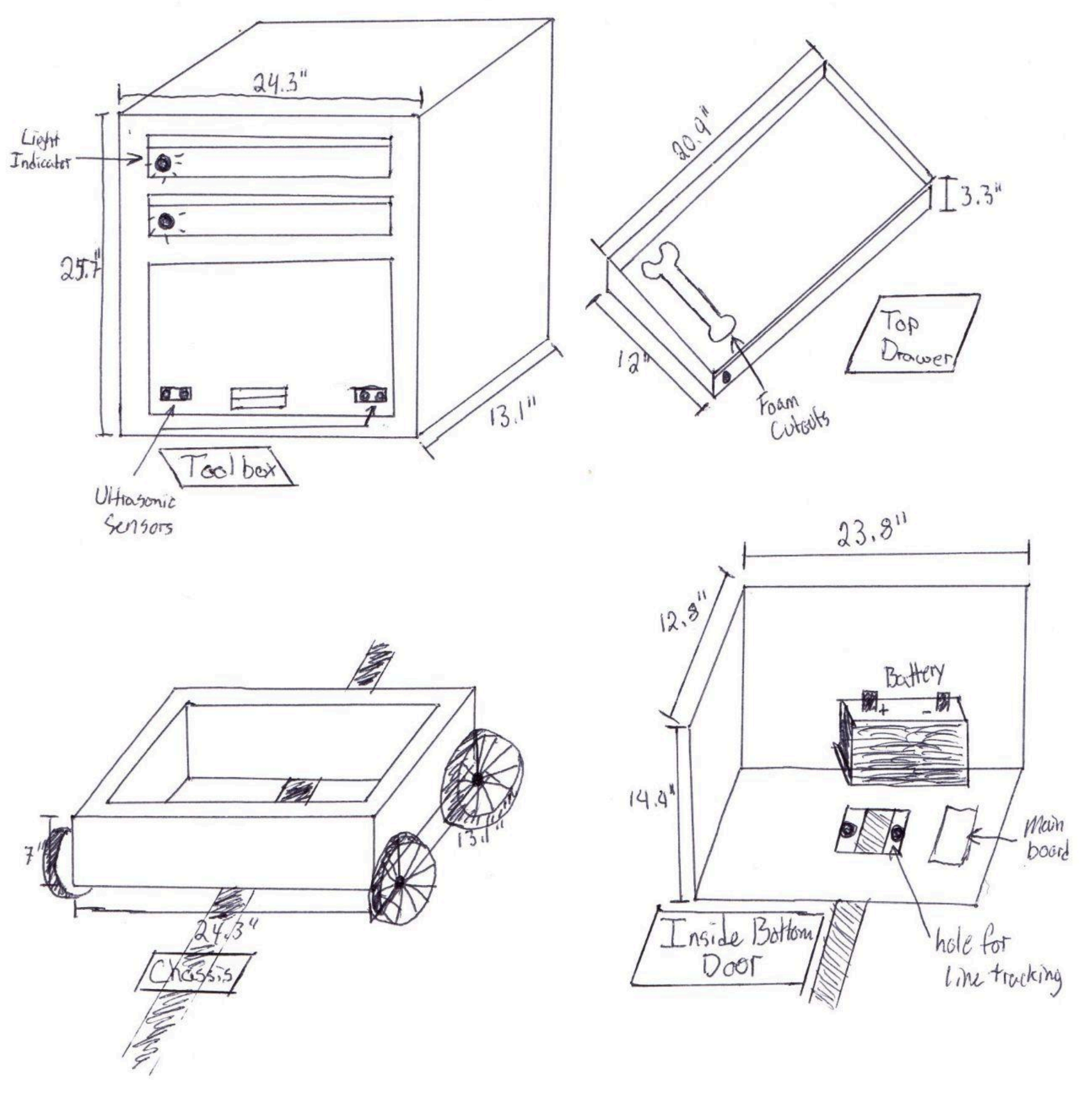
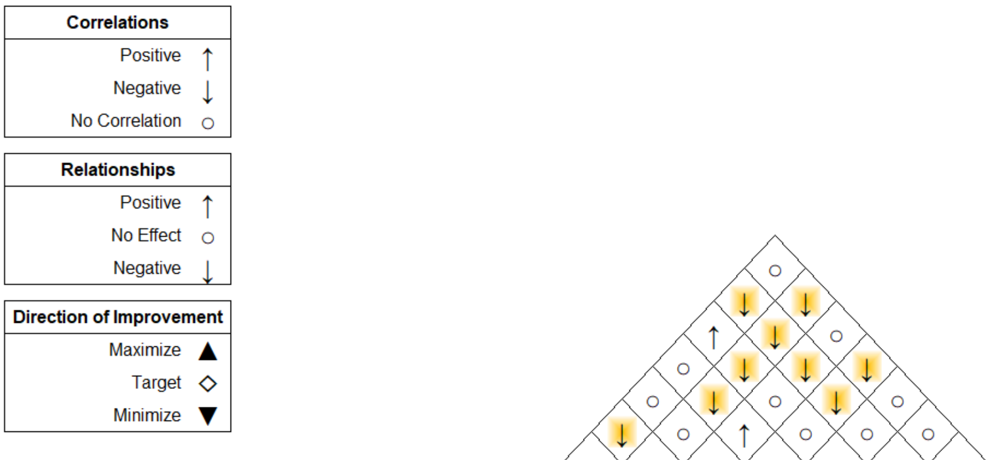


Figure 3: Several prototype sketches showing components and sizes

Section 2.10: House of Quality



Direction of Improvement	Customer Requirements (Explicit and Implicit) / Engineering Requirements	Weight	Energy Efficiency	Path Following Accuracy	Manufacturing Cost	Size	Response Time	Tool Detection Accuracy
	Column #	1	2	3	4	5	6	7
	Direction of Improvement	▼	▲	▲	▼	▼	▼	▲
▲	Affordability	○	↓	↓	↑	○	↓	↓
▲	Battery Life	↓	↑	○	↑	○	↓	↓
▲	Ease of Use	↓	↑	↑	↑	↓	↑	↑
▲	Reliability	○	↑	↑	↑	○	↑	↑
▲	Toolbox Speed	↓	↓	↓	↑	↓	↑	○
▲	Tool Capacity	↑	○	○	↑	↑	○	○
▲	Ease of Setup	↓	○	↑	↑	↓	○	↑
▲	Tool Tracking	○	↓	↑	↑	○	○	↑
▲	Path Obstruction Alert	○	↓	↑	↑	○	↑	○
	Target	<40kg	N.A	85%	<$1000	0.6m x 0.3m x 1.1m (LxWxH)	1 second	85%

Figure 4: House of Quality

Section 2.11 : Project Milestones

Research and Writing Milestones

Task	Description	Start Date	End Date
Recruiting	Getting all team members recruited	01/09/2024	01/09/2024
Project Topic	Having several in person meeting to decide on the project idea	01/11/2024	01/18/2024
D & C	Creating the second chapter, or the project proposal. (10 Pages Total)	01/18/2024	02/02/2024
Rough Draft	Writing the first 60 pages of our Senior Design document. (15 pages per person)	02/02/2024	03/29/2024
Final Document	Adding 60 more pages to the rough draft making it 120 pages total (30 pages per person)	03/29/2024	04/23/2024

Table 3: Research and Writing Milestones

Design and Prototype Milestones

Task	Description	Start Date	End Date
Drive System Design	Selection of drive system and CAD drawing of chassis.	2/5/2024	2/19/2024
Part Selection	Determine components that will best fit the needs of Wrench Monkey	2/12/2024	2/19/2024
Website Prototype	Creation of website that will be used to request tools.	2/19/2024	3/11/2024
Subsystem Prototyping	Prototype the subsystems such as the motor control, sensor,	2/19/2024	3/11/2024
PCB Design	Design control boards for the project (power, sensing, motor control)	3/11/2024	4/1/2024
System Integration	Putting together all the subsystems. Testing all the subsystems.	4/1/2024	4/23/2024

Table 4: Design and Prototype Milestones

We hereby declare that we have not copied more than 7 pages from Large Language Models (LLM).

Appendix A

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