C2.2 Project Deliverable E:

Design Constraints and Prototype 2

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E.1- Design constraints

1 - Introduction:

The purpose of this project deliverable E is to provide an in-depth insight and inquiry into two-functional design constraints that have a significant role in the development of our team's prototypes. Additionally, this document will entail what we have developed for a second prototype. The purpose of this prototype will be to lay a foundation for the final prototype and test our team's critical product assumptions. The prototype will then be evaluated using the previously created target specifications. Finally, an improved and updated version of the project plan will be submitted with the document that indicates tasks, milestones and dependencies.

2 - Non-functional design constraints:

Usability: This refers to the ease with which a user can interact with the product. A prototype may be technically sound, but if it is not user-friendly, it will not be successful. Usability factors such as intuitiveness, learnability, and ease of use need to be considered during the development of prototypes to ensure that the final product will be well-received by its intended users. A user-centered design approach can help in addressing usability constraints. This may come as problem in the app interface, which includes several buttons, each performing a certain task. However, we will optimize the app to ensure practicality for the client and seamless functionality across all devices, regardless of screen size.

Performance: This constraint refers to the speed, responsiveness, and scalability of the product. A prototype may have all the necessary features, but if it is slow and unresponsive, users may not be willing to use it. Performance issues can arise due to factors such as inefficient code, poor network connectivity, or inadequate server resources. Addressing performance constraints early in the development process can help ensure that the final product will meet user expectations.

3 – Changes need to make and Proofs

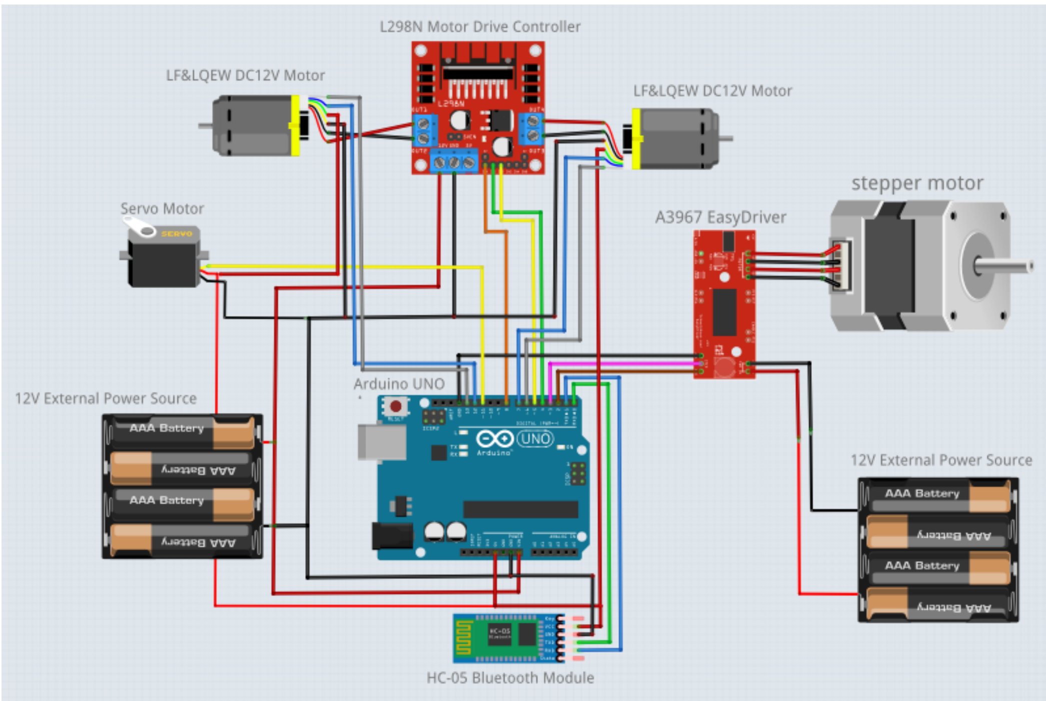
For reaching the lifting performance as defined within the critical product assumptions, the force need to lift the arm vertically cannot be provided from a 5V stepper motor that our team has on hand with a rated torque of 0.0343 Nm. As a result, we calculated the force and changed the motor to a 12V driven stepper motor, which can provide 1.9 Nm torque. Within the target specifications, it is noted that the motor must be able to lift an ideal payload of 1 kilogram and a marginal payload of 500 grams. The friction coefficient for the aluminum used is noted to be 0.2.

For the ideal payload of 1 kilogram, the stepper motor needs to be capable of overcoming the force of gravity acting on the payload. This was calculated using the formula of Fg = umg. This force was calculated to be 1.962 N, meaning that the motor will need to have enough torque to overcome this force. For a payload of 0.5 kg (marginal value), the force was 0.981N. From these values, the torque required can be calculated using the formula T = F*d. Where F is the force that was just calculated, and d is the distance the payload must travel (1.2m).

For the 1 kg payload, the torque required was calculated to be 2.35 Nm. Our selected motor is unable to provide this torque. However, based on recent client feedback it was determined that the priority should be shifted to the client's water cup which had a mass of around 0.5kg. For the 0.5 kg payload, the torque required was calculated to be 1.18 Nm which is well within the range for our chosen motor.

4 – Detailed Design

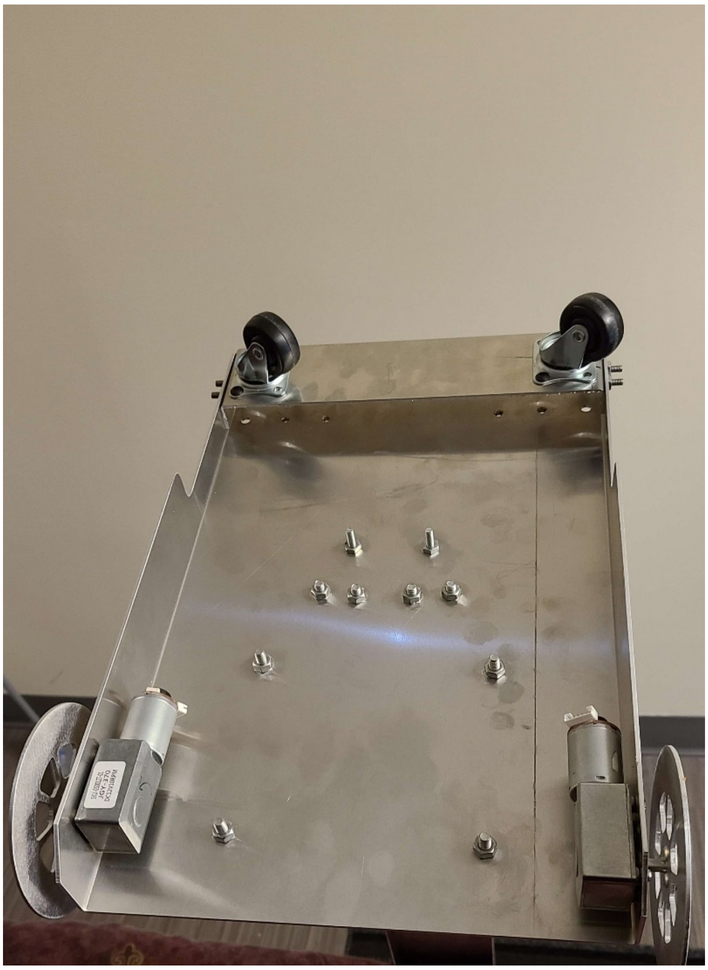
Microcontroller (Basic concept of Arduino) for robotic arm motion



We decided to remove a stepper motor that controls the horizontal motion to simplify the design, and based on the calculation of the torque requirements, the voltage supply for stepper motor changed from 9 to 12V since the motor needs. Two motors are switched to encoder motors as they are easy to mount due to the shaft being threaded as well as getting better feedback signals. As a result, the circuit is modified, and pin organization is updated based on the changes mentioned above.

Locomotion Method Update:

In the detailed design document, our team previously stated that the method of locomotion would be tracks. However, when developing this prototype, it was noted that using tracks presented a greater degree of complexity due to sourcing the tracks and their exact dimensions.



To resolve this issue, we have decided to use two casters in the front that will provide steering, where the other two wheels would be powered by motors in the back. For steering, one motor will run in the opposite direction of the other, therefore enabling it to steer. Regarding the critical product assumption of potentially tipping over at rest, it seems to be quite stable.

5 – Client Feedback

Tracks are preferred for mobility and simplicity, however based on further inquiry, tracks may prove to be potentially complex to fully implement.
Positive feedback on the design of iPhone app interface.
Claw-like hand is preferred for easy grasping and holding of items.

6 – Critical Product Assumptions

We assume that the DC 12V motor is strong enough to move the whole thing around the house freely, which haven't been tested yet. Also, based on the calculations, the torque provided from the stepper motor is enough to lift things at 0.5 Kg. However, it is hard to calculate the friction we may have during the motion, so it still needs verification. Since we are still waiting for some components, the test will be performed when things are ready.

7 – Second Prototypes

Mechanical Prototype:
A full 1:1 scale of the overall concept has been developed. The purpose of the prototype was determining the actual dimensions of the product showcased in a real-world environment. Additionally, this prototype allows our team to validate the target spec of maximum vertical reach of the arm. Where the ideal value was 2000 mm, and the marginal value was 1000 mm.

Additionally, there was also the target spec of lowest arm height where the ideal is 0 mm, and the marginal is 500 mm. Below is a picture of the physical prototype:

The maximum vertical measured reach of the arm was calculated to be around 1.2 m or 4 ft. Reflecting back on the target spec, the value of 2 meters proves to be unrealistic as the client emphasizes tables and counters with the height of them being around 3-3.5 ft. As for the minimum reach of the arm, it is noted that it can reach a minimum height of around 100 mm. This value sits in between the ideal and marginal values; therefore, it can be considered acceptable and passing the test.

8 – Conclusion:

In conclusion, this document provided an in-depth insight and inquiry into two-functional design constraints that have a significant role in the development of our team's prototypes. Additionally, this document contained what we have developed for a second prototype and the testing results. This prototype will assist us to lay a foundation for the final prototype and test our team's critical product assumptions as well as tested against our target specifications. Finally, the improved and updated version of the project plan will be submitted with the document that indicates tasks, milestones and dependencies.

Project Plan Updates: