Deliverable F: Prototype I and Costumer Feedback.

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Abstract

This paper discusses the first prototype construction for the project in preparation for design day. The basic motion of the robot as well as the scanning were the main areas tested.

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1.0 Introduction

This document outlines the construction and testing of the first prototype for the “greenhouse plant monitor” project. The prototype focuses on three core functionalities: autonomous movement, vision-based plant assessment, and user feedback through visual/audio indicators.

Following feedback from the second client meeting, the team prioritized simplicity and practicality in the prototype’s design. The approach includes using April Tags or visual markers for plant health detection, implementing basic navigation, and integrating LED-based feedback to indicate plant status. The primary objective of this phase is to validate these core functionalities, ensuring that they align with the project goals and user expectations.

This document details the planning, execution, and evaluation of Prototype 1, including test methodologies, results, and client feedback. The insights gathered from this iteration will guide future refinements, leading to an improved and more effective final product.

2.0 Feedback from Client Meeting II

After deciding on the “greenhouse plant monitor” and discussing it at the second client meeting we received key input and feedback on what to focus on:

- Keep It Simple: Focus on core functions, avoiding unnecessary complexity.
- Enhance Human Senses: The concept is promising but must be practical.
- Vision Capabilities: Utilize built-in recognition of lines, QR codes, and colors.
- Focus and Scale Down: Select one idea and refine it for efficiency.
- Simulating Data: Use pre-set visuals to demonstrate the concept effectively.
- Engaging Video: Present the system as a compelling, ad-style trailer.
- Audio Capabilities: Program up to 10 sound clips for user interaction.
- Data Input Limits: The robot can’t send or process external data.
- Simplified Plant Health Detection: Use three plant states (healthy, drying, overwatered) with April Tags triggering audio cues.

Taking this into account here are the next steps :

- Focus on autonomous navigation and basic plant assessment using April Tags.
- Create an engaging, ad-style video for presentation.
- Use built-in vision features instead of complex AI.
- Leverage audio feedback for plant health alerts. Simulate the system with predefined conditions for testing.

3.0 Prototype 1 plan

When thinking about what is necessary for the first prototype it is important to analyze why this prototype is necessary and how the clients feedback can aid this.

Firstly, motion and rotation of the robot is essential for the final product to function properly. So, an adequate understanding of these functions is necessary to evaluate in this prototype.

Secondly understanding how the robot interprets data is a must. From discussing our idea of scanning plants health with the client, it became clear that using AI and recognition patterns would be almost impossible to do with the technology and time at our disposable. This is why our group has decided to use vison markers as a way of 'faking' the process, while still getting the message of anti-war across in our video and manifesto. An understanding of how the robot scans and interprets information is necessary for this prototype.

Lastly, it is important that the robot be able to communicate with the user effectively through lights and auditory clips. However, this prototype only focused on one of those aspects being the lights and its changing of colors after scanning the vision marker.

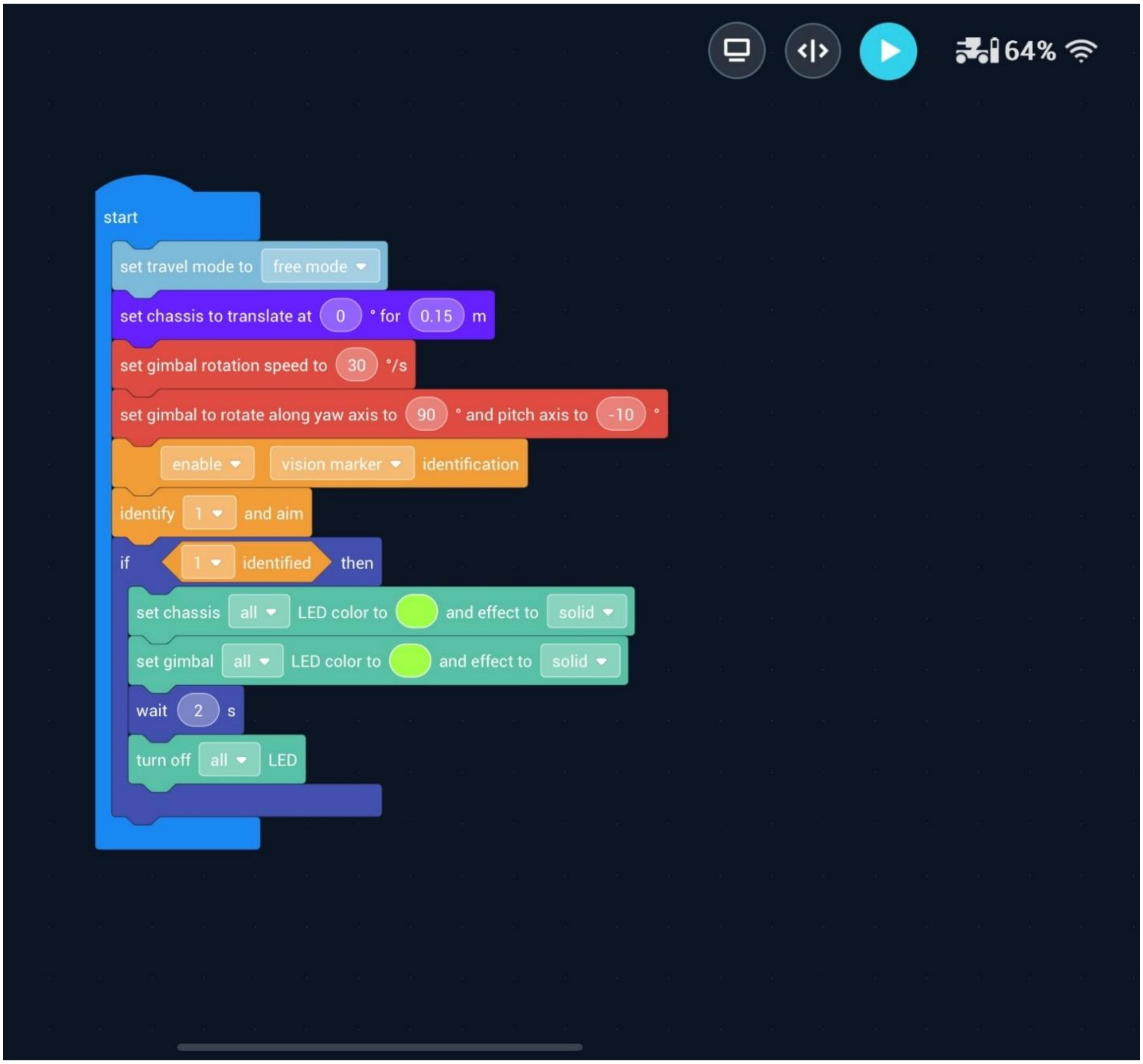
So, to summarize these why's into what is needed, here are bullet points on the specific goals to be accomplished from this prototype:

- Ensure the robot moves and rotates properly and that a proper understanding of these concepts is met.
- Ensure the robot scans a vison marker and processes what it means. This will be done by using vision markers similar to the ones developed by DJI (see references for more information)
- The Robomaster S1 communicates with the user properly by changing the color of its lights once 'scanning of the plant' is complete.

These goals are what will be driving this prototype and be the framework for the testing plan to follow.

Here is a concept of what the code will look like for this prototype to reach all of these goals. This is a screen shot taken directly from the Robomaster application.

Figure 1: Scratch code derived to address the goals for prototype 1



4.0 Test plan for Prototype 1

Our plan was to test the robot's accuracy, vision capability, and productivity under our operating conditions. By testing of movement accuracy, turning consistency, and scanning capability, we aimed to identify areas for potential improvement. The results of these tests will be beneficial to guide improvements in motor control, response time, and overall reliability.

Table 1: This table summarizes the key tests performed to assess the robot's capabilities. The results helped refine its accuracy and responsiveness.

N°	Objective	Test Methods	Usage of Results	Test Duration (hours)	Type	Fidelity
1	Measure accuracy of travel distance	Move robot a fixed distance, measure deviation	Adjust the distance robot is programed to move	1	Focused physical	Medium
2	Verify turning angle	Roate the turret of robot and measure the final angle	Adjust the turning angle of robot turret	1	Focused physical	Medium
3	Test scanning marker detection	Place marker and observe the robots behavior	Adjust size/ resolution/ type of marker	1	Focused physical	High
4	Measure response time to markers	Record delay between marker entering field of view and reaction	Optimize processing speed	1	Focused physical	High

Table 2: This table provides a brief overview of the test findings, showing how the robot performed and where improvements are needed.

N°	Prototype Feedback	Test Results	Actual Duration (hours)
1	Small drift observed	Travel distance must account for the ±3 cm deviation	1
2	Slight overshooting in some cases	Turning angle ~90°	1
3	Robomaster reliably identified marker	Locked onto marker and focusing turret on it	1
4	Delay of ~0.5 sec detected	Not significant enough to warrant action	1

5.0 Analysis and feedback

Test Plan Analysis and Observations

1. Accuracy of Movement

Test Goal: Determine if robot moves correctly and how much deviation occurs.

Findings:

- The robot consistently moved within ±3cm of the intended travel distance.
- While this deviation is minor, it could accumulate over multiple movements, potentially leading to misalignment in larger spaces.

Insights and Improvements:

- Implementing a feedback correction mechanism (e.g, recalibrating movement after scans) may help maintain positioning accuracy.

- Testing on uneven surfaces of introducing slight obstacles may provide information into real world performance.

2. Turning Angle Precision

Test Goal: Ensure the robot turns precisely to face the vision marker at the correct angle.

Findings:

- The robot successfully turned 90° in most cases, aligning itself with the April Tag vision marker.

Insights and Improvements:

- Small variations in turning angles can compound over time.
- A fine-tuned correction system or position recalibration after scanning each marker may improve consistency.
- Additional tests should determine how the robot performs with multiple turns in a row.

3. Vision Marker Scanning

Test Goal: Determine if robot moves correctly and how much deviation occurs.

Findings:

- The robot correctly identified the vision marker, adjusted its angle to center it in the camera, and successfully recognized it.
- This demonstrates that the chosen April Tag system is viable for simulating plant health detection.

Insights and Improvements:

- Since real-world applications may require identifying multiple plants at different distances, future iterations could explore multi-marker recognition.
- Lighting conditions should also be tested to assess performance in varying brightness levels.

4. LED-Based User Communication

Test Goal: Ensure the robot effectively communicates plant status via LED color changes.

Findings:

- The robot correctly changed its LED color upon scanning a marker, providing a simple and intuitive user feedback mechanism.

Insights and Improvements:

- While effective, LED indicators alone may not be sufficient for visually impaired users.
- Future versions could integrate audio cues, where a recorded voice or beeping sound provides additional feedback.
- User testing should determine whether the LED colors are easily distinguishable.

User Interview and Feedback

To gather qualitative insights, we conducted a brief feedback session with a potential end-user. The participant was presented with a demonstration of the prototype's core functionalities and asked to provide feedback.

User Feedback Highlights:

1. **Simplicity and Clarity:** The user appreciated the straightforward indication system (LED color changes) but suggested adding a more explicit explanation of what each color means.
2. **Sound-Based Feedback:** They mentioned that an auditory confirmation (e.g., Plant needs water, or Plant is healthy) would improve usability, especially in low-light conditions.
3. **Navigation Concerns:** The user questioned how well the robot would perform if obstacles were present and suggested testing in more dynamic environments.
4. **Practicality of Vision Markers:** They noted that real-world users might not want to manually place tags on plants. They suggested exploring alternative sensor-based approaches in the future.

Key Assumptions Identified

Several assumptions were made during the initial prototype development, which should be revisited for improvements:

- **Assumption**: ±3cm deviation is acceptable.

    - Reality: While small, consistent errors can accumulate over time, affecting large-scale deployments.
- **Assumption:** LED feedback is sufficient for user interaction.
    - Reality: Users expressed need for audio feedback to enhance accessibility.
- **Assumption:** Vision markers are a viable long-term solution.
    - Reality: While effective for a prototype, real users may prefer a system which doesn't require manual tagging.

The prototype successfully demonstrated basic navigation, scanning, and feedback functionalities. However, improvements are needed to refine accuracy, enhance user engagement, and ensure practicality for real-world applications.

6.0 Task planning and changes

Based on all the factors addressed in this document, here is an updated task list for the remainder of the semester. **Table 1:** Task division and planning for the 'Garden Helper'.

Task	Description	Desired Completion Date	Who will do it?
Adjusting and trouble shooting	This will be fixing the issues that arose from the first test and adjusting any faults during the first test. Should take about 3 days.	Monday March 3rd, 2025	Kiefer and Kailas
Make an outline of the defined path and how many times the robot will stop.	This will just be the robots set path to follow, how many times it needs tot urn its head, how far it needs to travel each time and so on. Should take 1 hour.	Thursday March 6th, 2025	Hassan and Aryan
Sound clip creation for all three condition of plants	This will be the creation and implementation of all the sound clips which will be played depending on the condition of the plant. IT will be paired with the color of the	Thursday March 6th, 2025	Kiefer and Antonios.

	condition ion the final stages of the product. Should take about 2 hours.		
Testing #2	This will be testing all the goals for prototype 2 and seeing if they have been accomplished. Should take 1 hour.	Friday, March 7thth, 2025	Entire group.
Creation of plant base	This will be 3D printing the bases for the plants to stand on and have the April tags on. It will take about 5 days.	Tuesday March 18th, 2025.	Antonios and Aryan.
Creation of plants	This will be just creating the plants and their different conditions to prepare for prototype 3(the final prototype before design day). This should take about 1 day to complete	Tuesday March 18th, 2025	Kiefer
Creation of multiple Vision Markers	This will be creating 2 more Vision Markers for us to have 3 tags total and have a set list of things the robot does for each plant/tag. This will take 2 days.	Tuesday March 18th, 2025	Hassan and Kailas.
Testing #3	This will be a test to see how well our message is conveyed and will be shown to a couple random people in different programs to see if the robot looks like its fitting our desired message.	Thursday March 20th, 2025	Entire Group

	Will take 3 hours		
Testing #4	This will be done to test the final product and how it will function. Will take 2 hours	Friday March 21st, 2025	Entire Group
Finalizing product	This will be bringing everything together and adding all the parts like the motion, lights, sound clips and scanning together. Will take 3 days.	Friday March 21st, 2025.	Entire Group.
Creation of the video for the client	This will contain all the components of the video which will be discussed in prototype 2. It should be completed and edited by this date. Will taker about a week to complete.	March 22nd , 2025	Entire group
Completion of the manifesto	This will be the manifesto as requested by the client and should contain all the desired components which will be discussed in prototype 2 Should take 1 week.	March 22nd, 2025	Entire group
Testing #5	This will be the final testing and simulation to ensure the robot is running for its desired use and programming in preparation for design day. There should be no issues that arise at this final testing.	Monday March 24th, 2025	Entire group

As seen in the table above, there have been changes to the original plan presented in the last deliverable. Overall, more tasks which were not considered before having now been added. This task list should ensure we reach our desired goal with no missed objectives. The only thing which has not been added here is the deliverables due throughout the design process, however they have been entered into Trello.

Although the tasks and overall plan have been updated, there are still concerns which must be considered throughout this process:

1. Tasks taking longer than initially hoped for. This can happen at any point which is why the deadlines for everything have been spaced out more to give some wiggle room before design day.
2. Falling behind is also a possible issue due to procrastination. The team has decided it will work together to ensure that if anyone falls behind, the work will be helped by others to ensure deadlines can be met.
3. Underestimating the complexity of certain tasks can occur during this design process. To ensure this is avoided, starting a task will be done sooner rather than last minute to avoid any pitfalls and effects on the desired completion dates.

7.0 Conclusion

The first prototype of the “greenhouse plant monitor” successfully demonstrated its core capabilities, including movement, vision-based plant assessment, and user feedback through LED indicators. Testing results revealed that while the system functions as intended, minor inaccuracies in movement and turning angles require calibration. Additionally, feedback from a potential user highlighted the need for auditory cues to complement the LED indicators, enhancing accessibility and user experience.

The insights gained from this prototype will inform the next iteration, focusing on refining movement precision, incorporating audio feedback, and further exploring alternative solutions for plant health detection. As the project progresses, these refinements will contribute to a more user-friendly system, ensuring that the final product meets both technical and practical expectations.

By addressing the challenges identified in this phase, the team is on track to develop a refined prototype that effectively aligns with the project’s overall vision and objectives.