Camera & Laser based distance control for Laser Weeding in Seeded Vegetables

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1. Concept Planning

1.1. Goal

The goal of this project is to build a system for our robot where the distance between the camera and the ground remains constant in relation to ground. The focus is strictly on the adjustment of the height by the linear actuator when the robot is not moving. Ideally, the robot will have to adjust per stop and adjust there before moving again. The desired goal of having it adjust while moving is an added bonus goal to the project after the main goal and the side goal is fulfilled.

1.2. Requirements

As stated above in the goal section, one of the most important requirements is to detect the change of height of the ground or obstacles (i.e. weeds, soil height, etc.) and to adapt the robot to those changes in height. To fulfill this goal, there are lists of requirements and constraints that the robot needs to meet. These requirements and constraints have to be precisely defined and put some considerations into accounts such as cost, feasibility, and project time limits.

For this project it is determined that the robot will utilize a Raspberry Pi 5 computer, a line laser and a Raspberry Pi compatible global shutter camera. After hardware requirements comes process requirements as well as functional requirements as follows:

Process requirements:

1. The height of the robot should not be lower than 10 cm to avoid collision with the obstacle.
2. The laser should be visible enough to be captured by the camera.
3. The budget of the whole project is restricted to 50€ if needed.

Functional requirements:

1. The accuracy of the measurement at minimum is ±2 cm and ±1 cm as ideal.
2. Adjustment of the camera and laser assembly based on the height measurement to maintain constant distance between ground (with or without obstacle) to the camera.

1.3. Solutions Finding

When brainstorming the solution of the task of the robot, there are some options of technologies that can be used to solve it. The first solution is a dot laser or point laser that comes to mind. By projecting the laser at an angle from the camera, the camera can detect the changing of height if the laser shifted. But after some considerations, this strategy is abandoned because the point laser has a small area and can be problematic when placing and detecting height changes on a bigger area.

The second option is using the current modern technology which is LiDAR (Light Detection and Ranging) sensors. This sensor emits rapid pulses of laser light usually in the infrared spectrum and the sensor measures the time it takes for each pulse to return as it reflects when it hits an object in the environment. The advantage of this sensor is that it can measure distance with high accuracy but one of the drawbacks is the price, which is much more expensive than the last option that is going to be used in this project.

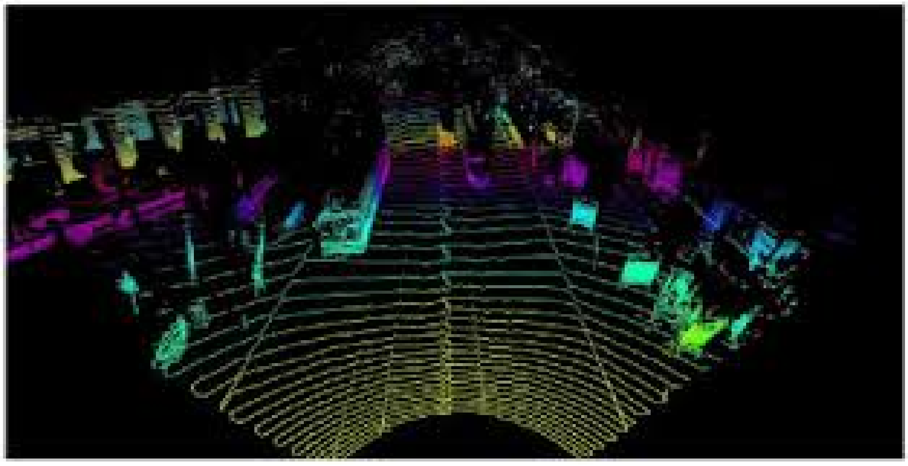


Figure 1.3-1 LiDAR Sensor

The last option is using a line laser. The concept is very similar to option 1 but now the laser is not a point but rather a line, which is much more visible and will be more robust on displaying the changes and unevenness of the terrain or obstacle. This option is also more economical than the LiDAR sensor but also reduces some of the accuracy. After some consideration, it is decided that this last option is the optimal solution for this project.

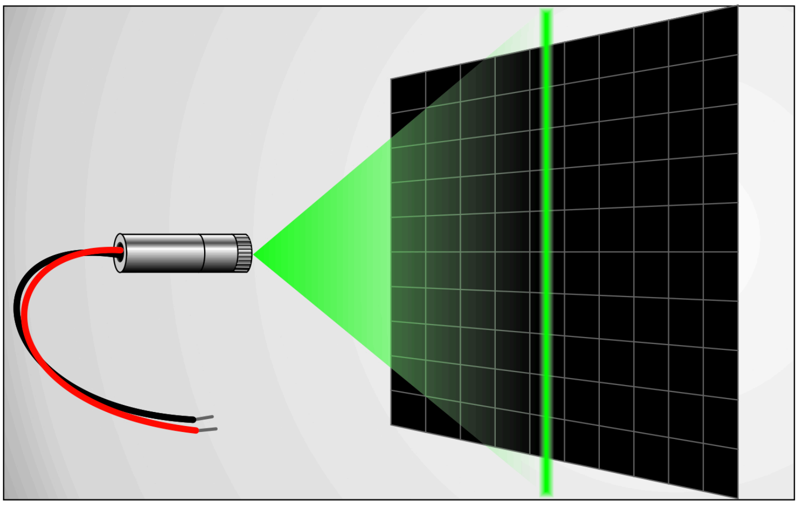
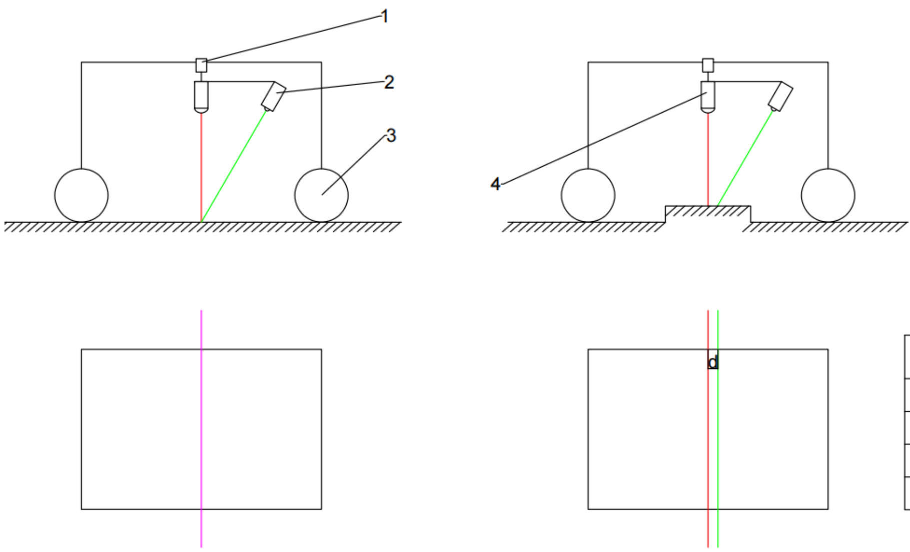


Figure 1.3-2 Line Laser Concept

1.4. Concept

1.4.1 Concept for baseline goal



Equipments	
1	Line Actuator
2	Line Laser
3	Wheels
4	Camera

Figure 1.4.1-1 Laser-Camera Concept

As shown in Figure 1.4.1-1, the camera and line laser are mounted at the front of the robot. When the robot stops at a stop station, the laser projects a line onto the ground, and the camera captures an image containing the laser line.

In an ideal scenario—when the ground is level—the center of the laser line aligns perfectly with the center of the image captured by the camera. However, when the robot encounters uneven ground, this alignment is disrupted. The center of the laser line and the center of the image no longer coincide.

The distance between these two lines, labeled as 'd' in Figure 1.4.1-1, can be used to calculate the height variation of the ground surface.

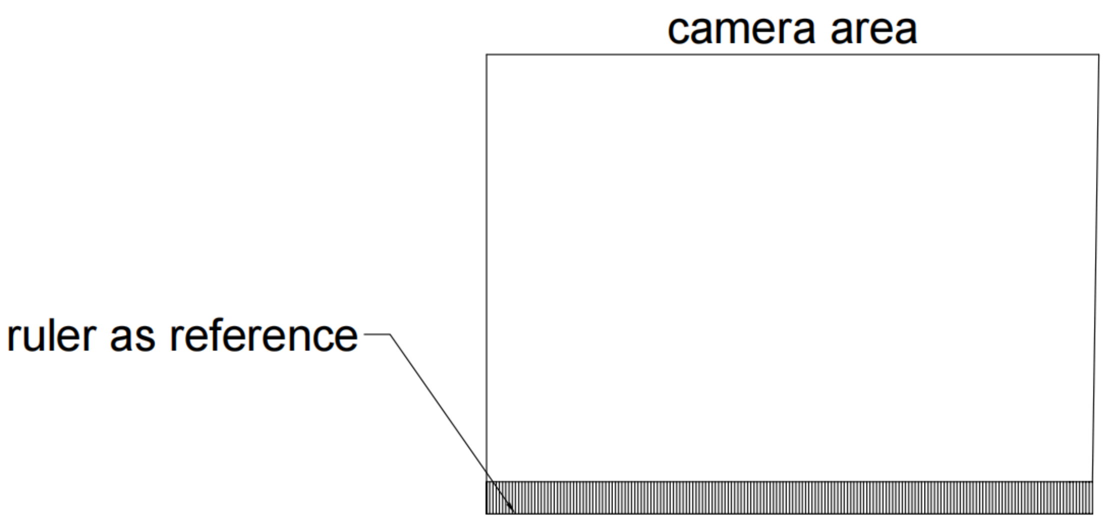


Figure 1.4.1-2 Reference Ruler in Camera View

As shown in Figure 1.4.1-2, a reference object, such as a ruler, will be used to calibrate the image. The number of pixels corresponding to 1 mm of d, for example, must be determined.

However, as the camera is raised or lowered, the scale per pixels will change due to perspective and distance variations. To mitigate this effect, the images will be recorded at intervals (for example every 5 mm) in camera height, as reference.

Using the collected data, an interpolation algorithm will be implemented to establish the relationship between d and the number of pixels. This relationship will then be used to calculate the vertical displacement ‘d’ at any arbitrary position in the captured image.

1.4.2 Desired Goal

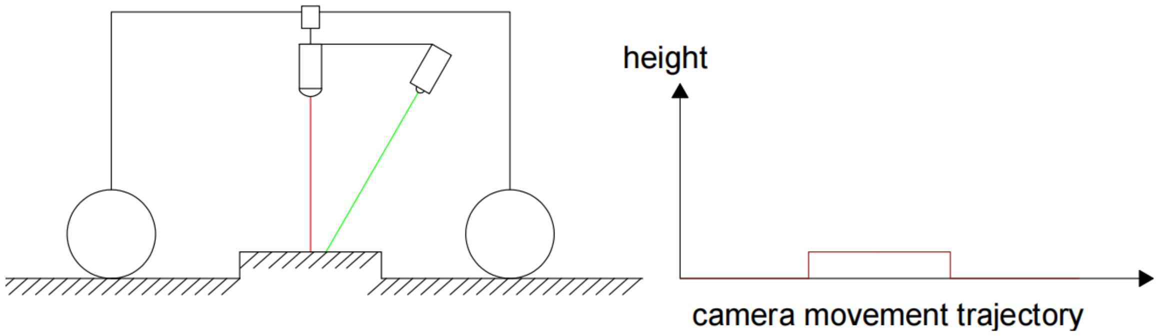


Figure 1.4.2-1 Ground Profile Detection

If time permits, Figure 1.4.2-1 illustrates the final goal of the system. The control system is capable of adjusting the positions of the camera and the laser in real time as the robot moves. The movement of the camera will follow the contour of the uneven ground over which the robot travels.

1.5. Project Time Plan

In order to finish the project in time, a scheduled timeline is required to know how the project is progressing. The starting phase, also known as the concept phase, determines the draft of the project to have it in a bigger picture. Many of the brainstorming happens here to find the best solution and possible obstacles that can be encountered later in the project during the other phases. The next phase is the design phase. This is where the design and implementation of some of the brainstormed ideas into the project like the hardware and software or the overall system design. Finally the testing phase is where the robustness of the robot is tested with an actual obstacle and on the field.

1.5.1. Concept Phase

In the concept phase the foundation of the project is thoroughly discussed by the group members. Brainstorming plays a crucial role in finding the concept solution, requirement list as well as the function structure. When discussing the concept solution, all plausible solutions were discussed. One of the points that were discussed was the laser as well as the way to measure the height. Each point will have some disadvantages and advantages to be considered and applied to the design.

Our group members were also divided into different roles. This ensures each person has their own individual assignment and responsibilities to help progress the project faster.

1.5.2. Design Phase

In the design phase, the solutions are applied to the project. One of the designs that were considered was the mounting design. In the mounting design, the equipment needs to be.mounted in a way so that it moves as desired. Some 3D printed designs might be needed to support the whole system

Another design that we have to do is software design. Some of the ideas that were discussed from the concept design was using Python's OpenCV to capture images and possibly a PID controller to control the linear actuator.

Since the project is being designed, a budget list will be required since we have a limited amount of resources to be used.

1.5.3. Testing Phase

The testing phase starts off with an individual test of each part to ensure its function before assembling them together. Once all of them function properly, the whole system is assembled accordingly.

The testing phase acts like a loop. It will go through the initial obstacle testing and then some modification is made if needed. The initial phase will keep on looping until the desired modification and result is achieved.

After it goes through the initial testing, it will be applied on the field. There the robot is tested on the actual field. Since it is now on the actual field, some adjustment might be needed since it is different from the obstacle test.

Finally if there is some time left some desired goals might be fulfilled during the testing phase.