Mobile Manipulation Final Project Proposal

Visual servoing for hydroponic plant monitoring and maintenance

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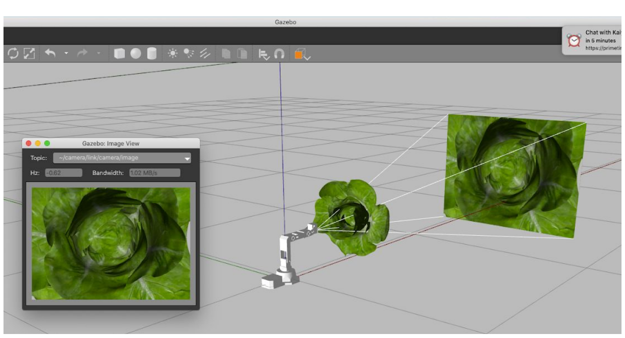
Problem Statement

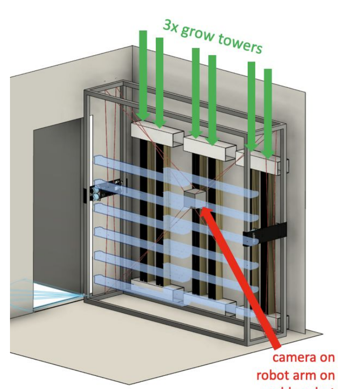
Robotics can find many applications in agriculture due to the ability of robotics to perform monitoring and maintenance at a faster frequency, greater consistency, and lower cost than is possible by humans.

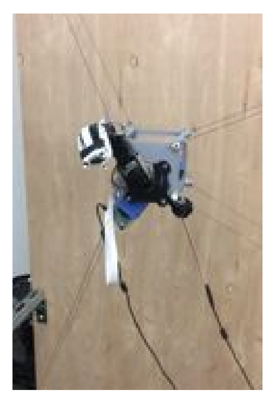
The application we are interested in is **tracking the growth of hydroponic lettuce** by taking thousands of photos of a lettuce plant over its growth cycle and performing 4D spatio-temporal reconstruction to extract the plant's geometry.

The current difficulty with our system is in **positioning our camera** to take high quality images of the lettuces. The proposed robot system consists of a 4-DoF arm mounted on the end effector of a planar cable robot which is placed in front of a wall of lettuce plants. Although the plants are arranged in a grid, each plant is subject to deviate from its expected location by several inches and may grow several more inches further in one direction than the other. The result is that positioning a camera to capture **in-focus images of the entire letture** (ie centered in frame without leaves cut off) is impossible without human tuning per plant or feedback control.

We seek to use **visual servoing** to solve the problem of positioning a camera to consistently take properly framed and focused images of lettuce plants from multiple viewpoints. We will work in **simulation**. In our problem, we will consider the **arm–cable system** to be functionally equivalent to an **arm on an omnidirectional mobile base**.







Related Work

In the domain of agricultural monitoring, current quantitative measures for tracking plant growth are often destructive (i.e. harvest the plant to take measurements). Although non-destructive methods, also known as indirect methods, exist such as Leaf Area Index (LAI), they fail to achieve good accuracy due to numerous assumptions and parameters which vary species-to-species and region-to-region [5][6]. Such methods perform especially poorly under leaf-leaf occlusion, which lettuce exhibits extremely strongly [7]. Therefore, high quality 4D reconstructions will be extremely helpful in non-destructively extracting the structure and visual properties of lettuce as proxies for data such as plant mass, health, nutrient uptake, photosynthetic efficiency, and harvest time.

Within the realm of robotics, the topics covered in class regarding kinematics of mobile manipulator provides significant background. Reference material includes [3].

Visual servoing was also introduced in class, as well as in [8][4]. Visual servoing specifically for photography has also been studied in drone controls and gimbals [1][2].

Goals

We propose to complete our project in three stages:

1. Simulation setup - completion of this task will allow us to command the robot base and arm as well as receive a video feed from the camera. The simulation world will include the robot and a lettuce whose pose is approximately but not exactly known. The deliverable will be a functional simulation environment.
2. Kinematic solver - before implementing visual servoing, we must be able to command the robot/camera to reach arbitrary poses and twists. The deliverable will be a joint planner and controller.
3. Vision to close the kinematic loop - finally, we will fulfill our ultimate task of using visual servoing to take images of a lettuce from different angles. The deliverable will be a system which can autonomously take high quality photos of an approximately but not exactly placed lettuce.

Evaluation

The ultimate objective of our project is to position a camera to take high quality pictures. Therefore, we will have 3 methods of evaluation: camera pose, image quality, and success rate.

Ground truth ideal camera pose will be calculated based on distance to the plant and the pose of the plant and compared to the achieved camera pose. This is feasible since we are working in simulation.

Image quality will be evaluated based on (a) how centered the lettuce is in the image and (b) how “blurry” the image is which, in simulation, we can evaluate as the maximum difference between camera focal distance and foreground pixel depth.

Finally, we will evaluate the rate of feedback control success/failure where failure would be something like losing track of the lettuce entirely.

Bibliography

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