Popular Summary:
Non-Destructive Biomass Estimation in Aeroponic Agriculture using Machine Learning and Multivariate Regression

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Food and water security is a crucial topic for ensuring the well-being of the human population. With the growing threat of global warming and its effects on arable land, safe drinking water, weather, and climate, it is of utmost importance to take sustainability into account when discussing our agricultural practices.

One way to decrease the environmental costs in agriculture is to improve the efficiency of input resources, such as water, nutrients, and land use. One option for this is to take advantage of hydrocultural growth platforms where the plants are grown directly in water. These kinds of platforms allow for vertically stackable farms that minimize the physical footprint of food production. These platforms also allow for a controlled climate that can used to improve the growing conditions for the plants, leading to more nourishing plants and reduced impact on the planet.

In order to optimize the plant growth, it is crucial to get a good understanding of what conditions are sought by the plants. This requires accurate measurements of the weight of the plants. In addition, these measurements need to be done without harming the plants, so-called non-destructively.

This thesis investigates the possibility to use images of plants during the growth period in order to estimate both the biomass of the plants (measured in grams), as well as the relative growth rate (measured in grams/day of growth per gram of existing plant). This thesis also compares the quality of prediction from images between two methods of machine learning; multivariate regression and neural networks. In addition, the effects of different camera capturing configurations are examined, with respect to the number of cameras, camera angle, and image capturing frequency.

The images used for this thesis were captured on plants grown specifically in an aeroponic cultivation platform. Aeroponics is a type of hydroculture where the plants are grown in an aerosol or mist, instead of in flowing water.

It was found that a high frequency capturing of 1 hour improved the predictions, as opposed to estimating the biomass based on single images. In addition, when using images taken from a top-down perspective the multivariate regression performed better, while the images taken from an angled perspective were better used with a neural network.

Using two camera angles improved the biomass estimates in the neural network, but did not improve the biomass estimates for the multivariate regression. The reason that multiple angles did not improve the multivariate regression is likely because the complex nature of the angled camera could not be understood by the more simple network.

The best biomass estimates were made using multivariate regression on images taken from a top-down perspective. This resulted in a root mean squared error (RMSE) on the test set of around 0.0391 grams. The biomass of the plants were up to 0.35g, meaning that the relative RMSE was around 11%, which is comparable to previous results.

The relative growth rate estimates were best made using the neural network using both camera angles. These estimates were, however, very poor and did not show a satisfactory result. The best RMSE for the relative growth rate on the test set was around 0.1767g/(g·day), corresponding to a relative RMSE of over 100%.

This shows that a larger data set, specifically one involving a larger set of individuals, is necessary to accurately estimate the relative growth rate. The number of individuals used in this data set was only 57, meaning that there was a lot of redundancy in the data set due to the correlation between images of the same individual at different time points. In addition, the plants in the data set were relatively young, which meant that the visual change in their canopy was quite small. Curating a data set over a larger time span would allow for images with more visual change.