CFAES

FOOD, AGRICULTURAL AND BIOLOGICAL ENGINEERING

Improved Canopy Estimation for Greenhouse Spray Applications

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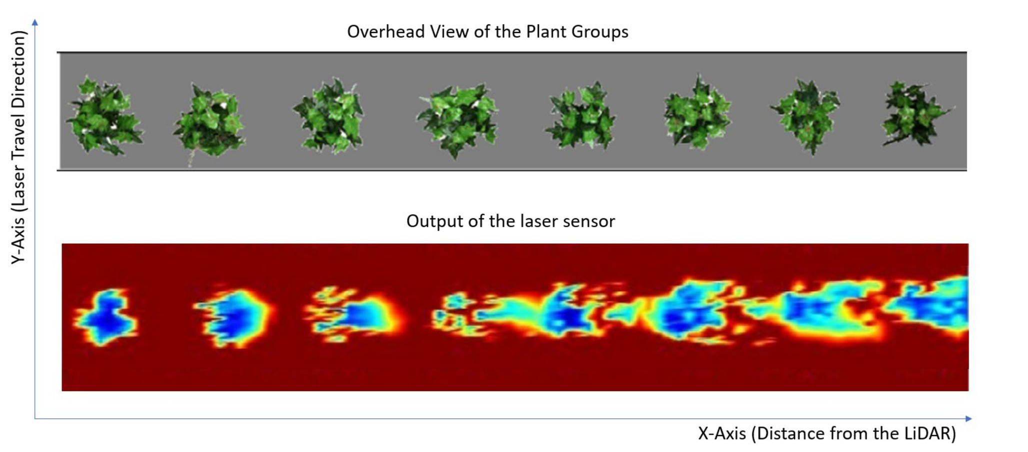
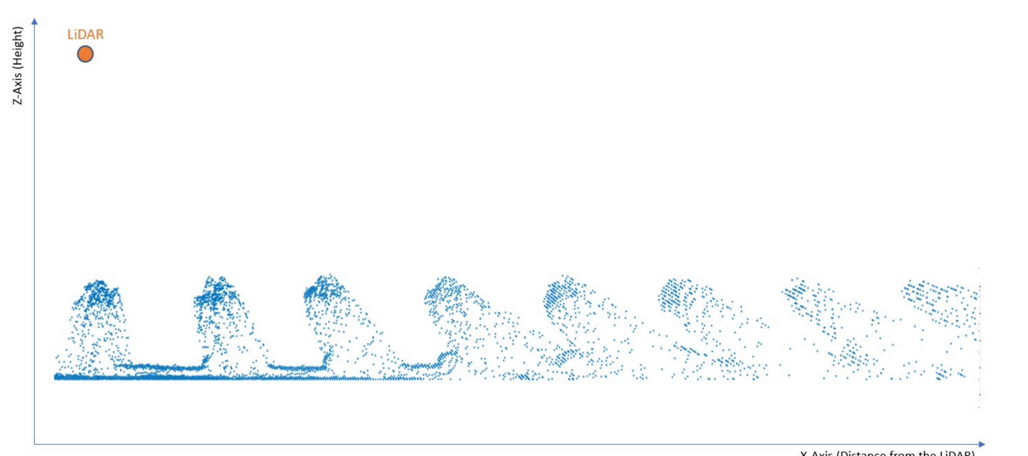
INTRODUCTION

Greenhouse production systems utilize fixed-rate sprayers for chemical application, which are wasteful and are not only a financial drain on the grower but also have a detrimental effect on the environment. The efficiency of these systems can be improved by 30% when utilizing an intelligent, variable rate sprayer[1]. [2],[3] determine the amount of chemical required based on the volume of the tree canopies and these systems have been tested for field applications.

The same principle can be used inside greenhouses, but the system must be adapted in order to function effectively. The LiDAR sensor used to generate 3D profiles of plant canopies has limited accuracy in its measurements due to problems of occlusion and distortion at greater distances from the laser (Yan et al., 2018) due to the incidence angle of the laser beam.



Distortion of the point cloud dataset with an increasing distance from the laser. (Fig 4. Yan et al., 2018) As a result, the last 4-5 plants away from the LiDAR sensor cannot be separated.



The incidence angle of the laser sensor creates a distortion in the point cloud as the distance from the sensor increases. This results in a large error in the X-direction (width) measurement.

This project overcomes these shortcomings by introducing a processing algorithm to estimate their shape and volume more accurately to determine the amount of spray required over each plant.

AIM

To improve the estimation of canopy dimensions, volumes and densities by introducing a processing algorithm that identifies individual plant canopies in a row and then further processes the data in order to make more accurate predictions.

METHODS

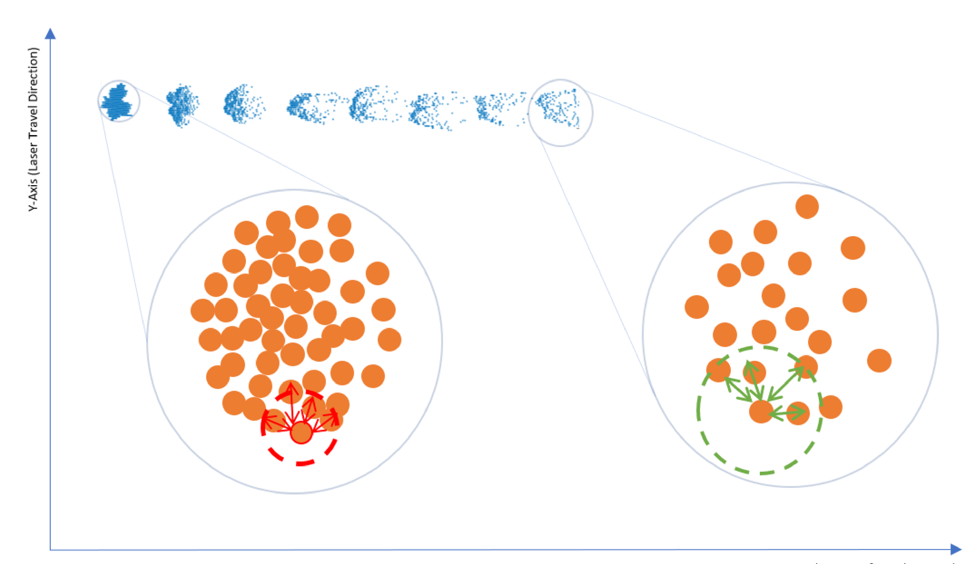
The data is first segmented/clustered in order to isolate individual canopies from the dataset. These clusters are then further processed to estimate the dimensions and volumes more accurately.

Clustering:

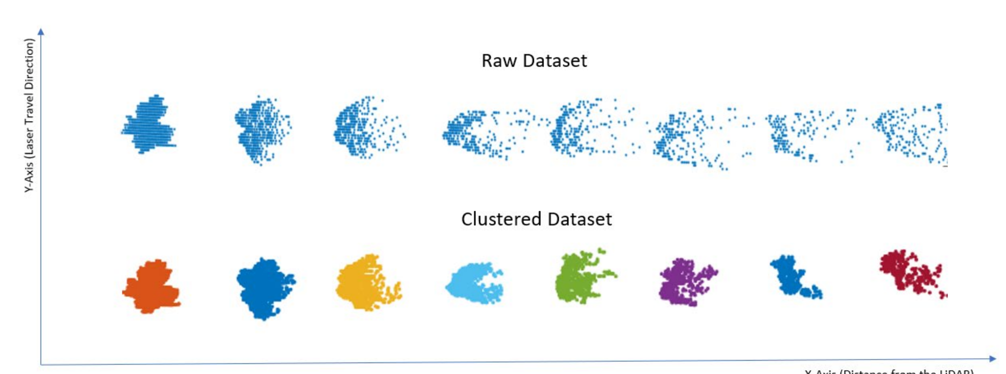
Clustering is the grouping of datapoints that are similar to each other. Points that are closer together are considered 'more similar' than points further away.

- All the points that lie within a certain distance threshold of each other are grouped together.
- The distance threshold is determined by the density of the point cloud dataset. The threshold is higher for a sparse dataset and is lower for a dense dataset.

These groups/clusters then represent individual plant canopies.



The density of the point cloud dataset determines the distance threshold. The increasing distance from the laser has a decrease in density of the point cloud.



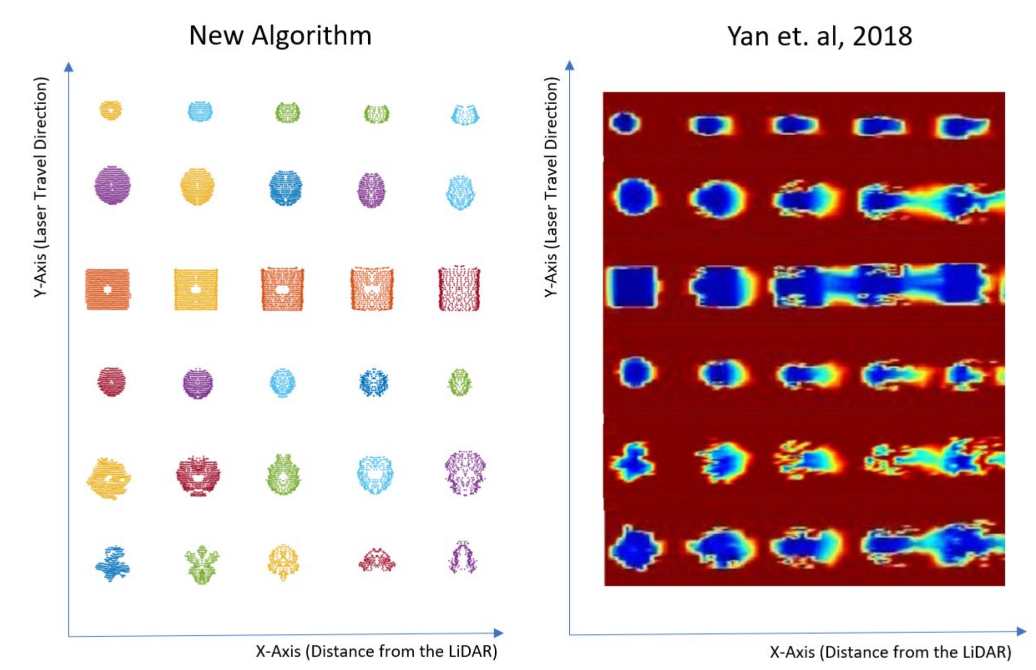
The segmented/clustered dataset after the clustering algorithm has been performed. Each color represents a separate cluster.

Mirroring:

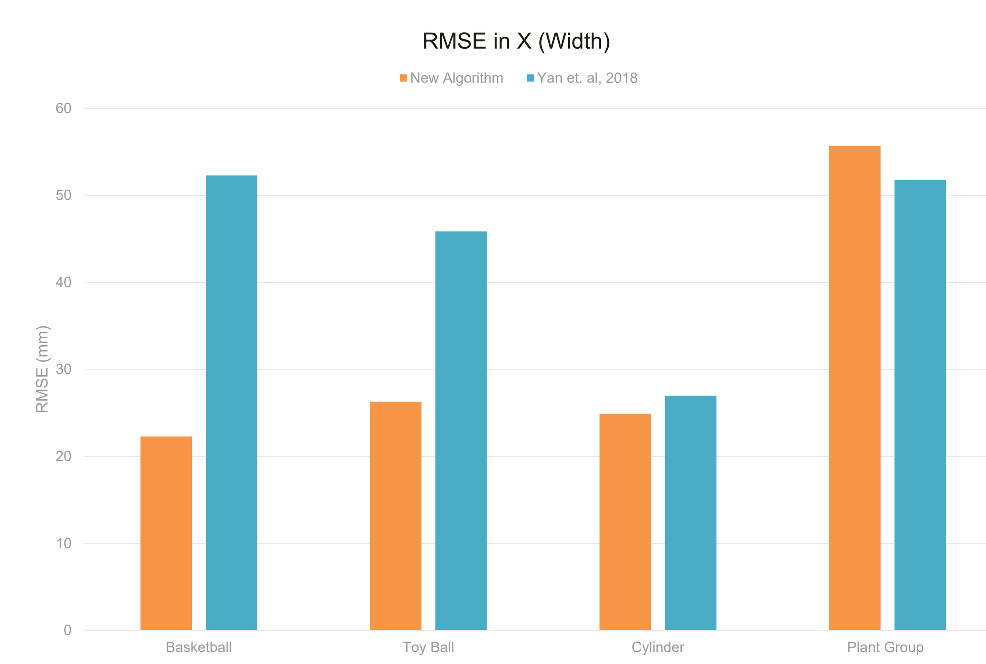
The individual clusters must be processed further in order to get accurate estimations of their dimensions and get rid of the distortion. Assuming that plant canopies are symmetrical, the well-defined face of the plant canopy is mirrored onto the occluded/distorted side.

RESULTS

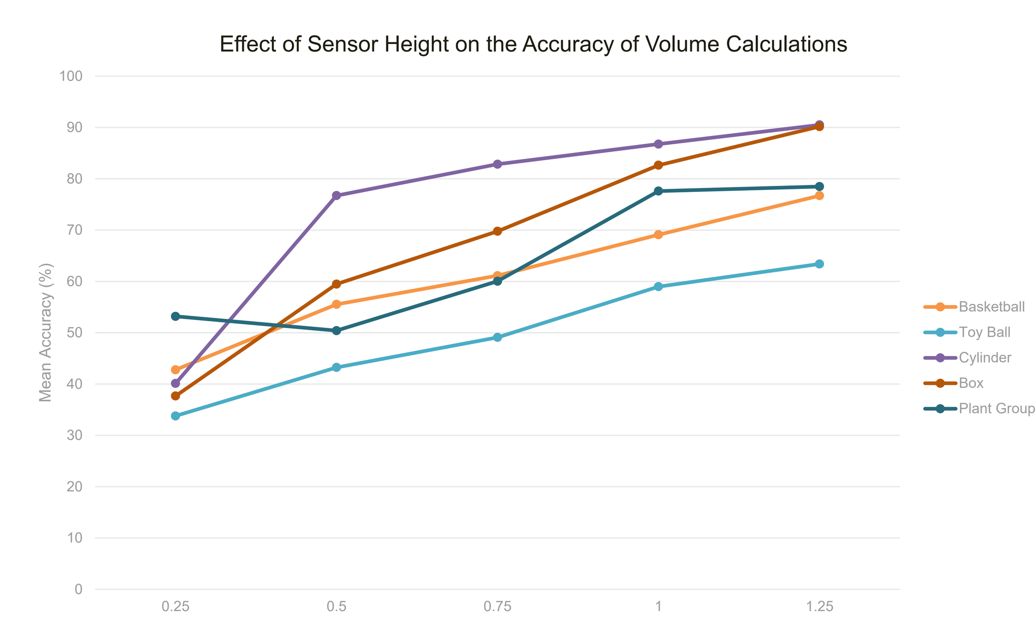
The performance of the algorithm was tested by scanning four regular shaped objects (Toy balls, basketballs, cylinders, and boxes) and a row of artificial plants at five different laser sensor (LiDAR) heights.



The new algorithm provides a better representation of the shape of the target objects and gets rid of the distortion.



The RMSE in the X-direction (width) is reduced with the new processing algorithm.



- There is a reduction in RMSE in the X-direction (width) when compared to [4].
- The algorithm theoretically improved spray efficiency by about 50% based on preliminary predictions when compared to [4].
- There is a general trend of an increase in accuracy with an increase in laser sensor height since there is less of each object occluded/hidden with an increasing sensor height.
- The algorithm performed better with objects that have flat bottom surfaces such as the box and the cylinder because the laser beams from the sensor are able to strike the bottom of objects without obstruction.
- It had the lowest accuracy for the spherical toy ball that had larger dimensions than the rest of the objects used and due to its shape, the problems of occlusion were amplified.

CONCLUSIONS

The processing algorithm used was able to effectively identify individual objects up to a horizontal distance of 3.5m with an average accuracy of 80% when the laser sensor was placed at a height of 1.25m from the top of the objects. The accuracy increased with an increase in laser sensor height. The algorithm performed well when there was a dense point cloud with sufficient row spacing. It was also able to effectively predict the occluded face of the objects by assuming symmetry and mirroring one side onto the other which resulted in the spray efficiency based on theoretical predictions.

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