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ACQUIRING PLANT FEATURES WITH OPTICAL SENSING DEVICES IN AN ORGANIC STRIP-CROPPING SYSTEM

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There is an increasing market for organic agriculture (Golijan & Popoviš, 2016). However, the lack of attention for biodiversity and soil fertility of current practices is a pressing issue. The SUREVEG project (CORE Organic Cofund, 2018) therefore looks at strip-cropping in organic production and its implementation in intensive farming to improve soil fertility and biodiversity throughout Europe. The aim is to enhance resilience (Wojtkowski, 2008), system sustainability, local nutrient recycling, and soil carbon storage (Wang, Li & Alva, 2010) among others. To counteract the additional labour of a multi-crop system, a robotic tool is proposed, which will operate upside down suspended from a wide-span mobile carriage. Within the project framework, a modular proof-of-concept (POC) version will be produced, combining sensing technologies with actuation in the form of a robotic arm. This POC will focus on fertilization needs, which are to be identified in real-time at the single-plant scale.
As a first approach towards facilitating field-mapping and growth registration on a single crop level, two LiDAR systems were mounted in front of a tractor, focusing on a single strip-cropping strip at a time. Performing these scans on a regular basis, which could be combined with other activities in the fields, could produce a time-dependent model of each individual plant, which allows for a comparison not only intra-strip or intra-field, but also across different fields. The point cloud data of the individual LiDARs was merged for each scanned strip, after which the points were subjected to a cost function evaluation in an effort to separate the plants from the soil. Plant clouds spanning multiple seeding locations were cut accordingly. Finally, each of the point clusters were used for a volume calculation. The procedure is visually summarised in Figure 11. It is assumed that the plant volume holds a direct relation to the current crop growth stage (Andaloro et al., 1983) and the yield.

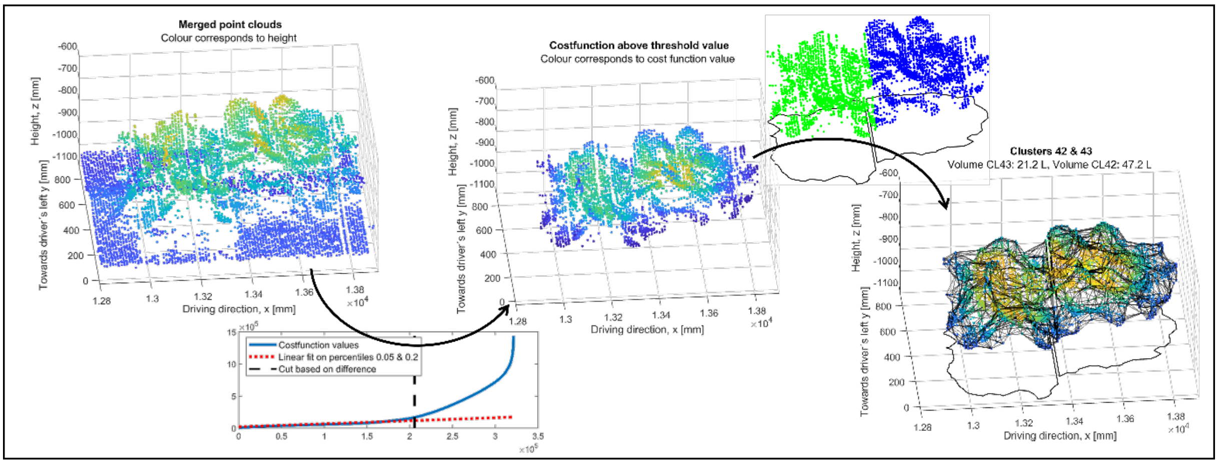

Figure 11: Summary of the developed methodology.
The aforementioned tractor set-up with the two LiDARs was used on a strip-cropping experiment field of the University of Wageningen on several strips of cabbages, which are alternated by wheat strips. Timewise the experiment was executed in the middle of the growing season (62 days after transplanting (DAT)), shortly after the mowing of the wheats. The automated GPS guidance inherent to the tractor was fixed to 2 km/h, with the LiDARs set to a scan frequency of 50 Hz and an angular resolution of 0.5°. The data was processed using Python 3 and Matlab 2018b. To separate the soil from the plant points the following cost function (Equation 1) was calculated for each point.

$$J_k = \sum_{i=1}^{N} \frac{h_i^2}{d_{ik}} \qquad \text{Equation 1}$$

The cost function value J of point$k$ looks at all the points N present in the sphere with a radius of $150mm$ immediately surrounding point$k$. The height h_i of each of these points as squared and divided by its distance d_{ik} from point k to form its contribution to the total value. In other words, the height of the points surrounding each point effectively defined its cost function value, while their proximity acts as a multiplier bonus. For the separation between soil and plants all resulting cost function values were sorted. A roughly linear slope can be identified that defines the soil points, where at some point the increase in values becomes larger. Cutting the point cloud based on the cost function value where this happens gives very promising results. As the percentage of detected soil points varied considerably for different fields, the following method was proposed to define this cut c dynamically, Equation 2.

$$c = min\{m\}, \qquad \left\{m \in \left(J_s(m) - L_{[0.05;0.2]}(m)\right) > 50000\right\} \qquad \text{Equation 2}$$

Here, the cut value c corresponded to the first point m on the sorted cost function curve J_s where the difference between the curve and the linear reference curve L exceeded a predefined threshold. The linear reference was established based on two values on the lower end of J_s which correspond to the 0.05 percentile and the 0.2 percentile. The minimal difference of 50000 was established empirically to fit the obtained data of all measured strips. For the clustering of the obtained plant points, a Euclidian segmentation with a distance of $75mm$ was used. Knowing the sowing locations, every cluster that spanned two or more is assumed to contain multiple crops. Visual inspection of the point cloud showed the separate crops to validate this assumption, allowing for average crop size estimation. After splitting the larger clusters into smaller ones to fit this estimation all clusters were subjected to a volume estimation using the boundary function in Matlab. Unfortunately the harvest of the fields that were measured occurred 3 months after the scans (at 140 and 166 DAT), which resulted in a rather poor correlation between these estimations and the actual yield. Even though the ground truth data was not present in this first approach, the algorithm generated promising results that will be very useful in upcoming experiments within the project.

In conclusion, merging the two point clouds provideed a model with surprising levels of accuracy. The growth stages of the cabbages showed a large variation intra-strip in all of the scanned fields. As the scanned fields were not harvested for another couple of months the yield data does not directly correspond to the field status as measured. The first and foremost recommendation is thus applying these methods on another field closer to the actual harvest to fine-tune the variables used. We cannot say anything about changes over time, since we only had the opportunity to execute these measurements once. Finally the clustering of plants that touch each other is something that needs to be looked into, to separate them more accurately.

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Acquiring plant features with optical sensing devices in an organic strip-cropping system

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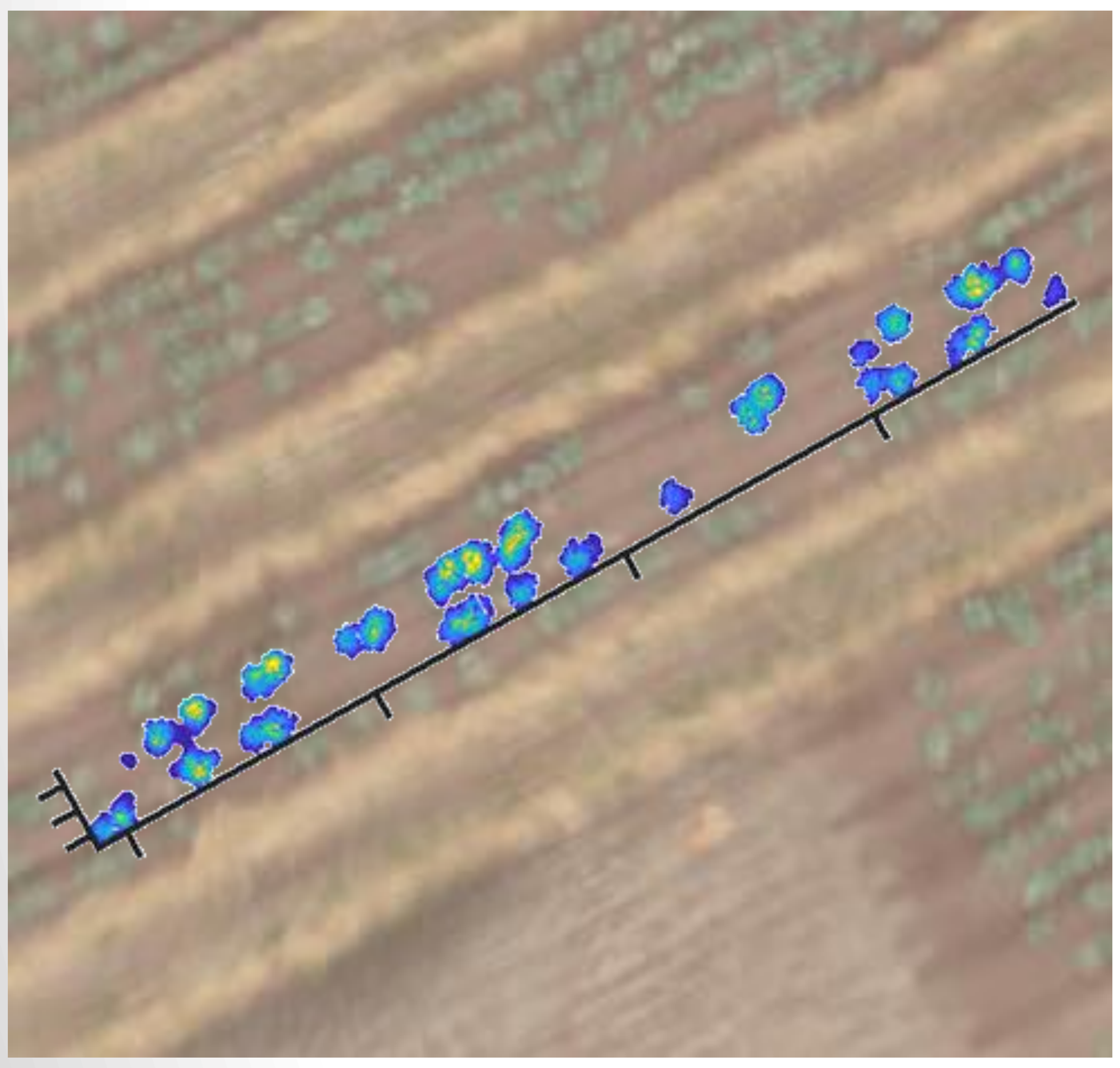


1 - Introduction

The increased scale of modern agriculture is impacting our biodiversity and soil quality. To combat this, several inter-cropping systems, such as strip-cropping, have been proposed. The SUREVEG project looks at vegetables in such a setting, which furthermore are to be treated organically. In this setting, a proof-of-concept machinery solution will be developed, using non-invasive optical sensing to track the development of the different crops.

2 - Materials

Two lidars were mounted on the front of a tractor and used to drive through cabbage strips in the experimental set-up at Wageningen University, where the cabbage strips were alternated with wheat. The experiment was executed in the middle of the growing season, at 62 days after transplant (DAT). A set speed of 2 km/h was used, with a scanning frequency of 50 Hz and an angular resolution of 0.5º.

3 - Soil Separation

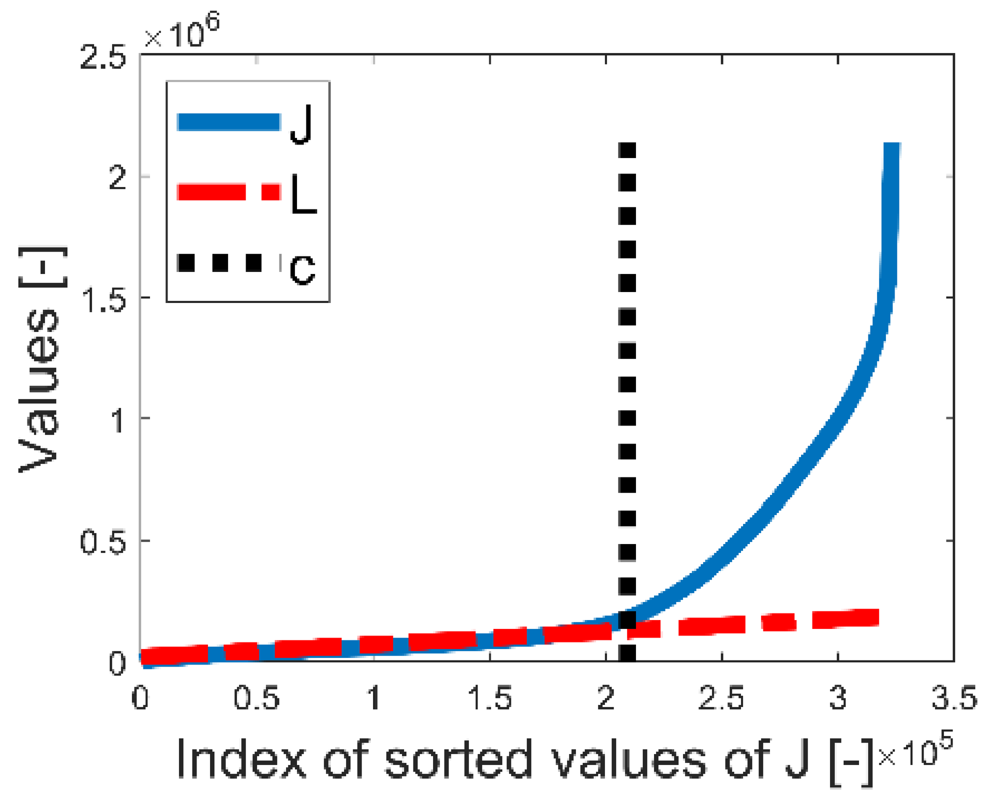
To identify the part of the point clouds that describe the crops, the weighted sums were calculated as follows:

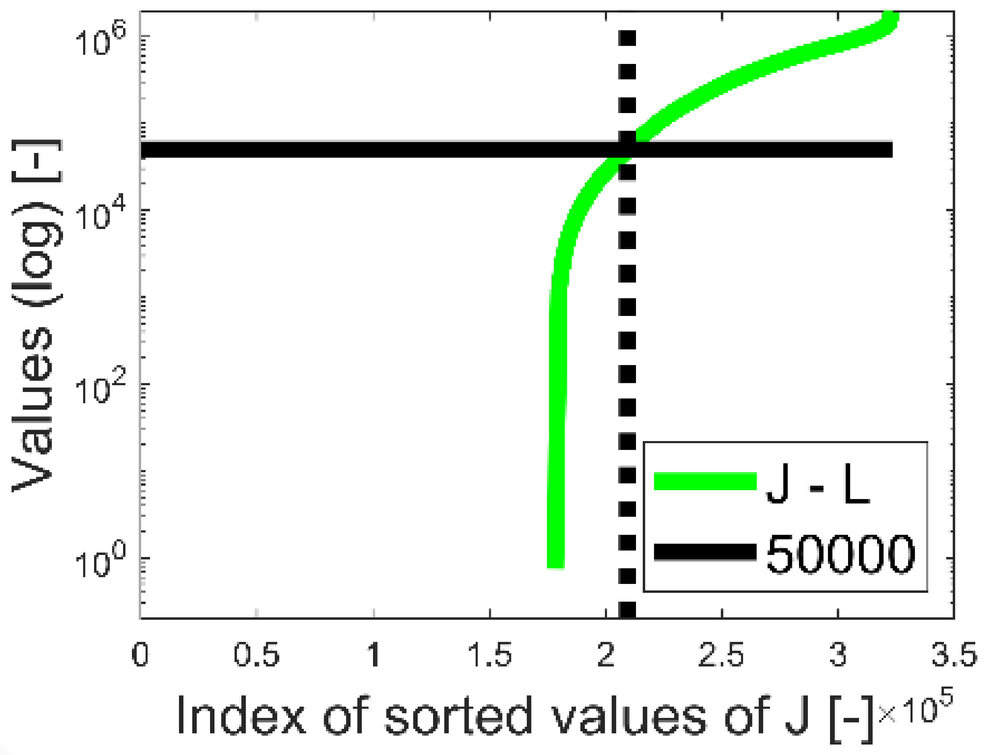
$$J_k = \sum_{i=1}^{N} \frac{h_i^2}{d_{ik}}$$

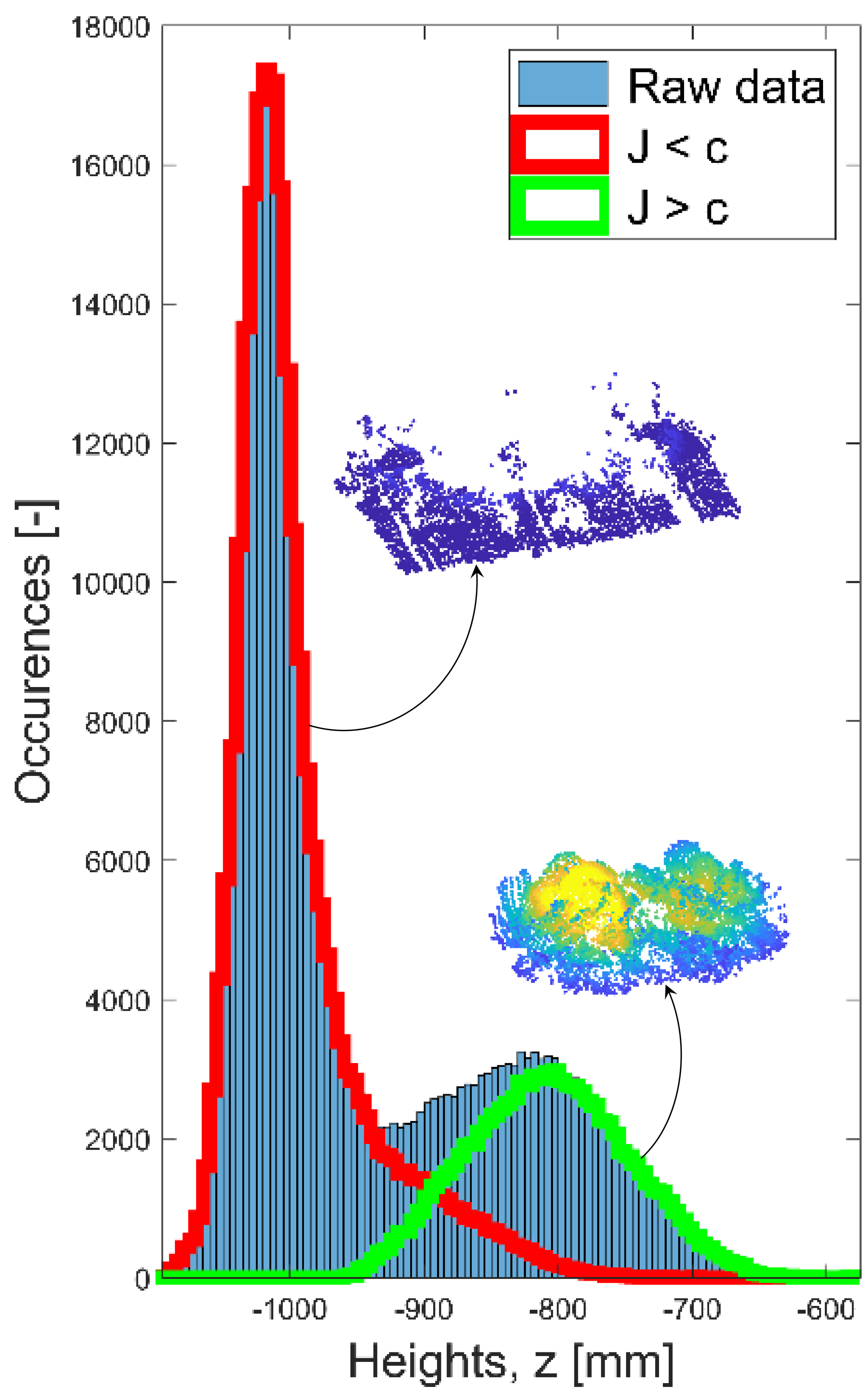
Here, J_k is the weighted sum of point k calculated using the height h and relative distance d of all N points within a radius of 150 mm. When sorted, the resulting values show a linear tendency in the lower regions, denoting the floor points. The breaking point c is defined dynamically:

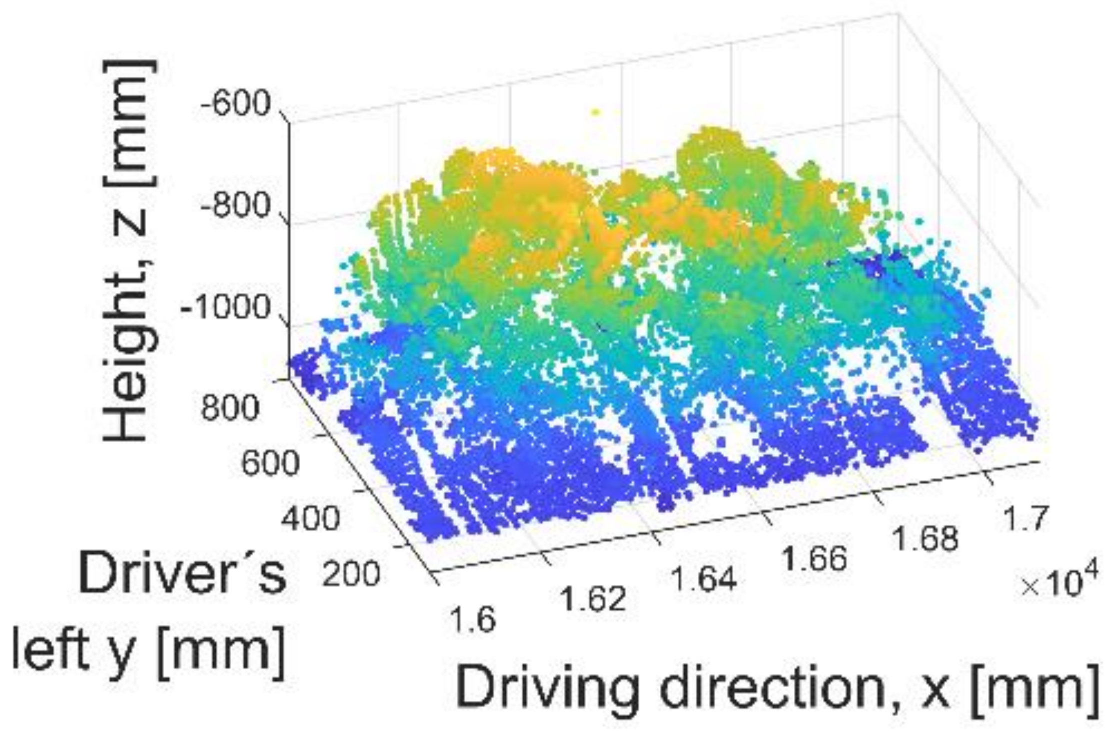
$$c = \min\{m\},$$
$$\left\{m \in \left(J_s(m) - L_{[0.05;0.2]}(m)\right) > 50\ 000\right\}$$

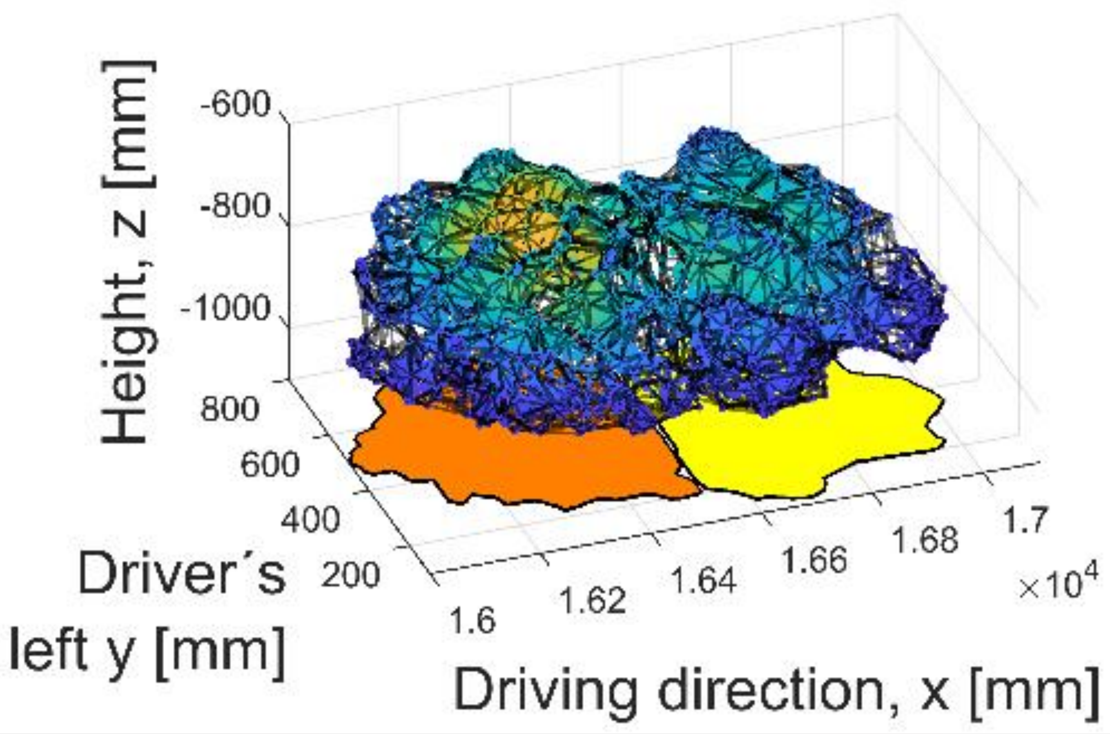
where J_s denotes the sorted values of J, and L the linear tendency as defined by the values of J in two percentiles. The threshold was established empirically to suit all data-sets, with $J \leq c$ identifying all soil points, and $J > c$ all plant points.











4 - Clustering

Using a Euclidian segmentation with a distance of 75 mm, and the known sowing distances, the points that exceeded the threshold c are clustered. The volumes are then calculated, although the harvest in this particular set-up didn't occur for another 3 months after the experiment and the yield therefore does not show a correlation with the volumes obtained.

5 - Conclusion

The developed method is easily applied to any field and uses only the GPS guidance of the feature and the lidar sensors themselves. The obtained point clouds show a surprising level of accuracy. Even though the results could only be verified using drone imagery, the algorithm generates promising results that will be very useful in upcoming experiments within the project.

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The French organisers are pleased to welcome the ECPA conference to France and to Montpellier. The conference will continue with the successful format of previous conferences of building in strong industry sessions and participation. More than 400 participants are expected. Taking advantage of the location of Montpellier on the Mediterranean coast, this 2019 edition will be an opportunity to focus on precision farming applied to small Mediterranean farms.

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