Measuring vegetative heterogeneity of sugar beet varieties with drone and deep learning phenotyping

INTRODUCTION

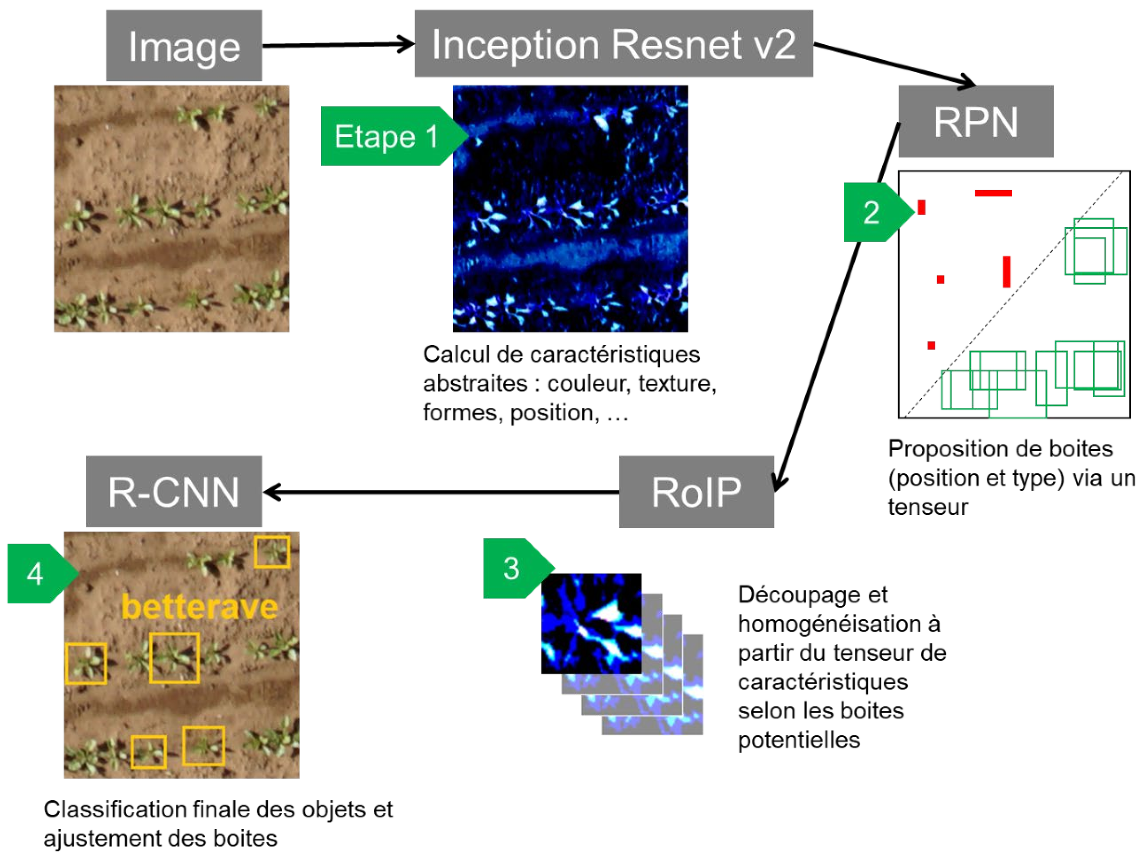
- Success in Sugar Beet cultivation depends on a good implantation in the first stages. The growth should be fast and homogenous. Those traits are expected to be correlated to an increased competition with weeds, a better photosynthetic potential and more uniform roots easier to harvest.
- ITB uses drones for their fast and precise image acquisition over trial-sized fields.
- Deep learning technics can detect complex shapes and organs.

➔In the present work, we combine both a high-throughput vector and an accurate detection tool in order to retrieve the individual leaf cover of the beets.

MAETRIAL AND METHODS

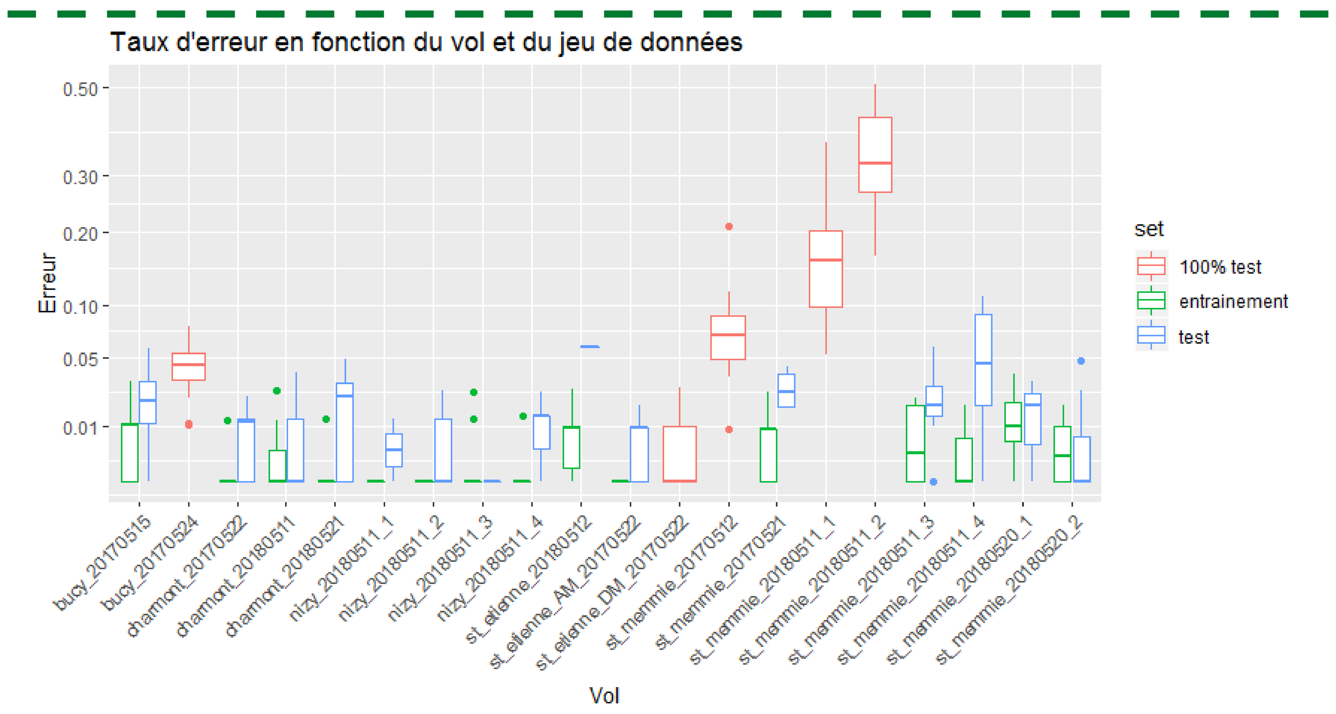
- The drone flew at 35m around zenith time with various lighting conditions (sunny, cloudy, overcast, …).
- Plants were between 4-leaves stage and canopy closure stage.
- Beet experts labeled approximately 45000 individual plants with bounding boxes on images from 13 field trials of 2017, 2018 and 2019.
- The model Faster R-CNN with Inception ResNet v2 was trained for 200000 epochs on a NVIDIA Quadro M4000 graphic card.
- Model validation was done by measuring an error rate $(FalsePositive+FalseNegative)/Positives$

➔For each processed plot, individual leaf cover, in-row distance and beet count were computed in order to test their statistical relation to the genetic variety.



RESULTS

- Loss figures show a slow convergence followed by a plateau indicating an opportunity for further fine-tuning.
- The average error rate for validation data was around 3% with higher numbers for some of the difficult "full-validation" samples.
- Green cover values obtained on individual plants were well correlated to global plot measures, but with a better power of statistical discrimination.



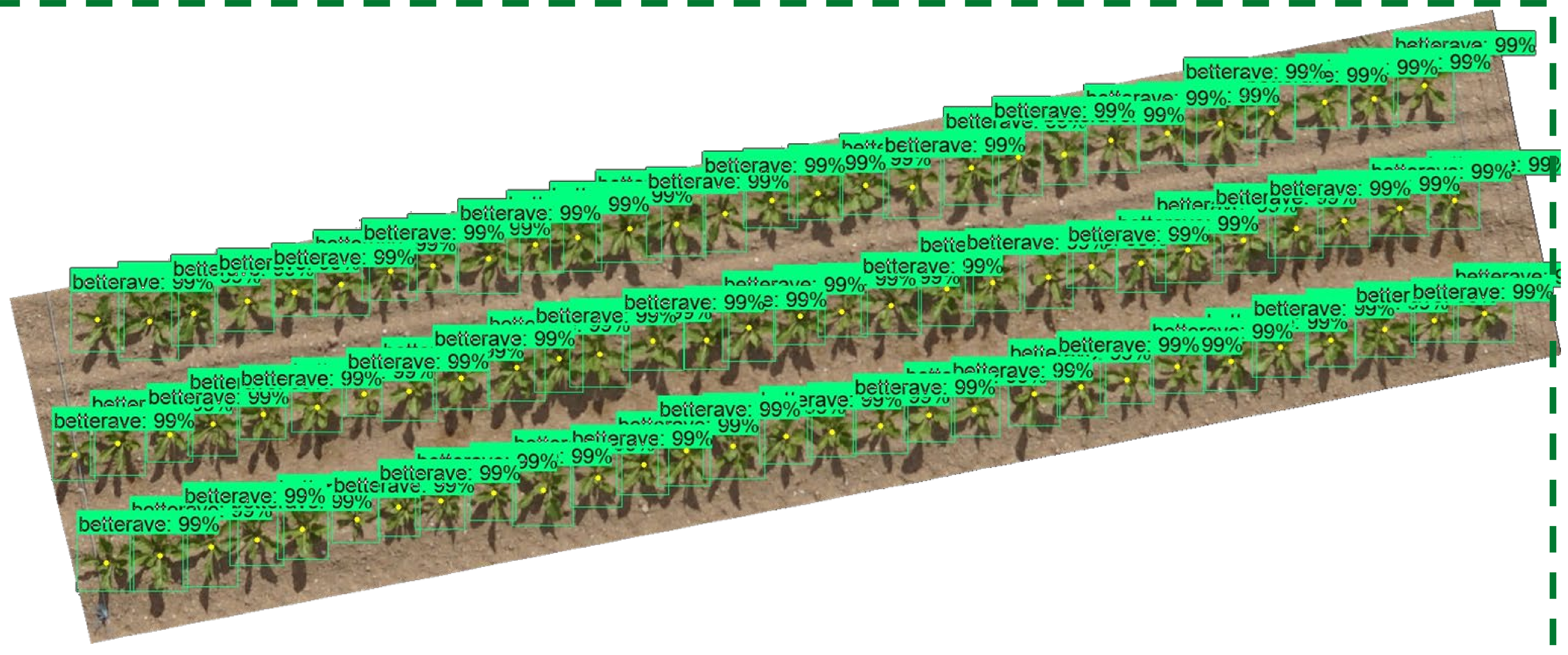
CONCLUSIONS

➔More information on varieties and field implantation

➔Model robust to common disturbances

➔Statistically more precise

➔New phenotyping traits linked with development speed, ease of weeding and harvesting.



PERSPECTIVES

➔Evaluate the relevance of newer and faster neural networks.

➔Streamline the process for faster use in the Institute.

➔Estimate other traits to pinpoint the varieties producing more sugar with less inputs.

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Introduction

Success in Sugar Beet cultivation depends on a good implantation in the first stages. All seeds should germinate and their growth should be fast and homogenous. Those traits are expected to be correlated to a increase competition with weeds, a better photosynthetic potential and uniform roots easier to harvest.

Drones allow fast and precise image acquisition over trial-sized fields. Their use is now part of the plot phenotyping routine at the ITB. The high resolution (5mm/pixel) of the images provide valuable informations on leaves cover yet remains not entirely exploited.

Deep learning, which no more needs introduction, is being used extensively to detect complex shapes and organs.

In the present work, we combine both a high-throughput vector and an accurate detection tool in order to retrieve the individual leaf cover of the beets.

Material and Methods

5 fields were phenotyped in 2017, 4 in 2018, and 4 in 2019 and 2019 with a Sony alpha camera mounted on a hexacopter. Flights were scheduled at maximum 2h before or after the zenith in various lighting conditions (sunny, cloudy, overcast, …). The shots were taken at 35m, allowing a 5mm/pixel ground resolution. The 200 plots were shot in 10 minutes between 4-leaves stage and near canopy closure. Flight data was later processed by Agisoft Photoscan to retrieve camera poses and extract plot data. The least blurred images were filtered to be stored.

Beet experts labeled approximately 45000 individual plants with bounding boxes on 2017 and 2018 plots. This ground truth was partitioned into a training and a validation dataset with a special attention of dedicating all the data of 5 flights to validation. This setup allows to better estimate the generalization capability of the detection model.

The model Faster R-CNN with Inception ResNet v2 from google’s object detection API was trained for 200000 epochs with a batch size of 2 on a NVIDIA Quadro M4000 graphic card.

Model validation was done by measuring an error rate $\frac{FalsePositive+FalseNegative}{Positives}$

For each processed plot, individual leaf cover, in-row distance and beet count were computed in order to test their statistical relation to the genetical variety.

Results

Loss figures show a slow convergence followed by a plateau indicating an opportunity for further fine-tuning.

The average error rate for validation data was around 3% with higher numbers for some of the “full-validation” samples. This can be explained by the deliberate choice of complex conditions : shadows, very small beets, … The validation data for 2019 (not shown here) shows similar values.

Green cover values obtained on individual plants were well correlated to global plot measures, but with a better power of statistical discrimination.

Conclusions

The combination of these modern tools allows actors of the sugar beet sector to get more information about their varieties and field plots. The models have been proven robust to common acquisition disturbances without the costly need to train again every year. The information extract is more precise statistically speaking and enable advicers to compare the leaf cover homogeneity of varieties for instance. We hope that the computation of new traits of this kind will help breeders and farmers to grow beets with a faster development and an eased weeding and harvest.

Perspectives

New neural network architectures have been developped since our work and may improve detection by few percents while taking less time to process images. The global toolchain is being streamlined to fasten phenotyping in the context of a advicing institute. What is more, we are looking forward to estimate new traits in order to highlight the beets of tomorrow : more producing with less inputs.

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