ETH zürich

Autonomous Systems Lab

Autonomous Crop Row Detection for a Laser-based Weeding Robot

Roxane Mérat
Semester Project

Supervisors :
Cornelius von Einem
Patrick Barton
Prof. Dr. R. Siegwart

The Caterra Project

Caterra's agricultural robot

Goal of Caterra :

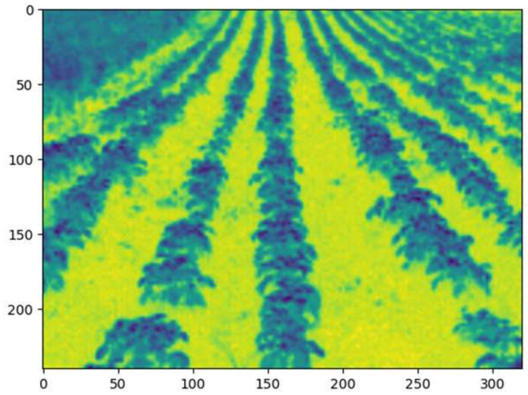
Develop an autonomous agricultural robot with a laser module for weed removal

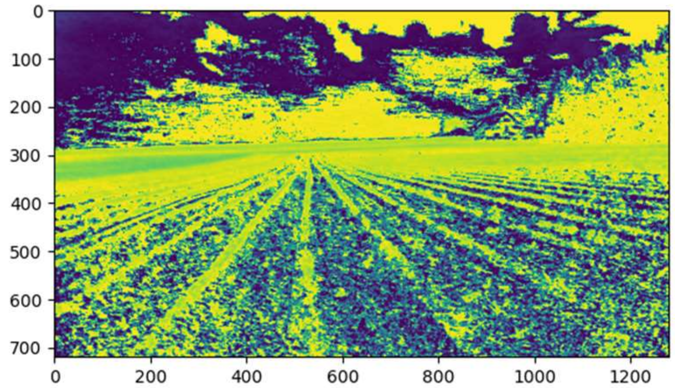
My goal :

Develop a robust crop rows detection algorithm using computer vision

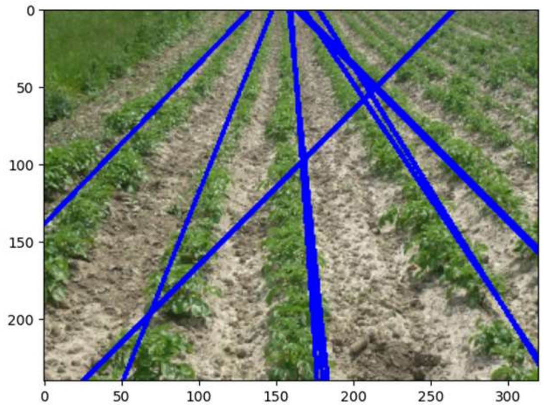
State of the art

- Excess green Index
- Hough transform [1]
- Deep Learning [2]





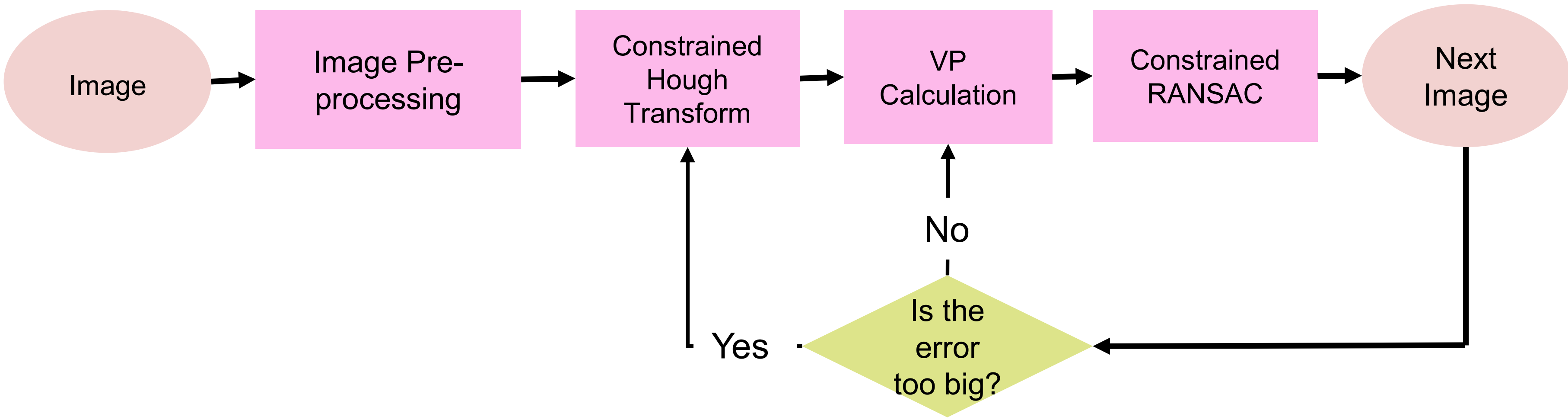
Excess green index images



Hough Transform results

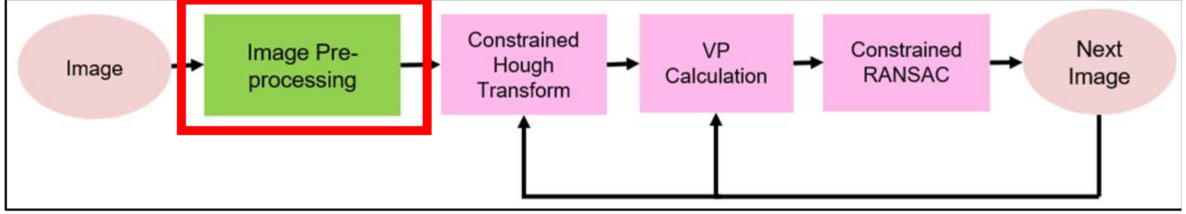
[1] : *Real Time Tracking of Plant Rows Using a Hough Transform,* John.A Marchant and Renaud Brivot
[2] : "*From plants to landmarks: Time-invariant plant localization that uses deep pose regression in agricultural fields*", Kraemer et al.

Algorithm



→ Use of temporal information : a crop should be in the same region in two sequential frames

Sky Removal



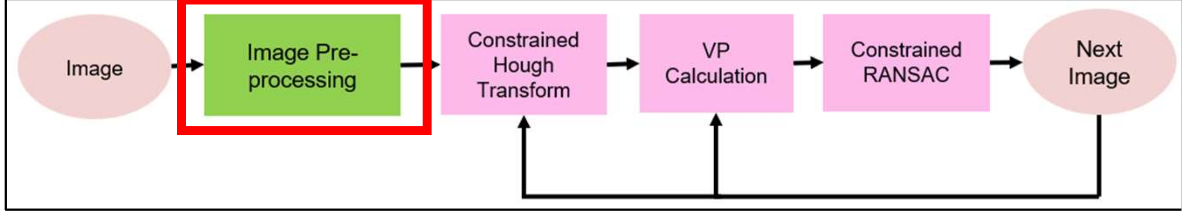
Original Image

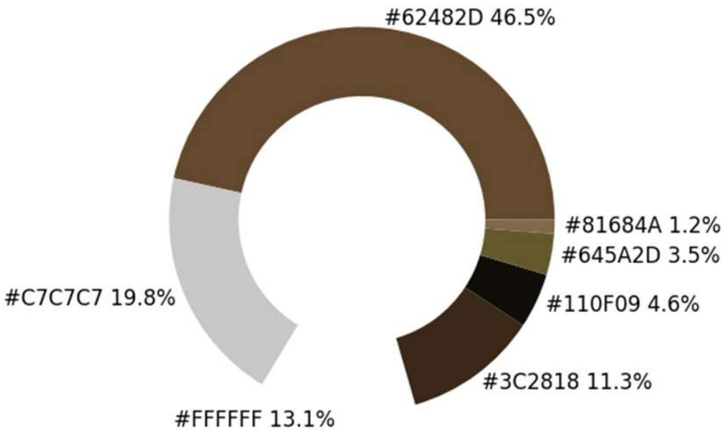
Calculate Laplacian

Mask of the region with high Laplacian

Image with sky cut-off

Vegetation Segmentation

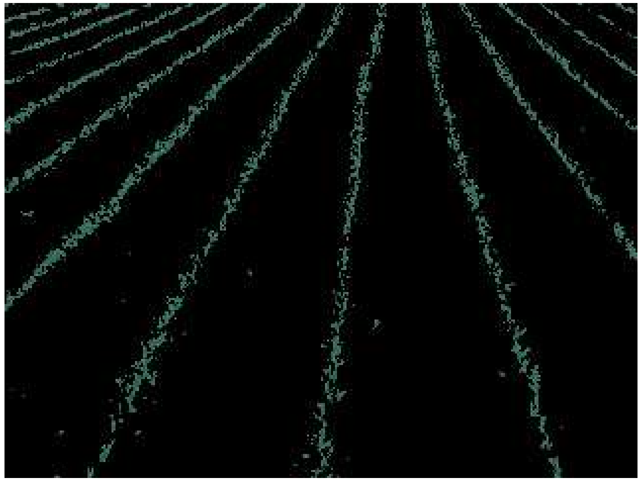




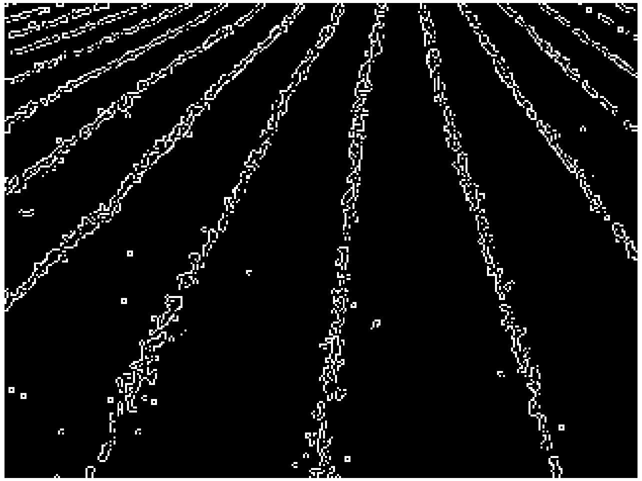
main clustered colours

Advantages :
- Threshold independent
- Robust to shadows and colour variation

Original Image

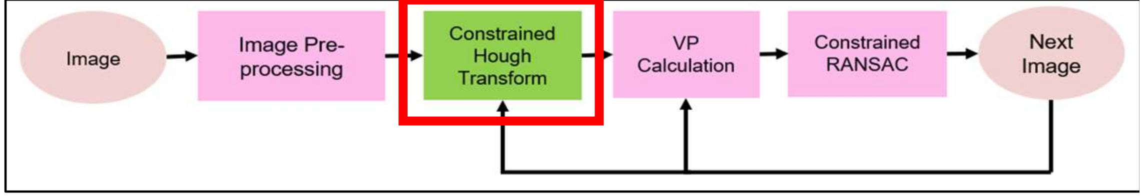


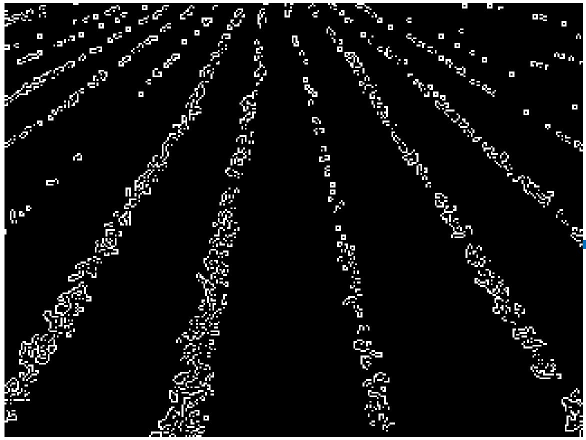
Vegetation segmented



Canny Edges Detector

Constrained Hough Transform





Vegetation Image

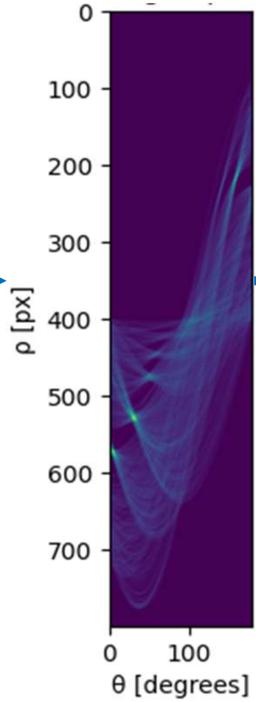
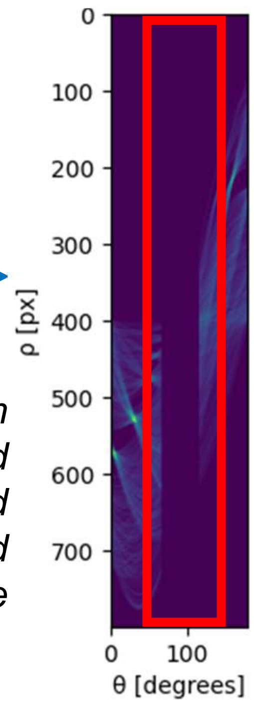
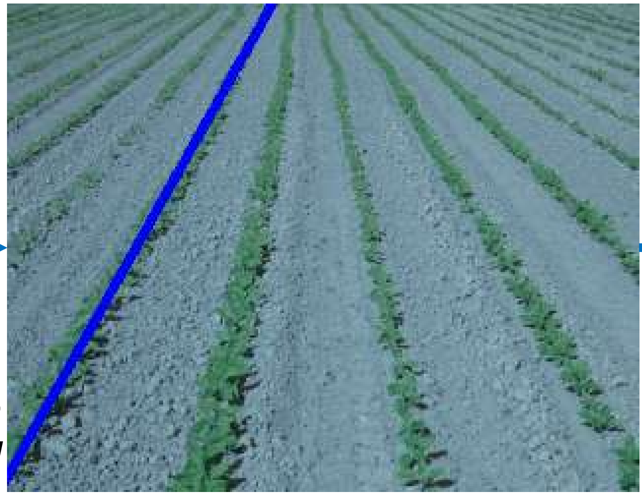


Image in Hough Space, the maximum value is taken

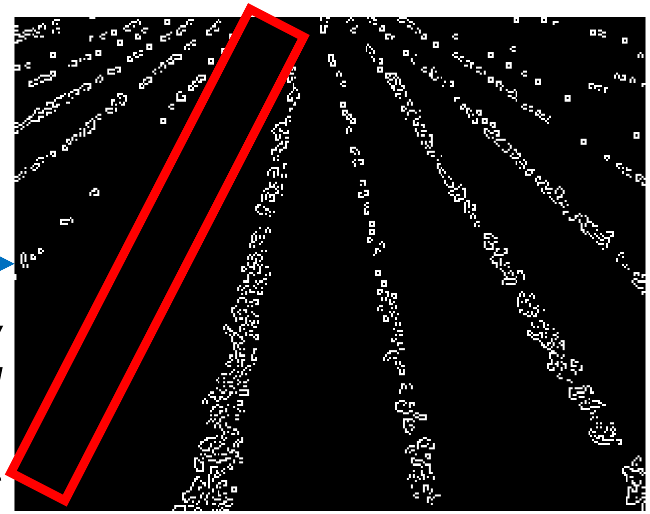
New Hough Space, band around detected angle



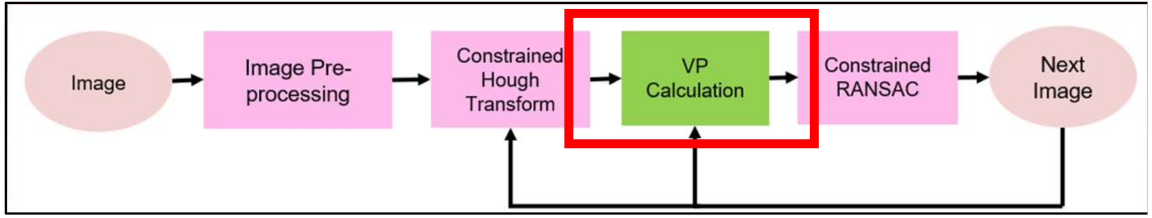
Line Detected



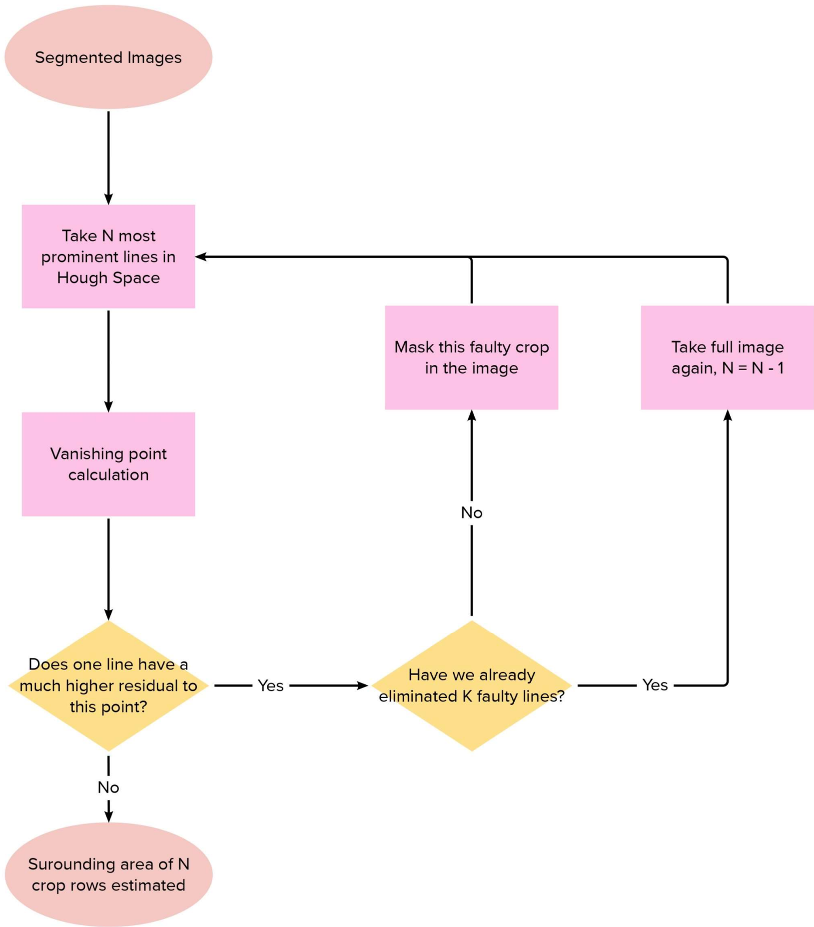
New masked image to be process

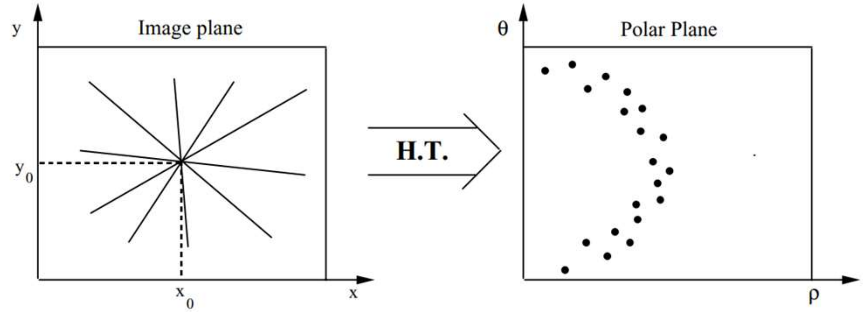


Vanishing Point Calculation

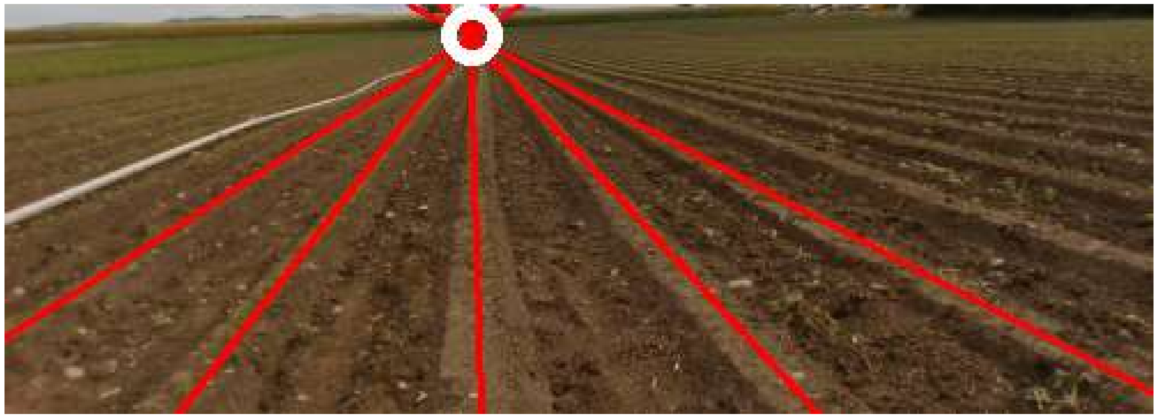


Vanishing point = point described by main sinusoidal in Hough Space



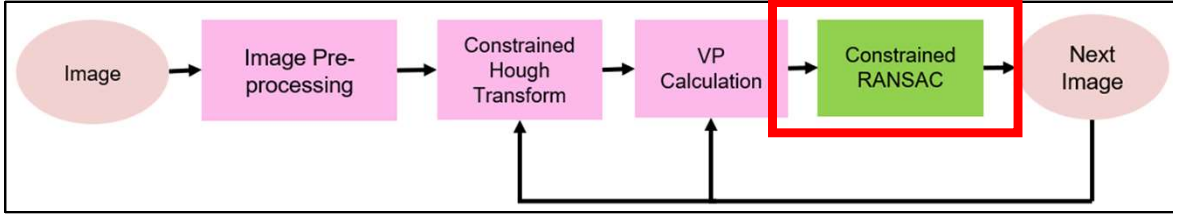


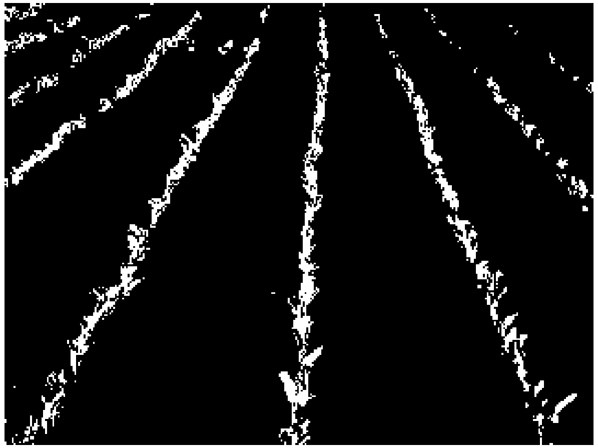
Hough Transformation of a set of lines that intersect in a single point [1]



[1] : *Vanishing Point Detection in the Hough Transform Space,* Andrea Matessi and Luca Lombardi

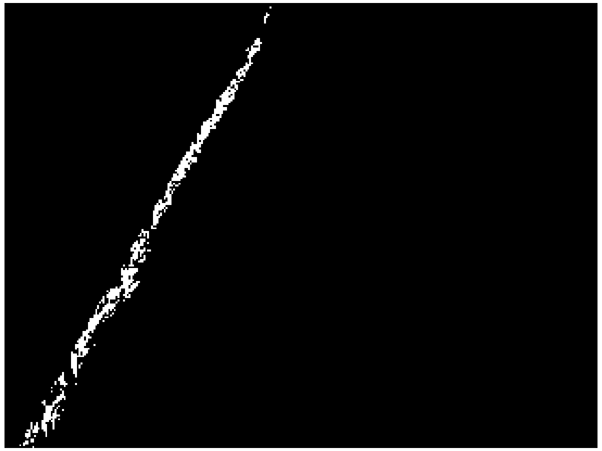
Masking per crop





Vegetation Image

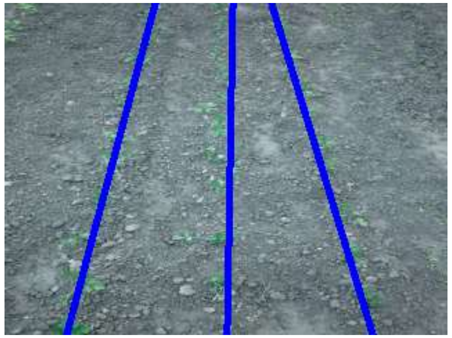
Mask



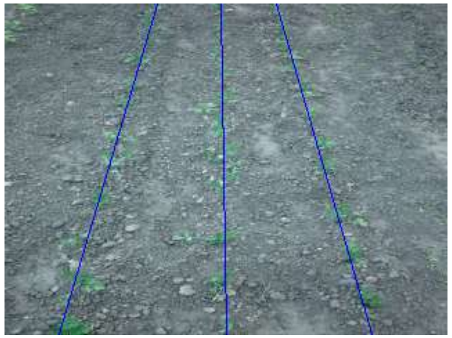
Crop Row masked

Each previously detected line is used to create the mask that will isolate the pixels corresponding to a single crop row in the next image

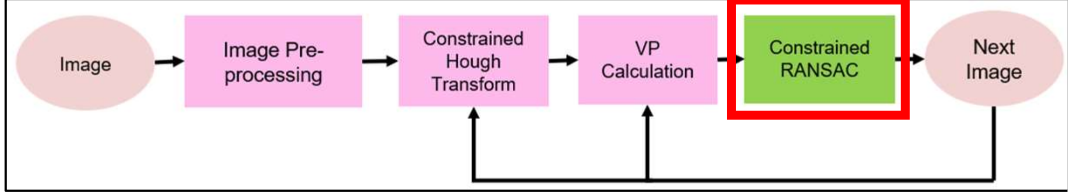
Lines found with Hough

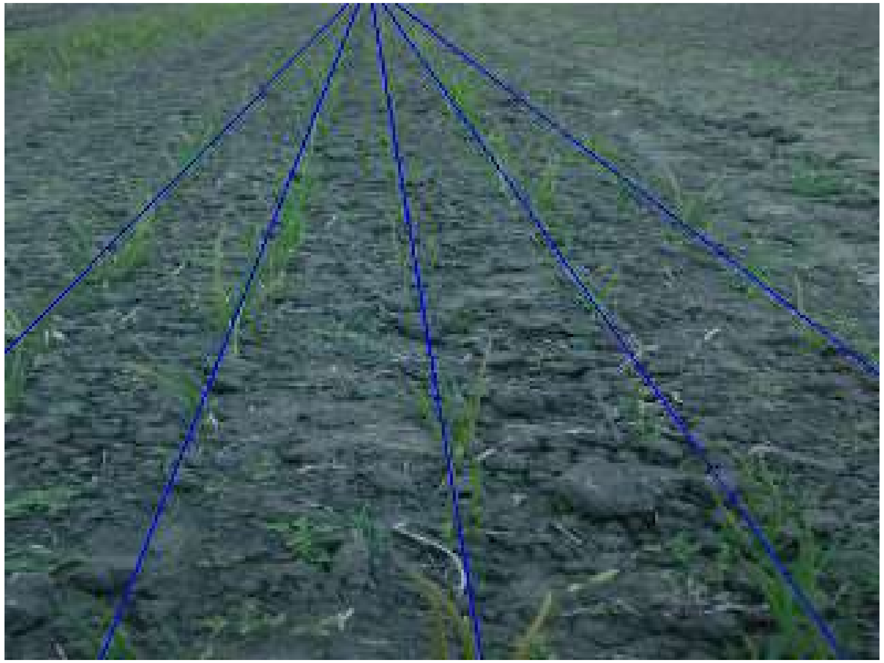


Lines found with RANSAC



RANSAC Lines





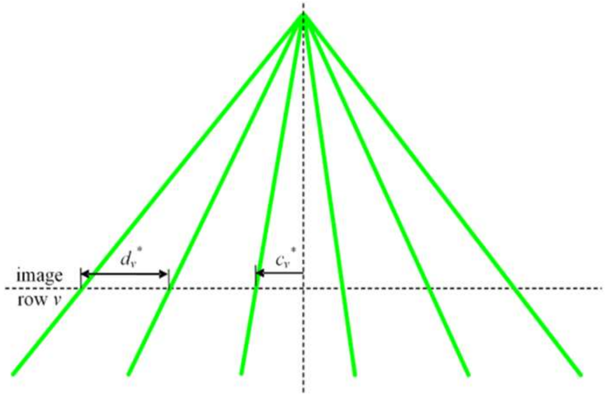
Detection with Hough Transform :

- Every K frames
- If distance between crop row too small
- If angle too close to the horizon angle
- If too few points for RANSAC

Evaluation

$$CRDA = \frac{1}{m(h-v_0)} \sum_{v=v_0}^{h-1} \sum_{i=1}^{m} s\left(u_{v,i}^*, u_{v,i}, d_v^*\right),$$

$$s\left(u^*, u, d\right) = \max\left(1 - \left(\frac{u^* - u}{\sigma d}\right)^2, 0\right),$$



Values [1] :

m – number of crop tbd

v0 – first line where evaluation starts

h – height of the image

u* – ground truth point on line v

u – my results of point on line v

d – distance between crops

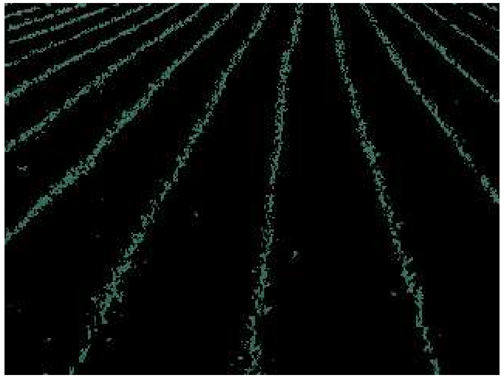
σ – desired accuracy needed, 0.25 in my case

[1] : Method proposed by Vidovic et al., http://www.etfos.unios.hr/r3dvgroup/index.php?id=crd_dataset

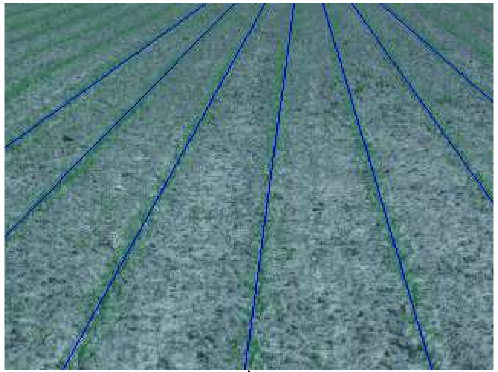
Results (1) :

Original Image

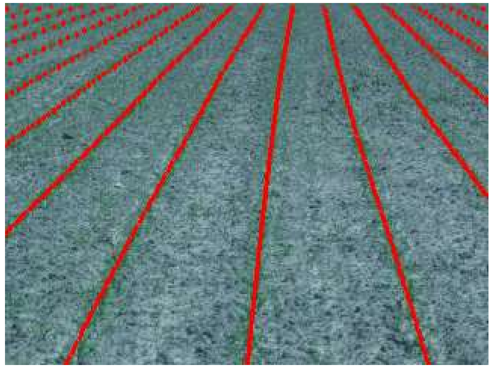
Vegetation segmented



Results



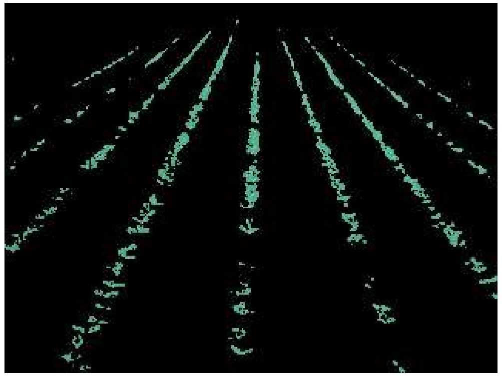
Ground Truth



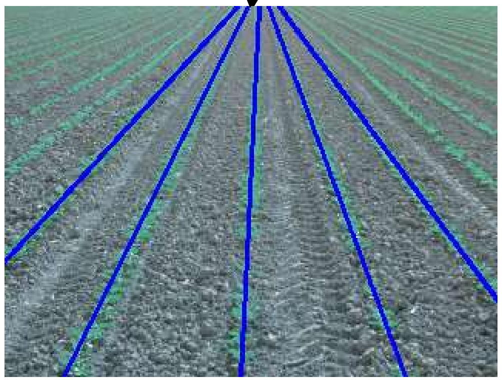
Score = 0.98

Score = 0.92

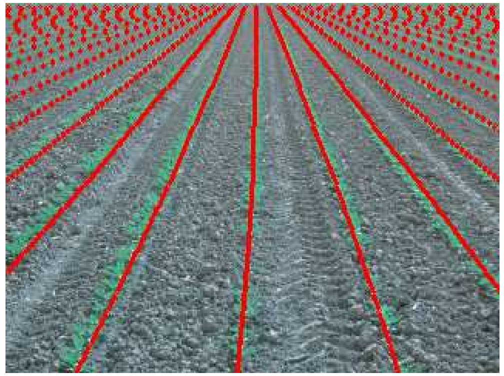
Original Image



Vegetation segmented



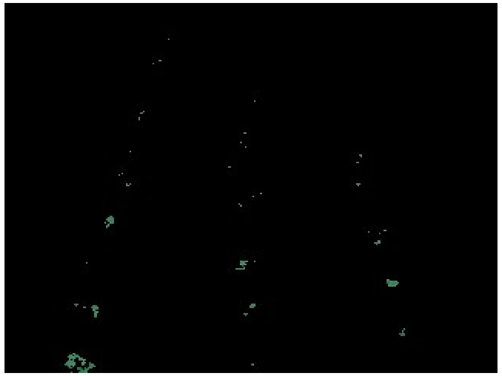
Results



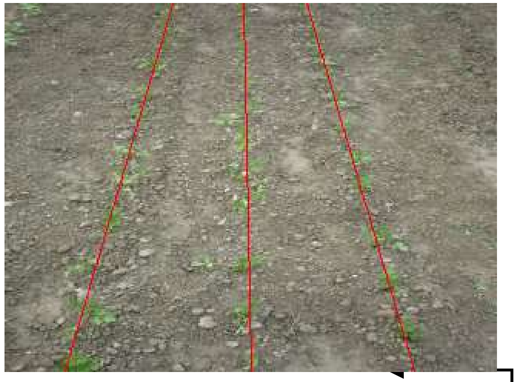
Ground Truth

Results (2) :

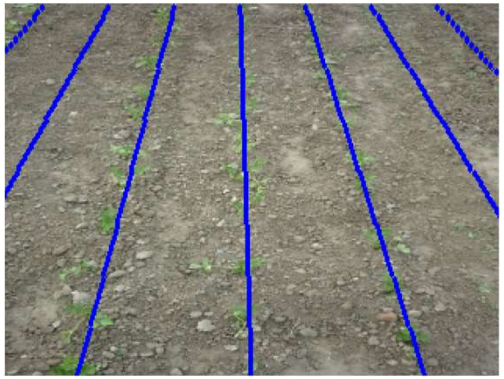
Original Image



Vegetation segmented



Results

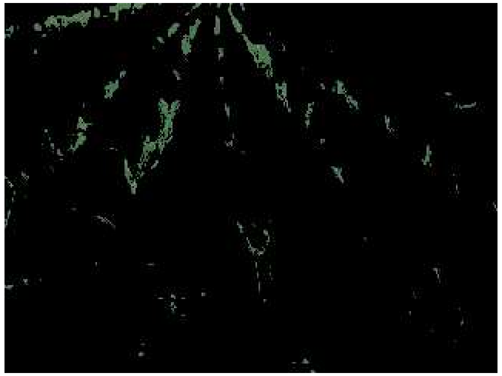


Ground Truth

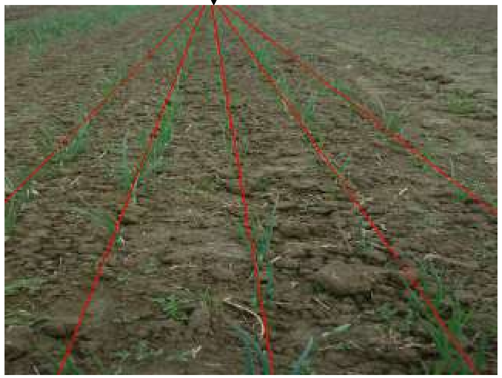
Score = 0.93

Score = 0.85

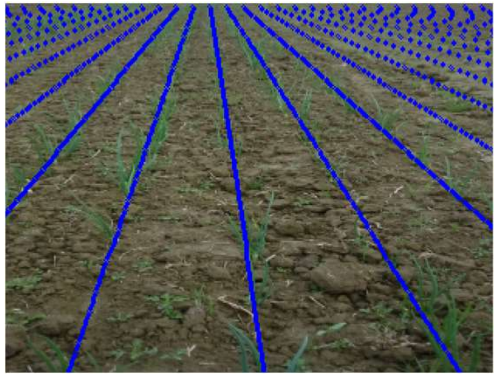
Original Image



Vegetation segmented



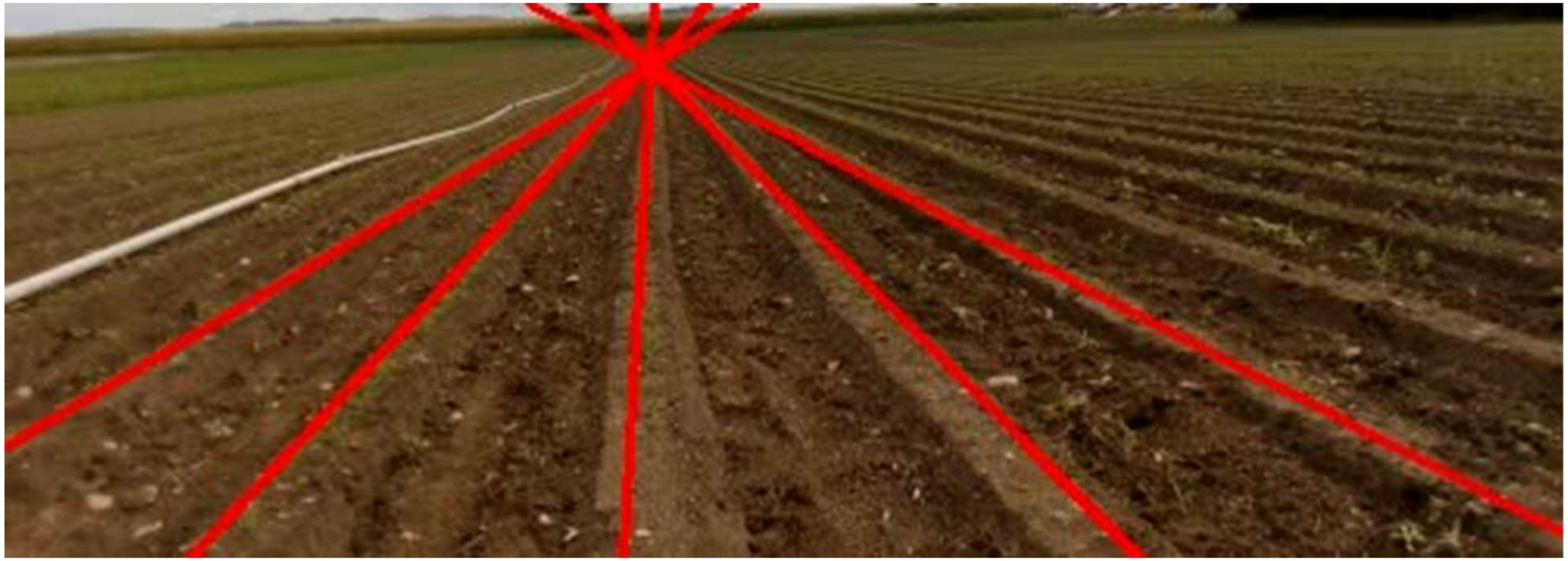
Results



Ground Truth

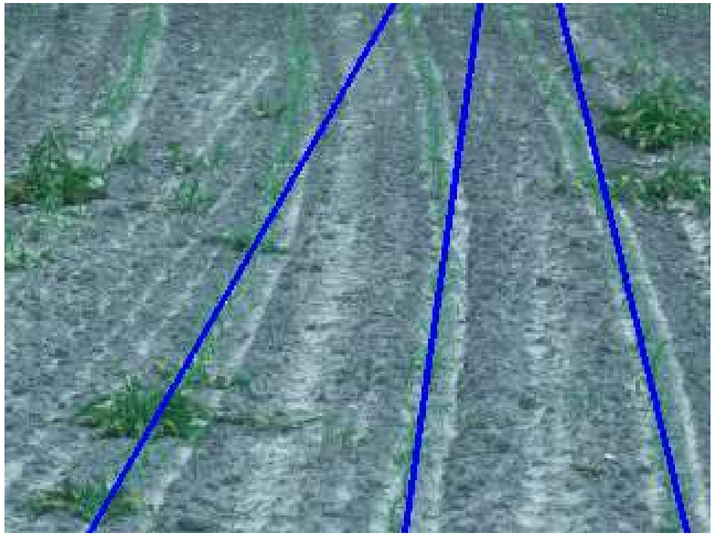
On complete dataset : average score of 0.92 for non bushy images, 0.6 for bushy images

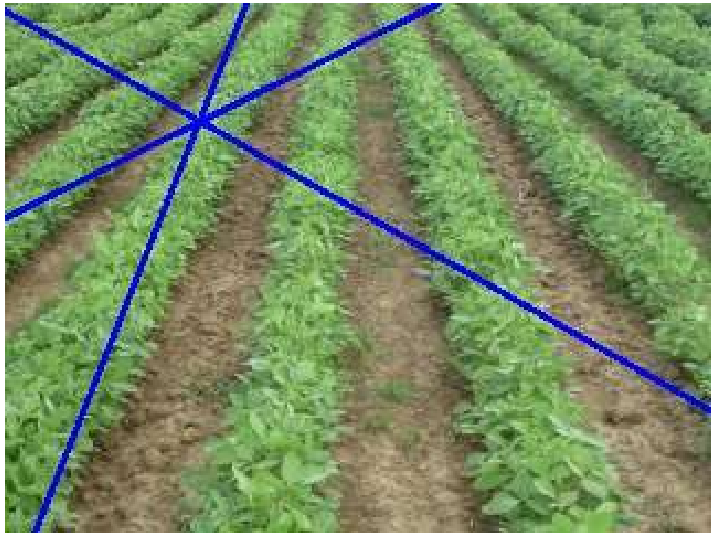
Results (3)



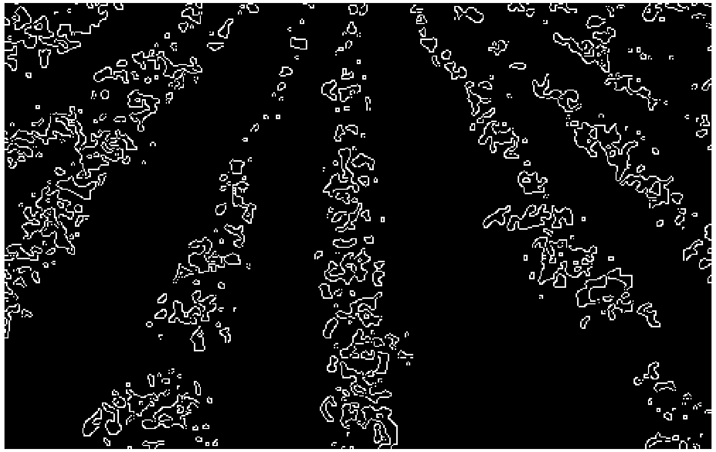
Result of Caterra's Dataset

Failure Cases



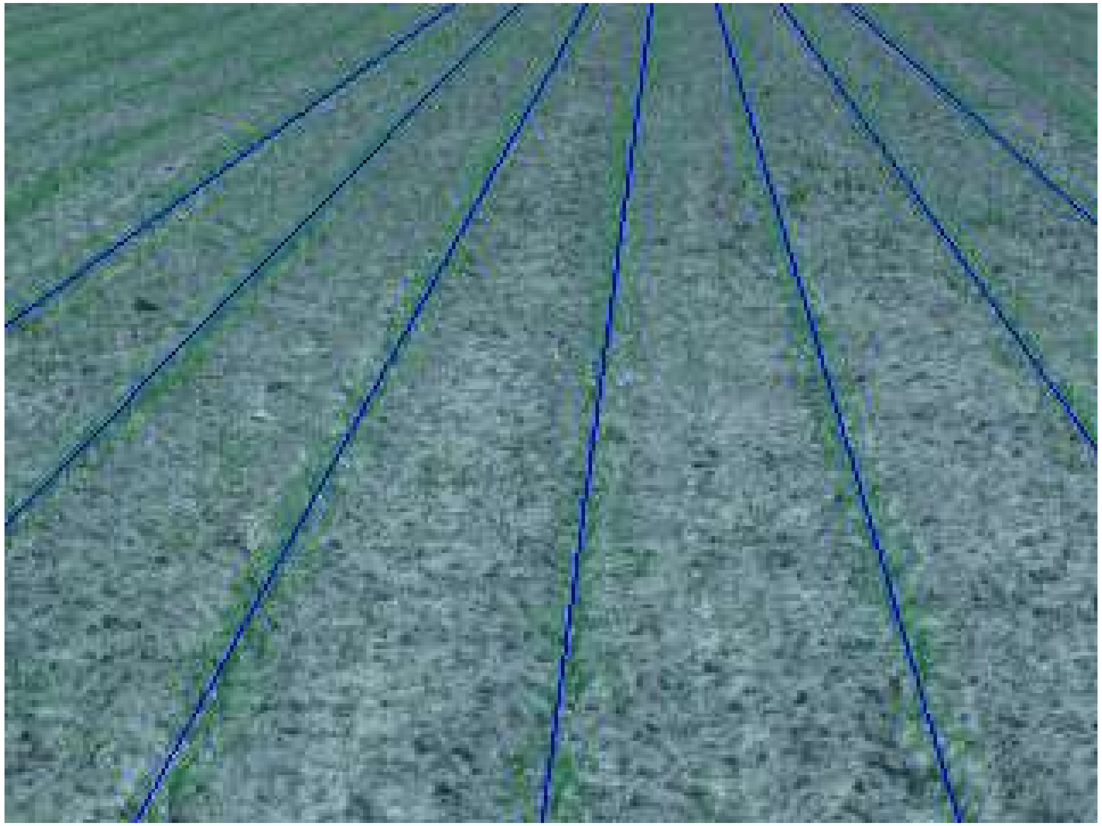


- Detection of curved crop rows
- Very bushy crops



Future Work

- Optimize the code
- Test it on different datasets : different soils and weather conditions
- Calibration process



Conclusion

- Robust to different illuminations, points of view
- Generalisable : not limited to one kind of plants
- Accurate for straight crop row
- Bushes can be a problem
- Too slow, not yet able to work in real time

Thank you !