Using Custom Algorithms to repair incorrectly segmented images

Martin Rupp
SCIENTIFIC AND COMPUTER DEVELOPMENT (SCD)
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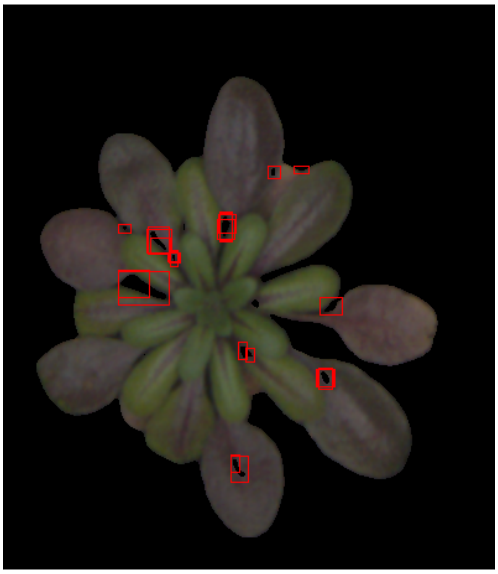
The project consisted in defining a custom algorithm to repair a set of images that had been segmented by U2net. U2net is one of the best neural networks for salient object detection. (see [1])

While U2net is very powerful, around 10% of the images were incorrectly segmented. This is because the images were representing plants of different phenotypes growing and the soil was not very different from the plant itself.

The set of plants were used for genetic selection and the segmentation had to be perfect. We streamed the defects into three categories:

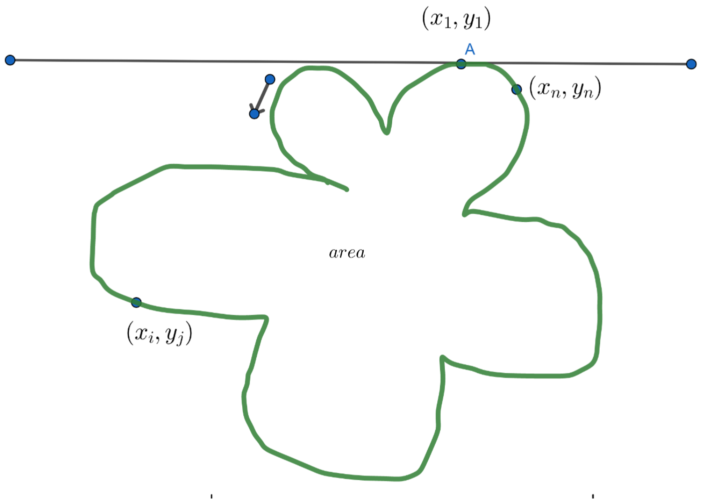
- *Holes in the plants*
- *Plants were cut into two or more connected components*
- *"Alien"/foreign materials was remaining in the background, such a soil or dead leaves for instance*



For the situation where holes were appearing in the plants surface, we had to develop a custom geometrical parser because no existing framework such as openCV was efficient. We also tried to remove the background using KNN or gaussian mixtures (integrated to the openCV framework) but this gave even worse results than U2Net.

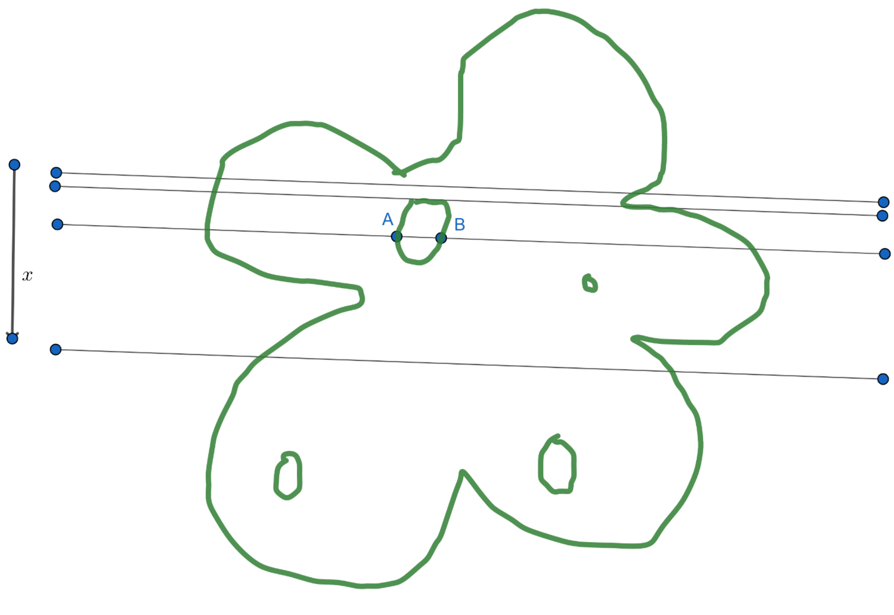
The algorithm used to detect holes is very simple but efficient, given the fact that the plants have always a specific shape. It is based on scanning the bitmap horizontally and counting the amount of transitions between a black and non-black area. The image is then rotated and flipped to make sure that all the holes are discovered. For the connected components discovery, the image is scanned from various starting points in various directions and, once a point is found which is not from the background, the border of the plant is computed.

Then the area is computed using the shoelace formula. If different areas are found during the process, this means that there are more than one connected component.

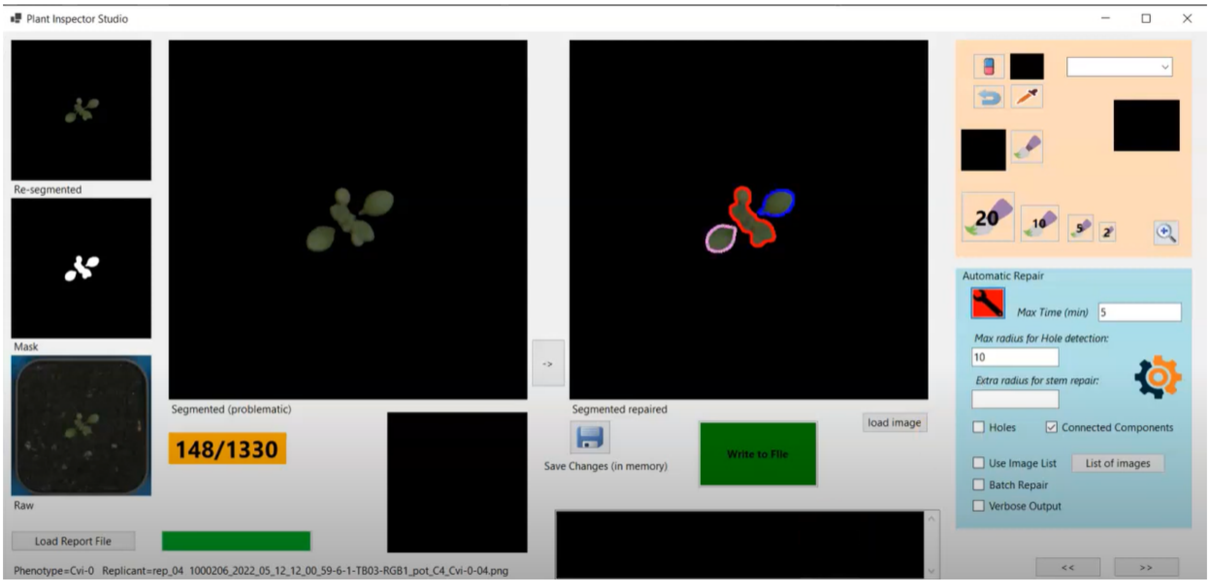


$$area = \begin{vmatrix} x_1 & x_2 & x_3 & \dots & x_n & x_1 \\ y_1 & y_2 & y_3 & \dots & y_n & y_1 \end{vmatrix}$$

N different initial points A are obtained after N scans in different directions. If the list of the N areas contains “significantly” different values, then the components are tested against the non-segmented image (raw). If they both belong to the plant area, then the missing part connecting both components is obtained from the raw image and properly resegmented then pasted into the repaired segmented image. If one of the components is deemed to be “alien”, it is erased from the segmented image.



A similar scanning is done for the detection of holes: when a transition is detected such as the segment [AB] , the distance $d(x) = d(A, B)$ is computed, where x is a parameter of the scanning. If the function $x \to d(x)$ have certain properties, then we label the corresponding area as a possible defect. Only after a comparison with the raw image, can we determine with certainty if the area is a detect (“hole”) and must be repaired, filled with the same area from the raw image.



During the process, after repair, there remain a certain amount of images who cannot be fully repaired , so we developed a “repair studio” with custom paint tools to quickly fix manually the remaining issues.

Conclusion: By using simple but efficient geometrical algorithms we could produce a fully repaired set of segmented images, See [3],[4],[5] and [6] for video demos.

[1] xuebinqin/U-2-Net: The code for our newly accepted paper in Pattern Recognition 2020: "U^2-Net: Going Deeper with Nested U-Structure for Salient Object Detection." (github.com)

[2] Developmental normalization of phenomics data generated by high throughput plant phenotyping systems Diego Lozano-Claros and Al. (https://plantmethods.biomedcentral.com/articles/10.1186/s13007-020-00653-x)

[3] https://www.youtube.com/watch?v=Dji2AyNc9gk

[4] https://www.youtube.com/watch?v=7e3qDviIVfU

[5] https://www.youtube.com/watch?v=A_PdvleBI5A

[6] https://www.youtube.com/watch?v=YOLz-EXApDQ