COMBINATION OF 3D ANALYSIS AND CHLOROPHYLL FLUORESCENCE EMISSION

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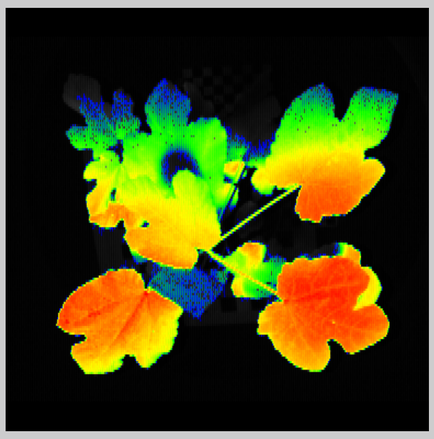
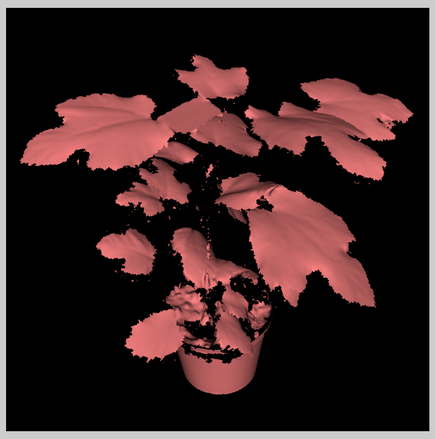


INTRODUCTION

Chlorophyll fluorescence is a powerful optical reporter signal yielding information about modulation of the light use efficiency. In standard imaging applications, fluorescence transients are captured in 2 spatial dimensions and in time [1], [2]. Here, we demonstrate that it is possible to combine the information obtained in the 2D-t format to 3D reconstruction of the entire plant in a process called co-registration. The leaf area, angles and distances are then available and used for deeper interpretation of fluorescence signals as well as for general characterization of the plants.

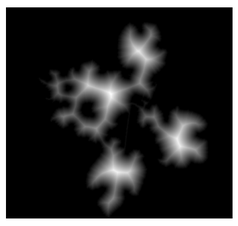


CO-REGISTRATION OF CHLOROPHYLL FLUORESCENCE EMISSION AND 3D MODELS OF PLANTS

The 3D model of a plant is created separately from capturing the CFE, therefore for the proper visualization a process called co-registration needs to be done. It is a process of combining two different modalities into a final model. It can be seen as a texturing of surface model with data representing the CFE. For this task two different approaches were tested. The first one is based on an image registration method, the second one is based on analysis of a known calibration object.

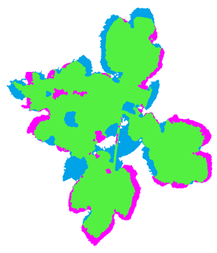
IMAGE REGISTRATION

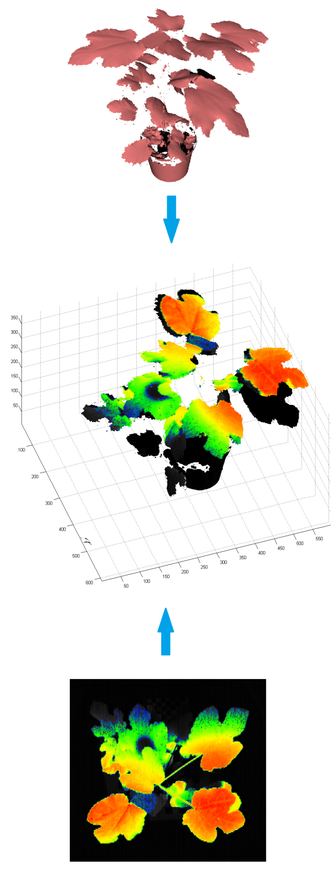
Goal of image registration is to estimate transformation parameters between two modalities, which are the 3D model and CFE in our case. Once both modalities are obtained the top projection of the model is used thereby the estimated transformation is reduced to 2D similarity transformation.



For faster convergence of the registration process a similarity measure based on difference of the distance image is used.

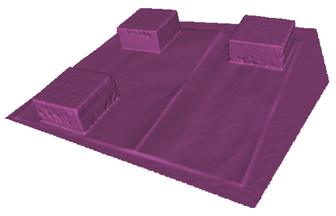
One disadvantage of image registration is that the transformation estimation could be trapped in local minima. Thus it is reasonable to use multiple initializations of the algorithm.

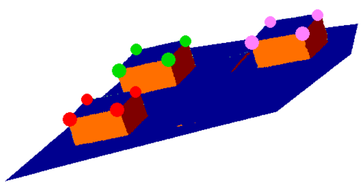




CALIBRATION OBJECT

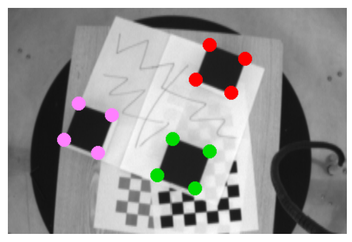
To overcome the assumption of the known initial position an approach based on a known calibration object was developed. As this calibration object three blocks of known size were used that were placed in known geometry.





Once the object is scanned, normals of every patch of the surface model are classified so it is possible to identify individual sites of the blocks and their intersections.

With similar image processing methods the blocks in the reflectance image were identified and after that it is possible to align the individual coordinate systems.

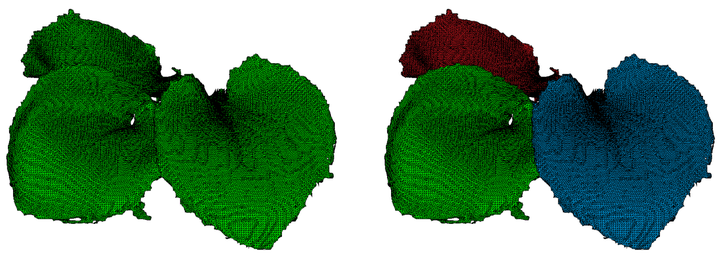


ANALYSIS OF PLANT STRUCTURE

Analysing plant structure is a good way for general characterization of the plants. Moreover, analysis of plants that are under a certain type of stress provide us with information about their capability to survive under difficult conditions. The image processing techniques are capable to deal with problematic associated with this task. So far it is possible to extract leaf area, orientation of a plane that approximate given leaf and the direction of leaves.

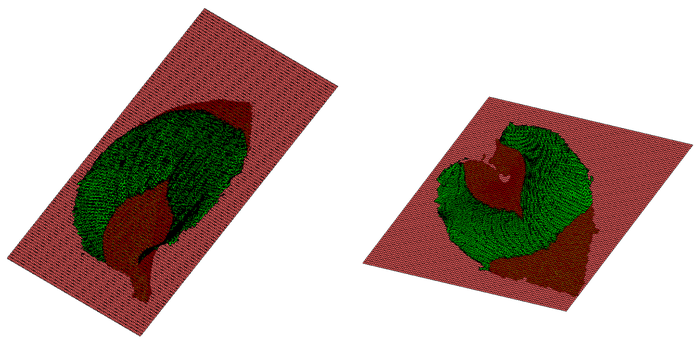
SEGMENTATION OF MODEL

For proper analysis of plant structure the surface model needs to be split into meaningful parts, e.g. leaves, by process called segmentation. For this purpose a method based on the distance from the border is used. The model is eroded and thus split into separate areas that corresponds to individual leaves.



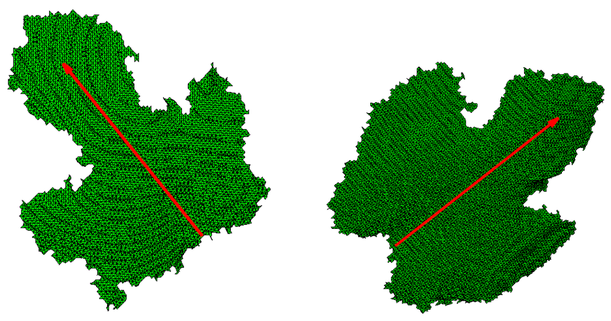
APPROXIMATION BY PLANE

Each segmented leaf is then approximated with a plane. Calculating orientation of this plane in the sense of dihedral angles (angles between two planes) is then possible. This way angles between this plane and coordinate planes (x-y, x-z, y-z) are obtained.



DIRECTION OF LEAVES

For even better description of the leaf orientation, directions in which the leaves are pointing are computed. This is done by using principle component analysis that provides us with a direction in which leaf points have largest variance. This orientation is then represented by azimuth and elevation.



CONCLUSION

Visualizing CFE of plants on their 3D model brings many benefits that not only make the data more readable but surely can also improve subsequent analysis. From the 3D model it is possible to extract different informative features, e.g. leaf area and orientation, that can be used for characterization of studied plants. Methods from image processing area have been shown to be very useful to deal with this kind of tasks.

FUTURE WORK

For further application the scanner is planned to be attached on a manipulator. It allows to use more suitable method for the co-registration. The method can profit on the known positions of the scanner and the camera and is based on direct mapping of their coordinate systems. Moreover, computation of the transformation could be done only once so the co-registration process should be much more faster then it was in the previous approaches.

REFERENCES

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