3D reconstruction of maize plants in the PhenoVision system

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In order to efficiently study the impact of environmental changes, or the differences between various genotypes, large numbers of plants need to be measured. At the VIB, a system named *PhenoVision* was built to automatically image plants during their growth. This system is used to evaluate the impact of drought on different maize genotypes.

PhenoVision comprises a conveyor belt system and a combination of visual, near-visual (VNIR), short-wave infra-red (SWIR), and long-wave infra-red (LWIR) cameras. Maize plants move through the imaging chambers on a regular basis, resulting in a set of visual-spectrum side views of the maize plants as well as visual, VNIR, SWIR and LWIR top views. The SWIR and VNIR cameras measure more than 400 different wavelengths between them, further compounding the big data aspect of the system.

The SWIR and VNIR cameras present several challenges, aside from the vast amount of data generated by these hyper-spectral cameras. They are so-called linear push broom sensors rather than perspective cameras (such as typical visual-spectrum cameras). This means that they image the scene by sweeping a single sensor line over the scene, rather than capturing the scene in one go with a grid of pixels. On the one hand this requires an adjusted calibration method, taking into account the hybrid perspective-orthogonal nature of the cameras. On the other hand, this also introduces a specific type of striping noise into the captures because of variable sensitivity of the pixels on the sensor line. We remove this type of noise using an advanced denoising technique tailored to hyper-spectral image data.

After calibrating the visual cameras, we reconstruct a 3D model of the maize plant using voxel carving. Starting from a big cube of 3D points and the camera calibration, we trim away any points that are not projected onto maize pixels in all of the images. Because of the large amount of hyper-spectral image data, we employ the voxel carving algorithm on the GPU, achieving speed-up factors of 40 to 50 compared to single-core CPU processing. The output of the voxel carving algorithm is a cloud of 3D points. After applying volume thinning on these points, we end up with a skeleton of the maize plant. This allows morphological measurements of the leafs and plant such as length, height, width, area, etc.

Bringing it all together, our image processing results in a 3D model of the maize plant at each measurement moment during the plant's development, combined with a de-noised hyperspectral recording of the plant. The 3D model allows the measurement of various aspects of the plant morphology. Combination of the 3D model with the calibrated hyperspectral data sets allows linking each measured spectrum with its location on the plant model and correlating it with the local orientation of the leaf.