Using Stereo Imaging to Determine Phenotypic Parameters of Cereal Crops in the Field

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Abstract

Currently, different computer vision systems are used to obtain 3D reconstructed plant models [1, 2, 3, 4]. Analyzing these models it is possible to estimate phenotypic parameters like leaf angle distribution or leaf area index [5, 6]. For cereal crops in the field available systems allow 3D reconstruction at the canopy surface level only. However, calculation of phenotypic parameters as leaf angle distribution requires a 3D reconstruction at the leaf level. For this purposes, methodologies can be affected by uncontrolled wind and light conditions, as well as the thin and flexible structure of leaves with little surface texture.

Therefore, we established a stereo camera setup in the field and developed a new image processing pipeline to obtain 3D plant models of cereal crops. The stereo setup consists of two automatable cameras to acquire images from top-of-canopy. Simultaneous triggering of the cameras makes the setup less sensitive to wind-induced changes in canopy structure. The challenge is to find an appropriate correspondence algorithm to deduce reliable depth maps from acquired stereo images. Considering that images contain locally ambiguous regions, we selected a semi-global approach, which performs a scanline optimization [7]. A radiometrically tolerant cost function was chosen to overcome the problem of light variations within both images [8]. The final step of the reconstruction includes the refinement of the depth map via plantbackground segmentation and noise removal. Our postprocessing includes a median filter with a box size of 3x3 pixels [9], occlusion filter [10, 11] and a jump edge filter [12] to remove outlier in the disparity map.

As a last step, a 3D point cloud of the depth map is obtained via triangulation [13] and a ‘surfacetwistfunction’ is fitted to the data to determine proximodistal twisting of leaves [14]. Normal vectors of the triangular mesh are used to compute the leaf angle distribution [15].

A crucial step in our method development is the approach evaluation via artificial models that feature specific plant properties. Therefore we developed a plant model with known and adjustable geometry. The model allows us to assemble a complete artificial crop plant of varying size and with known phenotypic parameters as leaf size, proximodistal twisting and leaf angle distribution. This model was used to determine accuracy and limitations of the newly-developed pipeline.

Experimental trials were carried out on two image datasets of wheat plants (Triticum L.) in different growth states. The first dataset was obtained in a climate chamber under varying, but controlled light and wind conditions, while the second one was achieved in the field under uncontrolled environmental conditions. For the field experiment, the automatable stereo camera system was fixed on a hand-driven field positioning platform. We present 3D reconstructions and phenotypic traits, which were derived for both datasets.

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