Virtual broccoli farmland by fusing close-range and aerial phenotyping*

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Abstract: Using drones and photogrammetry for aerial surveys allows for the efficient acquiring digital 3D models of the crop canopies for the entire farmland. However, due to limitations in survey efficiency and wind blurring caused by propellers, the flight altitude cannot be too close to plants, resulting in low resolution for analyzing the broccoli heads at the organ level. Meanwhile, the occlusion of canopies and broccoli heads themselves, only the surface of head crown is available for the aerial canopy 3D models. To better visualize and understand the growth condition of the broccoli heads, we attempt to build a virtual broccoli farmland by fusing the 3D models from close-range and aerial photogrammetry and the 3D-based morphological traits from plant phenotyping. We first build a high-quality 3D model database for broccoli head using the close-range 3D reconstruction pipeline. Then we extract the accurate broccoli head morphological traits and position from the high-resolution raw images and link results back to geographical positions. Afterwards, an automatic machine learning calibration model is trained to calibrate the aerial measured head morphological traits. Finally, we apply the template matching and transformation to pick up the closest head 3D models and place them into the canopy model as a virtual farmland for 3D visualization. The results show good correlations (r^2>0.9) on the head size between this method and manual measurements. The proposed 3D visualization system offers a great opportunity for virtual farmland and digital twin technology, which can provide a more intuitive feeling of growth status compared to numeric statistical values.