Estimating wheat grain weight using UAV-multispectral imagery and machine learning

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Abstract: Grain weight (GW) holds significant importance as a crop phenotype parameter, playing a direct role in determining grain yield. As a more stable crop yield parameter (Hamblin et al., 1978), it stands as a pivotal characteristic for crop breeders, agronomists, and farmers alike, serving as a crucial factor for assessing and choosing high-yielding varieties, refining crop management techniques, and projecting crop quality and nutritional composition. Through diligent observation of this parameter, researchers and farmers are empowered to make well-informed choices concerning strategies for enhancing crops, nutrient allocation, irrigation methods, and other elements that impact overall crop productivity.

Here we collected red-green-blue (RGB) and multispectral imagery from UAV throughout the entire wheat growth stages in November 2021 – June 2022, covering 300 wheat plots. Diverse crop features were derived from UAV-based imagery, namely vegetable indices (VIs) including NDVI to NDYI, texture indices (GLCM) including contrast to dissimilarity, canopy cover calculated by the ratio of canopy pixels over the total number of pixels within a plot, and canopy height extracted from the digital surface model (DSM) generated from the 3D point cloud model. The crop yield composition parameter of GW was estimated using artificial neural network (ANN) with different types of crop features derived from UAV-imagery.

Our machine learning model could estimate GW accurately with R^2 and nRMSE being 0.51 and 14.3%, respectively. We utilized the GW estimation model to predict the GW of various wheat types, including winter wheat, spring wheat, high-gluten wheat, and disease-resistant wheat, across more than 230 test plots. We also examined the stability of GW among repeated plots. Subsequently, we identified and selected wheat varieties with high GW. Furthermore, we analyzed the correlation between the GW of different wheat types and their corresponding yields, highlighting the significance of considering GW as a crucial parameter in the selection of high-yielding varieties.

Our study showcased the promising capabilities of utilizing multispectral sensor imagery acquired from UAV-captured data across different spectral bands to forecast the crucial crop phenotype parameter, GW. By harnessing the GW model and integrating GW data with other variables like grain number per unit area and crop-specific characteristics, we envision our model to be a valuable tool in constructing yield prediction models that provide reliable estimates of the final harvest (Bai et al., 2022). Furthermore, the application of our GW model exhibits potential in supporting researchers to identify genetic traits and management practices that influence GW, as well as evaluating the impact of weather conditions on crop productivity. This, in turn, can facilitate the advancement of enhanced crop varieties and cultivation techniques, ultimately benefiting the agricultural industry as a whole.

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