Insights from the Global Wheat Challenge on deep learning and dataset diversity

December 18 2023

Sample from the UQ Frame dataset. Credit: *Plant Phenomics*

Crowdsourcing has become pivotal in scientific research, particularly in data-intensive fields like plant phenotyping, leveraging platforms like Kaggle for data analysis and machine learning challenges.

While effective in controlled environments, the robustness and generalizability of deep learning methods in plant phenotyping, especially under variable field conditions such as wheat head detection, remains uncertain due to the scarcity of large, diverse real-world datasets. The current challenge is to generate extensive and diverse datasets to enhance the reliability and applicability of these techniques in practical agricultural scenarios.

In June 2023, *Plant Phenomics* published a research article titled "Global wheat head detection challenges: winning models and application for head counting."

In the Global Wheat Challenge (GWC) 2020 and 2021, researchers sought robust solutions for detecting wheat heads in field images from diverse regions, focusing on generalization. The top three solutions in both GWC_2020 and GWC_2021, using architectures like EfficientDet and Yolo variants, demonstrated high accuracy and the ability to generalize to unseen datasets.

The solutions faced challenges in detecting small wheat heads and managing false positives (FPs), with variations in performance across different sessions. The GWC_2021 solutions outperformed others in reducing false negatives (FNs), while GWC_2020 excelled in minimizing FPRs.

The winning solutions showed limitations in certain sessions due to factors like low resolution, wheat head bending, or intense illumination.

Despite these challenges, GWC_2021's approach detected small wheat heads more effectively, although it still missed some. The study also evaluated the performance of the solutions in head counting using relative Root Mean Square Error (rRMSE), revealing variability across sessions and datasets.

GWC_2021 demonstrated the lowest rRMSE values, indicating its robustness, yet still faced challenges in certain conditions.

The findings suggest that localization and regression metrics in applications depend on specific task requirements, with regression potentially more effective in dealing with uncertainty. Comparisons with field head density measurements showed good agreement with the

GWC_2021 solution, although discrepancies increased with density due to factors like spatial sampling and model uncertainties.

The solution's reliability in head counting was confirmed, outperforming manual measurements in some cases. However, for improved accuracy and robustness across diverse conditions, further enhancements are needed in areas such as image acquisition, data augmentation techniques, and model architectures

In conclusion, GWC 2020 and 2021 marked significant progress in wheat head detection using high-resolution RGB imagery, highlighting the challenges in generalization and the need for innovative approaches.

The competition attracted attention to this vital area in plant phenotyping and provided a diverse dataset for exploring domain shifts, laying a foundation for future advancements in this field.

More information: Etienne David et al, Global Wheat Head Detection Challenges: Winning Models and Application for Head Counting, *Plant Phenomics* (2023). DOI: 10.34133/plantphenomics.0059

Provided by NanJing Agricultural University