An Intelligent System for Insects Detection and Management for Precision Agriculture

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The growing population and food demands pose a tremendous challenge to existing and future food, fiber, and fuel demands. Unfortunately, aphids can damage wheat and sorghum fields and spread plant viruses, causing significant agricultural yield losses. This issue is compounded by the fact that aphid infestations are usually only partially present in the field and spread out spatially. Despite this, farmers typically apply whole field spraying, treating every plant equally, due to time and labor constraints. Unfortunately, this approach leads to an excessive and uniform continuous spray pattern across the entire field, resulting in only a small fraction of areas receiving the right amount of pesticide application, while other areas lose yield potential due to delayed timing and damage by aphids. It also causes severe pollution to the environment. Although automation could address this issue, the development of robotic technology for insecticide application has been hindered by the lack of camera vision to locate pest incidence and severity on the undersides of leaves.

To address this issue, the study aims to reduce high-value pesticide usage on crops by developing an intelligent autonomous spray system that conducts site-specific application based on a plant's critical pest population. We propose to develop an autonomous system that can sense, identify, and manage pests for all crop growth stages. We explore the latest advancements in artificial intelligence to detect pest incidence and severity on a high spatial basis and manage them using a machine-vision system to site-specifically spray insecticides. To train the neural networks, we captured millions of images from sorghum fields over two growing seasons and carefully selected and labeled 5,447 images that showed evidence of aphid infestation. We randomly split the labeled data into 10 group for 10-fold cross validation [1][2][3]. To better train the models, we propose to generate patches at three different scales, allowing the model to generalize to aphids and images captured at different scales. In total, we generated 54,742 image patches in the dataset.

Using the proposed dataset, we implemented and compared the performance of four state-of-the-art object detection models (VFNet, GFLV2, PAA, ATSS) [1][2], four real-time segmentation models (HRNet-Small, Fast-SCNN, BiSeNetV1, BiSeNetV2), and four nonreal-time segmentation models (PSNet, DeepLabV3, HRNet, FCN) [3]. The benchmark evaluation shows promising results of aphid detection and segmentation using deep learning models. Specifically, Fast-SCNN achieves 80.6% mean precision at 91.7 frames per second, with the best overall performance considering the tradeoff of accuracy and efficiency. The study enables an intelligent robotic system to accurately identify and spray the infested canopy, providing an intelligent solution that harnesses economic and agronomic advantages.

References

1. Zhang, T., Li, K., Chen, X., Zhong, C., Luo, B., Teran, I., McCornack, B., Flippo, D., Sharda, A., & Wang, G. (2023). A New Dataset and Comparative Study for Aphid Cluster Detection. AAAI 2023 Workshop.
2. Zhang, T., Li, K., Chen, X., Zhong, C., Luo, B., Teran, I., McCornack, B., Flippo, D., Sharda, A., & Wang, G. (2023). Aphid Cluster Recognition and Detection in the Wild Using Deep Learning Models. Scientific Reports, 2023
3. Rahman, R., Indris, C., Zhang, T., Li, K., McCornack, B., Flippo, D., Sharda, A., & Wang, G. (2023). On the Real-Time Semantic Segmentation of Aphid Clusters in the Wild. CVPR 2023 Workshop