Utilizing Neural Radiance Fields (NeRFs) Understand Nutrient Stress Phenotypes in 3D

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Abstract

In precision agriculture and plant biology, monitoring nutrient stress in crops is of paramount importance for ensuring optimal yield and resource utilization. However, nutrient stress phenotypes can be nuanced, subtle, and display in a variety of ways. We propose using Neural Radiance Fields (NeRFs) for the organized reconstruction of plant structures to observe the changes of plant structure and color under nutrient stress.

Neural Radiance Fields, a cutting-edge technique in computer vision, leverage neural networks to model complex high-frequency geometry directly from 2D images, offering high-fidelity reconstructions. This methodology holds immense potential for plant imaging, as it allows for the creation of detailed and organized 3D models that can capture subtle alterations in plant morphology associated with nutrient stress responses.

The proposed methodology involves the acquisition of high-resolution images of plants under different nutrient conditions. These images are inputted to the NeRFStudio *Nerfacto* implementation, a NeRF model that is a aggregation of many different existing models. A 3D reconstruction of the scene is outputted from the model and can be further reduced to a point cloud containing point locations, colors, and normals. Phenotypic traits are then calculated from the point clouds. The reconstructed plant models enable the quantitative analysis of morphological changes associated with nutrient stress. This includes alterations in leaf size, branching patterns, and overall plant geometry. The utilization of NeRFs allows for non-destructive monitoring, offering a significant advantage over traditional methods that may be labor-intensive or invasive.

This research not only contributes to the field of precision agriculture but also presents a powerful tool for plant biologists to deepen their understanding of how nutrient stress impacts plant architecture. The insights gained from this approach have the potential to inform precision nutrient management strategies, leading to more sustainable and efficient agricultural practices.

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