A Volumetric Segmentation Method for Learning Structural Representations of Plant Roots in 3D X-Ray CT Scans

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Critical factors that determine crop yields are located underground, making them difficult to analyze. Traditionally, these factors have been measured by growing plants in clear media and measuring traits with visible imaging. Modern phenomics technologies use one or several imaging modalities to capture traits that reflect plant physiology or performance.

Analytical techniques for plant phenomics are a crucial part of approaches to achieving desirable agronomic and biological traits. Advances in sensor technologies have paved the way for faster and more efficient plant phenotyping, with methods adapted from disciplines like high-resolution 3D X-Ray computed tomography (CT). A crucial step in their analysis is segmentation - the identification and classification of the scan's voxels as "root" or "non-root". Unlike roots in transparent mediums, roots in non-transparent mediums are difficult to segment from their surrounding materials as root and non-root voxels have overlapping CT values.

The challenge we address is the development of neural-driven approaches for volumetric semantic segmentation of plant roots in 3D CT scans, and discuss subsequent trait extraction methods that enable the quantification of root systems and their traits in several agriculturally important crop species. The framework learns structural representations to create segmentation maps that identify root system boundaries, and provides high quality data for trait measurements and multi-objective optimizations.

Our goal is to develop analytical strategies that enable phenotyping of critical plant species to further the development of crops with improved food, feed, and bioenergy performance under sustainable agricultural practices.