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A Novel Deep Learning Approach for Complete Segmentation of Roots, Soil and Pores in X-ray Tomography Data of Acrylic Resin Embedded Rhizosphere

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Correct image segmentation is the pre-requisite for identifying classes of objects in microscopic datasets in order to determine relationships between them. We recently reported on a novel embedding protocol for rhizosphere samples based on the hydrophilic acrylic LR-white resin.[1] X-ray µ-CT data measured on such embedded samples shows only minimal contrast between root and resin which renders segmentation of these data is difficult or even impossible using common methods based on thresholding of histograms or detection of edges.

Here, we demonstrate how this barrier can be overcome using deep learning of convolutional neural networks based on U-Net architecture.[2] We show successfully segmented roots from resin, where classical machine learning approach Random Forest was not successful in our attempts. Firstly, the embedded samples were characterised by X-ray µ-CT and cut by a water-jet. Roots on the exposed 2D section were identified using epifluorescence and helium ion microscopy. The analysed 2D image plane was then correlated with the X-ray µ-CT data for accurate classification of training 3D image pixels. With a given input image (in this case a greyscale micrograph of resin embedded soil), a trained U-Net model with minimal labelled pixels, semantically segmented the X-ray data set showing roots, soil and pores. Using multiple deep learning algorithms, the U-Net was the most promising architecture to segment rhizosphere X-ray µ-CT and we show the different input parameters which can improve the segmentation process. The deep learning experiment was carried out with the ORS dragonfly image processing software. We show an accurate and fast approach that can be used to segment LR-white embedded rhizosphere X-ray CT data to roots-soil-and pores for further correlative microscopy analysis to interpret complex rhizosphere processes in the future.

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