Reconstructing root system architectures from non-invasive imaging techniques for the use in functional structural root models

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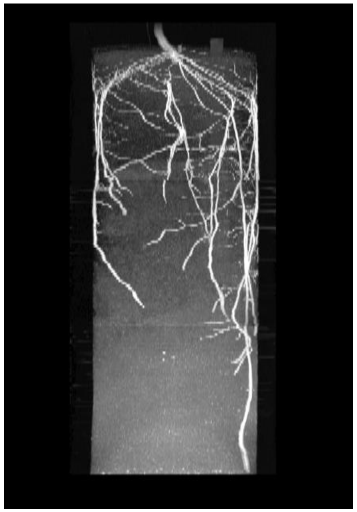
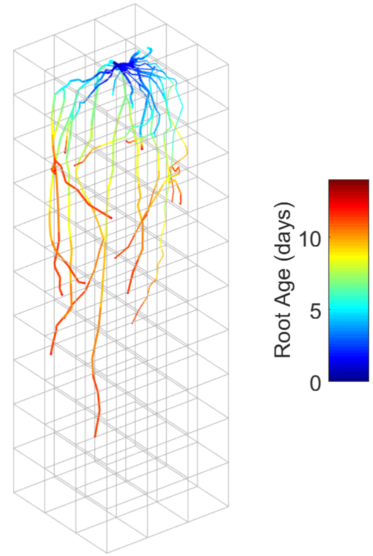
BACKGROUND & MOTIVATION



MRI scan of a lupine root system



Soil grid with lupine root system

Non-invasive imaging provides root architectures as input for functional-structural root models.

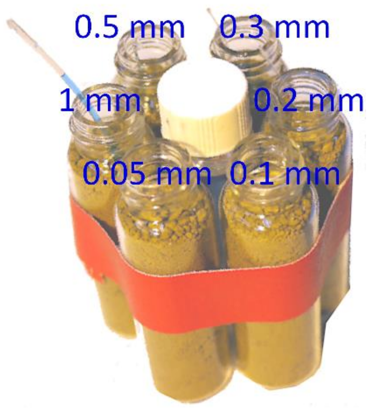
However, root systems can often only be recovered partially using imaging, which affects the model results.

How much of a root system can we possibly recover from MRI and X-ray CT images and how can we overcome the problem of low root system recovery fractions?

ROOT DETECTION AND ROOT SYSTEM RECOVERY

Experimental setup

Exp 1: What is the minimum detectable root diameter?



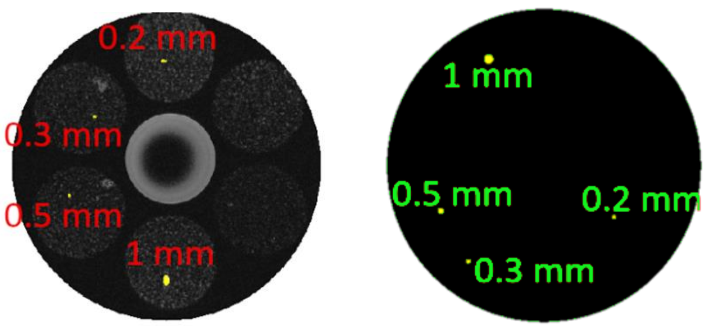
Water-filled capillaries of different diameters were emerged in soil and scanned with MRI and X-ray CT

Exp. 2: Which fraction of a root system can we possibly recover?

Lupine plants aged between 1 and 4 weeks were grown in soil - filled cylinders and scanned with MRI and X-ray CT

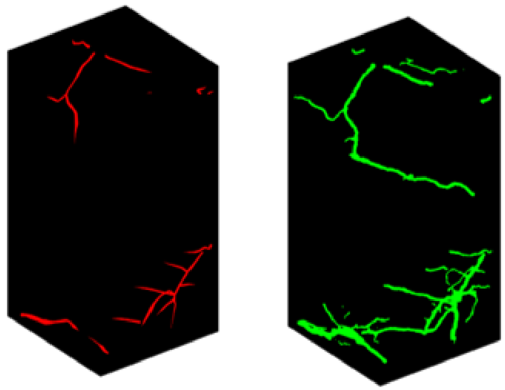
ROOT DETECTION AND ROOT SYSTEM RECOVERY

Axial slices of the scanned sample with water-filled capillaries



MRI X-ray CT

Recovered roots from a subsample of a soil - grown lupine plant



MRI X-ray CT

Root detection

MRI: Root detection below voxel size resolution

X-ray CT: Root detection of ~3 x voxel size

Root recovery

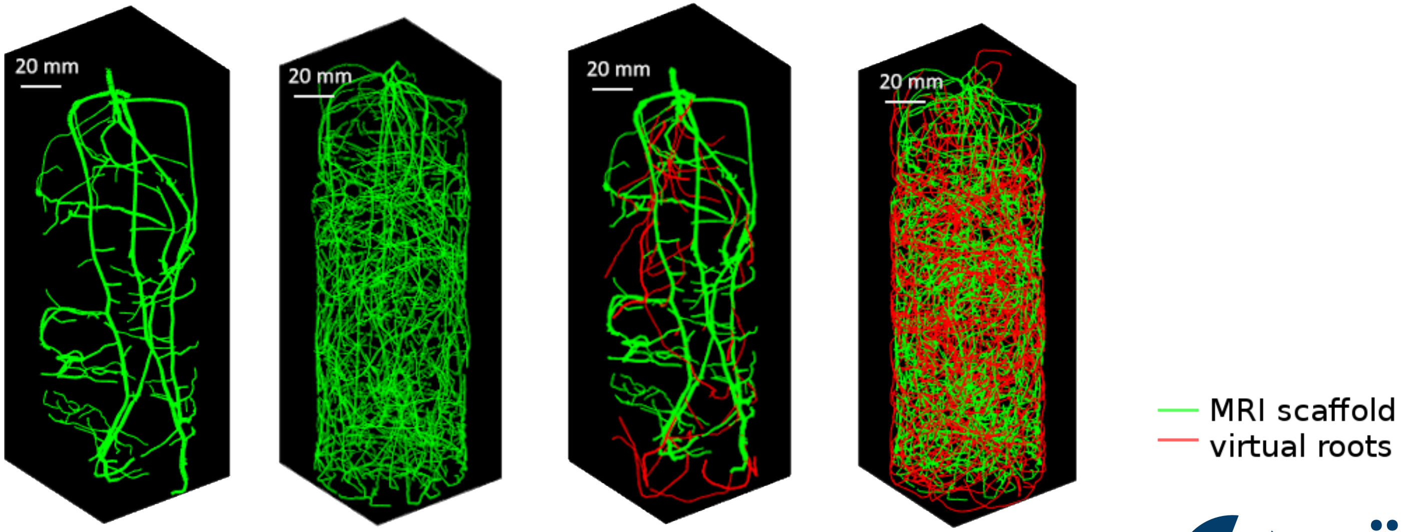
MRI: partly very low root system recovery fractions depending on root system density, soil type, water content

X-ray CT: only subsample reconstruction, most roots could be recovered

DEALING WITH LOW ROOT SYSTEM RECOVERY

Virtual completion of root systems → ‚semi-virtual root systems‘

- Root systems from non-invasive imaging are used as scaffolds onto which missing roots are virtually added using the root architecture model CRootBox
- Model input parameters for CRootBox are derived both from WinRhizo measurements and the distribution of roots in the root scaffolds themselves



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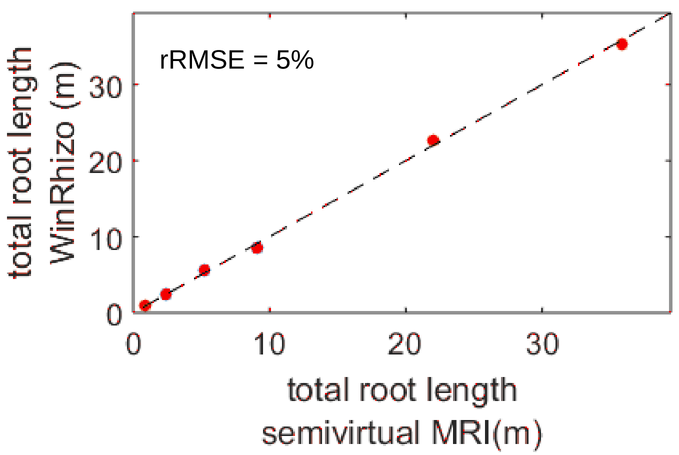
SEMI-VIRTUAL ROOT SYSTEMS

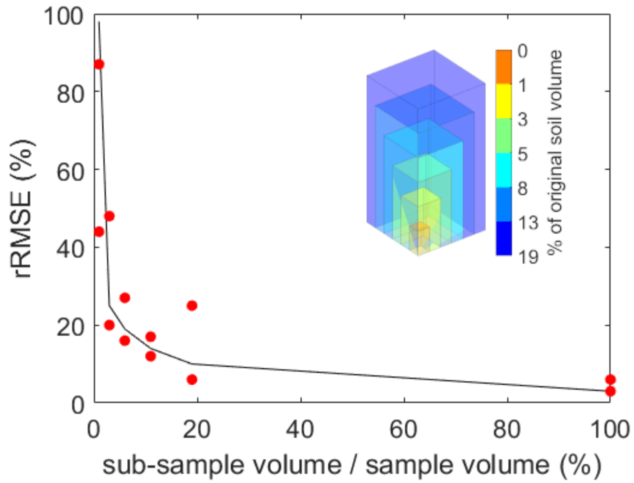
How well do they represent the real root systems?

Comparison of total root lengths



Comparison of total root lengths extracted from semi-virtual root systems and WinRhizo measurements

Comparison of spatial distribution of root length within the soil volume



Goodness of fit (expressed by rRSME) between root length contained within sub-samples of semi-virtual root systems and X-ray CT – derived root systems as a function of the ratio between subsample and sample volume

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CONCLUSIONS

- Root recovery from MRI images is poor for older and denser root systems and is impeded by high water contents for certain soil types.
- Our virtual root completion approach allows generating semi-virtual root systems of which not only the total length, but also the length distribution within the soil domain resembles the actual root systems.
- Considering that the parameterization of virtual roots can be done with data from WinRhizo measurements, our virtual root completion approach is very simple and inexpensive.

Thank you for your attention!

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