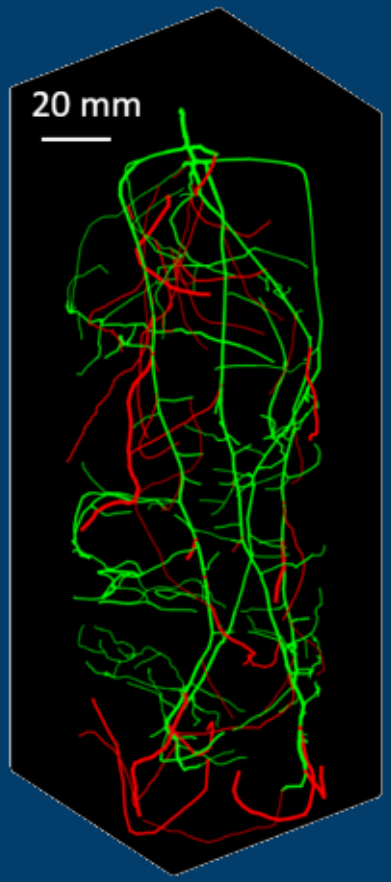
Reconstructing root system architectures from non-invasive imaging techniques for the use in functional structural root models



Landl M., Huber K., Pohlmeier A., Klebert V., Vanderborght J., Pflugfelder D., McKay Fletcher D., Koebernick N., Roose T., Meunier F., Schnepf A.

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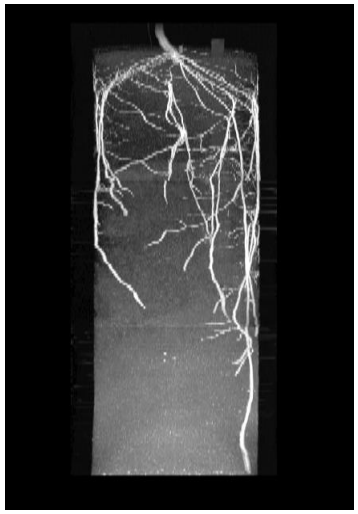
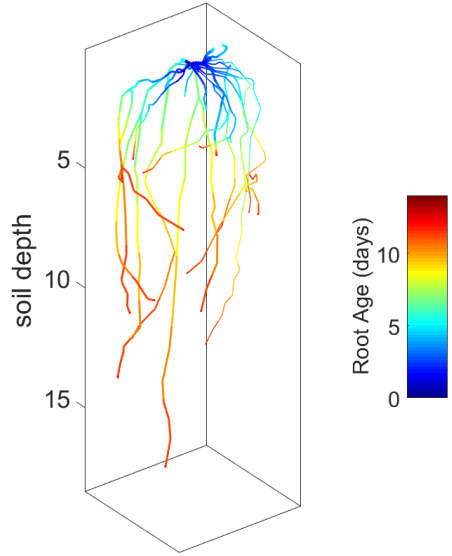
BACKGROUND & MOTIVATION



MRI scan of a lupine root system



Reconstructed lupine root system

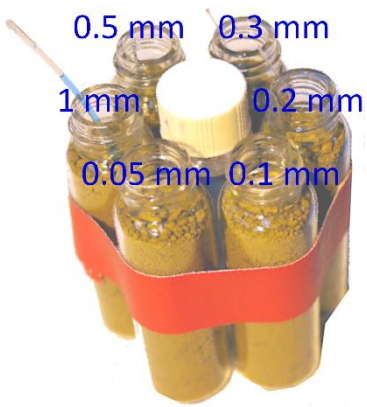
Non-invasive imaging provides root architectures as input for functional-structural root models. However, root systems can often only be recovered partially using imaging, which affects the model results.

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?



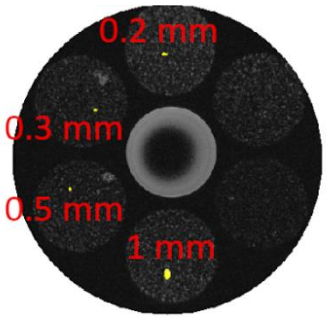
Water-filled capillaries of different diameters were emerged in soil and scanned with MRI and X-ray CT

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

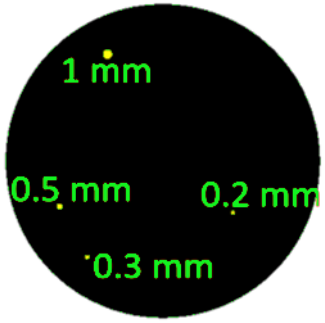
Lupine plants aged between 1 and 4 weeks were grown in soil - filled cylinders and scanned with MRI and X-ray CT

ROOT DETECTION AND ROOT SYSTEM RECOVERY

Axial slices of the scanned sample with water-filled capillaries

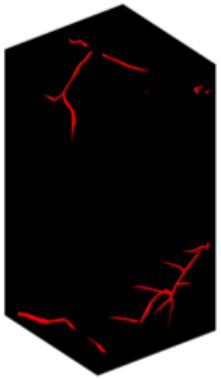


MRI

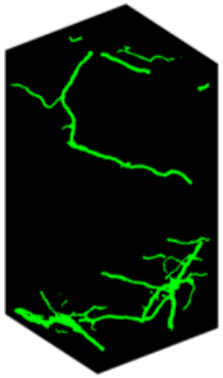


X-ray CT

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

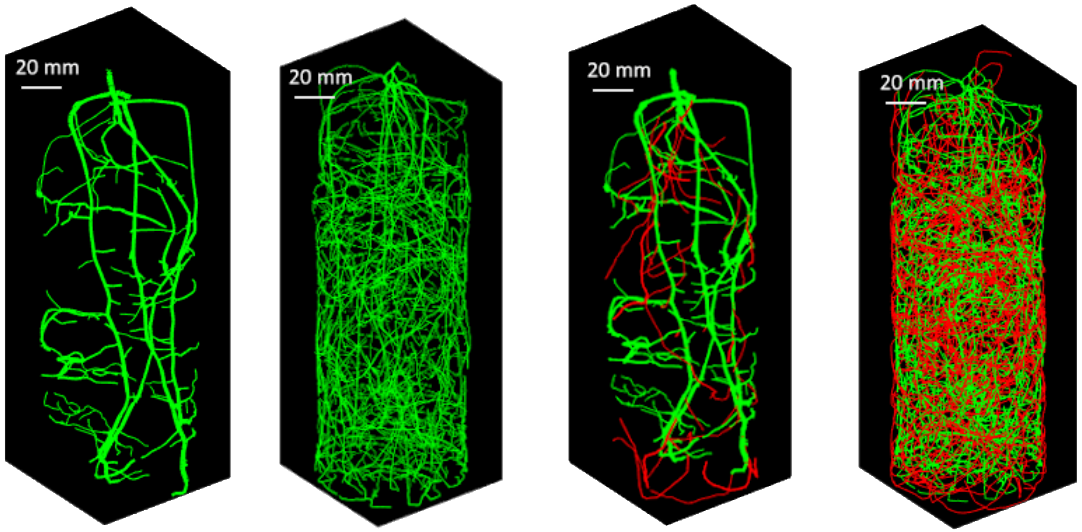
MRI: partly very low root system recovery fractions depending on root system density, soil type, water content

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

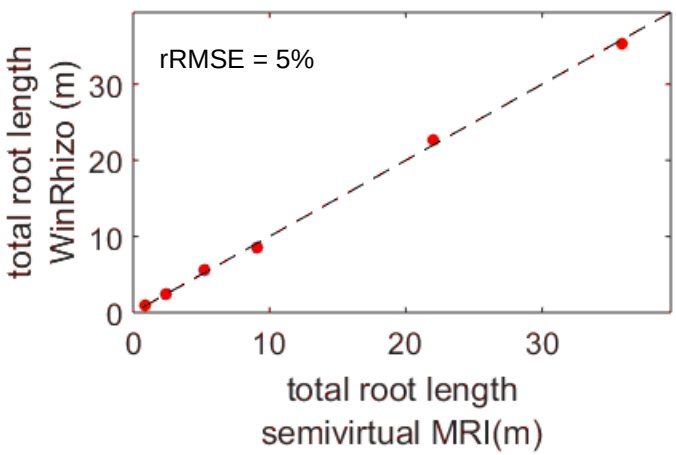


MRI scaffold
virtual roots

SEMI-VIRTUAL ROOT SYSTEMS

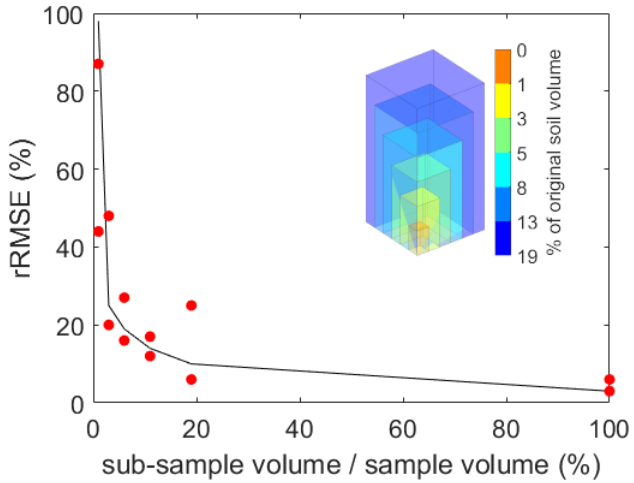
How well do they represent the real root systems?

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

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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