3D root system architecture of woody plant can be assessed using structure from motion photogrammetry

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Summary (max. 1700 characters, excluding spaces)

Background
Plant functioning relies on root system architecture (RSA), which can be best studied from a 3D database of root axes and segments. Most of such databases in woody plants grown in the field have been set up by semi-automatic digitising, using a low magnetic field 3D digitizer. As an alternative, Structure from Motion (SfM; photogrammetric range imaging technique) may require less manpower and produce more accurate data. However, no study offers a validated pipeline to obtain a 3D root system architecture database from SfM.

Objective / Research question / Hypothesis
We aim to propose a validated methodology to assess rapidly 3D root system architecture in woody plants using SfM.

Material and methods
Four 5 m high pines (*Pinus pinaster*) and four one-year-old grapevines (*Vitis riparia*) were uprooted. The RSA was captured using SfM and segmentation to get axes and segments was performed with the plant structures reconstruction software (PlantScan3D) and two packages dedicated to plant architecture analysis and visualisation (MTG and PlantGL from the OpenAlea platform). This pipeline was evaluated by comparing root traits estimated by SfM to root traits measured manually (i.e. length, diameter and volume of 100 root samples from different root types) and computed from 3D digitizing.

Results
SfM measurements required six times less manpower than semi-automated 3D digitizing measurements. The root traits estimated by the SfM pipeline (e.g. length, diameter and volume of root samples) were in very good agreement with the manual measurements. However, diameters of fine roots (i.e. less than 2 mm diameter) were overestimated. They were corrected using the pipe model to compute architectural traits. The number, total length and total volume of the first- and the second-order root estimated by SfM were similar to those estimated by 3D digitizing. On the contrary, the number of third- and fourth-order roots was higher in the root system captured by SfM.

Discussion
The SfM combined with the PlantScan3D and OpenAlea packages provided a suitable approach and environment to characterize the root system architecture. We show that the accuracy of 3D data obtained with SfM is similar to that estimated manually, except for roots less than 2 mm in diameter for which corrections have been necessary. Root systems captured from SfM were similar to those measured by 3D digitizing. SfM captured a higher number of small and fine roots of high root orders (third- and four-order root). SfM can save manpower by providing precise databases of 3D-RSA in woody plant agronomic experiments where around a hundred roots have to be measured. For biomechanical application, an

assessment of ovalisation (tridimensional diameter variation of the axes) is still needed, and it is not possible to deal with a too large number of non-rigid roots.

Content Snapshot (max. 250 characters, excluding spaces)
We aim to propose a validated methodology to assess rapidly 3D root system architecture, getting axes and segments, using Structure from Motion in woody plants grown in the field. An accurate pipeline has been setup for SfM, giving similar results to manual measurements and 3D-digitizing.