Automatizing MiniRhizotron Image Acquisition

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Introduction

Minirhizotron (MR) imaging systems are key instruments to study the hidden half of plants and ecosystems, i.e. roots, mycorrhiza and their interactions with pathogens, fauna etc. in the rhizosphere. However, despite scarce data on the 'hidden half' of plants and ecosystems, e.g. needed for better understanding species' ecophysiology, breeding resource efficient crops or determining soil carbon input, the technological advances remained yet limited. **In particular, the currently available MR devises provide a limited image resolution and lack automation of the imaging process.**

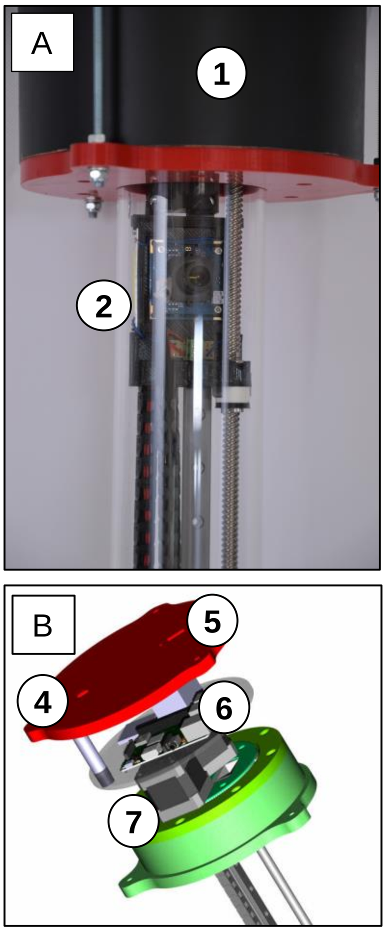
Low image resolutions hamper the detailed analysis of morphological structures in the rhizosphere such as the root hair length but also impede the correct determination of the root diameter or species identification by visual cues.

The **lack of automation** has several implications for root research: (1.1) it **significantly increases the workload** as images often need to be captured at regular intervals, this might (1.2) result in **the implementation of too infrequent imaging intervals** which might not capture the actual (root) dynamics, and (1.3) a potential exclusion of remote research sites from MR-based studies. In addition, MR automation provides the opportunity to decrease the amount of 'deficient' rhizosphere images due to operator mistakes, such as **preventing** (2.1) **motion blur** (caused by moving the camera while imaging is in progress), and (2.2) **wrong image labelling**. In addition, automation allows to implement new features such as the (3) creation of **super-resolution images**, the (4) eased overlay of images captured with different sensors (e.g. RGB and hyperspectral), the (5) creation of **time laps videos**, and the (6) **alignment of imaging positions** according to the soil surface or different soil horizons even in angled MR tubes.

In the following, we will thus feature our resent automatic MR prototype—allowing to implement all the above mentioned features (if not realized yet) facilitating studies on the hidden half.

Functionality

- The current UHD RGB camera module (Fig. 1A,C) features a fixed focus (with resolution in motion between 0.05-0.003125 mm) for 7 cm MR tubes (>64 mm inner diameter), interchangeable lighting with controllable intensity in 256 steps, are mounted on a carriage on industrial-grade linear guiding. Movement is induced by a trapezoidal lead screw. The whole carriage can be turned 360º, with an angle resolution between 0.36-0.0225º.
- Maximum MR tube length is currently 200 cm, where a rotary bearing housing secures the linear guide and the lead screw as well as stopping the carriage
- Imaging locations are programmable for automated use with the following parameters: the distance between images(longitudinal) and in degrees (rotational).
- Images can be automatically corrected for distortion and cropped before being stored on a flash disk inserted at the top part of the system (operation unit enclosure, Figure 1B)
- The control unit, operated by a raspberry pi micro computer, is watertight and enclosed in the top part with the motor. The system is powered by either 12V DC or 24V DC, possibly via solar panel, a buffer battery or AC-DC converter.



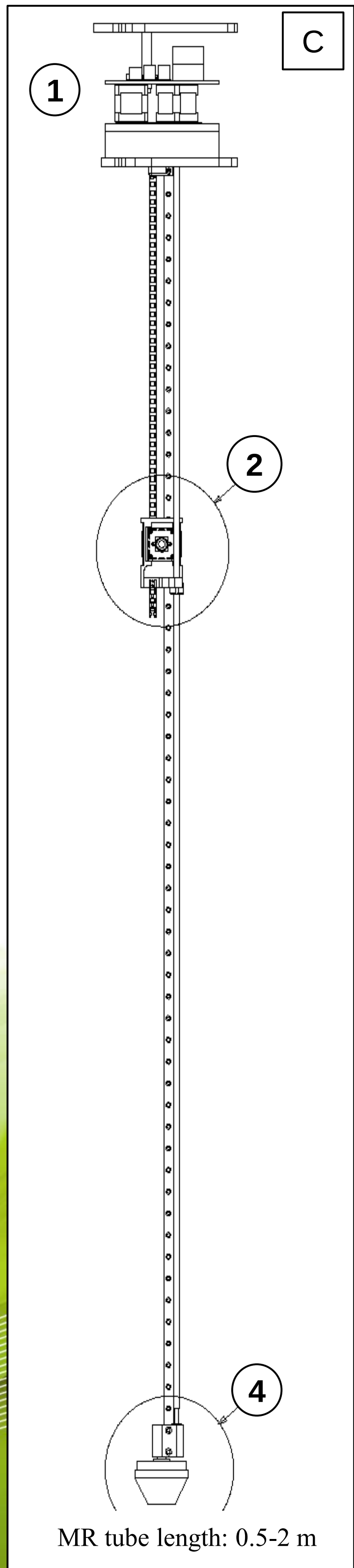


Figure 1. Image (A), rendering of the Operation unit enclosure (B), and technical drawing (C) of the automatic MiniRhizotron camera prototype. Different parts are labelled: 1-operation unit enclosure, 2-imaging module with carriage, cable management chain, trapezoidal lead screw, and industrial grade linear guiding, 3-rotary bearing housing, 4-USB port, 5-12V power socket, 6-Raspberry Pi, 7-motor.

Outlook

The next step for further development of this state-of-the-art, automatic MR imaging device will be the
- incorporation of the infrared light camera, which will enhance the root segmentation and allow to analyze some chemical characteristics of the root and soil, such as water and C contents, from the same picture.
- addition of super-resolution capabilities. Thanks to the high and accurate mobility of the camera, the interpolation of slightly shifted pictures of the same area will allow the application of the super-resolution technique.
- implementation of remote connectivity will allow the MiniRhizotron to operate and transmit the data (and potential status and warning messages such as 'low power') autonomously
- reduction of the operation unit enclosure housing to reduce the rain shadow effect if installed in vertical MR tubes
- extension of the maximum tube length to 3 to 5 m for deep soil explorations

We expect that the device is fully operable by late 2020, early 2021.

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