AN AFFORDABLE, FULLY-AUTOMATED MINIRHIZOTRON SYSTEM FOR OBSERVING FINE-ROOT DYNAMICS

Simon Thomsen[1], Kai Jensen[1]

[1]Applied Plant Ecology, Universität Hamburg, Germany

BACKGROUND

The study of fine root dynamics plays an important role for the understanding of the carbon cycle in terrestrial ecosystems as well as of plant stress responses to drought and hypoxia. However, commercial rhizotron camera systems tend to be expensive and hence, the number of studies using this technique still are quite limited. In addition, many of the study sites have harsh conditions (e.g. dust, moisture, standing water in leaking rhizotron tubes) which can quickly lead to damage to the mechanics and electronics of the sensitive minirhizotron equipment.

AIM OF THE PROJECT

The aim of this project was to develop a low-cost rhizotron camera system (<500 €) that can be used even under demanding environmental conditions. Furthermore, it should be designed in a way that it can be produced by the user without the need of advanced electronic and programming knowledge.

MATERIAL & METHODS

To protect the camera system from dust and water, it was encapsulated in a water-proof acrylic tube (Ø 60 mm), that can be used with rhizotron tubes with inner and outer diameters of 64 mm and 70 mm, respectively. To improve the operability under field conditions, we decided to build a fully-automated system that is able to reproduce exactly the camera position of the previous measurement in time series measurements.
Both the control unit and the camera are based on a Raspberry Pi system (Raspberry 2 model B, Raspberry Pi camera module V2). The maximum resolution of camera is 8 MP, resulting in a picture resolution of 3280 x 2464 pixel for a soil area of approx. 25 x 30 mm² (see Fig. 4 for example pictures taken with the same technique, but not the presented system [also see notification]) . The camera (L) is installed on a slider unit (J), sliding on two 6 mm stainless steel rails, that is connected via a flange nut (I) to a 5 mm threaded spindle (H), and driven by a 6 V stepper motor (E) (Fig. 1). The motor socket (F) contains a distance sensor that can measure the distance to the slider in millimeter resolution. Two 3W COB LEDs (P) serve to illuminate the area to be photographed. The brightness of the LEDs can be controlled with the help of a MOSFET (M) via software-based pulse width modulation. The handhold (A) offers a HDMI port and an eight-pole port to connect he camera unit and the motor / distance sensor unit, respectively, to the control unit (Fig. 2), containing a Raspberry Pi, an 8" touch-screen, a keyboard, and two voltage regulators, providing 5 V (Raspberry Pi, screen, LEDs, distance sensor) and 6 V (stepper motor). The complete system can be operated with a 12 V battery.
For the measurement, an adapter (R) helps to install the camera system into the rhizotron tubes. To set the same alignment for each measurement, the adapter has a pressure piece that snaps into a hole in the rhizotron tube, and a recess into which the camera system is inserted. The camera system is controlled by running a Python script. Before each measurement, the slider returns to the starting position, controlled by the distance sensor (F), to afterwards be able to reproduce the same positions of the pictures taken in previous measurements. Then, the camera is transported downwards, stopping every 2.5 cm to take a picture. When the measurement has finished, the slider returns into a position close to the starting position.

METADATA

The STL-files needed for the 3D-printed parts, a list of all used parts including distributor and part number, and the Python code, are available via e-mail (simon.thomsen@uni-hamburg.de).

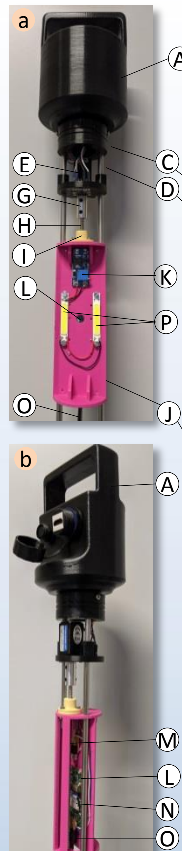
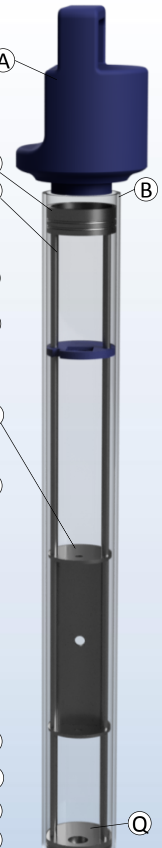


Fig. 1: Front (a) and rear (b) view of the camera system



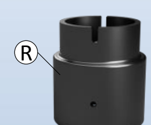


Fig. 2: 3D-model of all 3D-printed parts installed on two stainless steel rails into a 60 mm acrylic tube

LEGEND

- A. HANDHOLD WITH HDMI AND CONTROL PORTS
- B. 60 MM ACRYLIC TUBE
- C. UPPER RAIL FIXTURE WITH O-RINGS
- D. STAINLESS STEEL RAILS
- E. STEPPER MOTOR
- F. MOTOR SOCKET WITH DISTANCE SENSOR
- G. COUPLING
- H. 5 MM THREADED SPINDLE
- I. FLANGE NUT
- J. CAMERA RIDER
- K. VOLTAGE REGULATOR
- L. 8 MP CAMERA
- M. MOSFET FOR LED CONTROL
- N. CSI TO HDMI ADAPTER
- O. HDMI CABLE
- P. 3 W COB LED
- Q. LOWER RAIL FIXTURE WITH BEARING SOCKET AND ONE O-RING
- R. ADAPTER FOR RHIZOTRON TUBES

Fig. 3: Raspberry Pi-based control unit containing of a Raspberry Pi 2 model B, an 8" touch-screen, a keyboard, two voltage regulators (5 V and 6 V), and a CSI to HDMI adapter.

Fig. 4: Picture of fine roots taken with an identical camera system (Raspberry Pi camera module V2, 3280 x 2464 pixel), during the 2019 vegetation period, in a hardwood floodplain forest located in Jasebeck, Germany. Unfortunately, due to the COVID-19 regulations, it was not possible to carry out test measurements with the here presented system until now.

NOTIFICATION

Due to the COVID-19 related regulations of our university, we had only limited access to our lab and our experimantal sites within the past weeks. Therefore, the development of this rhizotron camera system could not be completed and tested under field conditions, so the system still has the 'prototype' status.