Automated minirhizotron for root detection

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1 Introduction

The funded project Scan@ArtIGROW is part of the ArtIGROW project in the ArtIFARM joint consortia. The aim of the project is to automate a so-called minirhizotron as a tool for economically viable data collection in agriculture. This study describes the technical challenges and requirements for the development of an autonomous minirhizotron.

Today's agriculture is designed to maximize yields. This makes it possible to combine feeding the population at moderate prices with economic activity on the part of farmers. The use of sensors and measurement technology is becoming increasingly common in order to make more precise decisions. As a sample, farmers usually use above-ground plant observation to maximize yields. Relying on their experience, measures such as fertilization, irrigation or harvesting are derived and implemented. However, changes to the above-ground part of the plant occur with a time lag in relation to measures, environmental conditions and in comparison with the condition of the plant at its roots. This approach therefore often leads to over-fertilization and thus to damage or pollution of soil and water [1, Chapter 3], high water consumption and harvesting at less than optimal times.

The effectiveness of measures and the condition of a plant can be recognized comparatively early at its roots. Data collection in the soil, directly at the root, is therefore a promising approach to countering the problems associated with conventional agriculture.

However, the possibilities for root observation are limited and time-consuming, as they are currently carried out manually:

- Individual plants can be pulled out and the roots sighted. The finest root strands that break off and remain in the soil are not detected. The removed plants also die.
- With manual minirhizotrons [2, Chapter 2] (root scanners) such as the CI600 root scanner from CID Bio-Science, Inc., U.S.A. (Figure 1), the plants are not damaged. The scanner setup, start of data acquisition and its evaluation must still be carried out manually (Figure 2 and Figure 3). Depending on the length of the minirhizotron, several scanning positions must be set. The result is images of the directly adjacent soil with the roots (Figure 4).

The aim of Scan@ArtIGROW is therefore to simplify root scanning by developing a fully automatic minirhizotron (Figure 6 and Figure 7) and to create the basis for broad and barrier-free use for every farmer.

Figure 1: Manual root scanner "CI600 In-Situ Root Imager" from CID Bio-Science, Inc.

Figure 2: Manual scanning in the field with computer set up in the lane.

Figure 3: Tube installed at a 45° angle, darkened above ground, with CI600 inserted

2 Working with a minirhizotron in agriculture:

To use minirhizotrons, a transparent tube must be inserted into the soil under the seed at an angle of approx. 45° after sowing. The roots of the plant grow around the tube from above. The scanning unit is manually pushed into the respective tube for each scanning process and brought into the scanning position. The scanning process takes place in a rotational movement along the inside of the tube using a line scanner. The soil directly adjacent to the tube wall is scanned together with the directly adjacent roots. An image document is saved in which the roots are sometimes difficult to recognize (Figure 4). Using specially trained AI [3], this image data can be efficiently evaluated (part of ArtIGROW, Figure 5). The transparent tube must be removed from the ground before harvesting.

Figure 4: Image of roots in the soil [3]

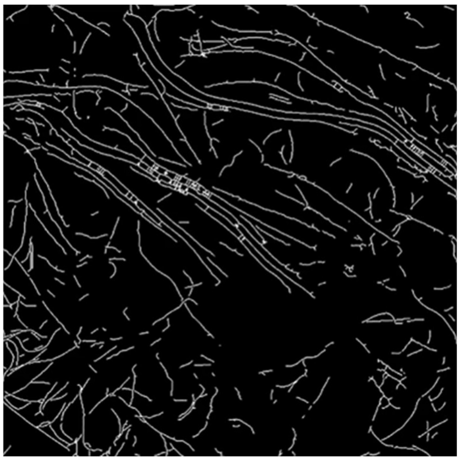

Figure 5: The skeletonized RootDetector estimation image [3]

3 Future work with an automated minirhizotron:

The essential arrangement in the soil is similar to that of the manual minirhizotron: a transparent tube is located in the soil, below an exemplary plant. In contrast to the manual minirhizotron, the scanning unit of the automated minirhizotron remains in the tube for the entire period of use. The presence of the user at the minirhizotron and manual handling are not necessary. Instead, a remote connection to the automated minirhizotron is also planned, which carries out all necessary scanning steps itself and transmits the scan data via mobile radio to an evaluation AI called "RootDetector" [3]. The user receives evaluated root data and can adapt his management strategy for each affected field [2, Chapter 4]. In the medium to long term, this is expected to optimize irrigation and fertilization behavior, which will lead to a minimization of fertilizer use. This will avoid crop failures or reduce their impact through timely harvesting and minimize the environmental impact of excessive fertilizer use.

Technical challenges to be solved:

- The biggest technical challenge is the integration of all functions in a very limited installation space. In order to keep irritation of root growth to a minimum, a maximum outer tube diameter of 70mm is planned. With a wall thickness of 3mm, this leaves 64mm inner diameter or 62mm usable inner diameter.
- In order to avoid a possible tilting moment due to top-heavy mass distribution, which could lead to a change in position of the minirhizotron in wet soil, an even mass distribution at the head and foot ends of the rhizotron is aimed for.

Another challenge is the cable routing from the static part of the minirhizotron to the moving scanner carriage. The system is intended for outdoor use. It must therefore be protected against the effects of the weather, in particular against moisture penetration.

Status in this study:

- At this stage, the main challenges have been solved, albeit with a delay.
- The developed scanning solution is functional under laboratory conditions.
- The construction of devices close to the final configuration has been prepared.

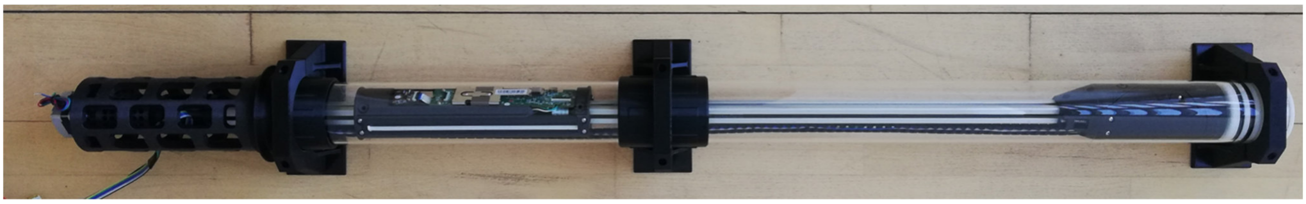

Figure 6: Automated minirhizotron demonstrator, in test device

Perspectives:

- In the next steps, devices will be set up for testing at the outdoor test facility and corresponding test series will be carried out.
- The concepts for the energy supply in the field and remote data transmission are to be implemented.
- Once the tests at the test facility have been completed, devices for field use will be set up at the ArtIGROW project partners.

Figure 7: Minirhizotron with integrated automated mechanics, without weatherproof head cover.

4 Summary:

The work and objectives of this study show that it will be possible for farmers and researchers in the field of plant cultivation to collect more extensive data with the help of an autonomous minirhizotron without having to visit the measuring points themselves every day. In addition to use in agriculture, particularly protected or hard-to-reach biotopes can also be equipped with research technology for root studies without causing permanent damage to flora and fauna due to the presence of people.

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