FAKOPP
Root Detector Manual

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1. Device



Figure 1: Complete Root Detector setup

1.1. Components

- 9V batteries
- String (5 mm diameter, 8 m length)
- Tape measure
- Soil sensor
- Start sensor
- Rubber hammer
- Steel hammer
- Amplifier box (black box)
- Link cable for connecting amplifier and battery box
- Battery box (gray box)

1.2. Soil sensor options

There are two options for soil sensors.

- Soil sensor with integrated nail
- Soil sensor (since 2023) with magnetic head with replaceable nail: 30 cm and 80 cm.

1.3. Handling the replaceable-head soil sensor



Figure 2: Soil sensor: carefully attach the magnetic head

Please take special care when attaching the magnetic head onto to nail. First connect the magnet's edge to the bar, then move slowly to reduce stress on full contact. Do not let the magnet snap in place.

1.4. Device assembly

- Connect the soil and start sensors to the (black) amplifier box. The order of connection on the amplifier box is not important.
- Connect the (black) amplifier box to the battery box using the link cable.
- Ensure that the (gray) battery box contains a fully charged 9V battery. To avoid damaging the device, please insert the battery according to the instructions on the box. Inserting the battery in the opposite polarity may damage the device!
- Optionally if a wired connection is desired, connect the (gray) battery box using the USB-Serial cable to the PC.

2. Principles of measurement

The device measures sound travel time from the start to the soil sensor. From the distance between the sensors and the time measurement, we can calculate the sound velocity between the two sensors. Soil sensor positions associated with high velocity indicate the presence of roots near the surface.

3. Device Connection

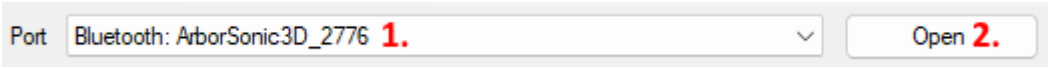
The Root Detector battery box can be connected to a computer using the provided USB cable, or using Bluetooth. Older devices use the Bluetooth Classic protocol, while devices manufactured since 2024 use the newer Bluetooth LE (BLE) protocol.

3.1. Bluetooth classic



- Bluetooth Classic protocol requires that each device be paired with the computer (if a code is requested during pairing, enter: 1234). This pairing creates a COM port on the computer, which then has to be selected in the Root Detector software.
- If the "*Bluetooth off*" warning is visible, then the Bluetooth module of the computer is turned off, or missing. Wireless connection is not possible while Bluetooth is not available.
- Select the item containing "*[ArborSonic3D]*" (**1**) from the "*Port*" selector, and click "*Open*" (**2**).

3.2. Bluetooth LE (BLE)



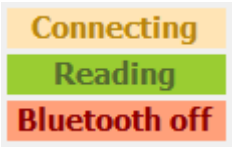
- The BLE protocol is used by devices manufactured since 2024
- Unlike Bluetooth Classic, pairing is no longer required as the computer detects the device automatically after it is turned on
- If the "*Bluetooth off*" warning is visible, then the Bluetooth module of the computer is turned off, or missing. Wireless connection is not possible while Bluetooth is not available.
- Select the item containing "*Bluetooth: ArborSonic3D*" from the "*Port*" selector (**1**), and click "*Open*" (**2**)

3.3. Cable connection



- Connect the USB-Serial cable to the PC
- Select the COM port containing "*Prolific*" from the "*Port*" selector (**1**) and click "*Open*" (**2**).

3.4. Connection state

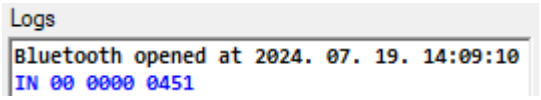


After clicking on the "*Open*" button, a colored strip indicates the current state of the connection to the Root Detector device.

- "*Connecting*" (yellow): the PC tries to connect.
- "*Reading*" (green): the PC is waiting for data.
- "*Bluetooth off*" (red) message indicates that the Bluetooth module of the computer was turned off.

3.5. Solving connection issues

- Bluetooth Classic devices should be paired with the computer
- The correct COM port should be selected for a Bluetooth Classic device
- If the battery is low, measurements may not be received. This affects both wired and wireless connections.
- Sometimes Bluetooth is disabled on laptops. In this case users should manually enable it.
- The "*Logs*" box shows diagnostic data. It indicates the kind of connection created, as well as the raw data sent from the Root Detector device.

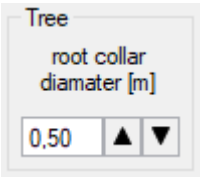


4. Setting up measurement in software

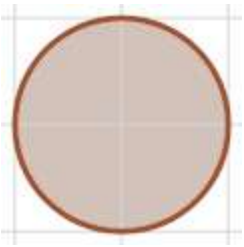
Before taking measurements, the following parameters should be entered: the size of the root collar diameter and the specific locations where measurements are to be taken.

4.1. Root collar diameter

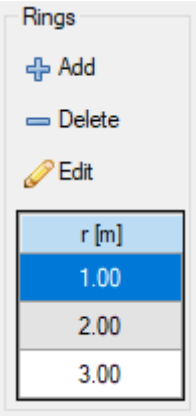
The root collar is the bottom part of the trunk.



- The diameter is a straight line that passes through the center of the trunk. The root collar diameter (meters) must be entered in the lower-left corner of the window.
- In the absence of a caliper, the diameter can be approximated using a tape measure (diameter = circumference / π)
- On the right side of the window, the root collar is indicated using a brown circle



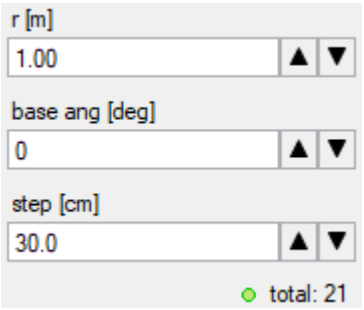
4.2. Rings of measurements



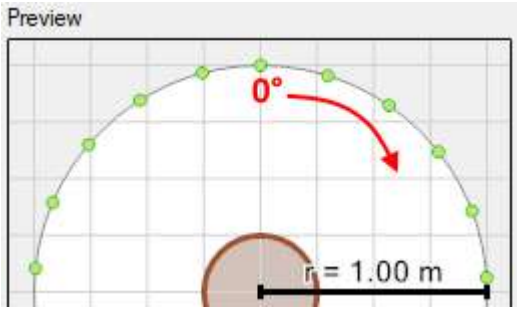
Measurements are taken in a circular layout around the trunk. You can take measurements in multiple rings.

- "**Add**" button: creates a new ring
- "**Delete**" button: deletes the selected ring
- "**Edit**" button: edit the ring
- The currently selected ring has a blue background in the "*Rings*" box. The "*Store*" button will add measurements to the selected ring.

4.3. Ring parameters



- Radius ("*r [m]*", meters): the distance between the center of the trunk and the ring of measurements to be taken.
- Base angle ("*base ang [deg]*", degrees): determines the angle of the first measurement. This can be used to shift the location of the measurements along the ring. The default value is 0°.
- Step ("*step [cm]*", centimeters): the length of the line segment between two consecutive measurements. Larger values mean fewer measurements and less resolution.
- The total number of measurement locations is displayed below the parameters.
- On the right side a preview of the current parameters can be seen. 0° is at the top-center of the image, and the angle increases in clockwise order. The brown circle indicates the root collar, while the green markers indicate the locations of future measurements.



- Recommendation: make sure that the first (top-most) measurement will be taken in a known compass direction (such as North). If you keep this information in the file name, it will be easier to know the orientation of the measurements when opening the project later.

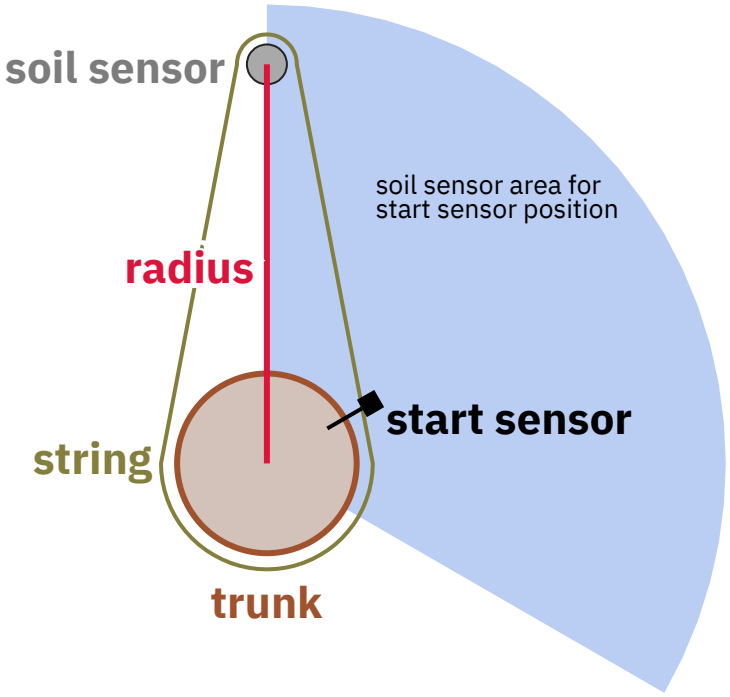
5. Measurement procedure

5.1. Soil sensor placement

- Before each measurement the soil sensor needs to be placed at the correct location along the ring.
- Make sure that the soil sensor is at an angle having its tip facing towards the tree
- Verify that the first measurement is taken at the correct direction and distance from the tree: the ring radius is defined between the **center** of the trunk and the soil sensor
- Measurements are taken in a clockwise direction (when the tree is viewed from above)
- A string should be used to ensure that the sensor is always at an equal distance from the trunk

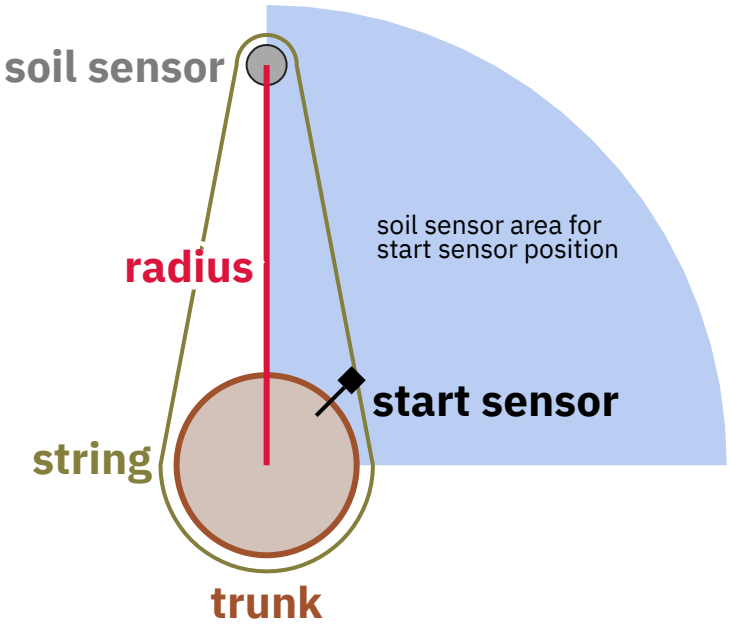
5.2. Start sensor placement

5.2.1. Trunk diameters below 80 cm



- Below 80 cm diameter the start sensor can serve a 120 degree area around the trunk. For a full 360 degrees measurement the start sensor should take up 3 different positions.

5.2.2. Trunk diameters above 80 cm



- Above 80 cm diameter the start sensor can serve a 90 degree area around the trunk. For a full 360 degrees measurement the start sensor should take up 4 different positions.

5.3. Start sensor usage

- Use the 100g steel hammer
- Tap the start sensor with a relaxed wrist for sharp, percussive impacts
- Let the hammer swing back after each hit
- Make sure to have at least 3 hits on the start sensor before pressing "*Store*" button in the software
- When you press "*Store*" the software will indicate the next position for the soil sensor with a dark green marker

5.4. Moving the soil sensor

- After pressing "*Store*", move the soil sensor to the next position along the ring. The distance between two positions is governed by the "*step [cm]*" parameter set for the ring.
- A string should be used to keep the soil sensor at a fixed distance from the trunk.

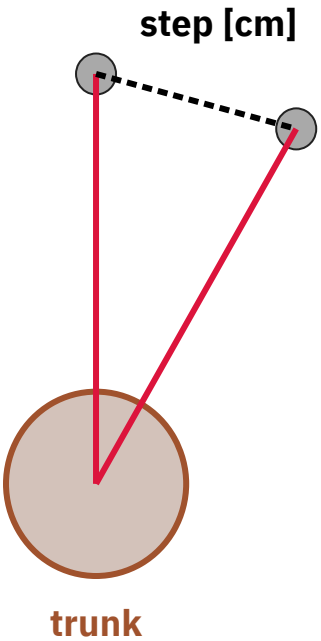


Figure 3: The step [cm] parameter is the distance between neighboring soil sensor positions

5.5. Moving the start sensor

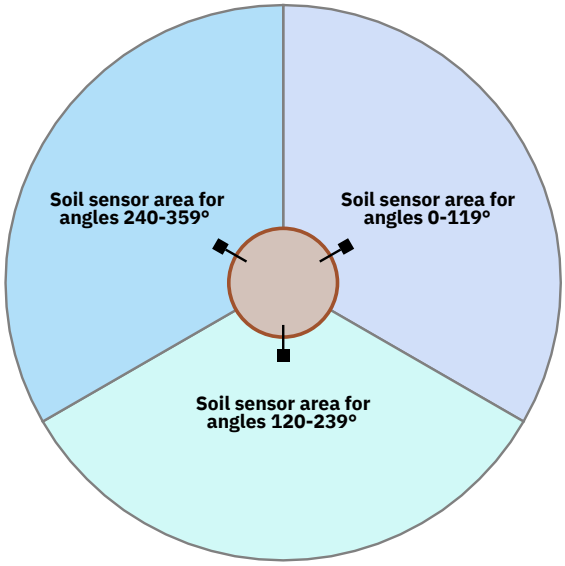


Figure 4: Start sensor positions for trunks below 80 cm diameter

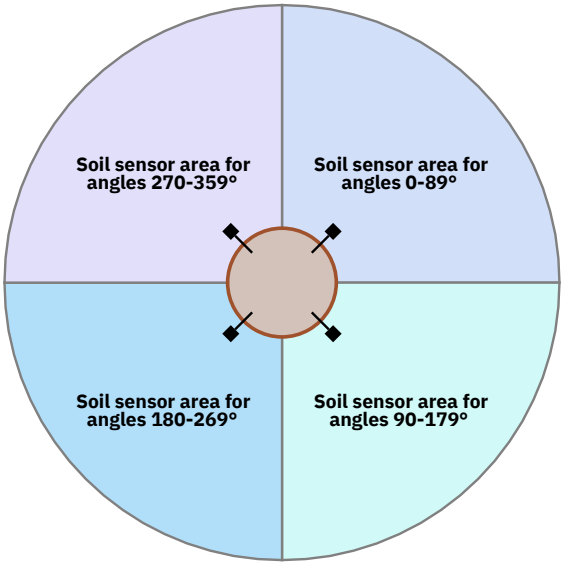


Figure 5: Start sensor positions for trunks above 80 cm diameter

The position of the start sensor is dependent on the trunk diameter. With trunks below 80 cm diameter, the start sensor has 3 possible positions (Figure 4); above 80 cm diameter there are 4 possible locations (Figure 5). The software always shows the angle of the next measurement (Figure 6). Use the charts above and the measurement angle to determine when repositioning the start sensor is necessary.

5.6. Software operation

5.6.1. Rings

- Before the first measurement is taken, ensure that the correct ring is selected in the "*Rings*" box.
- The parameters of the currently selected ring are displayed in the top of the "*Selected ring*" box.

5.6.2. Measurement location

- The current location is indicated using a dark green marker on the right side of the window.
- The angle of the current (soil) sensor location is shown in the "*angle [deg]*" field within the "*Sensor location*" box.

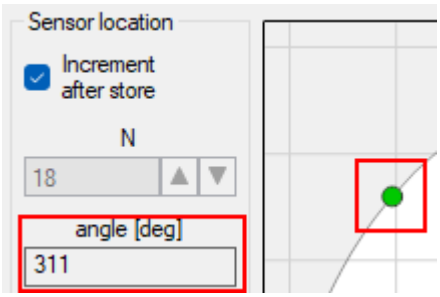
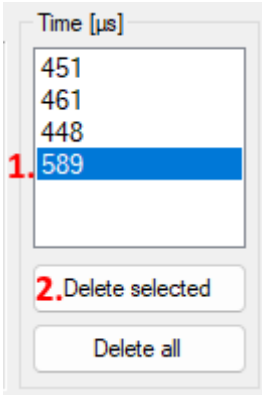


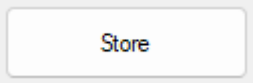
Figure 6: The angle of the next measurement

- A previous measurement location can be measured again by selecting a smaller "*N*" value (discarding the previous measurement). Uncheck "*Increment after store*" while editing "*N*".
- If there is an obstacle in the way of the soil sensor, one or more measurement locations can be skipped by increasing the "*N*" field.

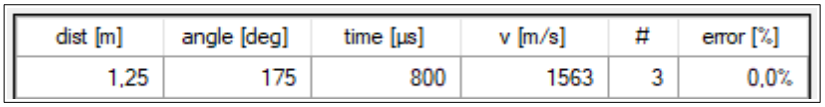
5.6.3. Time box



- Each time measurement is collected into the "*Time [µs]*" box, where sound travel time is measured in microseconds.
- The "*Delete selected*" button can be used to delete outliers.
- The "*Delete all*" button removes all items from the "*Time [µs]*" box.
- Once a sufficient amount of measurements are recorded (a minimum of 3 is recommended) clicking the "*Store*" button records the measurement into the current ring, and adjusts the angle to the next location if "*Increment after store*" is checked.
- It is recommended to save the current project after finishing each ring of measurements.



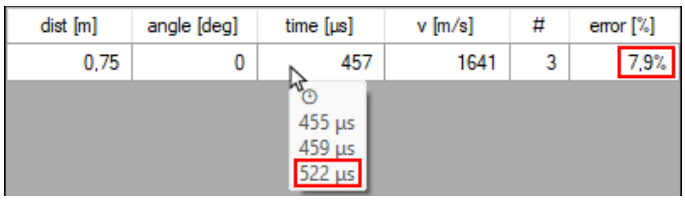
5.7. Ring measurements table



dist [m]	angle [deg]	time [µs]	v [m/s]	#	error [%]
1,25	175	800	1563	3	0,0%

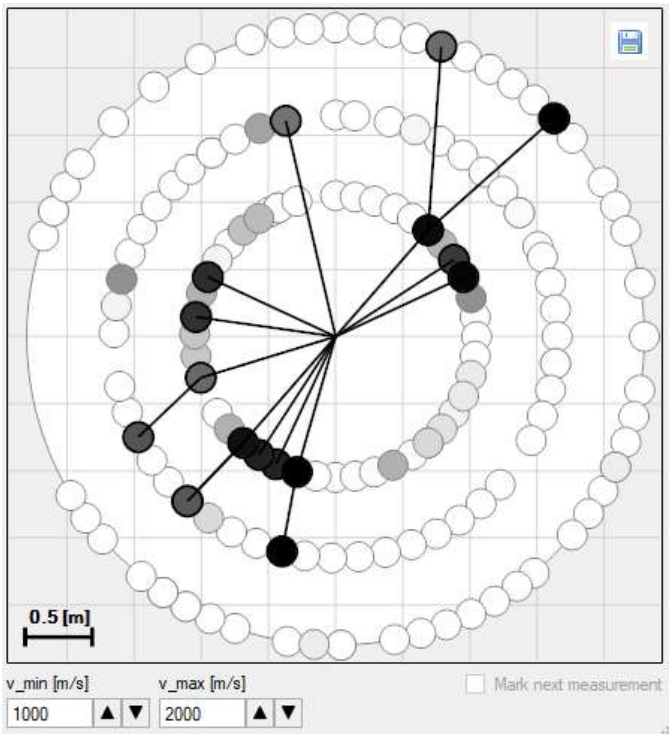
A summary of stored measurements for the currently selected ring are displayed in the "*Selected ring*" box. A single line in this table indicates a single location. When clicking on the "*Store*" button, a new row is inserted at the top of the table. The "*Delete last*" button deletes the last stored measurement, while the "*Delete selected*" button deletes the selected row from the table.

- **dist [m]**: the distance from the start sensor to the soil sensor. (This is equal to the ring radius minus half of the root collar diameter.)
- **angle [deg]**: the angle of the measurement location
- **time [µs]**: the average measured time for the location in microseconds
- **v [m/s]**: the velocity calculated from the distance and average time measured.
- **#**: Number of time measurements stored for the location
- **error [%]**: the *relative standard deviation* (*coefficient of variation*) of measurements taken at the location in percentage.
- A tooltip in the time column shows the raw time values for a stored measurement



5.8. Measurement visualization

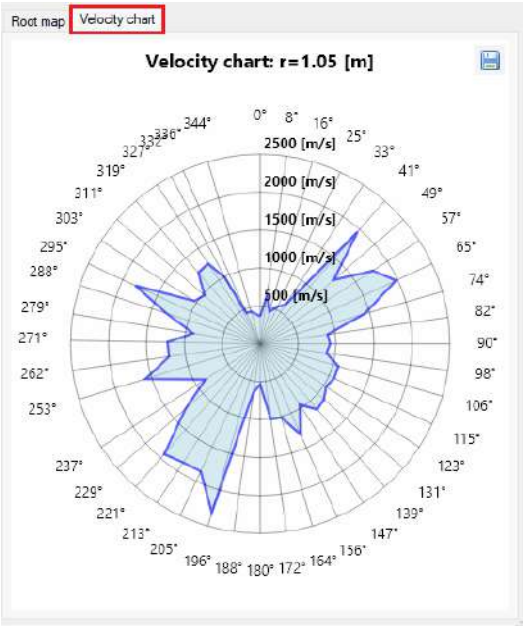
A visualization of all measurements is on the right side of the window.



- The root collar is indicated in the center with a brown circle
- Measurement locations are indicated with circular grayscale markers. The shade of the marker indicates the velocity. Darker shades indicate a higher velocity and the presence of roots.
- Parameters "*v_min*", "*v_max*" define the range of the velocities for the visualization.
- Below "*v_min*" the marker will be white, above "*v_max*" the marker will be black.
- Within the range of "*v_min*" and "*v_max*" the markers will take a corresponding shade of gray.
- Two measurement locations are connected with a black line when the velocities at both locations are above the midpoint of the range defined by "*v_min*" and "*v_max*".
- The "*Mark next measurement*" checkbox can be used to toggle the display of the green markers indicating the current and future sensor locations. It is disabled when no more measurements can be taken for the ring. The current sensor location (that is, the next stored measurement location) is a darker shade of green, and larger than the other green markers.

5.8.1. Velocity chart

The "*Velocity Chart*" displays the velocities on a radar style chart for the currently selected ring. This chart always corresponds to a single ring: the current selection. Change the selected ring to view the "*Velocity Chart*" for other rings.



5.9. Equalizing distances

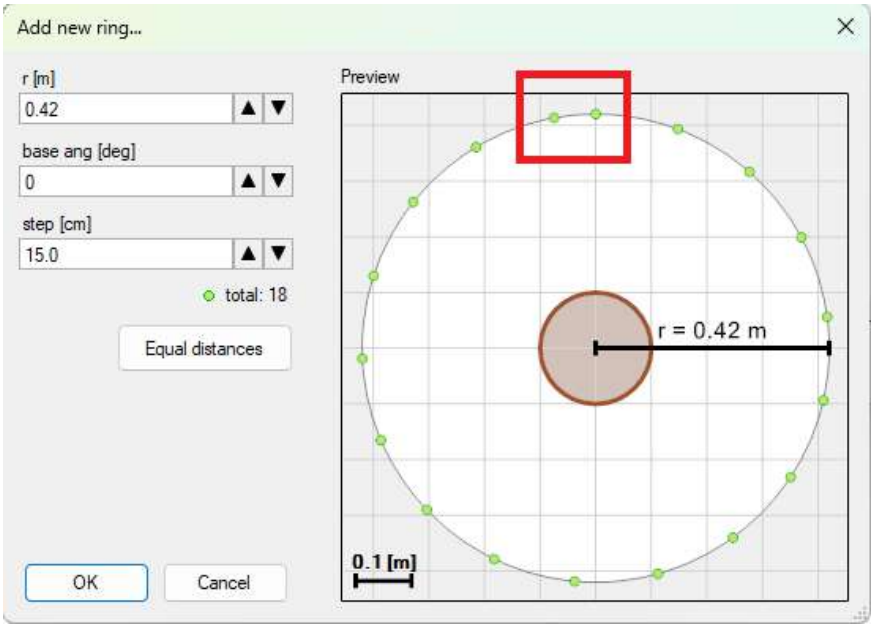


Figure 7: Irregular distance between the last and the first sensor positions

You can equalize sensor distances with following procedure:

- Click on the "*Edit*" button to edit the selected ring
- Click on "*Equal distances*"
- Afterwards the measurement location are distributed equally

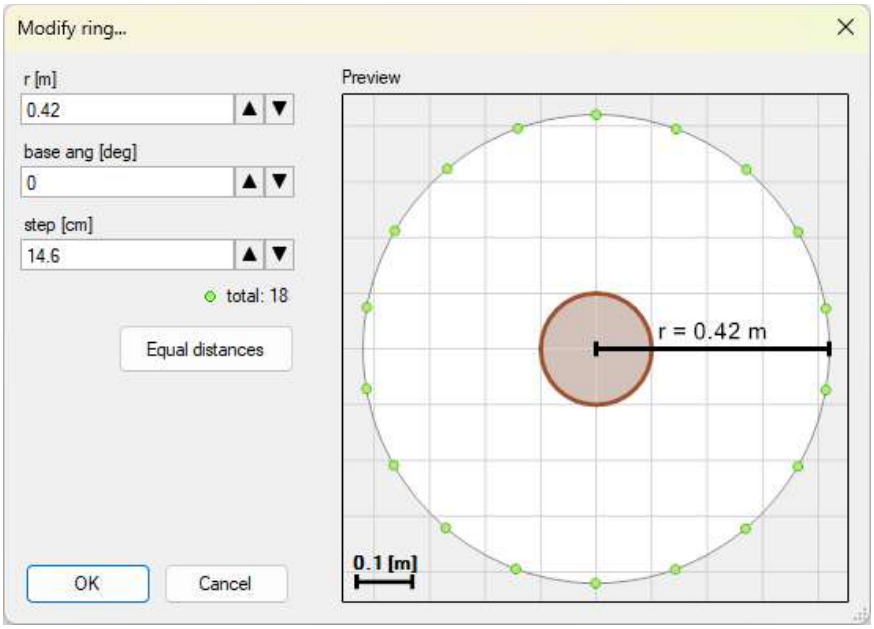
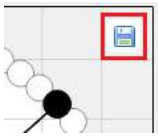


Figure 8: Sensor positions after equalization

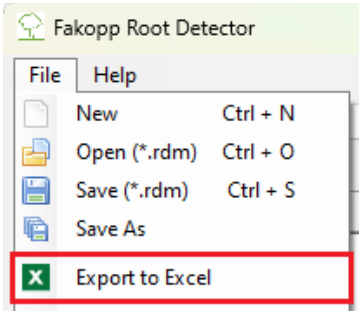
5.10. Exporting

5.10.1. Exporting the visualization image



You can export the image of the root system with the floppy icon displayed in the top-right.

5.10.2. Export to Excel



The measurement data can be exported to Excel from the main menu. The exported data will contain the same columns as the measurement data table.

5.11. Example measurement

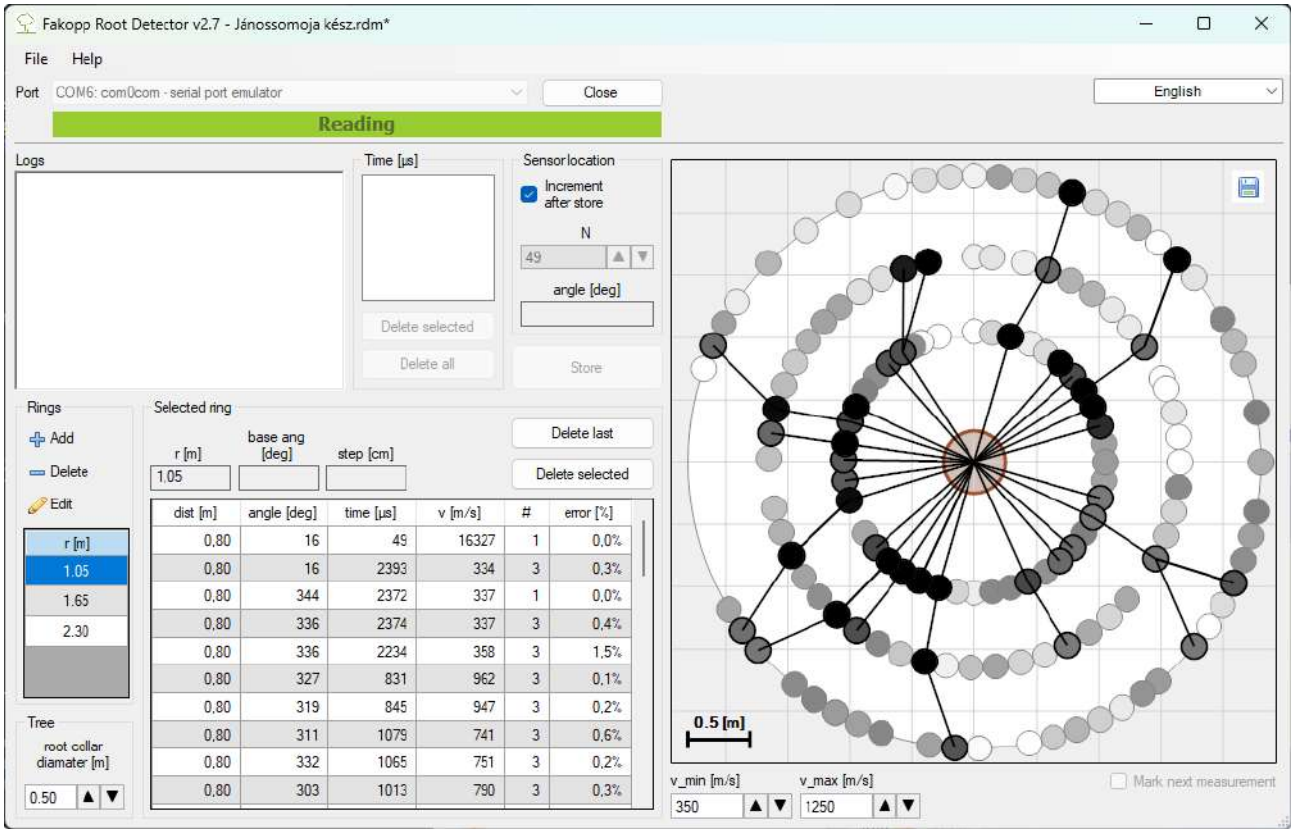


Figure 9: A completed measurement

6. Finishing the measurement

- Save the project: *File → Save*.
- Turn off the Root Detector battery box to save battery life
- When using the replaceable magnetic sensor head, please clean and keep dry the nail head to avoid rusting. The head is made of iron; the nail itself is stainless steel.