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PiCUS

IML Tree Inspection

Manual for PiCUS Tree Physiological Inspection Technology

This manual describes the use of the IML Tree Inspection Software together with PiCUS Sonic Tomograph 3, PiCUS TreeTronic 3, and PiCUS Calliper 3.

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1 Abbreviations and Conventions

1.1 About this Manual

This guide is valid for both the *PiCUS PC software* and the *PiCUS app*. Where there are significant differences between the two software versions or if reference is made to only one of the program versions, this is highlighted in colour.

Screenshots taken from the user interface are captured on a mobile device with Android. Screenshots from other program versions are only included and specifically mentioned where there are significant differences.

The structure of the manual follows the structure of the software or the layout of a project. It is aligned with the typical workflow during a tree inspection. Each section is divided into:

- Underlying theory
- Practical application of the devices
- Operation of the software
- case studies

Many of the example tomograms shown in this guide were generated in older program versions. They represent decades of experience from us, our customers, and partners. This has NO impact on the tomograms and the described facts themselves. Only the surrounding user interface in these older tomograms differs slightly from the current version of the software.

In the various menus, buttons, and input options are documented with their respective icons as displayed in the software, along with a brief description.



Example: Description

The arrangement of elements may vary slightly depending on the operating system, but the icons used are always the same.

Input options and displays in the software are written in **bold Courier font**.

Important notes on potential errors and sources of danger are indicated in ***bold italic font***.

General remarks are written in *simple italic font*.

Cross-references to other chapters are *italicized and underlined*.

Many of the icons and symbols used in IML Tree Inspection and in this manual come from the freely available section of the Font Awesome Library. The relevant licences can be viewed here: <https://fontawesome.com/license/free>.

The English translation of this manual (from its German original) has been assisted with AI tools, namely <https://www.deepl.com/en/translator>.

1.2 Abbreviations and Definitions

BT	Bluetooth
BT Classic	Bluetooth Classic wireless standard
BTLE	Bluetooth Low Energy wireless standard
USB	Universal Serial Bus
.pit	PiCUS Sonic Tomograph file extension (in software Q74 or older)
.ert	PiCUS TreeTronic file extension (in software Q74 or older)
PST 3	PiCUS Sonic Tomograph 3, name of the measurement system for sonic tomography
PCA 3	PiCUS Calliper
PRHD	PiCUS Radio Hammer with Display
PTT 3	PiCUS TreeTronic 3, name of the measurement system for electrical resistance tomography
SoT	Sonic Tomogram
ERT	Electrical Resistance Tomogram
TP	Tree Point - Each nail in the tree is a TP.
MP	Measurement Point - a point for which sonic data or electrical resistance has been measured. Each MP is always also a TP.
TapP	Tapping point - The TP on which to tap with the PRHD.
SP	Sensor point - A TP where a sonic sensor is currently mounted. Depending on geometry more TP than SP might exist.
BAP	Base point - Aids to reduce the number of necessary measurements during geometry measurement with a Calliper. Every BAP is always also a TP.
BL	Base line - the distance between 2 BAP

2. Field of Application / Disclaimer

The PiCUS measurement technology provides arborists with a comprehensive diagnostic tool for detecting and assessing defects in trees during tree inspections as part of advanced tree risk assessments. When it comes to evaluating the structural stability of a tree, PiCUS Sonic Tomography and TreeTronic Resistance Tomography are suitable methods for measuring the remaining wall thickness in detailed tree examinations.

The PiCUS® Sonic Tomograph and PiCUS TreeTronic® Resistance Tomograph were developed for the examination of standing trees during in-depth investigations.

The use of the devices on other objects may lead to damage to the devices or the object being measured.

The measurement results of the PiCUS Tomographs require interpretation by qualified professionals.

Conclusions about the tree's condition derived from the tomograms generated by the PiCUS Tomographs are the sole responsibility of the interpreter.

Neither the device manufacturer nor the seller can be held liable for consequences arising from the interpretation of the tomograms.

The PiCUS Sonic Tomograph detects differences in the wood's ability to transmit sound signals. There can be multiple reasons for variations in sound transmission properties.

The PiCUS TreeTronic resistance tomograph detects differences in the electrical conductivity of the wood. Here too, there may be a variety of reasons for the differences measured in the wood properties.

In evaluating a tree, it is crucial to determine the cause of the appearance of the tomogram. Make sure to identify whether fungi, cracks, or other defects are present.

If sonic or resistance tomograms indicate extensive damage suggesting the need for tree removal, thorough consideration should be given, and if necessary, other investigation methods should be applied to explain the measurement results. Trees should not be felled solely based on a tomogram!

All technical specifications are subject to change without notice.

3. Sonic and Resistance Tomography Introduction

The PiCUS Sonic Tomograph 3 (PST 3) is a measuring device designed for detecting damage (holes, decay, cracks) in standing trees. The device measures the travel times of sound waves generated by manual tapping. Using the geometry data of the measurement plane, measured with the PiCUS Calliper 3 (PCA 3), apparent sound velocities between measurement points are determined and presented in a sonic tomogram.

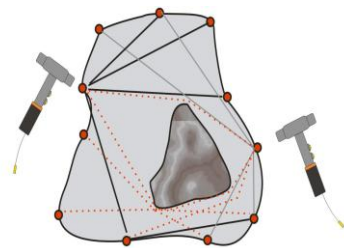
The speed of sound in wood primarily depends on the modulus of elasticity and the density of the wood. It varies not only between different tree species but also among different tree types of the same species.

The IML Tree Inspection Software compares the velocities based on specific criteria, accounting for the individual variation in wood properties of the examined tree through self-calibration. By overlaying the velocities from individual measurements, the sound conduction properties for the entire cross-section of the tree trunk are determined.

In the IML Tree Inspection Software, different sound conduction properties across the trunk cross-section are represented by arbitrarily chosen colours. Dark colours (blacks and browns) indicate areas with high sound velocity – representing healthy wood. Signal colours (purple, blue to light blue) highlight areas with low sound velocity – typically indicating defective wood or air.

The sound sensors themselves are acoustically coupled to the wood using thin nails or screws. The nails are driven through the bark and placed on the first annual ring. This way, the acoustically dead bark of the tree is overcome without causing significant harm to the tree.

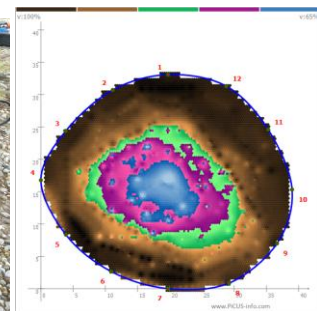
The sketch illustrates the theoretical paths of the sound waves when signals are introduced at different points on the tree.



Sound paths



PST 3 during measurement



sonic tomogram

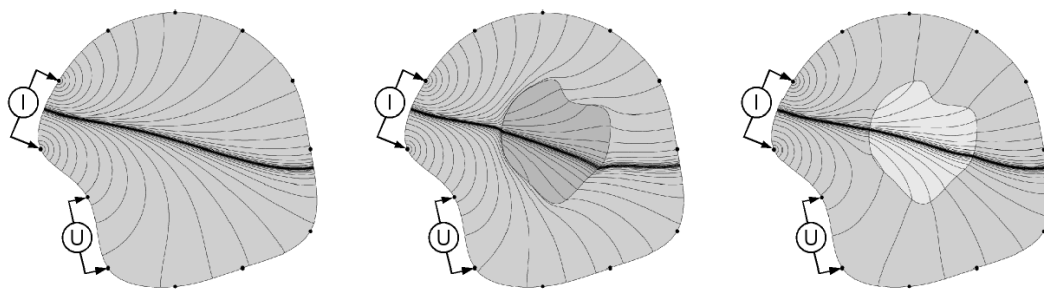
The PiCUS TreeTronic 3 (PTT 3) is a device that can examine the spatial distribution of electrical resistance in standing trees without causing damage.

The electrical resistance distribution depends primarily on the water content and ion concentration and can serve as an indicator of damage (holes, rot, cracks). It varies not only between different tree species, but also between trees of the same species, and can be subject to seasonal and weather-related fluctuations.

The IML Tree Inspection Software calculates the resistance distribution from the input currents and measured voltages and displays it in arbitrarily selected colours (blue – low resistance, high moisture / red – high resistance, low moisture), similar to the acoustic tomograms.

The PTT 3 was developed as a parallel measurement method to the acoustic tomograph. The same nails that can be used to attach the PST 3 sound sensors are used to contact the electrodes.

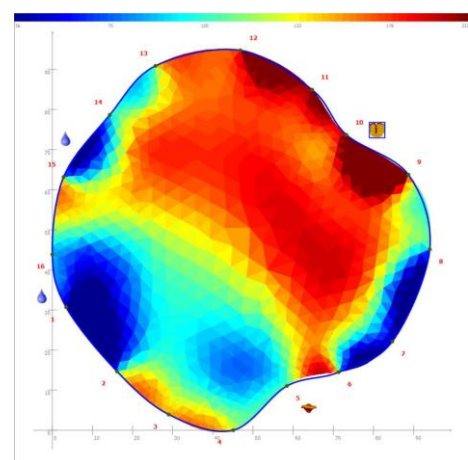
The combination of sonic and resistance tomography with shared measuring points resolves some of the ambiguities that can arise when using only one method. The two methods thus complement each other perfectly and, thanks to different physical principles of operation, allow an analysis of wood properties with a high degree of certainty.



Distribution of electrical fields



PTT 3 during measurement



resistance tomogram

4. Software Installation

4.1 Comparison of Software Functions

<i>Program functions</i>	<i>PC</i>	<i>App</i>
- Create and manage projects: - Project - Trees - Inspections - Geometries - Sonic measurements - Analyses/Tomograms - Tomogram compare/Timelines/3D view - Reports	Yes	Yes
Save and load projects in the Cloud	Yes	Yes
Compatibility BTLE	Yes	Yes
Compatibility BT Classic (older PST 3 / PTT 3 / PCA 3 Variants without BTLE)	Yes	No
Compatibility USB	Yes	Android only / not available on iOS
Reading of measurements saved directly in the PST 3 / PTT 3 (measured in standalone mode)	Yes	Android only / not available on iOS
Conduct sonic measurements with PST 3	Yes	Yes
Conduct resistance measurements with PTT 3	Yes	Yes
Measure tree geometry with PCA 3	Yes	Yes
Scanning of tree plaques (QR-Code or Barcode)	Yes (requires camera)	Yes (requires camera)
Measurement of tree or crown height	No (manual entry only)	Yes (requires camera and tilt sensor)
Measurement of crown diameter Not yet implemented	No (manual entry only)	Yes (requires compass)
Geolocation with GPS	No (only indirectly through PST 3 / PTT 3)	Yes (requires GPS)
Geolocation with external devices and direct entry into the software	Yes	Yes
Calculation of sonic tomograms	Yes	Yes
Calculation of resistance tomograms	Yes	Yes
Tomogram screenshot export of current view	Yes	Yes
Direct Tomogram comparison		

Positioning of comment and analysis markers in the tomogram	Yes	Yes
Geometry measurement functions in the tomogram - distances - angles - measurement value at a certain point	Yes	Yes
Crack detection	Yes	Yes
Calculation of residual wall thickness with VTA-0,3-Method (Mattheck & Breloer)	Yes	Yes
Calculation of residual wall thickness with TreeSA method	Yes	Yes
- Tabular Presentation of Measurement Results: - - Measurement Verification (Status Display) - - Sound Velocities Point to Point - - Individual Taps - - Averages	Yes	Yes
Timelines / Tomogram comparison	Yes	Yes
Capturing photos for documentation purposes	No (manual adding only)	Yes (requires camera)
3D view of tomograms from different measurement levels	Yes	Yes
Overlaying photo and tomogram Not yet implemented	Yes	Yes
Automated report generation	Yes	Yes

4.2 Installation of PiCUS App

The software can be downloaded and installed directly from the respective App Store on [Windows](#), [Android](#) and [Apple iOS](#) systems.

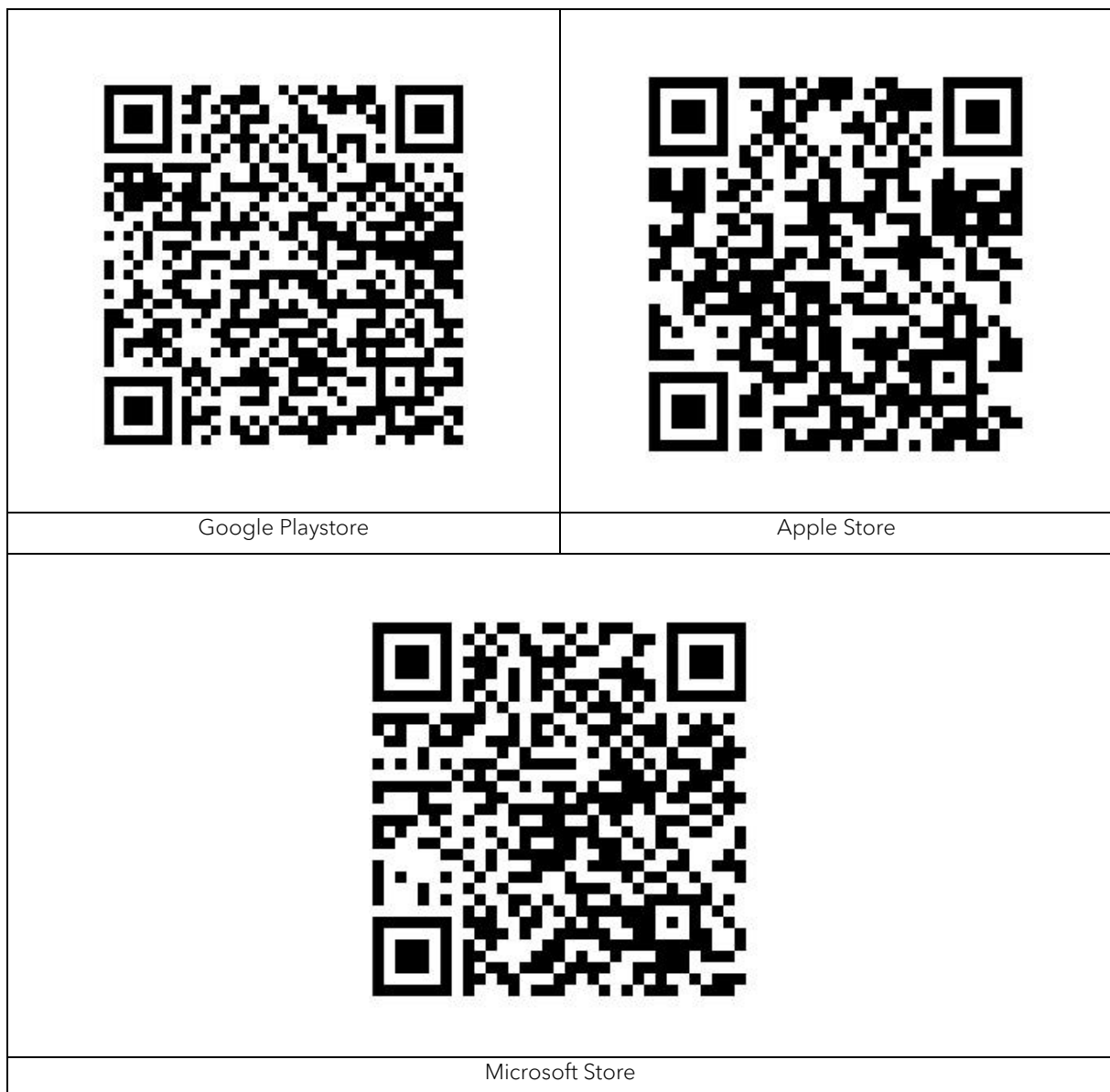
The Software can theoretically run on [MacOS](#) on devices with Apple Silicon Chips. However it was neither optimised nor tested for that platform.

Simply search for:



IML Tree Inspection

Or use the following QR codes:



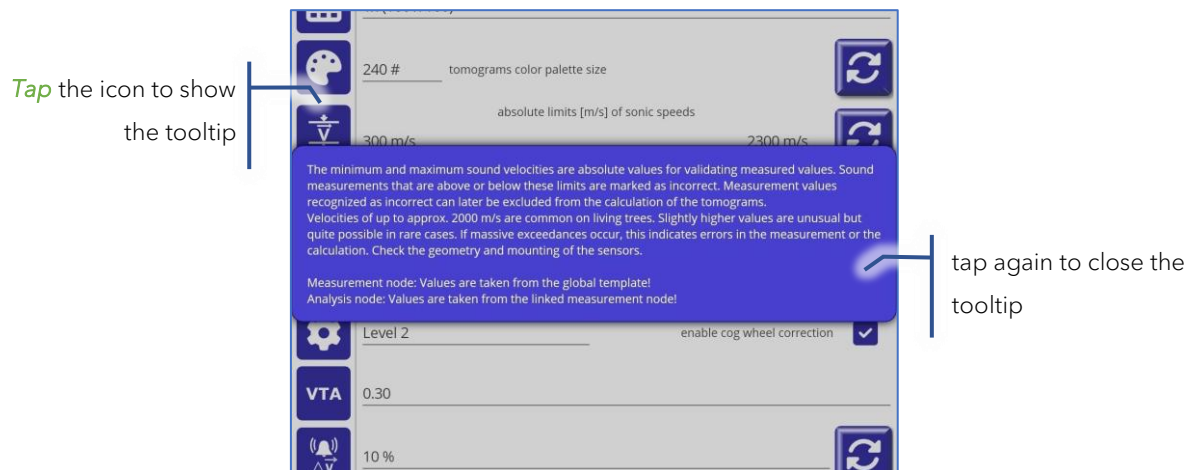
4.2.1 App Permissions

For the correct operation of the app, the following permissions are requested:

- **File access/internal storage:** Both manually entered project data and recorded measurements need to be stored in the *internal storage* of your mobile device. Your permission to use storage for reading and writing is required for this. If you deny this, the *app* cannot function.
- **Camera:** At many points in a project, accompanying photos can be taken to document the tree, environmental conditions, and measurement setup. The *app* provides the option to take these photos directly and automatically add them to the project data. Your permission to use the *camera* is required for this.
- **Location:** During data entry, the *app* offers the option to determine the position of the tree using the *GPS of your mobile device*. Your permission to use the *location system* is required for this.

4.3 Contextual Help

Almost all input options in the app and PC software have contextual help that provides a brief explanation text for the respective input. *Hover the mouse pointer over the icon* or *tap and hold the icon* to display the tooltip.



4.4 Software Configuration

Many settings and configuration options within the software need to be edited only once. The Settings menu allows you to set global parameters that apply to all projects.



You can find the Global Settings in the **main menu** of the app under **Settings**.



In the tabs, you can make the following settings:



Configuration: general settings for the Software



Devices: here, the BT or USB connections to the Tomographs and the Calliper are set up



Inspector: the user's personal business card, which is stored in multiple locations



Calculations: global parameters for measurement data validation and tomogram calculation

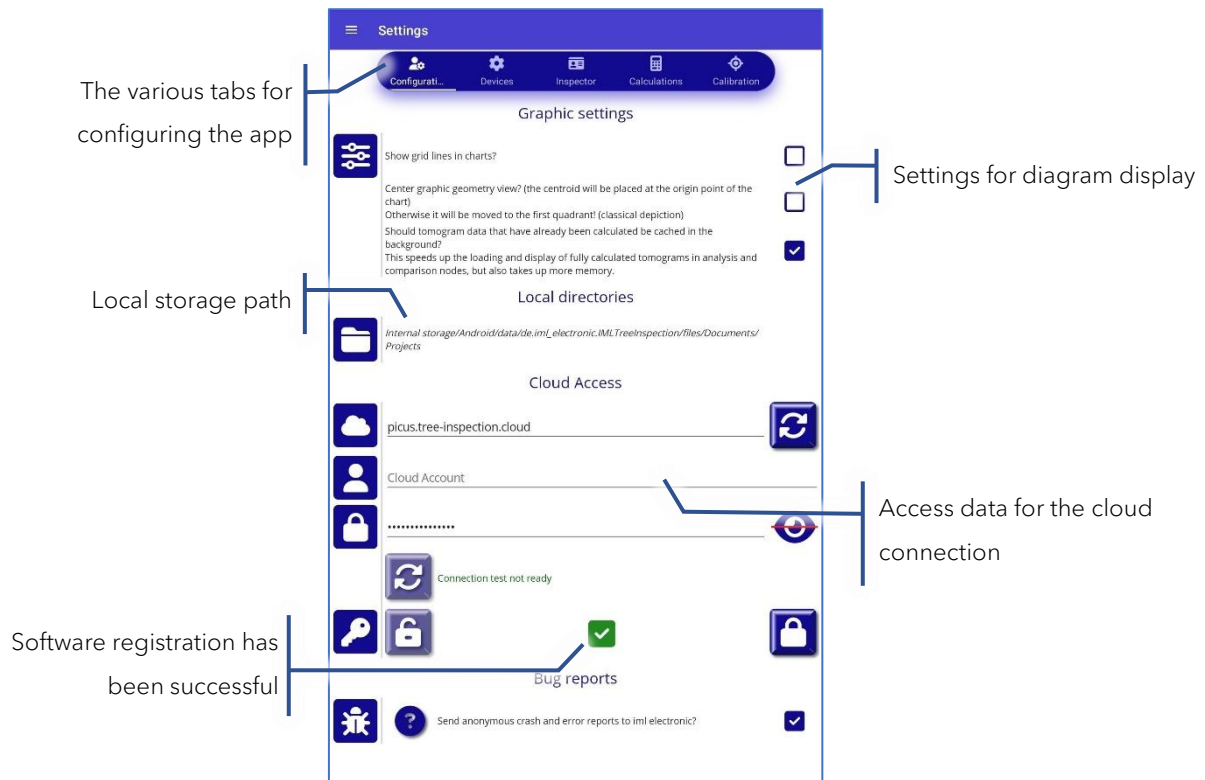


Calibration: determining a correction factor for the camera to set up the *altimeter*

The following sub-chapters explain the submenus in detail, with the exception of calibration, which is described under [6.1.1 Calibration of the Altimeter](#).

4.4.1 Configuration

Under Configuration, general settings regarding the software's behaviour are adjusted.



The options for **graphic settings** are applied in all diagrams. When the display of **gridlines** is activated, horizontal guide lines are shown in the background in bar charts to facilitate reading values. In geometries and tomograms (representations of the measurement plane), the gridlines assist in quickly estimating distances.



If the **Tomogram Cache** option is selected, all calculated tomograms are stored locally. This significantly speeds up the loading and display of tomograms since they don't have to be dynamically recalculated each time. However, it also requires more storage space, making the locally saved project larger. During data transfer between the cloud and the device, the calculated tomograms are not transmitted. After downloading to another device, tomograms must be recalculated once to store them again in the tomogram cache.



Under **Local Directories**, the storage locations of the project files can be viewed. This is purely a display feature in the *Android app*.

On *PC* there are additional options to



change or



to open the directory.



In the **Cloud Access** section, in addition to the cloud address (**picus.tree-inspection.cloud**), your personal cloud access credentials are entered, which you received along with your PiCUS measuring device.



The address is preset and can be reset with the **Reset** button



Account name for the cloud access



Password for the cloud access



*Ensure at all times that unauthorized individuals do not have access to your personal login credentials!
The visibility of the password can be toggled.*



The **connection test** checks whether a connection to the cloud server can be established with the entered data.



Separate credentials are required for **registration**, which you also received with your PiCUS measuring device.



Start the registration process to unlock the software. In the opening dialog box, enter



User name for software registration



Password for software registration



Deregistering releases the registration of this software installation and frees up the registration so that another device can be registered instead of the current one. *Always deregister the software before uninstalling, since otherwise one licence would be blocked permanently.*

A more detailed description of software registration can be found under:
[vX.X PiCUS Software Registration Manual XX.pdf](#)

Attention, risk of confusion! The credentials for the IML Cloud are not identical to the software registration data.



Error reports activates the automatic sending of anonymised error and crash reports to IML Electronic. Additional information can be displayed by clicking on the question mark.

4.4.2 Devices

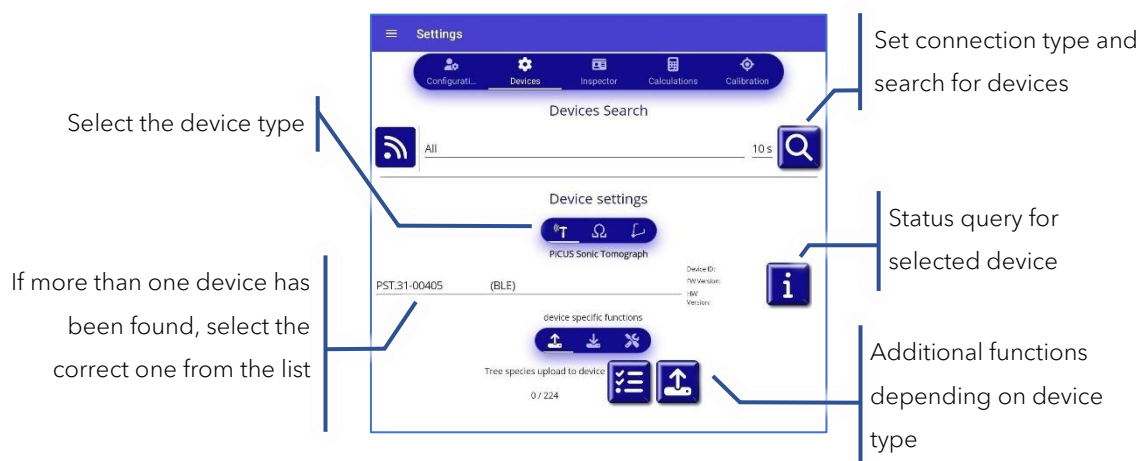
Here, the Bluetooth communication with the devices is set up for the first time.

In the PC software [USB](#), [BTLE](#) and [BT Classic](#) are available for device communication.

For the PCA only [BT Classic](#) and [BTLE](#) are available.

In the app, only [BTLE](#) is available as radio standard for all device types. Additionally, [USB can be used on Android devices](#). Older PiCUS devices that are not equipped with BTLE radio modules cannot be used with the mobile apps.

Contact us to explore the possibility of retrofitting your PiCUS devices with BTLE radio standard.



The additionally available options to configure the devices, that are only available via Bluetooth Classic or USB, are described in the chapters [7.5 Transfer of Stand-Alone Measurements](#) and [7.6 Updating the Devices Tree Species List](#).



First, make sure that the Bluetooth communication is active on your device. Using the **Search for Bluetooth Devices** button will then search for all powered-on PiCUS devices in the vicinity.

The last selected device and all devices found in the vicinity are entered in the list under Device settings after the device search is complete. The device type can also be selected here:



PiCUS Sonic Tomograph 3



PiCUS TreeTronic 3



PiCUS Calliper 3

When establishing a connection during a measurement later on, communication will always be established with the devices selected here.



The **Retrieve Device Information** buttons display the device ID, firmware version, and hardware version. These details may not be available for older devices. *Please have this device information ready if you have service inquiries, so we can assist you effectively.*

4.4.2.1 Switching between Radio and Cable Hammer

In most cases, the electronic PiCUS Hammer (PRHD - PiCUS Radio Hammer with Display) can communicate wirelessly with the PST3. For this, the hammer antenna must be installed. If there are large-diameter trees or other radio signals in the vicinity, the connection between the PRHD and PST3 may be disrupted. In such cases, it is possible to switch to a cable connection even during the measurement.

Procedure:

- Wait until the PRHD turns off.
- Exit the measurement window or the PC connection window of the PST 3
- Disconnect the connection in the software (if active)
- Remove the hammer antenna
- Install the hammer cable between PST 3 and PRHD
- Return to the measurement window or the PC connection window of the PST 3
- Re-establish the connection in the software

4.4.3 Inspector

It is assumed that only one person is using a mobile device or a PC. Here, the personal business card of this user is being edited.

It is possible that a project is edited by different individuals. For example, a common scenario is that some inspectors in the field inspect trees, send the data via the cloud, and then another clerk in the office creates reports from the inspection data.

To ensure traceability of the processing, the business card is stored in some data nodes. For a detailed overview of the project structure, refer to Chapter [7 Project Management](#).

At the project level, i.e., in the topmost level of the data structure, both the last editor and the creator are noted. For inspection, timeline, and report nodes, the creator is stored. Nothing is stored in the tree node since it is assumed that the creator of the first inspection is also the creator of the tree. In the data nodes, only an abbreviation for the respective editor is displayed. The complete business card is only used in the report generation.

For general information that does not fit anywhere else, there is almost always a comment field available.

Settings

Configurati... Devices **Inspector** Calculations Calibration

first name

Last name

agent's initials

Iml Electronic

DE

HRO

18057

Südstadt

Erich Schlesinger Str. 49d

contact@iml-electronic.de

0381-49681440

Mobile

comment

The user's business card is entered under **Inspector**

The following information is stored:



First name and **last name** of the inspector



agents' initials: the abbreviation displayed in the data nodes. It is formed by default from the user's initials but can be edited later.



Company name



Address: consisting of **country**, **city**, **zip code**, **city district** and **street**



Contact information: **eMail**, **phone number** and **mobile number**

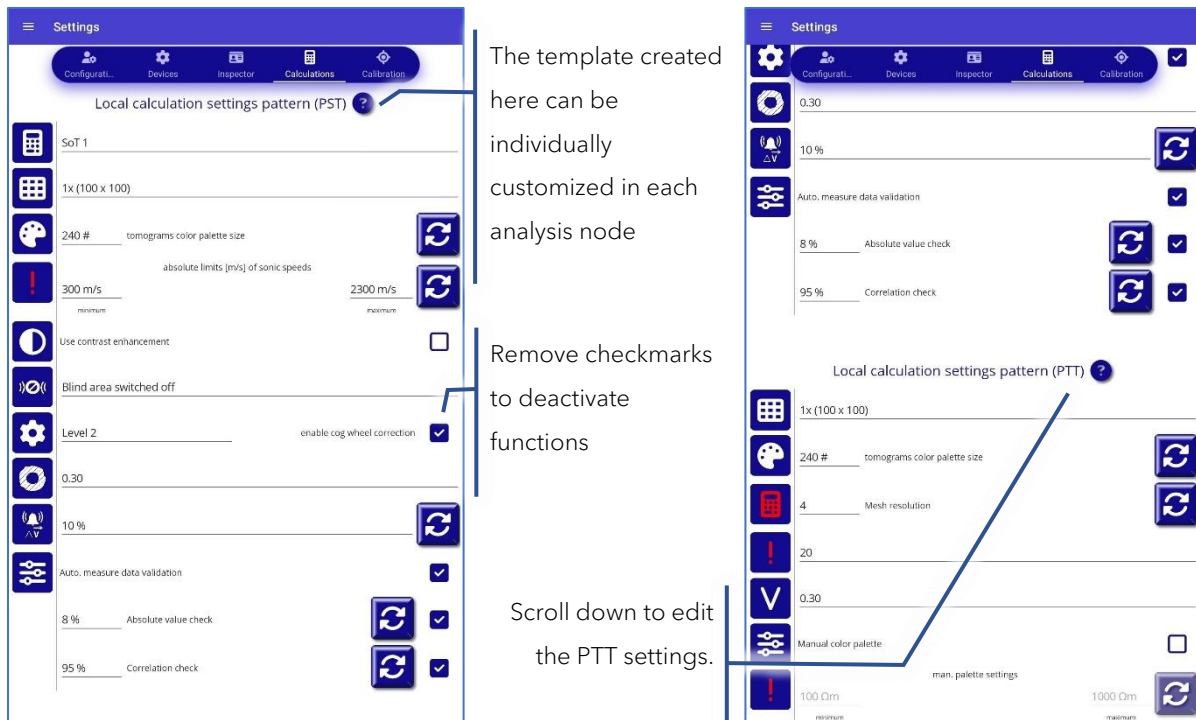


Comments: a free-text field for additional information

4.4.4 Calculations

In the Calculation tab, global settings for sonic and electrical resistance measurements and tomogram calculations are configured.

This serves as a template that is adopted when creating a data node. Once a data node has been created, only local settings apply to that node. Modifying global settings afterward has no effect on existing nodes.



The **local settings pattern (PST)** or **(PTT)** is the global default setting for all tomogram calculations. It is applied in the Sonic Measurement or Electrical resistance Analysis node. In the Analysis nodes, the default settings set here can be selectively adjusted locally for individual calculations.

The available settings are:



Calculation type: Here, you can switch between **SoT Type 1** and **SoT Type 2**. For details, see also [8.7.2.3 Velocity Profiles](#).



Grid size: Specifies how finely the tomogram is resolved. The larger the grid, the finer the structures displayed in the tomogram. However, finer structures also require significantly longer calculation times.



For tomogram representation, the size of the **colour palette** can be adjusted. The larger the number, the finer the gradations, resulting in smoother colour transitions. Conversely, smaller values lead to significantly sharper transitions between differently coloured areas. The lower limit is 6 colours (black, brown, green, violet, blue, white), and the upper limit is 240 colours.



The **minimum and maximum sonic velocities** are absolute values for the validation of measurement values. Sound measurements above or below these limits are marked as faulty. Identified faulty measurement values can be excluded from the calculation of tomograms later on.

- Default max value: 2300 m/s
- Default min value: 300 m/s

Velocities up to approximately 2000 m/s are common in living trees. Slightly higher values are unusual but can occur in rare cases. If massive exceedances occur, this indicates errors in the measurement or calculation. Check the geometry and the sensor installation.

The sonic velocities are not only used in the sonic analysis node, but also during the measurement process in the sonic measurement node.



Contrast enhancement: Helps to less prominently emphasize naturally occurring wood strength differences (reaction wood compared to normal wood). Especially in measurements with low-speed variances (80%...100%), this function often leads to a sharper coloration.



Blind area: The cogwheel effect can sometimes mask smaller, early defects in the centre of the trunk. In such situations, it is recommended to exclude the sensors adjacent to the tapping point, i.e., the sensors that cause the cogwheel effect due to slow sound transmission along the circumference, from the calculation. Larger values lead to compromises in the representation of the edge area.



Cogwheel correction: The detection of the cogwheel effect is always active. Here, the sensitivity of this detection can be adjusted. When such data constellation is detected, it is represented by a small cogwheel symbol in the top right corner of the tomogram. In this case, the crack detection function is no longer available (see also [8.7.2.2 The Cogwheel Effect](#)).

Additionally, the correction calculation for the cogwheel effect can be activated here. With cogwheel correction enabled, the effect is less prominently displayed in the tomogram. The status of the correction is indicated in the tomogram by the colour of the icon when the cogwheel effect is detected.



cogwheel effect detected and corrected



cogwheel effect detected but not corrected



Factor VTA Method: For the calculation of the remaining wall thickness with the VTA-0.3 method (Mattheck & Breloer), a factor deviating from the standard can be entered here. See also [8.7.7 Estimating Residual Wall Thickness](#).



Warning limit for averaged sonic speed discrepancy is a measure of the maximum allowed deviation between the averaged maximum velocities at all tapping point.



Enable automatic measurement data validation: Activates automatic application of absolute value check and correlation check. The checks can also be set independently of each other.

See also [8.7.10 Data Validation](#).

- **Absolute value check:** If individual values deviate by more than this percentage from all other taps at this measurement point, they are ignored.
- **Correlation check:** Checks how similar the measurements are at a tapping point.

The following calculation options can be set for electrical resistance tomography:



Grid size: Specifies how finely the tomogram is calculated. The larger the grid, the finer the structures displayed in the tomogram. However, finer structures also require considerably longer calculation times.



Colour palette: Specifies the size of the colour palette to be used for the electrical resistance tomograms. Higher values result in smoother colour transitions. The colour scale is automatically applied between the smallest (blue) and largest (red) resistance values.



Mesh resolution: The tree cross-section (the measurement plane) is represented in the ERT calculation by a mesh of many small triangles. The mesh resolution determines the number of triangles inserted between two TP along the perimeter. (see also [8.8.2.4 Mesh Resolution](#))



Smoothness: The smoothing level specifies how many details are visible in the calculated tomogram. Smaller values show more details in the tomogram, larger values show fewer (see also [8.8.2.5 Smoothness](#)).



Factor VTA Method: For the calculation of the remaining wall thickness with the VTA-0.3 method (Mattheck & Breloer), a factor deviating from the standard can be entered here. See also [8.7.7 Estimating Residual Wall Thickness](#).

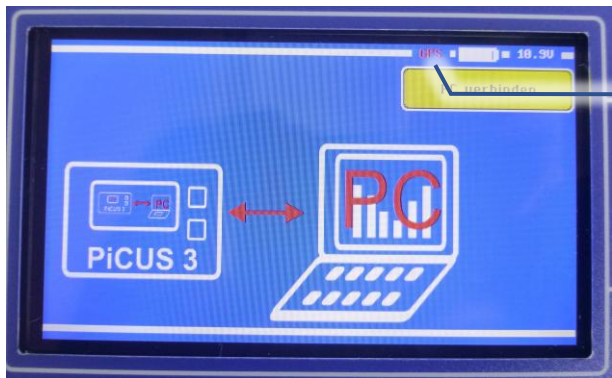


Manual colour palette: When the manual colour palette is activated, the smallest and largest resistance values defining the limits of the colour scale are no longer determined from the tomogram but are entered directly here. All values in the tomogram that are greater than the maximum are also displayed in dark red, and all those that are smaller than the minimum are displayed in blue.

4.5 GPS-Coordinates from PST 3 or PTT 3

GPS coordinates are stored in the tree node (see also [7.1.3 Tree](#)). They can either be *determined directly by the internal GPS module of a mobile device* or *determined via the internal GPS modules of the PiCUS tomographs and then read out* (the usual procedure on a PC).

To read the GPS coordinates directly from the PST 3 or PTT 3, the tomograph used must be switched on and must have already determined the GPS coordinates.



GPS: Position not yet determined

GPS: Position determination successful

The device is in the menu:

Data connections → to PC

Reading from the tomographs requires a Bluetooth Classic or USB connection. The source for the position data is queried in every case. Options that are not available on the respective platform are greyed out.

The **GPS button** opens a selection field for the position source. If a tomograph is selected, a connection is automatically established, and the GPS coordinates are read out.



5. Registration

The registration of the software is done in the Settings menu under the Configuration tab. For registration, you need the username and password provided with your PiCUS device.

Detailed instructions for the registration process can be found in:

[vX.X PiCUS Software Registration Manual XX.pdf](#)

The software can also be started without registration; however, some features are not accessible (device communication and file creation):

- **Bluetooth/USB communication:** Without registration, a direct connection to PiCUS devices cannot be established.
- **Tomogram-Export:** Without registration, images of tomograms (both 2D and 3D views) cannot be exported.
- **Report Export:** Automated report generation is not available without registration.

6. Helper tools in the App

The following helper tools require position and orientation sensors, which are typically only available in *mobile devices*.

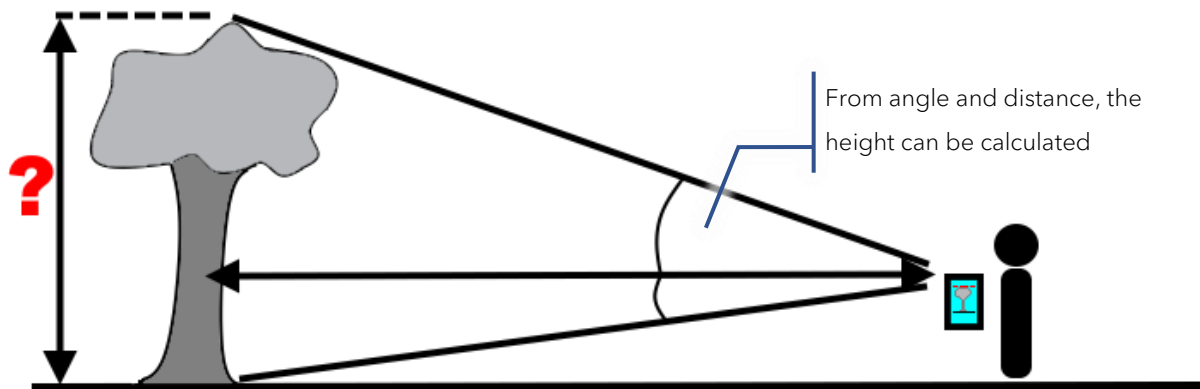
If your mobile device does not meet the necessary technical requirements to use these functions, the corresponding tools will be greyed out.

6.1 Altimeter



The altimeter determines the tree height or the height of the measurement plane through triangulation.

The necessary prerequisite is the presence of a camera and inclination sensors. With the camera, the highest and lowest points of an object (typically tree height or height of the measurement plane) are aimed at. From the angles at which the device is held during this process and the additional measured distance between the camera and the object, the height of the object can be calculated.



6.1.1 Calibration of the Altimeter

To use the altimeter, a correction factor for the camera must first be determined. A known object is measured for this purpose. Door frames have proven to be very suitable calibration objects. Their height can be measured very well, and the distance to the door frame is easily determined during calibration, typically 2 to 5 meters.

To calibrate, follow these steps:

In the **main menu**, select **Settings → Calibration**



Start the altimeter calibration with the tool button.

The camera image is displayed with 3 lines. The middle line is parallel to the Earth's surface, and the two outer guiding lines are used to align the camera as straight as possible. Hold the camera during all height measurements so that the 3 lines are aligned as straight as possible.



Aim at the upper edge of the calibration object and take an angle measurement with the upper tool button.



Repeat the process with the lower edge of the object and the lower tool button.



Abort
calibration

upper edge

lower edge

Distance and
height of the
door frame



Enter the following values:



Distance from object



Height of the object



Complete the calibration measurement, and the correction factor will be calculated automatically.

6.1.2 Using the Altimeter



In all menus where a height measurement is required, it can be entered directly, or the altimeter can be started using the tool button. The height measurement is performed similarly to the calibration measurement:



Aim at the **upper edge** using the camera and determine the angle with the tool button.



Afterwards, aim at the **lower edge** in a similar manner and determine the angle using the tool button.



Enter the **Distance**



In in the last line the calculated **object height** is shown.



The height will be automatically calculated once all three inputs are made, and it can be confirmed and applied to the calling dialog box using the **Confirm** button.

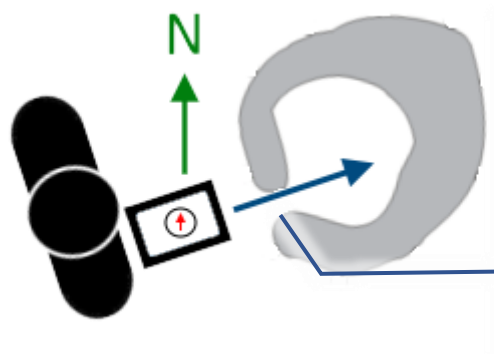
6.2 Compass



The orientations to be entered can either be input directly, or the **compass** can be opened using the button next to the input field to measure the orientation directly.

If your mobile device has a magnetic field sensor, the compass tool can determine the north orientation of tree points or diagnosis markers (horizontal angle). Additionally, the tilt sensors can determine vertical angles.

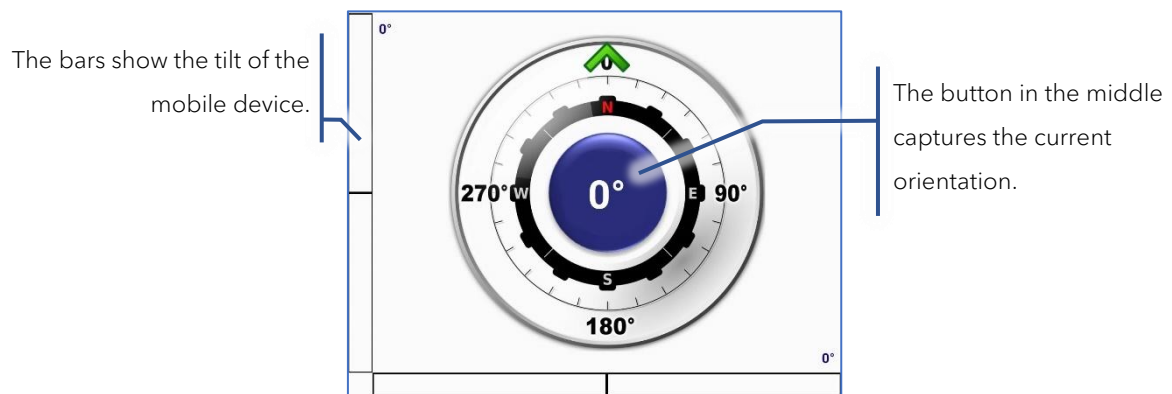
To determine the direction, stand in front of the point on the tree or the defect to be measured. Align the top edge of the device with the point to be measured. Depending on the object to be measured, either hold the device horizontally, so that the device, point, and tree centre are on a line, or angle the device so that it is in line with the line whose orientation you want to determine.



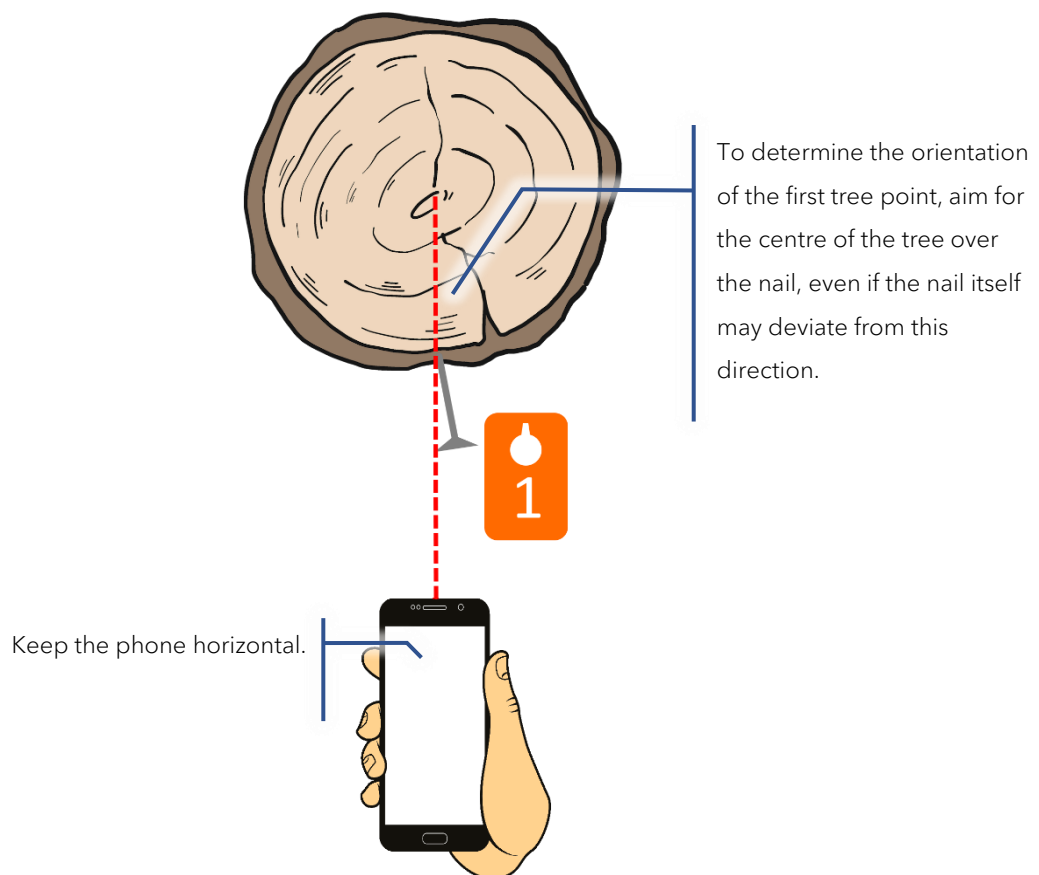
Aim the top edge of the phone at the interesting point (here, a cavity, where the aim points towards the centre of the trunk)

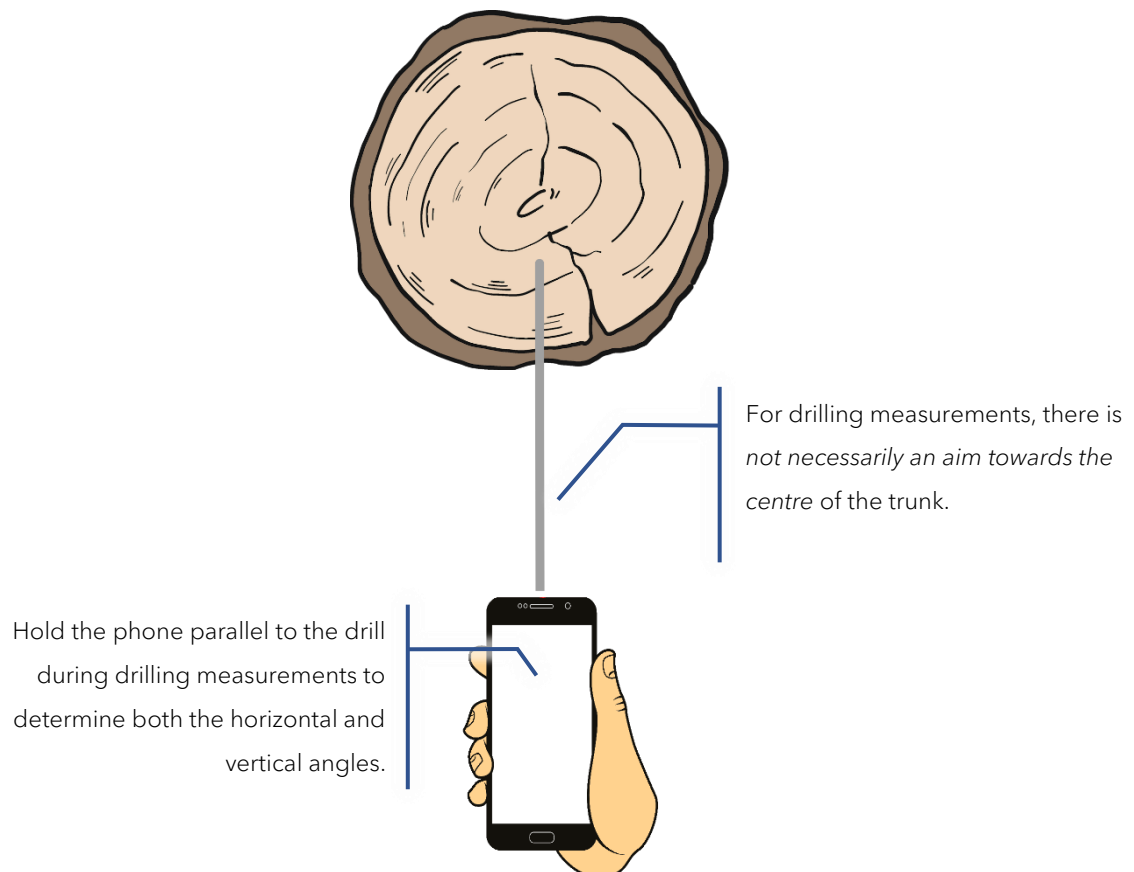
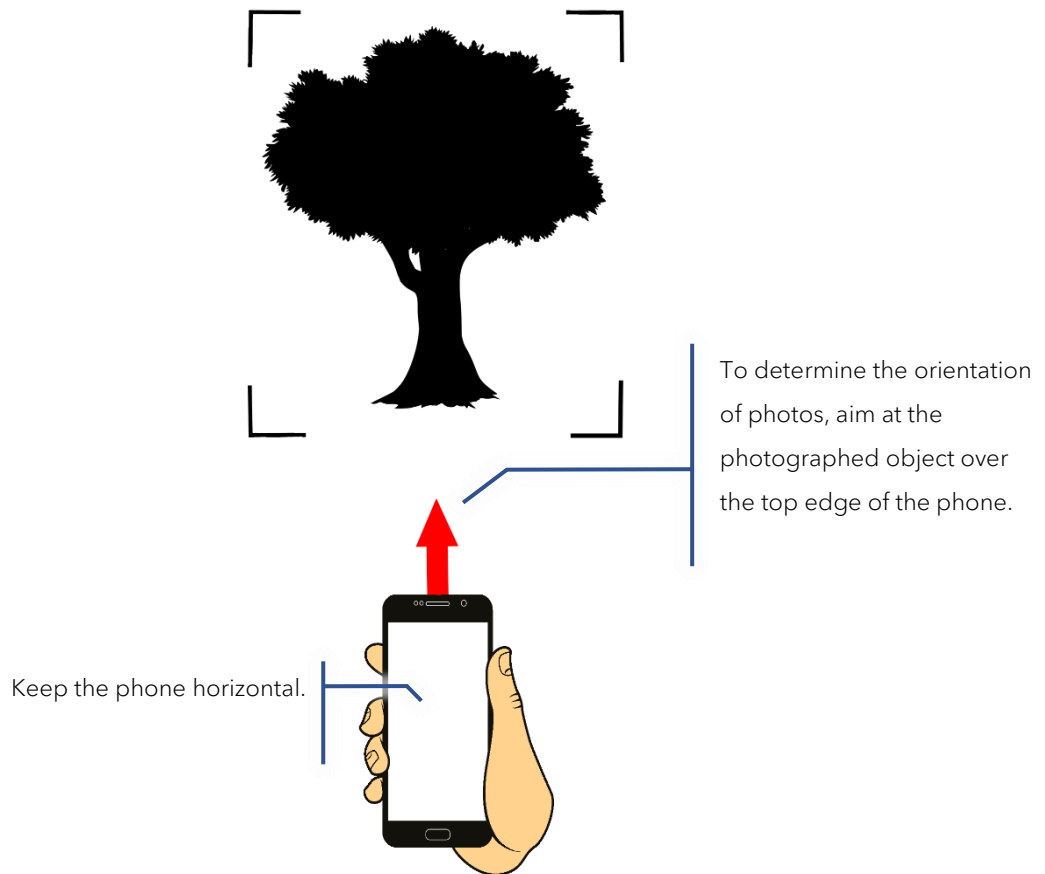
Then press the button to capture the orientation.

Tap the button in the middle of the compass to capture the orientation.



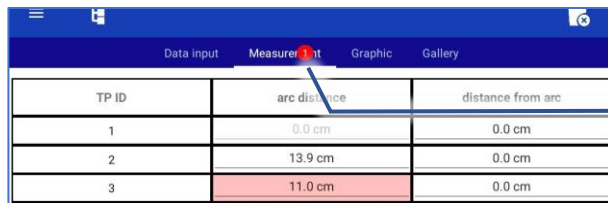
Above the compass rose, a diagram indicating the measuring direction is always displayed. These diagrams are documented here for the sake of completeness, enabling standardized directional information even for users without a magnetic compass in their device.





6.3 Error Counter

The tabs in the various data nodes often display an error counter. When this error counter is visible, there are unexpected or erroneous inputs or calculation results on the respective tab. These may include missing mandatory inputs, value range violations, or failed plausibility checks for measurement values.



TP ID	arc distance	distance from arc
1	0.0 cm	0.0 cm
2	13.9 cm	0.0 cm
3	11.0 cm	0.0 cm

Error counter indicates a problem

Here: Plausibility of measurement values - Measurement points not in ascending order on the tree (Point 3 is closer to the origin than Point 2).

Since the typical workflow involves working through one tab after another, and the tabs build on each other, it is advisable to proceed only after all errors on the current tab have been resolved.



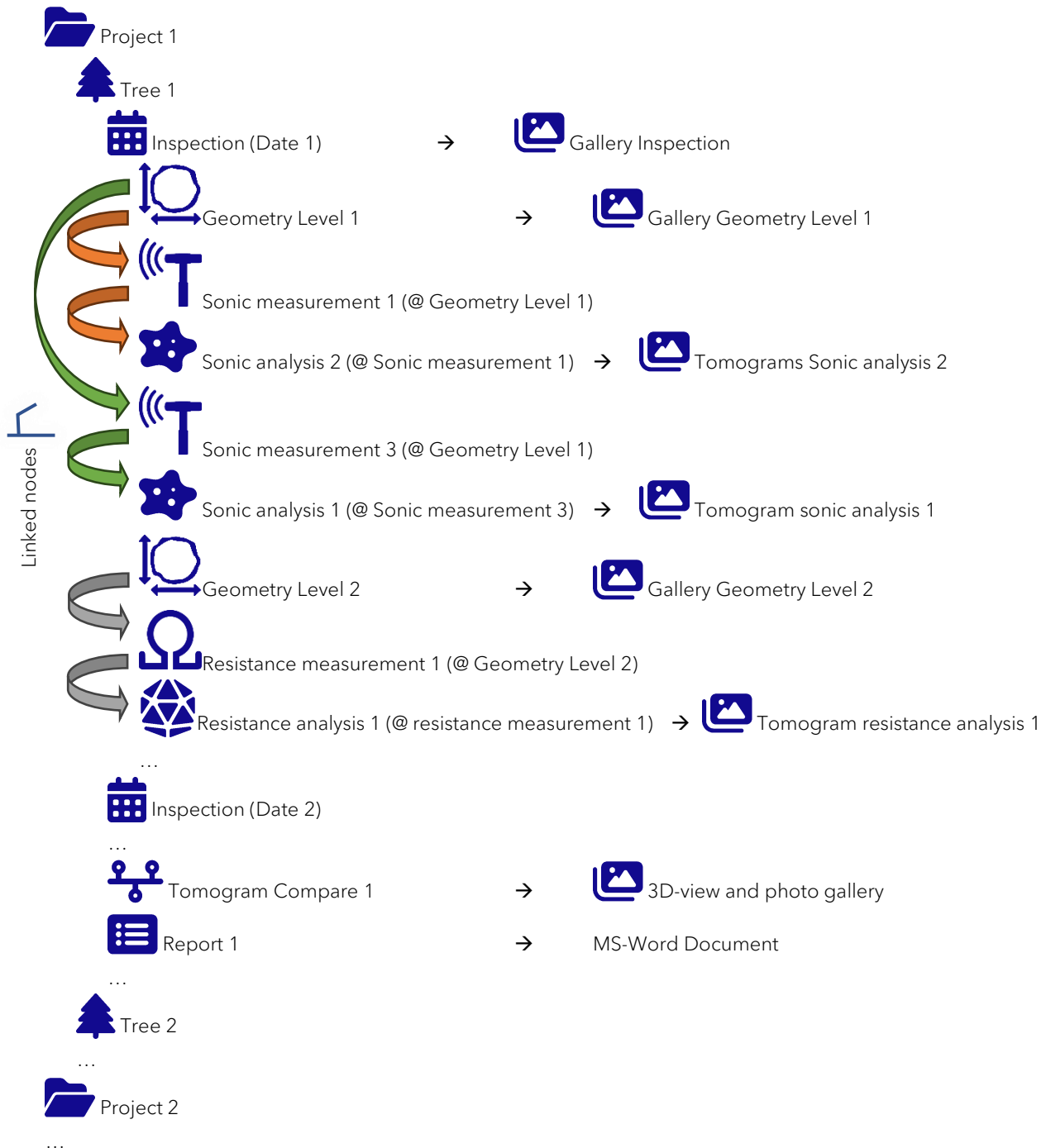
	v max [m/s]	Tap	Tap 1	Tap 2	Tap 3
Tap P 1	1407 (-> MP 3)	3	OK	OK	OK

If the error counters are displayed in orange instead of red, it indicates a warning. Warnings indicate values that are generally valid but atypical. Warnings should be checked for plausibility but do not necessarily need to be corrected.

7. Project Management

7.1 General Project Structure

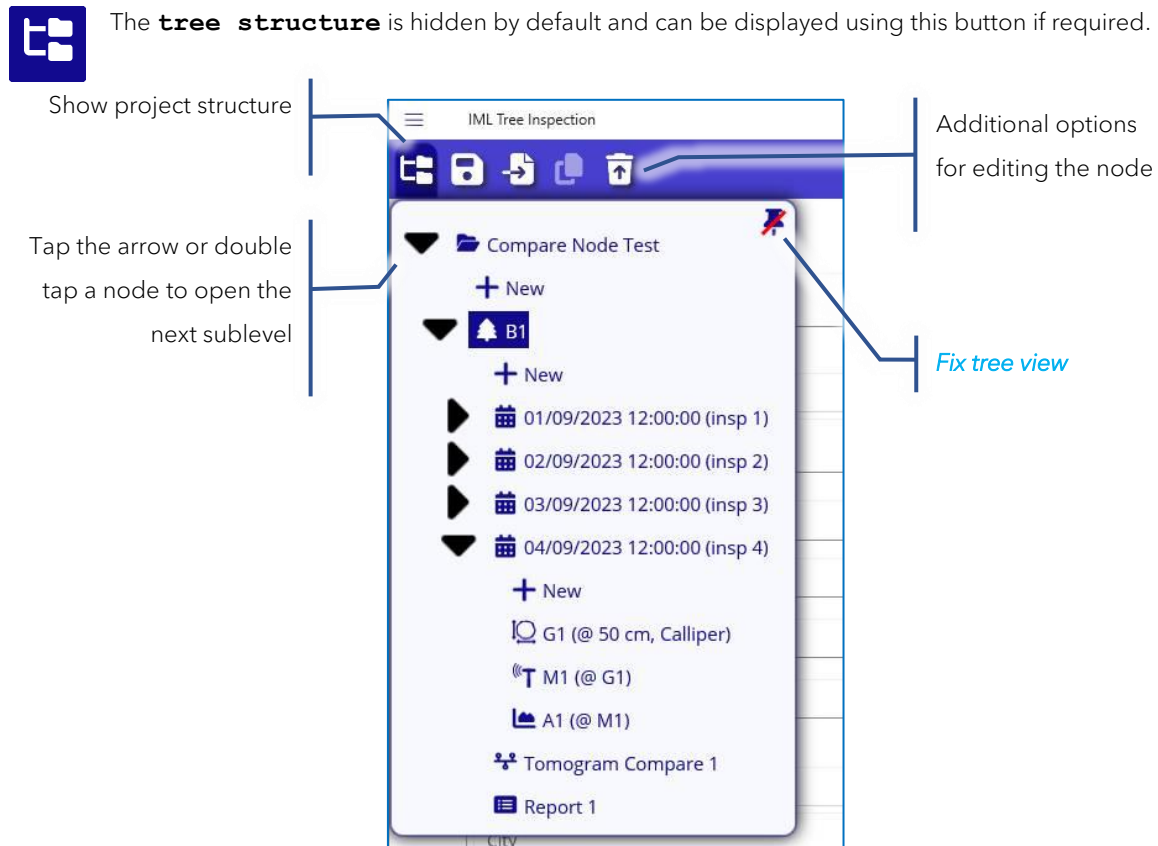
To facilitate the organization of a large amount of data in the typical workflow, there is a predefined organizational structure in which all recorded information is stored. This tree structure is structured as follows:



The function of each node in the tree structure and how they can be created, manipulated, and deleted, will be described in the following chapters.

7.1.1 Navigation in the Project

Between the different nodes in a project, navigation is done in the tree view.



The tree structure can be fixed in the [PC software](#) so that it is always visible.



Individual nodes in the tree structure can be expanded or collapsed using the arrows or by double-clicking on the respective element.

A single click on a node opens it for editing.



The New button can be used to add additional nodes at the selected level.

Further options for editing the nodes are available in the toolbar:



Save: saves the current work progress in the currently open node. *Nodes are also saved automatically when you leave them (either by switching to another node or by leaving the project). However, switching to another tab within a node does NOT save it.*



Import: The Import button opens a file dialog via which *.pit and *.trt files can be added to the project. Ensure that the files to be imported are stored in such a way that they can be accessed. Due to restrictions in file access rights, only certain folders can be accessed on [Android](#) and [iOS](#). For more information, see also [7.4 Importing Old Files on PC](#).



Copy: This function is only available for geometry nodes. A 1:1 copy of the selected geometry node is created. This allows for easy adjustments to the copied geometry without affecting the measurements associated with the original (see also [8.4.9 Subsequent Changes to Geometries](#)).



Delete: To delete a node, first select it and then click this button. Only nodes that are not referenced by other nodes can be deleted.

The elements in the tree structure are sorted according to the following scheme:

- Trees / Tomogram Comparisons / Reports: alphabetically
- Inspections: chronologically
- Geometry Nodes: according to height on the tree
- Sonic Measurement Nodes: sorted under the linked Geometry Node
- Analysis Nodes: sorted under the linked Sonic Measurement Node

If more than one linked node is created, Sonic Measurement and Analysis nodes will be listed in the order they were created in the tree structure.

7.1.2 Project



A project is the top level in the organizational structure. It contains all related data nodes and their connections. When transferring data between devices or the cloud, a complete project is always copied (see also [7.2 Data Storage](#)).

A project includes one or more trees and is usually assigned to a location or a customer. A typical project could be, for example, a park, a street, or a private customer's property.

7.1.2.1 Create Load and Delete Projects

Switch to project management via the main menu first.



In project management, you will see a list of all existing projects. Select and load an existing project by **tapping** on it or **double-clicking** it. You can also open a project through its context menu.

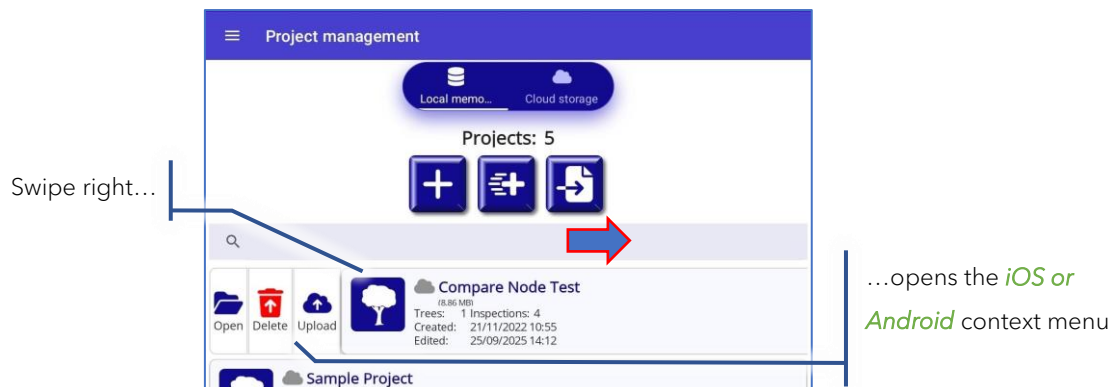


The **New Project** button creates a new, empty project.



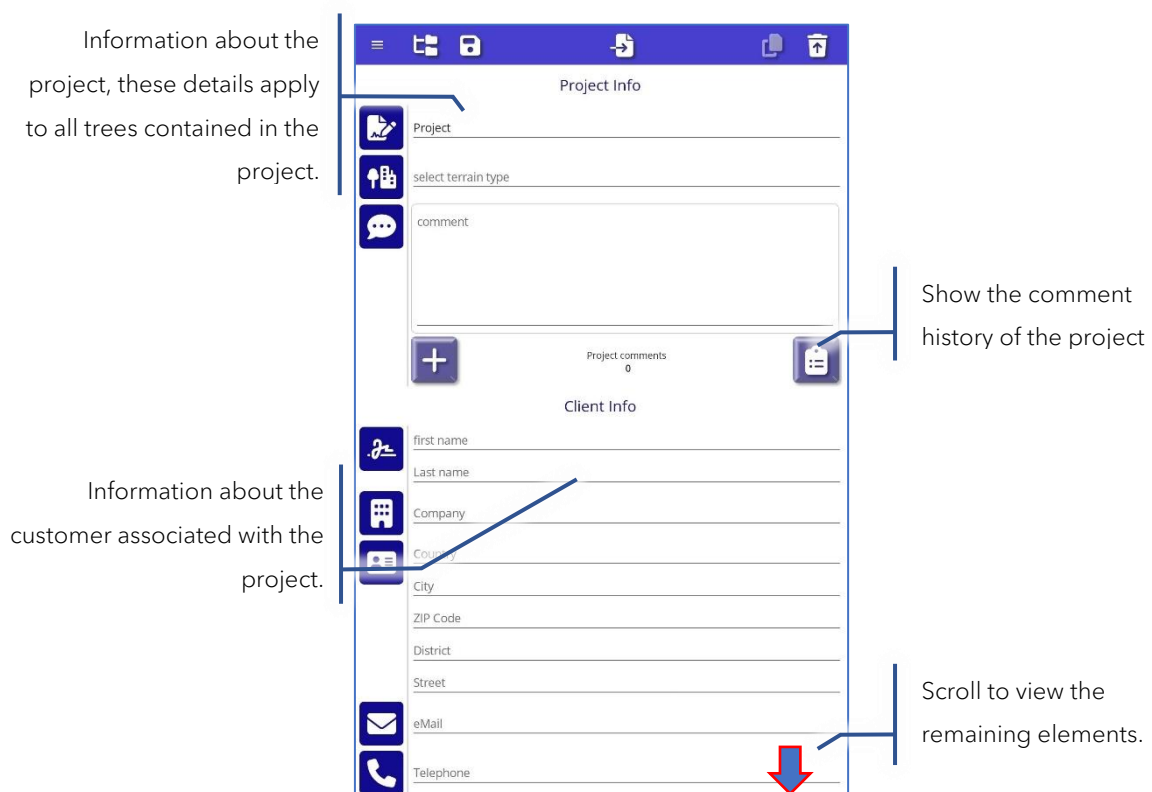
The **Quickstart** button generates a new project with tree, inspection, and geometry nodes already created. You can immediately start with the geometry measurement. The parent nodes (Tree/Inspection) are empty or not filled out. They should still be edited later to document the measurements as completely as possible.

To delete a project, go to the context menu of the respective project and *swipe right (iOS or Android)* or *right click (PC)* and choose the delete option.



7.1.2.2 Entering Project Data

If the project node is selected in the tree view, general data about the project can be entered:



Project name: To facilitate identification, each project can be assigned an individual name (e.g., the name of a park, a street name, or the name of the customer).



Terrain type: Here, you can choose between Lake, Landscape, Suburb, and City, providing a rough classification for average development and expected wind load in the respective region.



Comments: A free-text field where project-specific comments can be entered and saved.



The current comment is logged in the journal with a timestamp.



Displays the journal with the comment history.

Client info: All relevant information associated with the customer linked to the project can be stored in the business card:



First name and **last name**



Company name



address (**country**, **city**, **zip code**, **city district** and **street**)



E-Mail-Address, **phone number** and **mobile number**



Comments: A free-text field for customer-specific comments.

7.1.3 Tree



Each project includes one or more trees. Each tree is assigned its own data node, where all the relevant data for that specific tree is stored.

The position of the tree can be determined using the device's internal **GPS**.

The **Scan Button** automatically reads tree tags

Here: Coordinates in **green** indicate good accuracy.

To find the tree again, you can display the coordinates on a map service.



Tree ID: A free-text field where the tree number is entered. The *Scan Button* accesses the camera to scan tree tags. Both barcodes and QR codes can be scanned. The scan result is interpreted as text and can be edited later. The Tree ID also serves as the name for the data node.



Tree Genus: A selection list where a tree genus is chosen, combined with a free-text field where additional information can be entered if needed. Choose **Other Tree Genus** if you don't find the desired genus in the list.



Position: The tree coordinates (longitude, latitude, and elevation above sea level) can be entered directly, for example, if the coordinates are already known or if a highly precise external GPS system is used.



The **GPS button** determines the current position (see also [4.5 GPS-Coordinates from PST 3 or PTT 3](#))



The achieved accuracy in position determination is color-coded:

- Accuracy better than 10m
- Accuracy better than 30m
- Accuracy better than 100m
- Accuracy worse than 100m
- Error in position determination



The **map** button displays the tree's position in a mapping service, which is helpful for relocating the tree during repeated site visits.



Address type and address: The tree is classified as an **avenue tree**, **city tree**, **forest tree**, **park tree**, or **other**. This classification is helpful, for example, in estimating building density and wind load afterward.

The labels of the following three address fields adapt dynamically to the address type and classification of the tree. However, they are always three free text fields.



Comments: A free-text field where a comment specific to this particular tree is entered.

In the tree node, only information that does not change over time is stored. Details such as tree height, crown shape, and crown diameter can change from inspection to inspection due to both tree growth and external interventions (e.g., pruning branches or storm damage).

7.1.4 Inspection



Each tree is assigned one or more inspections. An inspection represents the condition of the tree at a specific point in time and typically corresponds to an on-site visit for tree assessment.

To create an inspection node, a sub-node is created under a tree node with **New**. The options include **On-Site inspection**, **Report**, and **Tomogram Compare**. Selecting **On-Site inspection** creates a new inspection node.

In the Inspection node, characteristic data for the tree at the time of inspection is entered in the **Data Input** tab:

The screenshot shows the 'Data Input' tab of the application. The form is titled 'Mutable tree data' and contains the following fields:

- Inspector: (Icon of a person)
- Timestamp: (Icon of a calendar) 25/09/2025, 16:29
- Name: (Icon of a document) (optional) name of the inspection
- Crown base height [m]: (Icon of a tree with a vertical line) 5.0 - 1000.0 m
- Crown diameter [m]: (Icon of a tree with a horizontal line) 0.0 m
- Trunk circumference at 130 cm [cm]: (Icon of a tree with a horizontal line) 0.0 - 10000.0 cm
- Age: (Icon of a tree with a horizontal line) VS 0
- TreeSA relevant data: (Icon of a tree with a horizontal line)
- Sphere: (Icon of a sphere) Sphere
- Tree height [m]: (Icon of a tree with a vertical line) 0.0 - 1000.0 m
- Trunks cross diameter at 100 cm [cm]: (Icon of a tree with a horizontal line) 0.0 - 10000.0 cm
- Trunks cross diameter at 100 cm [cm]: (Icon of a tree with a horizontal line) 0.0 - 10000.0 cm

Callouts:

- The **altimeter** can be used to determine tree and crown base height.
- The reference images adjust automatically to the selection

The information is divided into general data and data that will be required later for the TreeSA calculation (see also [8.7.7.1 TreeSA Tab](#)). The general information is as follows:



Inspector: Here, the name and initials of the inspector who created this inspection node are displayed. It is purely for documentation purposes.



Timestamp: The **date** and **time** are automatically recorded upon creation and also serve as the name of the inspection node. The timestamp can be adjusted later if needed.



Name: Optionally, a name can be assigned to the inspection. The name is displayed in the tree view along with the timestamp.



Crown base height: The height of the trunk from ground level to the base of branches and foliage in meters is entered directly or triangulated with the **altimeter** in the **app** (see also [6.1 Altimeter](#))



Crown diameter: The diameter of the crown in meters is entered directly.



Trunk circumference at 130cm: The circumference is measured with a tape measure at a height of 130cm and entered directly.



Age: the age of the tree in years. This is purely for display, the value is calculated from the planting year in the tree node (see [7.1.3 Tree](#)).



Vitality class: As part of assessing the tree's vitality, the vitality class is selected from the Roloff 2016 scale in the dropdown menu. Small pictures corresponding to the selected vitality level are displayed as visual aids.

The information that will later be used for the TreeSA calculation is:



Crown type: The shape of the tree crown is selected from a list. An icon representing the chosen shape is displayed as a visual aid.



Tree Height: The height of the tree from ground level to the tip of the crown in meters. The value can be entered directly. In the *app*, the height can also be triangulated using the *altimeter* (see also [6.1 Altimeter](#)).



Cross diameter: The diameters at a reference height of 100 cm are measured at right angles to each other.



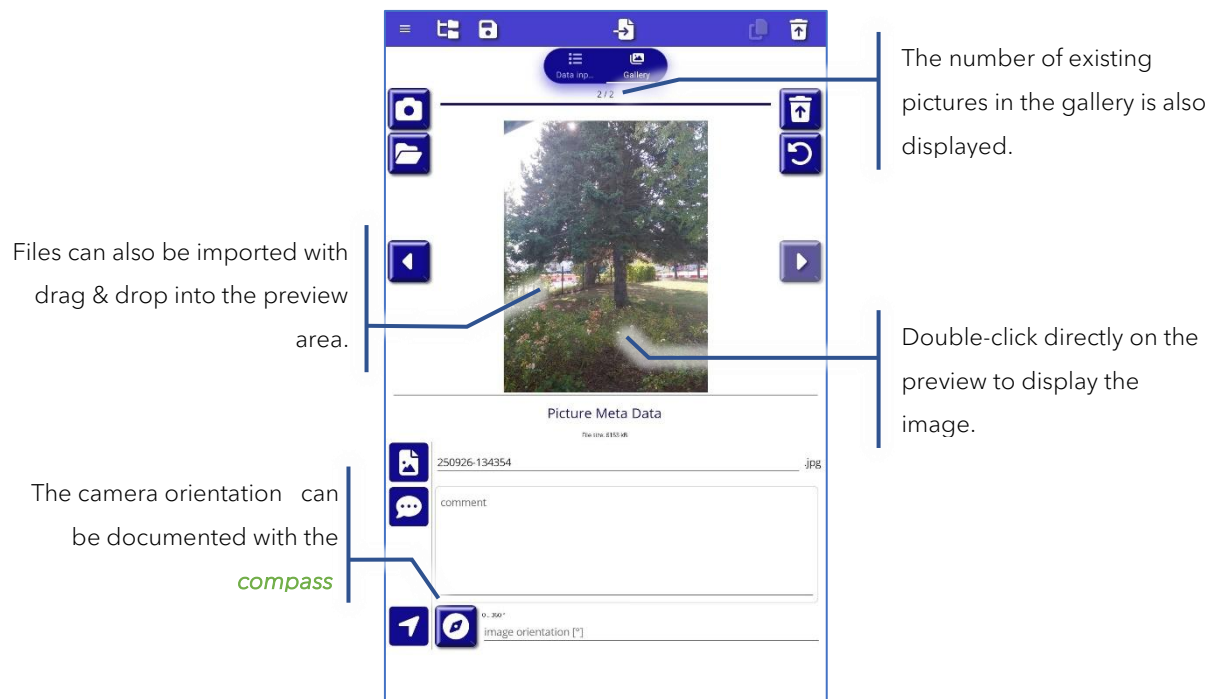
Bark thickness: Specified in cm, this value can be used as a correction parameter to infer the geometry of the heartwood from the outer geometry.

Finally, there are options for general documentation:



Comments: A free-text field where the overall condition of the tree at the time of inspection is described.

Under the **Gallery** tab, photos documenting the condition of the tree are stored.



With the *camera button*, another image can be captured, or



use the folder icon to **add an existing image**. If a *.pdf file is imported instead of an image file (e.g. a report containing drilling measurements exported from the IML Studio software), the *.pdf file is converted page by page into consecutively numbered *.png files, so that it can be integrated into reports later.



The **rotate** button allows you to rotate the image by 90 degrees.



The **trash bin** button allows you to delete the currently selected image.



The displayed, automatically generated **filename** can be edited. The file size is also displayed.



Additionally, each photo has its own comment field where a description of the taken shot can be entered.



With the *compass*, the viewing direction can be documented. This helps later in the analysis to correlate the defects visible in the tomogram with the visible damage in the photo. The north orientation can, of course, also be entered directly.

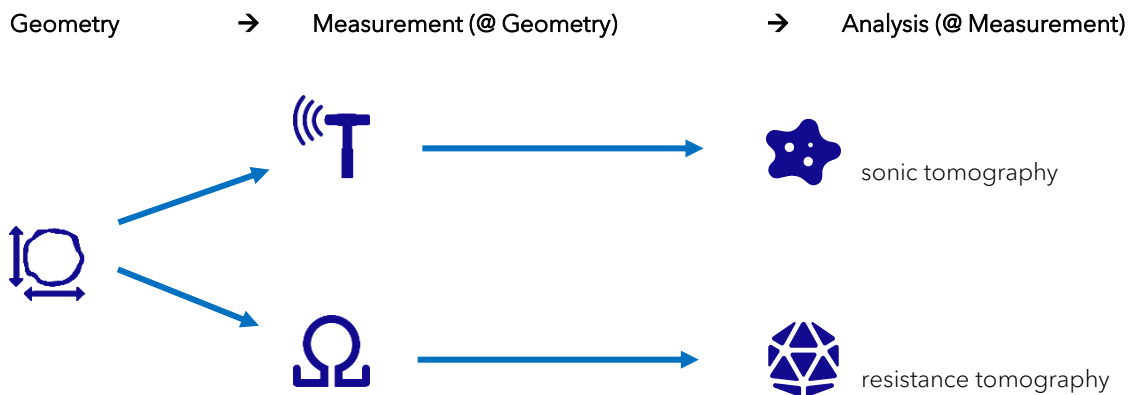
Double clicking the preview opens the currently shown image.



With the arrows, you can switch between the existing images.

7.1.5 Measurement and Analysis Nodes

During each tree inspection, one or more geometry, measurement, and analysis nodes are created under the respective inspection node. The typical workflow is as follows:



Each of these three points receives its own data node. *The nodes are interconnected*, where a measured geometry is a prerequisite for conducting a measurement, and a measurement is a prerequisite for an analysis.

7.1.5.1 Geometry Node

In the Geometry node, the tree geometry is measured in the measurement plane. If the tree is measured in multiple planes, a separate Geometry node must be created for each plane. At least one geometry is mandatory to perform a sonic measurement.

When creating a new Geometry node, the following information is initially expected:



Node type: Geometry, Sonic Measurement, Sonic Analysis Electrical Resistance Measurement or Electrical Resistance Analysis (here, always Geometry)



Geometry name: The display name in the project's tree structure is also used to reference this geometry from the Measurement node.



Geometry type: You can choose between regular (Circle, Ellipse) and irregular geometry (Calliper). The geometry type is always displayed along with the geometry name in the project's tree structure.



After the basic inputs are made, the new Geometry node is created with the **Save** button.

A detailed explanation of the Geometry Measurement node and the procedure for measuring tree geometry can be found under [8.4 Recording Tree Geometry - Geometry Node](#).

7.1.5.2 Sonic Measurement Node

In the Sonic Measurement node, sonic measurements are carried out in a measurement plane using the PiCUS sonic tomograph. At least one sonic measurement is required to perform the tomogram calculation in the Analysis node.

When creating a new Sonic Measurement node, only two pieces of information are initially required besides the node type:



Node type: Geometry, Sonic Measurement, Sonic Analysis Electrical Resistance Measurement or Electrical Resistance Analysis (here, always Sonic Measurement)



Measurement Name: The user-chosen name is displayed in the project's tree structure and referenced by the Sonic Analysis node.



Select Geometry: A geometry plane must be chosen for the sonic measurement. This selection menu displays all geometries contained in the inspection node. Geometries located in other inspection nodes, tree nodes, or projects are not available for selection. It is possible to choose the same geometry for multiple sonic measurements.



After the basic inputs are made, the new Sonic Measurement node is created with the **Save** button.

A detailed description of conducting sonic measurements can be found under [8.5 Performing a Sonic Measurement - Sonic Measurement Node](#).

7.1.5.3 Sonic Analysis Node

Sonic Analysis nodes display and evaluate the data from a sonic measurement, both in tabular form and in a tomogram. A variety of tools are available for data analysis (crack detection, determination of residual wall thickness, plausibility checks for measurement data, and more).

When creating a sonic analysis node, as with the sonic measurement node, initially only 2 pieces of information are required, in addition to the node type:



Node type: Geometry, Sonic Measurement, Sonic Analysis Electrical Resistance Measurement or Electrical Resistance Analysis (here, always Sonic Analysis)



Measurement name: The freely chosen name is displayed both in the project's tree structure and is referenced by the Tomogram Comparison node.



Select Sonic Measurement: A Sonic measurement must be selected, and its values will be used for tomogram calculation. This selection menu displays all Sonic measurements contained in the Inspection node. Sonic measurements from other Inspection nodes, Tree nodes, or projects will not be available for selection. It is possible to select the same Sonic measurement in multiple Sonic analyses.



After the basic inputs are made, the new Sonic Analysis node can be created using the **Save** button. A detailed description of the Sonic Analysis node can be found under [8.7 Tomogram Evaluation and Interpretation - Sonic Analysis Node](#).

7.1.5.4 Electrical Resistance Measurement Node

In the Resistance Measurement node, electrical resistance measurements are carried out in a measurement plane using the PiCUS TreeTronic. At least one resistance measurement is required to perform the tomogram calculation in the Analysis node.

When creating a new Resistance Measurement node, only two pieces of information are initially required besides the node type:



Node type: Geometry, Sonic Measurement, Sonic Analysis Electrical Resistance Measurement or Electrical Resistance Analysis (here, always Electrical Resistance Measurement)



Measurement Name: The user-chosen name is displayed in the project's tree structure and referenced by the Electrical Resistance Analysis node.



Select Geometry: A geometry plane must be chosen for the electrical resistance measurement. This selection menu displays all geometries contained in the inspection node. Geometries located in other inspection nodes, tree nodes, or projects are not available for selection. It is possible to choose the same geometry for multiple electrical resistance measurements.



After the basic inputs are made, the new Electrical Resistance Measurement node is created with the **Save** button.

A detailed description of conducting electrical resistance measurements can be found under [8.6 Electrical Resistance Measurement - The Resistance Measurement Node](#).

7.1.5.5 Electrical Resistance Analysis Node

Electrical Resistance Analysis nodes display and evaluate the data from an electrical resistance measurement as a tomogram. A variety of tools are available for data analysis (measurement tools, determination of residual wall thickness and more).

When creating an Electrical Resistance Analysis node, as with the Electrical Resistance measurement node, initially only 2 pieces of information are required, in addition to the node type:



Node type: Geometry, Sonic Measurement, Sonic Analysis Electrical Resistance Measurement or Electrical Resistance Analysis (here, always Electrical Resistance Analysis)



Measurement name: The freely chosen name is displayed both in the project's tree structure and is referenced by the Tomogram Comparison node.



Select Electrical Resistance Measurement: An electrical resistance measurement must be selected, and its values will be used for tomogram calculation. This selection menu displays all Electrical Resistance measurements contained in the Inspection node. Electrical Resistance measurements from other Inspection nodes, Tree nodes, or projects will not be available for selection. It is possible to select the same Electrical Resistance measurement in multiple Electrical Resistance analyses.



After the basic inputs are made, the new Electrical Resistance Analysis node can be created using the **Save** button. A detailed description of the Electrical Resistance Analysis node can be found under [8.7 Tomogram Evaluation and Interpretation – Sonic Analysis Node](#).

7.1.6 Tomogram Compare Node



For each tree, tomogram comparisons can be created. In a tomogram comparison, multiple analyses are linked together to allow for a direct comparison. This allows, for example, the visualisation of slow changes over periods of several years, a comparison over multiple inspections.

In principle, it is also possible to compare multiple Sonic Analyses from just one Inspection Node, for example, to compare different calculation methods or to display multiple measurement planes simultaneously.



To create a new Tomogram Comparison Node, select the **Tomogram Compare** option for the node type under a Tree Node with **New**. The only necessary information here initially is:



The **name of the Tomogram Compare node:** this name is displayed for the node in the project's tree structure.

A detailed description of the comparison options available in the Tomogram Comparison Node can be found under [8.9 Timelines and 3D View - Tomogram Comparison Node](#).

7.1.7 Reports



For each tree, reports can be created that summarize the results from one or more inspection nodes. In a report, a conclusion about the conducted tree examination can be presented along with tomograms, accompanying photos, business cards of the involved experts, and other information, all consolidated into a single document.

The resulting document itself is a Microsoft Word .docx file and is therefore easily further processable.



To create a new Report node, select the **Report** option for the node type under a tree node with **New**.



Report Name: This name will be displayed in the project's tree structure. It is also used as the name for the folder and the generated Microsoft Word .docx file.

Comprehensive information about the Report node can be found under

[8.10 Generating Reports - Report Node.](#)

7.2 Data Storage

The entire data storage in a project is organized in a multi-tiered folder structure, which is analogous to the project itself. The folder names are identical to project and node names. For the project folder, a timestamp is additionally appended to the folder name. File management is largely automated, making direct access from outside not advisable.

To ensure compatibility across all possible platforms, the lengths of folder/node names are limited (50 characters for the project name and 20 characters for all other nodes). Keep the path length of the working directory as short as possible so that the maximum permitted path length is not exceeded.

The data itself is not stored in a human-readable format. It is strongly discouraged to manually edit, move, or rename the files. Files often reference other files, and changes can corrupt the entire project and make it unreadable.

The only files that are directly viewable are the images and reports stored in each data node. In the folder of each data node, the image files can be found in a subfolder named **Images**. The reports are saved as Microsoft Word .docx files in a subfolder specific to each tree. This folder has the same name as the respective Report node.

Creating and editing projects always happens locally. Cloud storage can be used to transfer projects between devices or to utilize additional storage space. Alternatively, projects can be manually transferred between a PC and a mobile phone via a USB connection.

7.2.1 Data Transfer via Cloud

The project management section is divided into two areas:

Local Storage: All projects that are stored on the device. All newly created projects are initially local.



New Project creates an empty project



Quickstart creates a project in which the project structure has already been created up to the first geometry node.



Import creates a project based on a .pit or .trt file (old file format or stand-alone measurement, see also [7.4 Importing Old Files on PC](#)).

Cloud storage: all online-stored projects in your personal IML Cloud.



The **Refresh** button synchronizes the project overview with the current cloud state, but the projects themselves are *not* downloaded.

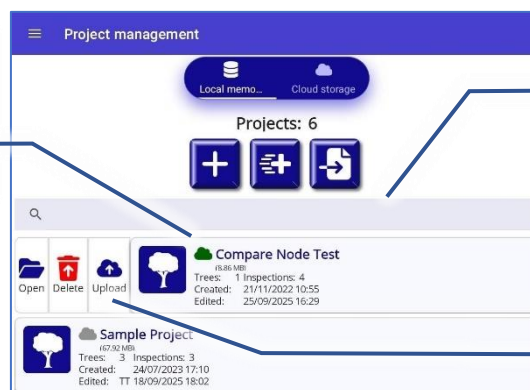


Download the sample project (see also [7.3 Sample Project](#))

Data stored in the cloud must always be downloaded before it can be edited.

To transfer files between the cloud and local storage, first open the project management. Open the context menu of the project you want to upload. In the context menu, select the option **Upload** or **Download**. The entire project will then be transferred to the respective storage location.

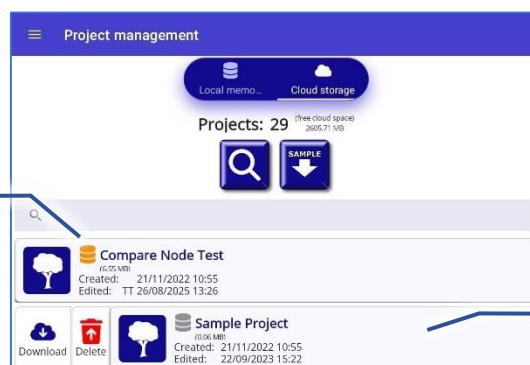
The project also exists in the cloud, and the local project is more up to date.



Individual projects can be found via the search bar.

Projects are copied between local and cloud storage via the context menu.

The project also exists locally, and the project in the cloud is less up to date.



Swipe right or right click to show the context menu

For traceability of the editing, in the project list, in addition to the name, the creation date and the last edit date are displayed. Additionally, a small icon indicates the synchronization status between local and cloud storage.



There is also a local copy of the cloud project



There is also a copy of the local project in the cloud

The colour of the icons indicates which project is more recent:

- **Green**: This project is more recent than the copy in the other storage.
- **Orange**: This project is less recent than the copy in the other storage.
- **Blue**: Both projects are identical.
- **No icon**: The project does not exist in the other storage.

Multiple projects with identical names can exist. Internally, these are differentiated by considering the creation date (which is automatically appended to the project folder name).

If a project already present in the other storage is copied again, only the files that are not identical are updated. The modification date is not taken into account. Therefore, it is theoretically possible for an older project version to overwrite a newer one uploaded by another user.

To keep data as consistent as possible, follow these steps:

- If the cloud project is more recent, always create a copy in local storage first.
- Edit the project locally.
- Upload the local project ***immediately*** after editing.

7.2.2 Data Transfer via USB / Project File Paths

As a backup to the IML Cloud, data between a *mobile device* and a *PC* can also be transferred directly via a USB connection. For the transfer of a project, the complete project folder (including all subfolders) must always be copied.

At the *PC*, the project storage path is freely selectable (see also [4.4.1 Configuration](#)).

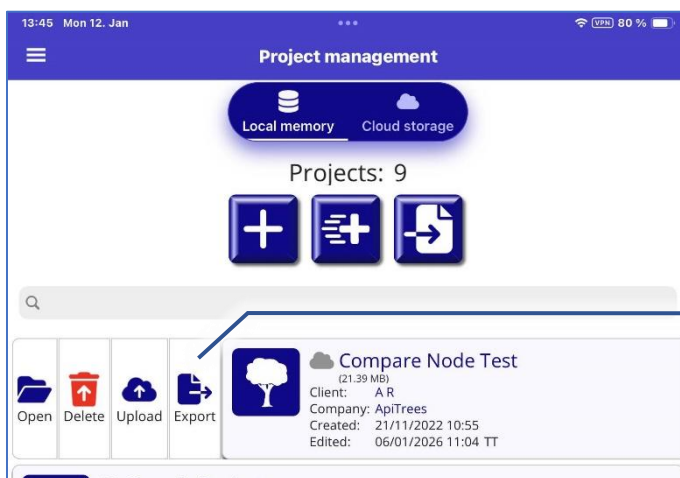
On *Android* systems, you can find the local storage path in the Settings menu under the Configuration tab. With an existing USB connection, you can navigate through the entire folder structure on *Android* devices using the *PC's file browser*. This is not possible directly on the mobile device since the project data is located in the app's protected sandbox area.



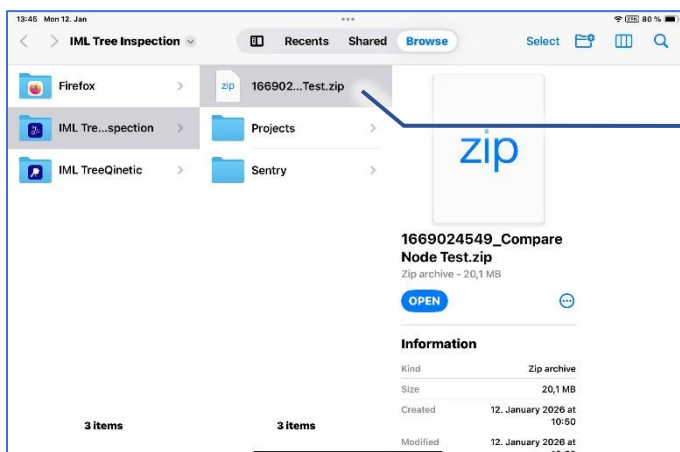
Through a *PC* connected via *USB*, access can be gained to this folder on an *Android* device.

Unlike *Android* with a *PC*, the *MAC* file browser cannot navigate deeper into the folder structure of an *iOS* mobile device.

Projects cannot therefore be transferred to a mobile device with *iOS* via USB. Only the reverse is possible, by first packing the project as a ZIP file and then transferring it.



On *iOS*, individual projects can be packed directly in local project management as a ZIP file via **Export**.



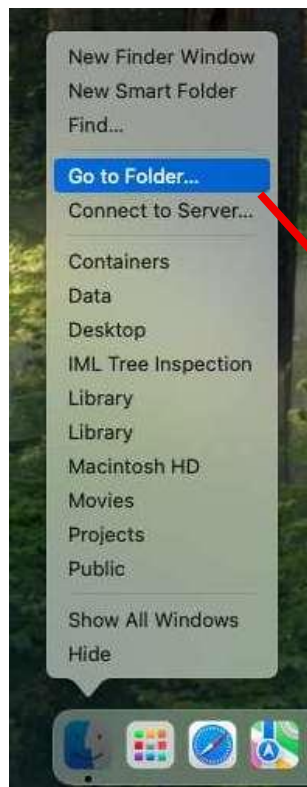
The ZIP files created in this way can be found directly in the root directory of the **IML Tree Inspection** App.

If the iOS mobile device is now connected to a MAC, the packed project can be copied.



After copying and unpacking, reports or photos, for example, can then be accessed within the project folder structure.

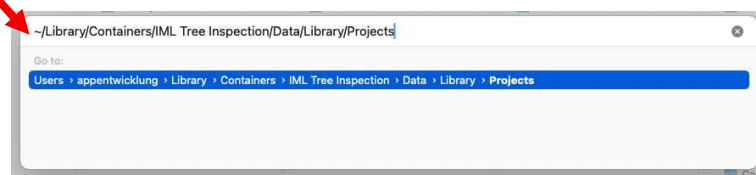
On a Mac, you cannot access the project storage path directly, as the app's sandbox folder is usually hidden. To access the project files anyway, proceed as follows:



In the **Finder** app's context menu, select **Go to Folder**

Enter the following path here:

**/Users/<User>/Library/Containers/
IML Tree Inspection/Data/Library/**



The first Library folder is a hidden folder that is not normally displayed.

The IML Tree Inspection folder is a virtual folder whose name may be replaced by a HASH value via autocomplete.

Within the project directory, the subfolders are then organised according to the familiar structure (see [Z.1 General Project Structure](#))

7.3 Sample Project

The tree inspection with PiCUS measuring devices is a very complex field. Correct application of measurement technology and interpretation of measurement results requires not only expertise but also experience. For individual users, acquiring this knowledge and experience can be very challenging. The downloadable **Sample Project** is our attempt to make our accumulated wealth of experience from the tree surveyor community available to everyone in the future.

Our goal is to continuously expand the sample project with interesting case studies. To achieve this, we also rely on your assistance.

To contribute, users can voluntarily provide interesting case studies and scenarios that are extensively documented for integration into the sample project. IML Electronic will process, anonymize if necessary, and incorporate these measurements into the sample project.

Contact us at contact@iml-electronic.de if you would like to contribute.

Once the sample project has been downloaded, it can be edited like any other project. When the sample project is uploaded back to the cloud, it will always be stored, along with any changes you have made, in your personal IML Cloud.

7.4 Importing Old Files on PC

Measurement files in *.pit or *.trt file format that were created with older versions of the PiCUS PC software (Q74 or older) or during stand-alone measurements cannot be loaded directly. To be able to use these files in the future, the IML Tree Inspection Software has an import function that reads the old *.pit and *.trt files and automatically integrates the information they contain into the project structure (see also [7.1.1 Navigation in the Project](#)).

The names of the nodes created are initially determined based on the file to be imported. They can be edited later.

*During import, all required nodes are automatically created below the currently selected node. For example, when a project node is selected, tree and inspection nodes as well as geometry and measurement nodes are created, while when an inspection node is selected, only geometry and measurement nodes are created. **Make sure to import the files to the correct location within the project structure from the outset, as it is not possible to move them later (e.g., from one inspection node to another).***

*The amount of information in the old *.pit and *.trt files is less than that in the new project structure. Systematically go through all automatically generated nodes and complete any missing information in input fields that could not be filled in during import or add documentation photos to the galleries.*

PiCUS TreeTronic 1/2 Measurements cannot be imported due to a difference in the used data structures.

7.4.1 Comparability of Tomograms

The calculation of tomograms involves numerous mathematical operations applied to a large amount of data. With each new software version, these calculation algorithms are further optimized.

More efficient programming languages with new features, as well as optional calculation settings that have been expanded, summarized, replaced, or integrated by default, have a significant impact on the appearance of tomograms.

As a result, when importing old data and recalculating tomograms, differences may arise.

If the appearance of the newly calculated tomograms changes significantly, please thoroughly check the calculation settings in the old and new software. Also, ensure that manually sorted measurement values in data validation are treated the same way in both old and new software.

If significant differences still occur between old and new software, please contact us at contact@iml-electronic.de.

7.5 Transfer of Stand-Alone Measurements

The PiCUS tomographs are in principle capable of carrying out measurements without PC software or the app. Since the options for calculating tomograms are very limited in the PST 3 and not available at all in the PTT 3, it is almost always necessary to **transfer the stand-alone measurement data from the device to the PC**.

The transfer of measurement data is not possible on all platforms, because USB or Bluetooth Classic are required to do so.

The measurement files created by the PST 3 are initially in the old *.pit or *.trt file format.

The measurement data is therefore transferred in two steps:

- Downloading and saving the *.pit or *.trt files
- Importing the *.pit or *.trt files into a new project (see [7.4 Importing Old Files on PC](#))

The measurement data is downloaded under **Settings → Devices**.

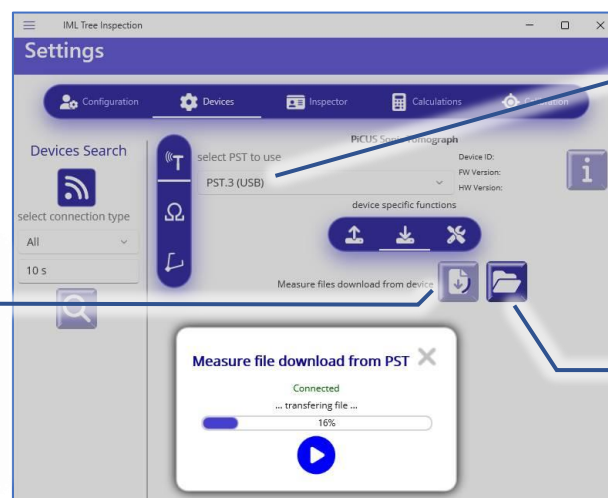
Either **USB** or **Bluetooth Classic** must be selected as connection method.

When the tomograph is switched on, the menu **Data connections → to PC** must be selected.



The **download** can then be started under the device-specific functions.

The download button automatically establishes a connection to the device



Choose either **Bluetooth Classic** or **USB**

The target directory can be opened here



Open folder: Opens the storage location of the downloaded files. A subfolder is created in the project directory for each tomograph type as the storage location:

- *.pit files: ~Project directory\PSTDownload
- *.trt files: ~Project directory\PTTDownload

The downloaded stand-alone measurement files can be moved without any problems, as they are not accessed directly within the project structure, but only once via the import function.

7.6 Updating the Devices Tree Species List

The list of tree species stored in the device is limited to 27 (PST 3) or 10 (PTT 3) entries due to the limited storage space in the device. This list can be edited and adapted to individual needs using the software.

The tree species list cannot be uploaded on all platforms, as this requires USB or Bluetooth Classic.

- In the device, navigate to the **Data connections → to PC** menu.
- In the PC software, navigate to **Settings → Devices**.
- As connection type either **USB** or **Bluetooth Classic** must be selected.



Under **device specific functions** the list can be edited.

Connection type must be either **USB** or **Bluetooth Classic**

The tree species list can be edited in the **upload** section

Only show selected elements

Searching for specific tree species can be done via the search field

Deselect all elements

The number of already selected tree species is shown here

Confirm or cancel all changes to the list



Upload list writes the selection made to the memory of the connected tomograph.

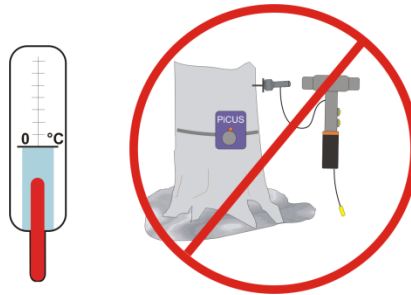
8. Conducting an Inspection

8.1 Measurement and General Conditions

Before conducting the sonic measurement, ensure all batteries (laptop, tablet or mobile phone, PiCUS Sonic Tomograph (PST 3), PiCUS Calliper (PCA 3), PiCUS Radio Hammer with Display (PRHD)) are charged!

Caution

Wood properties depend on various factors, and an important factor is temperature. If the temperature falls below 0°C (32°F, 273K) for an extended period, wood properties can change significantly. Therefore, sonic or resistance measurements cannot be conducted during or immediately after prolonged periods of frost.



Spread of Diseases through Nails?

It is theoretically possible to transmit diseases (such as Massaria) from tree to tree through nails. Therefore, it is essential to disinfect the nails after a measurement or use them only once. Various methods of disinfection include:

- *Temperature of $\geq 150^{\circ}\text{C}$ for at least 15 minutes.*
- *High-percentage alcohol for several hours.*
- *Use of disinfectants for tree care tools (according to the instructions).*
- *Boiling water for at least 15 minutes.*

8.2 Procedure of a Measurement

A PiCUS Sonic or Resistance measurement essentially consists of the following six steps, which are described in this chapter:

1. Definition of measurement plane and the number and position of measurement points.
2. Determination of the tree's geometry in the measurement plane.
3. Attachment of measurement devices to the tree.
4. Conducting Sonic or Resistance measurement.
5. Tomogram calculation and interpretation.
6. Dismantling the device and removing the nails – only after tomogram evaluation!

This chapter describes each step in detail.

8.3 Defining Measurement Plane, Number, and Position of Measurement Points

8.3.1 General Notes

The PiCUS measurement method distinguishes between different types of points. Every nail in the tree is a Tree Point (TP). When a PiCUS Sonic sensor is attached to the nail, it becomes a Sensor Point (SP). Therefore, every SP is always also a TP. However, a TP doesn't have to be a SP at all times. The number of SPs is limited by the hardware to a maximum of 6 with one sensor chain or a maximum of 12 with two sensor chains. The number of TPs can be significantly larger. The nail that is currently being actively tapped on, the "transmitter", is called the Tapping Point (TapP). If the sonic signals generated at a TapP are recorded at an SP, then an SP/TP becomes a Measurement Point (MP), a point for which measurement data exist, the "receiver".

The size and shape of the measurement plane determine the number and position of TPs. It typically ranges between 8 and 30. In rare cases, 50 or more TPs may be necessary. The number of TPs should not be less than 8. Recommended are at least 12 TP.

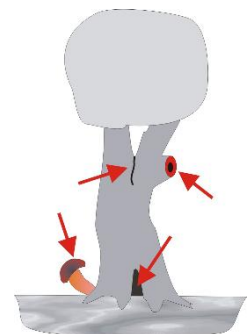
The theoretical minimum is 4 TPs. However, with fewer than 8 TPs, the achievable accuracy and spatial resolution decrease significantly, both in mapping the tree geometry and in tomogram calculation.

As part of the measurement preparation, the following decisions need to be made:

- Determining the measurement plane
- Deciding on the number of TPs
- Determining the position of the TPs

Note: *The determination of the measurement plane and the position of the measurement points have a crucial impact on the quality of the tomogram.*

To determine the measurement plane, the tree should be carefully examined for external signs of defects or diseases. Fruiting bodies of fungi on the tree or in the vicinity, cracks, hollow spaces, foliage condition, etc., are indications of defects in the tree. Depending on these observations, the measurement plane and position of the TP should be selected. Many diseases require the use of the device directly above ground level! For example, the fungus *Kretzschmaria deusta* is much more easily recognizable at the base of the trunk than at a height of 130 cm.



The TP should be placed primarily according to the requirements and observations on the trunk. In addition, attention should be paid to approximately uniform distances between TP.

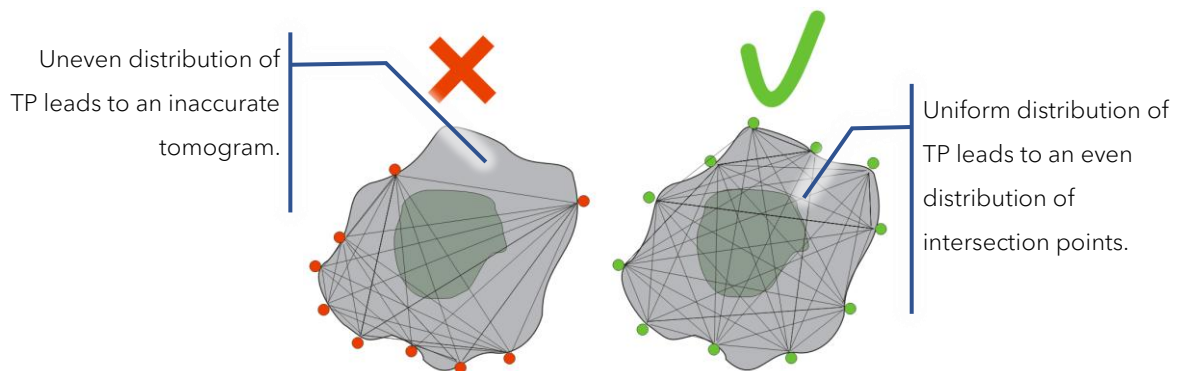
The maximum distance between TP: ≈ 45 cm (length of the sensor chains)

The minimum distance between TP: $\approx 12-15$ cm.

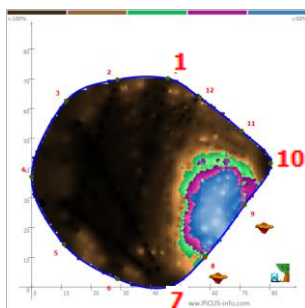
8.3.2 Tree Point Positions for Sonic Tomography - Attaching the Nails

Observance of the guidelines for the placement of the TP/MP is an important prerequisite for good sonic tomograms. Only through correct placement of the measurement points can the necessary information for assessing the remaining wall thickness (structural integrity) of the trunk be obtained for tree assessments.

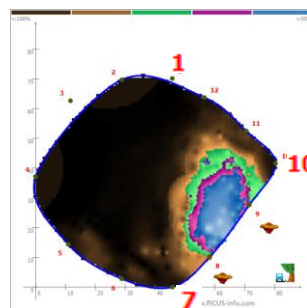
In general, efforts should be made to maintain an even spacing between measurement points. This ensures that the intersection points necessary for the calculation are evenly distributed, and the tomogram is accurately computed.



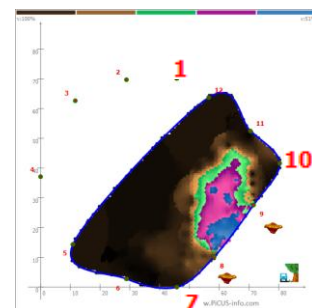
Even in cases where damage is present on only one side of the tree, it is important to place TP in the intact areas of the tree as well. The following example shows a tomogram of an oak tree with a fungal infection. In the variations, sensors on the healthy side of the trunk were disabled for calculation. It can be observed that the depiction of the damage also changes if too many MP are missing on the opposite side.



All TP



without TP 1, 3



Without TP 1, 2, 3, 4

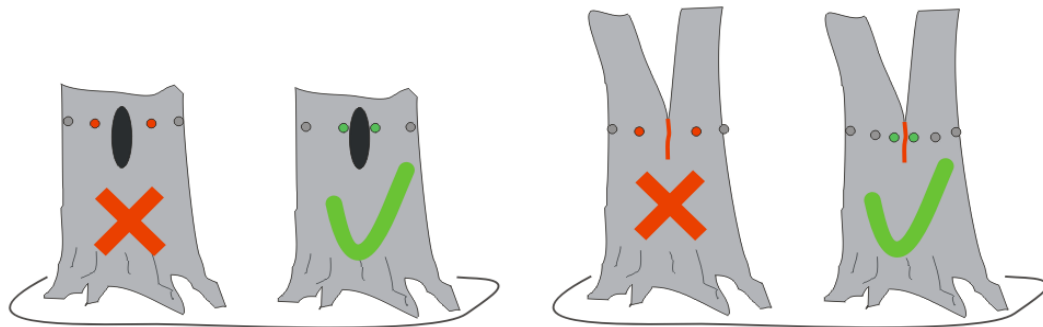


Note: TP 7 and 10 were placed in healthy wood close to the defect to capture the defect well.

The TP distance should be approximately 15 to 40 cm. In any case, a minimum of eight BPs must be used, which can lead to smaller TP distances in the case of small trees.

Caution: *The smaller the TP distance, the greater the risk of generating calculation errors due to errors in geometry recording and measurement.*

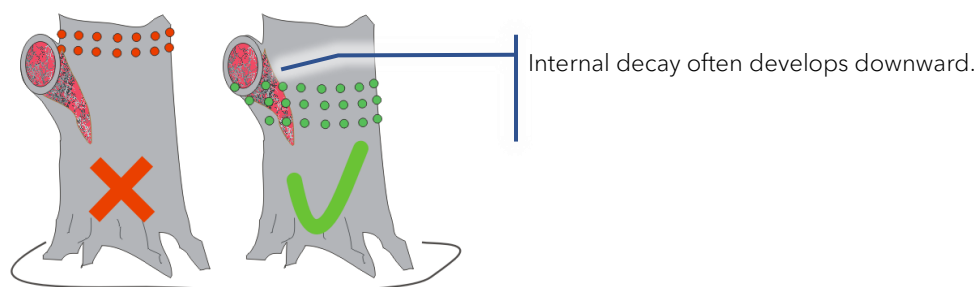
To more accurately determine the size of a defect (or the size of the load-bearing wood), it may be necessary to deviate from the above rule. For example, TPs can be placed close to defects such as cracks or open cavities to increase imaging accuracy, even if the TP distance becomes very small.



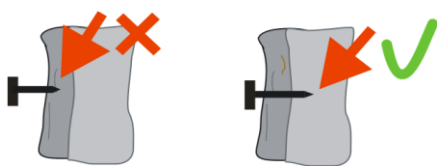
TP can be placed in areas with decay. However, there is a risk of strongly influencing the color scale of the tomogram due to very poor measurement values. In this case, for the calculation, the TP in defective areas must be turned off as either receivers, transmitters, or completely.

In case of doubt, always place a TP in questionable areas. This TP can be easily ignored during the tomogram analysis if the measurement values are incorrect.

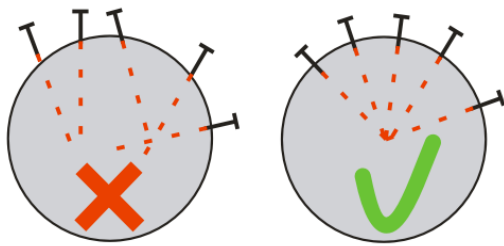
Measurement plane for branch wounds: Since decay in branch wounds typically develops downward, tomography measurements should be conducted below the wound in most cases.



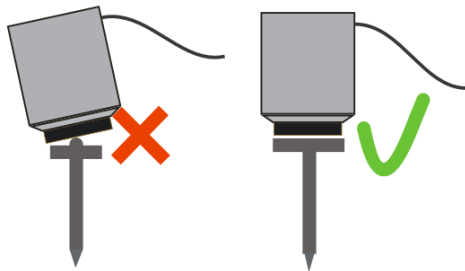
Nails must penetrate through the **bark** into the sapwood! Check the thickness of the bark if necessary. The bark represents an acoustically dead area that the nails must overcome.



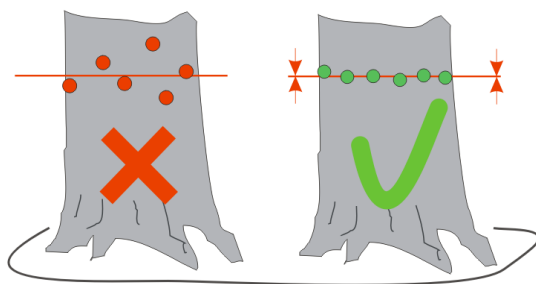
Drive the nails in such a way that they point **towards the center** of the trunk.



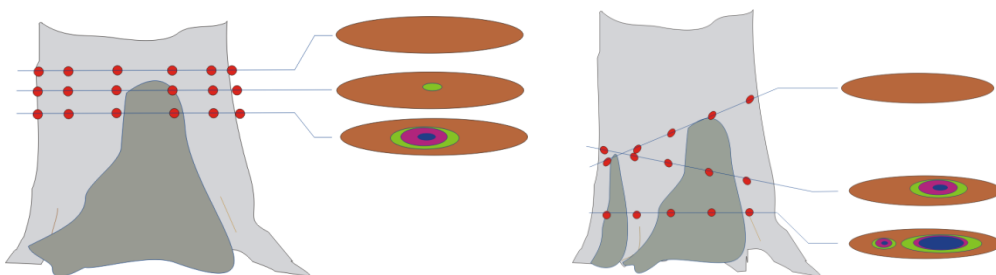
The magnet must fit well on the **nail head**.



Install nails in a **single plane**

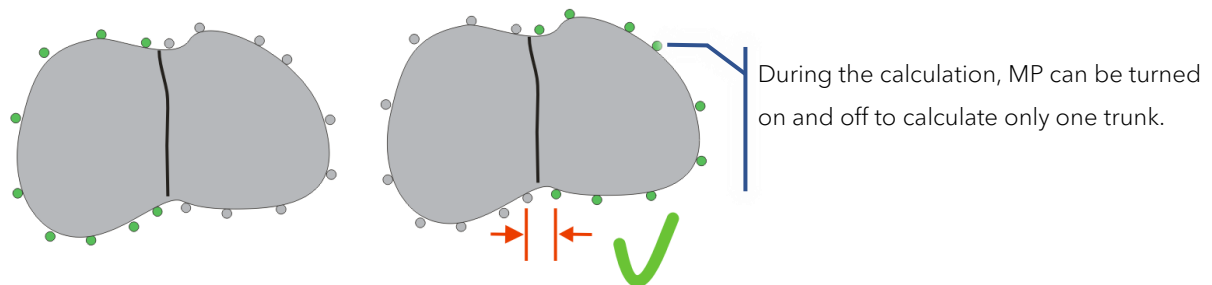


When attaching the nails in **oblique planes** to capture a larger area of the tree, consider the cases depicted in the sketch.



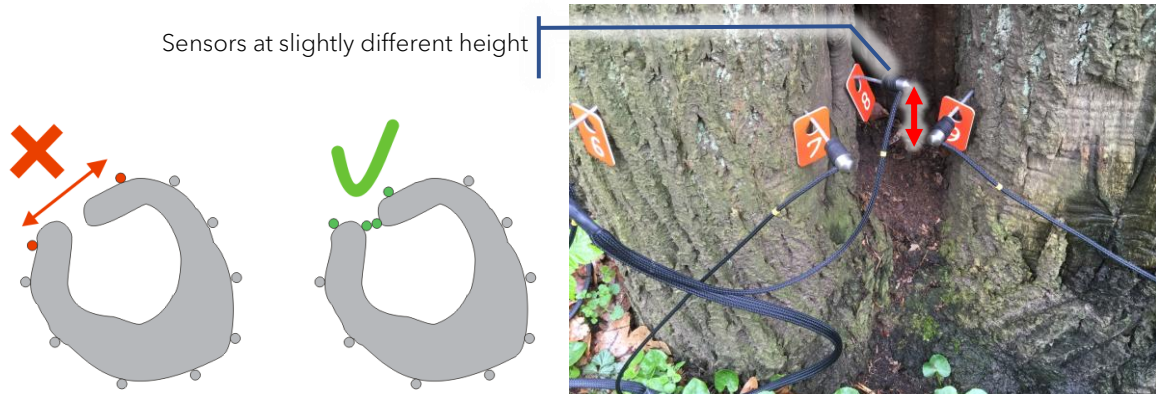
At **co-dominant stems**, tomography measurements can be performed in one step. If necessary, the trunks may need to be calculated individually. TP can be placed closely at the presumed separation point. There is often bark between the trunks, which affects the measurement due to its poor sound transmission properties. By individually calculating each part of the trunk, the influence of the bark on the measurement can be estimated.

Caution: In not every case, the actual position of the separation point is clearly visible!

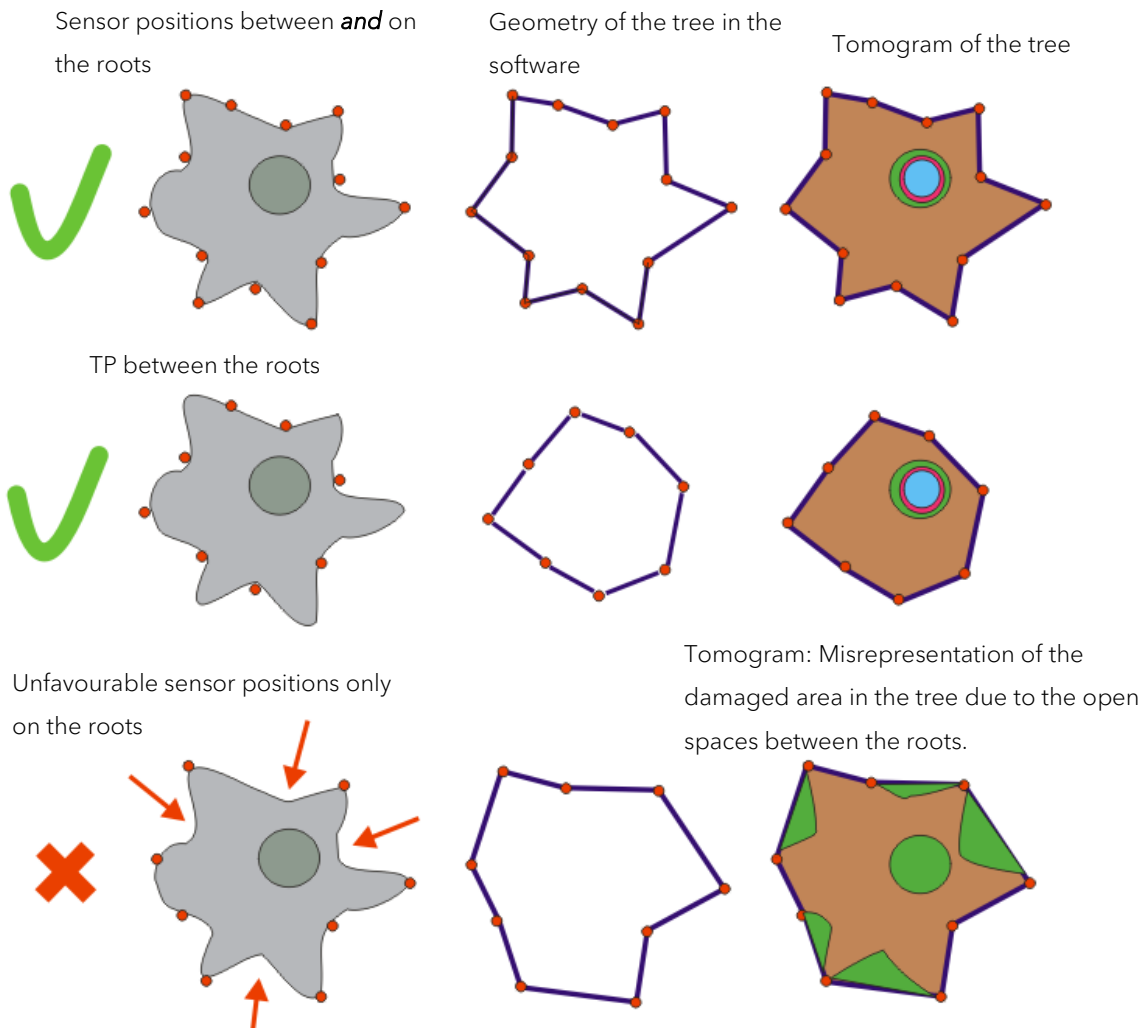


TP positioning at cavities. Do not place sensors inside the cavity. Place TP at the outermost points around the cavity to measure the quality of the encasement.

Tip: Since the sensor distance, as shown in the example photo, may be very small, the nails on the left and right of the gap can be set at different heights (to obtain necessary clearance space around the nail/sensor). This avoids disturbing the neighbouring sensors with the hammer when tapping.



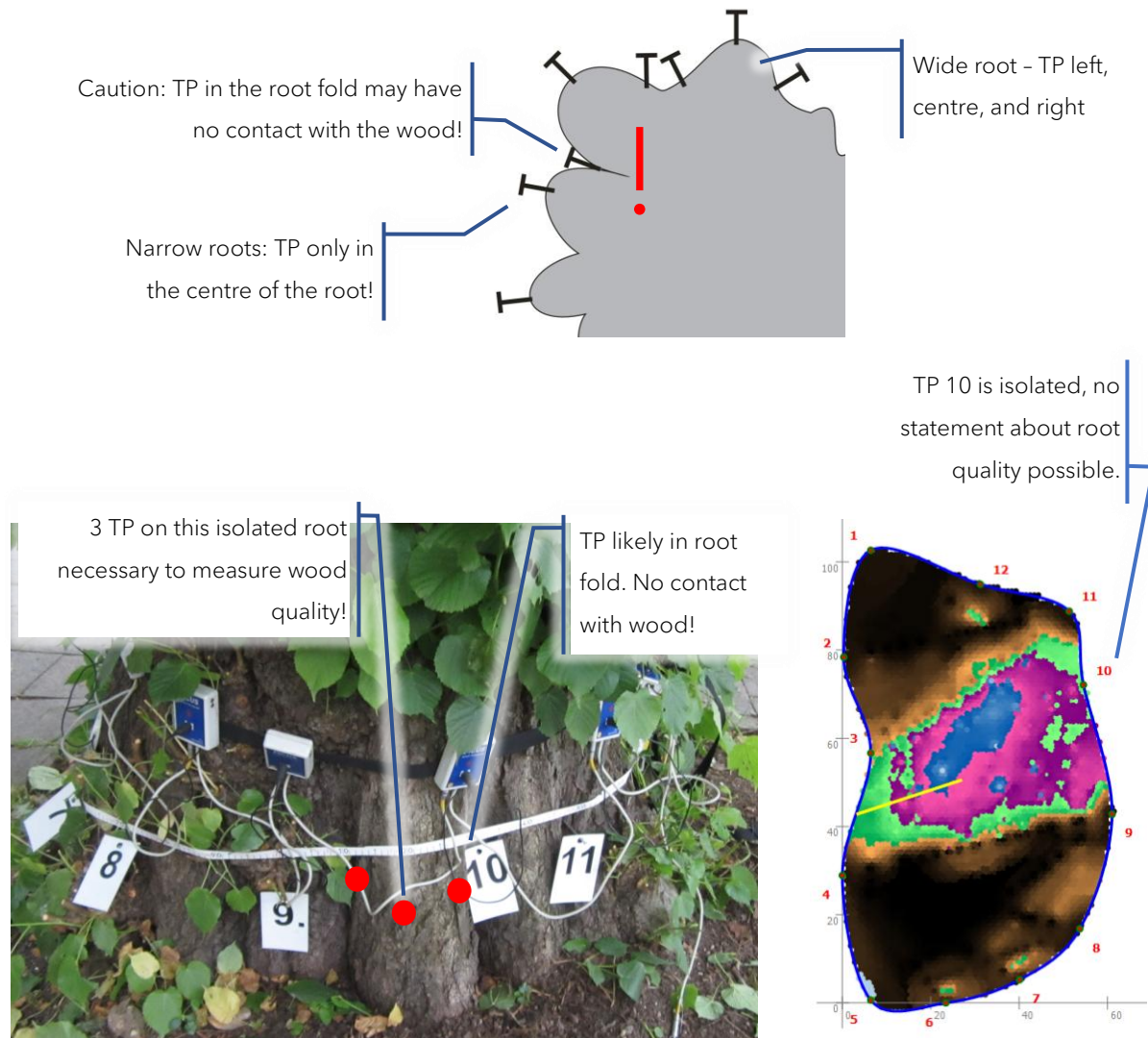
TP positioning on trees with strong root flares. If the tree has large root flares or buttress roots, the TP is either placed between the root flares or, following the outline, at every outer and inner point.



Wood that exists but is outside the geometry and tomogram, and therefore excluded from the calculation, is okay and has only a minor impact on the tomogram calculation in the measured part. However, the unmeasured sections of the trunk cannot be assessed, and their influence on overall stability remains unknown.

Wood that does not exist but is assumed to be present in geometry and tomogram is not okay and distorts the results.

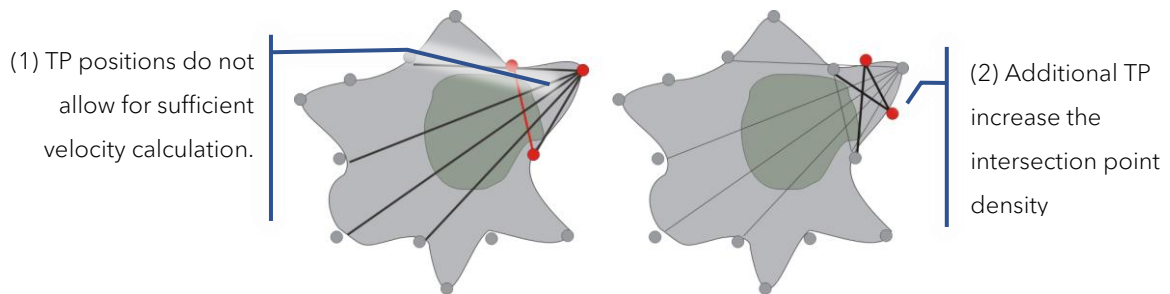
BP positions on adventitious roots¹. There are no universally applicable guidelines for placing BP on subsequently formed roots. If the roots are still small, i.e., less than 15-20 cm wide, it is sufficient to place only one TP in the centre of the root. Inserting the nails into the root fold exactly between these roots carries the risk of not achieving good contact with the wood. For wider roots, the left-centre-right placement method should be applied.



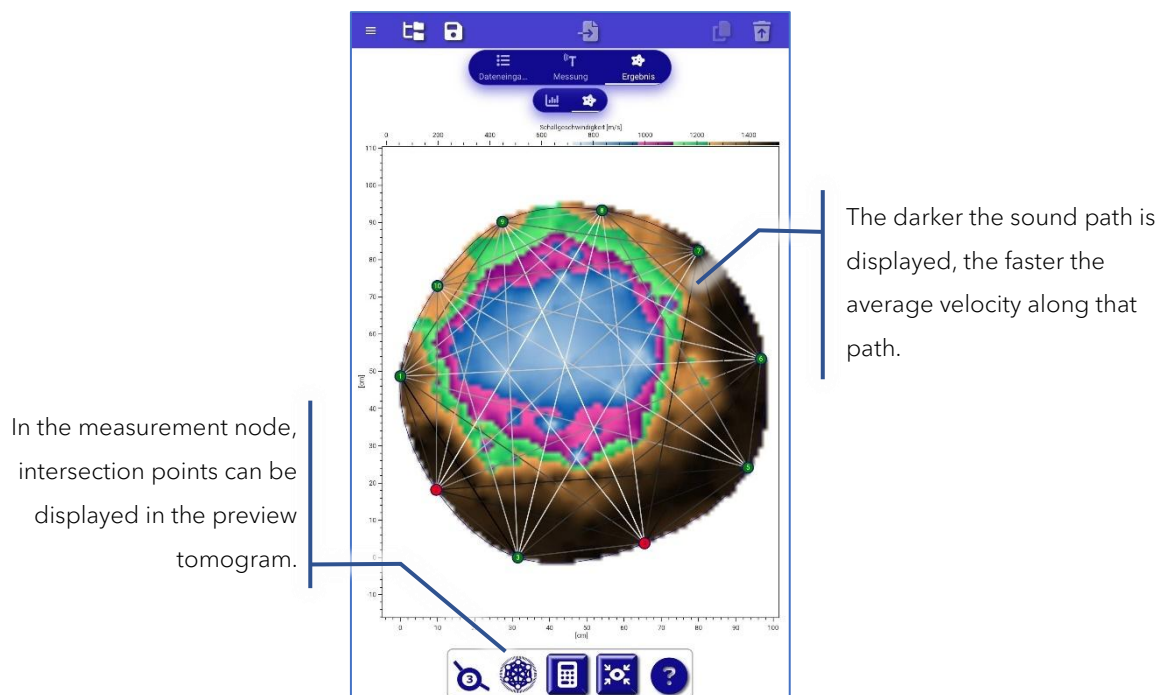
In the example above, TP 10 has no contact with the wood. The nail is likely embedded in the overgrown bark. The point is consequently recorded as part of the damage. Allocating three more TP (marked with red dots in the image) would make the root between TP 9 and 10 visible in the tomogram. Since the root is small, geometry determination must be done very carefully.

¹ Adventitious formations (Latin *adventus* 'added') refer to parts of a plant that do not arise from the main vegetation point, but from tissues of a plant that have become capable of division and growth, such as residual meristems or callus tissue at a wound site. Adventitious roots = sprouting roots. Source: wikipedia.com

Isolated parts of the trunk. If the damage has isolated a part of the tree (e.g., a root), the position and number of intersection points (1) may not be sufficient to calculate the root correctly in this case. It is necessary to add more TP (2) to increase the density of intersection points in a trunk area. See also [8.4.6 Adding Additional Tree Points](#).



The display of intersection points can be activated in the preview tomogram of the measuring node. This allows the recognition of whether additional TPs are necessary during the measurement. Additionally, displaying the sound paths is also possible in the sonic analysis node.

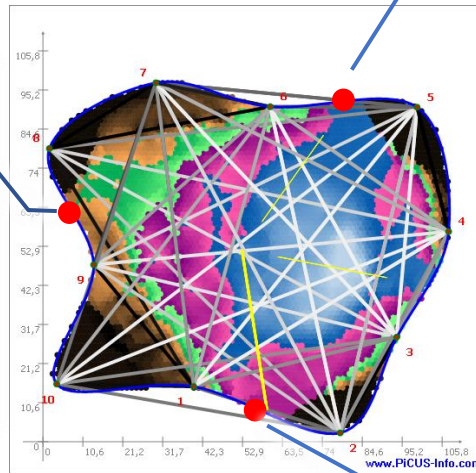


Example

In the following tomogram, the number of tree points near TP2 and TP5 should be increased to obtain a better measurement result.

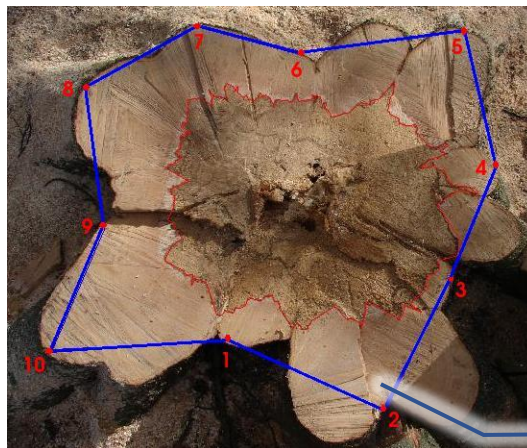
The line 7-9 is relatively slow.
One possible cause is that there is a sound barrier near TP 9.

To better measure the wood quality in the triangle 7-8-9, it is recommended to add another TP between 8 and 9.



Areas where violet/blue colours directly border brown colours indicate that the number of intersection points is too low. The tomogram is inaccurate.

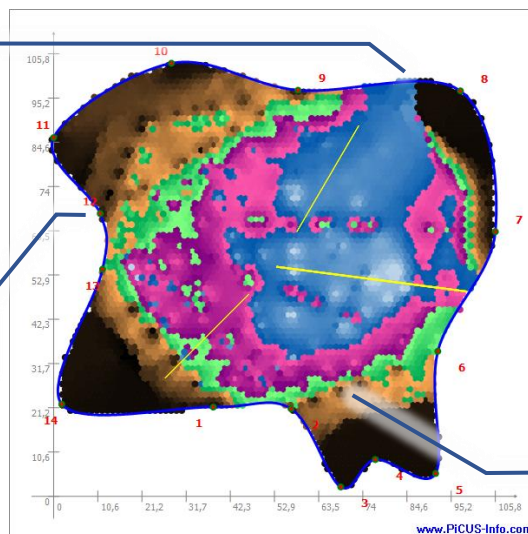
The red dots indicate possible positions for additional measurement points.



A comparison with the actual tree cross-section clearly shows that the tree geometry has not been adequately replicated. A single measuring point for two roots is insufficient.

Additional measuring points are still lacking here. Blue areas border directly on brown areas.

Additional measurement point



With additional points, the damage in this area is depicted much more accurately. The colour transitions in the tomogram are now smooth.

8.3.3 Tree Point Positions for Resistance Tomography

The rules for the correct positioning of tree points and for attaching nails set out in Chapter [8.3.2 Tree Point Positions for Sonic Tomography - Attaching the Nails](#) also apply to use with the PTT 3:

- BP should be distributed as evenly as possible along the circumference
- Nails should be positioned as close as possible to, but not in, defects
- Nails should penetrate the bark completely and have secure contact with the core wood, as bark has significantly different conductivity properties
- Nails should all be positioned in one plane
- The position and probable direction of spread of defects must be taken into account when positioning the measurement planes
- Nails should be positioned on and between roots in order to map the tree shape as accurately as possible

Since all rules for positioning the nails apply to both tomographs, the measurement points of a sonic measurement can also be used for resistance measurements without any problems. The only restriction that applies is the following:

The maximum distance between tree points in a resistance measurement should not exceed 25 cm on average. PTT measuring chains have twice the number of sensors as PST measuring chains of the same length, i.e., the distance between the sensors is only half as large.

For more information on reusing a recorded geometry for further measurements, see also chapter: [8.4.9 Subsequent Changes to Geometries](#).

8.4 Recording Tree Geometry - Geometry Node

8.4.1 General Information

The calculation of the tomogram requires converting the measured sonic travel times into sonic velocities with the help of the distances between the sensors. Therefore, the shape of the measurement plane must be entered as accurately as possible.

The speed of the sound waves is calculated from:

$$v = \frac{s}{t}$$

with

v = velocity

s = distance between measurement points

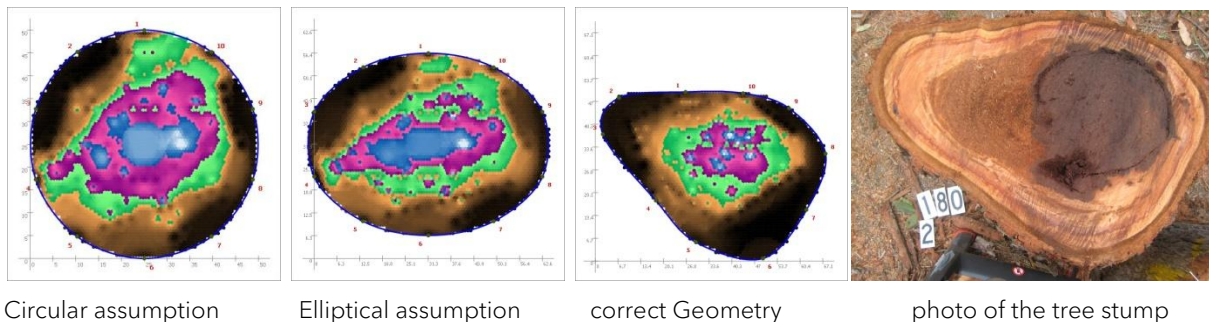
t = time, travel time of the acoustic wave

The travel time of the sound wave is precisely determined by the PST 3. The distances between the measurement points are calculated from the entered geometry. If the geometry is entered incorrectly, the distances between the sensors are incorrect, and thus the calculated sonic velocity is also incorrect:

inaccurate geometry = inaccurate velocity = inaccurate tomogram

For example, if the error for the distance between two sensors is 10 cm and the tree has a diameter of one meter, the resulting error in sonic velocity is already 10%. An error of this magnitude is significant for tomogram calculation. Subsequent images show the influence of geometry on tomogram calculation:

What happens when the same sonic data is calculated into tomograms with different geometries?



Only in a few cases is it sufficient to capture the measurement plane as an ellipse or circle. In most cases, a triangulation method must be applied to accurately determine the tree geometry.

The chapters [8.4.4 Geometry determination for circular and elliptical tree cross-sections](#) and [8.4.5 Geometry Determination for Irregular Geometries](#) provide applicable instructions.

To achieve maximum precision in the tomogram, using the "Calliper method" is recommended.

Trees to be examined should have a diameter of at least 25 cm ... 30 cm, otherwise the measurement errors could either become too large in relation to the measured distances, or the number of tree points would become too small. The number of tree points should be at least 8, preferably 12, in order to guarantee sufficient information density for the subsequent tomogram calculation.

8.4.2 Geometry Types

There are 2 measurement methods available for determining the tree geometry:

- **Regular geometry**, which includes the two methods
 - Circular geometry
 - Elliptical geometry
- **Irregular geometry** (geometry acquisition with calliper)

For regular geometries, a basic assumption is made that all TP are located on either a circle or an ellipse. The exact position is determined by a distance along the circumference and an optional shift perpendicular to the circumference.

For irregular geometries, sometimes also called the calliper method, triangulation method, or free geometry, the shape is composed of triangle calculations. With 3 known sides and 2 given points, the position of the 3rd point is calculated.

Regardless of the geometry type, a geometry node always contains the same tabs:

- **Data Input**: Basic data about the tree and measurement plane, from which the measurement table is created.
- **Measurement**: The measurement table that allows for a guided measurement; all recorded distances are entered here.
- **Graphic**: The result display for the fully calculated geometry. Diagnosis markers can be added here, and comments can be written for BP and diagnosis markers.
- **Gallery**: A list of photos for documenting the tree geometry. Individual photos can be linked with diagnosis markers.

A detailed description of the tabs is available in the following chapters.

8.4.3 Base Data for Geometry

The basic data entry differs depending on the chosen geometry type. Common to all geometry types are the following details:



Name: The name assigned when creating the geometry node can be edited here.



Comment: a generic text field for documenting additional information about the geometry.



Enter level height: Specifies the height in centimetres above the ground level where the measurement plane is located. In the *app*, the height can also be determined using the *altimeter*. The height of the measurement plane is always displayed along with the geometry name in the project's tree structure to facilitate easier differentiation between different measurement planes.



Bark thickness: Specified in cm, this value can be used as a correction parameter to infer the core wood geometry from the outer geometry. This is applied in calculating the remaining wall thickness with the TreeSA method (see also [8.7.7.1 TreeSA Tab](#)).



Use curved splines: This option determines how the final graphic should be calculated. If unrealistic distortions in the tree shape are caused by the calculation algorithm, deactivating this option allows the geometry to be represented by connecting all points with straight lines.

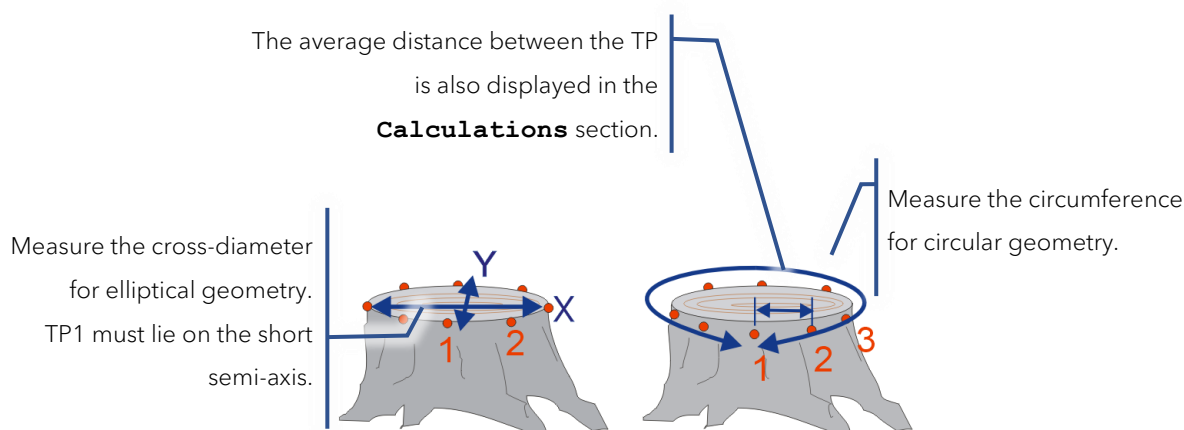


Geometry type: Here, the geometry type specified when creating the geometry node can be changed retrospectively.

Caution! This will delete all existing measurement data. It may be more sensible to create a new geometry node instead.



Trunk size: Depending on the chosen geometry type, either **trunk circumference** (circle, calliper) or the two **cross diameters** (axes of the ellipse) are specified. The cross diameters are the smallest and largest diameters in the measurement plane. The order in which the cross diameters are entered is essentially irrelevant. In the calculation, the ellipse is always positioned so that TP1 is at the top and on the short semi-axis in the Y-direction.



Number of tree points: Specifies the number of nails in the tree. The **Calculate** button can be used to calculate a proposal based on the size of the trunk. The proposal is chosen to have an average distance between the tree points of $\approx 15\text{cm}$. **Attention!** Changing the tree points in the basic data deletes all already existing measurement data. It may be more sensible to add additional tree points in the Measurement tab or create a new geometry. The maximum is 99 points.



Orientation TP1: Here, the deviation of TP1 from the north direction is given in degrees. The **compass** can also be used to measure the value directly.

For irregular geometries, some additional information is required:



Calliper size: Here, it is indicated whether the PiCUS Calliper should be used with (long) or without (short) arm extension. This option is only for calculating a recommended number of base points and does not affect the measurement itself. The PiCUS Calliper automatically detects the length of the arms used and will measure the correct distance in any case.



Basis point assignment: The **Calculate** button can be used to generate a recommendation for the number and positioning of the BP. The selection fields can be used to declare a TP as a BP. TP1 is always a BP, and all other points can be freely assigned up to a maximum of 6 BP. The software automatically checks whether the assigned BP are in the correct order and marks incorrect BP in red. A detailed description of the BP can be found under 8.4.5 Geometry Determination for Irregular Geometries.

For a plausibility check of the entered data, the **Calculations** section can be used. Here, calculations based on the basic data are displayed. Of particular importance here is the value for the average distance between the tree points.

If a different number of TP than the precalculated one is to be used, it should be ensured that with the most even distribution of TP, the average distance remains in the range of ≈ 12 cm to ≈ 45 cm (due to the length of the PiCUS sensor chains).

Data Input Calliper

If a linked measurement node exists, the subsequent editing of the geometry node is locked and must be manually unlocked.

The list of base points automatically adjusts its length when additional points are assigned (max. 6).

Data Input Ellipse:

In the **Calculations** section, additional information is provided. Of particular importance is the average distance between tree points.

Remove the check mark if strange calculation artifacts such as loops (red) occur in the measured geometry. The geometry will then be drawn with straight lines (blue) instead.

8.4.4 Geometry determination for circular and elliptical tree cross-sections

The table in the **Measurement** tab is automatically determined from the basic data. In the case of regular geometries, each row in the table corresponds to a TP. The table is initialized with values that represent an even distribution of TPs around the tree.

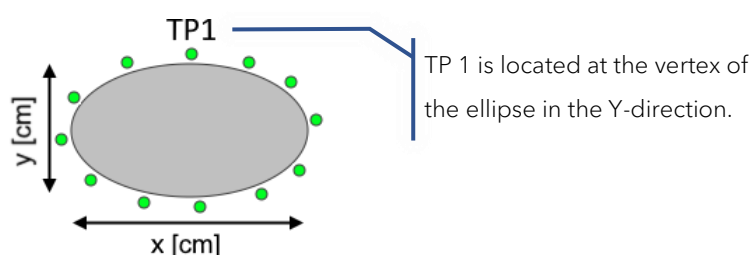
If the nails are not yet attached to the tree, the pre-initialized table can be used to ensure an as even distribution of TPs as possible. To do this, first place the tape measure at the level of the measurement plane around the tree and then drive the nails in the pre-calculated distances.

The steps taken so far are:

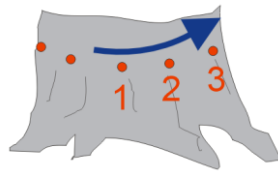
- Visual inspection of the tree and determination of the measurement plane
- Nails (tree points) attached in the measurement plane

During the measurement of the geometry, proceed as follows:

- Place the tape measure directly above (or possibly below) the nails. The zero point (TP1) should be on the short semi-axis in the case of elliptical geometry.



- Attach TP numbers to the nails. Each nail receives a number. The numbering is done counterclockwise, from left to right.



- In the measurement table, the distances read from the tape measure in centimeters are entered for each point in the **Arc Distance** column. Measurements are always taken from TP1. If distances are entered that would change the order of the BP on the tree, the point is marked as faulty.



MP 4 is at 49 cm, MP 5 is at 62 cm. These values are to be entered into the table.

The first column indicates the TP number. Each row corresponds to a TP.

Enter distances along the circumference in the middle column.

The arrows hide the preview graphic.

TP ID	arc distance	dist. from arc
2	15.8 cm	0.0 cm
3	31.6 cm	0.0 cm
4	49.0 cm	0.0 cm
5	62.0 cm	0.0 cm
6	79.1 cm	0.0 cm
7	94.9 cm	0.0 cm
8	110.7 cm	10.0 cm
9	126.5 cm	0.0 cm
10	142.4 cm	0.0 cm
11	158.2 cm	0.0 cm
12	174.0 cm	0.0 cm

Deviations perpendicular to the circumference are to be entered in the last column.

Deviations from the idealized circular or elliptical shape, such as hollows, bulges, or root flares, can be entered in the **Distance from Arc** column in cm. Deviations inward are represented with negative values, while deviations outward are represented with positive values.

In addition to the table with the measured values, a simplified preview graphic of the geometry is displayed. This graphic is updated in real-time as values are entered. In the *app*, this graphic can be hidden to save space on smaller displays.

If something went wrong during the measurement, both columns can be independently reset to the pre-calculated values.

To control the measurement procedure the following functions are available.



Add TP: Adds an additional TP at the specified position and inserts a row in the measurement table for the additional distance to be measured.



Remove TP: Removes a TP and the associated row in the measurement table.



The **Reset arc distance** button resets all arc distances to the calculated equal distribution of all TP.



The **Reset radial distances** button sets all distances from the arc (perpendicular to the circumference) back to zero.

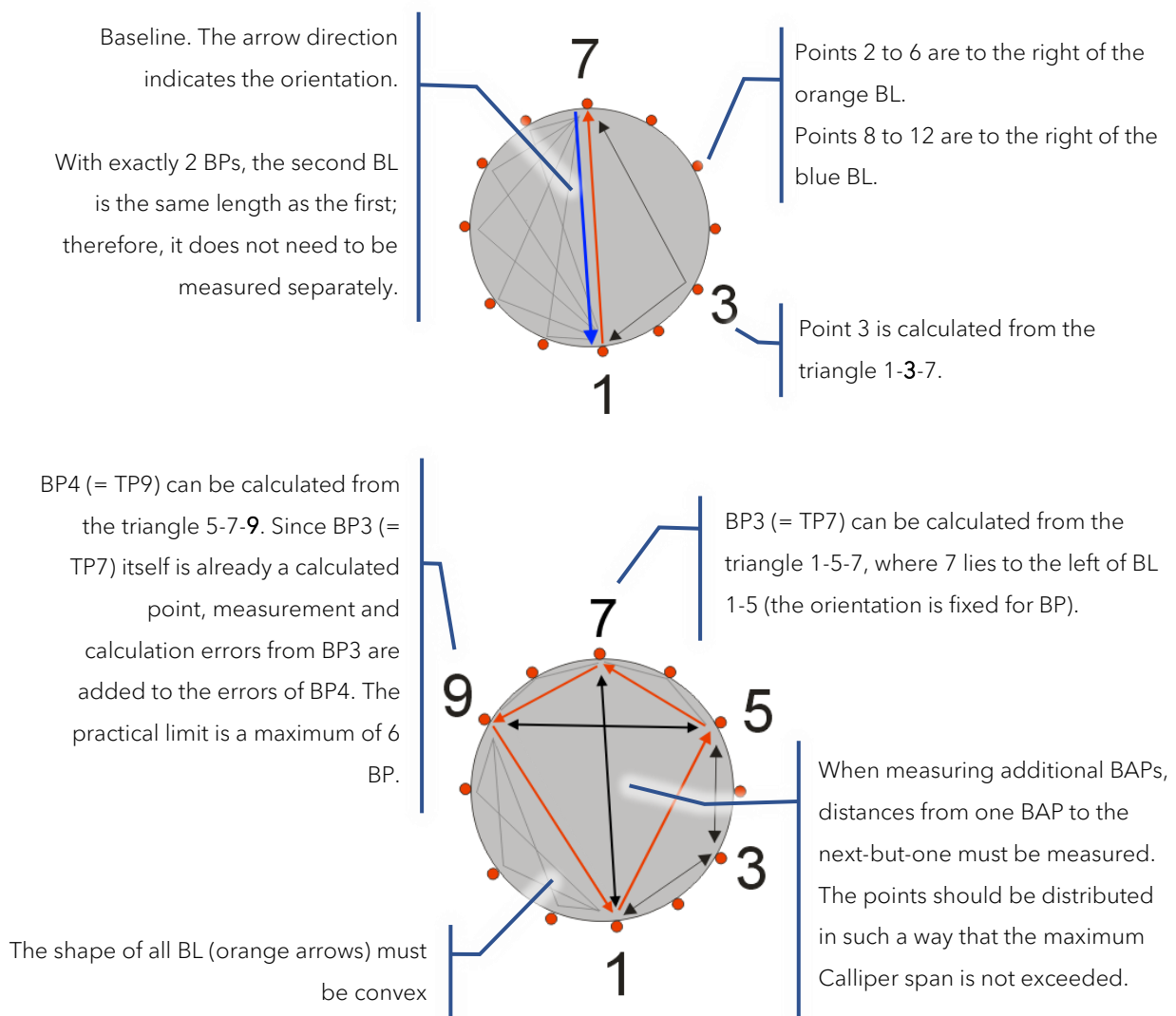
8.4.5 Geometry Determination for Irregular Geometries

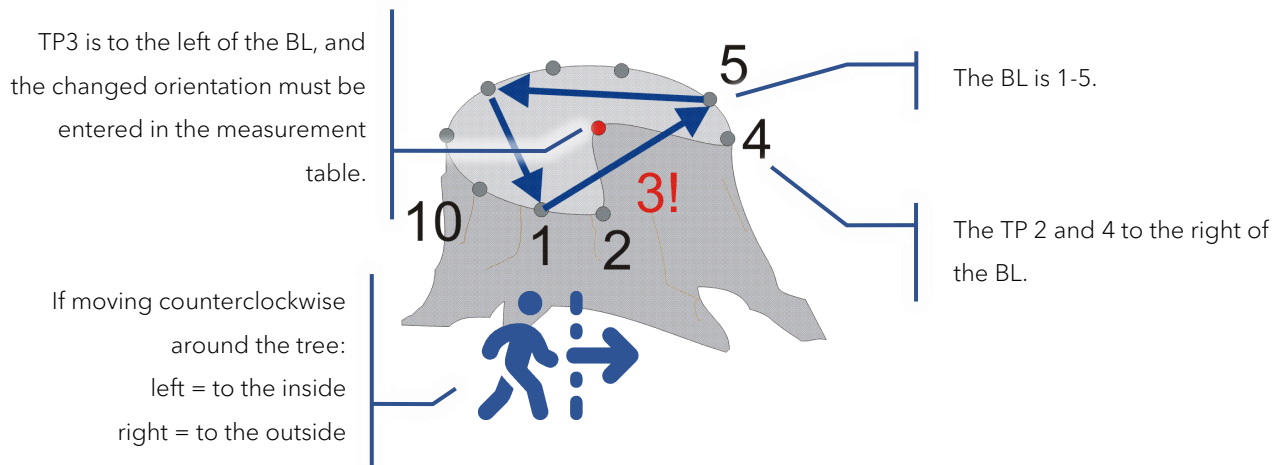
8.4.5.1 Overview and Basics

The geometry of the tomography plane in PiCUS sonic measurements is precisely determined using the triangulation method. In this method, the measurement plane is divided into triangles, and their side lengths need to be determined.

Each sought TP is assigned to a triangle. The other two points of the triangle are the Base Points (BP). The connection between these BP is the Base Line (BL). The position of the third point can be calculated when the lengths of all triangle sides are known. Since there are always 2 possible solutions for this calculation, left and right of the BL, the orientation of the sought point relative to its BL must also be specified.

For complex geometries or when the size of the tree diameter exceeds the working range of the Calliper, the number of BLs can be increased up to 6. The positions of additional BP are calculated using the same method. The coordinates of points BP3 to BP6 are also sought points determined through triangulation.



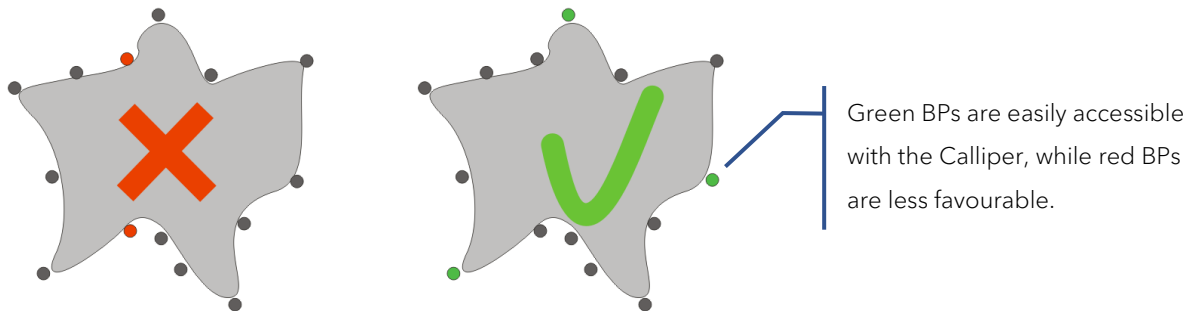


The nails are to be numbered counterclockwise around the tree. If you move counterclockwise around the tree during measurement, points inside are to the left of the BL, and points outside are to the right. The default assumption for all points is that they are to the right of their respective BL.

The triangulation function is optimized for use with the PCA. However, it can also be used by manually entering the measured values for the distances.

8.4.5.2 Determining the Baseline

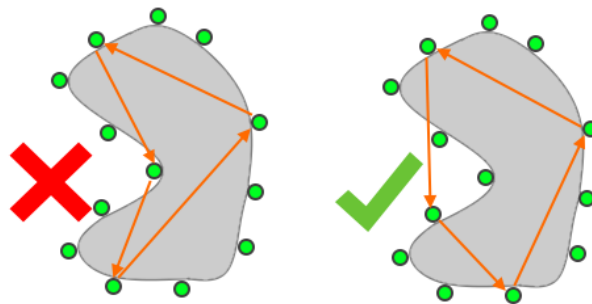
Before assigning the BP numbers, check with the Calliper to identify points suitable as BP. BPs must be easily reachable with the Calliper. To do this, take the Calliper and determine which points are easily accessible on the tree. *Keep in mind that Point 1 is always both TP and BP.*



Try to use just one baseline at first. If the tree is too large or too irregularly shaped, gradually increase the number of BP. Only once the points are known can the number plates be attached.

Since if there are more than 2 BPs, the subsequent BPs are also measured via triangulation (from 3 upwards, for the first 2 an initial basic assumption is made in the calculation), the maximum distance to be measured is not the distance between 2 adjacent BPs, but that of one BP until the BP after next. For example, BP5 is calculated from the triangle BP3 - BP4 - BP5. The longest distance here is typically BP3-BP5.

In addition to the maximum length of the distances to be measured and the easy accessibility of the BP, the shape generated by the baselines must also be taken into account. The baselines must always form a *convex shape*.



The assignment of the BP takes place when basic data is entered. Point 1 is always fixed (TP1 = BP1). All other BP can be freely assigned. It is automatically checked whether all BP are assigned in the correct order. If the points are mixed up, this will automatically be marked as an error.

It is not possible to make a subsequent change to the BP assignment without resetting all the measured values that have already been recorded.

8.4.5.3 Triangulation – Guided Measurement

The execution of the geometry measurement is strongly tailored to the use of the PiCUS Calliper 3 (PCA 3) for the distance measurements. Since there is no intelligence in the PCA 3 itself, the PCA 3 is purely a display and input device, it is in principle also possible to record all the required distances with other measuring devices and enter them manually.

The steps that have been carried out so far are:

- Visual inspection of the tree and determination of the measurement plane
- Nails (Tree Points) placed in the measurement plane
- Basic inputs were made, BPs are assigned

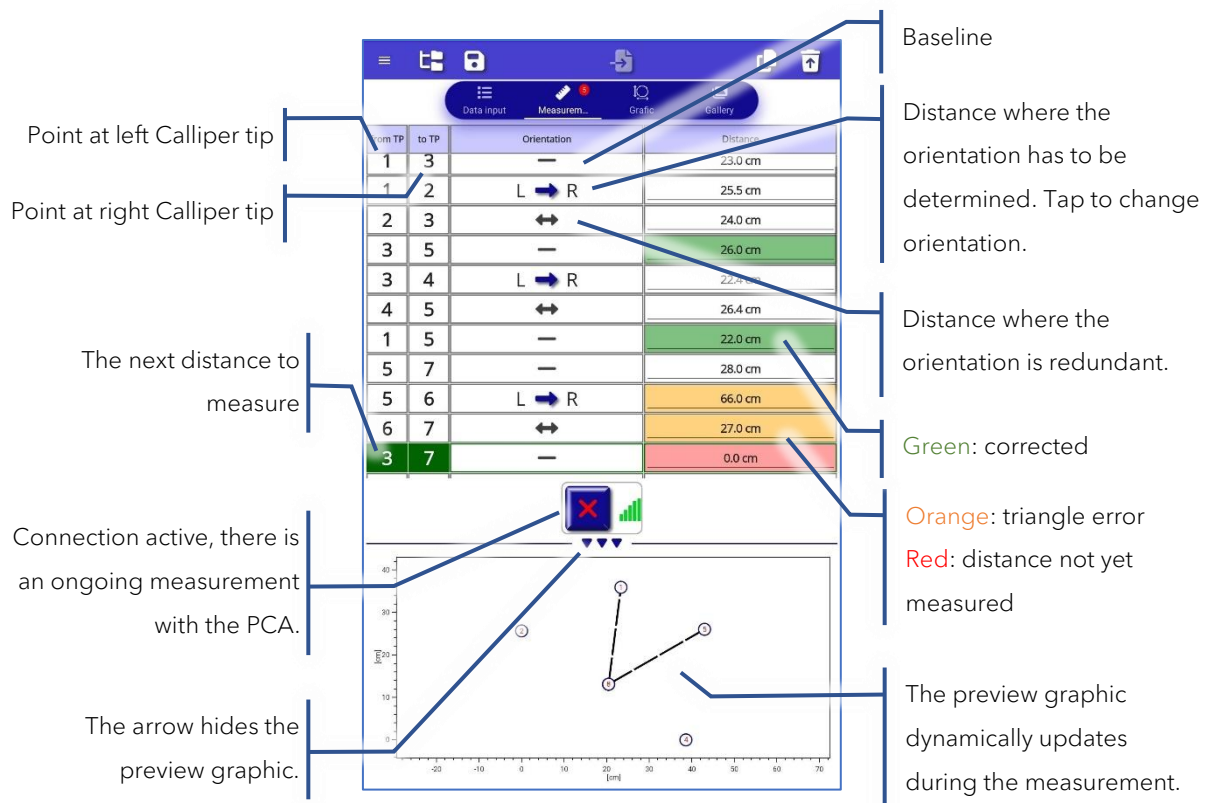
To perform the geometry measurements, switch to the Measurement tab. The tab contains the measurement table that guides the user through the entire measurement process. It includes all distances to be measured, with each row corresponding to a distance to be measured.

The Table contains the following columns:

- **from TP** - The TP where the measurement starts (left calliper tip)
- **to TP** - The TP where the measurement ends (right calliper tip)
- **Orientation** - The orientation of the TP relative to its BL, can take 4 different states:
 - **Baseline** - fixed orientation (display only), BLs do not allow variable orientation, the shape formed by all BL must always be convex
 - **Right** - Preset in the measurement table, all BP are initially assumed to be on the right side of the BL. Tapping the arrow in the software or using the left Calliper button (during distance measurement) changes the orientation to the left.
 - **Left** - Orientation can be switched to the left during input via PiCUS Calliper or directly in the table. Tapping the arrow again resets the orientation to the right.
 - **Redundant** - The orientation of the BP has already been specified on the other side of the triangle, a new specification is not necessary (display only)
- **Distance** - the distance to be measured between **from TP** and **to TP**

The background colour of the distance column is color-coded as follows:

- **Red** - Distance not measured
- **Orange** - Error in the triangle, one side is longer than the sum of the other two
- **Green** - Distance has been corrected, the row remains marked for subsequent plausibility check
- **None** - Distance measured, everything is OK



The toolbar below the table includes the following functions:



Establish Connection: Establishes a connection to the PiCUS Calliper and begins processing the measurement table.



Add TP: Adds an additional TP at the specified position and inserts a row in the measurement table for each additional distance to be measured.



Remove TP: Removes a regular TP and all associated rows in the measurement table



Correct Distances: Attempts to correct erroneous measurements



Reset: Clears all measured distances and set orientations

For adding and removing TP, see also [8.4.6 Adding Additional Tree Points](#).

Due to measurement errors, it can sometimes happen that the measured distances do not form a triangle (one side is longer than the sum of the other two). This often occurs when the 3 points are nearly in a straight line. The function **Correct Distances** (= triangle correction) can be used in this case to extend or shorten 2 sides of the triangle so that a valid triangle is formed. The BL is never changed because it is part of other triangles. Otherwise, correcting one triangle could distort other triangles.

If the geometry measurement should be cancelled or restarted, using the **Reset** function will reset all distance measurements to zero at once. Orientations are also reset to their default settings.

Before applying the triangle correction, it is crucial to perform a plausibility check of the marked incorrect distances. The algorithm cannot decide which of the distances is actually incorrect. A comparison of the recorded geometry with the tree can only be done by the user.

A simplified preview graphic displays partial tree geometry during the measurement, allowing for early detection of errors in the geometry measurement. In the app, the preview graphic can be turned off if needed using the large arrow.

If the PiCUS Calliper has been set up correctly under [4.4.2 Devices](#), the **Establish Connection** button can be used to initiate communication with the Calliper for guided measurement. Follow these steps:

Turn on the PiCUS Calliper and select **PiCUS-Mode**



Select and confirm with right Calliper button



Select **Establish Connection** in the software



The signal strength of the Bluetooth connection is represented as a small bar chart once the connection has been successfully established. If the Bar chart is displayed in blue, a connection has been established but the end device is incapable of measuring the signal strength.

The Calliper display will automatically show the first distance to be measured.

Measure the first distance: Hold the Calliper tips to the specified measuring points and press one of the two buttons.

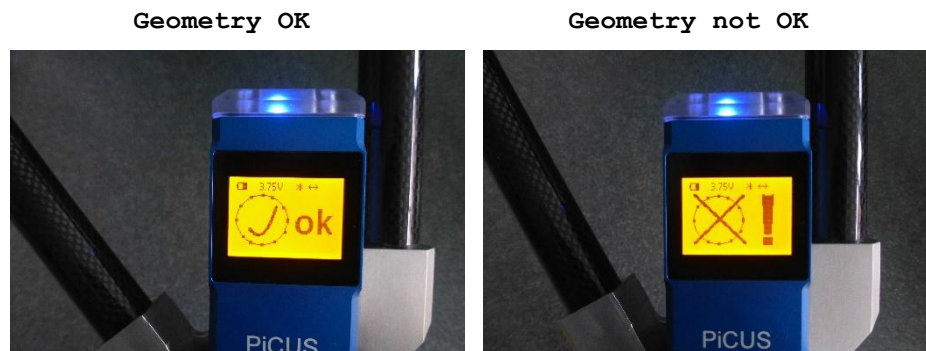


Since the first distance to be measured is a baseline (in the image: **BaseL: 1<->7**), no orientation needs to be considered. After pressing one of the Calliper buttons, the measured distance is displayed in the table.

Measuring additional distances: If the distance is not a baseline, follow the description above to press the left or right button to measure and capture the orientation. The standard orientation is indicated by the blinking of the measurement point number on the selection button. If no button is blinking, the orientation is not to be considered.

Power-saving mode: If the Calliper enters power-saving mode (display backlight off) during measurement, an additional button press is required before the actual measurement to wake up the device and make it ready for measurement.

When all distances have been measured, the result is displayed in the Calliper display:



If a single distance needs to be remeasured, the value for the distance in the table must be deleted or set to zero.

Do not use the Reset button for individual measurements, as it would reset all other measurements as well.



A running measurement can be stopped at any time with the **Cancel** button. This also happens automatically when the measurement is complete, i.e., when all distances are non-zero.

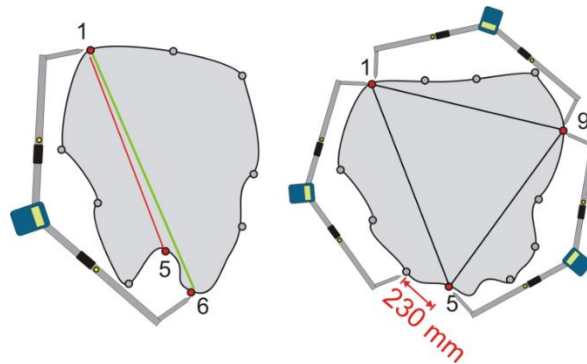


Pressing the **Establish Connection** button again after completing the measurement checks if there are any unmeasured distances, e.g., because they were manually reset or because additional points were added, and restores the readiness for measurement if necessary.

Canceling and restarting can also be used in case of connection problems to resend a lost command to the Calliper.

8.4.5.4 Calliper too small for the tree

If the Calliper is too small or if BP cannot be reached due to the tree's geometry, the first step is to check if choosing different BPs resolves the issue.



The **left sketch** illustrates this scenario: The program suggests BP 1 and 5. BP 5 is difficult to reach. Changing the BL to 1-6 (green line) is one possible solution. Alternatively, 3 BL can be used (e.g., 1-4-7).

In the **right sketch**, the Calliper is not large enough to measure a distance on the tree. The measurement value can be estimated as follows:

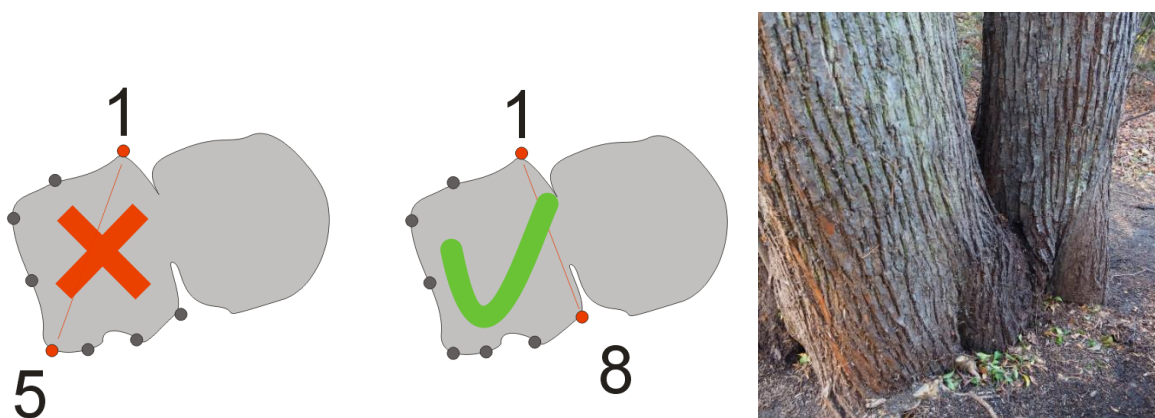
- Transfer the maximum measurement value (about 2150 mm extended calliper arms) to the PC program. Estimate the length of the remaining distance (with a measuring tape, etc.). In the example, it's 230 mm.
- Enter the sum of 2150 mm and 230 mm = 2380 mm into the table for the measurement value of the distance 1-5.

Alternatively, the number of BL can be increased here as well.

8.4.5.5 Measurements on parts of the trunk

Trees with large or unusual circumferences, such as multi-stemmed trees, may require performing a tomography measurement only on parts of the tree. The image shows a multi-stemmed tree where only one stem is to be examined. As usual, the BP is distributed over the part to be measured and measured with the Calliper. The question arises here about the choice of the baseline.

The software will suggest points 1 and 5 as BP for the 8 TP in the sketch (left sketch). However, the right stem prevents the use of the Calliper between TP 6, 7, 8, and BP 1.



Choosing the BL 1-8 (right sketch) avoids this problem.

8.4.6 Adding Additional Tree Points

If individual TP are to be added or removed in the geometry afterwards without changing the rest of the geometry, this must always be done in the Measurement tab.

Changing the TP in the Data Entry tab always resets the entire measurement! All previously recorded geometry measurements will be lost!

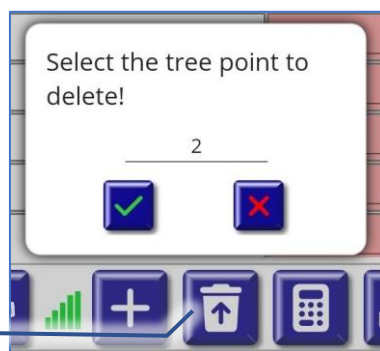
8.4.6.1 Editing Regular Geometries



To delete a TP, the menu for selecting the point to be deleted can be called up via the **Delete** button.

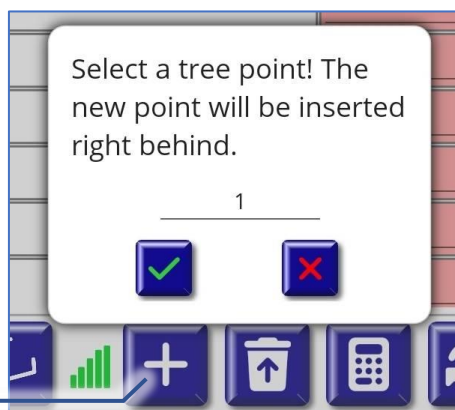
After confirming the selection, the corresponding TP is deleted, and the associated row in the measurement table is removed.

The **Delete** button opens a selection menu



When an additional TP is to be added, an existing TP can be selected with the **Add** button. The new point is then inserted immediately behind the chosen point. The position is calculated so that the new point is exactly in the middle of the circle or elliptical arc between its neighbouring points. The new point can be measured anew, just like all other points, after creation.

The **Add** button opens a selection menu



8.4.6.2 Editing Irregular Geometries

To delete a TP, the menu for selecting the point to be deleted can be accessed via the Delete button. After confirming the selection, the corresponding TP is deleted, and all associated rows in the measurement table are removed.

Only basic TPs can be deleted. TPs that are also BPs cannot be deleted. BPs can only be manipulated in the base point selection in the **Data Input** tab. This applies to both the number and the assignment.

Changing TPs or BPs in the Data Input tab always resets the entire measurement! All previously recorded geometry measurements are lost!

If an additional TP needs to be added, an existing TP can be selected from the menu in the Add section. The new point is then inserted immediately behind the chosen point. The position is calculated so that the new point is exactly in the middle of the spline between its neighbouring points. The new point can be measured anew, just like all other points, after creation.

8.4.7 Geometry Measurement Result Display

The **Graphic** tab displays the measured geometry. The display is significantly more accurate than the preview graphics in the Measurement tab.

Below the graphic, there is a workspace divided into several sections:

View: additional information can be toggled on or off in the graphic.



Show Compass Needle: The north direction is displayed live based on the current *compass* reading.

Note:

When the compass is active, diagnostic or drilling marks are automatically positioned based on the current viewing direction. To do this, hold the mobile phone in front of the relevant damage or drilling position towards the centre of the trunk. When the compass is deactivated, diagnostic marks are always placed at the geometry's centre, while drilling marks are always positioned at BP1.



Show North Direction: Displays a compass rose in the upper left corner of the diagram.



Show TP Numbers: Displays the assigned number for each TP. Numbers can take up a lot of space on smaller displays and can be hidden. TP1 is easily identifiable even with hidden numbers (triangle instead of dot).

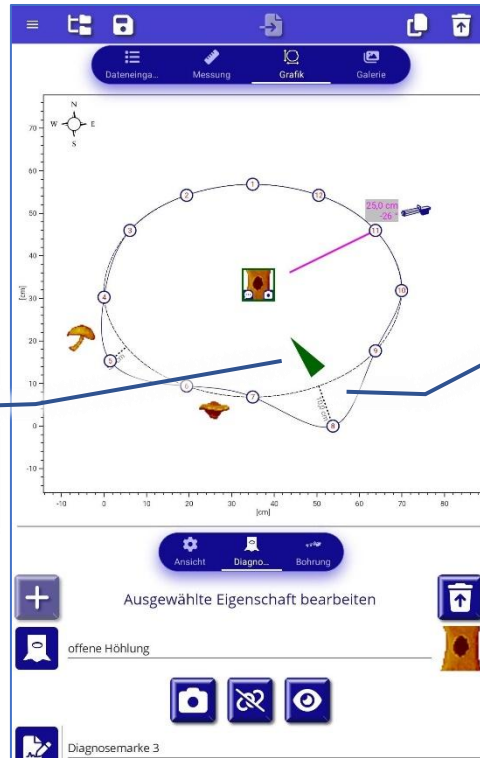


Show Base Form: Only for regular geometries, in addition to the measured geometry, the base form (circle or ellipse) can be displayed as a dashed line. For points that do not lie on the base form, the distance from the circle or ellipse arc is also indicated.



Scale Geometry: Adjusts the zoom level and shifts the graphic so that the entire geometry is visible, fully utilizing the available display space. Alternatively, the graphic in the app can be scaled and moved using *touch gestures*. On the PC, the graphic can be *moved with the right mouse button* and the *zoom level adjusted with the mouse wheel*.

The *compass* shows the current orientation of the device in real-time.



In circular and elliptical geometries, the basic shape can be represented as a dashed line. Deviations from this basic shape are also displayed.

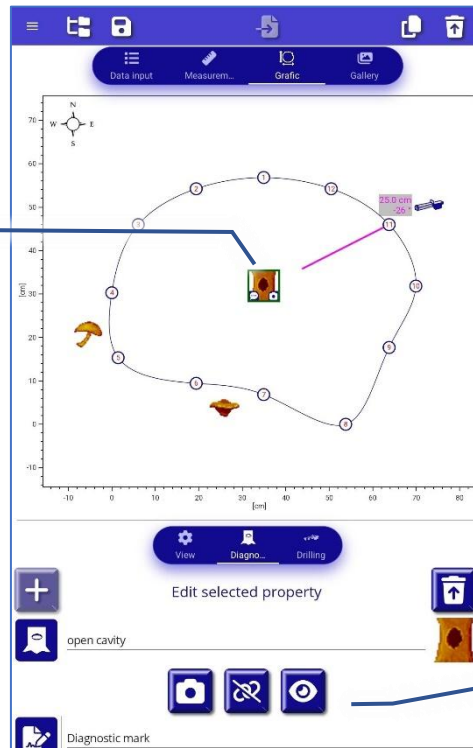
Diagnosis: Results of a visual inspection can be documented here. See also [8.4.7.1 Defect Description after Visual Inspection](#) for a detailed description.

Drilling measurement (ext.): If drilling resistance measurements were conducted externally (i.e., outside the IML Tree Inspection software), the position, direction, and depth can be documented here. See also [8.4.7.2 Documenting External Drilling Measurements](#) for a detailed description.

8.4.7.1 Defect Description after Visual Inspection

Visible defects on the tree, especially in the measurement plane, can be documented in the measured geometry. Drawing in presumed cracks, fungal fruiting bodies, and other abnormalities helps to later understand the measurement. Comments can be added to the BP, or freely movable diagnostic markers in the form of small symbols can be added to the graphic. Each diagnostic mark can be linked to a photo and annotated with a comment.

A freely movable diagnostic marker. The small icons on the diagnostic marker indicate that a comment and a photo have been created for this marker.



Scroll through the workspace to view additional editing options.

To add documentation to the geometry, follow these steps: Select the **Graphic** tab and then choose **Diagnosis** in the workspace.



Create new diagnosis mark: Adds a diagnosis mark to the geometry.

Select and position existing mark: Tap on a diagnosis mark or a BP in the graphic. The selected object will be highlighted in green (newly created marks are automatically selected). Selected diagnosis marks can be freely moved by tapping and dragging.

Editing Diagnosis markers:



Choose type: Opens a list of typical damage cases or special features from which a diagnosis marker suitable for the circumstances can be selected.



Create image: Opens the *camera*. A taken photo is automatically linked to the diagnosis mark. If an image is already linked, the button is greyed out, and a small camera icon is displayed directly on the diagnosis mark in the graphic.



Unlink: Deletes the link with a photo, allowing a new picture to be taken. The photo itself is not deleted and remains available in the gallery (see also [8.4.8 Gallery](#)).



Show image: Switches to the Gallery tab and automatically jumps to the linked photo.



Name: A free-text field where a name can be assigned to each diagnosis mark. Each diagnosis icon comes with a default name. If an icon is used multiple times, the default name is automatically numbered.



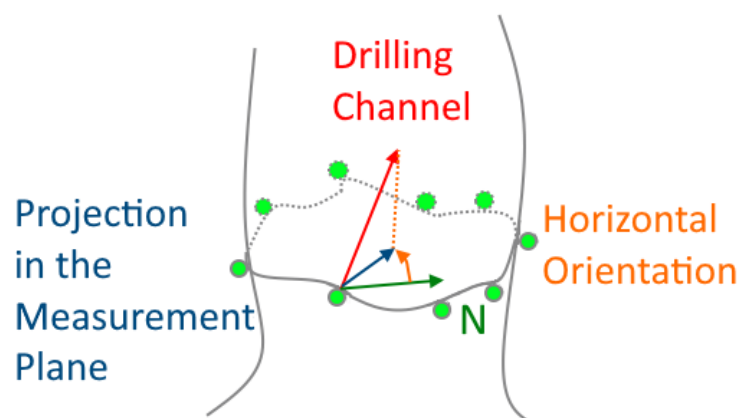
Comments: A free-text field where a short accompanying text can be written for the selected object (*comments are also available for TP*). In the graphic, a comment on diagnosis markers is automatically made visible with a small speech bubble icon.



Delete diagnosis mark: A selected diagnosis mark can be deleted with the trash can. This removes comments and the link to a photo. However, the photo itself remains and is still available through the gallery.

8.4.7.2 Documenting External Drilling Measurements

Drill resistance measurements or core samples can also be documented in the determined geometry. The drill channel is associated with a TP and drawn into the geometry with direction and drilling depth. The drill channel, whose direction can significantly deviate from the horizontal, is represented as a projection onto the measurement plane. This can result in a shortened representation in the two-dimensional graphic.



To add a drill channel, go to the **Graphic** tab in the working area and select **Drilling Measurement (ext.)**.



Then, use the **Add Drilling Measurement** button. The new drilling measurement will be added at TP1 and extend to the centre of the trunk. If the live compass view is active the drilling measurement is instead placed based on the current view direction. The newly entered drill channel is automatically selected and highlighted in green.

To assign a selected drill channel (clicking on the icon in the graphic) to another TP, simply click on the new TP in the graphic. Unlike diagnosis markers, drill channels cannot be freely moved. They are always linked to a TP.

Additional information can be entered for a selected drilling measurement in the working area:



Create image: Opens the *camera*. A taken photo is automatically linked to the drilling measurement. If an image is already linked, the button is greyed out, and a small camera icon is displayed directly on the drilling measurement in the graphic.



Unlink: Deletes the link with a photo, allowing a new picture to be taken. The photo itself is not deleted and remains available in the gallery (see also [8.4.8 Gallery](#)).



Show image: Switches to the Gallery tab and automatically jumps to the linked photo.



Name: A free-text field where a name is assigned to each drilling measurement. The default name is automatically numbered if multiple drilling measurements are added to a geometry.



Drill Depth: The length of the drill channel in cm.



North Orientation: The horizontal orientation of the drill channel is indicated as the deviation from the north direction in degrees.



Inclination: The vertical orientation of the drill channel is indicated as the deviation from the horizontal in degrees. A drill channel pointing upward is represented with a positive angle, while a channel pointing downward is represented with a negative angle.



Compass: In the app, north orientation and inclination can also be captured with the *compass* (see also [6.2 Compass](#))



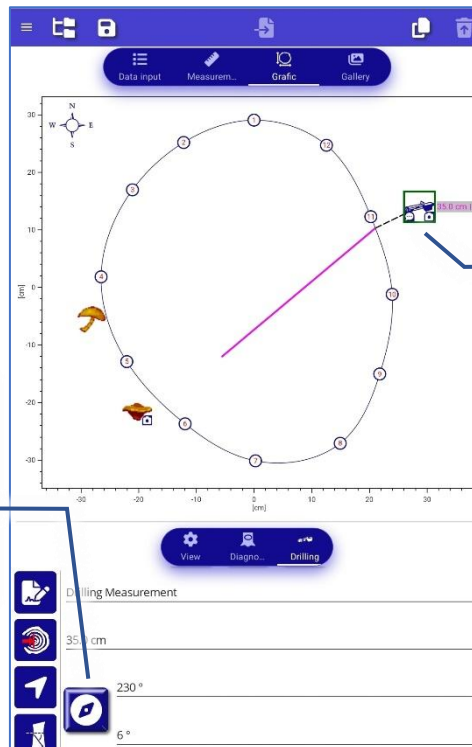
Comments: A free-text field where additional information about the drilling measurement can be provided.

From the values of drill depth, north orientation, and inclination, the projection in the measurement plane is automatically calculated.



Delete drilling measurement: A drilling measurement, once selected by clicking on it in the graphic, can be deleted with the trash bin icon.

The orientation and inclination of the drilling channel can also be measured using the *compass*.



A drilling mark can be moved freely. The small icons indicate the presence of both a comment and a documentation photo.

8.4.8 Gallery

The last tab in the geometry measurement node is the gallery, where the photos taken for documentation are stored. This gallery only contains photos linked to the respective geometry measurement node (see also [7.1 General Project Structure](#) and [7.2 Data Storage](#)).



Use the *camera* icon to either **capture a new image**



Or use the folder icon to **add an existing image**. If a *.pdf file is imported instead of an image file (e.g. a report containing drilling measurements exported from the IML Studio software), the *.pdf file is converted page by page into consecutively numbered *.png files, so that it can be integrated into reports later.



Delete Image removes the photo from the project.



In the gallery, you can navigate between all available images using the **arrow keys**. Double-clicking on the thumbnail of the current image opens it.



The **Rotate** button allows you to rotate the image view by 90°.

In the metadata section of the image, additional information is stored for each capture:



Filename: By default, the filename is a timestamp derived from the system time at the moment of capture, with the format YYMMDD-hhmmss. To facilitate easier identification, you can change the name [here](#).



Comments: A free-text field where additional information about the image can be noted.



Image Orientation: To associate the image with a specific position relative to the tree, the viewing direction relative to the north orientation is indicated here. Besides direct input, the *compass* can also be used to determine the orientation.



Object Link: If the photo was taken when creating a diagnosis marker, the name of the marker is displayed here. Alternatively, you can assign a diagnosis marker to the image here. **Caution! Each diagnosis marker can only be linked to exactly one image. If another image is already assigned to the chosen diagnosis marker, the original link will be deleted (only the link, not the image itself).**



Unlink: Removes the link between the image and the diagnosis marker.



Show object: switches to the linked diagnostic mark or drilling measurement in the **Graphic** Tab.

The metadata is stored within the project structure. Except for the filename, none of the information is contained within the image file itself.

Capture new image.

Add existing image.

Files can also be imported via drag & drop into the preview area.

The preview can be rotated in 90° steps.

Double-click opens the preview image in full-screen mode.

The file size of the image is also shown.

This image is linked to a diagnostic mark named **diagnostic mark**.

Unlink the diagnostic mark.

8.4.9 Subsequent Changes to Geometries

In everyday practice, it is often necessary to subsequently adjust an existing geometry. Such adjustments inevitably have an impact on the linked measurement nodes. To ensure the consistency of measurement data already recorded in the sonic and resistance measurement nodes, the following rules apply to adjustments to the geometry:

- Changing to a different geometry in the sonic or resistance measurement node:
 - **Same number of points:** a change is possible; all points/measurement values are assigned 1:1 to the new geometry.
 - **Different number of points:** a 1:1 assignment of the points from the old to the new geometry is not possible; all sonic or resistance measurement values that have already been recorded are deleted. *This process cannot be undone.*
- Changing an existing geometry:
 - **Change tree point position:** no effect on the recorded measurement values
 - **Add point:** no effect on the recorded measurement values, the new point has no measurement values and can be measured normally
 - **Remove point:** The measurement point and all associated sonic or resistance measurements are deleted. *This process cannot be undone.*

Several changes can be made at the same time. When an existing geometry is adjusted, a list of all changes is created internally and forwarded to all linked measurement nodes when the geometry node is saved or exited.

Created geometry nodes can be used for more than one measurement. It is irrelevant whether SoT and/or ERT measurements are assigned to a geometry.

A common scenario in practice is that a sonic measurement is first performed with 12 BP (no repositioning necessary, one round of tapping is sufficient). If this SoT measurement does not provide clear results, an ERT measurement can also be performed on the nails still in the tree. Since the PTT 3 has twice as many terminals as the PST 3 has sonic sensors, and these terminals only allow half the distance between them, the number of nails for the resistance measurement is doubled. To obtain this new geometry, in which every second point is already measured, one of the following procedures can be used:

- The geometry is **measured with 24 BP from the outset**. During the initial sonic measurement, only every second nail is assigned a sensor.
- **A further 12 BP are added** to the geometry originally measured with only 12 BP. Both measurements use the same geometry node.
- **The geometry with 12 measuring points is copied and expanded**, and only the newly added points are measured in the new geometry. SoT and ERT measurements each use their own geometry.

These variants are equivalent and can be selected individually based on an assessment of the respective measurement and documentation effort or according to your own organizational preferences.

8.5 Performing a Sonic Measurement - Sonic Measurement Node

In the sonic measurement node, a measurement plane, i.e., a measured geometry, is assessed with the PiCUS Sonic Tomograph 3.

8.5.1 Data Entry

Basic information about the measurement and device configuration can be entered in the Data Entry tab. The following information can be edited in the Basic Data section:



Name: The name of the measurement node, which was already specified during creation, can be modified here (see also [7.1.5.2 Sonic Measurement Node](#)).



Comment: a free text field in which additional information about the measurement can be entered.



Linked geometry: the geometry node for which a sonic measurement is to be performed. If measurement data has already been recorded in the sonic measurement node, the linked geometry may not be changed under certain circumstances. See also [8.4.9 Subsequent Changes to Geometries](#). All geometries present in the same inspection node can be chosen, and one geometry can be used in more than one measurement.

In the Device Data section, the serial number of the last PST 3 used in this measurement node is displayed under **Used PiCUS Tomograph** for documentation purposes.



In addition, the **number of sensors** can be set here

- 6 sensors: only one measurement chain is used
- 12 sensors: both measurement chains are used



The **minimum and maximum sonic velocities** are absolute values for validating measured values and are taken from the global template (see also [4.4.4 Calculations](#)). The values can be adjusted here only for this measurement node and all subsequently linked analysis nodes. Sonic measurements above or below these limits are marked as faulty. Measurement values identified as faulty can later be excluded from the calculation of the tomograms.

- Default max value: 2300 m/s
- Default min value: 300 m/s

Velocities of up to approx. 2000 m/s are common in living trees. Slightly higher values are unusual but possible in rare cases. If there are significant deviations, this indicates errors in the measurement or calculation. Check the geometry and installation of the sensors.

8.5.2 Mounting the Measurement Equipment on the Tree

Previous steps taken:

- Visual inspection of the tree and determination of the measurement plane
- Nails (tree points) placed in the measurement plane
- Numbers attached to the nails
- Geometry recorded

Procedure for installing the PiCUS 3 on the tree:

- Place the PST 3 approximately between TP 6 and 7 if the tree has 12 TPs. It is recommended to use the blue strap to avoid laying the device on the ground.

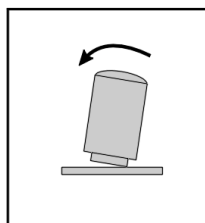


Place the PiCUS
approximately
between TP 6 and 7
- a total of 12 TPs.

- The red sensor cable harness with sensors 1 to 6 is plugged into the left socket A (1-6).
- The blue sensor cable harness with sensors 7 to 12 is plugged into the right socket B (7-12).
- If the hammer needs to be connected via the hammer cable, plug the right-angled connector of the hammer cable into socket C (bottom left corner of the device). Connect the straight connector of the hammer cable to the hammer. However, in most cases, the hammer can be used as a wireless hammer. In this case, the antenna must be mounted on the hammer instead of the hammer cable. ***The wireless connection between the hammer and PST 3 may not work in all locations. Thick trees and other electrical devices can interfere with the connection.***
- Slowly place the sensors on the nails. Be mindful of the strong magnets! The sensors should not jump onto the nails to avoid damage!



wrong



correct



- The sensor chains can be held on the belt with the "paperclips".

8.5.3 Measurement Points and Sensors

The PiCUS sonic measurement distinguishes between tree points (TP - the nails in the tree) and measurement points (MP - a TP for which measurement data has been taken) on the one hand, and sensor points (SP - a nail to which a sensor is currently attached) on the other.

In PiCUS sonic measurements, more tree points/measurement points can be used than sensors.

Through this technique, complete tomograms can be obtained from trees with 14, 20, or even 30 or more measurement points using a PST 3 with 6 or 12 sensors.



This is achieved by moving the sensors and repeating tapping rounds. The goal is that at the end of the measurement, each TP has been an SP at least once and becomes an MP by receiving tapping signals from all other TPs. The point where the sound is coupled is called the tapping point (TapP).

For a complete measurement, each point should receive data from every other point!

In practice, this goal is sometimes not necessary. In some cases, a meaningful tomogram can already be calculated from a partial measurement.

8.5.4 Sensor and Measurement Point Assignment

Since the PST 3 (or the IML Tree Inspection software) does not know on which TP the sensors are placed, the assignment of the sensors to the measurement points must be entered in the software (or in the PST 3 itself if measuring without software) before the measurement.

Caution: The correct assignment of sensors to measurement points in the software is crucial for a correct tomogram.

If the sensor assignment is correct and all sensors are properly placed on the nails, the measurement can proceed.

The number of available sensors (one or two sensor chains) is set globally once (see also [4.4.2 Devices](#)).

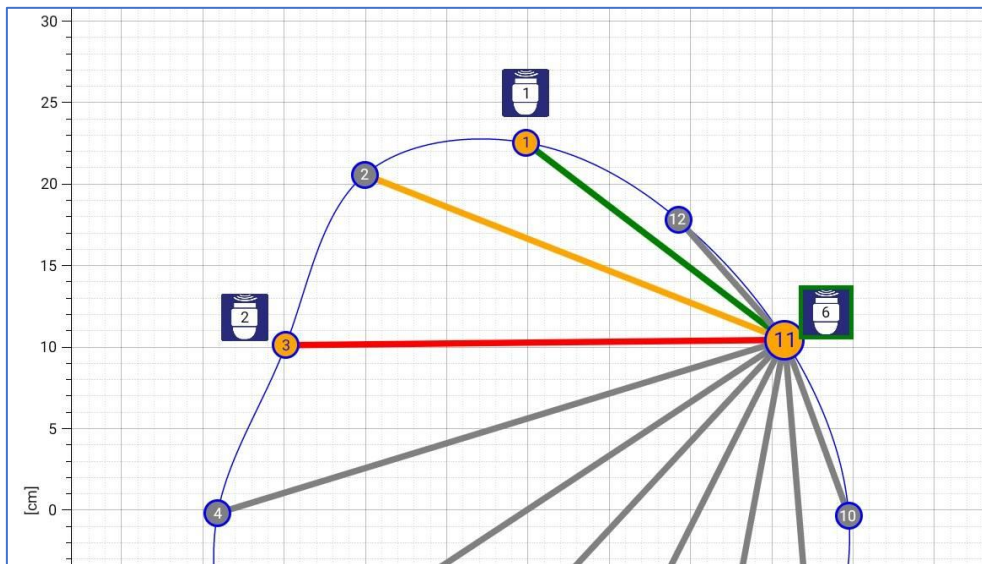
The sensor assignment is done in the Measurement tab. The tab is divided into 3 sections:

- **Status Area:** This area displays the sensor assignment either as a graphic or as a table, simultaneously indicating the status of the sonic measurement at each point with colour coding. In the table, each point is considered as a whole, while in the graphic, not only the status of each point is shown but also, when selecting a point, each sound path to that point is represented as its own-coloured line.

The measurement status is displayed from the receiver's perspective at the respective point.

- **Grey:** No data
- **Orange:** There is data, but not enough, i.e., fewer than three taps on this sound path, or the point has at least one sound path with fewer than 3 taps received.
- **Green:** There is sufficient data, and at least three are valid (i.e., within the expected value range)
- **Red:** Sufficient data, but some deviate from expectations; there are fewer than 3 taps within the expected value range. *This is NOT necessarily an error; unusual data can also be correct.*

Example:



In the image, MP11 (equipped with Sensor 6) has received sufficiently **good data** from TapP1. Signals **from TapP2 have been received, but the number of taps is insufficient**. The data from TapP3 is **outside expectations** (at least 1 tap either has too large a deviation from the mean or is outside the absolute velocity limits), and there are **no measurement values** from all other TapPs.

- **Sensor Storage:** All unassigned sensors are found here.
- **Workspace Area:** Various editing options are offered here, depending on the display form and assignment method.



Start Measurement: Establishes a Bluetooth connection to the sonic tomograph and initiates a measurement. Switches to the measurement data view, where all sound paths are displayed from the perspective of the TapP.



Measurement Data View: Displays all sound paths from the perspective of the TapP (see also [8.5.5 Conducting the Sonic Measurement](#)), but without an active connection to the sonic tomograph. Useful for reviewing the raw data of each tap after the measurement and identifying and deleting any faulty taps if necessary.

- **Sensor Allocation:** There are 3 different modes that can be switched between using the Allocation Mode button:



Section-wise: All sensors are placed on adjacent BP, and the rest of the BP remain free.



Alternating: The sensors are evenly distributed around the tree, with SP and free BP alternating as evenly as possible.



Free Arrangement: All sensors can be freely assigned.



Next arrangement or **previous arrangement** switches between different sensor arrangements in the case of section-wise or alternating arrangements.



In the case of free arrangement **Remove sensor allocation** or **Remove all sensor allocations** detach the sensor(s) from the TP and returns them to the sensor storage.



In free arrangement, **place sensors** will assign all remaining sensors from the sensor repository in ascending order from a selected TP up to the last TP.



Show TP Numbers: Displays the assigned number for each TP. Numbers can take up a lot of space on smaller displays and can be hidden. TP1 is easily identifiable even with hidden numbers (triangle instead of dot).



Show Sound Paths: For better clarity, the color-coded sound paths in the graph can be hidden. In the case of free arrangement, sound paths must be hidden before sensor assignment can take place (switches from "select this point" to "attach to this point").



Reset deletes ALL existing measurement data within the sonic measurement node.



Legend displays an info window briefly describing the interface.

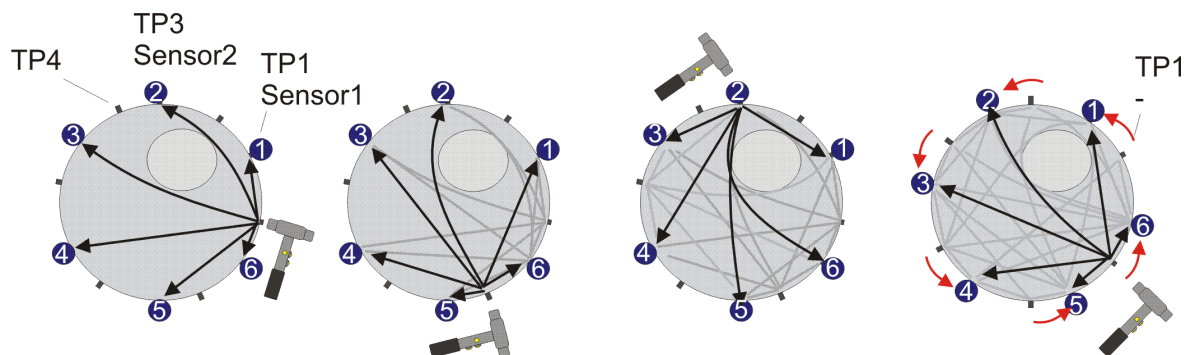
In all variants, sensors are to be positioned in ascending order and counterclockwise around the tree (analogous to the assignment of TP numbers).

Section-wise and alternating arrangements differ only when the number of TPs is greater than the number of sensors. If this is not the case, simply attach one sensor to each TP, while the rest of the sensors remain unused in the sensor storage.

In free arrangement, it may still be useful to replicate one of the other variants, as each has its own advantages. In the following sample arrangements, the image on the far right in each case shows how the sensors should be rearranged systematically for all TPs.



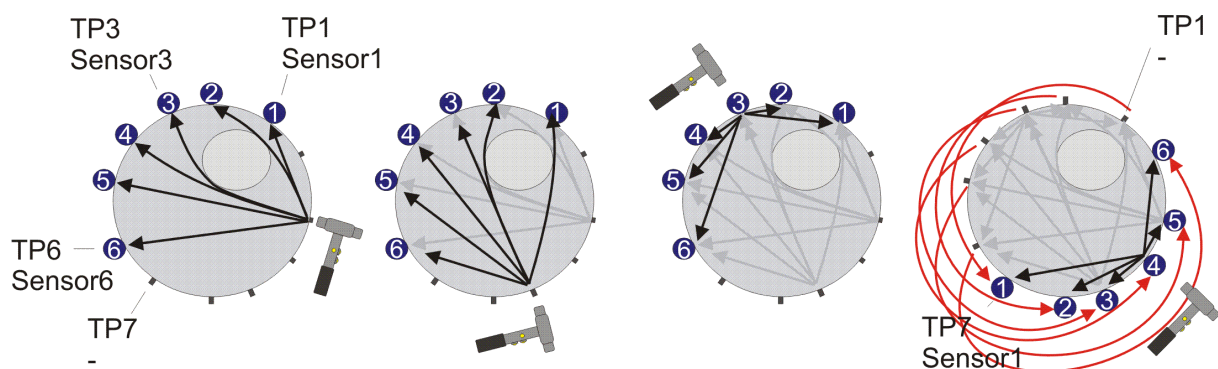
Alternating arrangement: If the cables are long enough, the "one sensor - no sensor" arrangement can be used. This approach is very effective, as often a meaningful image can be calculated after the first tapping round.



If the number of TPs does not represent a whole ratio to the number of sensors (e.g., 20 TPs - 12 sensors or 10 TPs - 6 sensors), the sensor count is automatically reduced for an even distribution.

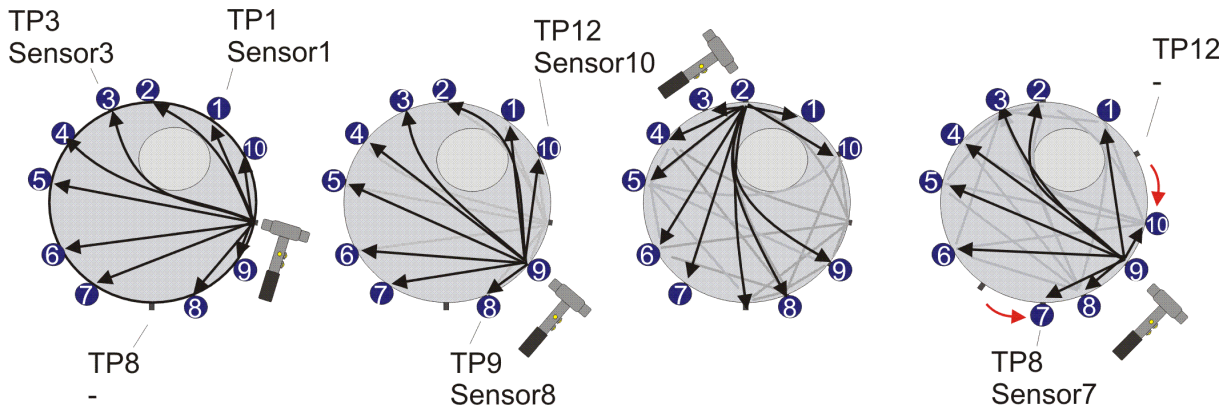


Install sensors section-wise: If the tree circumference is too large for the alternating method, the trunk can be measured section by section. If necessary, when moving in the last tapping round, the number of sensors is automatically reduced.

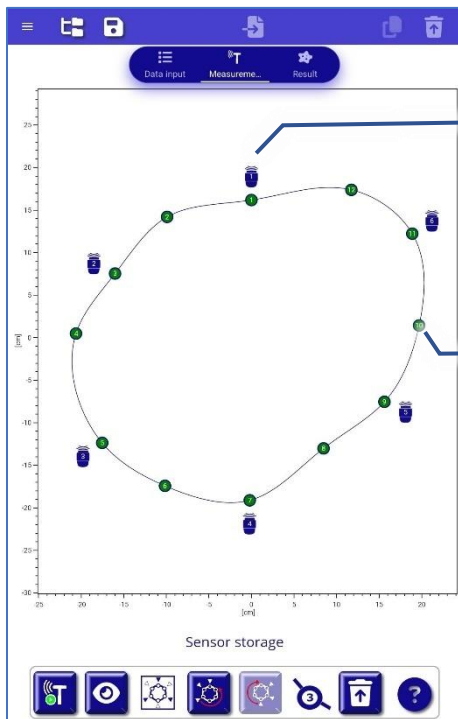




Number of sensors is only slightly smaller than that of TPs - **Free arrangement**. In this case, it is advisable to distribute the positions of TPs without sensors so that the unmanned measurement points are not next to each other. In many, but not all (!), cases, the measurement result is already good after the first tapping round. If only a portion of the sensors needs to be moved, the other sensors can remain in their original positions. They do not need to be removed from the chain.



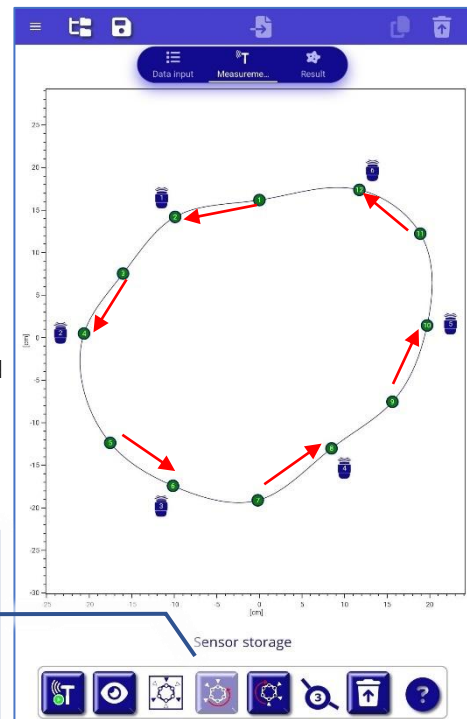
The assignment of sensors is automatic in section-wise and alternating arrangements. The relocation of sensors is done with a simple button press on the **next arrangement** or **previous arrangement** buttons.



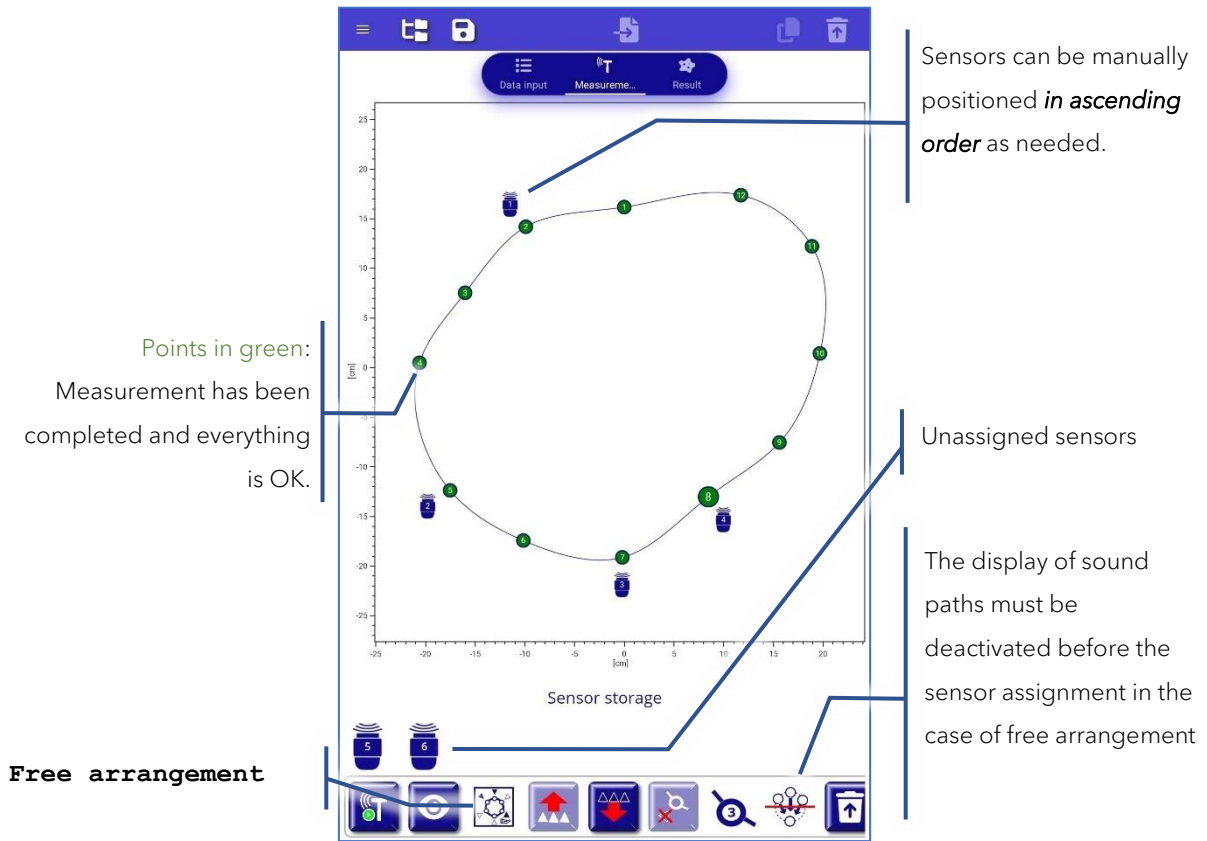
Alternating arrangement in the graphic view

Points in green: Measurement has been completed and everything is OK.

With **next arrangement**, all sensors are moved to the next TP.



In the case of free arrangement, each sensor is assigned manually. To do this, a sensor is first selected in the sensor storage (highlighted in green), and then the TP to which the sensor should be assigned is clicked. Assignments where the sensors would no longer be placed in ascending order are not possible. If the sensor is assigned to a TP that already has another sensor, to make room, all originally placed sensors are moved by one TP (if necessary).



8.5.5 Conducting the Sonic Measurement

Steps completed so far:

- Visual inspection of the tree and determination of the measurement plane
- Nails (tree points) placed in the measurement plane
- Numbers attached to the nails
- Geometry recorded
- Device attached to the tree
- Sensors positioned and assignment entered
- Optional: *Cable installed between PiCUS Sonic Tomograph and PC*

Note: The process of conducting the sonic measurement with PST 3 is also explained in the [vx.x PiCUS Sonic Tomograph 3 Hardware Manual XX.pdf](#) (Stand-alone operation without the app or PC).

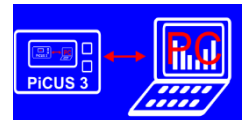
Before starting the measurement, the PST 3 must be turned on and ready to receive:

Activate PC measurement mode in the PST 3.

- **Sonic Tomogram (PC) -> Connect to PC**

- PST 3 will display:

- **Searching for Hammer...**
- **Searching for PC (BT - USB) ...**



- The PST 3 will automatically detect the Hammer (PRHD) in cable mode.
- In wireless mode, press the button on the Hammer (3 seconds) to turn it on.
- The PST 3 will also automatically detect whether the PC or mobile device wants to establish a connection via Bluetooth or USB.
- Once both connections are established, the PST 3 is ready for the sonic measurement.



In the software, the connection is established by clicking on **Start Measurement**.

Upon successful connection, the view switches to the measurement data view.

At the top of the view, there is a status display for the PiCUS Sonic Tomograph:



Connection Quality: The signal strength of the Bluetooth connection is represented in a bar graph.



Battery Level: The battery icon indicates the current charge level of the Sonic Tomograph. If the Status indicator is grey the charge level has not yet been communicated, that will automatically happen once communication resumes during tapping.

Tapping Point Status: It displays the currently selected tapping point and its status.

- Grey: No data
- Orange: There is data, but not enough, fewer than 3 taps.
- Green: There is sufficient data within the expected value range
- Red: Sufficient data, but less than three taps within the expected limits (at least 1 tap has either a too large deviation from the mean or is outside the absolute speed limits). *The data is unusual but not necessarily incorrect.*

Unlike during sensor assignment, while tapping, the status display is from the sender's perspective. This means it indicates whether the taps at the current point were received by the sensors.

To identify measurement errors and outliers cleanly and to obtain the most accurate measurement value through averaging, at least three taps are made at each TapP.

It is recommended to tap at least five times at each point for increased statistical reliability and to be able to remove individual poor measurements afterward without falling below the required minimum of three taps.

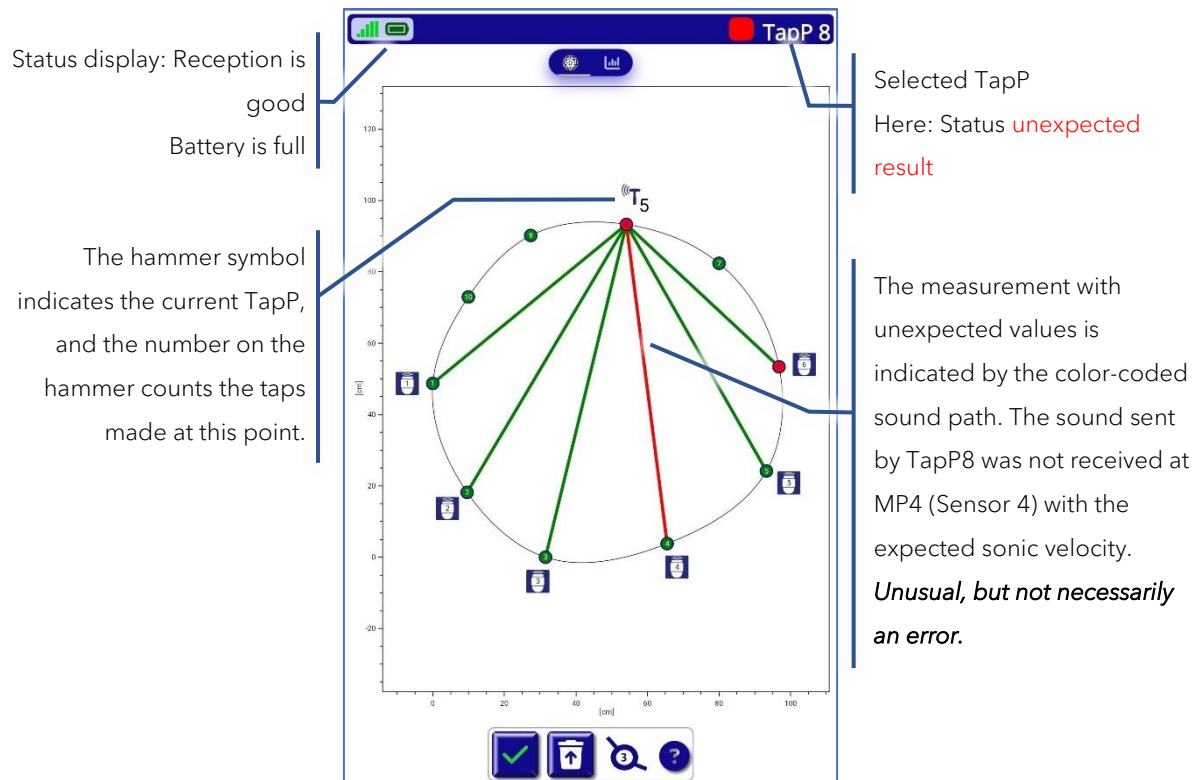
Possible sources of interference that can distort the measurement include dirt between the nail and sensor, flipped or poorly fitting sensors, poorly positioned cables hitting the sensors, heavy traffic on immediately adjacent roads, or natural cracking in the tree itself due to natural movement in the wind.

The central element of the tapping view is the measurement view, either as a graphic or as a list of diagrams.

In the graphic, the geometry and the assigned sensors are displayed.



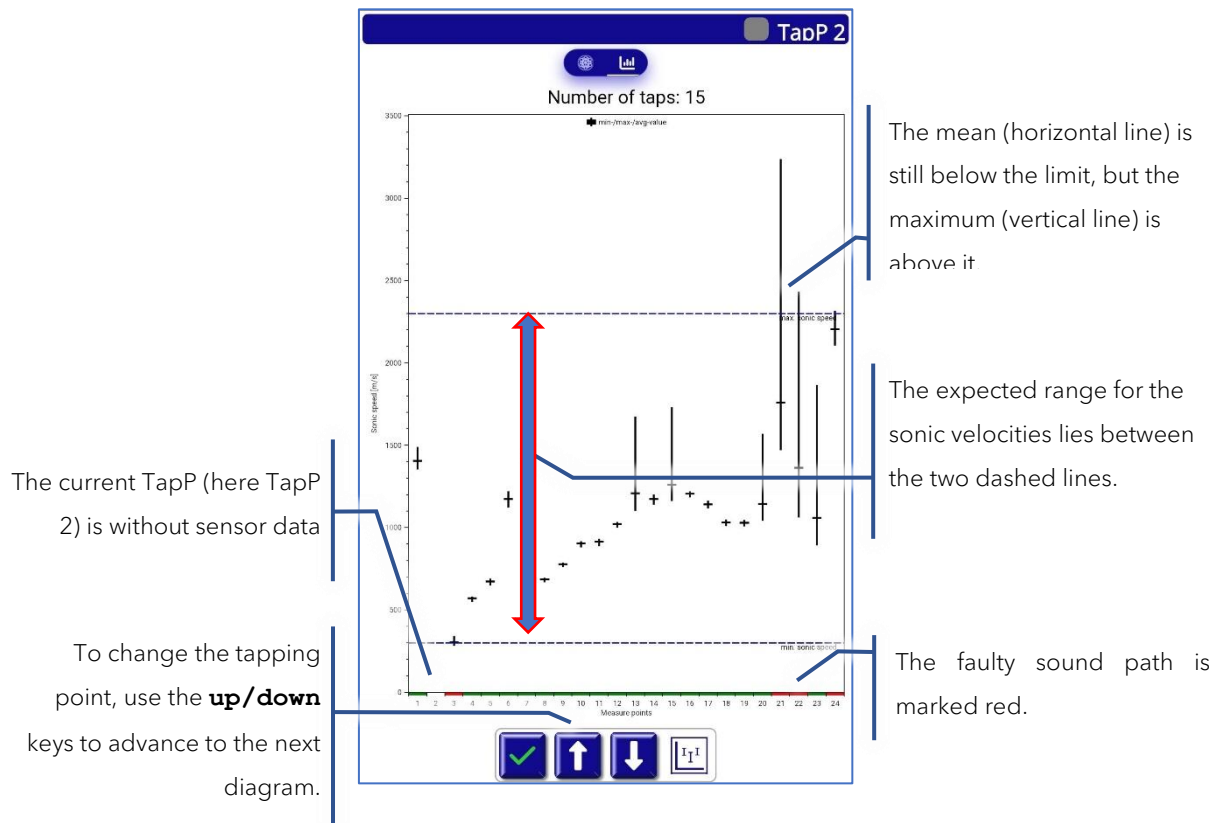
The hammer symbol is on the currently active tapping point, and the number on the hammer symbol indicates how many times tapping has been done at this point. The sound path from the tapping point to each mounted sensor is color-coded and displayed.



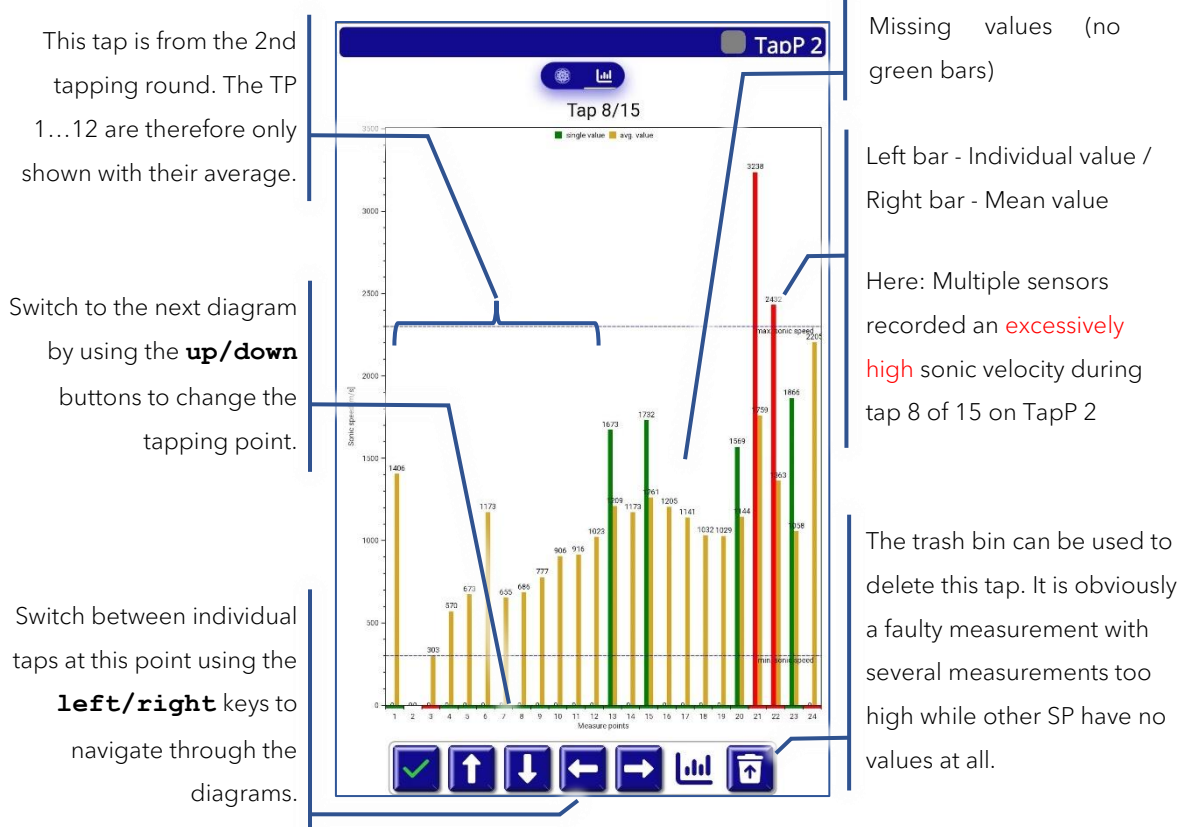
For a detailed display of the measured sonic velocities to the sensors, switch to the diagram view. The diagram view offers 2 possible display formats, between which you can toggle with a button in the workspace:



Averaged Representation: Here, you will find a separate diagram for each tapping point, displaying the mean values (horizontal lines), minima, and maxima (vertical lines) of the measured sonic velocities for each sensor.



Single Value Representation: Instead of showing all taps at a tapping point only through mean, minimum, and maximum in a common diagram, the Single Value Display creates a separate diagram for each individual tap. After navigating vertically to the tapping point, you can switch horizontally through the taps already recorded. The display shows the individual value of the tap and the mean value across all taps at the selected tapping point.



What both diagrams have in common is the display of the permitted range for the sonic speeds with blue dashed horizontal lines, and the color-coded status display for each sound path/sensor that can be found under the X-axis. If a sensor is temporarily removed from the nail in order to be able to knock, the status display for this sensor remains white.

Below the measurement view, the workspace dynamically adjusts to either the graphic or diagram view:



End tapping round / Exit measurement view: Ends the current measurement, disconnects from the PiCUS Sonic Tomograph, and exits the measurement view.



Delete tap: Removes the last made tap at the currently selected TapP from the measurement data if the averaged representation is selected.

Removes the currently displayed tap in the single-value representation. Can be called multiple times to remove multiple faulty taps.



Show TP Numbers: Displays the assigned number for each TP. Numbers can take up a lot of space on smaller displays and can be hidden. TP1 is easily identifiable even with hidden numbers (triangle instead of dot).



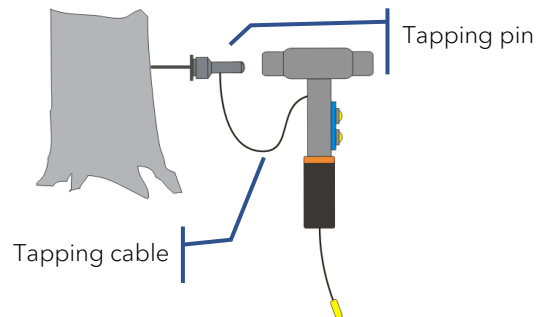
Averaged or Single Value Representation: Switches between the different diagram views described above.



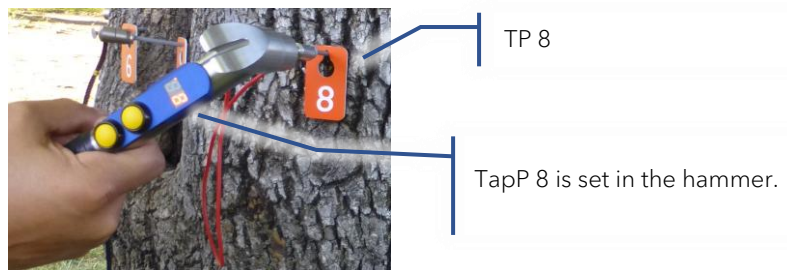
Legend displays a brief overview of the status information in the graphic view.

As soon as you are in the tapping view, meaning the connection has been successfully established, you can tap to record measurement values.

- **Place the hammer on a tapping point:** Place the tapping pin on a nail. Remove the sensor if necessary.



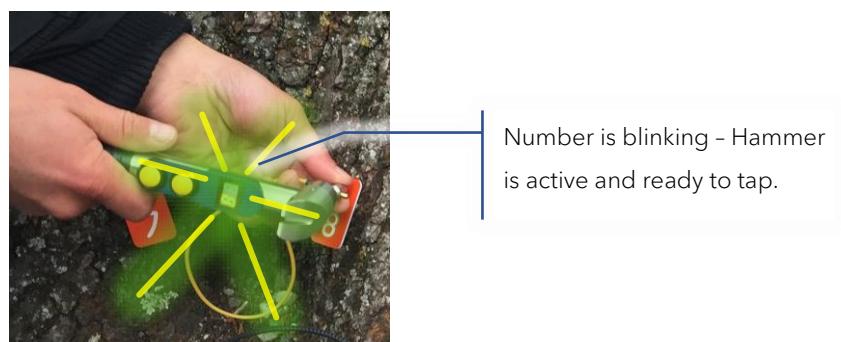
- **Set TapP:** Use the control buttons on the hammer to set the correct TapP number of the tapping point. It must always be set to the TP number indicated by the number plate.



Alternatively, the tapping point can also be selected in the software, either by tapping on the point in the graphic or by scrolling to the row with the corresponding diagram.

ATTENTION: *Incorrect sensor-BP assignment leads to unusable measurement values!*

- **Establish readiness to measure:** The hammer is only ready to measure when the displayed number is blinking!!! If the number does not blink or does not light up at all, the hammer is not active and must be activated again by pressing the button. Pay attention to the displayed number on the hammer display. Although the hammer queries the current TapP in the software after reactivation, it is not always guaranteed that the communication *IML Tree Inspection software - PST 3 - PRHD* is working flawlessly immediately after leaving the idle state. Change the TapP if necessary to synchronize the app and the hammer.



- **Wait for signal transmission:** After generating a signal, the hammer display shows circling lines. During this time, the data is saved and/or transmitted to the PC or mobile device. If a number is displayed again after about 1 second, tapping can resume. If the circling stops, there is a disruption in the connection between the hammer and PiCUS or between PiCUS and the PC/mobile device. Adjust the position of the hammer or device and press the buttons until a number is displayed again.



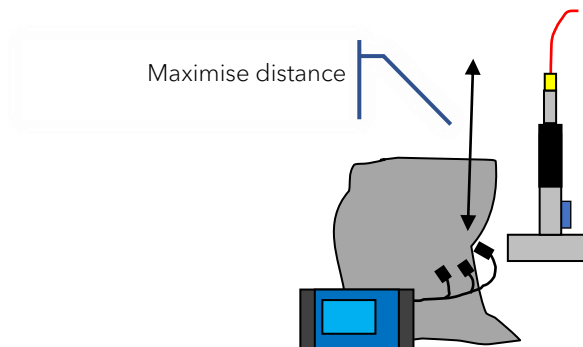
Circling lights - hammer is NOT ready to measure

- **Repeat measurement:** Tap at least three times on each (!) TapP. In the diagram view, the quality of the measurements can be checked. On the hammer, a glowing dot in the upper left of the display indicates that there are enough measurements available.



Measurement finished at this point (min 5 taps)

- **Caution,** please note the following instructions:
 - Do not touch other sensors with the cable or antenna while tapping.
 - Do not hold the antenna of the PiCUS 3 hammer directly next to the sensor cables.



- **Put the sensor back on the nail:** After a successful measurement at a point, the sensor must be placed back on the nail.
- **Continue the measurement:** Continue the measurement at the next TapP. Tapping will be done at all points, including points without sensors!

The following steps need to be performed only if more measurement points are used than there are sensors available.



End tapping round: After tapping at all KPs, the tapping round is concluded with the **End tapping round** button, and the connection to the PST 3 is temporarily disconnected.



Move sensors: In the software, switch the sensor assignment to the next tapping round, or manually reassign the sensors by placing them on BPs that did not have sensors before. Similarly, physically move the sensors on the tree to new nails.



Start next tapping round: You can now reestablish the connection to the PST 3 by pressing **Start Measurement** to continue with the next tapping round.

8.5.5.1 Hammer position

The hammer position must be adapted to the situation: In narrow spaces, it is often easier to hold the hammer vertically to be able to tap well at low points. In addition, the antenna or the hammer cable cannot collide with other sensors in this position.



The antenna is far away from the sensor cables.

Point is in a recess: Hold the hammer vertically to tap.

The tapping cable should also not come into contact with neighbouring sensors.



Hold the hammer loosely.
Short snappy taps are easier that way.

Antenna is far away from the sensor cables.

Tapping cable has no contact with other cables.



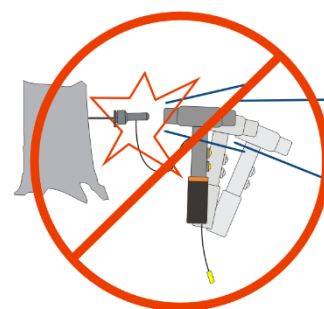
The antenna is far away from the sensor cables.

Hold the hammer upside down and allow it to "swing" as you knock. A consistent signal can be generated by swinging.

8.5.5.2 Tapping strength

The tapping strength should be kept low as the PiCUS sonic sensors are very sensitive and respond to the slightest vibrations. High tapping strength can also drive the nails further into the trunk. Avoid bouncing the hammer multiple times in quick succession on the tapping point.

It is crucial to tap evenly.



8.5.6 Result Display and Tomogram Preview

After completing a tapping round, a preliminary evaluation of the tapping results can be performed in the **Result** tab.

The Result tab is divided into 2 sections:



The **bar charts** provide a graphical overview of measured sonic transit times and sonic velocities.

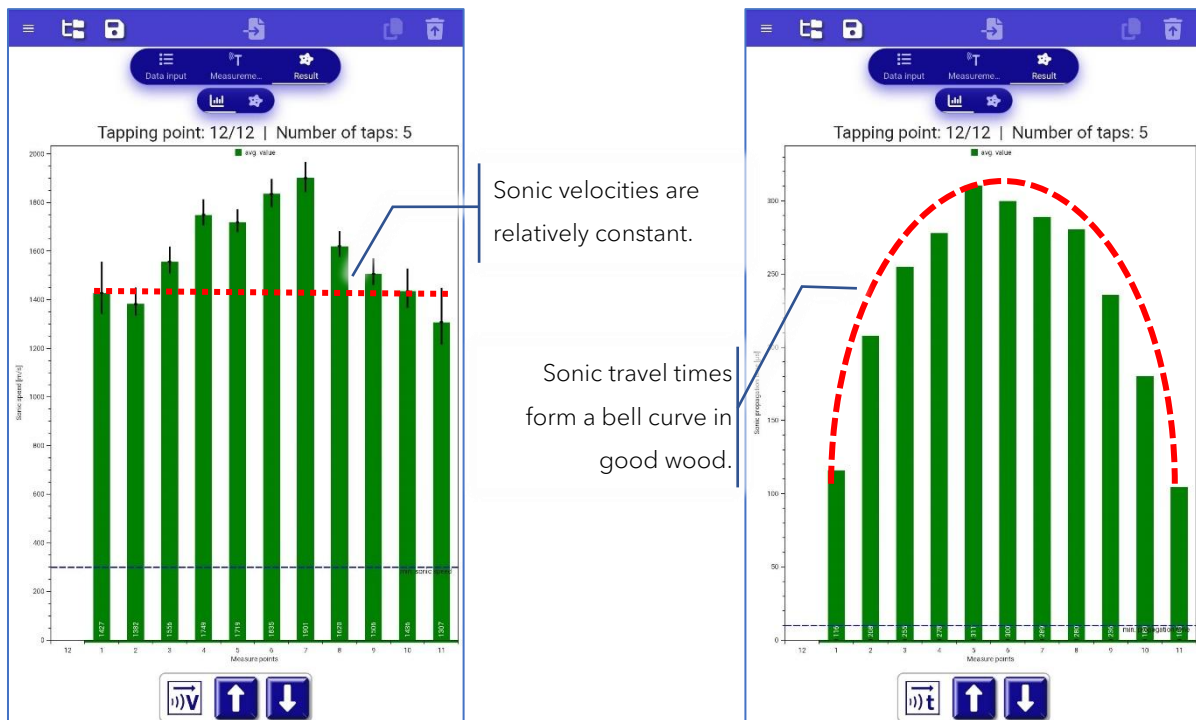


The **preview tomogram** shows a simplified calculation result.

In the diagram display, both sonic travel times and sonic velocities for each TapP can be represented as bar charts. The individual sensors are shifted so that the TapP is always in the first position (without distorting the order of the sensors on the tree). It is possible to switch between the diagrams.

In case of homogeneous sound transmission properties and a circular geometry uniformly equipped with sensors from all sides, a straight line results for sonic velocities ($v = \text{constant}$ throughout the cross-section), and a bell curve is observed for sonic travel times (distances and travel times increase up to the point exactly opposite and then decrease in the second half of the circle).

In practice, the measured values may deviate more or less from this pattern, as wood is not a homogeneous material, and irregular geometries and tree defects can further alter the results (see also [8.7.2 Theory of Sonic Velocity Measurement](#)).



The button in the diagram's workspace toggles between display modes:

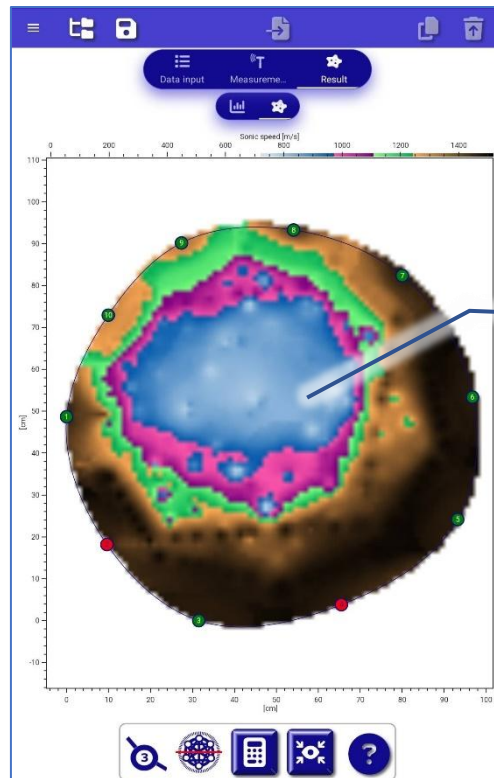


Currently displaying sonic velocities.



Currently displaying sonic travel times.

In the tomogram view, a preliminary tomogram is calculated from the measurements taken so far. Standard values set in the settings (see also [4.4.4 Calculations](#)) are *NOT* used. It is not possible to modify the parameters used for calculation or exclude individual faulty measurements from the calculation in the sonic measurement node. These and other analysis options are only available in the sonic analysis node (see also [8.7 Tomogram Evaluation and Interpretation – Sonic Analysis Node](#)).



The preliminary tomogram is always calculated with reduced accuracy. Further calculation options are only available in the analysis node.

The workspace of the tomogram display offers the following options:



Show TP Numbers: Displays the assigned number for each TP. Numbers can take up a lot of space on smaller displays and can be hidden. TP1 is easily identifiable even with hidden numbers (triangle instead of dot).



Show Sound Paths: All recorded sound paths are displayed in the tomogram. The location of the intersection points and the tomogram can be used to estimate whether the BP is strategically placed, whether another tapping round is necessary (in the case of alternating sensor arrangement), or whether additional tree points need to be inserted into the geometry (see also [8.3.2 Tree Point Positions for Sonic Tomography - Attaching the Nails](#)). The sound paths are coloured according to their average sound velocity. Higher velocities are represented darker, and lower velocities are brighter.



Recalculate Tomogram: Performs a recalculation of the tomogram preview. If the tomogram calculation with the given parameters is not informative enough, an evaluation can also be done in the sonic analysis node using additional options. The measurement in the sonic measurement node can then be continued at a later time.



Scale Geometry: Adjusts the zoom level and shifts the graphic so that the entire geometry is visible, fully utilizing the available display space. Alternatively, the graphic in the app can be scaled and moved using *touch gestures*. On the PC, the graphic can be *moved with the right mouse button* and the *zoom level adjusted with the mouse wheel*.



Legend: Displays an info window briefly describing the interface.

8.5.7 Dismantling the Measurement Equipment from the Tree

The dismantling of the equipment should only be carried out after evaluating the tomogram. It must be ensured that the number and position of the measurement points are sufficient and that no incorrect data have been recorded.

After the measurement, the coupling nails must be removed from the tree. The head of the PRHD is designed as a fork that can be used for nail removal if no other tools are available.

The handle of the soft hammer should be used to create a lever point if necessary.



Caution: Only apply moderate leverage forces! The hammer contains sensitive electronics. Strong bending or severe shocks can damage the hammer.

8.6 Electrical Resistance Measurement - The Resistance Measurement Node

In the resistance measurement node, a measurement plane, i.e. a measured geometry, is measured with the PiCUS TreeTronic 3.

8.6.1 Data Entry

Basic information about the measurement and device configuration can be entered in the Data Entry tab. The following information can be edited in the Basic Data section:



Name of measurement: The freely selectable name is displayed in the project tree structure and referenced by the resistance analysis node (see also [7.1.5.4 Electrical Resistance Measurement Node](#)).



Select geometry: A geometry node must be selected in which the resistance measurement is to be performed. All geometries contained in the inspection node are displayed in this selection menu. Geometries located in other inspection nodes, tree nodes or projects are not offered for selection. It is possible to select the same geometry in multiple resistance measurements. If measurement data has already been recorded in the resistance measurement node, the linked geometry may not be changed under certain circumstances. See also [8.4.9 Subsequent Changes to Geometries](#).



Comment: A free text field in which comments on the measurement process can be stored.

In the Device Data section, the serial number of the last PTT 3 used in this measurement node is displayed under **used PiCUS Tomograph** for documentation purposes



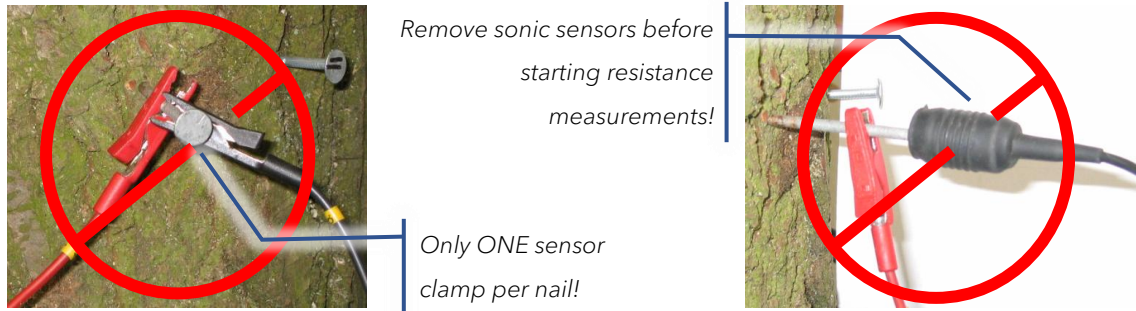
Number of Sensors: This field is used to specify whether one (12) or two (24) measurement chains are to be used. This setting affects the number of sensors that can be assigned to the individual TP.

8.6.2 Mounting the Measurement Equipment on the Tree

Once the geometry of the measurement plane has been fully recorded in the geometry node, the PTT 3 can now be mounted on the tree. The blue tension strap can be used to attach the device to the tree if the measurement plane is more than ≈ 30 cm above ground level.

- The PTT 3 main control unit is placed between TP 12 and 13.
- The red sensor cable harness with terminals 1 to 12 is plugged into the left socket A (**1-12**).
- The blue sensor cable harness with terminals 13 to 24 is plugged into the right socket B (**12-24**).
- Connect the terminals to the nails. Ensure that the numbers are in the correct order; the red-black-red sequence of the cables helps to avoid errors. An incorrectly attached sensor will always result in incorrect data.

- *Attention: Do not attach more than one electrode to a nail.*
- *Attention: If necessary, remove the sonic sensors (PiCUS sonic tomograph) from the nails! The high voltage from the TreeTronic can damage the sonic sensors!*



Ensure that the nails are free of rust or dirt. Good electrical contact between the nail and the sensor clamp is essential for accurate measurement. If necessary, use the abrasive cloth from the nail box to clean the contact surfaces.

8.6.3 Measurement Points and Sensor Clamps

PiCUS resistance measurement distinguishes between tree points (TP – the nails in the tree) and measurement points (MP – a TP for which measurement data was recorded) on the one hand, and sensor points (SP – a nail to which a sensor is also attached) on the other.

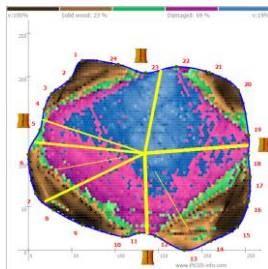
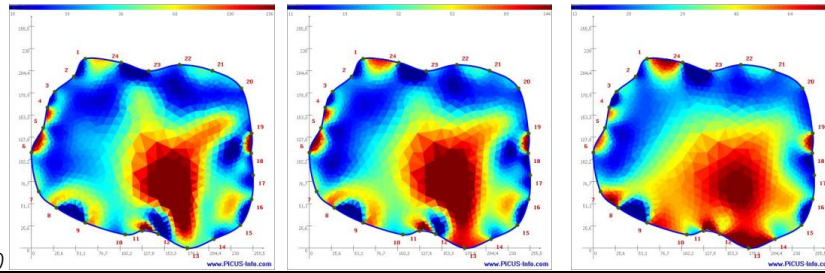
With PiCUS resistance measurements, more tree points/measurement points can be used than sensor clamps.

This technique allows, for example, a PTT 3 with 12 or 24 terminals to be used to obtain complete tomograms of trees that require 14, 30 or even 50 or more measuring points.

This is achieved by moving the sensor clamps and repeating the measurements. Each measurement covers part of the measurement plane. The aim is to create as many overlapping areas as possible in order to then calculate a complete tomogram covering the entire cross-section from the partial tomograms measured in this way.

A detailed explanation of how to move the clamps during resistance measurements and the restrictions that apply

can be found in Chapter 0



Smoothing = 1

Smoothing = 3

Smoothing = 20

SoT

Moving Measurement Points.

8.6.4 Sensor and Measurement Point Assignments

Since the PTT 3 (or the IML Tree Inspection software) does not know on which TP the sensors are placed, the assignment of the sensors to the tree points must be entered in the software before the measurement.

For standalone measurements with the PTT 3 (without IML Tree Inspection software), relocation is not possible and the number of TP is limited to 24.

Attention: The correct assignment of the sensors to the measuring points in the software is crucial for a correct tomogram.

If the sensor assignment is correct and all sensors are positioned correctly on the nails, measurement can begin.

The number of available sensors (one or two sensor chains) has already been set under **Data Entry**. The sensors are assigned in the **Measurement** tab.

The Measurement tab is divided into two areas:

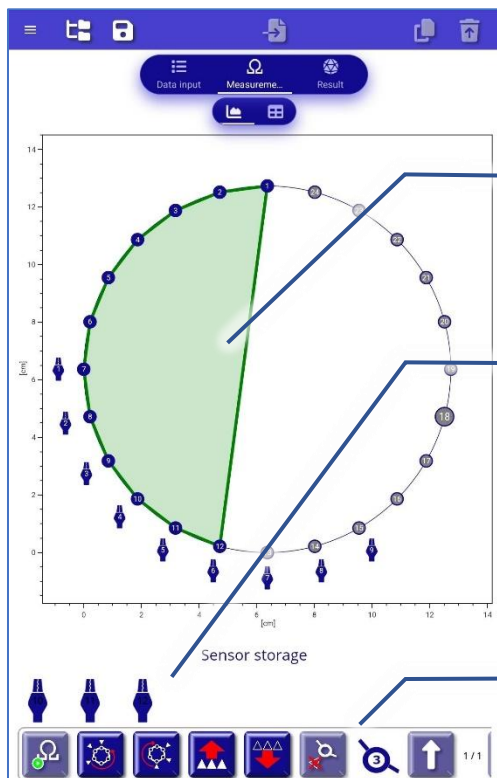


The **graphical view**, in which sensor assignment and measurement execution take place and the sections already measured are displayed.



The **measurement value display**, in which the measurement values of the individual partial measurements are displayed in tabular form.

The **graphical view** is divided into the **status display**, the **sensor storage** and the **toolbar**.



Status display: the geometry and the assignment of the sensor clamps are shown graphically here. The green areas show areas of the geometry that have already been measured.

Sensor storage: all unassigned sensor clamps can be found here.

Toolbar: Here, individual partial measurements can be started, selected for display or deleted. In addition, the assignments of the sensor clamps can be adjusted via the toolbar.

The individual elements of the toolbar have the following functions:



Start measurement: this button starts a measurement cycle (see also [8.6.5 Performing a Resistance Measurement](#)).



Assign all sensor clamps: after selecting a TP in the graphic, this button can be used to place all sensor terminals in ascending order, starting counterclockwise from this TP. The terminals are also positioned beyond the last TP if the first TP still has no sensor assignments. If there are more sensor terminals than tree points, the excess sensor terminals automatically remain in the sensor store.

Sensor clamps can also be assigned individually by first selecting them in the sensor storage and then assigning them to a tree point.



Remove all sensor clamps: cancels all assignments and returns all sensor clamps to the sensor storage.



Remove individual sensor clamp: simply removes the assignment of the sensor clamp to the selected BP and returns the sensor clamp to the sensor storage.

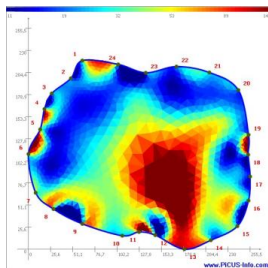
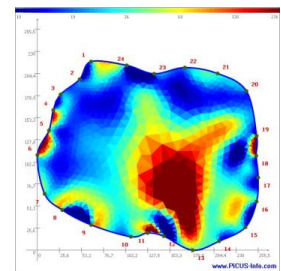


Show TP numbers: displays the assigned number for each TP in the graphic. The numbers can take up a lot of space on smaller displays and can therefore be hidden. TP1 is easy to identify even when the numbers are hidden (triangle instead of dot).

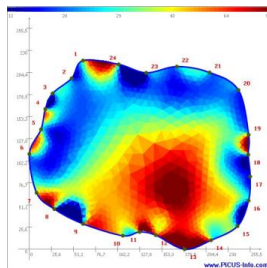


Cycle through measurements: Use the arrow buttons to cycle through the individual partial measurements in both the graphical and tabular views. In the graphical view, each partial measurement is framed by a green area with all MP involved. The aim is to cover as much of the entire

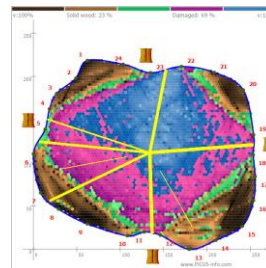
trunk cross-section as possible with these green areas (see also [0](#)



Smoothing = 1



Smoothing = 3



Smoothing = 20

SoT

Moving Measurement Points).



Delete this measurement: Deletes the selected partial measurement.



Delete all measurements: Deletes all existing partial measurements and thus resets the measurement node to its initial state.

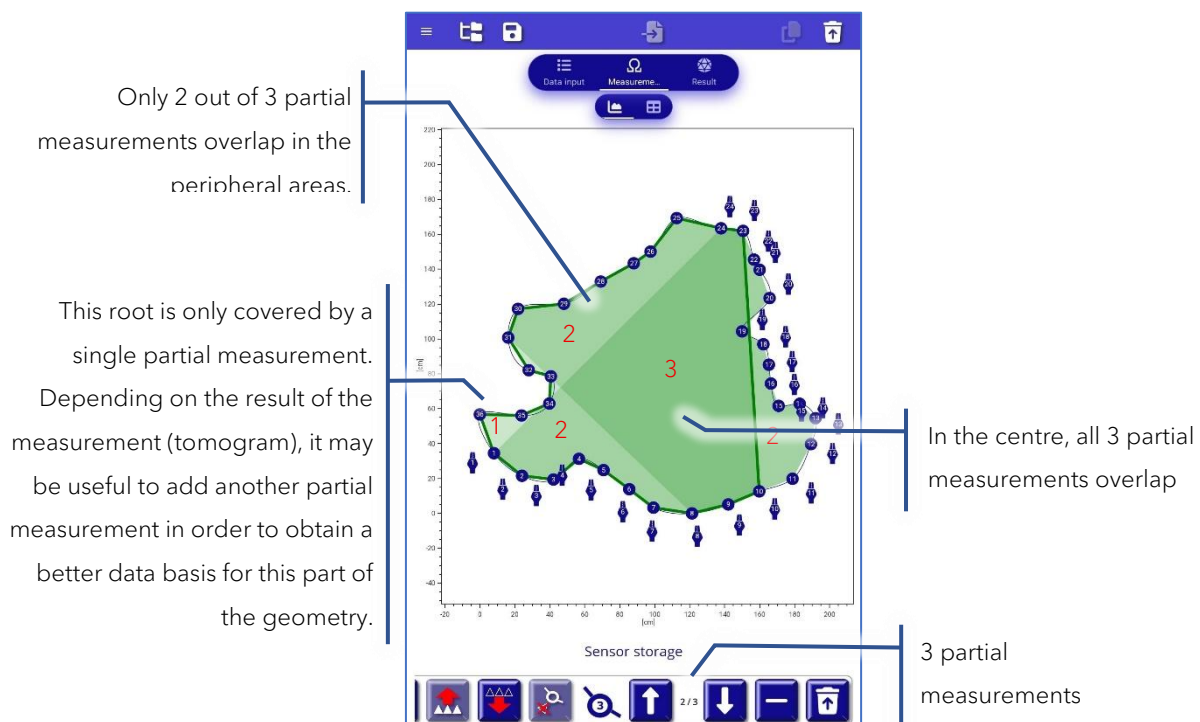
8.6.5 Performing a Resistance Measurement

The actual measurement process is almost completely automated with the PTT 3. When **Start measurement** is selected, the following steps are performed automatically

- A connection to the device is established
- All necessary measurements for the selected sensor assignment are processed
- The measurement results are read out from the PTT 3
- The connection to the device is disconnected
- The measured values are analysed for possible contact problems at the nails

After the measurement, the measured area of the geometry is highlighted in transparent green in the status display. Areas of the geometry that have been measured multiple times are displayed darker due to the overlapping of several of these areas.

The following example shows the implementation for a tree with 36 measuring points:



In addition, the recorded measured values are checked for plausibility. If contact problems are detected during this check, the corresponding tree points and the connecting lines of the relevant terminal pairs are marked in colour.

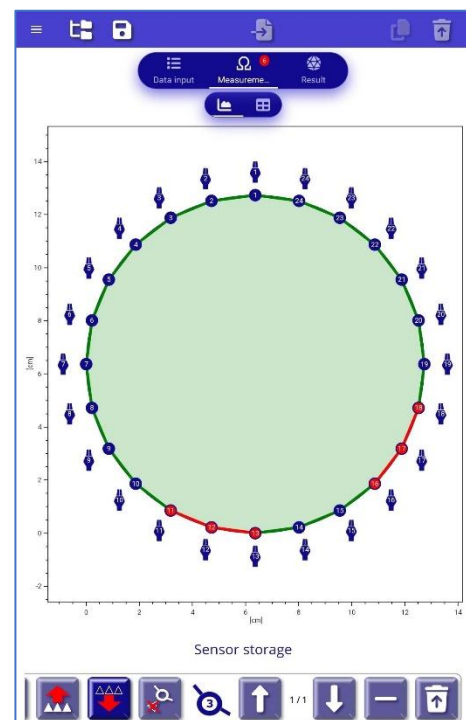
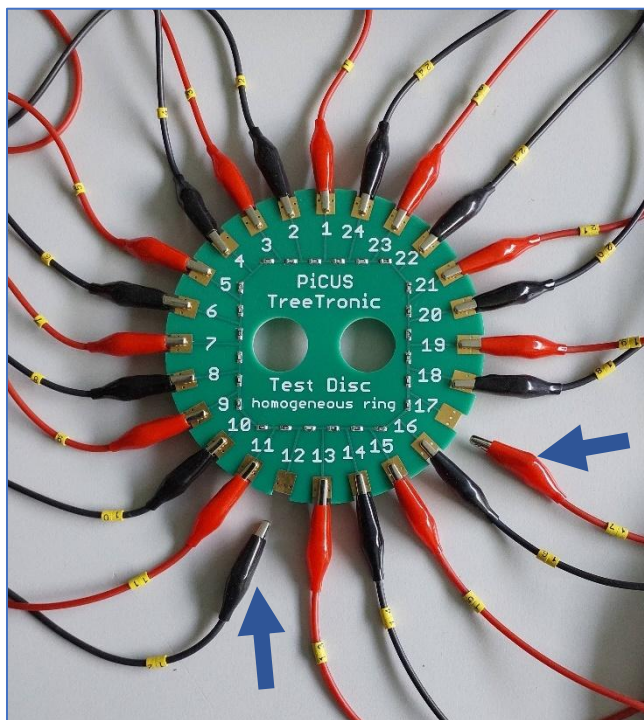
The following applies to the connecting lines:

- Grey: this terminal pair is deactivated as a connection point
- Green: no error detected
- Red: there is a contact problem with the connection at this terminal pair

The following applies to the tree point colours:

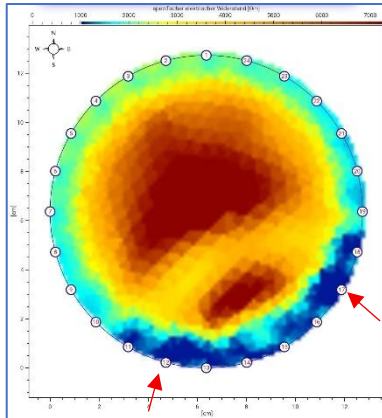
- Grey: the BP has not yet been measured
- Blue: the BP has been measured in at least one partial measurement
- Red: a contact problem is suspected at this BP during feed-in

For technical reasons, several points are always marked, as a nail with contact problems is always part of two terminal pairs, and it is not possible to determine clearly whether only one or both nails of a terminal pair are problematic. In the following example, contact problems at terminals 12 and 17 are simulated by not connecting all terminals to the test disc. In the status display, terminals 11-12-13 and 16-17-18 are marked in red together with the lines between them.



In the tabular representation of the measurement results, the current and voltage measurements that were identified as faulty are also highlighted in colour.

If a contact problem is detected, the nails at the affected tree points must be checked for correct fit (completely through the bark with good contact to the heartwood) and the clamps must be checked for good electrical contact (no corrosion or contamination on the nail).



Once the errors have been corrected, the measurement should be repeated. If the subsequent measurements also show errors at the affected TP, it can be assumed that the 'error' is instead due to particularly poor wood properties of the tree (e.g. complete encapsulation of a trunk area by cracks). In such a case, the tomogram can still be calculated. The problematic TP is automatically ignored. However, the reliability of the tomogram may then decrease. The tomogram for the above example with missing contact at TP 12 and 17 is shown on the left.

The tabular representation of the measurement results contains the following columns:

- **A** and **B**: the terminals at which the current **I [mA]** is fed in.
- **M** and **N**: the terminals at which the voltage **U [V]** was measured.
- **PWM**: a dimensionless value that documents the control signal of the current source in the PTT 3. This parameter is usually only relevant for fault diagnosis and can normally be ignored.

8.6.5.1 Deactivating Sensor Clamp Pairs

After measurement, individual terminal pairs can be deactivated as feed points. This process can be carried out separately for each partial measurement. To deactivate a terminal pair, either click on one of the lines that has this terminal pair in columns **A** and **B** in the measurement value table of the partial measurement (in the **Measurement** tab), or click directly on the connecting line between the two relevant points in the graphical status display (the line is then greyed out).

The measured values are not deleted and can be reactivated at any time.

8.6.6 Result Display and Tomogram Preview

The Results tab summarises the measurement results of all partial measurements and calculates a preview tomogram.



The tabular overview summarises all combinations of feed-in and measurement point terminal pairs.

- **A** and **B**, as well as **M** and **N**, are again the feed-in and measurement points
- **U/I [Ω]** is the quotient of the fed-in current and the measured voltage. This pseudo-resistance (U and I are *not* measured at the same point) is the average value across all partial measurements carried out on the respective terminal combination.
- **Discrepancy [Ω]** is the maximum deviation from the average value for **U/I [Ω]**.



The preview tomogram calculates a simple view using the standard parameters, which allows a rough assessment of the measurement result and can be used as a basis for deciding whether to perform additional measurements. For a detailed analysis, the tomogram must be recalculated in the resistance analysis node. There, the calculation parameters can also be individually adjusted (see also [*8.8 Tomogram Evaluation and Interpretation – Electrical Resistance Analysis Node*](#)).

Only the following options are available in the toolbar of the tomogram preview:



Show TP numbers: displays the assigned number for each TP in the graph. The numbers can take up a lot of space on smaller displays and can therefore be hidden. TP1 is easy to identify even when the numbers are hidden (triangle instead of dot).



Recalculate tomogram: recalculates the tomogram preview. If the tomogram calculation with the given parameters is not meaningful enough, an evaluation can also be performed in the resistance analysis node using additional options. The measurement in the resistance measurement node can then be continued at a later point in time.



Scale geometry: Adjusts the zoom level and moves the graphic so that the entire geometry is visible and the available space in the display is fully utilised. Alternatively, the graphic in the app can also be scaled and moved using *touch gestures*. On a PC, the graphic can be *moved with the right mouse button* and *zoomed with the mouse wheel*.

8.6.7 Dismantling the Measurement Equipment

The device should only be removed after the tomogram has been evaluated. It must be ensured that the number and position of the measuring points are sufficient and that no incorrect data has been recorded.

After the measurement, the coupling nails must be removed from the tree. To do this, either the PRHD (see [*8.5.7 Dismantling the Measurement Equipment from the Tree*](#)), if available, or the pliers from the PTT case can be used.

8.7 Tomogram Evaluation and Interpretation – Sonic Analysis Node

8.7.1 General Guidelines

The measurement results of the PST 3 require interpretation by qualified professionals.

The sonic tomogram does not determine whether a tree is safe or not.

Conclusions about the tree's condition, derived from sonic tomograms, are the sole responsibility of the interpreter.

Neither the device manufacturer nor the seller can be held liable for consequences arising from the interpretation of the tomogram.

The PST 3 detects differences in the wood's ability to transmit sound signals. The device does not identify the cause of different sound transmission properties.

For the assessment of a tree, it is crucial to determine the cause of the tomogram's appearance. Make sure to establish whether fungi, cracks, or other defects are present.

The statements made here regarding species-specific sonic and resistance distributions within the measurement planes do not claim to be exhaustive or accurate. These statements are often based on a very limited data set. Where appropriate, please refer to current research findings or, if necessary, carry out comparative measurements on healthy trees.

Caution! Do not fell the tree solely based on the tomogram. Use additional examination methods and, most importantly, apply your knowledge of trees before making a decision!

Some of the case studies shown in the following chapters are accompanied by electrical resistance tomograms in order to better explain certain issues. For a better understanding, you should therefore also read Chapter [8.8 Tomogram Evaluation and Interpretation – Electrical Resistance Analysis Node](#), even if you only have a sonic tomograph.

8.7.2 Theory of Sonic Velocity Measurement

8.7.2.1 Sound Conduction in Wood

The PST 3 recognizes and displays differences in the wood's ability to transmit sonic waves. In solid wood sections of the trunk, the ability for sound transmission is closely related to the modulus of elasticity (E-modulus) and the density of the wood. Natural variations in wood quality (sapwood, heartwood, uneven growth rings, etc.) result in different sonic velocities. The following formula for the propagation of longitudinal waves in bars approximates these dependencies:

$$v = \sqrt{\frac{E - \text{Modulus}}{\varrho}}$$

with

v = sound velocity

$E - \text{Modulus}$ = Modulus of elasticity

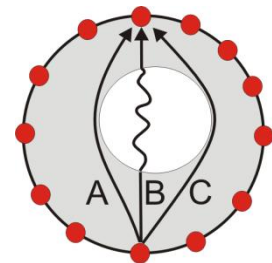
ϱ = Density

In damaged trees, various causes lead to differences in sonic velocity. Depending on the type of defect, sound waves can be either slowed down, such as in cases of decay, or forced to bypass the damaged area, as is the case with cavities.

It is often challenging to determine whether the wave has *passed through* a specific section of the trunk or *circumvented* the area. Since the true path of sound waves through the wood is often unknown, a straight connection between measurement points is assumed for tomogram calculation. This line is assigned an **apparent** velocity because the actual path of the waves is not known.

Sonic tomograms, therefore, often provide, but not necessarily, direct information about wood quality. Correctly expressed, the apparent sonic velocities in tomograms indicate the **wood's ability to transmit sound**.

Nevertheless, there is a strong correlation between the sonic conductivity of wood and the integrity of the trunk: anything that reduces the apparent sonic velocity also represents a loss of stability.

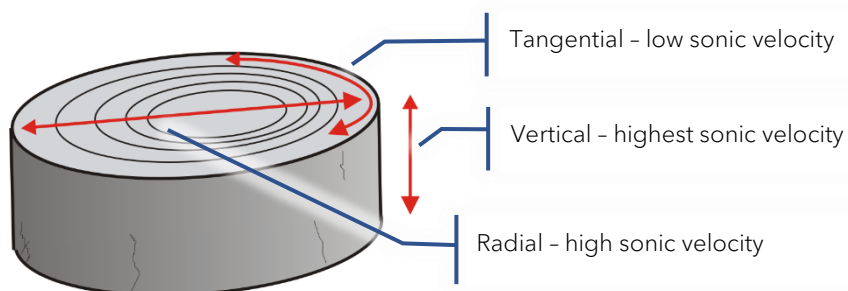


Note: In order to interpret tomograms correctly, a good understanding of trees and their diseases, as well as knowledge about the functioning of the measuring device, is essential.

8.7.2.2 The Cogwheel Effect

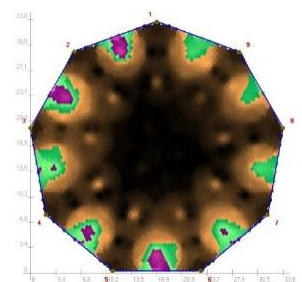
A frequently occurring data constellation in healthy trees is the *cogwheel effect*. The reason for this effect lies in the different sound-conducting properties in the outer and inner parts of the trunk.

The arrows in the sketch indicate the different sound-conducting paths: In the direction of the trunk (vertical), you find the best sound transmission properties. Radially (perpendicular to the annual rings), sound waves also spread relatively quickly. The slowest transmission direction is tangential, along the circumference.



For this reason, a tomogram of a healthy tree often looks like the one depicted. The green-violet areas between the sensors indicate lower tangential speeds. The more pronounced the annual rings, the more noticeable the cogwheel effect is generally observed.

Based on our experience, we know that the wood between the sensors at the edge of the trunk may have different sound transmission properties but is not damaged.



8.7.2.3 Velocity Profiles

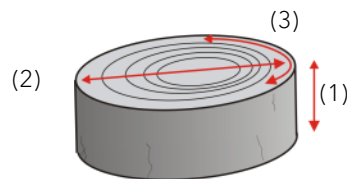
As mentioned above, wood is an anisotropic material with respect to sound transmission speed. The propagation speed of sound waves depends on many parameters.

Some of them are:

- Angle between the direction of propagation and the annual rings. One can distinguish between three main directions: axial along the trunk, tangential along the circumference, and radial through the centre of the trunk.
- Moisture content in different layers of the trunk
- Wood type. Reaction wood at wounds has significantly higher speeds than "normal" wood in defect-free trunks.
- Others

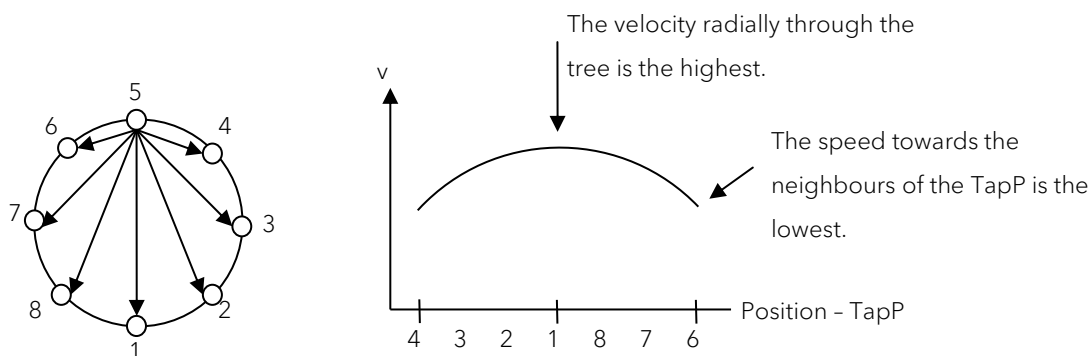
Regarding the horizontal propagation speed, there are two main groups:

- Type 1: radial speed (2) is **greater** than tangential speed (3)
Practically all European tree species belong to this group.
- Type 2: radial speed (2) is **smaller** than tangential speed (3)
Many palm species are representative for this group.

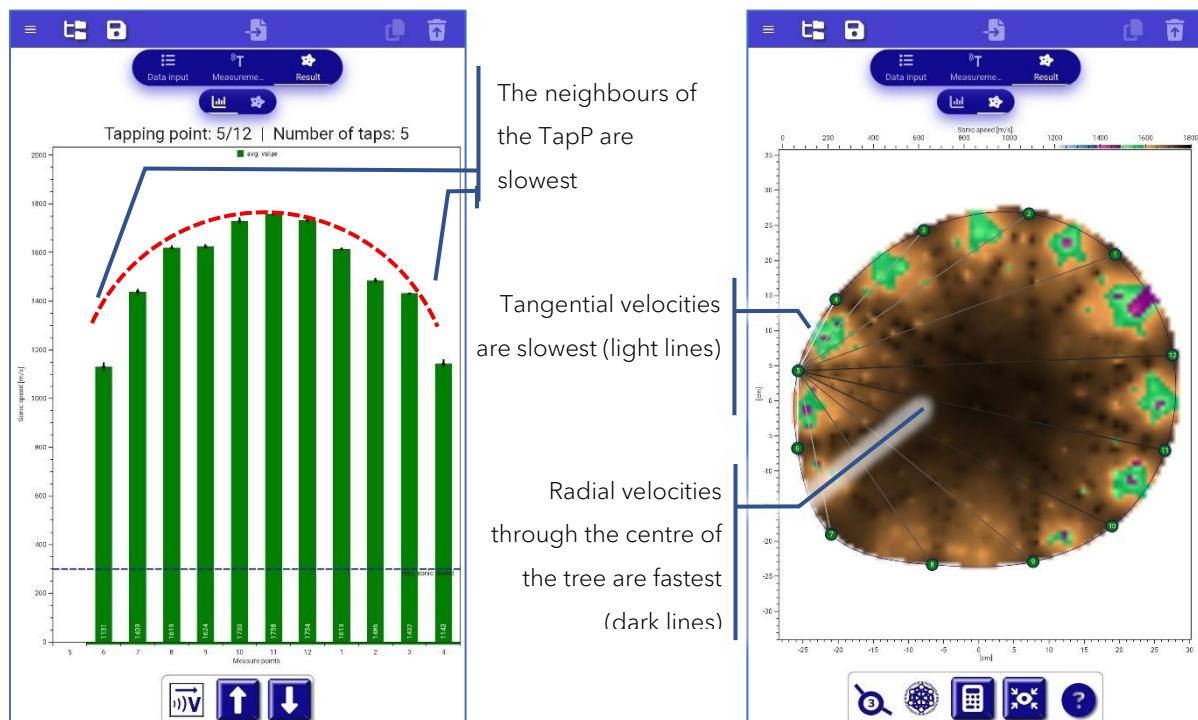


In Type 1 trees, the radial speed (2), i.e., through the centre of the tree, is higher than the tangential speed.

The tapping point in the following example is TapP5:

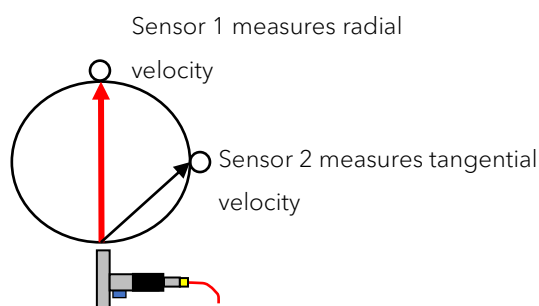


The speed profile is displayed in the sonic measurement node through the bar chart under **Results**. The following example is from a healthy fir tree:



In most - but not all (!) - tree species, the radial speed is higher than the tangential speed. The "point-to-point" or 3-point test takes advantage of this fact. By comparing a radial speed with a tangential speed, a rough estimate can be made of whether there are significant defects in the measurement plane or not. Small defects are NOT detected.

For a 3-point test, the nails should be placed at approximately 6, 9, and 12 o'clock.

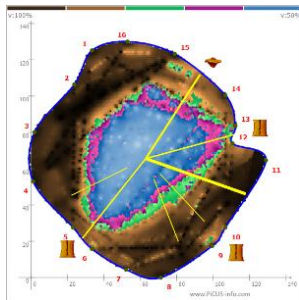


If the radial speed is higher than the tangential speed, this is an indication that there are no major defects in the trunk.

Note: This test is not foolproof. There are situations in which a defect, with unfavourable positioning of the device, can influence the measurements in such a way that the result indicates a healthy tree.

8.7.2.4 Tomogram Colours - Legend

To represent the different acoustic conductivities in the tomogram, arbitrary colours have been chosen.

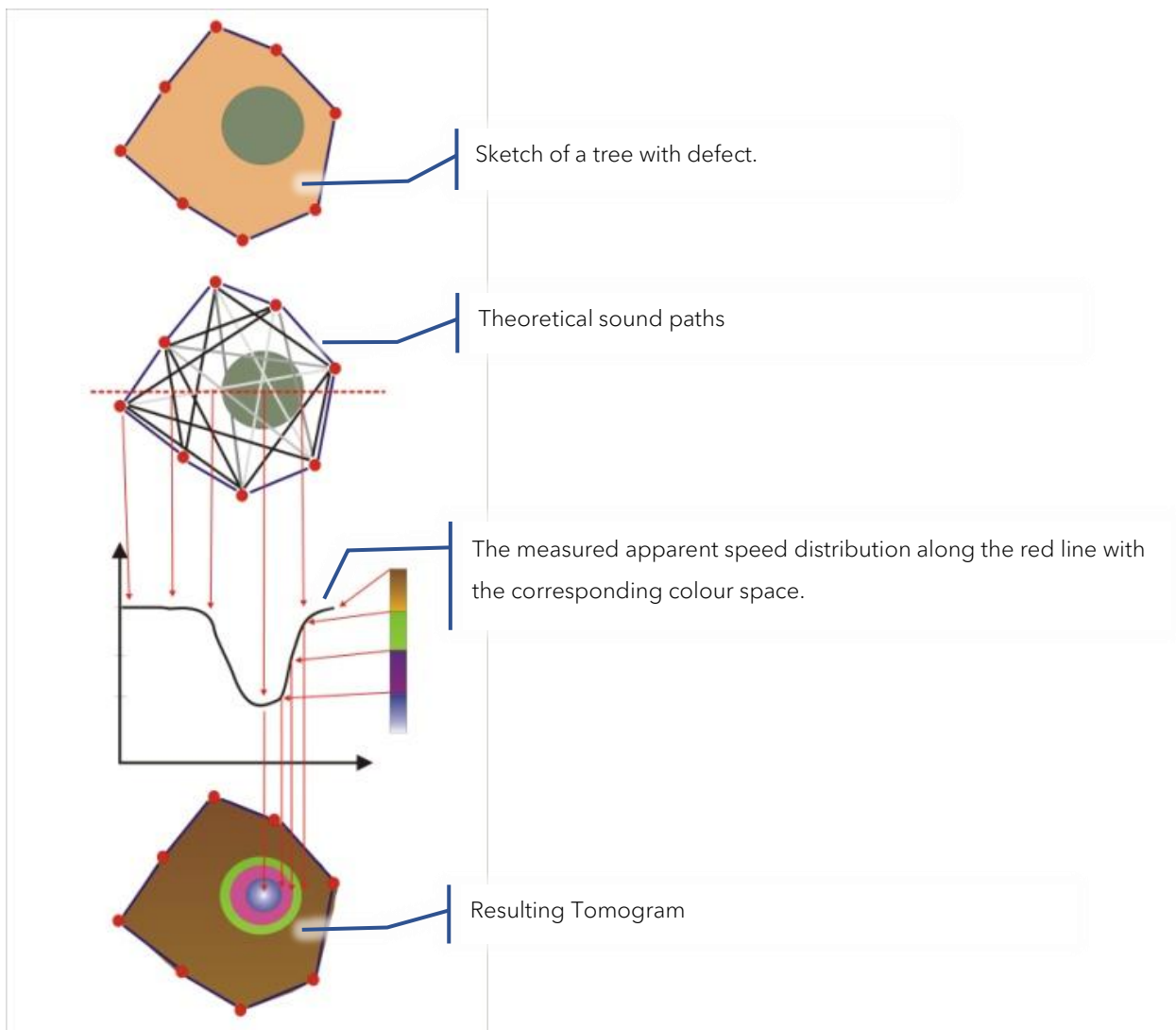


Dark brown to light brown colours describes areas in the trunk where sound can propagate quickly.

Violet and blue, on the other hand, indicate areas where sound propagates less effectively. Defects are suspected in these areas. Blue areas do *not necessarily* mean that there is a cavity at these locations, but simply that sound travels slowest here.

Green areas could not be definitively assigned to either fast or slow speeds. Green areas must be interpreted depending on the defect.

The colour space of the PiCUS standard colours (white/blue to brown/black) spans between areas with maximum speed (i.e., 100%) and areas with minimum speed. The colour switch points are assigned to specific speeds. The following sketch illustrates this.



There are three main colour groups to distinguish:



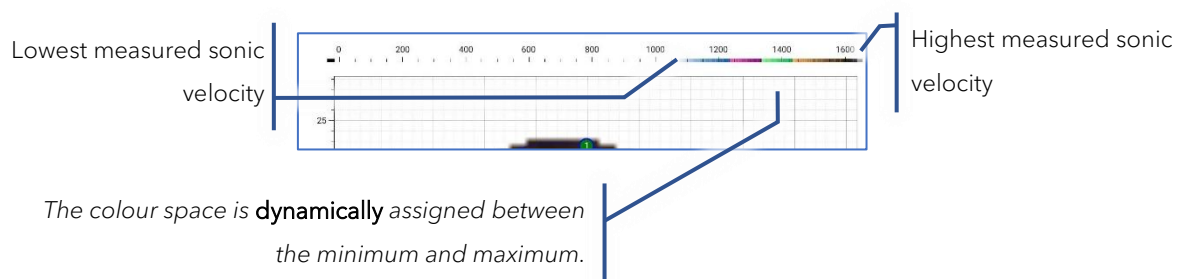
Violet and blue/white are considered one class.

In general, with this sonic tomography method, no statements can be made about the nature of the damage. It is not possible, in principle, to differentiate between a hole, decay, or crack as the cause of a violet (or blue) area. *However, a typical distribution of tomogram colours provides additional information about the interior of the tree.* Solid knowledge of trees and their diseases is necessary for image interpretation in all cases. Additionally, experience from other tomograms is helpful.

Caution! For proper interpretation of a tomogram, a solid understanding of trees, tree diseases, and the fundamental operation of the PiCUS sonic tomograph is required.

Determine the reasons for poor sound transmission in the tomogram. Never should a tree be felled based solely on a sonic tomogram WITHOUT further investigations!

The legend above/beside the tomogram provides information about the velocity differences that occurred during a measurement. The minimum and maximum velocities determine the limits of the colour scale. The colour space is **dynamically** adjusted to each measurement.



As the colour scale in relatively homogeneous wood would be limited to a very small speed range, and within this range, many image artifacts would occur, the scale is spread over a range of at least 20% of the maximum speed. Conversely, the colour scale is limited to a maximum of 50% of the maximum speed because otherwise, too large speed differences would be represented with the same colour. All velocities below 50% are automatically assigned to the same colour.

In the interpretation of tomograms, one should never only look at the colours. The tomogram colours must always be interpreted in relation to the absolute speed values.

8.7.3 Tomogram View - Workspace

In the workspace below the tomogram, in the View section, you will find the controls with which various information in the tomogram can be toggled on and off.



Calculate: initiates a recalculation of the tomogram. It is also triggered automatically when a calculation parameter is changed.



Show TP Numbers: Displays the assigned number for each TP. Numbers can take up a lot of space on smaller displays and can be hidden. TP1 is easily identifiable even with hidden numbers (triangle instead of dot).



Show North direction: displays a compass rose in the top left corner.



Diagnosis marks: toggles the display of diagnosis marks set in the geometry node. See also [8.4.7.1 Defect Description after Visual Inspection](#).



Drilling Measurements: overlays the projections of boreholes onto the measurement plane, added in the geometry node. See also [8.4.7.2 Documenting External Drilling Measurements](#).



Markers: toggles the display of distance and angle measurement markers. See also [8.7.4 Distance and Angle Measurement Markers](#).



Cracks: shows the positions of cracks and other acoustic barriers calculated using Crack detection. See also [8.7.5 Crack Detection](#).



Residual Wall Thickness: displays the auxiliary ring for estimating the required residual wall thickness. For various methods of estimating the residual wall thickness, see also [8.7.7 Estimating Residual Wall Thickness](#).



Show sound paths: All recorded sound paths are displayed in the tomogram. The sound paths are coloured according to their average sonic velocity. High velocities are shown in darker colours, lower velocities in lighter colours. Clicking on a single BP displays only the sound paths that converge at this BP.



Scale Geometry: Adjusts the zoom level and shifts the graphic so that the entire geometry is visible, fully utilizing the available display space. Alternatively, the graphic in the app can be scaled and moved using *touch gestures*. On the PC, the graphic can be *moved with the right mouse button* and the *zoom level adjusted with the mouse wheel*.



Save: saves the current tomogram view, based on the above settings of the view control, as an image file. The tomogram can be saved as a vector graphic in *.svg and *.pdf formats or as *.jpeg or *.png. The filename is user-selectable, and the default name will be automatically numbered if necessary. All created image files are visible in the gallery. The formats *.jpeg and *.png can also be used for integration in reports (see also [8.10 Generating Reports - Report Node](#)).

8.7.3.1 Tomogram Gallery

Saved tomograms can be viewed in the **Gallery** tab of the Analysis node.



Delete Image removes the currently selected capture from the project.



In the gallery, the **arrow keys** can be used to switch between all available captures.

In the **Tomogram Meta Data** section, additional information is stored for each capture:



Filename: The name is freely selectable. Descriptive names corresponding to the content depicted in the tomogram facilitate further processing.



Comments: A free-text field where additional information about the image can be noted.

The sections **View Settings** and **Calculation Settings** display all values for calculation and presentation used in creating this tomogram. This makes it possible to reproduce a tomogram. These pieces of information can also be displayed in the Report node to document the tomogram creation.

View settings



Calculation settings

 300 .. 2300 m/s

 SoT 1

 1x (100 x 100)

 240

 Blind area switched off

 Level 1 (lowest)

 10 %

☐ Use contrast enhancement

☐ enable cog wheel correction

☒ Auto. measure data validation

☒ Absolute value check: 8 %

☒ Correlation check: 95 %

8.7.4 Distance and Angle Measurement Markers

To measure the size of defects in the tomogram, measurement markers can be added. Both distances and angles can be determined.

In the working area of the tomogram, go to the Measurements section. Here, all previously set measurement markers are always visible. Choose either:



Add distance measurement:

- Tap the starting point on the tomogram.
- Tap the endpoint on the tomogram.
- The distance is measured between the two points, and a double arrow is drawn.
- For fine-tuning, the arrowheads can be moved in the tomogram.



Add angle measurement:

- Tap the base point of the angle to be measured on the tomogram.
- Tap the point through which the left leg of the angle should pass. The first leg is drawn in the tomogram.
- Similarly, tap a point for the right leg.
- The angle is drawn and measured.
- For fine-tuning, both the base point and legs can be moved in the tomogram.



Show inner angle or **show outer angle** switches the display.



Add measurement mark:

- Tap the location in the tomogram for which you want to display the local sonic velocity.



You can cancel the drawing process at any time with **Cancel**.



Delete: To delete a set measurement marker, it must first be selected in the tomogram (highlighted in green). Then it can be deleted using the trash can.

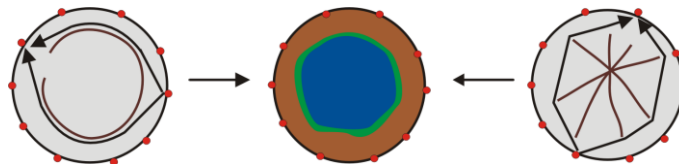
In the View section in the working area, measurement markers can be permanently displayed or hidden.

8.7.5 Crack Detection

Due to the characteristics of living wood, there are some special data constellations that may cause the tomogram to appear differently than it corresponds to reality.

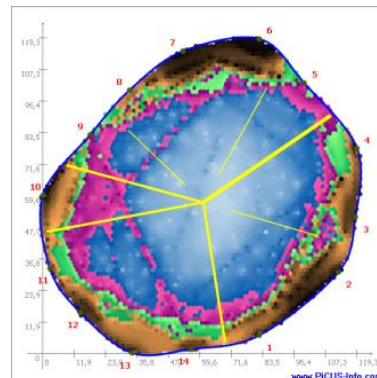
Radial cracks can lead to these special data constellations. Cracks in wood pose insurmountable obstacles to sound propagation. We distinguish between two main types of cracks:

- Star cracks: run from the centre of the tree outward.
- Ring cracks: run like a ring approximately parallel to the circumference of the tree.



Both forms of cracks lead to misrepresentations in the tomogram. Crack detection searches the sound data for large differences in velocity between adjacent measurement points, indicating possible sound barriers (e.g., cracks).

Radial cracks, running from the centre of the tree outward, are typical sound barriers. The calculated positions of the sound barriers (cracks) are represented in the tomogram with yellow lines.

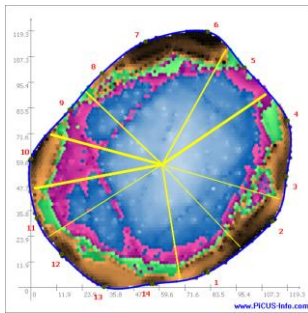


The example of this plane tree² shows that large cracks in combination with decay reaching to the periphery of the tree can influence the tomogram.

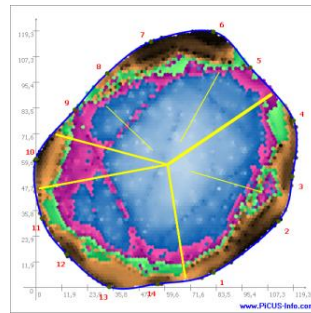


The thickness of the lines is a measure of the clarity of the crack data constellation. Sensitivity can be configured or deactivated in the tomogram's workspace in the crack detection section.

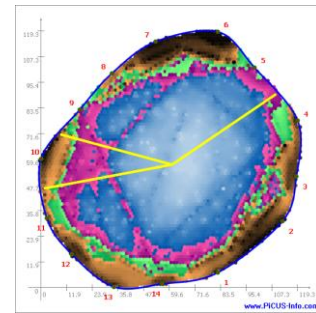
² Data from: City Strasbourg, France



Sensitivity: high

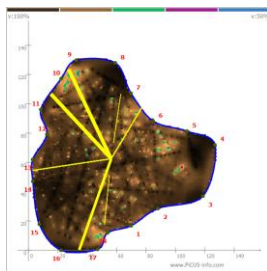


medium

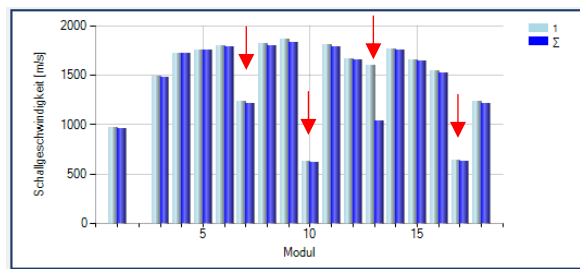


low

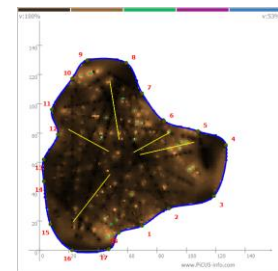
The yellow lines of the crack detection can also indicate errors in the measurement by the user. In the following example, sensors 7, 10, 13, and 17 were not properly coupled to the wood, presumably due to incorrectly installed nails. Another source of error is that the sensors have not been placed on the nails or are loosely attached. In the measurement window, some sensors consistently provide low sonic velocities. By deactivating these measurement points as "receivers", these errors can be reduced (see also [8.7.10 Data Validation](#)).



SoT 1



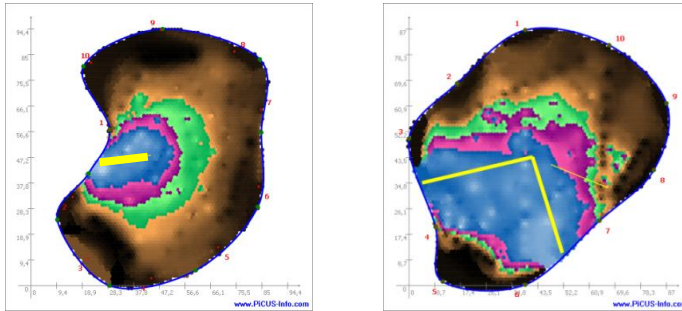
Bar Chart of velocities



SoT with deactivated MP

Notes:

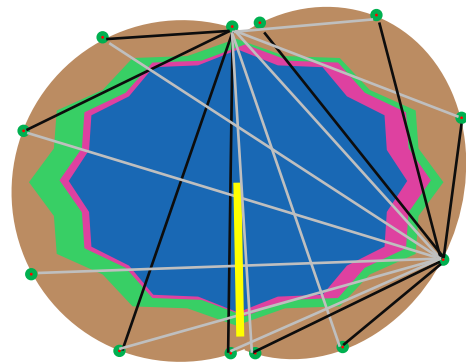
- Crack detection requires reception data at all measurement points. If a measurement with more measurement points than sensors is performed, it must be ensured that all knocking rounds are completed.
- The more cracks there are in the wood, the more difficult their detection and representation becomes.
- Large, wide cracks that extend to the outside are easier to detect than small, short internal cracks near the centre of the trunk.
- The position of a sound barrier is always assumed to be exactly in the middle between two MP. If an MP is flanked by two yellow lines, often only one crack is the cause.
- If a large sound-deficient area, such as an open cavity or a strong decay extending to the outer edge, is present between two MP, this location is often also marked by a yellow line. Of course, there is no crack in this case, but the crack detection analysis function indicates when large variations in sonic velocity exist between adjacent points.



The above tomograms show trees with pronounced decay extending from one measurement point to the outside. The sound waves travel very slowly between these points, and consequently, this location is marked by the crack detection with a yellow line. However, a crack in the true sense is not present.



The option **Show sound paths** can be useful in some cases to identify large continuous cracks in the centre of the trunk. Individual large cracks can cast a sound shadow that is visible in the tomogram as a large cavity. By showing the sound paths, it is possible to recognise this faulty representation. In such a case, sound paths parallel to the crack would pass through the tree almost unhindered at high speed, while sound paths crossing the crack would be blocked or greatly slowed down. If there were actually a large cavity, no directional dependence of the sonic velocity would be detectable within the damaged area. If such a data constellation is suspected, it is advisable to calculate the tomograms for the trunk parts on both sides of the suspected crack separately. This can be done by selectively switching off MP in the Data Validation tab. See also Chapter [8.7.10.5 Excluding faulty measurements](#).



Crack detection and the recognition of the cogwheel effect work with similar algorithms (see also [8.7.2.2 The Cogwheel Effect](#)). Slow velocities are sought in the peripheral area of the tree (between adjacent points). The distinction between a crack and the cogwheel effect is primarily made based on how regularly the effect occurs:

- Cogwheel effect: evenly distributed around the entire tree
- Crack: occurs only in specific points

If a cogwheel effect is detected, crack detection is deactivated.

Otherwise, a crack would be indicated between all measurement points, even though, in practice, no damage is present with the cogwheel effect.

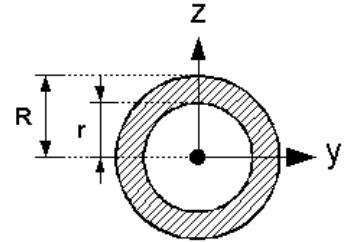
8.7.6 Moment of inertia and bending resistance

The moment of inertia describes the stiffness of bodies, in other words, the resistance of a body to bending. Only the geometry of the body plays a role: large or small diameter, hollow or solid inside, etc.

Material properties are not described by the moment of inertia.

The moment of inertia of a circular ring is calculated by the formula:

$$I = \pi * (R^4 - r^4)$$



The formula makes it clear that areas far from the centre have the greatest influence on the moment of inertia (essentially the stiffness). Hollow areas near the centre have little effect on the stiffness.

8.7.7 Estimating Residual Wall Thickness

To assess the fracture strength of trees, an estimation of the residual wall thickness is essential. The residual wall thickness required for stability can be determined using various methods and can be marked in the tomogram as a red line.



In the workspace of the tomogram, in the section **Residual Wall Thickness**, the following methods are available:

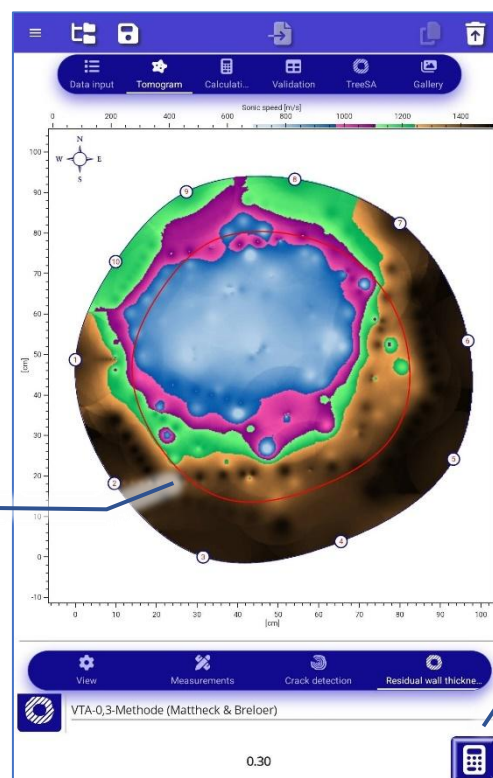
- **VTA-0,3-Method:** „Visual Tree Assessment“ - Mattheck & Breloer
- **TreeSA-Method:** „Tree Stability Assessment“. The TreeSA calculations are based on the publications of Dr. Wessolly, Günther Sinn, and Martin Erb in the "Handbuch der Baumstatik", Patzerverlag. The form and number of selectable crown shapes have been expanded, causing slight differences from the SIA method of Dr. Wessolly.



After selecting a method, you can jump to the configuration of the method using the **Calculate** button.

In the case of the VTA-0.3 method, switch to the **Calculations** tab. Here, a different factor for the residual wall thickness can be entered (default value = 0.3).

The red ring indicates the required residual wall thickness that has been calculated. The red ring always corresponds to a proportional reduction in the geometry towards the centre of gravity.



By clicking **Calculate**, depending on the method, you will be taken to the corresponding tab for configuration.

8.7.7.1 TreeSA Tab

For the TreeSA method (as of 2009), you will be directed to the corresponding tab with the same name. The values determined here for the required residual wall thickness apply to mostly round trees at a height of about 100 cm above the ground. The denser the tomogram measurement plane is at this point, the more accurate the estimation.

Many of the calculation parameters are automatically loaded from other data nodes, but some must be entered separately here:



Tree genus: automatically taken from the tree node

Tree species: must be additionally specified here to determine material properties.

Material properties:



Compressive strength [kN/cm²] and



The **CW value** is either entered directly or taken from a stored table by selecting genus and species.



Trunk geometry: The **bark thickness** is taken from the geometry node.



The two values for the **cross-diameter** must be entered again. This is necessary because the cross-diameter was determined in the geometry node at the level of the measuring plane, but here the cross-diameter at reference height (100 cm) is needed.



Wind load: **Tree height** and **crown type** are loaded from the inspection node, and the **terrain type** is loaded from the project node.



For the result calculation, the **target value of the safety margin** is entered. Values from 1.5 to 2 are recommended here.

Then the following are calculated:



Basic safety factor: "The basic safety is the safety that results when... one statically weighs a tree without its damages. The three factors relevant to the basic safety: load, shape, and material." ³ A basic safety factor of 1 (or 100%) means that the tree's fracture safety reaches the calculated failure limit in hurricane-force winds. For a secure tree, a basic safety factor of at least 1.5 (150%) is recommended. This value is formally determined from the entered values.

³ Translated from „Handbuch der Baumstatik“ from Wessolly and Erb, Patzerverlag



Required residual load-bearing capacity: Compared to an undamaged trunk, the load-bearing capacity of the examined tree may be reduced to this percentage. In other words, for the trunk to achieve the chosen safety factor, its flexural strength (load-bearing capacity) must not be less than this percentage compared to the undamaged trunk.



Factor for the residual wall thickness: A dimensionless factor calculated from the required residual load-bearing capacity, with which the maximum allowed degree of hollowing is calculated from the geometry, representing the line for the minimum residual wall thickness in the tomogram. *This factor corresponds to the scaling parameter directly entered in the VTA-0.3 method.*

It is possible that the calculation produces mathematically correct but extremely impractical results. In extreme cases, the calculated residual wall thickness may be rounded to zero. Before interpreting the tomogram, it should be ensured that the residual wall thickness is at least 5 cm (see also [8.7.4 Distance and Angle Measurement Markers](#)).



The **Calculate** button incorporates the result for display in the tomogram.

8.7.8 Options for Calculation

The standard values for the calculation options are the global parameters set under Settings (see [4.4.4 Calculations](#)). In the **Calculations** tab, these standard parameters can be specifically adjusted for an individual tomogram calculation.

The available settings are:



Calculation type: Here, you can switch between **SoT Type 1** and **SoT Type 2**. For details, see also [8.7.9 Application of the SoT Calculation Variants](#).



Grid size: Specifies how finely the tomogram is resolved. The larger the grid, the finer the structures displayed in the tomogram. However, finer structures also require significantly longer calculation times.



For tomogram representation, the size of the **colour palette** can be adjusted. The larger the number, the finer the gradations, resulting in smoother colour transitions. Conversely, smaller values lead to significantly sharper transitions between differently coloured areas. The lower limit is 6 colours (black, brown, green, violet, blue, white), and the upper limit is 240 colours.



The **minimum and maximum sonic velocities** are absolute values for the validation of measurement values. Sound measurements above or below these limits are limited to within these boundaries for the calculation. These values are not taken from the global template, but from the linked measurement node, and can be adjusted there.

- Default max value: 2300 m/s
- Default min value: 300 m/s

See also [8.5.1 Data Entry](#).



Contrast enhancement: Helps to less prominently emphasize naturally occurring wood strength differences (reaction wood compared to normal wood). Especially in measurements with low-speed variances (80%...100%), this function often leads to a sharper coloration.



Blind area: The cogwheel effect can sometimes mask smaller, early defects in the centre of the trunk. In such situations, it is recommended to exclude the sensors adjacent to the tapping point, i.e., the sensors that cause the cogwheel effect due to slow sound transmission along the circumference, from the calculation. Larger values lead to compromises in the representation of the edge area.



Cogwheel correction: The detection of the cogwheel effect is always active. Here, the sensitivity of this detection can be adjusted. When such data constellation is detected, it is represented by a small cogwheel symbol in the top right corner of the tomogram. In this case, the crack detection function is no longer available (see also [8.7.2.2 The Cogwheel Effect](#) and [8.7.5 Crack Detection](#) The Cogwheel Effect). Additionally, the correction calculation for the cogwheel effect can be activated here. With cogwheel correction enabled, the effect is less prominently displayed in the tomogram. The status of the correction is indicated in the tomogram by the colour of the icon when the cogwheel effect is detected.



cogwheel effect detected and corrected



cogwheel effect detected but not corrected



Factor VTA Method: For the calculation of the remaining wall thickness with the VTA-0.3 method (Mattheck & Breloer), a factor deviating from the standard can be entered here. See also [8.7.7 Estimating Residual Wall Thickness](#).



Warning limit for averaged sonic speed discrepancy is a measure of the maximum allowed deviation between the averaged maximum velocities at all tapping point.



Enable automatic measurement data validation: Activates automatic application of absolute value check and correlation check. The checks can also be set independently of each other. See also [8.7.10 Data Validation](#).

- **Absolute value check:** If individual values deviate by more than this percentage from all other taps at this measurement point, they are ignored.
- **Correlation check:** Checks how similar the measurements are at a tapping point.

8.7.9 Application of the SoT Calculation Variants

The calculation variants **SoT 1** and **SoT 2** represent minor damage areas and the transition areas between high and low sonic velocities differently:

SoT 1: Even minor damage areas are shown, transition areas are drawn less sharply defined, transition areas that may still be good enough are assigned to the damage area, and the damage may be represented too large.

SoT 2: The transition areas are depicted with much sharper boundaries, minor defects are concealed, the peripheral areas of spreading defects may be concealed, and the damage may be depicted as too small.

Especially in the case of non-central defects, the tomogram version **SoT 1** tends to show artifacts in the tomogram due to unfavourable intersection point evaluation of the theoretical sound paths. The **SoT 2** method largely ignores these "false" intersection points.

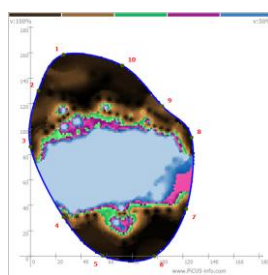
The **SoT 2** calculation should be applied in particular for:

- Cracks, especially continuous cracks
- Twin stems
- Non-central damage

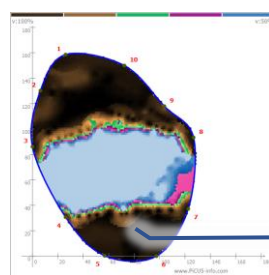
The **SoT 2** calculation should *not* be applied to trees:

- suspected of being infected with *Kretzschmaria deusta*
- where early stages of decay are suspected

The following example shows the improvement of the tomogram in an oak tree with a crack:



SoT 1



SoT 2

Wrong intersection points were removed.

8.7.10 Data Validation

In the Data Validation tab, all recorded measurement values are displayed in a table and undergo range and absolute value checks. These checks can detect measurement errors, allowing corrections to be made during the tree measurement. Even after the fact, erroneous measurements can often be salvaged by selectively excluding individual, faulty TapP or MP for tomogram calculation.

8.7.10.1 Absolute Value Limits for Sonic Velocity

The first step in data validation has already been performed in the Acoustic Measurement node. The minimum and maximum sonic velocities set in the settings (see [8.5.5 Conducting the Sonic Measurement](#)) are already compared with the measured values during tapping to set the MP status to red in case of discrepancies. This initial test provides the opportunity to identify and correct errors during the measurement process.

However, during tapping, no measurement values are automatically deleted. Unusual values can also be valid and correct.

8.7.10.2 Calculation Information – Maximum sonic velocity Monitoring

During maximum sonic velocity monitoring, the maximum velocities determined at a measurement point are compared with the average maximum velocity obtained from the velocity maxima at all points. If the value at a point is unusually low, it could be an indication of the following situations:

- The nail is not driven far enough into the tree, sticking in the bark.
- The nail was placed in damaged wood.
- The nail has good contact with the wood, but the part of the tree is not connected to the rest of the trunk through intact wood.

In this case, it is necessary to check whether the corresponding nails are properly placed.

Unusually high values are typically used. However, in this case, it should also be checked whether the measurement point position was accurately measured, and the sensor is correctly placed on the nail. In the example below, connections 6-7 and 7-6 are very fast. This could indicate inaccuracies in the geometry: the actual distance between MP6 and MP7 is smaller than determined.

If unusually low velocities occur at a measurement point despite correct nail installation, an automatic compensation function is applied. At these points, the local maximum velocities are replaced by the (global) median value.

The maximum sonic velocity at this point occurred on line 6-7 (7-6) and is *above* the median value for this measurement.

Check geometry and sensor attachment.

	v max [m/s]	Tap	Tap 1	Tap 2	Tap 3
TapP 1	1407 (→ MP 3)	3	OK	OK	OK
TapP 2	1559 (→ MP 11)	3	OK	OK	OK
TapP 3	1542 (→ MP 11)	3	OK	OK	OK
TapP 4	1630 (→ MP 7)	3	OK	OK	OK
TapP 5	1662 (→ MP 7)	3	OK	OK	OK
TapP 6	1995 (→ MP 7)	3	OK	OK	OK
TapP 7	2091 (→ MP 6)	3	OK	OK	OK
TapP 8	1737 (→ MP 6)	3	OK	OK	OK
TapP 9	1711 (→ MP 6)	3	OK	OK	OK
TapP 10	1517 (→ MP 6)	3	OK	OK	OK
TapP 11	1467 (→ MP 4)	3	OK	OK	OK
TapP 12	1365 (→ MP 3)	3	OK	OK	OK
Median	1594,5				

The maximum sonic velocity at this point is below the median value for this measurement. Is the sensor in damaged wood?

Median over all v max

The display of the averaged maximum velocities at a tapping point is shown in the **View** table. At the end of the table, the median value across all tappers is also displayed. If a value is considered critical, it will be highlighted in red.

Since the cause of unusual measurements is not known to the software, no measurements are automatically deleted during the maximum velocity monitoring. To proceed with the tomogram calculation without a critical TapP, it must be manually excluded. Click on the leftmost column of the point to be excluded, the row will be greyed out and no longer considered in the calculation.

8.7.10.3 Status Display

The **View** table in the validation tab also provides information about the results of the absolute value and correlation checks. In addition to the averaged maximum velocities, the number of taps at each TapP is initially displayed. Then, for each individual tap, there is a separate column showing the test result:

- **OK**: The test did not find any anomalies.
- **Ignor Abs**: Absolute value check failed. At least one individual measurement point deviates too much from the average in the contested tap.
- **Ignor Corr**: Correlation check failed. The entire tap deviates too much from the others.
- **Ignor Std-Dev**: The standard deviation of this tap is too large.
- **Empty**: There is either no data available for this tap at this TapP, or the existing data has already been automatically averaged across all taps and summarized in one value. Tap 1 then shows **OK**.
- **Nbr**: An insufficient number of taps is available at this TapP.

As the same velocities should be measured on the same sound path, and the tree does not change during the measurement, a failed test indicates a measurement error. Therefore, contested taps are automatically excluded from the calculation.

The most common cause for individual taps deviating too much from the other taps at the same point is an incorrectly attached sensor. Contaminants between the nail and sensor or a folded-down sensor that is no longer sitting flat on the nail are possible errors. Also, excessive tapping, where the nail is driven further into the tree with each tap, can cause different measurement results between individual taps, especially if the nail originally did not reach into the heartwood.

8.7.10.4 Sonic Velocities

The tables **Ø** (average over all taps) and **Tap#** show the measured velocities in m/s from each TapP (one row per tap point/sender) to each MP (one column per measurement point/receiver). The number of tables is automatically scaled with the largest number of taps at a point.

In the diagonal, the velocities are zero because a point cannot be both a TapP and a MP simultaneously. Connections between points with too large variations between forward and reverse velocities are highlighted in orange in the tables. Since not all rows and columns can be displayed simultaneously with a large number of points, not only individual cells but also the row and column headers are marked. This makes it easier to locate the affected cells. However, values are not automatically excluded from the calculation, as the software cannot determine whether the error lies on the sender or receiver side, or whether it is an error at all.

To exclude faulty tap points from the calculation, individual rows can be excluded by clicking on the row header, and the row will then be greyed out. Similarly, measurement points can be deactivated for the calculation by clicking on the column header. If a tap point or measurement point is deactivated, *ALL* taps at that point are excluded from the calculation, i.e., a deactivated row or column is always deactivated in *ALL* tables simultaneously.

[m/s]	MP 5	MP 6	MP 7	MP 8	MP 9	MP 10	MP 11	MP 12
TapP 1	1387	1220	1110	988	1104	1321	1326	1004
TapP 2	1351	1207	1243	1042	1147	1469	1609	1456
TapP 3	808	729	937	797	832	1185	1499	1367
TapP 4	1005	984	1653	1368	1232	1218	1537	1368
TapP 5	0	391	1622	1358	1284	1247	1313	1243
TapP 6	403	0	2051	1612	1506	1440	1173	1058
TapP 7	1836	2363	0	528	965	1202	1029	1034
TapP 8	1433	1582	505	0	902	1126	1030	969
TapP 9	1456	1729	1039	1052	0	1017	1124	1137
TapP 10	1321	1554	1269	1365	1027	0	1088	1315
TapP 11	1296	1177	1079	988	961	964	0	956
TapP 12	1270	1084	1022	972	1074	1217	1004	0

Absolute value violation, this velocity is greater than the allowed maximum.

Receiver MP 8 deactivated

Sender TapP 8 deactivated

Speed difference is too big between the sound paths TapP10→MP8 and TapP8→MP10

8.7.10.5 Excluding faulty measurements

The values marked in orange in the tables **Ø** (average over all taps) and **Tap#** are not necessarily errors.

In most cases, the values marked here can be ignored. *If individual KP or MP are excluded here, ALL sound paths in ALL taps starting or converging at the selected point will be deactivated.* This almost always removes good values in other taps (in the other tables), which is often not desired.

This function is intended for systematic measurement errors, for example, if a nail is directly in a defect, but you cannot move or omit the measurement point as a whole because, for example, the point is necessary for correct geometry determination or because the measurement point distances would become too large due to the extent of the defect.

To identify and selectively exclude faulty measurements, the following criteria should be followed in this order:

- During the tapping rounds:
 - **Obvious errors in the experiment execution** (e.g., not hitting the nail properly, visibly coarse contamination between the nail and sensor/tapping pin, or accidentally pulling a sensor off the nail)
 - Immediately delete the last tap and tap again.
- After the measurement or retrospectively during evaluation:
 - **Identify individual taps that contain faulty or poor data**, while other taps at the same TapP are ok.
 - In the measurement data view of the measurement node, identify individual outliers based on absolute value and deviation from the mean.
 - Delete individual taps selectively. *Deleted data in the measurement node CANNOT be restored. Tap more than five times from the outset to have enough leeway for later sorting out measurement values.*
- During the evaluation in the validation section of the analysis node:
 - **Exclude TapP or MP that systematically provided poor or faulty values across ALL taps.** For example, nails that did not fully penetrate the bark or were positioned directly in a defect, preventing them from receiving or transmitting sound signals. A whole measurement point can be excluded in case of suspected hardware defects in an individual sound sensor. Individual tapping points can also be excluded if no tapping was performed on them (e.g., hard-to-reach nails).
 - Exclude specific TapP or MP selectively in the tables of the measurement data validation. Measurement data excluded from the calculation can be reactivated at any time.

Ideally, all faulty data should be removed during the measurement process because, while still at the tree, new data can be collected if needed.

In the measurement data validation of the analysis node, removing measurement values is rarely necessary if the work in the measurement node is done correctly.

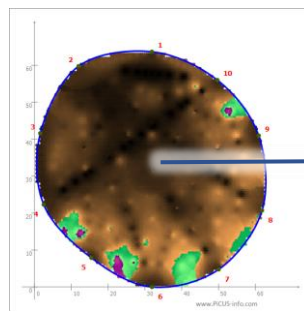
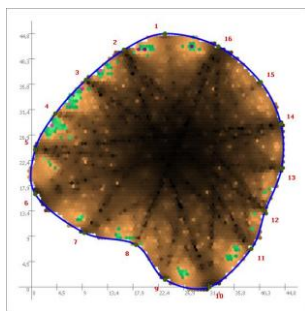
8.7.11 Interpretation Criteria

To evaluate a tomogram, the following questions should be addressed:

- What is the velocity distribution - where are the highest velocities?
- Are low and high velocities closely spaced?
- Do the tomogram colours form typical patterns?
- Legend: What velocity differences have occurred?
- Analyse calculation information (measurement validation, absolute velocities).
- Apply compensation functions for specific data constellations as needed (e.g., cogwheel effect).
- Check the density of the measurement grid with line graphics (in the preview tomogram of the measurement node).
- Verify the presence of radial cracks - crack detection
- Exclude or add new measuring points (MP) from the calculation as needed.

8.7.11.1 Velocity Distribution – Where are the Highest Velocities?

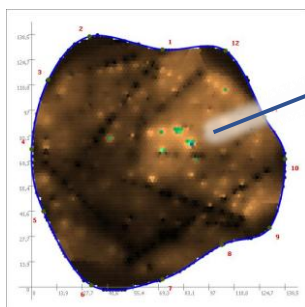
Since practically all tree species belong to Type 1 (radial sonic velocity is greater than tangential), the centre of the trunk always has the highest sonic velocities in healthy trees. Tomograms of defect-free trees thus look something like this:



The sonic velocity increases towards the centre, indicating a tree without defects but with a non-central pith. The growth rings become narrower in the upper-left quarter, indicating uneven thickness growth in the tree.

The slow areas between measurement points are due to differences between heartwood and sapwood and do not represent a defect. See also [8.7.2.2 The Cogwheel Effect](#). In contrast, trees that have higher velocities at the periphery than in the centre have a defect.

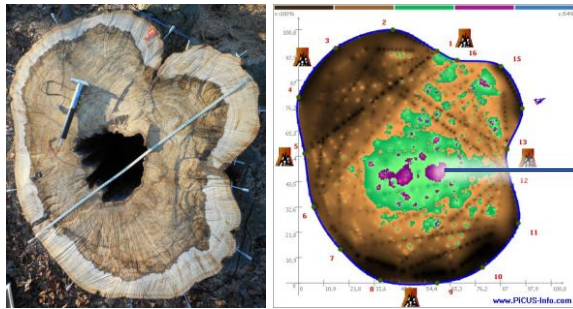
Example: Beech⁴ with early defect (possibly crust fungus, *Kretzschmaria deusta*):



The centre of the tree does **not** have the highest velocity

⁴ Measured by: Christian Knaus, Germany

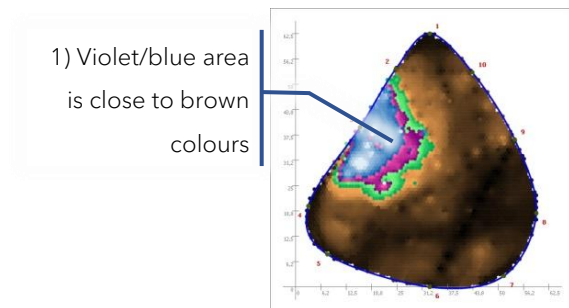
Beech⁵ with *Kretzschmaria deusta*:



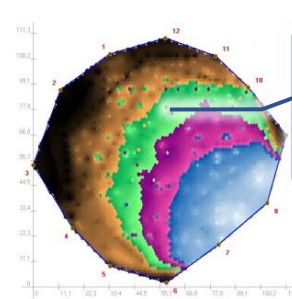
The sound velocity decreases towards the centre. Only the outer dark brown ring represents healthy wood.

8.7.11.2 Are low and high velocities close together?

If brown (= fast) and violet (= slow) areas are close together - i.e., the green area is very narrow (1 - left tomogram⁶) - it indicates a well-contained defect. The left tomogram shows a typical case: the small distance between violet and brown areas suggests a sudden change in acoustic conductivity.



1) Violet/blue area is close to brown colours



2) Wider green area - gradual change in sound velocity

If the colours are further apart (2 - right tomogram⁷), or if the presumably damaged area has no clear demarcation, fungal infections can be assumed. The example shows a *Ganoderma* infection on a maple. This tomogram is very typical of a fungal infection in various stages.

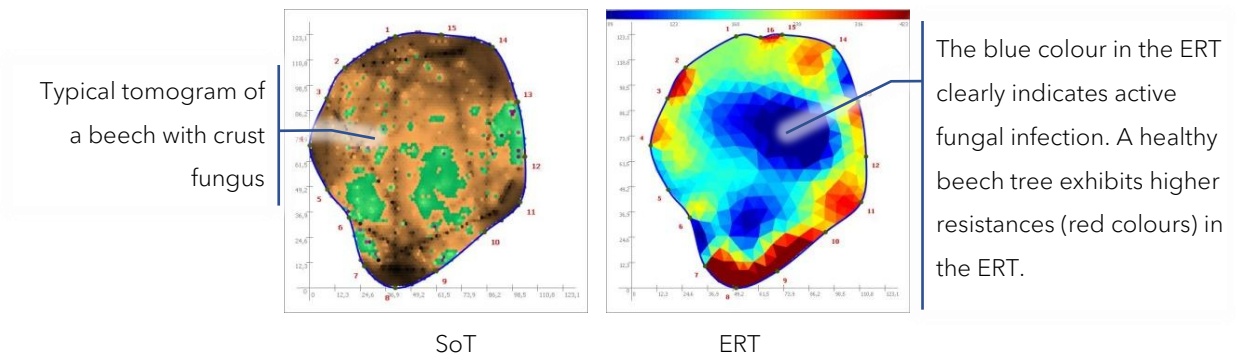
⁵ Measured by: Aernout Theunissen, BoomOntzorging, Netherlands

⁶ Measured by: Henrik Weiß, Germany

⁷ Measured by: John Harraway, Great Britain

8.7.11.3 Do the tomogram colours form typical patterns?

Some defects in trees result in typical colour distributions in the tomograms: especially, the presence of the crust fungus in beech trees leads to non-uniform changes in sonic velocity across the tree cross-section, unlike holes. The following tomograms are typical for beech trees affected by the crust fungus (*Kretzschmaria deusta*) – on the right is the ERT (Electrical Resistance Tomogram).

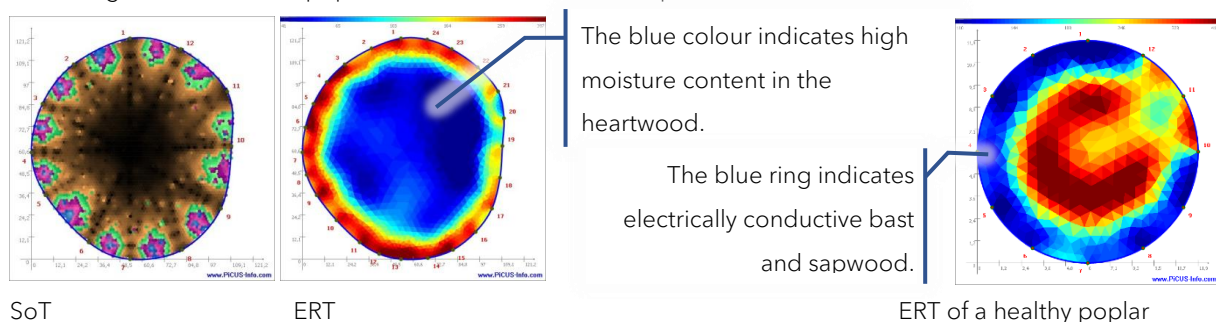


The SoT shows brown/green patterned areas with violet dots. Based on this pattern, it can be confidently determined that this defect is *NOT* a hole and *NOT* a crack but an area destroyed by a fungus! The size of the fungal infection can be estimated by drawing a line around the green/brown dotted area. In the left tomogram, practically the entire cross-section of the trunk is affected.

8.7.11.4 Wetwood

Wetwoods are not always detectable and are not always shown in the sonic tomogram as damaged areas depending on the age and severity of the infestation. The example shows SoT and ERT of a poplar with an early stage of wetwood: The SoT shows *no defect*; hence, the mechanical properties of the wood are still good. However, the ERT shows a very high conductivity (blue colours) in the centre of the trunk. The conductivity is even higher than in the sapwood.

On the right is the ERT of a poplar without wetwood for comparison.



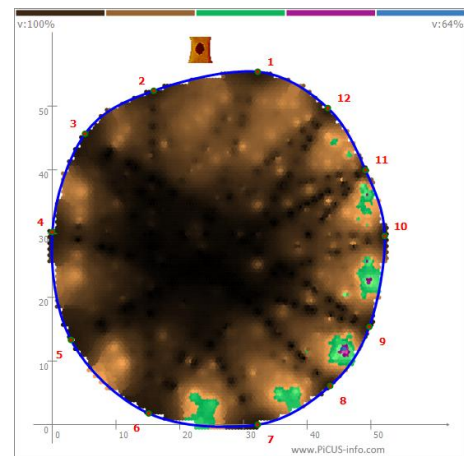
The photo after the felling of the poplar with the early wetwood shows brown discoloured wood, indicating a high water content (significant water leakage after felling).

8.7.11.5 Defect Reconstruction at Reaction Wood

Reaction wood at wound edges has significantly better acoustic sound transmission properties due to its high modulus of elasticity than "normal" grown wood. A measurement at overgrowths therefore shows particularly dark colours at these locations. In some cases, the good sound transmission properties of the reaction wood can even mask small defects: the waves simply travel outside the measurement plane through the stiff reaction wood! If defects are indicated as too small in such a situation, it indicates the following:

- The defect is surrounded by very good wood, especially in the vertical direction. That is, the tree is actively working on compensating and demarcating the damage.
- The defect does not extend deep into the trunk; otherwise, the sound paths passing through the centre would more clearly show the defect.

The example shows a measurement on a beech tree into which a hole was cut years ago with a saw. The opening is directly above MP 1-2. The hole is not visible in the tomogram.



8.8 Tomogram Evaluation and Interpretation – Electrical Resistance Analysis Node

8.8.1 General Guidelines

The measurement results of the PTT 3 must be interpreted by qualified experts.

The electrical resistance tomogram does not indicate whether a tree is safe or not.

Conclusions about the condition of the tree derived from the resistance tomograms are the sole responsibility of the interpreter drawing the conclusions.

Neither the manufacturer of the device nor the seller can be held liable for any consequences arising from the interpretation of the tomogram.

The PTT 3 detects differences in the electrical conductivity/electrical resistance of the wood. The device does not detect the cause of the different electrical properties.

When assessing a tree, it is always very important to determine the cause of the appearance of the tomogram. Be sure to check for fungi, cracks or other defects.

The statements made here regarding species-specific sonic and resistance distributions within the measurement planes do not claim to be exhaustive or accurate. These statements are often based on a very limited data set. Where appropriate, please refer to current research findings or, if necessary, carry out comparative measurements on healthy trees.

Caution! Do not fell the tree solely based on the tomogram. Use additional examination methods and, most importantly, apply your knowledge of trees before making a decision!

Electrical resistance tomography is often used in conjunction with sonic tomography. Some of the case studies shown in the following chapters are therefore presented together with sonic tomograms in order to better explain certain issues. For a better understanding, you should therefore also read Chapter [8.7 Tomogram Evaluation and Interpretation – Sonic Analysis Node](#), even if you only have a resistance tomograph.

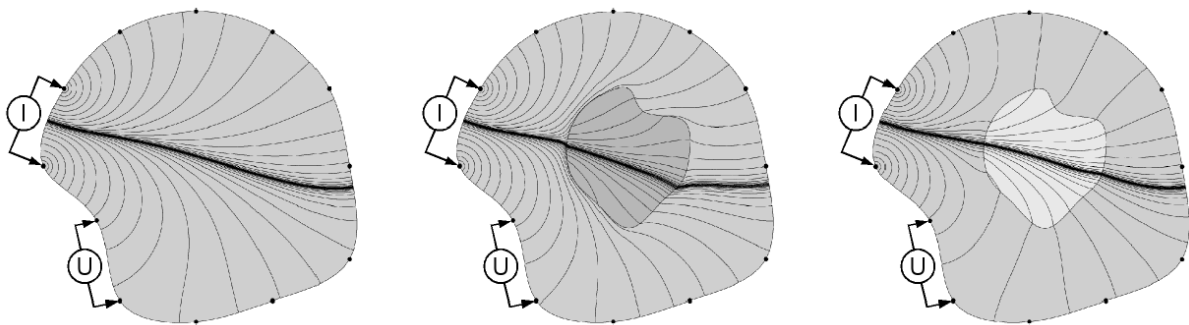
8.8.2 Theory of Electrical Resistance Tomography

8.8.2.1 History of Electrical Resistance Tomography

Electric resistance tomography (ERT) refers to a measurement method originally developed in geophysics. In this measurement method, electric currents and voltages are fed into the earth via electrodes on the earth's surface in order to detect differences in resistance in the underlying layers of earth, caused, for example, by groundwater or different materials. The ERT method was first applied to trees by geophysicists Just and Jacobs (1998). The PiCUS TreeTronic Tomograph uses the ERT measurement principle to determine the resistance distribution in tree wood. The electrical resistance of wood is mainly influenced by the moisture content in the wood, the cell structure, the ion concentration and other wood properties.

8.8.2.2 Physical Operating Principle

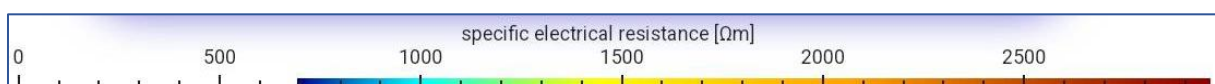
The measurements are carried out using pinpoint electrodes (nails) attached around the edge of the object. A current is fed into the object via two such electrodes. The resulting electric field depends on the resistance distribution and is measured via the voltage at the other paired electrodes. The following graph shows the electrical potential for homogeneous conductivity in normal wood. In cases where there is a stronger anomaly (centre), the potential lines move outwards and we obtain increased voltages along the circumference. If the anomaly is more conductive (right), the potential lines are attracted and we see lower resistance⁸.



"I" - current is applied and measured, "U" - voltage is measured

Once all measurements have been taken, the resistance distribution can be reconstructed. The main problem with using a numerical solution to describe the internal resistance based on the measured voltages is ambiguity, i.e. different models can be used to explain the data. By introducing additional constraints, e.g. the requirement for a smoothed model, we can limit this ambiguity and achieve a unique solution. This method is a non-linear reconstruction that is solved iteratively.

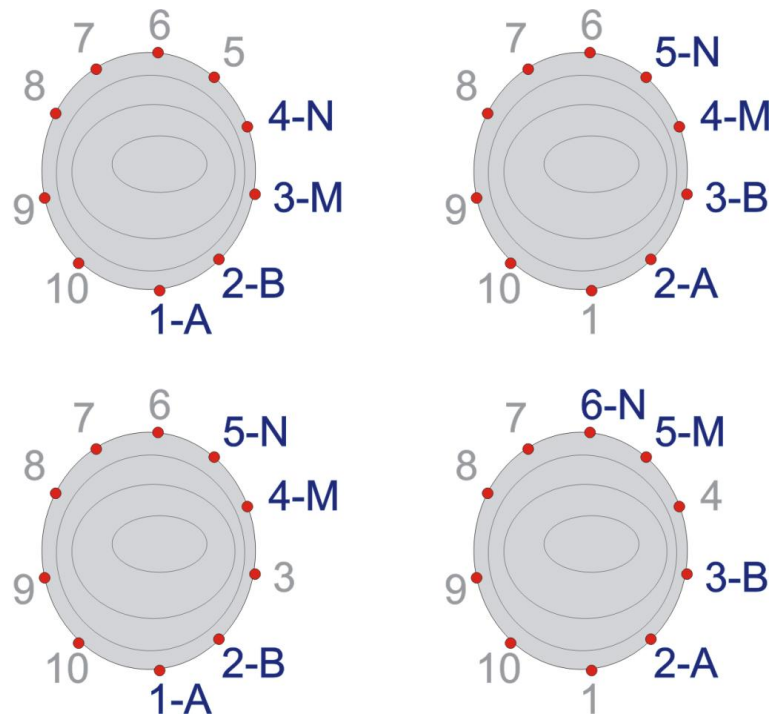
The colours in the ERT tomogram represent values in the unit [ohm * metre]. The colour scale is logarithmic and typically ranges between the lowest (blue) and highest (red) resistance.



⁸ Grafik von Dr. T. Günther und Dr. C. Rücker

8.8.2.3 Resistance Measurement

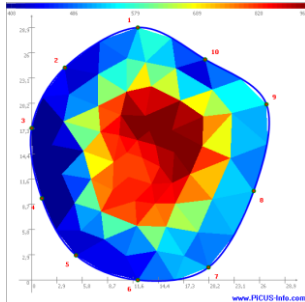
During resistance measurement, a voltage is applied between two adjacent electrodes A and B. The resulting current flow is measured. At the same time, the voltage drop across two further electrodes M and N is measured. The current feed points A and B and the voltage measurement points M and N are systematically switched through.



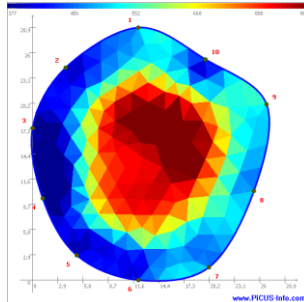
Additional Information about the resulting measurement table can be found in chapter [8.6 Electrical Resistance Measurement - The Resistance Measurement Node](#).

8.8.2.4 Mesh Resolution

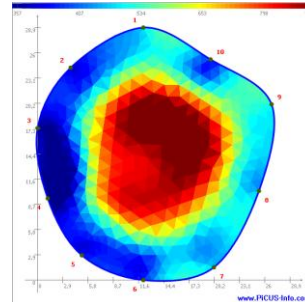
The tree cross-section (the measurement plane) is represented in the ERT calculation by a mesh of many small triangles. The mesh resolution determines the number of triangles inserted between two adjacent TP along the circumference. The higher the number of triangles, the longer the calculation time. The default value is 4. It should be noted that higher values have visual effects but do not significantly improve the ERT quality.



Mesh resolution = 2



Mesh resolution = 4

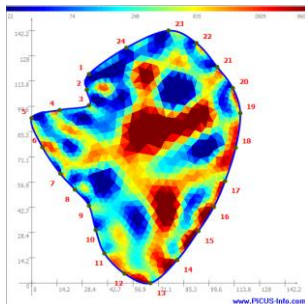


Mesh resolution = 8

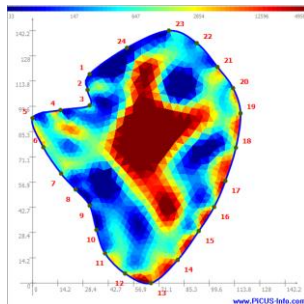
8.8.2.5 Smoothness

The smoothing level determines how much detail the ERT shows. Small smoothing values (1-10) show more detail than large values (100-1000), but they are also more susceptible to measurement errors. Smoothing levels 10 or 20 (standard) are commonly used values.

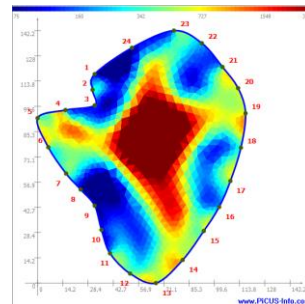
The example below shows the results of different smoothing parameters. The smoothing 10 ERT is easiest to understand here.



Smoothing = 3

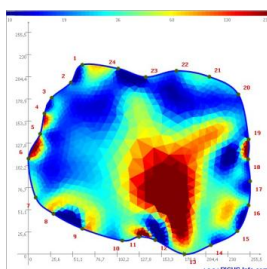


Smoothing = 10

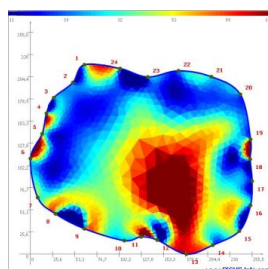


Smoothing = 100

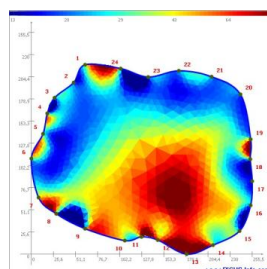
The next example was recorded on a Sequoia Giganteum, which has a circumference of 810 cm at the measurement level. The sonic data (SoT) suggests that significant cracks have formed in the tree. The ERT, calculated with smoothing level 1 (very sharply interpreted data), shows the probable positions of the cracks most clearly. These positions correspond well with those determined in the SoT, indicated by yellow lines (see also [8.7.5 Crack Detection](#))



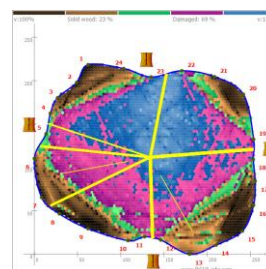
Smoothing = 1



Smoothing = 3



Smoothing = 20



SoT

8.8.2.6 Moving Measurement Points

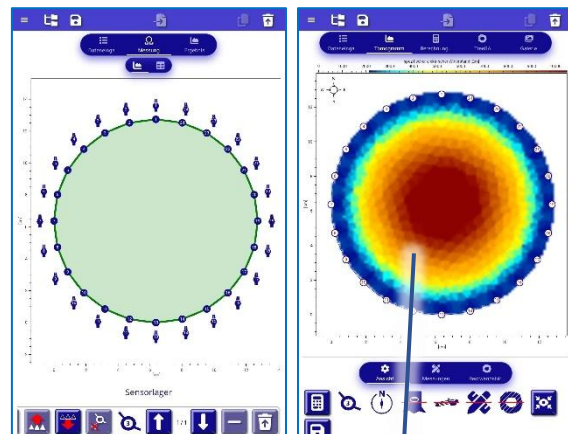
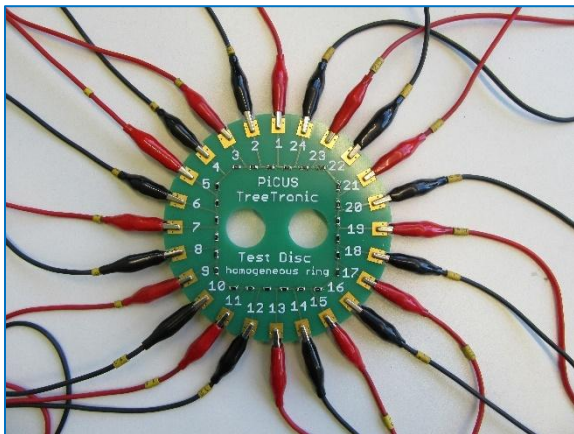
Similar to the PiCUS Sonic Tomograph 3, the PiCUS TreeTronic 3 can also be used on trees with more TP than measuring clamps. By moving the measuring chains, the tree can be measured step by step across its entire cross-section. However, this results in limitations in the accuracy of the result compared to a measurement carried out in a single step without moving the clamps.

Unlike the PiCUS Sonic Tomograph 3, the PiCUS TreeTronic 3 does not have separate transmitters and receivers. Each terminal of the measuring chains is used for both feeding and measuring during a measuring cycle.

*It is therefore possible in principle that **not every pair of clamps can be measured in relation to every other pair of clamps**. If there are more TP than measuring clamps, there may always be combinations of feeding and measuring points that cannot be covered. The limits of the method are determined by the number of TP, the number of clamps used and the number of partial measurements that can realistically be carried out.*

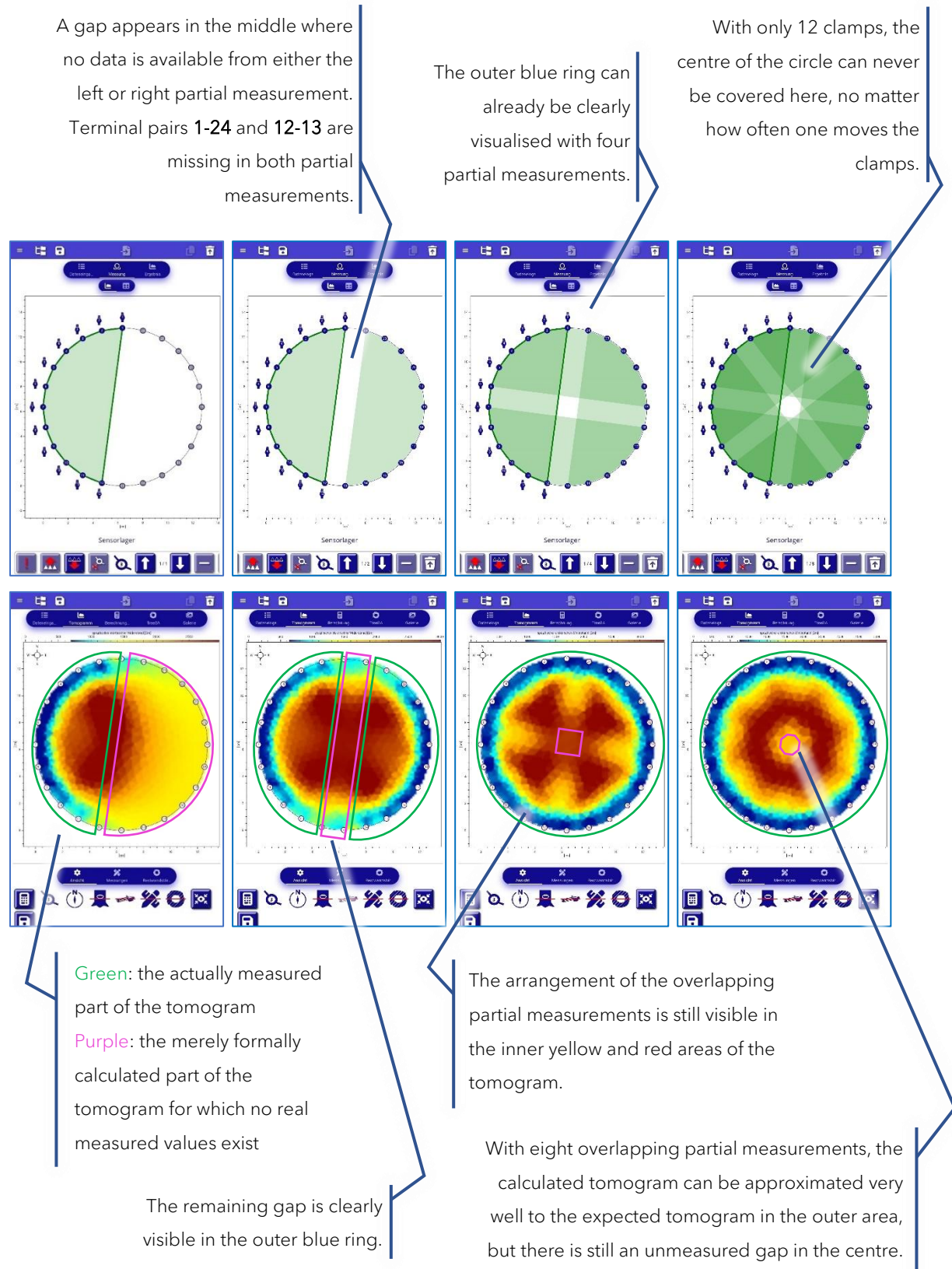
Formally speaking, each partial measurement represents its own tomogram, which can be calculated across the entire stem cross-section beyond the area actually measured. The individual partial measurements can all be combined with each other. To do this, clamp combinations that occur in more than one partial measurement are averaged together.

The following tomograms show measurements taken with only one measuring chain (12 clamps) on the PiCUS TreeTronic test disc (24 points), relative to the expected result of the test disc when measured with both measuring chains (24 clamps). The terminal assignments of all partial measurements in the measurement nodes and the resulting tomograms in the analysis nodes are shown in each case.



The expected result when all 24 clamps are used: The tomogram of the test disc shows a continuous blue ring around a red core.

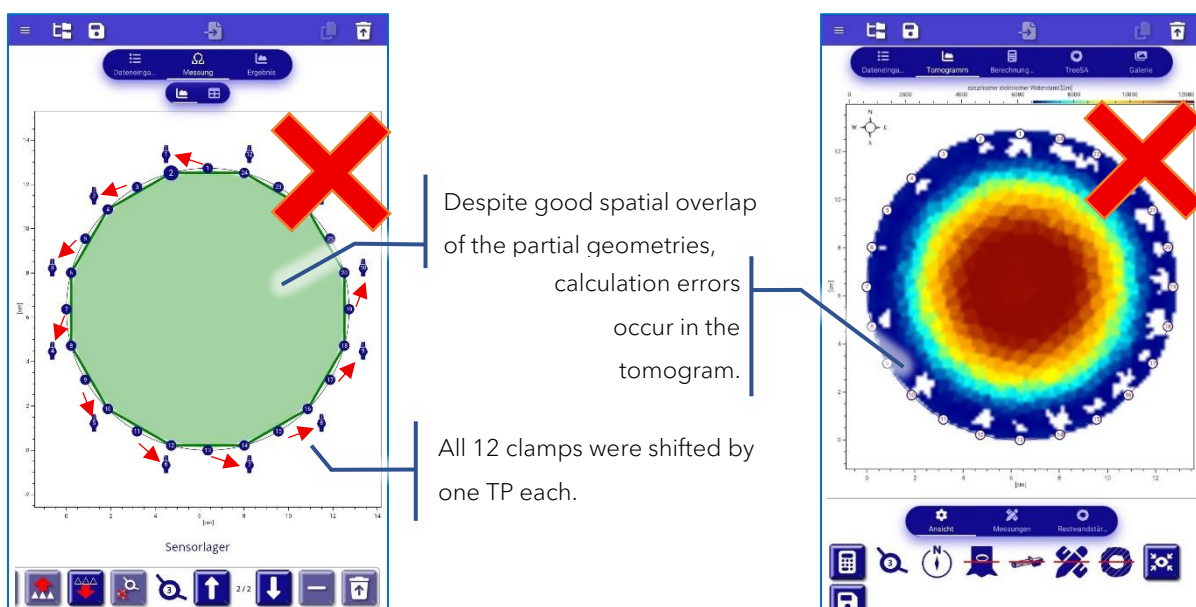
By overlapping partial measurements, the values calculated from the measured values can be systematically adjusted towards the expected tomogram. The theoretical optimum is achieved when the number of partial measurements corresponds to the number of BPs, and each partial measurement is shifted by exactly one BP (an effort that is usually not justified in practice):



The overlapping areas of the measured partial geometries in the measurement node are a measure of the reliability of the calculated tomogram. The more areas overlap, i.e. the darker the green area, the closer the tomogram data calculated in this part of the measurement plane is to reality.

To ensure that the averaging of several partial measurements in the overlapping areas can be carried out cleanly, no tree points may be skipped or omitted in measurements in which sensors are moved. In the following example, the clamps have been positioned **wrong**. In the first measurement round on all odd TP, in the second measurement round on all even TP. By skipping every second TP when assigning clamps (within a partial measurement), no identical clamp pairs are created that are present in both partial measurements (even though the partial measurements both cover the entire area).

A correct combination of the measurements therefore fails in this example.



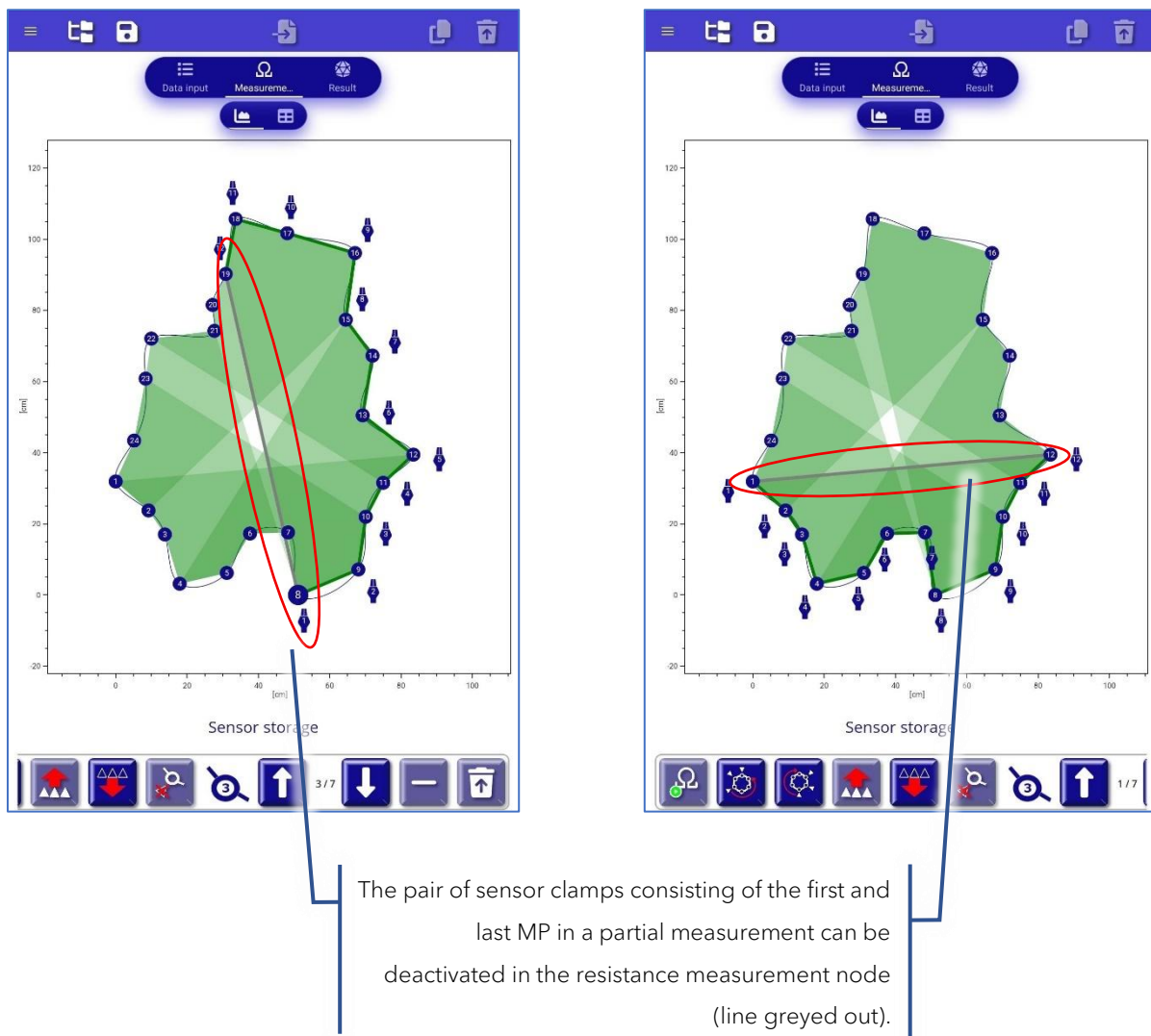
In order to obtain good tomograms when implementing PiCUS TreeTronic 3, the following points should be noted:

- ERTs consisting of several partial tomograms can, in principle, always contain inaccuracies due to incomplete measurement data.
 - The reliability of the measurement data can be estimated in the measurement node at the overlapping green areas: the more overlapping partial geometries, the darker/better
- Within a partial geometry, no TPs should be skipped in the terminal assignment
 - If a TP is skipped nonetheless, this TP should also be skipped in all other overlapping partial measurements to avoid conflicts when combining the measurement data
- Partial measurements should always cover more than half of the tree cross-section, otherwise an unmeasured *hole* will appear in the centre of the trunk
 - The position of the *hole* depends on the tree geometry and TP positions.
 - The green areas in the measurement node indicate which parts of the trunk geometry are covered.

Partial geometries always have an inner line from the last measuring point back to the first. This inner line typically has considerably larger distances between the nails than all other clamp pairs (adjacent nails). From a purely mathematical point of view, this inner line does not pose a problem. The clamp pair can be used without restrictions in the tomogram calculation.

However, there are restrictions resulting from the measurement hardware used. Due to the unusually large distances between the nails, considerably more energy is required to feed a constant current through these nails. In extreme cases (large distances in dry wood), this can cause the power source in the PTT 3 to reach its load limit and become overloaded. In such a case, measurement errors occur which can distort the resulting tomogram. It is therefore advisable to perform the tomogram calculations both with and without inner lines. If there are significant differences in the tomograms, the inner lines should not be used.

The internal lines can be deactivated separately for each partial measurement in the resistance measurement node (see also [8.6.5.1 Deactivating Sensor Clamp Pairs](#)).



8.8.3 Tomogram View - Workspace

In the work area below the tomogram, the **View** tab contains controls that can be used to show or hide various information in the tomogram.



Calculate: recalculates the tomogram. This is also triggered automatically when a calculation parameter is changed.



Show TP numbers: Shows the assigned number for each TP. The numbers can take up a lot of space on smaller displays and can therefore be hidden. TP1 is easy to identify even when the numbers are hidden (triangle instead of dot).



Show north direction: Shows a compass rose in the top left corner.



Diagnostic marks: shows or hides the diagnostic marks set in the geometry node. See also [8.4.7.1 Defect Description after Visual Inspection](#).



Drilling Measurements: overlays the projections of boreholes onto the measurement plane, added in the geometry node. See also [8.4.7.2 Documenting External Drilling Measurements](#).



Markers: toggles the display of distance and angle measurement markers. See also [8.7.4 Distance and Angle Measurement Markers](#).



Residual Wall Thickness: displays the auxiliary ring for estimating the required residual wall thickness. For various methods of estimating the residual wall thickness, see also [8.7.7 Estimating Residual Wall Thickness](#).



Scale Geometry: Adjusts the zoom level and shifts the graphic so that the entire geometry is visible, fully utilizing the available display space. Alternatively, the graphic in the app can be scaled and moved using *touch gestures*. On the PC, the graphic can be *moved with the right mouse button* and the *zoom level adjusted with the mouse wheel*.



Save: saves the current tomogram view, based on the above settings of the view control, as an image file. The tomogram can be saved as a vector graphic in *.svg and *.pdf formats or as *.jpeg or *.png. The filename is user-selectable, and the default name will be automatically numbered if necessary. All created image files are visible in the gallery. The formats *.jpeg and *.png can also be used for integration in reports (see also [8.10 Generating Reports - Report Node](#)).

8.8.3.1 Tomogram Gallery

Saved tomograms can be viewed in the **Gallery** tab of the Analysis node.



Delete Image removes the currently selected capture from the project.



In the gallery, the **arrow keys** can be used to switch between all available captures.

In the **Tomogram Meta Data** section, additional information is stored for each capture:

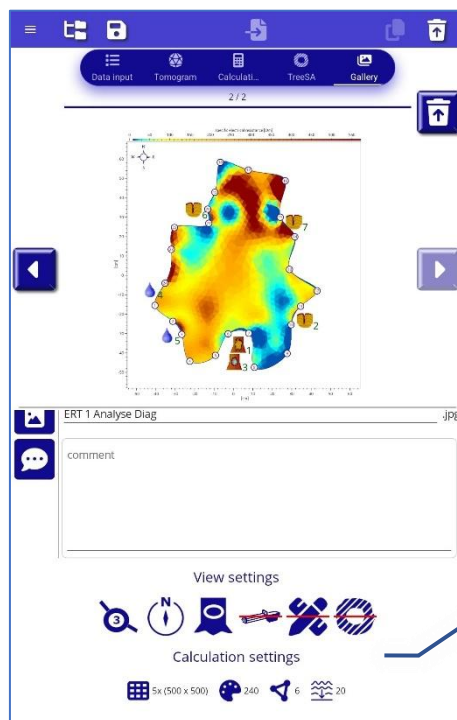


Filename: The name is freely selectable. Descriptive names corresponding to the content depicted in the tomogram facilitate further processing.



Comments: A free-text field where additional information about the image can be noted.

The sections **View Settings** and **Calculation Settings** display all values for calculation and presentation used in creating this tomogram. This makes it possible to reproduce a tomogram. These pieces of information can also be displayed in the Report node to document the tomogram creation.



All tomogram settings that were active when the screenshots were created are documented here.

If the image is inserted into a report, the settings can also be transferred to the report.

8.8.4 Estimating Residual Wall Thickness

The calculation of the remaining wall thickness necessary for the tree's stability does not differ between sonic and electrical resistance tomograms. It is performed purely formally based on the data entered in the project, tree, inspection, and geometry nodes. A complete description of this tab can be found in section [8.7.7 Estimating Residual Wall Thickness](#).

8.8.5 Options for Calculation

When creating an analysis node, the settings from the global template are initially used for the calculation options (see also [4.4.4 Calculations](#)).

These settings can then be adjusted locally in the Calculations tab.



Grid size: Specifies how finely the tomogram is calculated. The larger the grid, the finer the structures displayed in the tomogram. However, finer structures also require considerably longer calculation times.



Colour palette: Specifies the size of the colour palette to be used for the electrical resistance tomograms. Higher values result in smoother colour transitions. The colour scale is automatically applied between the smallest (blue) and largest (red) resistance values.



Mesh resolution: The tree cross-section (the measurement plane) is represented in the ERT calculation by a mesh of many small triangles. The mesh resolution determines the number of triangles inserted between two BP along the perimeter. (see also [8.8.2.4 Mesh Resolution](#))



Smoothness: The smoothing level specifies how many details are visible in the calculated tomogram. Smaller values show more details in the tomogram, larger values show fewer (see also [8.8.2.5 Smoothness](#)).



Factor VTA Method: For the calculation of the remaining wall thickness with the VTA-0.3 method (Mattheck & Breloer), a factor deviating from the standard can be entered here. See also [8.7.7 Estimating Residual Wall Thickness](#).



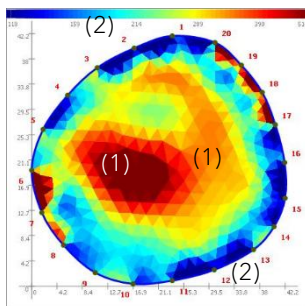
Manual colour palette: When the manual colour palette is activated, the smallest and largest resistance values defining the limits of the colour scale are no longer determined from the tomogram but are entered directly here. All values in the tomogram that are greater than the maximum are also displayed in dark red, and all those that are smaller than the minimum are displayed in blue.

8.8.6 Typical Patterns / ERT Types

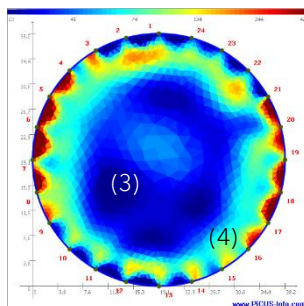
The main aspect in interpreting ERTs is the distribution of high and low conductivity areas. It is important to note where high resistances are and where low resistances are. This information must be compared with the normal resistance distribution in healthy trees of this species.

The actual resistance value shown in the tomogram is not that important, nor is it that accurate, due to the ambiguity of the measurement and calculation method.

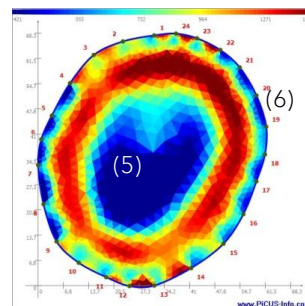
So far, three types of typical resistance distributions have been found in trees. Here, these are simply referred to as ERT types 1, 2 and 3.



ERT-Type 1



Type 2



Type 3

8.8.6.1 ERT Type 1

Low resistance (high conductivity – blue colours) on the outside of the tree and relatively **high resistance** (low conductivity – red colours) in the centre of the trunk. The ERT shows the typical resistance distribution of a healthy beech tree. The heartwood of a beech tree is less conductive (**high resistance**) than the edge of the tree. The blue ring on the outside (2) shows the bark/sapwood, through which water is transported.

Many tree species, especially most European tree species, belong to this group:

Acer (maple), *Aesculus* (chestnut), *Betula* (birch), *Castanea sativa* (sweet chestnut), *Cedrela odorata* (West Indian cedar), *Cinnamomum camphora* (camphor tree), many *Eucalyptus* (eucalyptus trees), *Fagus* (beech), *Fraxinus* (ash), *Larix* (larch), *Pinus* (pine), *Picea* (spruce), *Populus* (poplar), *Salix* (willow), *Sorbus* (service tree), *Swietenia macrophylla* (American mahogany), *Tilia* (lime), *Ulmus* (elm) and others.

Tree species such as *Aesculus* or *Populus* often develop wet wood inside, even when they are still young. The wet wood changes the conductivity of the heartwood. Early stages of this wet wood do not pose a risk to the breakage resistance of the trunk.

Mimosaideae (Mimosa family / acacia) and *Elaeis guineensis* (oil palm) also typically exhibit this resistance distribution.

8.8.6.2 ERT Type 2

High resistance (low conductivity – red colours) on the outside of the tree and relatively **low resistance** (high conductivity – blue colours) in the centre of the trunk. The example above is an ERT of a healthy *Sequoia Giganteum* (giant sequoia) showing low resistance in the core ((3) – blue colours). The bark/sapwood shows higher resistances ((4) – red colours) than the heartwood.

This does not mean (!) that the sapwood is dry!

The absolute values of the sapwood suggest that the wood is conductive – it is not dry due to its moisture content – but the low resistance is higher than the resistance in the heartwood.

Examples probably are: *Sequoiadendron giganteum* (coastal redwood), *Casuarina* (casuarina), *Samanea saman* (rain tree), *Tectona grandis* (teak).

8.8.6.3 ERT Type 3

Type 3 ERTs show a **ring-like distribution of resistance**. The example was taken from an English oak (*Quercus robur*).

In the ERT, the blue ring (6) indicates low resistance in the bark/sapwood on the outside. The blue centre with low resistance (5) in this *Quercus robur* is caused by high concentrations of various ions. These tomograms are typical for healthy English oaks (*Quercus robur*). Given its close relationship with other European oak species, it seems likely that other oak species, particularly *Quercus petraea*, exhibit similar characteristics. Furthermore, random samples have provided consistent evidence that *Quercus rubra*, and probably other red oak species as well, also belong to this group.

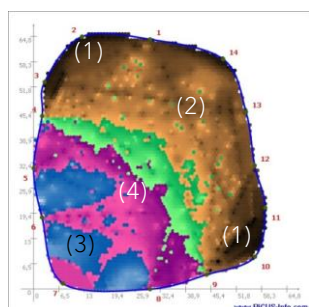
8.8.7 Combined Analysis of ERT and SoT

The following decision tables can be used to interpret SoT and ERT in combination.

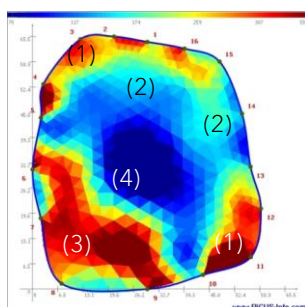
8.8.7.1 ERT 1 Decision Table

SoT -sonic velocity [m/s]	ERT specific resistance [$\Omega \cdot m$]	Wood status	# in the tomogram
 High (brown)	 High (red)	Healthy wood	(1)
 High (brown)	 Low (blue)	Still safe, early state of rot	(2)
 Low (blue / violet)	 High (red)	Cavity / crack / dead rot	(3)
 Low (blue / violet)	 Low (blue)	Active rot	(4)

The example shows a *Tilia* tree with various stages of decay.



SoT



ERT



Photo

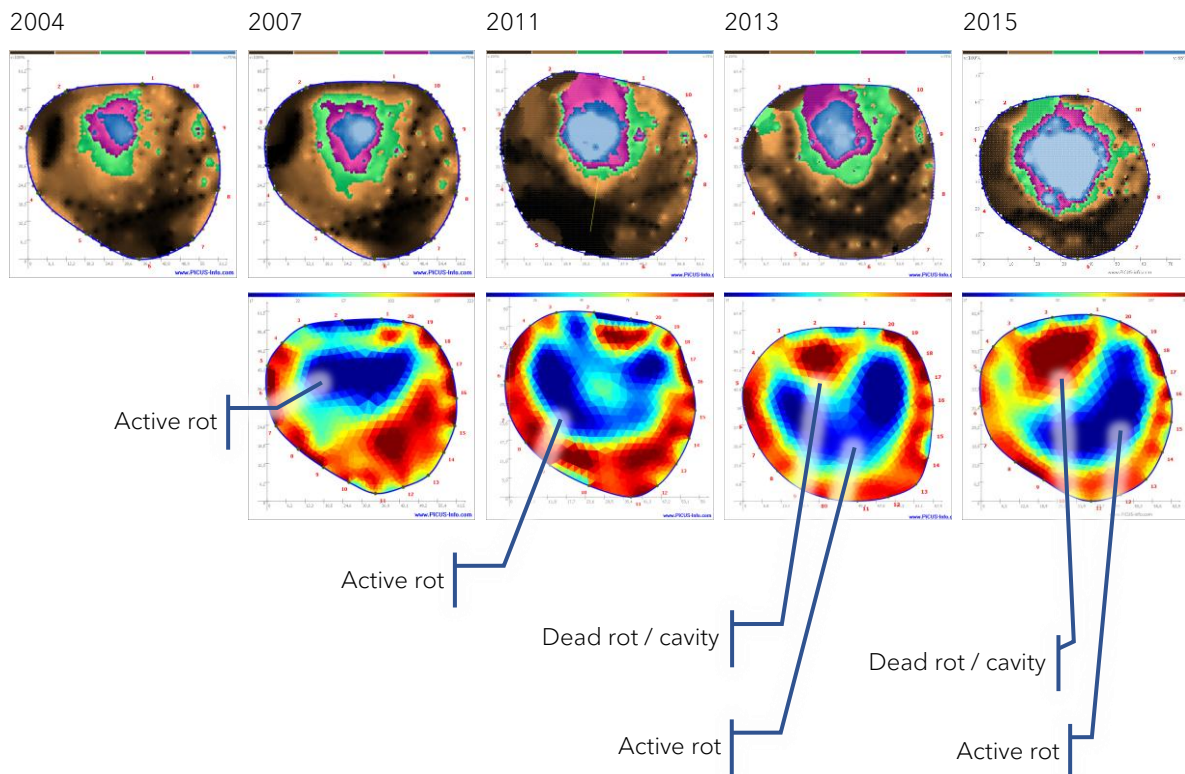
8.8.7.2 ERT 2 Decision Table

SoT -sonic velocity [m/s]	ERT specific resistance [$\Omega \cdot m$]	Wood status
 High (brown)	 Low (blue)	Healthy wood. Not clear, possibly early stages of rot.
 High (brown)	 High (red)	Not clear. Could be dry, hard fungus.
 Low (blue / violet)	 High (red)	Cavity / crack / dead rot
 Low (blue / violet)	 Low (blue)	Active rot

8.8.7.3 Temporal progression – a look into the future

A comparative analysis of sonic and resistance tomography not only allows an assessment of the current condition but also enables a prognosis of the future development of defects. This is particularly possible when a tree is examined repeatedly over a period of several years.

The following time series illustrates this clearly:



The wet areas with active and spreading rot are clearly visible in the ERT. The rot spreads continuously into still intact, solid wood and weakens it over time (the extent of the damaged area is always smaller in the SoT than in the ERT). The future development of the damaged area can be estimated well on the basis of its development to date.

The tomogram comparison node can be used to create timelines and for comparative analysis of sound and resistance tomograms (see Chapter [8.9 Timelines and 3D View - Tomogram Comparison Node](#)).

8.8.8 Limits of the Method

The measured ERT data is ambiguous; different distributions in the tree can cause the same measurement results at the circumference. Therefore, the electrical resistance measurements might be displayed incorrectly in the following situations:

- **Measurements close to the ground** The ERT calculation always assumes a (theoretically) infinite extension of the test object below and above the measurement plane. This condition cannot be met for measurements close to the ground, as the more or less cylindrical tree cross-section branches out into the root system in the soil. Nevertheless, good measurements can be obtained for trees with high conductivity, caused for example by fungal infections, despite the violation of the measurement condition.
- **Hollow trees** The remaining ring of wood is very electrically conductive compared to the hollow. Under certain circumstances, the calculation may not be able to correctly calculate the hollow (the hollow should have high resistance) if the distance between the measuring points is too great.

- Example 1:

Tree diameter: 1 metre

Remaining wall thickness: ~10 cm

Distance between MP: 30 cm

Result: The ERT cannot clearly identify the high resistances of the hollow.

- Example 2:

Tree diameter: 1 metre

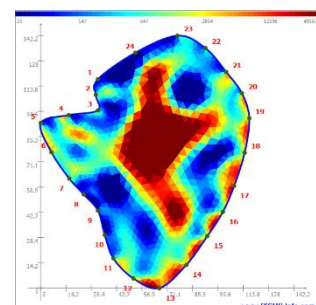
Remaining wall thickness: ~10 cm

Distance between MP: 5-10 cm

Result: the ERT shows the high resistances of the hollow.

- **Water-bearing cavities** A cavity filled with water is shown in blue (high conductivity) in the ERT.
- **Multiple defects** The ERT of trees that have various defects, such as cavities, rot, cracks, bark ingrowths in the tomography plane, is not as accurate as an ERT on a tree with only one of these defects.

- **Obviously incorrect colours** for healthy wood The ERT shows the relative resistance of the wood. In cases where the tree has a large cavity (dry and empty), this cavity determines the upper end of the resistance scale and is displayed in red colours. In relation to this very high resistance range, the remaining healthy wood is wet. Therefore, the healthy wood is displayed in blue colours (low R). The image on the right shows an example: the red area in the centre is a cavity and cracks. Most of the blue areas around it are *normal* wood. The *normal* wood is naturally *wetter* than the cavity.



In order to detect incorrect measurements, it is always advisable to cross-check the measurement results using a different physical measurement principle (e.g. sonic tomography).

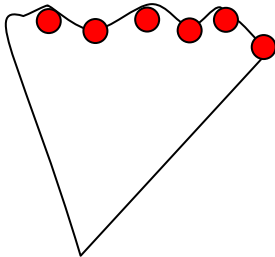
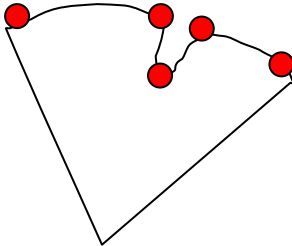
8.8.9 Troubleshooting

The mesh generator calculates a mesh consisting of triangles, to which resistance values are then assigned. In certain cases, the calculation of the mesh may fail. To avoid problems in the evaluation, a tomogram calculation should always be performed once on site so that any necessary changes can be made to the measurement setup.

If this is not possible, most problems can also be circumvented retrospectively through skilful data manipulation. Critical problem cases and possible solutions are described in the following chapters.

8.8.9.1 Mesh Generation Errors due to Unfavourable Geometries

The most common source of error is a small distance between adjacent measuring points or a very different distance between adjacent points and the centre of the tree.

The mesh generator works reliably. The distance between the TP is small and all TP lie approximately on a radius, i.e. the distance from the TP to the centre of the tree is approximately the same.	The mesh generator can generate an error: - the distances between neighbouring TP are small - the distance of the TP to the centre of the tree varies greatly (sharp, inward-pointing corners).
	

Errors in mesh generation are explained below using two examples. On the left are the incorrectly calculated tomograms and on the right are the corrections.

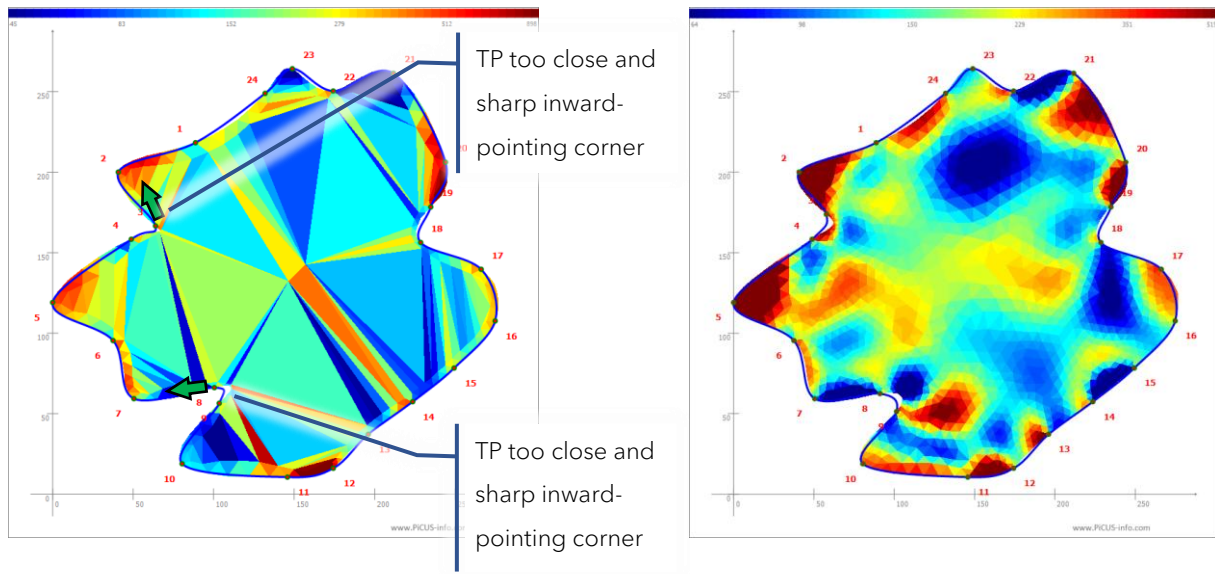
The geometry was measured precisely with the calliper in both examples.

However, the distances and positions of individual TP are unfavourable for the mesh generator.

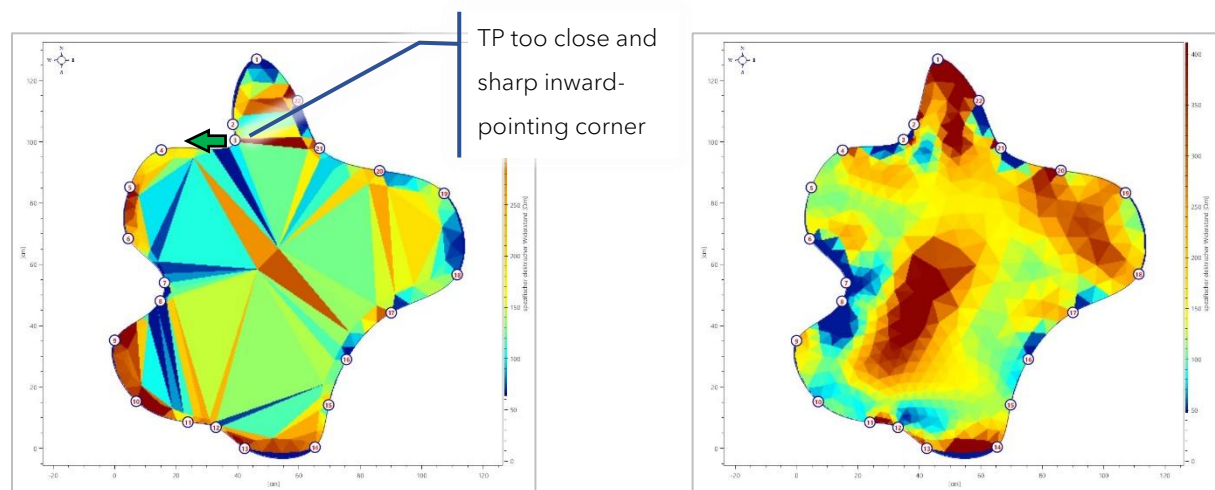
A targeted shift of individual measuring points by a few millimetres corrects the errors without negatively affecting the overall shape of the geometries.

The green arrows show the direction in which the points were shifted.

In the first example, the distances and positions of TP 3 and 4, as well as 8 and 9, are unfavourable for the mesh generator. By slightly shifting TP 3 and 8, the distance to the neighbouring points was increased and the inward-pointing corners were rounded so that the mesh generation could be carried out successfully.

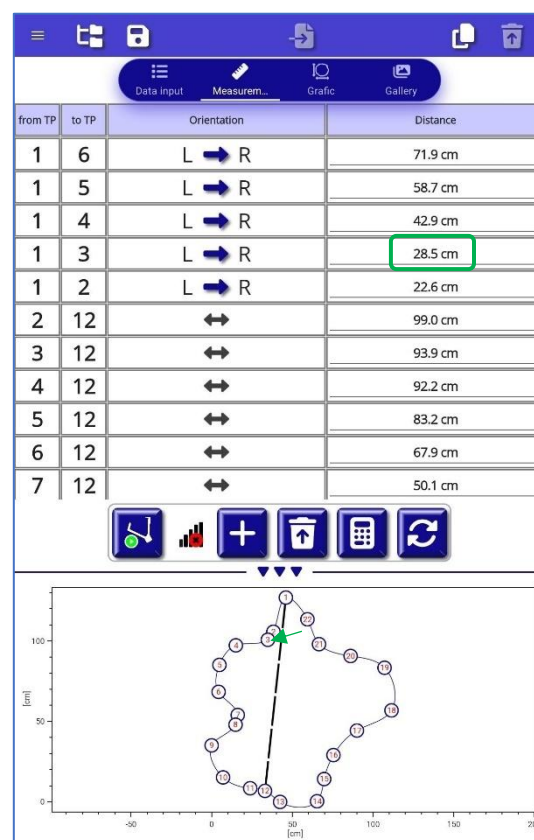
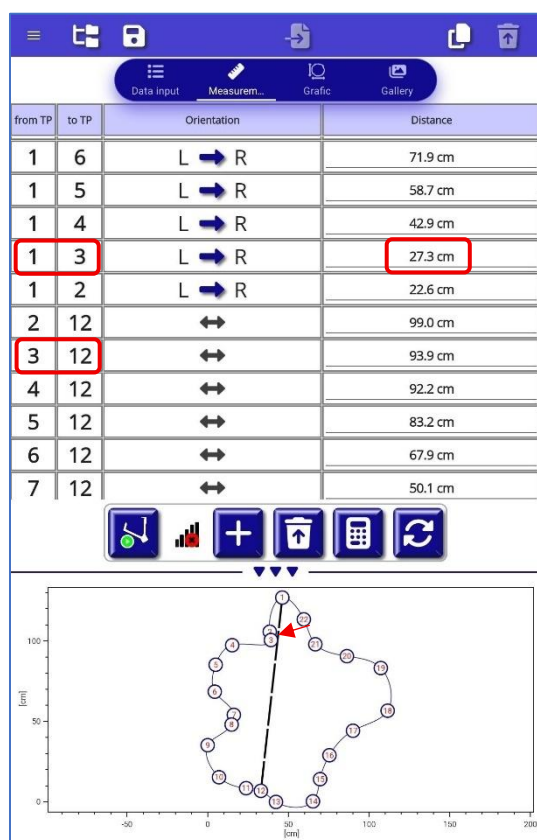


In the second example, the distance between TP 2 and 3 is very small. In addition, there is again a sharp, inward-pointing corner in the triangle formed by TP 2, 3 and 4.



For the correction, TP 3 was shifted slightly to the left, which rounds off the shape of the geometry at the critical point.

To correct the position of TP 3, the distances determined in the calliper measurement can be selectively adjusted in the geometry node. To do this, first determine the two distances belonging to the point. Then one or both distances can be adjusted as required. In this case, it was sufficient to slightly increase distance 1-3.



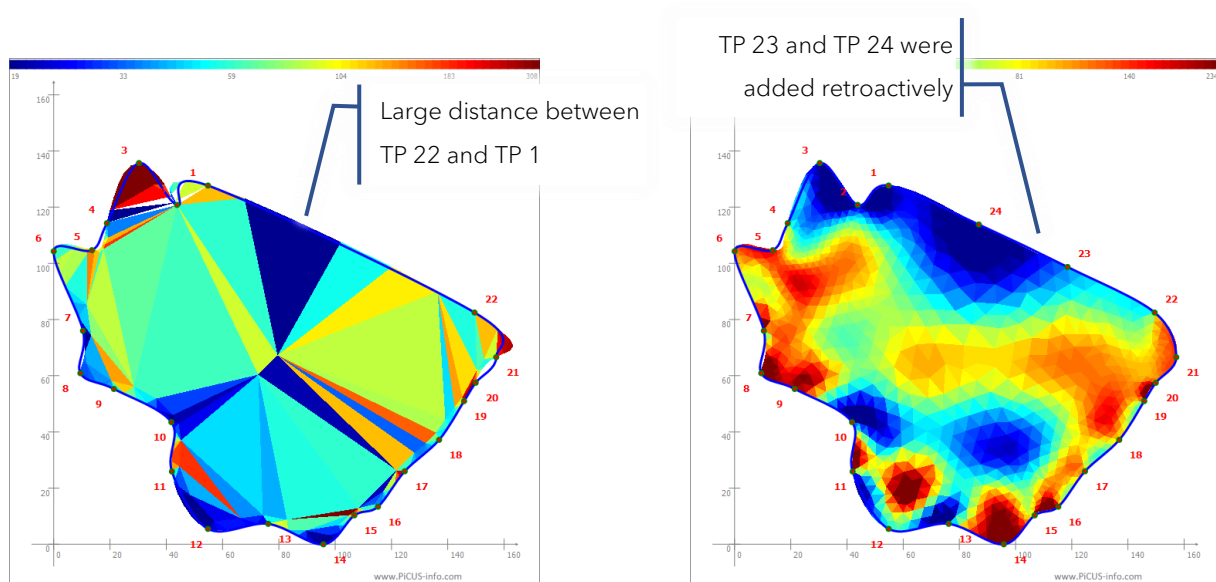
The **Use curved splines** option available in the data input page of the geometry node does not affect the calculation of the triangles but only influences the graphical representation of the outer contour line of the geometry.

In some cases, problems with the mesh generator can also be resolved by increasing the mesh resolution. Values of 6, 7 or 8 generate more triangles between the tree points, giving the mesh generator more options for adjusting the triangles.

8.8.9.2 Mesh Generation Errors on Trees with Large Open Cavities

The mesh generator works best when the tree points are distributed fairly evenly around the trunk circumference. These conditions may not be met on trees with large open cavities.

The left ERT was measured on a lime tree with a large open cavity near the ground. No tree points could be set between TP 22 and 1 due to the cavity. The mesh generator calculates incorrect triangles because it cannot compensate for the large differences in tree point spacing.



To avoid this problem, additional points can be added in the geometry node after the actual measurement.

*Always add additional TP individually in the **Measurement** tab of the Geometry node!*

*Under no circumstances should you change the number of tree points in the **Data Entry** tab, as this would cause the assignment of measurement points and measured values to be lost. Be sure to observe the restrictions described in chapter [8.4.9 Subsequent Changes to Geometries](#) when changing the number of tree points.*

The calculated resistance values may be inaccurate without actual measured values at the added points. In the above example, a low resistance, i.e. blue colours, is incorrectly determined for the open cavity around TP 24.

8.9 Timelines and 3D View - Tomogram Comparison Node

For a comprehensive assessment of the condition of a tree, often more than just one tomogram is required. The tomograms to be analysed can be spatially separated (at different heights) as well as temporally (inspections at different time points), or they can be made with different methods (sonic or resistance tomography). To track the temporal development of a defect over months or years, to visualize the vertical extent of damages through multiple measurement planes and to juxtapose sonic and resistance tomograms, the Tomogram Comparison node can be used.

In the project structure, a Tomogram Comparison node is always associated with a tree. This node has access to all inspections conducted on this tree and all tomograms created in these inspections.

What the Tomogram Comparison node *cannot* do is compare a tree with another.

The Comparison node is divided into the following tabs:

- **Data Selection:** This is where all tomograms to be compared are selected.
- **Compare:** Two tomograms are displayed simultaneously, and each of the two graphs can be individually switched between all the selected tomograms for display.
- **Timeline:** Selected tomograms are arranged on a timeline based on their timestamp (in the Inspection node). Tomograms can be scrolled through in chronological order. Additionally, a difference image between the first and the current tomogram is calculated. This difference image allows an assessment of how damages in the tree have developed. Alternatively, instead of the difference image, a simultaneous display of sonic and resistance tomograms can be provided for the selected time stamp.
- **3D View:** All selected tomograms from an inspection are stacked simultaneously in a three-dimensional view, depending on the height of the measurement plane. Through interpolation, the spatial extent of damages through the tree can be estimated and visualized.
- **Gallery:** Screenshots can be taken from the 3D view and displayed here. Additionally, accompanying photos of the tree can be taken, ideally capturing the tree from the same angle as the corresponding 3D view.

The following sections describe each of these tabs in detail.

8.9.1 Data Selection for Tomogram Comparison

The various comparison options rely on numerous parameters that need to be determined or entered during the data acquisition process. Of particular importance are:

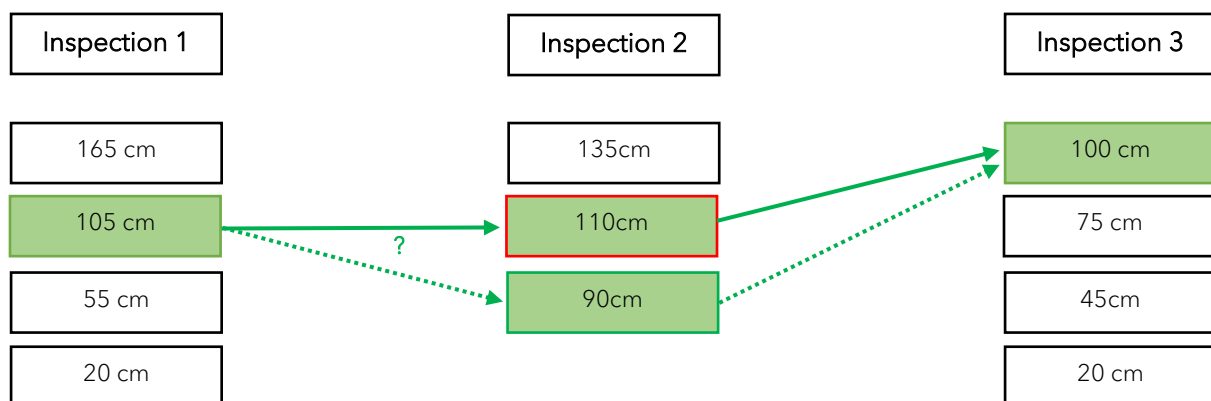
- **Date:** The timestamps of the inspection nodes ensure correct sorting on the timeline.
- **North orientation:** To display all tomograms with a consistent orientation, tomograms are always rotated so that north is at the top.
- **Height of the geometry plane:** The height determines the vertical spacing of the tomograms in the 3D view.

The more thoroughly these parameters are captured, the more accurate and meaningful the comparison options will be.

8.9.1.1 Data Selection and Planning Data Acquisition

Due to inherent limitations in data selection, the software cannot autonomously resolve certain issues. The following example illustrates this:

In three inspections, 3 or 4 tomograms were obtained in different measurement planes. The development of damage at a height of 100cm needs to be determined and presented in a timeline. The software cannot decide which tomogram is correct here since not all tomograms have exactly the same height. It is also not always the second tomogram in the list that is closest to the height under investigation. If you manually select the highlighted green tomograms from all available tomograms, only the first selected tomogram at 110cm (red box) is displayed in the timeline for Inspection 2 (solid green arrow).



Assuming that decay tends to spread downward, it is more sensible to use the tomogram at 90 cm for comparison (dashed arrow). Such a context-dependent decision cannot be made autonomously by the software.

It is therefore very important to MANUALLY restrict the data selection to those tomograms that have the highest significance.

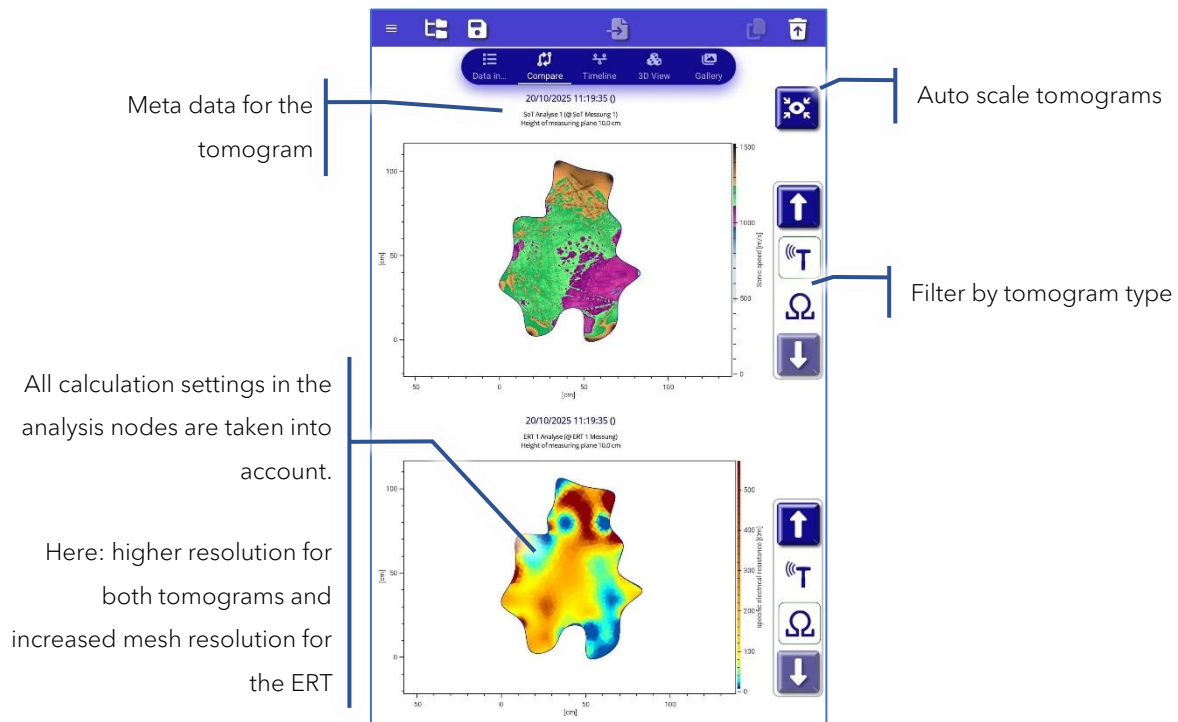
To make it easier to decide which tomograms to use for comparative analysis and to generate easily comparable tomograms, consider the following tips:

- In the planning of measurements, consider a later comparison with older and upcoming inspections.
 - Review older inspections if necessary and base your measurement setups on them to achieve consistent measurement conditions across all inspections:
 - Always use measurement planes at consistent heights.
 - Keep the tree points consistent in number and orientation (e.g., always place BP1 facing north, and distribute the same number of nails around prominent points, such as root attachments).
 - Thoroughly document the measurement setup in preparation for the next inspection.
- Use descriptive names: In the selection list of the Tomogram Comparison node, all available tomograms are displayed with the name of the respective analysis node. Assign meaningful names so that you can easily select the relevant tomogram for comparison even after years, without having to sift through each tomogram.
- If you have to review a larger number of older tomograms, simply load all tomograms into the comparison node. Irrelevant tomograms can then be gradually removed. This approach is faster than systematically navigating through a large number of analysis nodes for review, especially if no further calculation options are needed.

8.9.2 Direct Tomogram Comparison

On the **Compare** tab, any two tomograms can be compared. The tomograms are displayed as they are in their respective analysis nodes. All set calculation options, such as resolution, colour space size, or measurement data validation limits, are respected for each tomogram separately.

However, accompanying documentary information such as diagnosis and drill marks, as well as additional calculation results like crack detection, length and angle measurement, or remaining wall thickness, are not displayed.



Each of the two diagrams can be systematically cycled through all the tomograms selected in the **data selection**. The current filter setting is taken into account.

For the currently displayed tomograms, the following metadata is shown:

- **Inspection node:** Timestamp and name of the inspection under which the tomogram was created.
- **Analysis node:** Name of the analysis node, i.e., the tomogram itself, as well as the name of the measurement node to which the analysis node is linked.
- **Height of the measurement plane:** in cm, to indicate where in the tree the tomogram was measured.



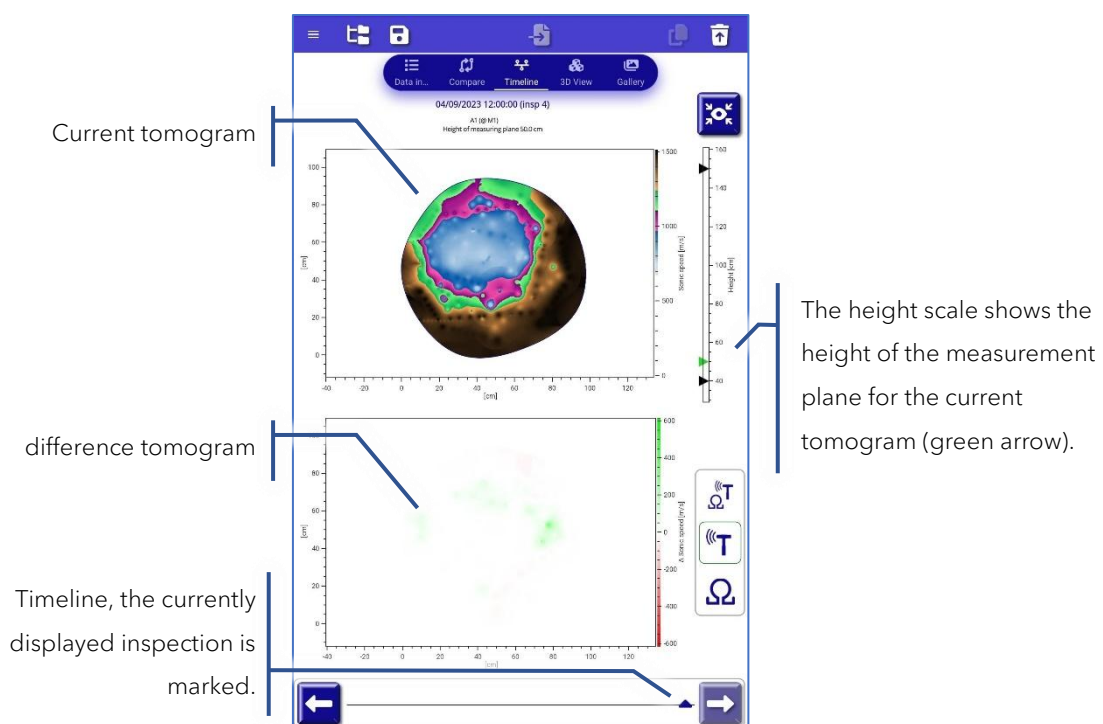
Scale Geometry: Adjusts the zoom level and shifts the graphic so that the entire geometry is visible, fully utilizing the available display space. Alternatively, the graphic in the app can be scaled and moved using *touch gestures*. On the PC, the graphic can be *moved with the right mouse button* and the *zoom level adjusted with the mouse wheel*.

8.9.3 Creating Timelines

To assess the long-term development of a defect and the tree's response to it, and to make a prognosis for the future, tomograms from multiple inspections can be summarized in a timeline.

Below the tomograms, there is a slider that allows switching between tomograms from all selected inspection nodes (i.e., between all points in time). Large time intervals between inspections result in large gaps between the individual positions of the slider.

For the use of the timeline function, only one tomogram of a specific type per inspection should be selected. For example, if two sonic tomograms from one inspection node are selected, only the first one in the list will be considered.





Scale Geometry: Adjusts the zoom level and shifts the graphic so that the entire geometry is visible, fully utilizing the available display space. Alternatively, the graphic in the app can be scaled and moved using *touch gestures*. On the PC, the graphic can be *moved with the right mouse button* and the *zoom level adjusted with the mouse wheel*.



The arrow keys switch between the inspections of the timeline. Only the first tomogram from each inspection node is displayed. See also [8.9.1 Data Selection for Tomogram Comparison](#).

8.9.3.1 Choosing the Timeline Type

In the timeline, similar to the direct tomogram comparison, 2 tomograms are always displayed simultaneously. For these tomograms, the following display modes are available, which can be selected via the control buttons next to the tomograms:



Sonic tomogram and resistance tomogram: A direct comparison of sonic and resistance tomogram. If only one tomogram is selected for an inspection, the respective other diagram remains empty.



Sonic tomogram and difference tomogram: The current sonic tomogram and a difference image between the current and the first tomogram in the timeline are displayed. If the current tomogram is also the first tomogram, the difference tomogram remains empty.



Resistance tomogram and difference tomogram: The current resistance tomogram and a difference image between the current and the first tomogram in the timeline are displayed. If the current tomogram is also the first tomogram, the difference tomogram remains empty.

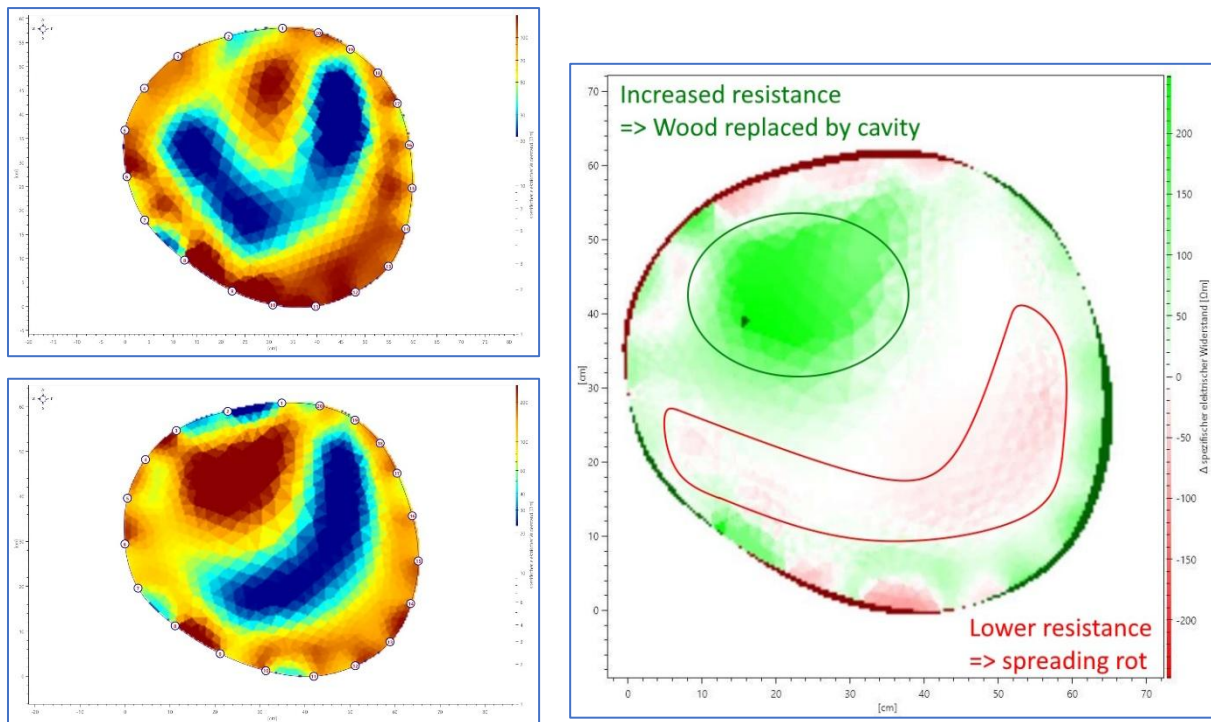
8.9.3.2 Interpretation of the Difference Tomogram

The difference tomograms calculated in the timeline represent the change in absolute speeds or resistances for each point in time relative to the first tomogram in the timeline. It does not determine a difference between the displayed tomogram colours but rather relies on the underlying speeds or resistances for the calculation. Differently scaled colour spaces in individual tomograms are automatically factored out.

A new colour scale is symmetrically applied based on the absolute value of the determined minimum and maximum differences:

- **Dark green:** Areas where new wood has been added. This region of geometry did not exist in the older tomogram.
- **Light green:** Areas where the sonic velocities or electrical resistance has increased.
- **White:** No change compared to the older tomogram.
- **Light red:** Areas where the sonic velocities or electrical resistance has decreased.
- **Dark red:** Areas where wood has disappeared. This region of geometry is no longer present in the more recent tomogram.

The following example shows a lime tree with severe rot. The two left-hand resistance tomograms were taken in the summers of 2013 and 2015. The calculated difference tomogram is shown on the right.



Whilst an individual examination of the individual tomograms reveals very similar patterns of damage, the difference tomogram clearly shows the progression and, consequently, predicts the future trend.

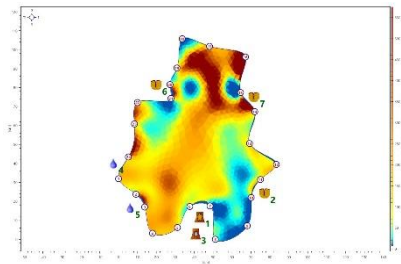
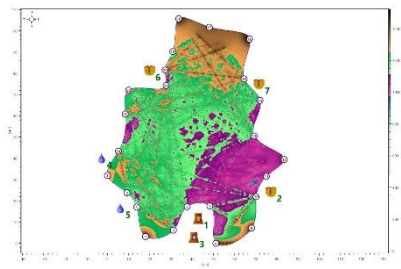
The interpretation of the difference tomogram must consider that the measured wood properties are partially dependent on environmental conditions. Temperature (sonic speed) and water content in the wood after extended periods of rain/dryness (electrical resistance) are particularly significant.

If the difference tomograms are uniformly weakly coloured across their entire surface, the likelihood is high that the tree has not changed, and the difference in the measurement values primarily results from a change in environmental conditions.

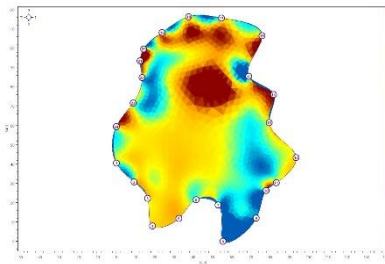
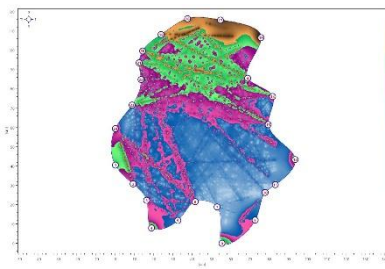
Conversely, if specific areas are distinctly more strongly coloured than others, or if both green and red areas are present, it is assumed that the tree has actually changed.

These effects are particularly evident under frost conditions, as both sound propagation times and ion conductivity change significantly when water freezes. In the following example, a chestnut tree with rot (bottom right in the tomograms) was examined twice over a period of two and a half months. The measurement in January was taken after more than a week of continuous frost, so it can be assumed that the tree was already completely frozen through at this point.

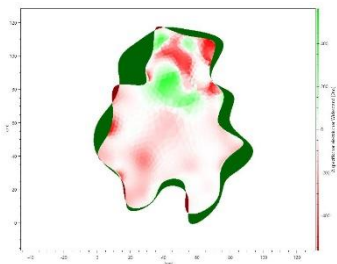
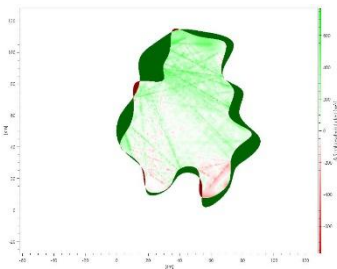
October 2025 ($\approx 15\text{ }^{\circ}\text{C}$)



January 2026 ($\approx -5\text{ }^{\circ}\text{C}$)



Difference tomograms



It is clear that measurements in frosty conditions are strongly discouraged, as the measured values are hardly comparable to those obtained under normal conditions.

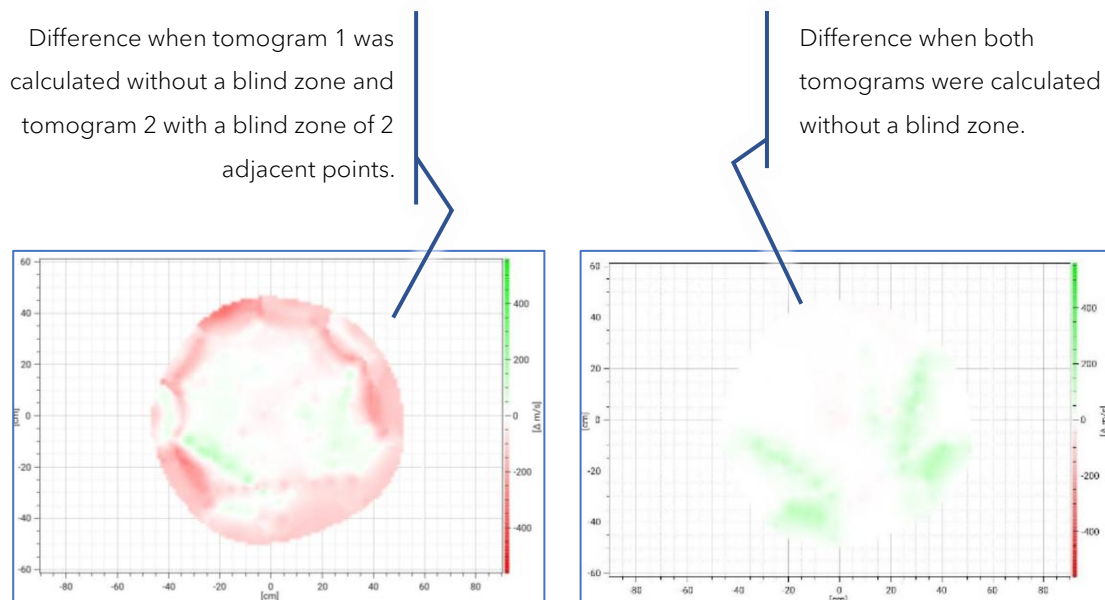
The measurement level in the second inspection is a few centimetres below that of the first inspection. The dark green areas at the edges of the difference tomogram show the root bases, on which the nail positions are further out.

The sonic tomograms show consistently higher sonic velocities except in the area of decay. The evenly frozen wood is significantly harder. However, the sonic travel times in the area of decay are lower. In combination, this further widens the colour scale, making the damaged area appear significantly larger than before.

The electrical resistance increases significantly across almost the entire cross-section, as ice has a significantly lower ion conductivity than liquid water. In addition, there are seasonal changes in the water balance. During the first measurement, the tree was still half covered in green foliage, while during the second measurement it was completely bare.

In addition to environmental conditions, the calculation options of individual tomograms also influence the resulting difference tomogram. Consistent calculation options improve the comparability of tomograms and enhance the significance of the difference tomograms.

In the following example, the difference between two tomograms was calculated, with the second tomogram being calculated with different settings for the blind zone.



If the blind zone option is activated, the edge areas are not fully captured in the second tomogram. The calculated sonic velocity is lower, resulting in clearly red areas in the difference tomogram (see [8.7.2.2 The Cogwheel Effect](#), difference between tangential and radial velocities).

However, the wood has not changed. If identical calculation options are used for both tomograms (no blind zone), then the difference tomogram shows almost no change (the very weakly pronounced green areas rather indicate changed measurement and environmental conditions).

Under comparable environmental and calculation conditions, it can be summarized as follows:

In the sonic difference tomograms, green areas indicate the formation of particularly stable reaction wood, while red areas indicate a larger or worsening defect. The defect can be either decay, a crack, or a hole.

In resistance difference tomograms, red areas indicate increasing moisture and thus spreading decay. Green areas allow two possible interpretations. Either the wood has become drier due to a reduction in decay or due to the death and drying out of the wood, or the decay has completely destroyed the wood, creating a cavity.

8.9.4 3D View of Tomograms

In the **3D view** tab, multiple tomograms from one inspection can be displayed together to create a three-dimensional representation. The tomograms are displayed based on the height of the measuring plane and north orientation (entered in the geometry node).

The following basic assumptions are made for the initial representation:

- All measuring planes are perfectly horizontal. The inclination of the actual measuring plane is not considered.
- All centroids are exactly on top of each other; lateral displacements of individual measuring planes due to a curved trunk are not yet considered.
- All diagrams are displayed in a common colour space. A new common colour space is spanned between the minimum and maximum values of all tomograms

Due to changes in the colour space, the contrast at defects compared to the representation in individual analysis nodes can be significantly different.

In the workspace below the diagram, you will find the following options:



Save: Saves the current 3D view as an image file. The view can be saved in *.jpeg, *.png and *.pdf format. The filename is user-selectable, and the default name may be automatically numbered. All created image files are visible in the gallery.



Scale 3D geometry: Adjusts the zoom level and shifts the graphics so that the entire 3D geometry is visible, and the available space in the display is fully utilized. Alternatively, the graphic in the app can be scaled and moved using *touch gestures*. On the PC, the graphic can be *moved with the right mouse button* and the *zoom level adjusted with the mouse wheel*.

The next button switches between two modes of gesture or mouse control:



Move: If this mode is selected, the camera is moved relative to the centroid of the 3D geometry without rotating the geometry.



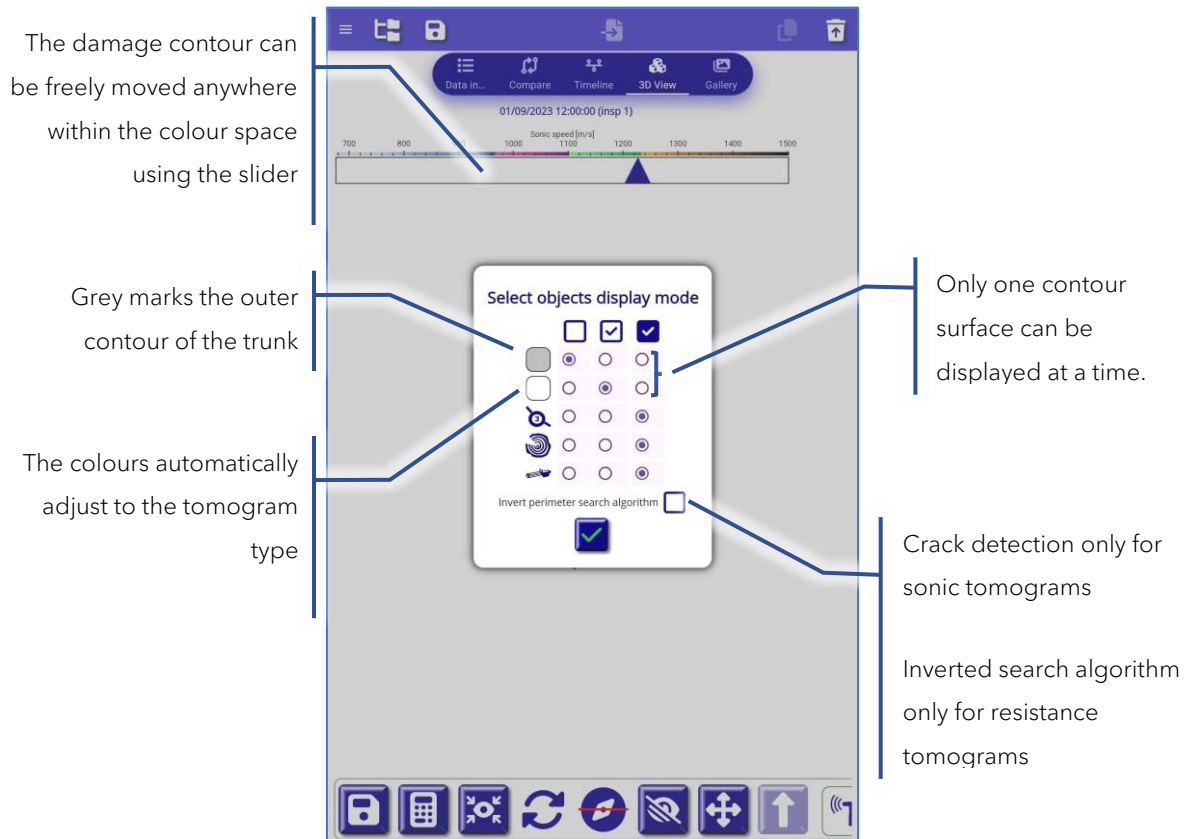
Rotate: In this mode, the centroid of the entire three-dimensional geometry is fixed, and the camera is freely rotated around this centroid.



Rotate graphic to north: If this option is active the 3D view rotates based on the current *compass* reading. The 3D view has the same orientation as the tree itself. This allows one to understand damages optimally while standing in front of the tree. It is advisable to align images of the 3D view and accompanying photos ([8.9.5 Gallery](#)) with this tool.



Select objects display mode opens a window in which the display of the 3D view is configured:



There are three modes in which all display options can be shown:



Hidden: the corresponding element is not visible:



Transparent: the selected element is displayed transparently



Solid colour: the selected element is displayed without transparency

The contour options can be used to connect the planes with a grid:

Show trunk contour: creates a connection between the individual measurement planes with a close-meshed grid. This grid reproduces the outer contour of the trunk. This option is identical for sound and resistance tomograms and is always displayed in grey.

Show damage contours: The contour is drawn around areas with the same sonic velocity or the same resistance and connected to similar areas in the other measurement planes. The position within the colour scale can be chosen freely. To do this, the slider below the colour scale can be moved freely by holding and dragging it, or set directly to a specific position by tapping it.

Only one contour can be displayed at a time.

The search for boundaries is always carried out from the outside to the inside in the respective tomogram. For sonic tomograms, it is assumed that the transitions are from high sonic velocities to low sonic velocities.

However, there is no clear pattern for resistance tomograms. Depending on the ERT type and the damage pattern, the transitions can occur both from high to low and from low to high resistances (see [8.8.6 Typical Patterns / ERT Types](#) and [8.8.7 Combined Analysis of ERT and SoT](#)). It is therefore possible to reverse the search direction with the **Invert Perimeter Search Algorithm** option.

For the areas between the measurement levels, no measurement data is available. Therefore, both the trunk and damage contours are only estimated approximations that may deviate significantly from reality in individual cases. The larger the distance between the measurement levels, the more likely it is that the approximation of the contours deviates from the actual condition in the tree.



Show Tree Points displays the position of all tree points in each plane. TP 1 is always displayed as a cube, while the other TPs are displayed as spheres.



Show Cracks displays the cracks found in the underlying sonic analysis nodes. The crack detection settings from the analysis nodes are used. This setting has no effect on the display of resistance tomograms.



Show drilling measurements displays the drill measurements documented in the geometry node. Both the horizontal and vertical angles are taken into account in the 3D view. By design, the starting point of a drill path always lies exactly within the measurement plane (see also [8.4.7.2 Documenting External Drilling Measurements](#)).



Horizontal tomogram alignments opens a window in which the tomograms can be shifted relative to each other. This allows for better adjustment of the 3D view to curved or slanted trees. The inclination of the individual planes relative to each other cannot be adjusted. The basic assumption is that all planes are parallel to each other. Each individual plane can be shifted in the north-south and east-west directions. The top plane is always listed first in the list.



Confirm applies the changes and closes the window.



Reset resets all changes.



Cancel discards the entries and closes the window.



Switch through inspections: If multiple inspection nodes are selected, you can switch between the 3D views generated from these.

The **tomogram type selection** allows you to switch between sonic tomograms and resistance tomograms, if more than one tomogram type has been chosen in the **Data Selection**.



Displays the sonic tomograms



Displays the resistance tomograms

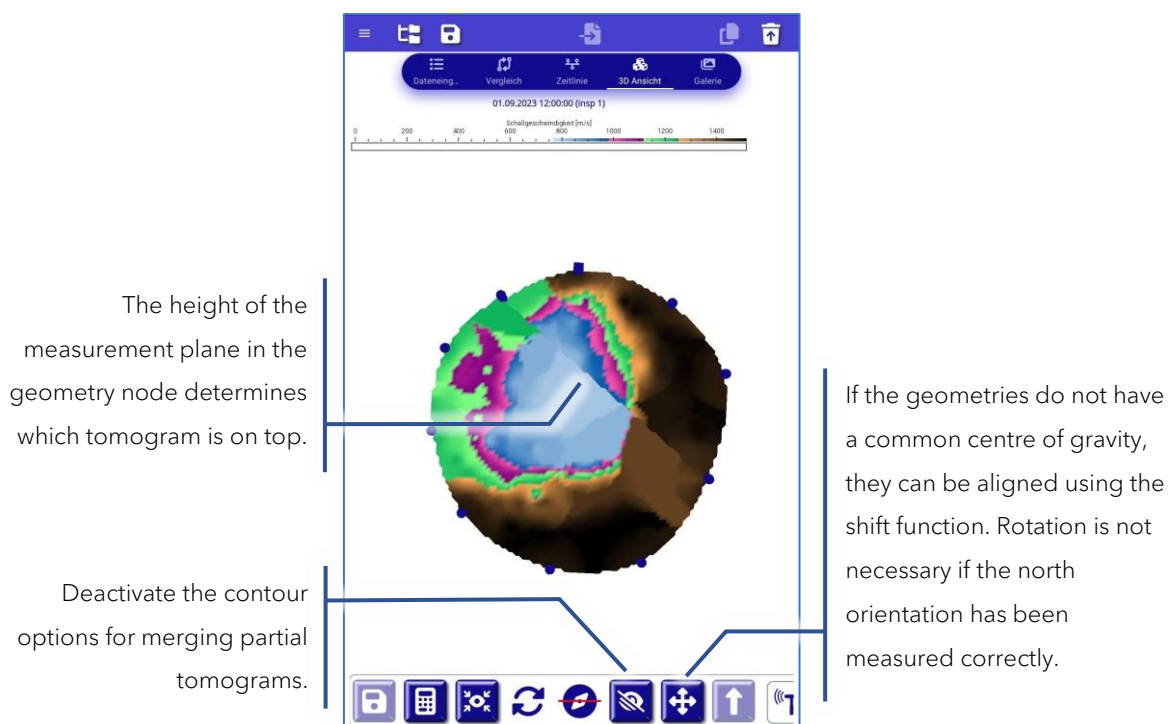
8.9.4.1 Combining multiple partial tomograms

In many situations, it may be useful to perform tomography on a tree in sections, e.g. if cracks are suspected or if there are multiple stems. Only a single partial tomogram can be displayed in the analysis node at any one time. If several partial tomograms are to be displayed together, they can be combined using the 3D view.

To do this, a separate analysis node must first be created for each partial tomogram. All partial tomograms can then be loaded into a common 3D view. If the 3D view is now rotated so that a direct top view is obtained, the combined total tomogram is displayed.

If all partial tomograms are based on the same geometry, there must be no overlaps, as otherwise the overlapping planes will cause image artefacts. Consider using the copy function to create multiple instances of the geometry node.

If the partial tomograms are based on different geometries, there should be a minimum vertical distance between the planes. 1 cm is sufficient here (this can be set in each geometry node). Overlapping partial tomograms will then no longer cause image artefacts. In the top view, the order of the partial tomograms can then be set using different heights. Tomograms below are covered by those above.



The partial tomograms are automatically aligned correctly when using a common geometry. When using individual geometry nodes for each individual partial tomogram, the horizontal shift function of the 3D view can be used to align the individual planes correctly with each other.

8.9.5 Gallery

In the **Gallery** tab of the Tomogram Comparison Node, all captured screenshots from the 3D view can be viewed. Additionally, accompanying photos can be taken.



With the camera a **New Image** can be captured.



The **Add Image** function allows image files to be loaded from the file system into the gallery. If a *.pdf file is imported instead of an image file (e.g. a report containing drilling measurements exported from the IML Studio software), the *.pdf file is converted page by page into consecutively numbered *.png files, so that it can be integrated into reports later.



Delete Image removes the file from the project.



The **Rotate** button rotates the image view by 90°.



In the gallery, the **arrow keys** can be used to switch between all available images. Double-clicking on the thumbnail of the current image opens it.

Additional information is stored for each file in the **Picture Meta Data** section of the image:



Filename: By default, the filename is a timestamp derived from the system time at the moment of capture in the format YYMMDD-hhmmss. To make it easier to identify images, the name can be changed [here](#).



Comments: A free-text field where additional information about the image can be noted.



Image Orientation: To assign a photo to a specific position relative to the tree, the viewing direction is indicated here relative to the north orientation. In addition to direct input, the **compass** can also be used to determine the orientation.

For screenshots of the 3D view, the image orientation is automatically calculated from the rotation of the 3D representation and the tomogram orientation (Geometry Node).

8.10 Generating Reports - Report Node

As a final step in creating a tree assessment, a report or protocol is typically required for the client or customer. In the Report Node, a document can be created from all available information, serving as a standardized template. Since it is provided as a Microsoft Word .docx file, it can be easily customized to meet the individual needs of the user.

To create a report, very few inputs are required. *A significant portion of the information is automatically populated into tables by making simple selections from the Inspection, Analysis, and Tomogram Comparison nodes.*

The more thorough the completion of the nodes and documentation of the measurement process, the more informative the resulting report will be!



The **name** of the report is used both in the project's tree structure and for the folder and filename in the device storage. It can be adjusted at any time.

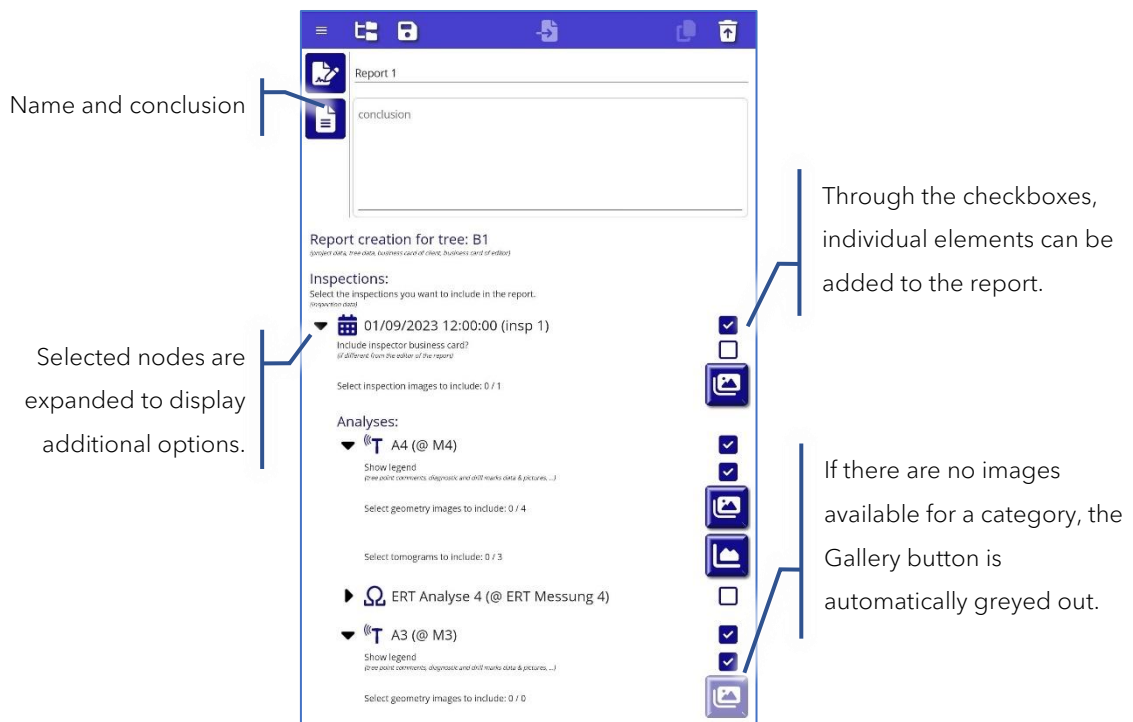
At the beginning of the report, data on location and tree, as well as the customer's business card from the Project and Tree nodes, are automatically inserted. The inspector's business card is also automatically added to the report (from the app settings).

When transferring this data, the comment fields are also included. The information stored there does not need to be reformulated in the conclusion.



Conclusion: In this free-text field, a summary, a final assessment, or recommendations for action can be formulated. The conclusion is the only free-text field that needs to be filled out when creating a report.

All other information and comments are taken from the Inspection, Geometry, and Analysis nodes.



8.10.1 Adding Inspections



By checking the boxes, individual inspection nodes can be selectively included in the report.

When an inspection node is selected, it is automatically expanded to show additional options and all analyses associated with this inspection.

The option **Include inspector business card?** adds the creator of the respective inspection node to the report. This may be useful if there is a division of labour in a company, and the report creator is not the same as the inspector on-site. The assessor's business card can be included in the report for each inspection node separately, as it is possible that not every inspection was conducted by the same person.

For each inspection node, all provided information about the tree is always included (crown shape and size, vitality level, age, etc.).



If documenting photos were taken during the inspection, they can be viewed and selected with the selection button. A gallery opens where images can be individually selected by tapping.



Select All Images or **Deselect All Images**



Confirm Selection adds all chosen images to the report and exits the gallery.



Cancel discards the made selection and exits the gallery without making changes to the report.

The selected images, along with their metadata (image name and, if available, comments and orientation), are incorporated into the report. If the image view in the gallery has already been rotated, the current image orientation is also taken into account and included in the report.

8.10.2 Adding Analyses



Under a selected inspection node, analysis nodes are included in the report by checking the box. Geometry and measurement nodes are not selected separately because they are automatically included in the analysis node, thanks to the existing links between the nodes (see also [7.1.5 Measurement and Analysis Nodes](#)).

The key data from the conducted measurement are always included in the report when selecting an analysis node. This includes data from the geometry and measurement nodes that are the same for all created tomograms within this analysis (geometry type, height of the measurement level, bark thickness, circumference, orientation, and number of TP, etc.). In addition, a legend is generated for the elements that are always visible in all tomograms and cannot be turned off through the display settings, such as BP and geometry contour, remaining wall thickness, cracks, and drill channels.

The selectable option **Show Legend** adds additional tables for each tomogram, summarizing additional information about tree points, diagnosis marks, and drill marks. In these optional tables, both comments and, in the case of diagnosis marks, all linked photos are included.



Photos that are not linked can be separately included in the report by selecting them through the gallery **Select geometry images to include**. These images will then be appended at the end of the section for the selected inspection node.



Select All Images or **Deselect All Images**



Confirm Selection adds all chosen images to the report and exits the gallery.



Cancel discards the made selection and exits the gallery without making changes to the report.



The tomograms themselves are not directly embedded in the report. To integrate them into the resulting Word document, a screenshot of the tomogram must always be created first. For report integration, the *.jpeg option should be selected for the screenshot file format. How to create screenshots can be found in chapters [8.7.3 Tomogram View - Workspace](#) and [8.7.3.1 Tomogram Gallery](#). The tomograms are selected in the gallery **Select tomograms to include**.

For each selected tomogram, the checkboxes under the image can be used to specify whether the calculation settings and display settings used when creating the screenshot should be included in the report.

The selection of images is done here again using the control buttons:



Select All Images or **Deselect All Images**



Confirm Selection adds all chosen images to the report and exits the gallery.



Cancel discards the made selection and exits the gallery without making changes to the report.

8.10.3 Including Additional Images

The screenshots of the 3D view created in the Tomogram Comparison node, as well as accompanying photos, can also be included in the report.



All available images of the 3D view can be selected in the gallery in the **Additional Images** section.



Select All Images or **Deselect All Images**



Confirm Selection adds all chosen images to the report and exits the gallery.



Cancel discards the made selection and exits the gallery without making changes to the report.

The selected images, along with their metadata (image name and, if available, comments and orientation), are incorporated into the report. If the image view in the gallery has already been rotated, the current image orientation is also taken into account and included in the report.

8.10.4 Save, Rename, or Delete Reports

Once the configuration of the report is completed, the actual Word document can be created in the storage.



The **Create Report** button writes all selected information into the template.

A Repeated **Create Report** overwrites the existing document. If a new version of the report is to be created instead, two options are available:

- **New Report Node**: creates a new entry in the project folder structure, and all configurations of the report must be made again.
- **Rename Report Node**: changes the folder name and the name of the newly created document. The original document remains with the old name in the renamed folder.

The created reports can consume a significant amount of storage space, depending on the number of included photos and tomograms. All included image files are essentially duplicated; they exist once in the project and once in the report. Therefore, especially on devices with limited storage, it may be useful to remove the resulting Word document from the device after saving, either by storing it in the cloud or on a PC.

To delete a created Word document from the device storage, either delete the corresponding report node (removing the entire folder, including the Word document, from the project structure) or navigate to the appropriate subfolder in a file browser and manually remove the resulting Word document from the project structure.



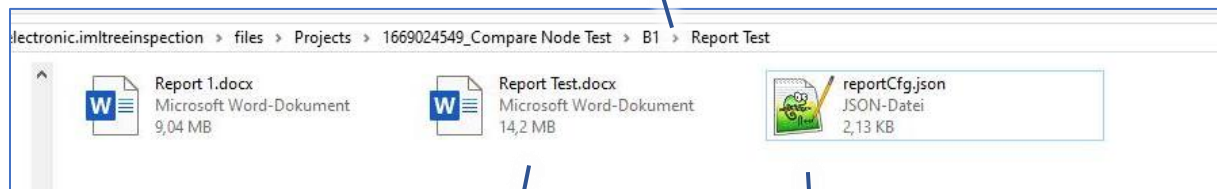
On **PC** the folder containing the created report can be opened directly.

When manually deleting the Word document, the JSON file (and the folder itself) in the directory should not be removed. It contains the configuration of the report node. As long as this configuration is present, the Word document can be recreated at any time.

Project name (**Compare Node Test**)

→ Tree name (**B1**)

→ Report name (**Report Test**)



Renaming the report node creates an additional version of the report.

Here the node was renamed from **Report 1** to **Report Test**

Do NOT change the configuration file

9. Requirements

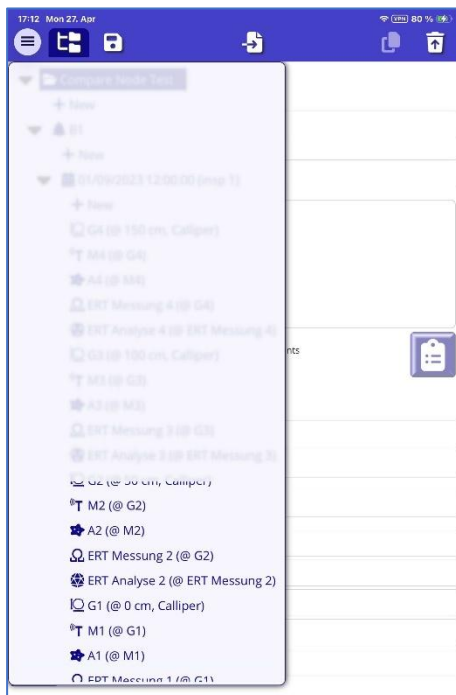
Android	
Software	Min. Version 8 (recommended min. Version 16) 250 MB free disk space
Hardware	Required hardware: Bluetooth 4.2 low energy or newer Recommended Hardware: camera, magnetic compass, tilt sensors, GPS The Software is optimised for use with tablets (7 inch or larger)
iOS	
Software	Min. iOS 12.2 250 MB free disk space
Hardware	Required hardware: Bluetooth 4.2 low energy or newer Recommended Hardware: camera, magnetic compass, tilt sensors, GPS The Software is optimised for use with tablets (7 inch or larger)
Windows	
Software	Windows10 or 11 250 MB free disk space Min. 1 GB free RAM (recommended 4GB) Direct X 11
Hardware	Bluetooth 4.2 low energy or newer USB 2.0 or newer Recommended Hardware: camera, magnetic compass, tilt sensors, GPS

9.1 Known Issues

The display of contour surfaces in 3D views (especially for ERTs) can generate incorrect results under unfavourable conditions. The calculation algorithms for contour surfaces are the target of further optimisation measures.

The screenshot function for 3D representations is currently not working properly on iOS and MAC. As a workaround, screenshots can be created at the operating system level and then manually inserted into the project.

Screen rotation cannot be locked on iPads. When using the compass function, this often leads to unwanted flipping of the displayed measurement orientation.



On iOS devices with the "Liquid Glass" design, the tree view does not always render correctly when expanded.

If repeatedly expanding the tree view does not resolve the issue, scrolling through the tree view (if it is long enough) or rotating the screen may help to complete the stalled animation.

Hover tooltips are always displayed in the main window. Nested windows, such as the measurement window in the sonic measurement node, therefore always open their hover tooltips in the background.



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