PiCUS Sonic Tomograph

Software Manual Q74

Refers to PiCUS 1, 2, 3 Version:
PC program version: Q74.2
Manual version: 01. February 2017

With Passion and Precision

Content

1 Abbreviations

BT   Bluetooth

.ert   PiCUS Treetronic electric resistance data file extension

GPS   Global positioning system

MOI   area moment of inertia

MP   Measuring point. Each nail that used for the sonic scan is a measuring point.

m/s   Unit of the speed in "meter per second"

.pit   PiCUS sonic tomogram data file extension

PRHD PiCUS Radio Hammer with Display. Works only with PiCUS 3.

SPP   Serial port profile. For Bluetooth communication.

USB   Universal Serial Bus.

UTC   Universal Time Coordinated. This time is delivered by the GPS signal. For most common purposes, UTC is synonymous with Greenwich Mean Time (GMT).

V   Volt

2 Field of application / disclaimer

The PiCUS tools box offers a comprehensive range of diagnostic instruments for advanced tree risk assessments. Measuring the thickness of the residual walls of trees with decay or cavities is done with the PiCUS Sonic Tomograph and the TreeTronic.

The PiCUS® Sonic Tomograph was developed to examine living trees. Using the device inappropriately can lead to damage, both to the unit and to the tree itself.

Although every effort has been undertaken to present the results of measurements as comprehensibly as possible, interpretations of readings do require qualified technical expertise. The user bears the sole responsibility for all conclusions made about the status of any tree examined. Neither the manufacturer nor the distributor of the PiCUS® Sonic Tomograph can be held liable for any decisions made based on measurements made with the PiCUS®.

We strongly recommend attending a training course conducted by the distributor or by a certified institution in your country. A list of such institutions can be found at the IML Electronic web site.

The PiCUS® Sonic Tomograph detects differences in the ability of the wood to transmit sound waves. It cannot identify the specific reasons for such differences. This means the instrument is not able to identify the exact type of damage: it may be decay, hollowness, cracks, or something else.

Before taking any action or deciding to fell a tree, please be sure to identify the underlying reason for the defect you see in the tomogram.

All technical information is subject to change without notice.

3   Sonic Tomography introduction

The PiCUS® Sonic Tomograph unit can detect decay and cavities in standing trees non-invasively by tracking the speed of sound waves in the trunk, roots, and larger branches. The velocity of sound in wood depends on the modulus of elasticity (MOE) and the density of the wood itself. Damage and disease in trees can cause fractures, cavities, or rot, which reduces elasticity and density of the wood. Wood characteristics can vary, both between species and within a tree species itself. Such damage can be found by comparing individual sound velocities measured on a specific tree with tabulated standard values. The PiCUS® Sonic Tomograph uses relative sound velocities so that the system calibrates itself automatically at each measured cross-section.

The PiCUS® Sonic Tomograph consists of a set of sensors (PiCUS 3 offers 6 or 12), which are placed at strategic points on a tree trunk. Each sensor is connected to a pin or nail (0.8 - 2 mm in diameter), which is placed on the outer trunk with a pin hammer at an inspection point. By manually tapping the sensors with a small hammer, sound waves are induced and their delays recorded. The time the sound wave travels between the sensors is used to calculate the apparent sound velocities.

Because each sensor on the tree records delays (times) of every impact at each point, a dense network of sound velocities is collected across all cross-sections. A full-coloured tomogram of the tree's cross-section can be made on site using a PC. This tomogram shows the presence of decay and cavities within the tree. It can also indicate the remaining wall thickness or opening angles of cavities.

The left sketch shows the measuring principle of PiCUS® Sonic Tomograph: theoretical travel pathways of acoustic waves when the tree is tapped at different positions.
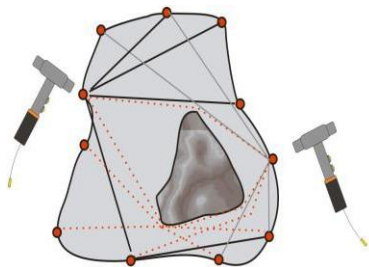
Travel paths of acoustic waves   PiCUS 3 at work   Sonic Tomogram
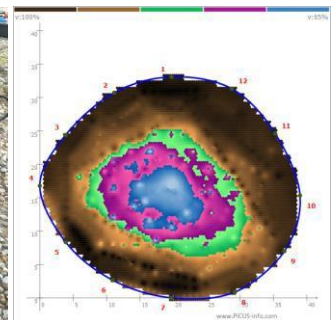
4 PiCUS software installation

4.1 Software installation

Before you install the PiCUS program, make sure that all Windows updates are loaded on your computer. Check the Microsoft homepage for updates.

The setup files are located on the USB stick in program folder.

Attention: Windows 7/8/10 requires running the Setup.exe with "Administrator" rights. To do so right-click "setup.exe".

This side up!

Select "Run as administrator" in the menu.

setup.exe

The setup program installs the following on your computer:

1. USB driver for communication between the PiCUS and the PC. The latest version of this drive can be found here:

   http://www.ftdichip.com/Drivers/VCP.htm

2. Microsoft .NET Framework (if not installed before)

3. PiCUS Q7x.x

Depending on the configuration, your computer may shut down and reboot after step one. If the installation does not continue automatically, please start the setup.exe again.

4.2 Registration of the PC software

Each licence issued for one PiCUS device entitles you to install the PiCUS program on five computers. Each installation requires a registration to unlock the software.

There are three ways to register your program:

1. via Internet directly in the PiCUS Program or through

2. Through the PiCUS web site

   https://www.iml-electronic.com/treeinspection/contact/

3. By sending the request code by email to us

In order to register through the PiCUS program, the computer must have an internet connection. Use an Administrator login for this registration.

Firewall:

If there is a firewall in your network or on your computer, this firewall may block the PiCUS web service that provides the unlock code. If your firewall reports that the "picus.exe" is trying to access the internet you should allow this access. Turn on "session cookies" in the "Internet Explorer" Options to use this service.

4.2.1 Registration window

The PiCUS program requires a registration that is unique to every installation. The program can be installed on maximal 5 computers. The activation of the program requires an unlock code that can be found on our web site in the section *Tree inspection* and *Support*. When you first start the program the following window will appear:

Enter your *user name* (1) as it appears on the sticker of the CD cover. It may look like this:

"PST1234-1234"

Enter your "*Identnumber*" (2) . This identification number is case-sensitive and may look like this: "fX56GW"

Enter your data in other fields. All fields marked with an asterisk (*) are mandatory.

Pressing the "OK" button will take you to the registration window (below). There, press "Request Authentication code" (3). Your numbers will appear in the "Keynumber" box (4). These numbers are to be transferred to our registration service. If the PC is connected to the internet press the "Registration via Internet" button and the numbers will be transferred to our web service. The unlock code is sent back automatically if the firewalls did not block the web-access.

You can also get the unlock code from the support section of our web site using the above login data.

Alternatively, you can now send these numbers by e-mail to contact@iml-electronic.de. The unlock code must be entered here (5).

Click on "Registration" to proceed.

## 4.3 Configuration of the PC Program

4.3.1 PiCUS Hardware settings

When the program is started for the first time the user needs to select the instruments that need to work with that PC. The settings can be changed later on too.

Procedure:

Configuration of the PC program

PC program   *"Configuration" → "Select Hardware"*

Enter number of sensors here. PiCUS 3 instruments require 6 or 12 sensors.
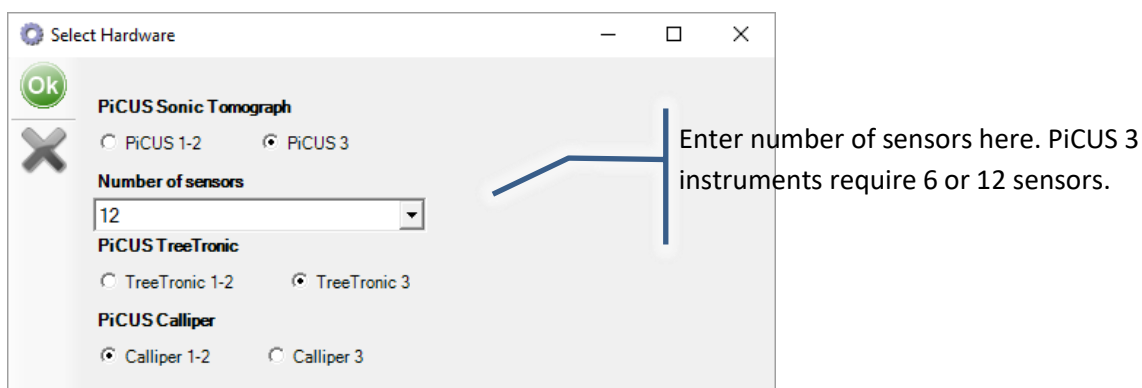
All herein settings affect the measuring window. The calculations are NOT affected. Therefore both old and new data files can be processed with Q74.

Enter the number of available sonic sensors here. The program will use this number in the sonic scan window.

4.3.2   COM port setup

The PiCUS 1, 2, 3 and the TreeTronic 1, 2, 3 can be connected to the PC using USB or Bluetooth. The PiCUS calliper can only be connected to the PC via Bluetooth. The COM connections between PiCUS and PC must be installed and configured before using the PC program for data collection in the field or for uploading data from the PiCUS 3 to the PC.

The communication between PiCUS 3 and PC can be done through USB or Bluetooth connection.

Once the COM port for a device (Calliper, PiCUS, Treetronic) does exist the PiCUS PC program needs to configured accordingly. Each device requires a different COM port, but the connection procedure is always the same.

Note: the COM port must exist before the PiCUS COM configuration window is opened! That means: do create the COM port first, then open the PiCUS COM settings window.

4.3.2.1   Create Bluetooth COM ports at the PC

In order to select a Bluetooth COM ports proceed as follows.

Note: The COM port setup process does vary from version to version of Windows.

Procedure for Bluetooth connection:

1. Turn on PiCUS 3 and enter a data communication menu. *"Data connection" → „to PC"*

2. Turn on PC and activate Bluetooth. The Bluetooth icon should be visible in the task bar.

3. Identify the COM ports

    a.   Windows 7

       • Pc: Add new Bluetooth device: using the Bluetooth manager (right-click on) or open "devices and printers"

       • The PiCUS is shown like this: "PiCUS 3 16B7". The last four characters represent the last four address digits of the Bluetooth address of the device. The Bluetooth address is unique and therefore varies from device to device.

- Select the PiCUS and press "continue" and enter the **pairing – code "0000"** (four times character zero)

- After a short installation the PiCUS is shown in the device list.

- Right click on the PiCUS icon to get the option menu. Select → properties → *tab „Services"* . The COM ports created are shown here. We need the **outgoing COM port** to connect to the PiCUS.

b. Windows 8/8.1710

PiCUS 3 in the Bluetooth manager

Bluetooth options: COM Port Number etc.
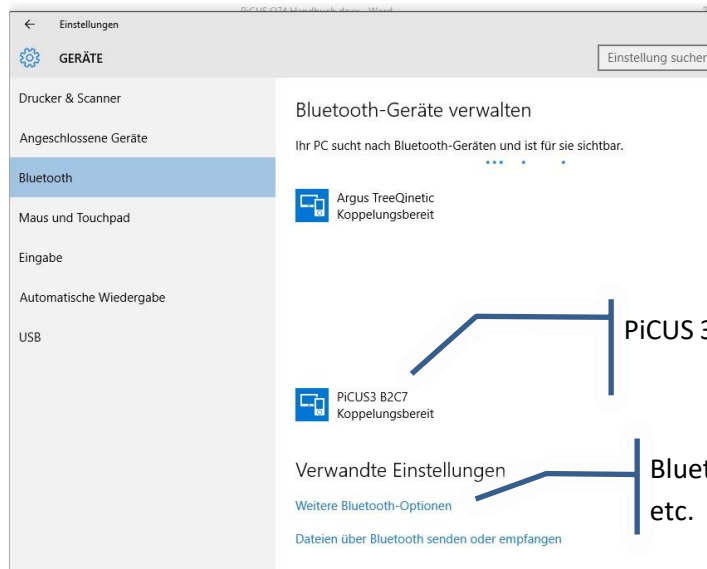
- Click the PiCUS icon and then "pair".

- Enter **pairing code "0000"**. (Four times character zero).

- Click "Bluetooth options"

- Go to tab "COM.."

- Identify the **outgoing COM port** of the PiCUS

Outgoing PiCUS port SPP
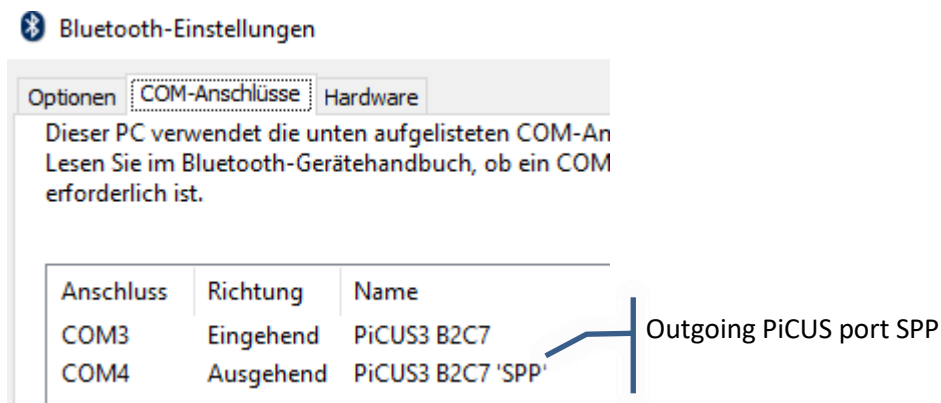
4. Start the PiCUS program and got to

   "Configuration" → "Select COM Port" → Tab "Port PiCUS"

5. [Enter the COM port number](#) that was identified. Click the (still) red COM symbol to open the port. This may take several seconds. The button turn green when successfully opened.

6. Click "PiCUS 3 Test". The response "PiCUS 3 ok" confirms that data communication now works.

7. Close the window using the OK Button to save the settings.

4.3.2.2 Create USB Ports at the PC

The required USB COM drivers are installed during the PiCUS program installation.

After the installation no USB COM port does exist yet! The USB COM port is being created by the operating system when the PiCUS/TreeTronic is connected to the PC using the USB cable.

Attention: The USB port only exists after the USB cable is installed between PC and PiCUS/TreeTronic. That is why the COM configuration window must not be opened before the cable was installed.

Note: The COM port number and settings must be changed every time the type of connection is changed (USB or Bluetooth).

4.3.3 COM port settings

To set-up the COM port for each device proceed as follow:

1. **Open** COM **configuration** window:

   PiCUS PC Software main menu → " Configuration " → "Select COM Port"

   The COM port window will open.

2. **Select the device** you want to connect.

3. **Select the COM** port from the drop down list (hit the arrow next to the red COM button).
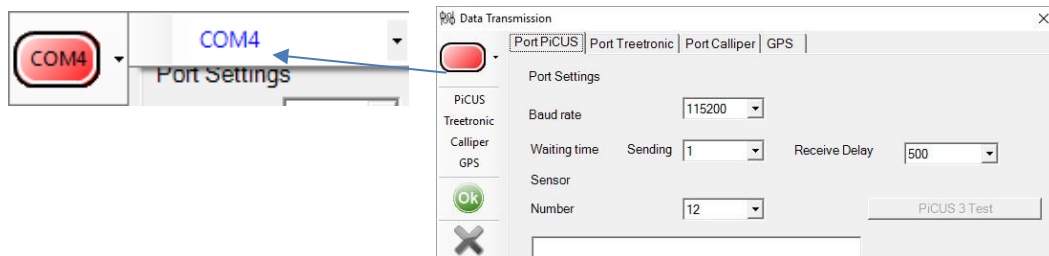
Set the **"Baud rate"** according to the following table

Instrument	Baud rate
PiCUS 1	9600
PiCUS 2, 3	115200
PiCUS calliper	9600
TreeTronic 1, 2, 3	9600

The option "Waiting time" affects port options that should not be changed unless data transfer is not working correctly.

Example: One of the Windows® the surface tablet PCs requires the value 100 at "receiving data".

4. For the PiCUS sonic tomograph only: The number of PiCUS sonic sensors can also be set here. The program will use this number in the sonic scan window.

5. **Test the connection**. Turn on the device and activate Bluetooth or USB mode.

    PiCUS 3, TreeTronic 3:   Main menu → *"Data connections"* → *„to PC". Screen shows* "Searching for PC (BT – USB)…"

    Open the COM port (Click). When the button turns green the port is open. Push the test button to see if the communication works.

6. **Close the Configuration window** using the **OK button** to save all settings.

7. **Set TreeTronic / Calliper accordingly.**

The GPS port only needs to be configured if an external GPS device is available. Both PiCUS 3 and TreeTronic 3 have an inbuilt GPS receiver, so no extra GPS receiver is needed.

5 Sonic measurements with the PiCUS tomograph

5.1 Conditions of the sonic scan

Note:

Check all batteries (PiCUS radio hammer PRHD, PiCUS, PiCUS Calliper, Laptop PC) for sufficient voltage BEFORE you leave your office.

Attention:

The properties of wood in a tree depend on many factors, one of which is the temperature. Wood changes dramatically when the temperature is below 0°C (32° Fahrenheit, 273° Kelvin) for a long period of time. Therefore, the PiCUS© Sonic Tomograph should not be used on trees during or after periods of frost.
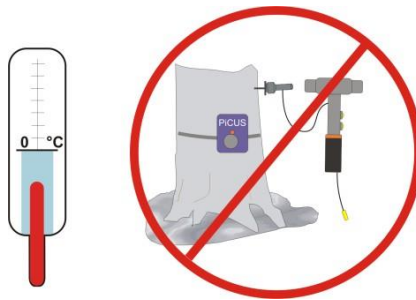
Spreading infection with dirty nails?

It is possible to spread diseases from one tree to another by using dirty nails. This is why it is so important to disinfect the nails each time you move to a new tree. There are several disinfection methods:

- Exposure to heat (>= 130 °C, for at least 15 minutes)
- Soaking in high percentage alcohol (or liquid disinfectant) for several hours.
- Boiling in water for at least 15 minutes

5.2 Workflow of a sonic scan

There are several steps involved in taking a PiCUS Sonic measurement:

1. Determining the measuring level, number, and positions of measuring points

2. Measuring the geometry of the measuring level

3. Mounting equipment on the tree

4. Sonic measurement

5. Calculation and Interpretation of the tomogram

6. Dismantling of the instrument and removing of nails – after the tomogram interpretation!

The following chapters describe these different procedures.

5.3 Determining measuring level, number and positions of measuring points

5.3.1 General notes

The PiCUS technology differentiates between sensors and measuring points (MP). A MP is a simple (roofing) nail. The size and shape of the measuring level determines the number and location of meausring points. Typically 8 to 30 measuring points are used. In rare cases a tree might require 50 or mor MP. **The minimal number to use is 8 MP**.

Before starting to work on the tree, you must decide:

- At which level you wish to measure,

- Where to place the measuring points (MP) and

- how many points to use.

Note: The correct level of tomography and the number and positions of measuring points is extremely important for the quality of the subsequent tomogram.

Look for external signs of internal defects, such as fungus growth, cracks, cavities, damaged bark, etc. Use all of your knowledge about trees and diseases and choose the measuring level according to your visual assessment of the tree.

You should also examine the tree near ground level, as many types of fungus grow from the root system upwards into the trunk. Example: the dangerous fungi *Kretschmaria deusta* often develops in the root system first before it grows into the main trunk.

The maximum distance between MP: ~ 45 cm

The minimum distance between MP: ~ 12 -15 cm
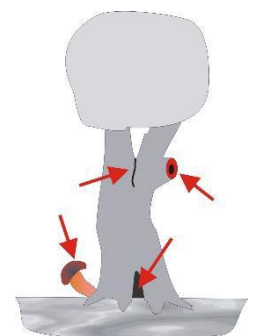
5.3.2   Installing the nails

The guidelines for placing the measuring points (MP - nails) should be considered carefully before the nails are set.

- Try to use approximately the same distances between MPs. That is essential for obtaining an equably distribution of acoustic travel path intersections that are needed to calculate the actual tomogram.

Unbalanced distribution of MP: insufficient resolution of the tomogram

Evenly distributed MP leads to a good distribution of intersections.
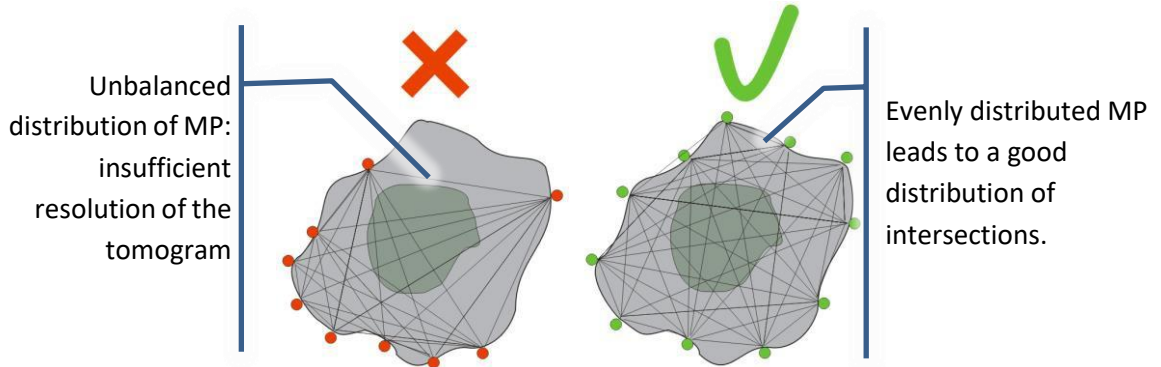
Measuring points must be distributed evenly even when the defect is clearly only at one side of the tree. The following example shows an oak with fungi infection. The tomograms show what happens if MP opposite to the defect are turned off when calculating (refer to interpretation chapter). The picture of the defect is affected if too many MPs are missing.
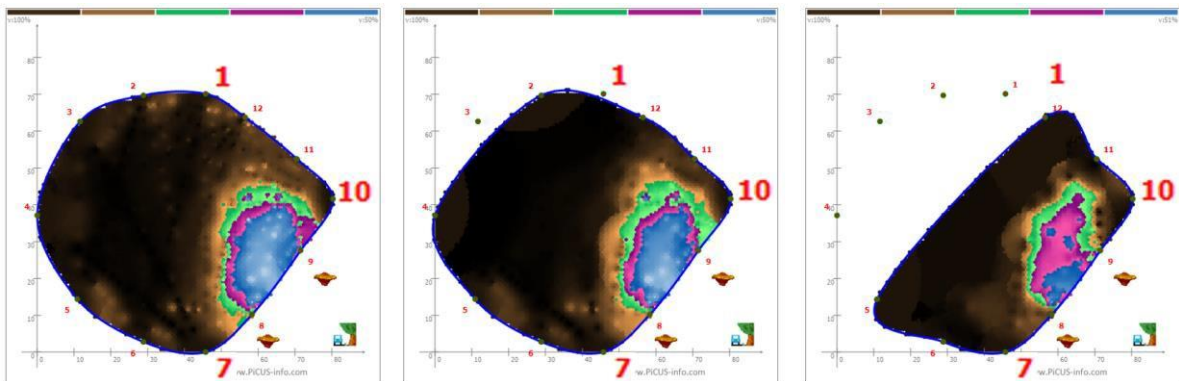
All MP used   MP 1, 3 turned off   MP 1, 2, 3, 4 turned off

Note: MP 7 and 10 have been put in the last part of good wood to encircle the defect closely.

- The **distance between MPs** should range from approximately **15 to 40 cm**. Do use **eight MP minimum**, although this can lead smaller distances when working on small trees. Small distances like 5 or 10 cm between MPs can cause errors in geometry measurement, so they should be avoided.

- However, in order to show the size of defects more precisely placing MP can be deviant from the above rule: MP need to be set close to defects even though the distance between MP might become very small.
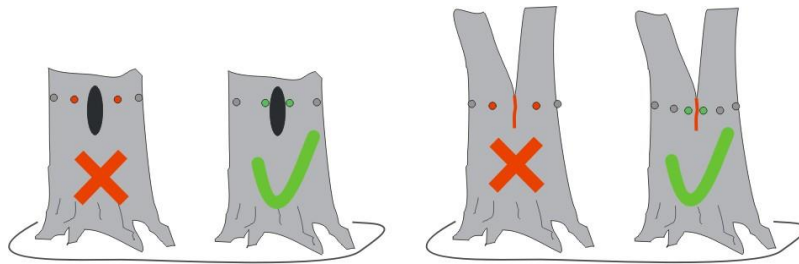

- **Expert** Program version: MP can be set in damaged parts of the trunk. However, there is a risk of de-calibrating the colour scale of the tomogram. In such cases those MPs need to be turned OFF as receiver or transmitter or both when the tomogram is calculated.

  Hint for Expert version only: in case of doubt do set an MP into questionable areas. This MP can be disabled easily later on by using the "MP used" function.

- **Standard** program version: DO NOT assign MP for sonic measurements in damaged areas of the trunk because MP cannot be switched off for calculations. Place MP on either side of such damage in order to ensure more accurate readings.
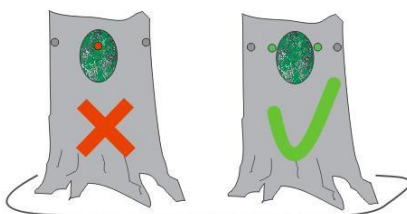
- You will, however, need to place MP in damaged areas when measuring the ERT (electric resistance measurement) in order to have equidistant MP positions.

- **Measuring level at pruning wounds** at branches: Decay will most often develop downwards. Thus, it is recommended to place the levels of tomography underneath the wound rather than above.

Internal decay often develops downwards.
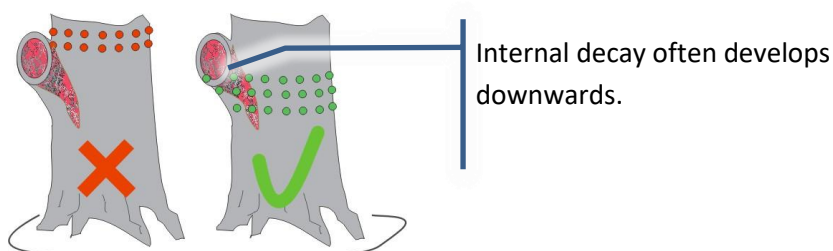
- The **nails must be touching the wood** itself. Make sure that nails are longer than the thickness of the bark so that they penetrate past the outer bark.
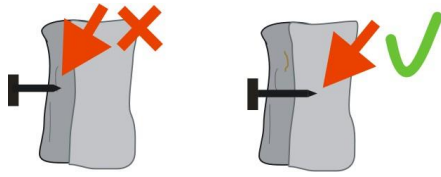
- All nails should **point to the centre** of the trunk
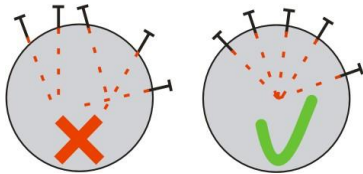
- Only use flat-headed magnetic nails. The size of the **nail must fit the sensor** magnet.
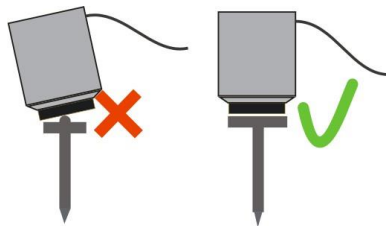
- Tap in the nails for the measuring points **along an imaginary straight (horizontal) line**.
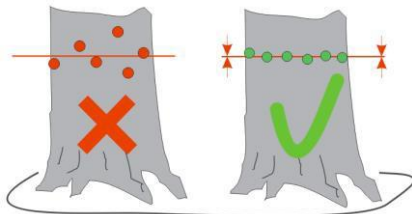
- It is possible to use a non-horizontal straight line in order to obtain results for a larger section, but this can produce unintended results, as shown here:
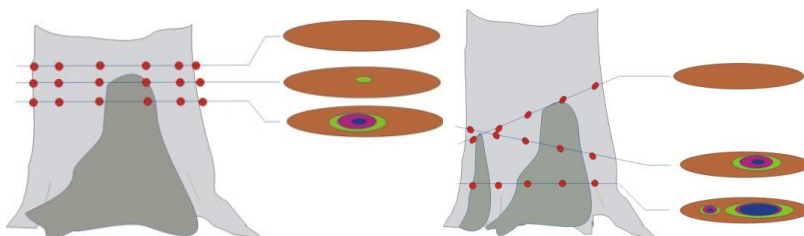
- **Co-dominant stems**: The scan on co-dominant stems can be carried out at once. However, it might be necessary to calculate each trunk separately. Where the trunks meet it is often recommended to put the MPs closer than usual. In-between the trunks there is often included bark which will block the sonic wave transmission. The impact of the bark inclusion can be avoided when calculating each trunk on its own.

  Attention: the position of the included bark is not always easy to identify!

MPs can be turned off during the calculation in order to show each trunk separately (Expert version only).
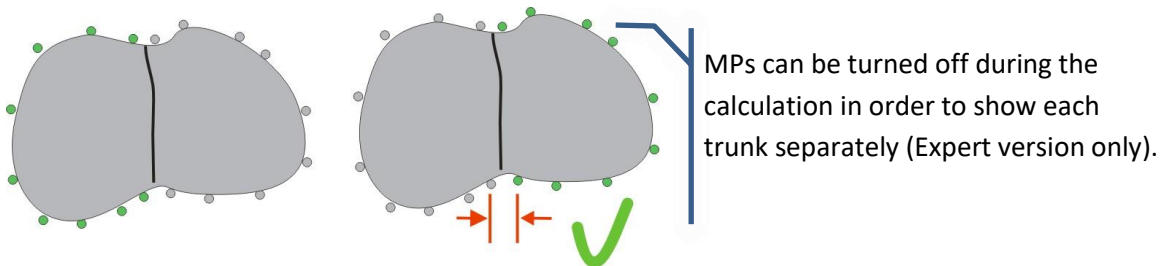
- **Installing MP on cavities**. If the tree you are working with has an external cavity, please do not install any sensors inside the cavity. Instead, space the sensors around the furthest outer points of the tree. Record the geometry of the tree as usual – disregarding the cavity. Put MPs close to the opening. Hint: since the distance between MPs may become very small it is useful to set adjacent MPs at different heights. When done so it is easier not to touch and disturb the adjacent sensor while tapping.

Sensors are at slightly different heights

- **Installing MP on trees with buttress roots. T**hese diagrams show how to proceed on trees which have larger roots.

geometry of the tree in the PiCUS program

tomogram of the tree

MP between <u>and</u> on roots

alternate correct MP

unfavourable MP positions

Tomogram of the tree, in which the decayed area is not registered
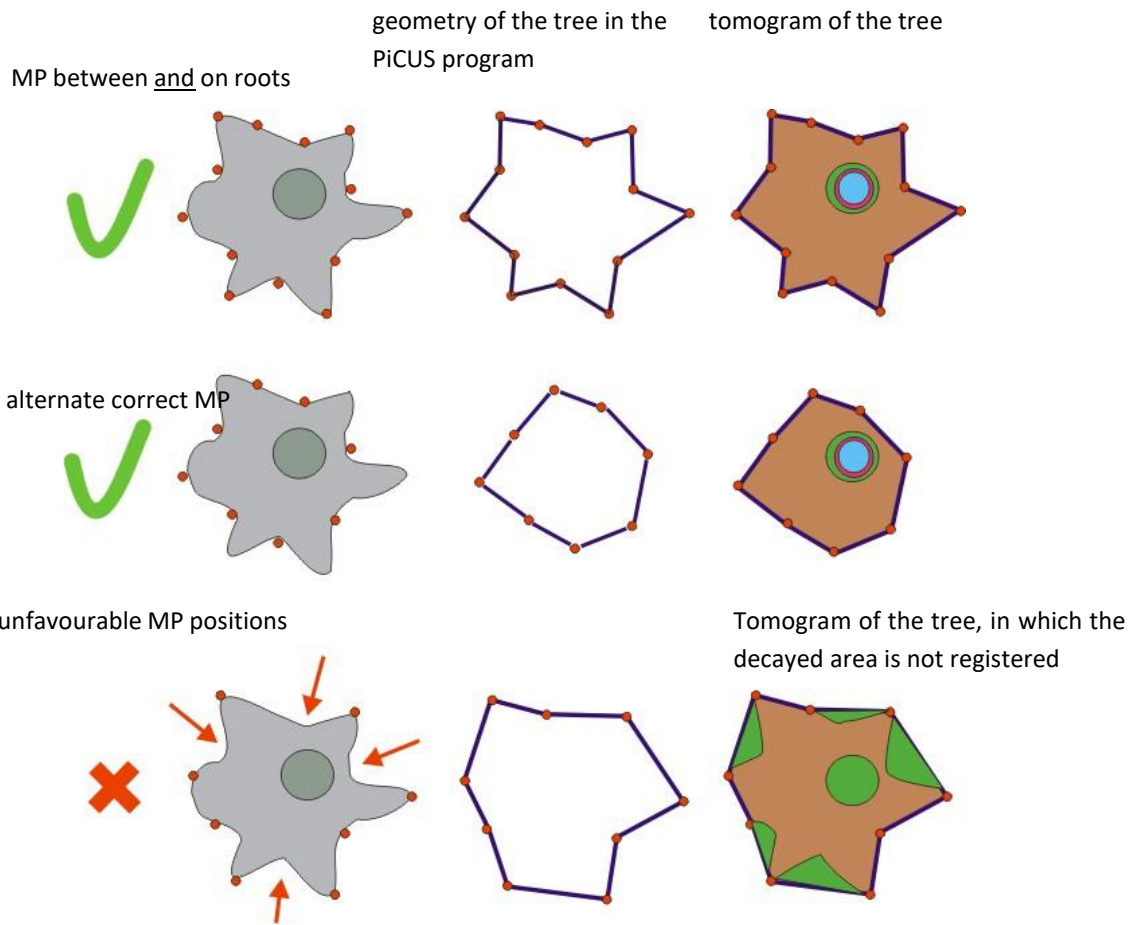
- **MP positions at adventitious roots[1]**: There is often no standard method for placing test points at adventitious roots that have been developed in response to internal damages. In case the roots are still small - less than 15-20 cm in diameter – then the placement of just one pin in the middle of the root is sufficient most of the time. Placing MP's in-between those small roots creates the risk of having no good contact to the wood. At larger roots the left-centre-right method should be used.

Attention: MP in bark inclusion may not have good contact to wood.

Large roots – three MPs: left - center - right

Small roots: MP only at the top of the root.

MP 10 is isolated – no information about wood quality at this location.
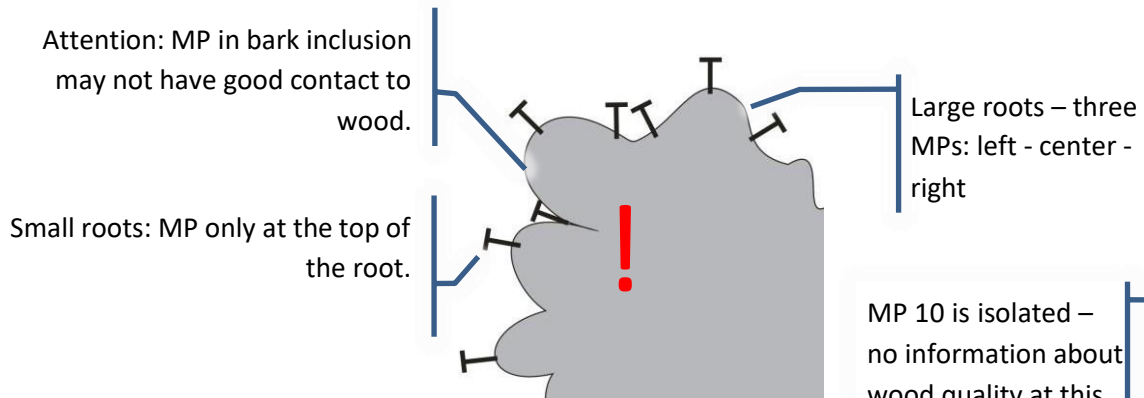
3 MP on an isolated root are needed to see the wood quality!

MP likely placed in bark inclusion – no good contact to wood!
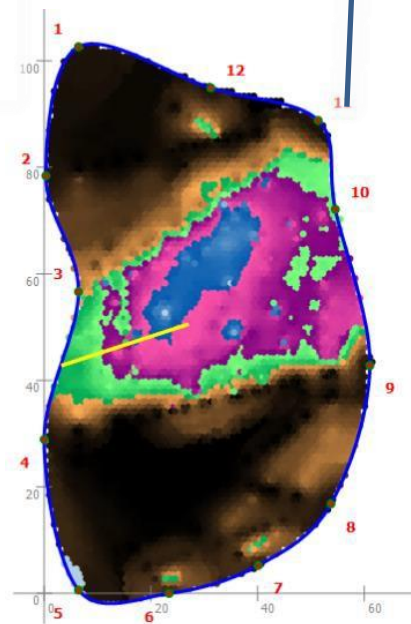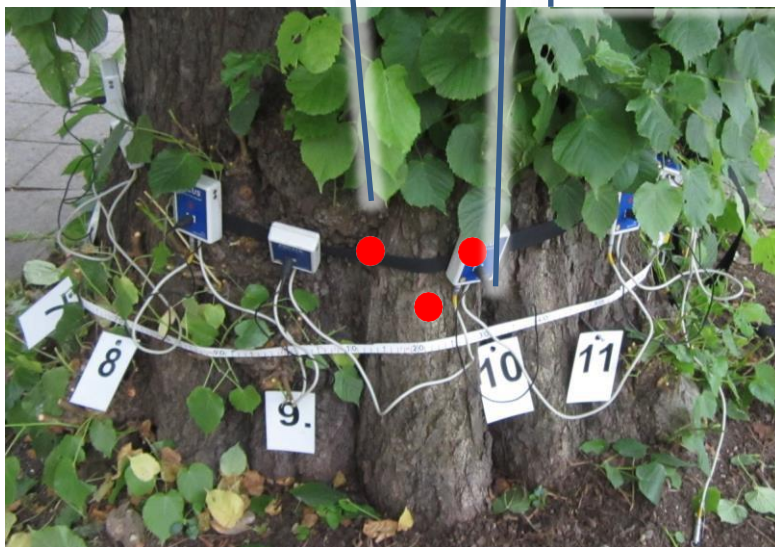
In the example above MP 10 has no good contact to wood. Likely the nail is in the bark in-between two roots. Consequently MP 10 is shown as part of the damage. In order to see wood quality of the root (left of MP 10) one would need to place three MP in that root. Care must be taken when doing so because of the small distances between MPs.

- **Isolated parts of the trunk**. If the decay has isolated parts of the tree (for instance a root), the position and number of intersections (1) might be too small to calculate the root correctly. Additional MP may be necessary. In this example we have added two more (2) in order to increase the density of

---

[1] Adventitious roots arise out-of-sequence from the more usual root formation of branches of a primary root, and instead originate from the stem, branches, leaves, or old woody roots. Source: Wikipedia.org

intersections at this part of the trunk. The next section discusses how to add new MP once you have already started.

(1) MP positions do not allow sufficient velocity calculations

(2) Additional MP's increase the number of intersection
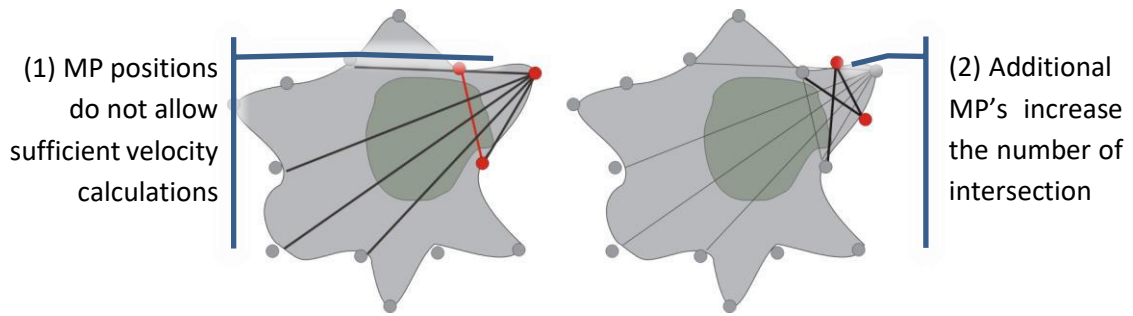
Left: MP Positions do not allow for sufficient calculation

Right: Additional MP increase the density of intersections

The function "Calculation C" should be used to check the intersection positions.

Access this function in the menu by:

PiCUS PC Software main menu → "Calculation" → "Line graphic"   or use the icon:

Line-Graphic
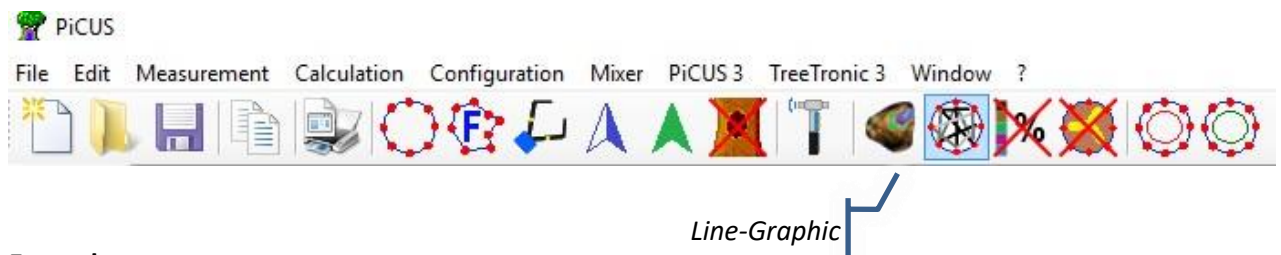
Example

The following tomogram needs more measuring points (MP) near MP2 and MP5 in order to obtain more precise results.

Line 7-9 is relatively slow. A possible reason might be an acoustic barrier close to MP 9. In order to measure wood quality of the triangle 7-8-9 more precisely it is recommended to place an additional MP in-between 8 - 9.
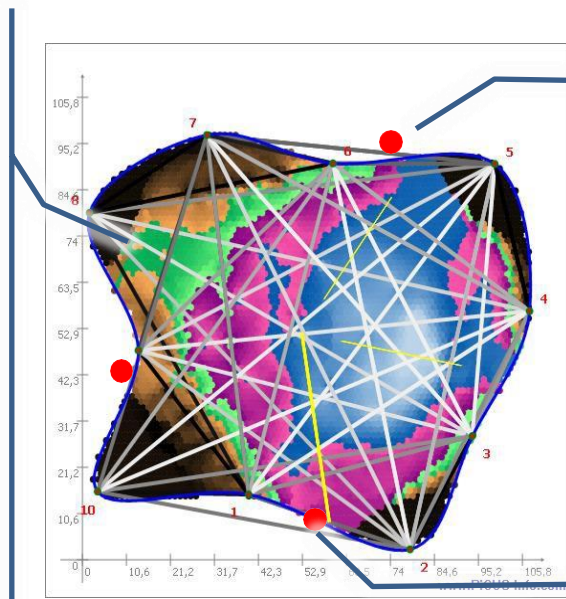
The areas where violet or blue colours meet directly with browns are an indication that there are not enough intersections. This makes the tomogram less precise.

Green dots indicate the positions of additional MP needed.

5.3.3 Adding additional measuring points

In case the first tomogram requires to add more measuring points (MP) retroactively (after taking a measurement) proceed like this:

1. Place the new MP (nail) into the tree,
2. In the program, select:

   PiCUS PC Software main menu → "Measurement" → "Geometry" → "Add one MP"

MP shift function
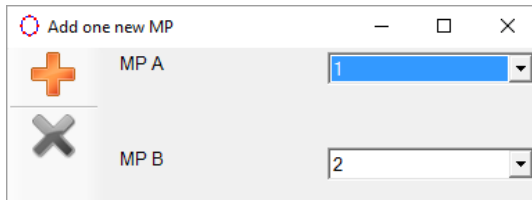
The existing sonic data will be automatically assigned to the new MP numbers when adding new MP.

3. Enter numbers of the two current MP on either side of your new point. Click "Add".
4. Adjust the position of the new MP in one of these ways:
   a. *Menu at the left side → Geometry → Move-function*
      - Move the MP to the new position by holding the left mouse button.
      - Green numbers show the distances to the neighbouring MPs, the blue number is the distance to the connection line of both adjacent MPs. The example shows the shifting of MP 3.

Distance of the new position of MP 3 to its neighbor (MP 2) is 9,8 cm

The length of the perpendicular of the new position of MP 3 to line MP 2-4 is 9 cm.
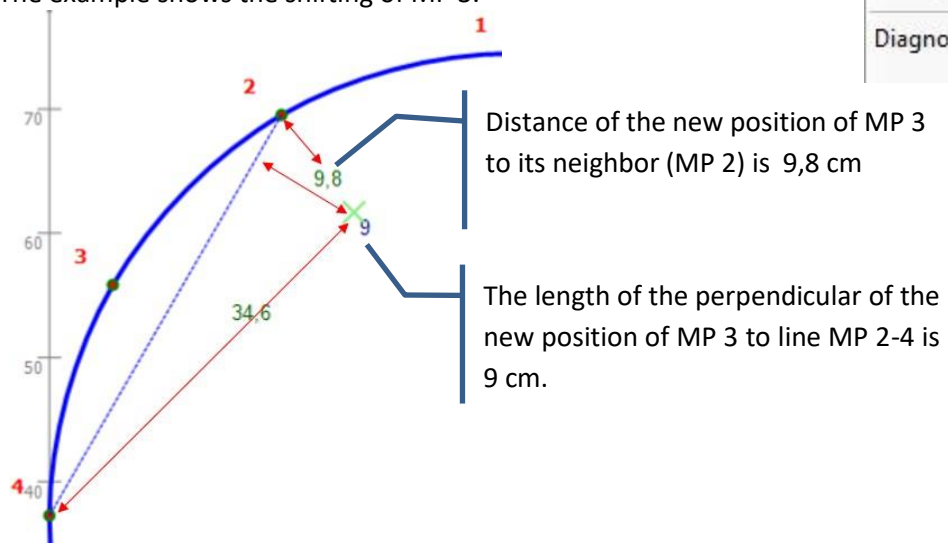
   - The un-do icon takes back changes.
   b. Measuring → Tree Geometry → Free shapes calliper
      - On tab "Baseline" click "continue"
      - Set the distances of the new MP to "0 mm"
      - Click "Begin again" in order to get the new distances with the calliper, or measure distances differently and enter them directly into the table.
      - Click "Calculate".
5. ALL MP numbers at the right site of the newly added MP need to be updated.
6. Adjust the sensor-MP allocation table in sonic – measurement window before continuing tapping.
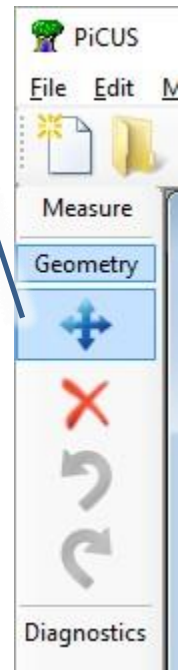
Hint: When more than one MP is to be added then it is recommended starting with the highest number first. Doing so causes less orientation problems and requires to re-number the nails only once.

Example: The tree has 14 MP. In order to increase the resolution at some parts of the trunk it is required to add additional MP at the following positions: in-between MPs 1 – 2, 6 - 7 and 13 – 14.

Recommended procedure:

1) Add the new MP (nail) in-between MP 13 and 14 first. That means we start at the end of the at MP-numbers, at the highest numbers. Doing so the new nail becomes the new MP 14 and the old 14 becomes the new 15. At this time we do NOT YET need to correct the number plates.
2) Add new MP in-between 6 and 7. The old 7 becomes the new 8 and so on. Still, do not yet correct number plates.
3) Add new MP in-between 1 and 2.
4) Correct number plates now, start at the beginning at number 1.

Attention: an incorrect MP-Sensor allocation table leads inevitably to incorrect tomograms!

5.3.4   Describing defects after visual inspection
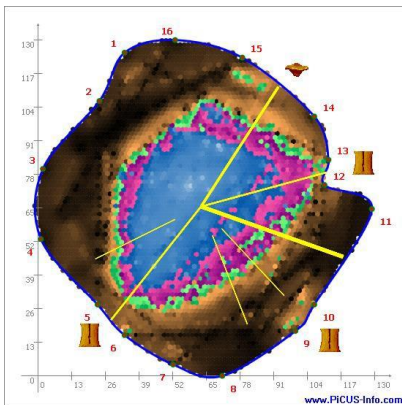
Visible defects at or near the measuring level can be marked in the PiCUS data file with icons after recording the geometry. Marking such defects - such as cracks or fungus growth- in the tomogram will help you reconstruct the measurements later on. Access to the icons:

Menu on the left → Diagnostics

Left-click on one of the symbols copies the icon into the tomogram

Right-click offers options for entering brief data or moving the icon.

Description is in the appendix.

5.4 Measuring the geometry of the measuring level

5.4.1 General information

In calculating the tomogram, the sound velocities are measured using distances and time recorded between points. This means that it is important to note the geometry of the measuring level (positions of nails) as accurately as possible.

The velocity of the acoustic waves is calculated using this equation:

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

With:

v = velocity

s = distance between MP

t = time, travel time of the acoustic wave

The travel time of the acoustic waves is measured precisely by the PiCUS tomograph. The distance between MPs is calculated using the data of the recorded geometry. If the geometry was entered incorrectly the distances are incorrect as well and consequently the velocities are incorrect: incorrect geometry = incorrect velocity = incorrect tomogram.

Example: the real distance in-between two MP is 100 cm. An error of 10 cm – which can easily happen when doing guess work – means 10% error!

The next tomograms have been calculated using the very same acoustic data. The tomograms show the impact of using different geometry data.
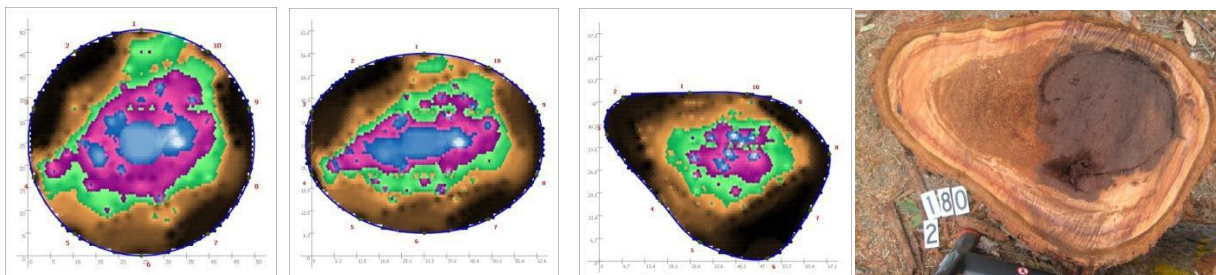
Circular assumption   Elliptical assumption   Precise calliper geometry   photo of the stump

There are two ways to record and enter the positions of the MPs:

- Assuming the tree is a circle and entering the distances of all MP along the circumference

- Use triangulation method to measure positions of all MP accurately on any shape of trees

In a few cases only, the tree geometry can be calculated by assuming a simple ellipse or a circle: more or less circular cross sections. However, in most cases the triangulation method ("Free Shapes") yields better results.

No matter which method you use, the measuring process always begins with creating a new file:

1. Start the PiCUS program

2. Create a new PiCUS file:

   File → New → Sonic Tomogramm (SoT)

follow the wizard. It takes you to one of the options for geometry recording.

When geometry is recorded additional tree data can be entered:

Edit → Tree data

to enter information about the tree, such as:

- Tree species (botanic and common names)
- Height of measuring level from ground (in cm).

5.4.2 Measuring the geometry of circular or elliptical trees

Completed work steps so far:

- Visual inspection of the tree and identification of measuring level

- Nails (measuring points – MP) are installed

In order to record the geometry using the "circle or ellipse method" proceed as follow:

1. Fix the measuring tape around the tree at the measurement height. The zero point (MP1) should be at the zenith point of the largest diameter set.

MP 1 is at the zenith point of the ellipse in Y-extent.
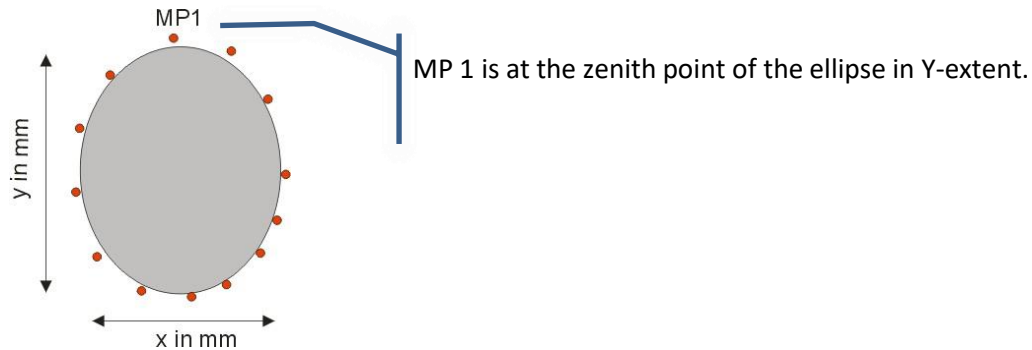
2. Attach number tags to the nails. Each nail is given a number. Numbering is done anti-clockwise, from left to right.
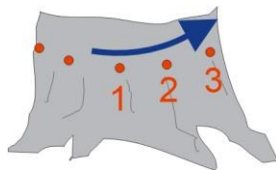
3. Open Ellipse/Circle Geometry window:

   Measurement → Tree geometry → Ellipse

Start Circular / ellipse geometry function
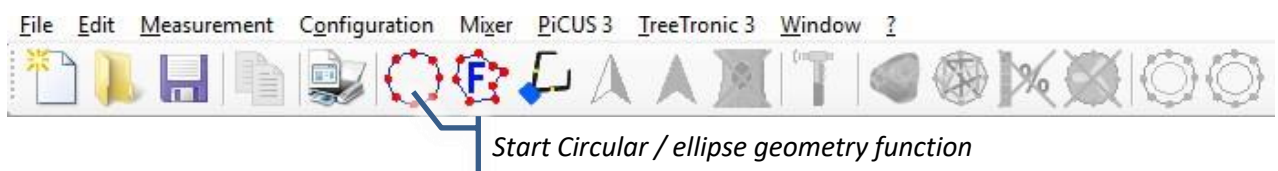
4. Measure circumference and enter it in the circumference textbox.
   Attention: the input requires "mm"!
5. Enter number of measuring points (MP).
6. Optionally – to create an ellipse – measure the largest diameter and type it into the "Y-diameter" textbox. Measure a second diameter, perpendicular to the Y-axis and type it into the "X-diameter" text box. **Attention: unit is mm**!
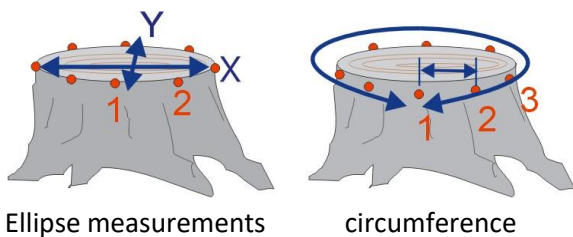
Ellipse measurements   circumference
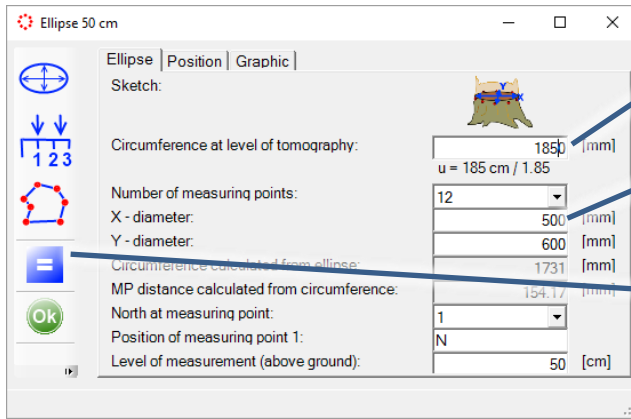
Circumference **in mm!**

Optionally enter X/Y diameter to get an ellipse in **mm!**

Calculates the circle/ellipse.

7. The program calculates the theoretical distances between MPs. You can view these supposed positions of the nails (along the measuring tape) with the tab "Positions".

8. Because the distance between nails (MP) is rarely equidistant, the real positions of the nails (along the tape) will need to be measured and then entered in column "User Pos". Check the box for "use user defined position" to do so. Click "=" to re-calculate.
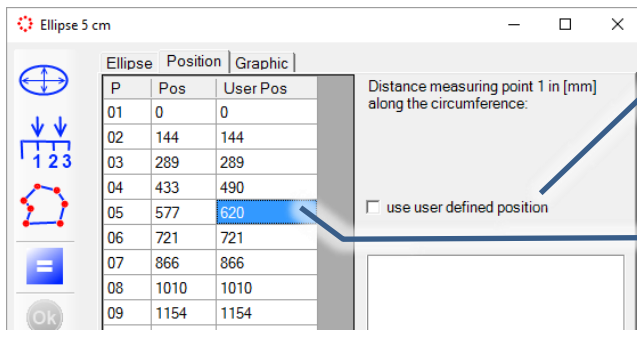
Set check for "user defined positions"

Enter the real position here and push „=" to calculate

Example:

MP 4 is at 490 mm, MP 5 is located at 620 mm. These values must be entered into the table.

9. On tab "Graphic" the positions of sensors can be moved by left-touch-and drag MPs. The distance to neighbouring MP is shown.

10. Close window using the "OK" button.
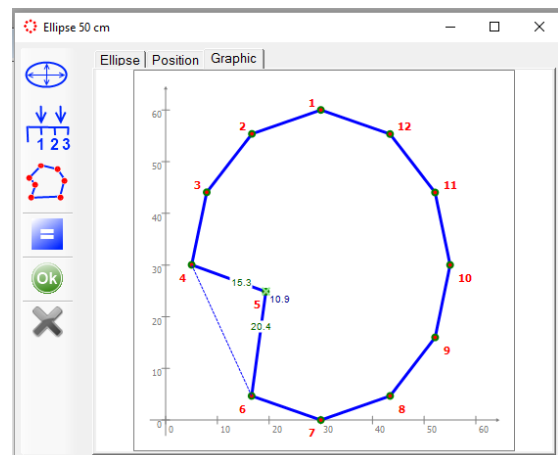
5.4.3 Measuring free geometry with calliper

The geometry of the measuring level can be recorded precisely using a triangulation method. The measuring level is split into many triangles, and the lengths of all the sides of that triangles are measured.

Each MP is part of a triangle. Two MP are part of all triangles (1-Baseline method, in the sketch on the left). The line between these two points is called the "baseline". The position of the third point of the triangle can be calculated using the length of the sides.

When using the 3-Baseline method (in the sketch to the right) the tree is split into 3 segments. However, the theory and working procedure are virtually the same. Using the 3-baseline method may become necessary when the calliper is too small to cover the diameter of the tree.

MP 2 to 6 are located **right** of the baseline

Baselines in red. Arrow indicates the orientation.

Measuring the length of the black lines is required to calculate the position of MP 3.
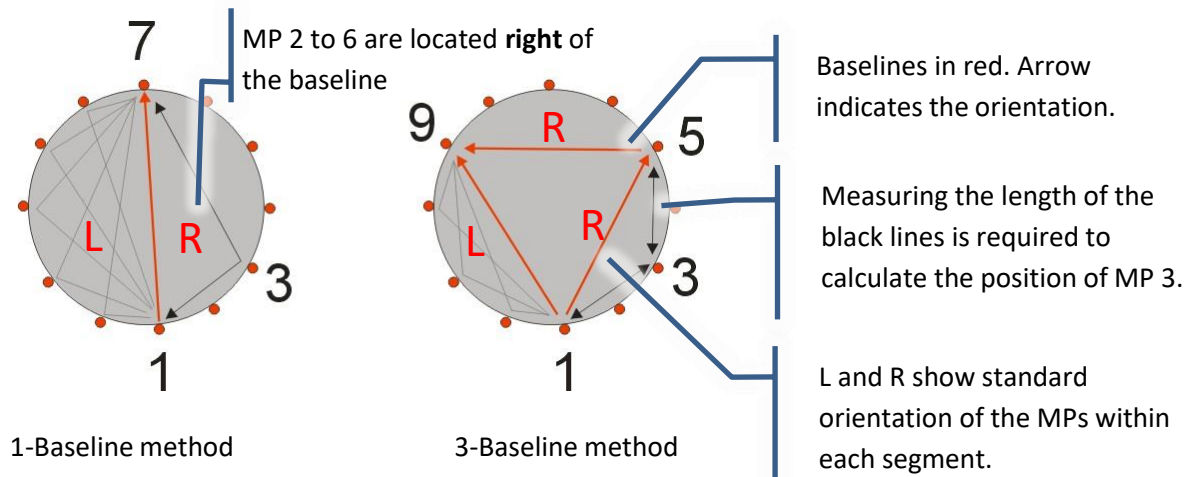
L and R show standard orientation of the MPs within each segment.

1-Baseline method   3-Baseline method

Based on one or three baselines, the software calculates the x/y positions of all MP in an x/y coordinate system.

The above sketch on the left shows which distances (grey lines) need to be measured using one baseline (red) in order to calculate the positions of MP 8 to 12. The sketch on the right shows the distances (grey lines) needed to calculate MP 9 to 12 using 3 baselines.

The directions of the baselines is given by the arrow: The baseline runs **from 1 towards 5**: then MP 2, 3 and 4, all in-between 1 and 5, are located on the **right hand site** of the baseline if the tree is more or less round shaped. The operator must enter this orientation.

This triangulation function is optimized for work with the PiCUS calliper. However, it can also be used when the distances are recorded with other tools. In this case the distances can be entered manually.

The "**PiCUS Calliper**" is an optional tool for measuring distances on a tree quickly and accurately. The photo shows the PiCUS Calliper version 3.

5.4.3.1 Triangulation work procedure

Completed work steps so far:

- Visual inspection of the tree and identification of measuring level

- Nails (measuring points – MP) are installed

- The calliper Bluetooth® connection to the PC (respectively PiCUS 3 or Treetronic 3) was configured

Proceed as follows:

1. **Open new file.**

   PiCUS PC Software main menu → " File" → "New"

   Follow the wizard.

2. **Start triangulation function.**

   PiCUS PC Software main menu → " Measurement" → "Tree Geometry" → "Free shapes calliper"

   Or hit calliper icon:

   PiCUS Calliper triangulation methods
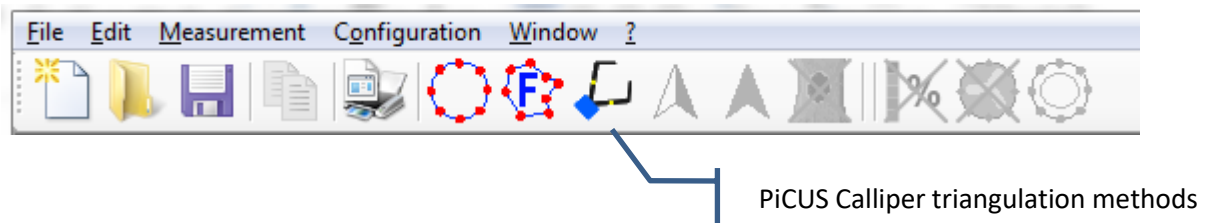
3. **Attach number tags to the nails**

   Attach number tags to the nails. Each nail is given a number. Numbering is done anti-clockwise, from left to right.
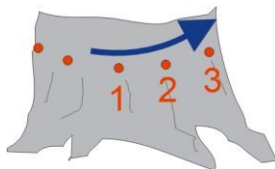
   Advice: find out about which base points can be used **before** the number tag are distributed! Basepoints must be easy to reach using the calliper. To do so, take the calliper, go to the tree and find out which points can be reached easily. Those point become basepoints. Try first to use the 1-baseline method - it will work for trees with up to approximately 130cm in diameter. If the tree is larger, then use the 3-baseline method.

   When basepoints nails are known then the number tags can be put to the nails.

4. **Enter data**

   Start at the top and enter circumference of the measuring level (the unit is **mm!**), followed by the number of MP. The program might suggest a number but you have to use the number of nails that you have tapped into the tree.
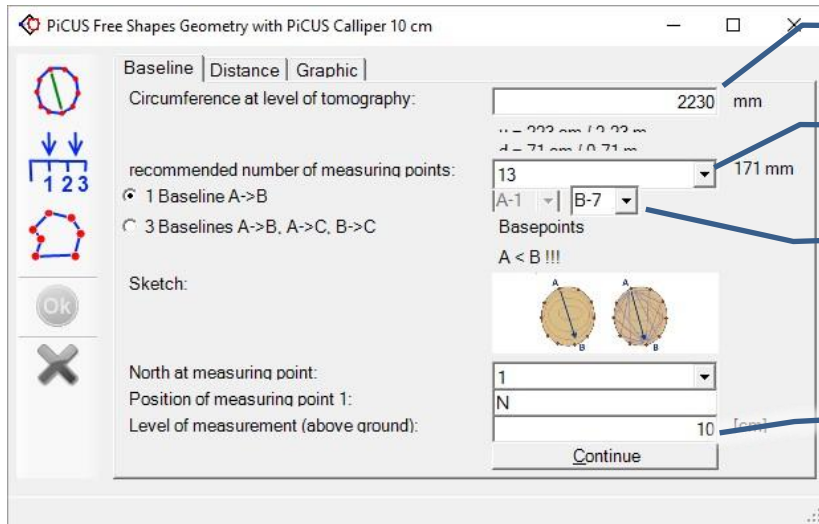
Circumference measured

Enter number of MP

Select 1 or 3 baseline method and select base points

Enter height of measuring level. Important to 3D graphics.
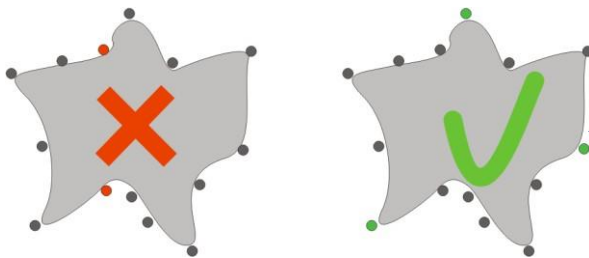
Green base-points are easy to reach with the calliper. Red points are difficult to reach.

5. Click *"Continue"* when done. The program creates the table at the tab "Distance". This table shows all the distances that need to be measured. Click "New values" on tab "Baseline" would allow to changes settings if needed.

6. **Turn on calliper** and select **PiCUS Mode.**

7. **Open COM port**.

   Hit red COM port button to open the COM port and wait until connection is made, which is indicated by the button turning green.

   If the connection is successfully opened then the first distance to measure is displayed on the calliper screen.

8. **Take the first reading**.

   Hold the tips of the calliper on the nails: left arm touches MP 1, right arm touches MP 7. Press any of the yellow buttons to take the reading and transmit the reading to the PC.

Since the first line to measure is a baseline, no orientation needs to be considered. After pushing the button the distance recorded is shown in the table.

Current baseline: MP 1 – 7.

9. **Take all readings**. Check the orientation of every MP in relation to its baseline and hit the corresponding calliper button: hit left button if the MP is at the left side of the baseline or hit right button if the MP is at the right side of the baseline. The PiCUS calliper version 3 will show flashing numbers next to the buttons on the arms. A flashing number indicates the standard orientation of that MP.

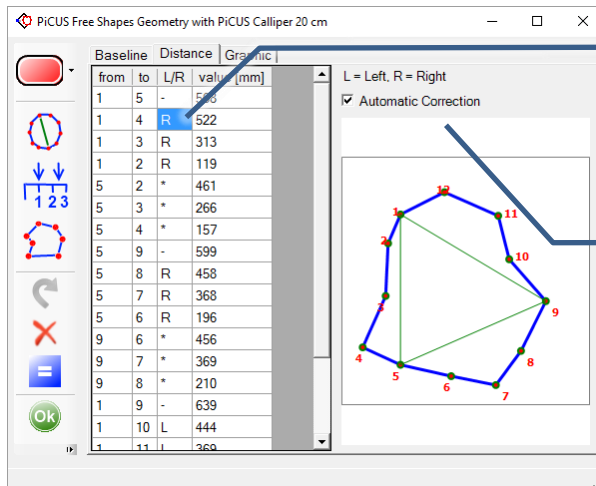10. When all distances have been measured the calliper display shows "OK" and the PC screen shows the outline of the tree.

Orientation of the MP in relation to its baseline. R = right, L = Left
„-" = base line
„*" = Orientation is already set

Automatically removes small mistakes of the distance measurement. Revised values are shown in red.

11. If an **orientation is accidently incorrect** it can be changed by left-click the "L" or "R" letter in column "L/R". Lines having the "-" or "*" character do not require an orientation.

12. **Erroneous readings**. If an incorrect reading was taken the error can be corrected like follows: enter a "0" (zero) in the "value" column. Push "Begin again" button in order to re-send the command to the calliper. Alternatively a new value can be entered by hand.

13. **Check the geometry**.

    The graphic on the screen should fit to the real shape of the tree. Example: if MP 5 is located far out, because it is on a root, then this should be shown on the display too.

14. **If needed rotate the geometry**. Click on tab "Graphic" and use rotation or move buttons in case you want to rotate or move the entire outline.
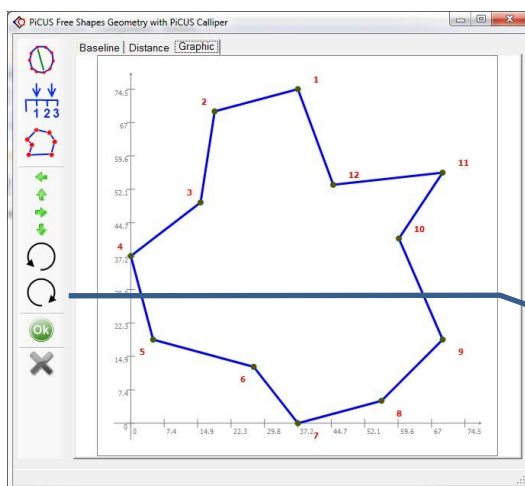
Rotate the outline.

15. Terminate the Bluetooth connection before the calliper is turned off.
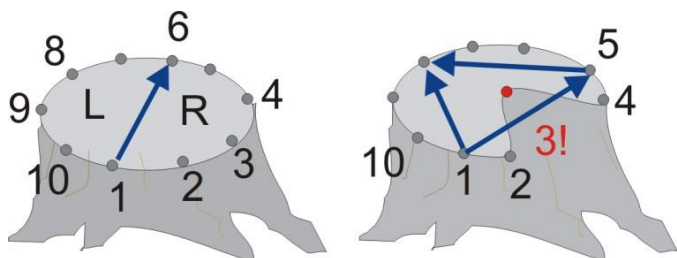
16. Hit "OK" button when done.

17. Save the file.

Note: The orientation of measuring points

An orientation needs to be entered for all non-base points (points at the end of a base line).

Example: the baseline runs from point 1 to point 6. The orientation of point 3 must be entered. In the left image MP 3 is situated on the right hand site of the base line. That is the "standard" orientation. In the right image MP 3 is located on the left side of the baseline 1 → 5. If a point is not in the standard orientation, a "!" is shown in the "L/R" column.

Baseline	Distance	Graphic	
from	to	L/R	value [mm]
1	6	-	1245
1	5	R	911
1	4	L!	890
1	3	R	503
1	2	R	435

Left click at the orientation column flips the MP to the other side of the base line.
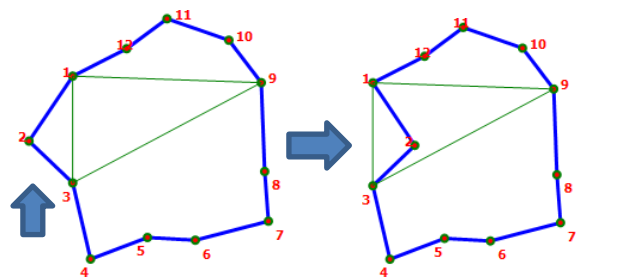
von	nach	L/R	Messwert [mm]
1	3	-	30
1	2	R	22
3	2	*	17

von	nach	L/R	Messwert [mm]
1	3	-	30
1	2	L	22
3	2	*	17

5.4.3.2   Entering data by hand

In order to enter or change the distances by hand proceed as follow:

1. Left-click in the cell of the table.

2. Enter/change the number and move curser to a different cell.

3. Click "=" – calculate button.

5.4.3.3 Calliper too small

If the calliper is too small for a particular tree or if the tips of the calliper cannot reach certain MP because of the tree geometry, you first need to check if the problem can be solved by selecting different base points. The image on the left shows such a situation. In this case the program suggests using base-points 1 and 5, but MP 5 is difficult to reach. One solution is to change the baseline to 1 – 6 (green line). Alternatively, three baselines could be used.

MP 5 difficult to reach   Calliper too small.

If the calliper is not large enough to measure a distance, the value can be estimated as follows. (The image on the right illustrates the situation.)

Transmit the maximal value to the computer (~ 2150 mm).
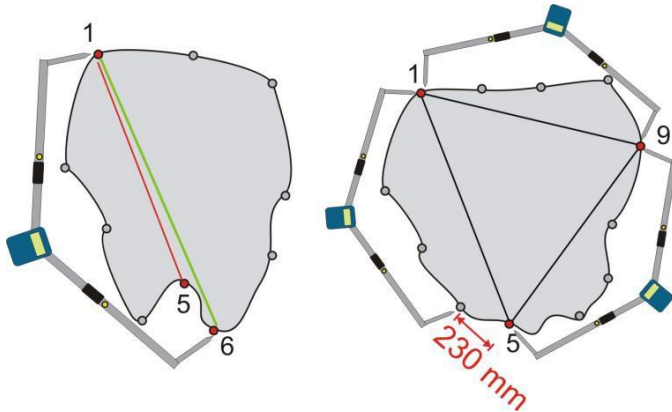
1. Estimate the length of the remaining distance by using a measuring tape or ruler. In our example it is 230 mm.
2. Left-click in the table on the field "1-5". Add the values you have (2150 mm and 230 mm) and type in the sum (2380). Click on "Calculate" ("=").

5.4.3.4 Measuring parts of trunks

Trees with large or very odd shaped circumferences, like multi-trunk tree for example, might require to scan parts of the tree only. The photo shows a multi-trunk tree. After the visual inspection it was decided to scan only one of the trunks.

The MPs are distributed around the trunk to measure as usual. The calliper should be used to determine the positions of the MPs correctly but the software would suggest base points 1 and 5 like the sketch on the left illustrates. The trunk at the right will impede the use of the calliper at MPs 5, 6 ,7, 8 and 1.
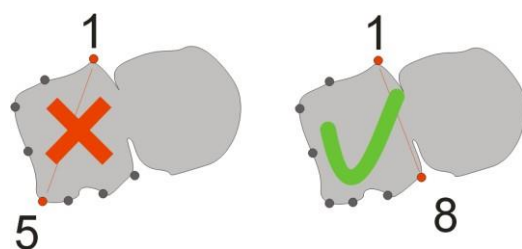
The problem is solved when we chose MP 1 and 8 as basepoints like the sketch on the right shows.

5.4.4 Partial triangulation – "free shapes"

There is a special version of the triangulation method that can be used to measure the position of single MP. This may become necessary when the geometry was first measured by the circular method and then the distances between some points are required to be more accurate.

It is also possible to use this function to record entire geometries by doing a chained free shapes measurement. Theoretically the geometry of any size of trees can be measured this way. However, the unavoidable error propagation limits the use of this method. It is never as accurate as the 1 or 3 baseline method.

The basic idea of this method is to develop the outline of the measuring level by calculating the position of an unknown MP by using the coordinates of two known MPs. Afterwards there are three known points and again we can calculate the position of a fourth point by using two known points. Theoretically every size of tree contour can be calculated this way. Unfortunately the unavoidable errors sum up step by step so that the result is more inaccurate.

In the sketch is shown how we can derive the coordinates of an unknown MP (red) from two known points (green). Read the sketch from left to right. The position of the three points is critical for the accuracy of the calculation: if all three points lie in a row (blue dots in the right sketch) then the error is large and gets worth with error propagation.
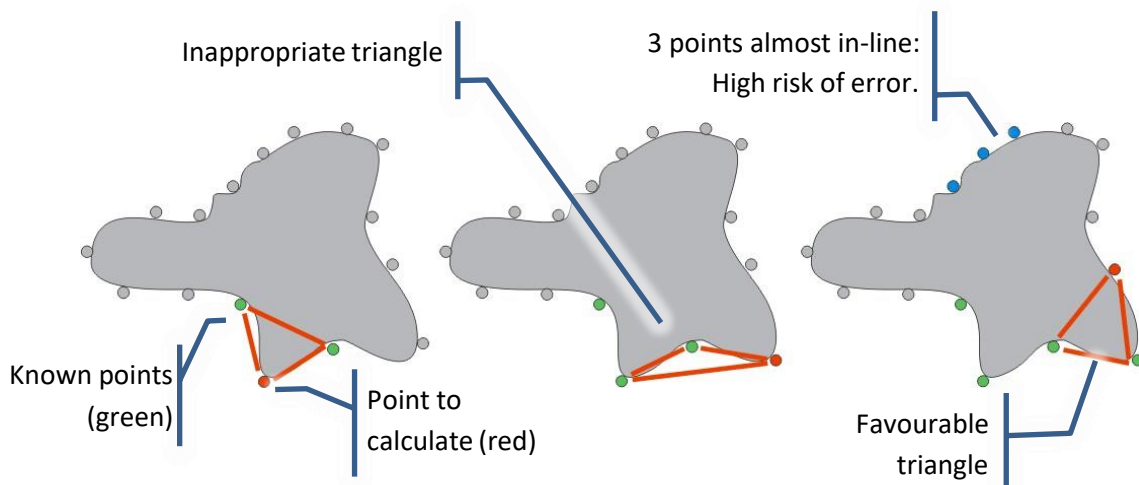
5.4.5 Partial triangulation – working procedure

The basic concept of partial triangulation is to calculate the position of an unknown point by using the coordinates of two nearby known points. These points are not necessarily the adjacent neighbouring points. It is better to choose points that create a roughly equiangular triangle rather than points that represent an acute triangle. The use of acute triangles leads to larger errors like the sketch in the previous chapter explains.

1. Start the free Shapes Window. And activate tab Baseline and enter the number of MP.

Free shapes method
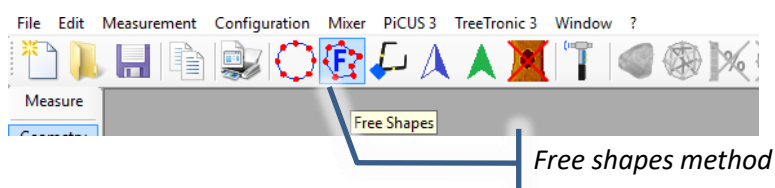
2. Define a base line by selecting points A and B. This line is basically the starting point of the geometry measurement. Try to use distant points that delineate an equiangular triangle with as many as possible other MPs. Enter the length of this (first) base line.
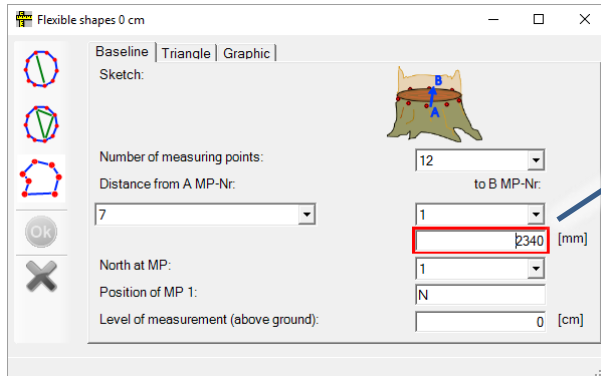
Type in length of the first baseline here. Unit is mm!

3. Select the point to calculate on tab "triangle"
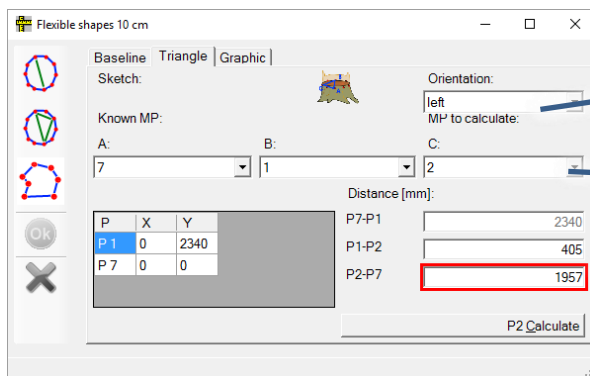
Set orientation

Select point to calculate

Enter distances to basepoints

4. Click "P.. calculate"

5. Proceed with next point. For every point the related base points A and B can be chosen. Mind to use equiangular triangles!

5.4.6 Manual adjustments of the geometry

Small changes of the geometry can be done by hand: mouse drag and drop. Access to this function is in the tool box on the left side of the screen (new in Q74 Expert). Refer to chapter toolbox.

5.4.7 Export the geometry to "*.abt" file format.

Remark: the geometry export function is available in special program versions only.

The calliper and a special version of the PiCUS software can be used to export the geometry to "*.abt" files.

Proceed as follows:

1. Open an existing PiCUS file or recorded the geometry using the "Ellipse" or "Free shape calliper" function (previous chapter).

2. Close the geometry window with "OK" Button.

3. Click on "save as" and select ".abt" extension.

4. Enter a short (!) file name. Avoid space characters or other non-character characters.

5.5 Installation of the instrument at the tree

5.5.1 Installation of the PiCUS version 1 / 2

Completed work steps so far:

- Visual inspection of the tree and identification of measuring level
- Nails (measuring points – MP) are installed
- Number tags attached to the nails
- Geometry recorded

To mount the PiCUS 1 or 2 to the tree proceed as follow.

1. Mount the strap on the tree. If you plan to measure at two levels, it is often useful to place the strap in-between those levels so that the sensors can reach both levels without having to replace strap and modules.

   Place the strap in-between measuring levels.

2. Mount the modules anti-clockwise from the left to the right. Module 2 will be to the right of module 1 and so on.
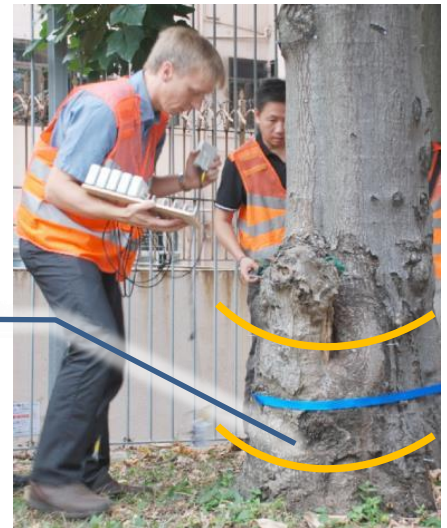
It is best to hold the board in your right hand and place the modules/sensors on the strap using your left hand.

3. Place the sensors on the nails **carefully** and make sure they fit well. The entire sensor head must be touching the nail, making sure there is no gap inside the rubber cover. Remove dirt or grime from the magnets before mounting. Place the sensors on the nails slowly by first inclining them slightly and then guiding them gently onto the nail heads. Do not allow the sensors to "jump" on to the nail heads suddenly.

4. Connect the modules with each other, starting with module one. Plug the cable of module one into module two and continue around. The last cable does not connect with anything and its head should be protected from dirt and moisture with a cap.

5. Optional: If the PiCUS shall be connected to the PC through a USB cable connection the USB cable needs to be installed **before** the sonic scan window is opened. Otherwise the COM port does not exist.

### 5.5.2 Installation of the PiCUS version 3

Completed work steps so far:

- Visual inspection of the tree and identification of measuring level
- Nails (measuring points – MP) are installed
- Number tags attached to the nails
- Geometry recorded

To install the PiCUS 3 at the tree proceed as follow:

1. Place the PiCUS main unit in-between MP 6 and 7 when the trees has 12 MP. The use of the blue strap is recommended so the device is not lying at the ground.

Install the PiCUS in-between MP 6 and 7

2. The sensor cable loom 1 to 6 is plunged in the left sensor socket "A" (named "1-6").

   The sensor cable loom 7 to 12 is plunged in the left sensor socket "B" (named "7-12")

3. In case the hammer needs to be used the hammer cable (right-angled connector) is plunged in socket "C" on the left bottom corner. The other end of the cable goes to the hammer grip (remove antenna before). In most situation the radio connection between hammer and PiCUS will work. Large diameter trees or allot of other radio signals in the open frequency the hammer is using may require the use of the cable.

4. Put sensors slowly onto the nails! Sensors must not "jump" on the nails to avoid damages.
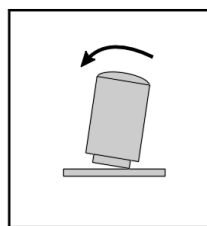
Incorrect!   Correct.

5. Use the large metal "paper clips" to hold the sensor cable loom in position if needed.

6. Optional: If the PiCUS shall be connected to the PC through a USB cable connection the USB cable needs to be installed **before** the sonic scan window is opened. Otherwise the COM port does not exist.

5.6   Sonic measurement execution

5.6.1   Measuring points and sensors

The PiCUS sonic tomograph technology differentiates between measuring points (MP) – a nail in the tree – and sensors. For a PiCUS scan you can use **more measuring points than sensors**!

Thanks to this technology one can record full tomograms on trees that require 14 or 20 or even more than 30 measuring points by using a PiCUS machine with 6 or 10 or 12 sensors only!

Measuring point with sensor attached.

Measuring point (nail) with number tag. No sensor installed currently.

Since the PiCUS (program) does not know on which nail the operator puts the sensors the measuring process requires a sensor-nail allocation table.

The current positions of sensors must be configured in that MP-sensor-allocation table. Care must be taken when the entering the sensor positions (on which MP is which sensor) into the PiCUS software!

An incorrect MP-Sensor allocation table leads inevitably to incorrect tomograms.

Before starting the actual sonic scan make sure that all sensors are sitting correctly on the nail heads! In particular when using the hammer cable, pulling the cable around the tree can lead to incorrect sensor attachments.

5.6.2   Note for PC data file handling

It is a good working practice to create a new file folder for every tree. Inside this folder a sub-folder is created every time a scan was done. In this event specific folder all data of that day is saved: data files, comments, photos, everything.

An example of the recommended folder structure is given here:
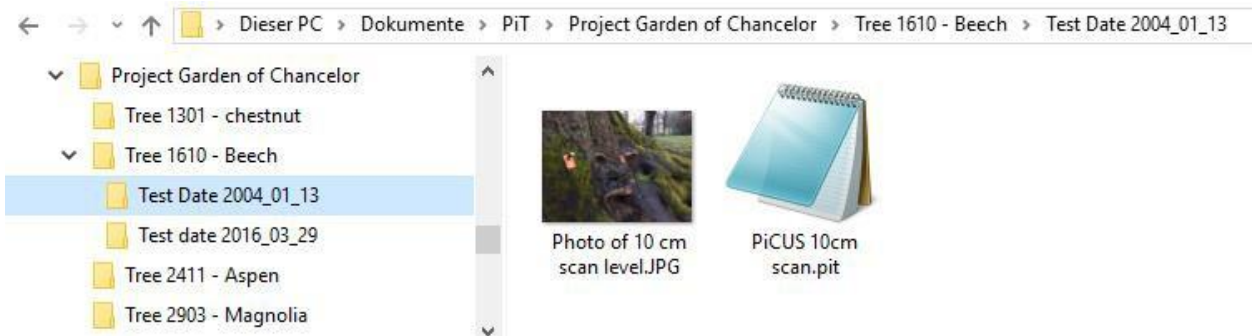
5.6.3 Temporary backup files

The data recorded is being saved while measuring in a temporary file in the standard temp-path of the PC. This is done to avoid data loss in case of unexpected termination of the measurement. The temporary directory is opened when typing "%temp% " in a file explorer window. Many files are being created during the sonic scan in this directory. Different stages of the scan can be examined if needed. These temporary files are not deleted by the PiCUS software. Running a standard windows disk clean function the temp directory is deleted.
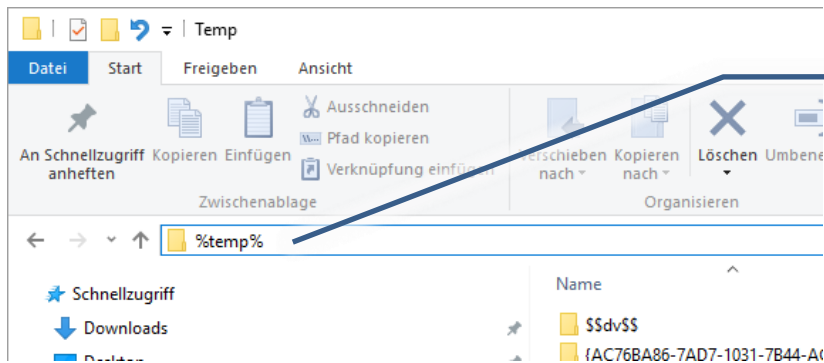
Type in %temp% here and press Enter key.

5.6.4   Sonic scan

Completed work steps so far:

- Visual inspection of the tree and identification of measuring level
- Nails (measuring points – MP) are installed
- Number tags attached to the nails
- Geometry recorded
- PiCUS instrument installed at the tree
- Optional: USB cable PC-PiCUS installed

Hint: you will find instructions about the sonic scan in the PiCUS 3 hardware manual as well.

The Q74 sonic scan work procedure is here:

1. **Connect the USB cable or activate Bluetooth**

   Install the USB cable between PiCUS and PC before the sonic scan window is opened. Otherwise the COM port does not exist. If you intend to use the Bluetooth connection make sure that the Bluetooth function of the PC is activated.

2. **Open sonic scan window**

   PiCUS PC Software main menu → "Measurement" → "Measure sonic"

Start acoustic scan
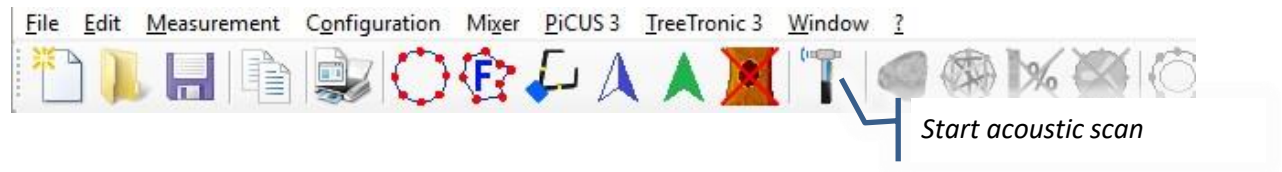
3. Adjust the sensor – MP allocation table

You can skip this step if each MP has sensor attached (number of MP = Number of sensors).

In case the number of MP is larger than the number of sensors the Sensor-MP mapping table needs to be adjusted.

- a. Enter number of sensors

- b. Enter position of sensors. A good practice is to walk around the tree with the laptop/PiCUS 3 in your hand and typing in sensor location by sensor location

- c. Click "adopt positions"

Hint about the COM port

Every time the COM Port connection is changed, for instance when changing from USB to Bluetooth connection, the COM port settings in the COM configuration windows need to be customized. The COM port number can also be changed directly in the sonic scan window. However, all changes made here are not permanently saved.

4. Turn PiCUS device ON

- a. PiCUS 1 / 2: turn on power supply. All modules flash twice.

- b. PiCUS 3: turn on and enter PC mode:

  "*Sonic Tomogram PC*" → "*Connect PC*"

  Display shows:

  "Search hammer"

  "Search PC (BT-USB).."
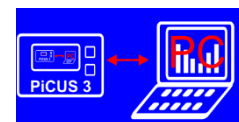
  The PiCUS 3 automatically recognizes the hammer (PRHD) in cable-connection. In radio operation the hammer needs to be turned on (push either hammer button for 3 seconds). The PiCUS 3 automatically connects through BT or USB.

5. **Open COM port**.

The COM button turns green when connection is made. COM13

6. **Push hammer buttons**

Check communication by pushing hammer buttons (several times eventually) till numbers are shown on the hammer.

7. **Attach hammer to an MP**

Put tapping pin of the hammer on an nail. If necessary take off sensor before.
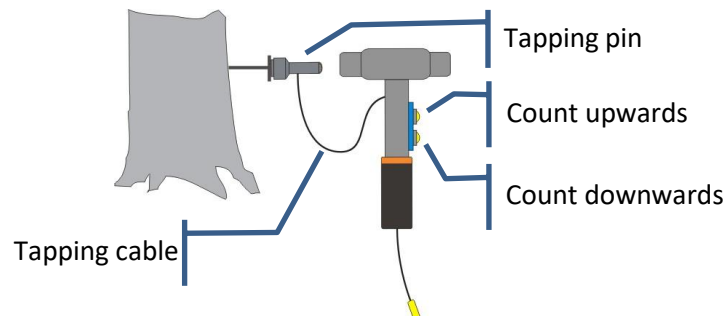
8. **Adjust MP number at the hammer display**

Use both hammer buttons to set the number of the tapping point to the display of the hammer. Always use the MP number, shown by the number tag on the nail! Disregard the sensor number that can be different.
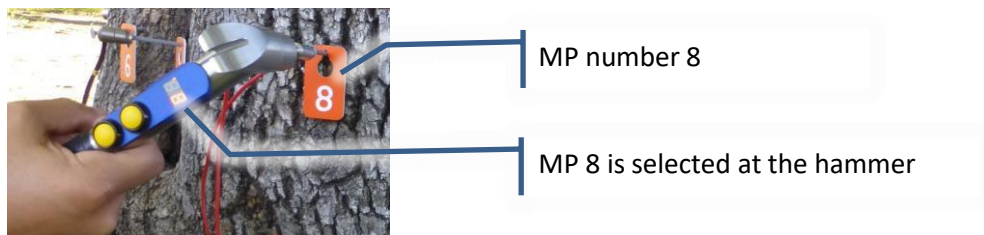
Attention: the incorrect selection of the tapping point leads to unusable data.

The hammer is ready for tapping when the number shown is flashing! If the number does no flash (solid light) or if no number is shown the hammer needs to be woken up by pushing either button.

Number is flashing – hammer is active and ready for tapping.
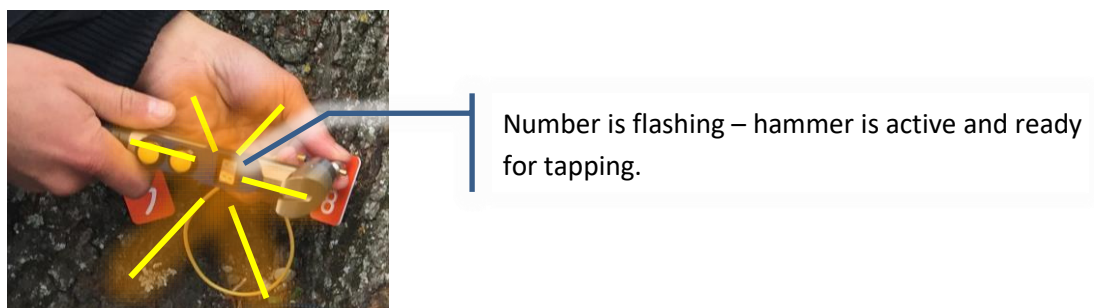
9. **Signal transmission**

Just after tapping the data needs to be transferred to the PC. The hammer display shows orbiting lines while data is transmitted. After approximately one second the (flashing) number is shown again and the hammer is ready for the next tap. If the circling of the LED continues then the connection between hammer and PiCUS 3 is interrupted. Push either hammer button again until the number is shown. Change hammer position to support reconnecting.
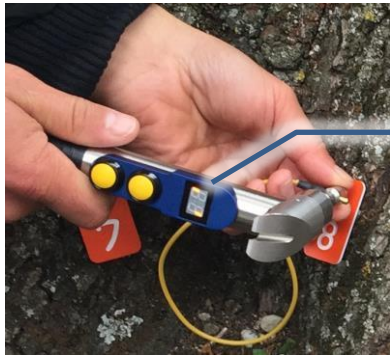
Orbiting lights – hammer NOT ready.

Measurement completed at this MP

10. **Repeat tapping**

Tap again to allow the computer to analyse the data quality. Three or more good taps are required. A little dot in the top left corner of the hammer display indicates sufficient data.

General hint: when using the wireless radio connection between hammer and main unit try to keep the distance between hammer antenna and cable loom as large as possible since the radio signal may interfere with the sonic scan. This can be done by holding the hammer upright.

Attention, mind the following handling notes:

- Do not touch other sensors or cables while tapping.

- Try to keep a larger distance between hammer antenna and sensor cables.

Large distance
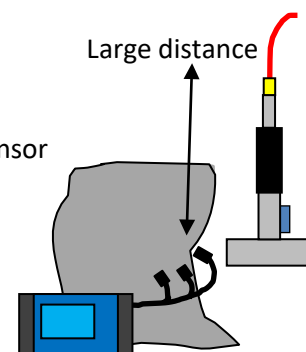
11. **Sensor back on nail**

Set sensor back on nail when data recording is completed

12. **Continue measurement**

Go to the next MP and tap. Continue and tap on **all** MP, irrespectively of the MP holding a sensor or not. Tap on all MPs: with and without having a sensor!

The next steps only apply if the measuring level has more MP then sensors being used.

13. **Change over sensors**

    When the test level has more MP than sensors then the second round of tapping can begin. To do so change over sensor(s) to the next position (previously empty nails).

14. **Adjust the sensor-MP mapping table**

    Enter the new position of the sensors in the MP-sensor mapping table.

    Attention: an incorrect MP – sensor assignment will lead inevitably to incorrect data.

15. **Tap again on all MP**.

16. Close measuring window with **OK button**.

17. **Save** the file.

5.6.5   How to swap the hammer – PiCUS connection: radio or cable

In the majority of cases the radio connection between PiCUS and hammer will work sufficiently. However, very large-diameter trees or other ambient radio signals may jam the radio connection. In such cases it might be necessary to switch from radio to cable connection during the scan.

Proceed as follow:

1. Wait until the hammer turns itself off!

2. Terminate the measuring window or leave the PC-connection window, depending on the operation mode.

3. Disconnect the hammer antenna from the hammer.

4. Connect the hammer cable to both hammer and PiCUS 3.

5. Re-enter the measuring window or re-start the "Sonic Tomogram PC" function.

5.6.6   More MP than sensors – examples and hints

In case the number of MP exceeds the number of sensors available the tree needs to be scanned in two or rounds of tapping. In every working step the sensors are put on different MPs.

This chapter gives an example.

The work steps of a PiCUS 3 model in stand-alone or PC mode are similar in principle but details are different. In this manual we only describe the PC program working steps. Handlings notes for the PiCUS 3 in stand-alone mode can be found in the PiCUS 3 hardware manual.

The tree requires 14 MP. The PiCUS is equipped with 12 sensors. In the sonic measurement window proceed as follow:

1. Set "number of sensors" at the tab "Sensors and sensor allocation"

2. At tab "Sensors and sensor allocation" adjust the MP-Sensor mapping table. For instance sensor 1 to MP 1, sensor 2 to MP 2 etc.

3. Put all sensors to the nails accordingly.

4. Tap on all nails: 1 to 14. This is called the first round of tapping.

5. Put sensors to the nails that did not have sensors before. In our case it is nails 13 und 14. For instance: sensor 12 can be moved from nail 12 to nail 13 and sensor 1 can be moved to MP 14.

6. Enter new position of sensors 1 and 12 into the MP-sensor mapping table.

7. Tap again on all 14 MP.

Attention: an incorrect sensor – MP assignment will lead to useless data.

The next sketches show examples for sensor placement.

- **Alternating order.** If cables are long enough then the "one sensor – no sensor" should be used because it is most time efficient: very often a meaningful tomogram can be calculated after the first round of tapping.
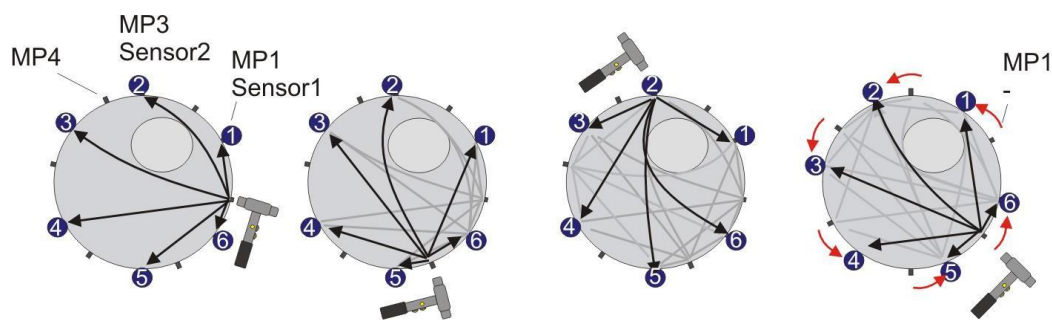
In case the number of MP is not a whole-number multiple of the number of sensors (for Example: 20 MP – 12 sensors or 10 MP – 6 sensors) it might be appropriate to decrease the number of sensors in the software in order to use the alternating order method.

- **Sectional scan.** When the circumference of the tree is too large for the alternating sensor distribution then trunk can be scanned in sections
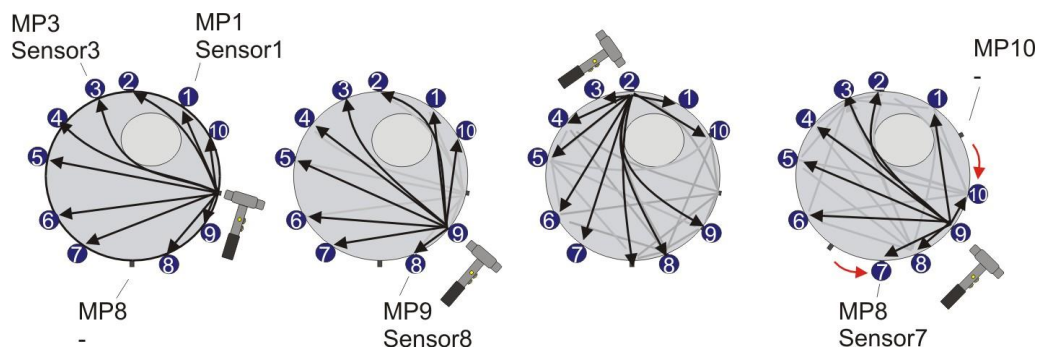
- **Number of sensors is slightly smaller than MP number**. In this case it is recommended to distribute the unmanned MPs around the circumference. In many – not all – cases the tomogram is sufficient after the first round of tapping. This is because we tap on all MPs, with our without the sensors.
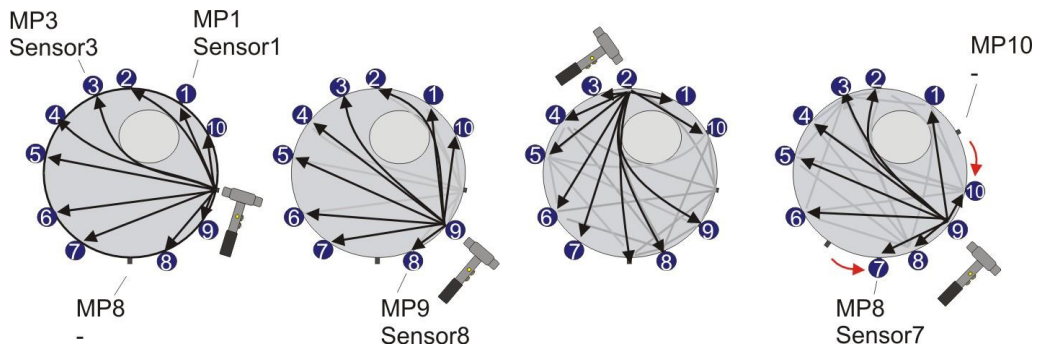
5.6.7 Hints for the sonic scan

5.6.7.1 Hammer handling

Hammer operation/stance need to be adopted to the actual situation: at narrow locations at the stem, for instance in-between roots, the hammer can be hold vertically to be able to tap on inside MPs. Apart from this the vertical hammer position guaranties a large distance between hammer antenna and sensor cables.

Antenna is far away from sensor cables.

Point to tap is in an fold. Hold hammer vertically.

The taping cable should not touch other nails or sensors!

Hold hammer loose. Short sharp taps with constant power are easier to obtain this way.

Antenna is far away from sensor cables.

The taping cable does not touch other nails or sensors!

Antenna is far away from sensor cables.

Let the hammer swing gently. This is another method to perform constant taps.

5.6.7.2 Tapping power

The PiCUS sensors are very sensitive and react to tiny vibrations. The tapping power does not need to be very height. If you tap too hard the nail might be driven into the tree even further.

To tap constantly is most important.

5.6.8 Read GPS signal from PiCUS 3

The PiCUS 3 has an in-built GPS receiver that is turned automatically on when the PiCUS is turned on. In stand-alone mode the GPS coordinates are automatically saved to the file. In PC guided modus the GPS signal can be transmitted to the PC through the "Sonic measurement" window of the Q73 software. Proceed as follow:

1. Turn on PiCUS 3 and bring it to PC modus.

   PiCUS 3   *"Sonic Tomogram (PC)" → "Connect PC"*
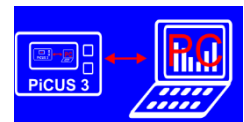
2. PC program   "Measurement" → "Measure sonic" or click icon:

3. PC program   Clicking [COM4] to open port. The button should change to [COM4].

   The screen of the PiCUS 3 should show "PC <-> USB ok" (or BT ok)

4. PiCUS 3   Activate the hammer by pushing either hammer button.

   The screen of the PiCUS 3 should show "Radio hammer active" if hammer is in radio modus.

5. PC program   Click the satellite icon 📡 to start reading GPS data. The icon changes to: 📡
    The readings take a few seconds. The function is turned off automatically. If GPS signals are available
    the bottom line shows both UTC and coordinates.

    > GPS Mode UTC 7:45:23 AM 54.074697°N 12.116655°E

    Depending on signal quality the signal acquisition may take up to 5 minutes. The longer the GPS module
    can read the signal the better is the quality of the coordinates.

    Therefore it is a good strategy to do the sonic scan and get GPS coordinates afterwards.

    The GPS coordinates are saved to the PiCUS data file and can be found in the tree data window.

5.6.9   Download data files to PC

To download data files from the SD card of the PiCUS 3 to the PC proceed as follows:

1. Prepare the PiCUS 3 for data files upload by going to menu:

    PC program   "*Data to PC*".

    The PiCUS 3 now waits for the serial connection (either BT or USB) to the PC.

2. Start the PiCUS Q73 program on the PC. Make sure that the Q73 program is configured for PiCUS 3
    operation.

    PC program   "*Configuration*" → "*PiCUS sonic Tomograph Hardware*" → "*PiCUS 3*"

3. Make sure the COM port is selected correctly (BT or USB) in menu

    PC program   "*Configuration*" → "*Select COM port*" → Tab "*Port PiCUS*"

4. Go to:

    PC program   "*PiCUS 3*" → "*Data Import*".

    The download window will open

5. PC program   Open the COM port in
    the download window and select a valid
    path on the PC.

6. PC program   Click "Import" button to
    start the data file download.
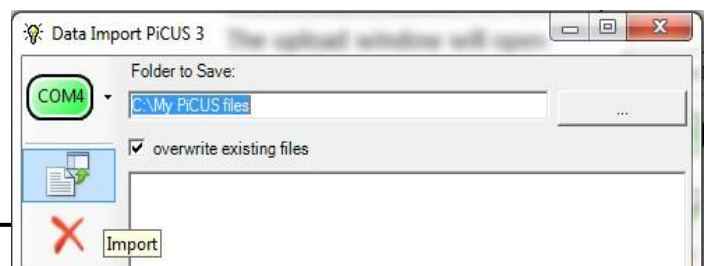
7. After downloading all files you are being asked to delete all files on the PiCUS 3. If you press yes then
    all files on the SD card of the PiCUS 3 are being deleted.

    Attention: deleted files cannot be restored!

Note: The files downloaded are renamed according to the local settings of the PC. The TreeTronic 3 derives
the filenames from the GPS time and date. GPS time and date are always given UTC. The local time and date
will differ from UTC. In order to keep track of files the PiCUS PC program calculates local time and date of
the measuring file and adds this information (prefix "LT" – local time) to the filename. The local time
information is derived from the time settings on the PC the program is running at.

5.7   Dismantling of the instrument

5.7.1   General hints

The quality of the tomogram should be checked before dismantling the instrument. We need to make sure that the number and position of measuring points was sufficient and the data quality was good.

5.7.2   How to unplug the nails with the electronic hammer

After the sonic scan the nails need to be removed from the tree. The head of the PiCUS hammer is shaped like a "fork" and can carefully be used to pull out nails if no other more robust tool is available.

The grip of the wooden hammer can be used to have a crank-point like shown in the photos.

Attention: Take care when using the electronic hammer to pull nails out. Use moderate force only. The hammer contains sensitive parts which can be damaged by strong vibrations or high forces that can bend the grip.

6 Tomogram and interpretation

6.1 General information

The PiCUS Sonic Tomograph was developed to examine living trees. Using the device inappropriately can lead to damage, both to the unit and to the tree itself.

Although every effort has been undertaken to present the results of measurements as comprehensibly as possible, interpretations of readings do require qualified technical expertise. The user bears the sole responsibility for all conclusions made about the status of any tree examined. Neither the manufacturer nor the distributor of the PiCUS® Sonic Tomograph can be held liable for any decisions made based on measurements made with the PiCUS®.

We strongly recommend attending a training course conducted by the distributor or by a certified institution in your country. A list of such institutions can be found at the IML Electronic web site.

The PiCUS Sonic Tomograph detects differences in the ability of the wood to transmit sound waves. It cannot identify the specific reasons for such differences. This means the instrument is not able to identify the exact type of damage: it may be decay, hollowness, cracks, or something else. Before taking any action or deciding to fell a tree, please be sure to identify the underlying reason for the defect you see in the tomogram.

Warning:

Do not fell a tree based solely upon a tomogram reading. You should always apply different arboriculture investigation methods before making a final decision.
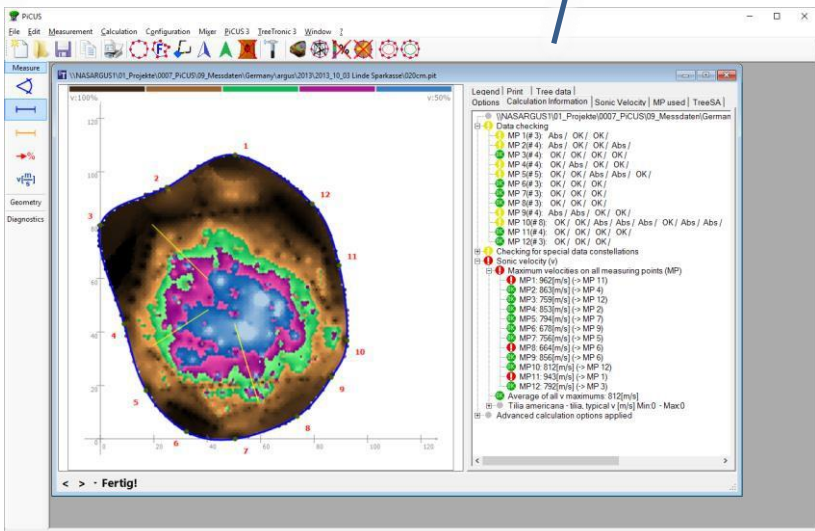
6.2 Tomogram window overview

After opening a PiCUS data file and calculating the tomogram the tomogram window looks like this:

Tool-menu: For measuring distances, geometry changes and adding icons to the tomogram.

Functions-menu: Open files, start scans etc

Calculation information

6.3 Theory of sonic speed measurements

6.3.1 Acoustic wave propagation in wood

The PiCUS® Sonic Tomograph detects differences in the ability of the wood to transmit sound waves. It cannot identify the specific reasons for such differences. When traveling through solid wood the acoustic velocity is closely linked to the modulus of elasticity (MOE) and density of the wood.

The formula below describes the relation between speed of sound, MOE and density for longitudinal waves in long wooden poles. To a certain extend it can be applied to our measurements too.

$$v = \sqrt{\frac{\overline{MOE}}{\partial}}$$

With

v = sonic velocity

MOE = Modulus of elasticity

∂ = Density

In damaged trees there are various reasons for variations of the sonic speed: depending on the type of defect the acoustic waves can be slowed down (for instance in areas of decay) or be forced to bypass a defect such as a cavity.

Often it is difficult to say whether the waves have travelled through an area or not. Thus, the real path the waves took is often not known. And since the path is not known a straight line from sender to receiver is assumed to represent the travel path. This straight line, the bee-line so to say, is then taken to calculate the velocity of the wave. Because the bee-line is only an assumption the velocities calculated are therefore called **apparent velocities**.

Consequently, sonic tomograms do often but not necessarily show information about the wood quality. Strictly spoken the apparent sonic velocities show the

Ability of the wood to transmit acoustic waves.

However, there is a strong correlation between the ability of transmitting acoustic waves and the integrity of the stem: everything that slows down the acoustic waves does cause a loss in stability.

Hint

A sound knowledge about trees and the working principle is indispensable in order to read and interpret the sonic tomograms.
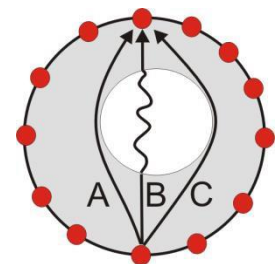
6.3.2 The "cogwheel" data constellation

The cog wheel data constellation often occurs on sound trees due to the different sonic wave transmission properties of the inner and outer areas of the trunk.

The arrows in the sketch show three different ways in which sonic waves travel. Sound travels best in a vertical direction– along the grain of the trunk. The next best transmission is radial - straight through the middle of the trunk. The slowest direction is tangential– along the circumference.

Tangential – slow velocity

Vertical – highest velocity

Radial – high velocity
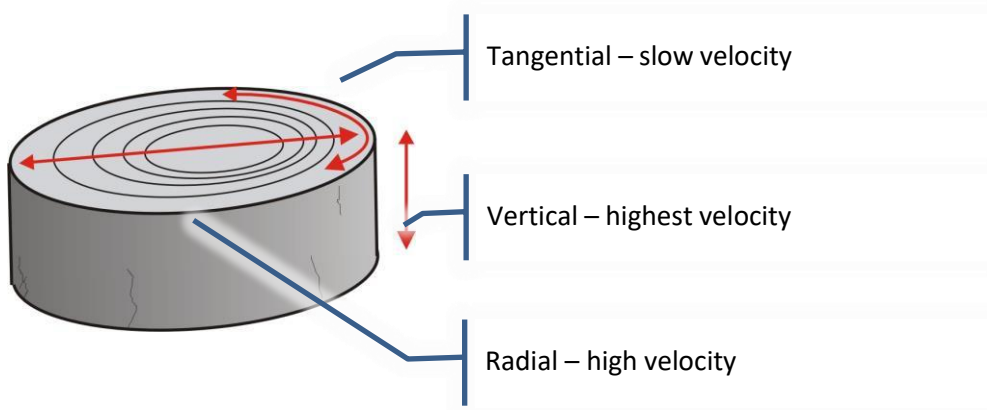
Because of this, the tomogram of a healthy tree sometimes looks like a "cog wheel". The green or violet areas between the sensors indicate a lower sonic velocity along the circumference.

Experience tells us that in such cases the wood between the sensors is not damaged. If the PC program identifies a cog wheel constellation, the colour scale of the tomogram is shifted to hide this effect. The middle tomogram shows the results applying the cog wheel compensation.

To turn on the compensation, click:

 "Configuration" → "Settings" → Tab "Cog Wheel "

Select "*Detect … and APPLY*" and re-run the calculation.
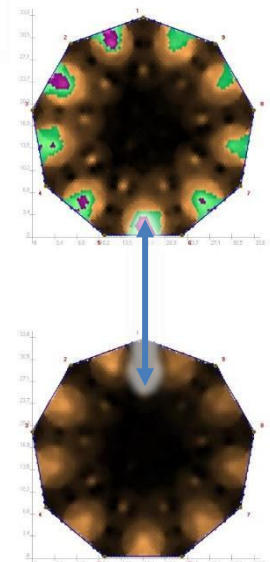
6.3.3 Velocity profile - SoT Type 1

Continuing the previous chapter the term *velocity profile* and its consequences can be briefly discussed.

There are two groups of trees regarding the velocity profile:

SoT "Type 1": the radial velocity - straight through the middle of the trunk - is **higher** than the tangential.

SoT "Type 2" the radial velocity - straight through the middle of the trunk - is **lower** than the tangential.

The graph below shows the "velocity profile" of "type 1" trees.

Tapping point is MP 5
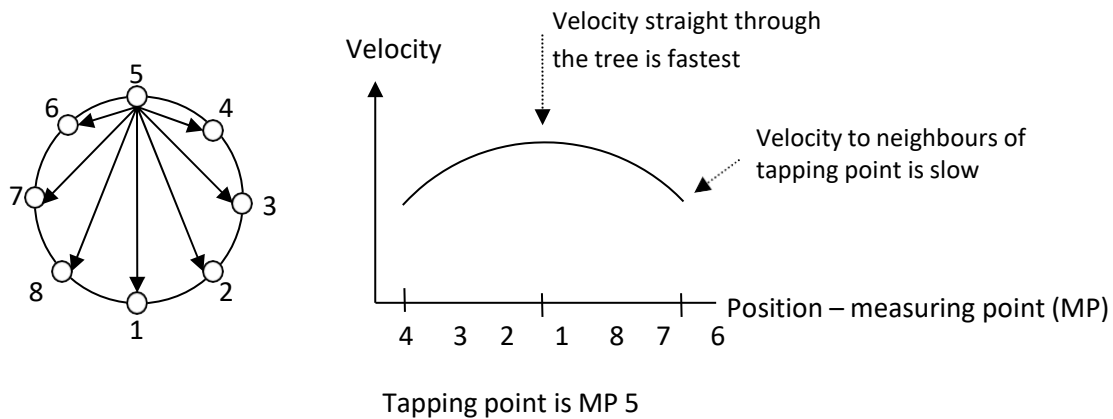
The velocity profile is shown in the sonic scan window: the bar graph that shows the actual readings.
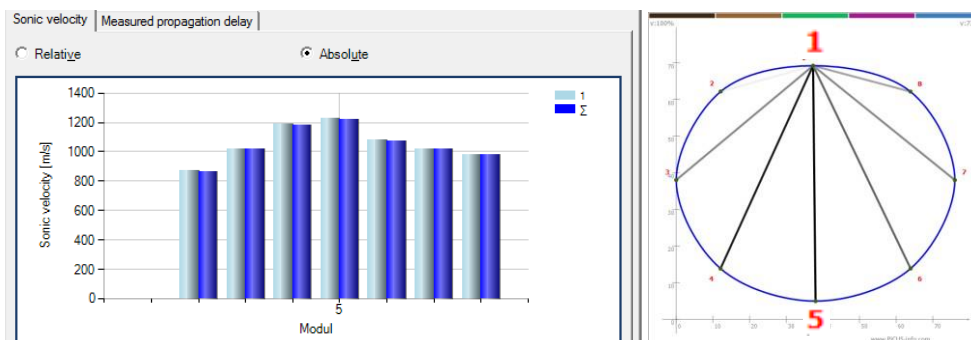
Virtually all European tree species belong to this group.

Exceptions are palm trees and *taxodium distichum* and likely ironwood. They belong likely to SoT type 2.

Based on this theory one can do a 3-point test to get a quick idea about the situation in the trunk.

The "3-Point" or "Point to point" test uses the above fact to give a quick and rough estimate about the wood quality. The 3-Point test measures both radial and tangential velocities at the same time using three test points at the positions six, nine and 12 o'clock. If the "6-to-12" o'clock velocity (red) is slower than the "6-to-3" o'clock velocity (black) then the trunk has major/big (!) structural defects. Smaller defects cannot be located with this test.

Sensor, measuring radial velocity

Sensor, measuring tangential velocity
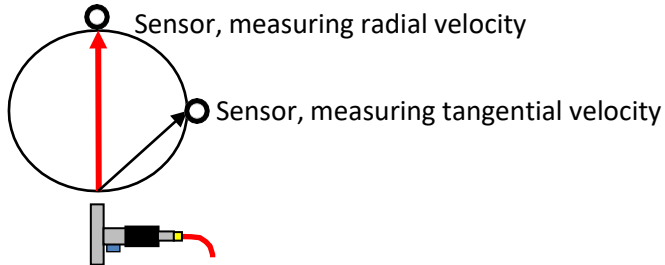
Hint: This test is not 100% save: there are defect constellations in which a defect cannot be detected using the 3-point test.

6.4 Colours of the sonic tomogram

To display different acoustic conductivity of wood, the PiCUS program uses set colours, assigning one colour to each point of the tomograph.
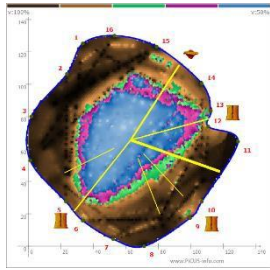
Areas of high velocity are represented in black or dark brown.

Areas of low velocity appear in violet, white or blue, and these are the areas that indicate problems. Those colours do not mean that there is a cavity, it just mean that the acoustic waves travel slowest in that area.

Green areas mark those sections which could not be classified as being either fast or slow, and these areas must be interpreted together with the overall damage.

The colour scale (black, brown, green, violet, blue, white) ranges from 100% velocity (brown) to the slowest velocity (blue). Colours are switched as specific special trigger levels to show the differences, as shown in the following sketch (not drawn to scale):

Plan of a tree with a decayed area

Theoretical lines of the sonic signals

Velocities along the red line and their associations with the colour scale

The tomogram produced
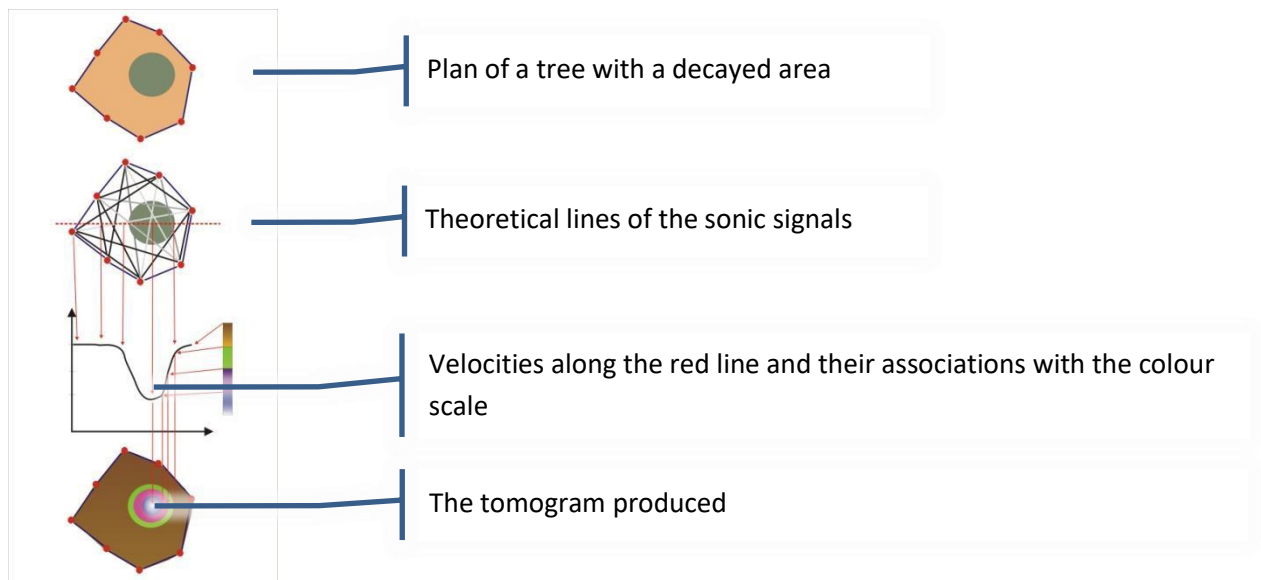
There are three main colour groups to be considered:

1. black / brown
2. green
3. violet / blue / white

Decreasing velocity
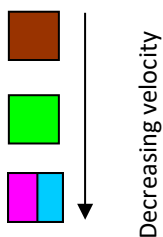
The colours violet, blue, and white should be treated as a single class. There is a function to shut off the blue and white colours and present these areas in violet only.

Unfortunately, the results of sonic measurements cannot give information about the exact type of structural loss in a tree. This means a tomogram does not tell us if the violet or blue areas are caused by a cavity, a crack, or by decay – it can only display the levels measured.

Nevertheless, observing how the colours are distributed (colour allotment) across the tomogram provides us with additional information about the type of damage. You need knowledge of trees and their diseases

in order to interpret a tomogram correctly. It is also helpful to have experience in operating the PiCUS unit and in reading other tomograms as well.

Warning!

In order to read a tomogram correctly, you need **sound knowledge of trees and their diseases,** and you must be familiar with the **working principles of measuring instruments.**

DO NOT fell a tree based solely on a tomogram reading. You must first analyse all possible reasons for slow acoustic conductivity, and eventually you will have to apply different investigative methods (TreeTronic etc) as needed.

6.4.1   Coloured or grey tomograms

Very early versions of the PiCUS program (1997-98) used a grey scale for tomograms, which made it difficult to determine the exact extent of the damaged area. PiCUS now uses colours to display the areas of different acoustic conductivity more clearly. These examples show tomograms of the same tree in standard, violets-only, and in grey:
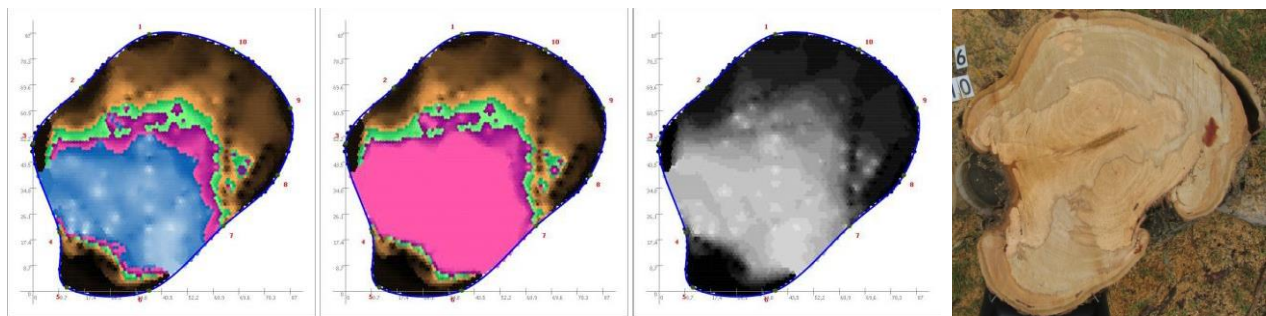
standard   no blues   greyscale   photo of trunk

6.5   Tomogram calculation

The coloured tomogram (SoT) is calculated by the function "Tomogram" (formerly named "calcB2000"). Moreover there is a function called "Line graph" (formerly names "Calc C") that shows all the straight-line pathways between the MP.

Main menu → "calculation" → „ Tomogram"

Start/Stop tomogram calculation   Line graphic
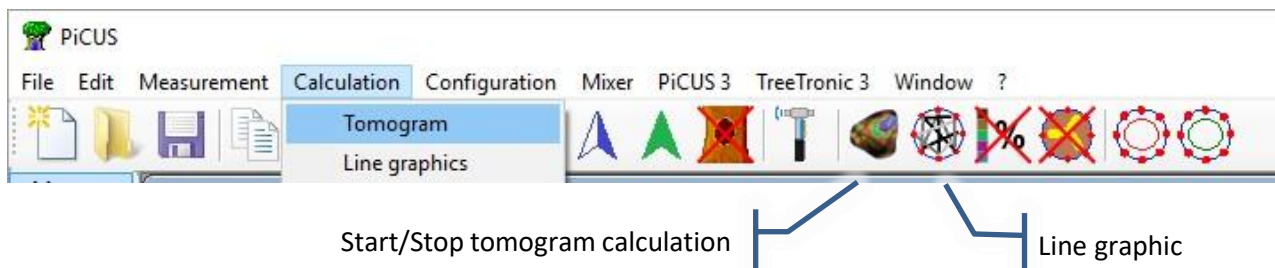
Calculation time depends on number of MP.

6.6 Legend

The legend gives you information on the velocity range that occurred during the measurement.

To show the legend click on the icon.

Show/hide legend

The legend appears at the top of the tomogram:

Key:

v:100%   A relative calculation was done. The fastest velocity is set to 100%. Areas of high velocity are shown in dark browns.

V:50%   The slowest velocity measured is 50%, in relation to the fastest (100%). Areas of slow velocity are shown in blues.

Solid wood: 61%   Brown colours (high velocities) compose 61% of the tomogram.

Damaged: 26%   Blues and purples (slow velocities) compose 26% of the tomogram.

These values of solid or damaged wood are only estimations. Please note that accuracy depends on the:

1. shape of the tomography level
2. position of measuring points
3. shape of the damaged area
4. type of damage (cracks, decay, cavities).

The following sketches show how these factors differ between the real size of the tomography level and the total number of points counted. That is why the total number of pixels is smaller than the actual size of the cross-section.

The computer does not have any correct information about the real shape. Therefore, the value of sound wood given in the legend is usually too small.

The first row in the following sketch shows the difference (right sketch) between the real size of the tomography level (left) and the size in the tomogram (middle).

True cross section of the tree

Not considered areas

Area of the tree shown in tomogram

Damaged area discerned is too large
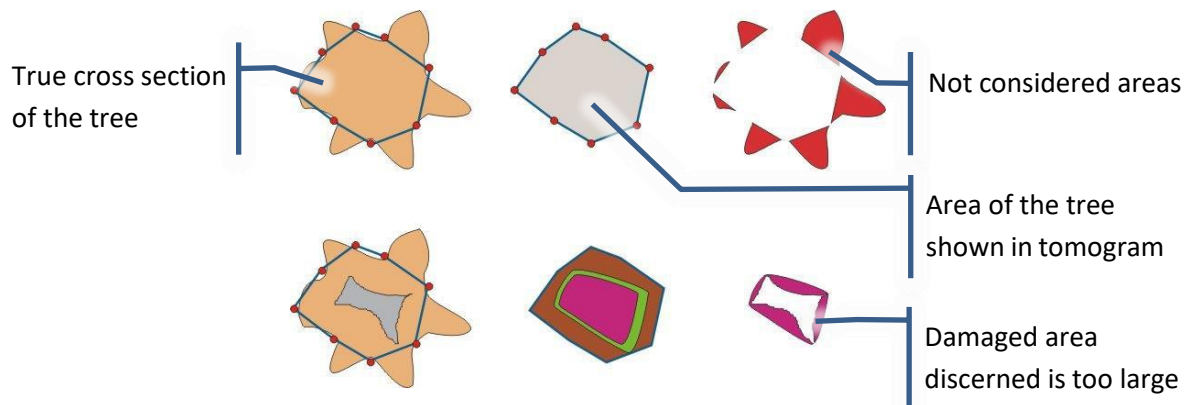
Note:

You should not draw any conclusions about felling a tree based simply on the measurements of the damaged areas. In order to estimate the breaking risk at tomography level please use methods such as SIA, TreeSA (integrated into Q74) or the web-service at www.treecalc.com (most advanced).

This information about the size of the damaged area can be used to compare tomograms recorded on the same tree at different points in time. For instance, if the size of the defect was 20% in 2005 and 40% in 2009, this means that the size of the defect has increased by ~20 %.

6.7 The Toolbox menu

1. Measurement of angles in the tomogram (left-click)

2. Measurement of distances in the tomogram (left-click and drag)

3. Measurement of distances in the tomogram in different colour (left-click and drag)

4. Rough estimate of the remaining bending resistance based on theoretical calculations of the geometrical moment of inertia. Left-click on the „border-line" between green and brown.

5. Shows local absolute sonic speed when curser is moved over the tomogram. Left-click to mark a velocity at a certain location.

### 6.7.1 Estimate of the bending resistance using the geometrical moment of inertia

The second moment of area, also known as moment of inertia of plane area, area moment of inertia (MOI), or second area moment, is a geometrical property of an area which reflects how its points are distributed with regard to an arbitrary axis. In the field of structural engineering, the second moment of area of the cross-section of a beam is an important property used in the calculation of the beam's deflection and the calculation of stress caused by a moment applied to the beam.[2]

This way, the second MOI can be understood as a measure of the resistance of an object against bending. The MOI only considers the geometrical shape of the body – no material properties are considered. The MOI of bodies like cylinders (a tree is shaped basically like a cylinder) is strongly influenced by the diameter: large diameter cylinders (and trees) do have a very large MOI and are difficult to bend. They are stiff – purely because of the geometry. Small diameter cylinders (and trees) have a low MOI. That means they are more easy to bend.

The MOI of a circular ring is being calculated according to this formula:

$$I = \pi * (R^4 - r^4)$$
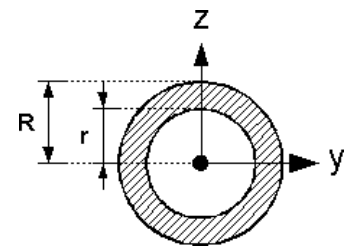
When analysing the equation it becomes obvious that the outer areas have the largest impact on the MOI, so to say, on the stiffness of the body. The cavity in the inside near the centre hardly affects the MOI.

The example shows a linden tree with only 61% solid wood left. But the bending resistance (MOI) is very high in most of the places. That means the pure size of the defect is less important, the location of the hollowness also needs to be considered!
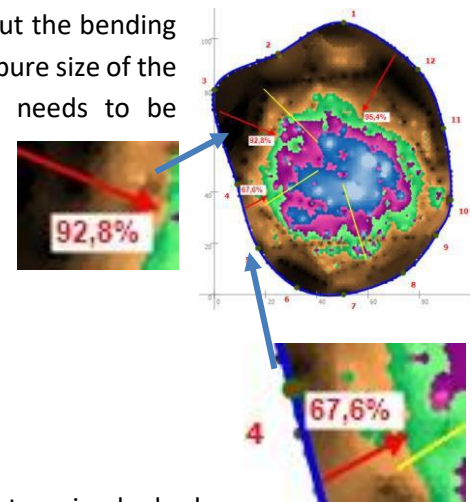
Operation

1. Select the tool:

2. Left-click at the borderline brown-green

Interpretation

At MP 4 the stem has still 68% of bending resistance left (in relation to a circular body with no defect).

Limitations

- This approximation only considers the geometry of the trunk at this level. Material properties such as "normal" wood or "reaction" wood are not considered but do have an important impact.

- The calculation is more accurate if the correct outline of the tree is recorded. The use of the triangulation method is indispensable.

---

[2] Source: www.en.Wikipedia.org

- If the shape of the tree is derived from a circle then the almost always occurring ovality is disregarded and leads to large errors in the MOI estimate.

- The number and positions of MP is critical to the accuracy of the calculation of the MOI. The sketch shows a cross sections of a tree using different MP positions. Areas drawn in red will be disregarded in the MOI calculation simply because the program does not know about it. The MOI calculated is therefore too small. Green areas would be included although they do not exist. The MOI would be too large in this case.

This MP distribution would wrongly include the green areas in the MOI calculation.

This MP distribution will be wrongly ignored in the MOI calculation.
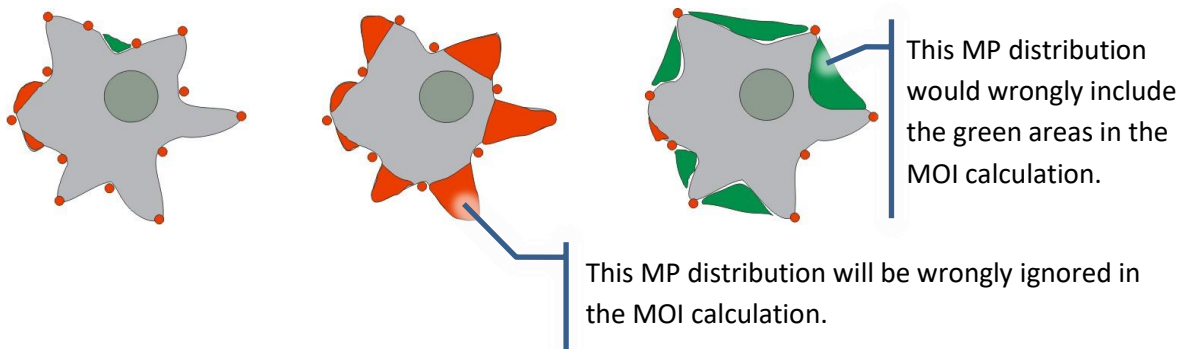
- The bending stiffness of a tree is not only determined by the shape of the cross section. It is the result of the three dimensional bond of the wood body. This 3D bond is not incorporated into MOI considerations. The MOI calculation of trunks that are divided at the level of tomography are very incorrect because it does not incorporate that both parts may be grown together at higher levels.

6.7.2 Changing geometry by hand

This function can be used to do small manipulations of the positions of some measuring points. The "undo"

function takes back changes.
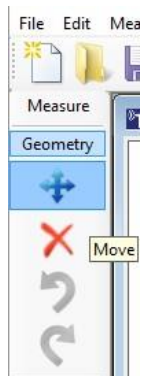
More information can be found in chapter "Manual adjustments of the geometry".

6.7.3 Diagnostic icons

Diagnostic icons can be used to enter the visual observations into the "pit" or "ert" file.

Operation

1. Load icon into the tomogram: left click

2. Move icon in the tomogram: right click and choose "move" option

Meaning

Diagnostics

Open Cavity

Crack

Co-dominant stem

Bark inclusion

Decay

Fungus (Type 1 – Toadstool fungus)

Fungus (Type 2 – Bracket fungus)

Armilaria fruiting bodies

Kretschmaria deusta fruiting body

Old pruning wound

Moisture emerging (water, sap, etc.)

Callus, strong-growing wood

Bark abnormalities

Foreign material in the tree (concrete, steel etc)

Mechanical (bark) damage (e.g. due to car impact)

Root damaged

This side towards the street

Tension load

Compression load

6.8 Function menu

| 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. | 15. | 16. | 17. | 18. |

1. Start new file, sonic- or electric resistance tomogram. Starts the wizard.

2. Open an existing file

3. Save file

4. Copy the tree graphic into the Windows clipboard

5. Print the tomogram

6. Enter (or change) the geometry of circular or elliptic trees

7. Enter (or change) the geometry of irregularly-shaped tree (free shapes, partial triangulation). This version should only be used when all other functions fail.

8. Enter (or change) the geometry of irregularly shaped tree using the PiCUS Calliper (free shapes, triangulation with calliper). This is the standard function for geometry measurements, which can and should also be used even if the electronic PiCUS calliper is NOT available.

9. Show/hide North indicator arrow

10. Show/hide prevailing wind indicator arrow

11. Show/hide diagnostic icons

12. Sonic velocity measurement

13. Calculation of the tomogram, starts both SoT1 and SoT2

14. Calculation of the line graphic, direct lines between measuring points

15. Show/hide legend

16. Show / Hide the yellow lines of the CrackDect function

17. Draw a radius for remaining wall thickness (1/3 – red circle)

18. Show / Hide minimal remaining wall thickness according to TreeSA (green circle)

6.9 Tomogram information

After the calculation of the SoT is completed you can review information about the quality of the data on the tabs next to the tomogram.

It is recommended to check data step by step if a tomogram does not show plausible results. This is most easy in the sonic scan window.

6.9.1 Calculation information

All the acoustic data recorded is automatically checked. Most of the errors are detected automatically. The most important test functions are:

- Absolute value test: "Abs". This function checks the absolute run times of the acoustic waves. They must not exceed certain limiting values.

- Corelation test: "Korr". This function checks for similarity of the signals.

The results of these test functions are shown on the "Calculation information" tab.

Red exclamation mark: checking recommended. In this case the red mark is shown because no data was collected at MP 5.

No data at MP 5

Yellow exclamation mark: the first tap (set of data) when tapping on MP 9 was ignored: correlation test failed.

Green Ok: all tapping data can be used. #4 = this MP was tapped 4 times.


```
Options | Calculation Information | Sonic Velocity |
        Z:\0007_PiCUS\09_Messdaten\Germany\argus\2013\2(
   ⊟ ❗ Data checking
        MP 1(# 3):  Abs /  OK /  OK /
        MP 2(# 4):  Abs /  OK /  OK /  Abs /
        MP 3(# 4):  OK /  OK /  OK /  OK /
        MP 4(# 4):  OK /  Abs /  OK /  OK /
        MP 5(# 0):
        MP 6(# 3):  OK /  OK /  OK /
        MP 7(# 3):  OK /  OK /  OK /
        MP 8(# 3):  OK /  OK /  OK /
        MP 9(# 4):  Abs /  Abs /  OK /  OK /
        MP 10(# 8): OK /  OK /  Abs /  Abs /  Abs /  OK /  Ab
        MP 11(# 4): OK /  OK /  OK /  OK /
        MP 12(# 3): OK /  OK /  OK /
```

6.9.2 Calculation information – maximum velocity supervision

The "maximal sonic velocity supervision" test compares the maximal sonic velocity which occurred at each measuring point with the average of the maximal sonic velocities of all points. There are three main reasons for the velocity to be <u>very low</u>:

- The nail is not in direct contact with the wood (put it in deeper)
- The nail was placed in a damaged area (move it and reconfigure)
- The nail is placed in good contact to wood but the part of the tree is not connected to the rest of the tree.

The most frequent reasons for <u>too high</u> velocities are geometry errors: the following example shows very fast connections between MP 6-7 and MP 7-6. The reason is likely a problem with the geometry. The real distance between MP 6 and 7 is smaller than calculated in the outline.

If you are still on site, you should make sure that all nails were placed correctly. If this was done and the calculation still reports this problem, a compensation is applied as follows.
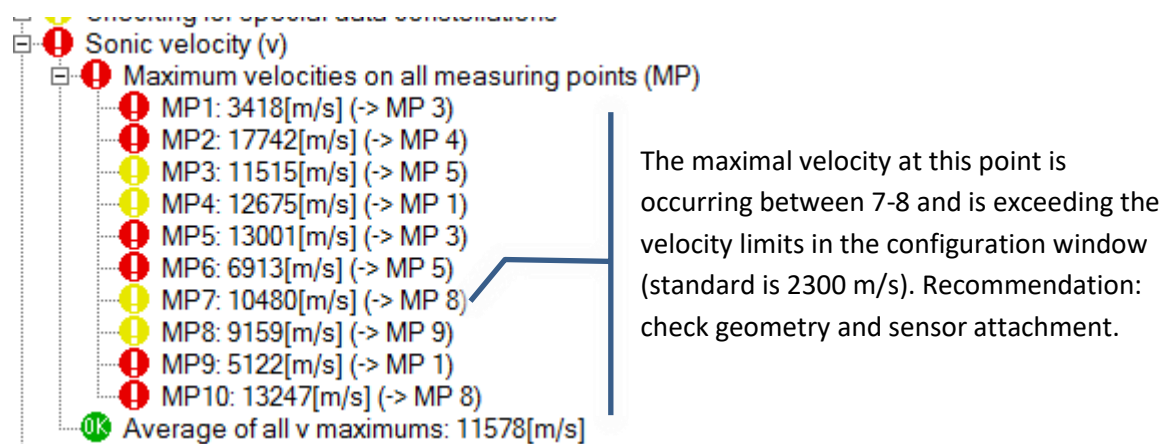
Instead of using the fastest local velocity, the average of all fastest velocities is used for the 100% reference at this point.

The result of the check and the velocity "substitution" is shown in the information part of the window.

The maximal velocity at this point is occurring between 6-7 (7-6) and is higher than the average. Recommendation: check geometry and sensor attachment.

The maximal velocity at this point is below the average. Check the nail: deep enough?

The median maximal velocity of this scan is 1153 m/s
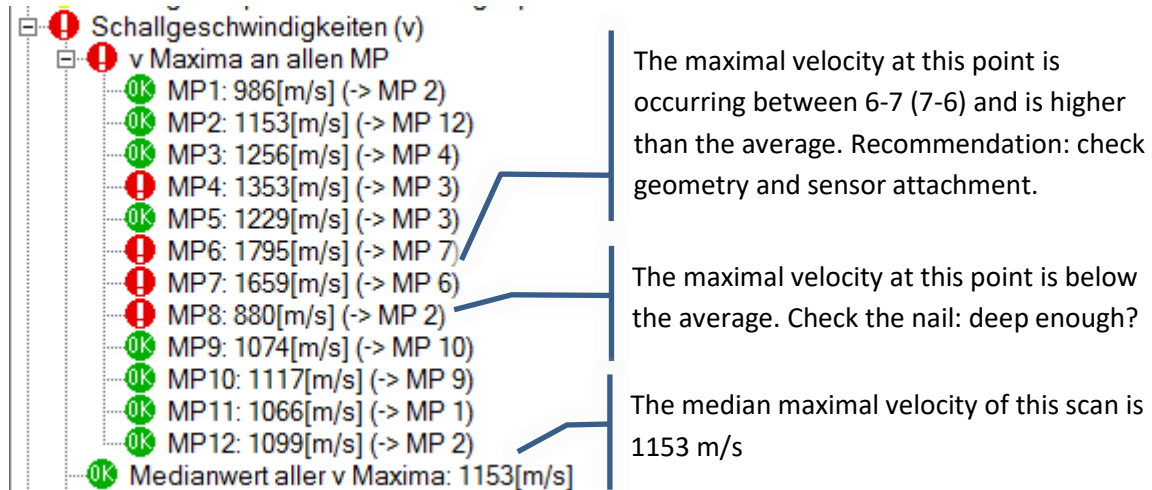
In the following example all the velocities exceed the settings in the data checking tab of the configuration window.

The maximal velocity at this point is occurring between 7-8 and is exceeding the velocity limits in the configuration window (standard is 2300 m/s). Recommendation: check geometry and sensor attachment.

The following example shows a linden tree several years after a car created impact damage to the trunk. The left tomogram was created without any maximum velocity supervision, the right tomogram with it:
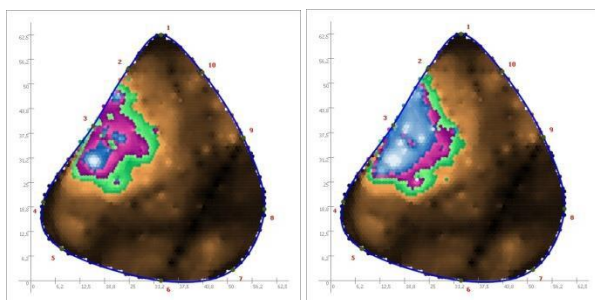
Sensor number 3 was placed in the damaged wood.

The maximal velocity supervision can be configured on the calculation settings.

Main menu → "configuration" → „settings" at tab "Calculation 2"

6.9.3   Options – Toggle tomogram version

This switch can be used to toggle between tomogram version "SoT 1" (formerly named "calcB2000") and "SoT 2" (formerly named "calcB2007").

In particular for non-central defects the SoT 1 method tends to show artefacts caused be incorrect calculation of the intersection of the bee-lines between MPs. The tomogram version "SoT 2" widely ignores those incorrect intersections.

The tomogram version "SoT 2" should be used at trees with:

- Cracks, in particular cracks that divide the tree into halves.

- Co-dominant trees when scanned and calculated at once.

- Off-centre defects

"SoT 2" should <u>not</u> be used at trees that have

- Kretschmaria deusta infections

- Early infections of any fungi

The example shows the improvement of the tomogram at an oak that is split.

Incorrect intersections have been removed

SoT 1   SoT 2
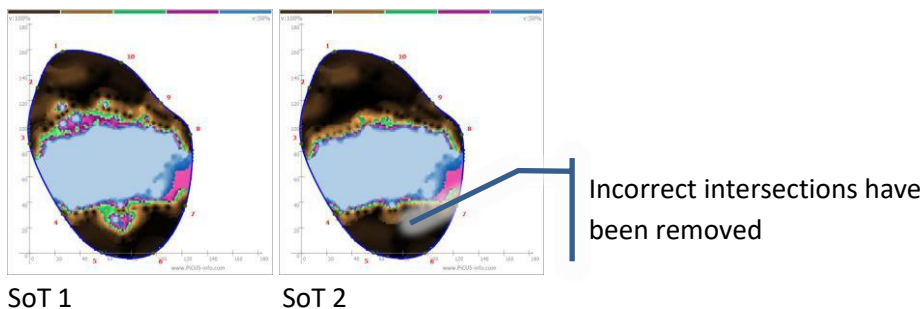
6.9.4   Options – PiCUS Crack detection "CrackDect"

The manifold nature of living trees can lead to misinterpretations of the data in tomogram calculations. Radial cracks are one cause of faulty interpretations because they can create tomograms which do not reflect the true composition of the wood. Cracks present severe barriers for sonic waves. There are two main types of cracks:

- "Star-shaped cracks" – emanate from the centre to the outer fibres

- "Ring cracks" - run parallel to the tree's circumference
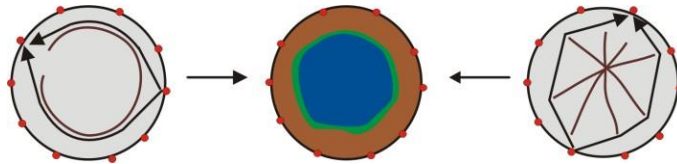
Both types of cracks can lead to erroneous tomograms. The function PiCUS CrackDect analyses the sonic data and searches for small but severe radial sonic barriers. The CrackDect function is always active as a standard function. To de-activate (or re-activate) it, click the icon in the icon bar.

Show/hide acoustic barriers

The sensitivity of the CrackDect function can be adjusted with the slider at the options tab.

Radial cracks – that means running from the centre towards the edge – are typical sonic barriers. The PiCUS software tries to calculate the positions of those cracks and shows it by drawing yellow lines.
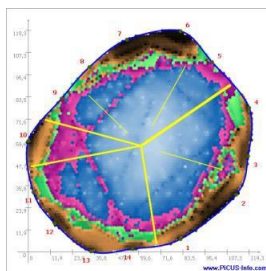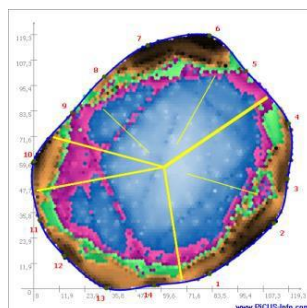

The example of a London plane tree[3] shows a plane tree with large cracks reaching to the edge of the cross section of the tree. The cracks, together with the rotting sections, would significantly affect sonic measurements.

The thickness of the lines shows the intensity of the crack-data constellation. Use the slider on the "options" card to the right of the tomogram next to change the sensitivity of the CrackDect function.
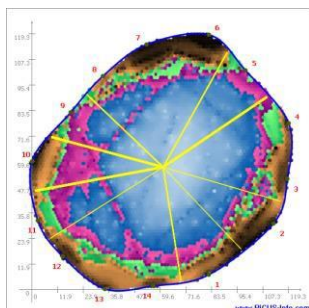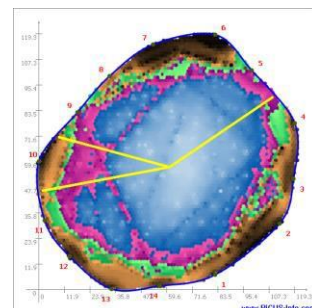

Slider setting: very sensitive   normal   less sensitive

---

[3] Data provided by: the city of Strasbourg, France

The yellow line can also indicate errors of the operator while tapping. In the next example sensors 7, 10, 14 and 17 have not been correctly attached to the wood, likely because of incorrectly installed nails. Or the sensors have not been put on the nails correctly.

When checking the measuring window we see that some sensors permanently have low readings. That does not seem to fit to the rest of the data. The tomogram can be improved by turning those sensors off as receivers (see chapter „MP activation".
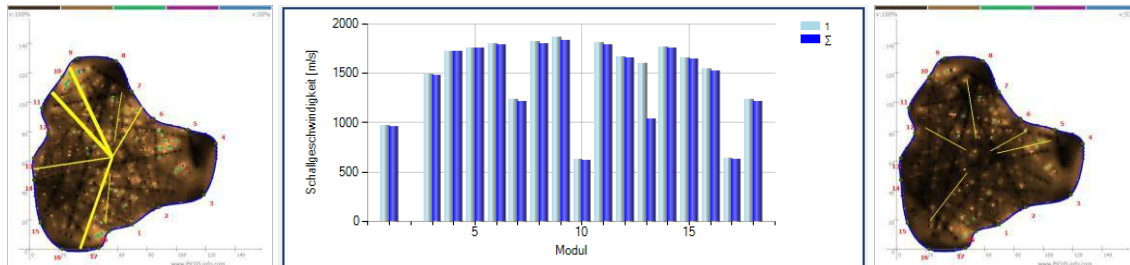

SoT 1   Bar graph in measuring window   SoT with disabled MP

Hints

- The CrackDect function requires data from all MP – use sensors on all available MP to achieve a full set of accurate readings.
- The more cracks there are in a section, the more difficult it is to determine their locations.
- Cracks that lie close to the edge of a section are easier to detect than small cracks in the centre. The position of cracks is assumed to be between two MP.
- The position of the crack cannot be calculated accurately if yellow lines are shown on both sides of a MP. It is likely that only one crack is located in this area.
- Severe defects between two MPs can also be shown by a yellow line.
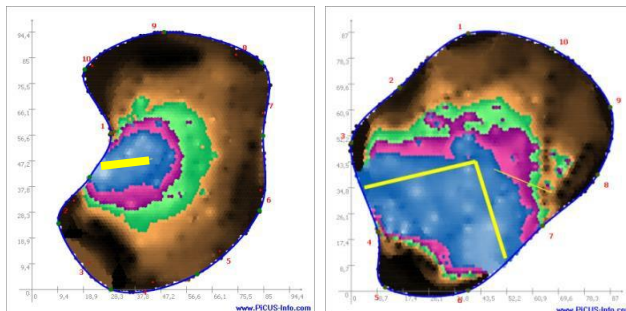
The tomograms above shows two examples of trees with decay. In both cases the decay is reaching to the edge of the trunk so that the sonic waves cannot travel in that part. That causes a huge drop of velocity in-between both points and consequently a yellow line is shown.

6.9.5   Table of sonic velocity

The tab-page "Sonic velocity" shows the absolute times of every measurement and the velocity that is used for the calculation (the average). When the "v" (velocity) background colour is green, the average velocity is shown.

At every path between two measuring points there can exist two velocity values: at the pathway MP 2 – MP 7 there is the value of the measurement from MP 2 to MP 7 and the opposite direction: from MP 7 to

MP 2. The y-column is giving the starting point of the measurement ("from" point) . The x-axis is the receiver ("to" MP).

Connections showing large variations of the sonic velocity are marked in red.

Velocity MP 1 -> 7 = 597m/s
Velocity MP 7 –> 1 = 337 m/s
Deviation is larger than 20% -> red marker

Display of the maximal and minimal velocities of every tap. When the field is green then the data is shown that is used for the calculation.

Exporting the velocity table

Right-click on the table and select a function from the menu. The data of the table can be copied to the windows clipboard to paste it directly into other applications or to a text file (extension *.txt).

This function is available in the expert version only.

6.9.6   Tab MP used and Coordinates of MP

In some cases it might be necessary to exclude sonic data from certain MP from the calculations. The positions of all the MPs is given in columns X and Y. Right click offers to copy the coordinates into the Windows clipboard.

X/Y coordinates of the MPs in [mm]

Right click to copy the table into the windows clipboard

The tab "MP used" controls the usage of the "transmit" and "receive" data at each MP.

Remove the check at "Receiver" to ignore all data that was underline received on this MP. This might be useful if a nail did not have good contact to wood or the sensor was not sitting on the nail correctly.

Remove the check at "Transmitter" to ignore the data collected when underline tapping on this MP.

Remove both checks: Most often used for partial calculation of the tomogram. In particular for co-dominant stems, segmented trees or trees with bolting's it can be useful to calculate parts of the trunk separately. If both checks are removed, the MP will not be used at all, and even the geometry data will be ignored.
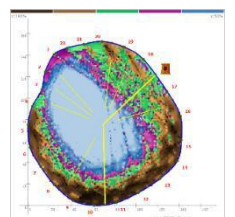
The Example[4] shows an oak with iron bolting. The tomogram cannot be calculated at once (to the right) because the steel bolts influenced the scan.
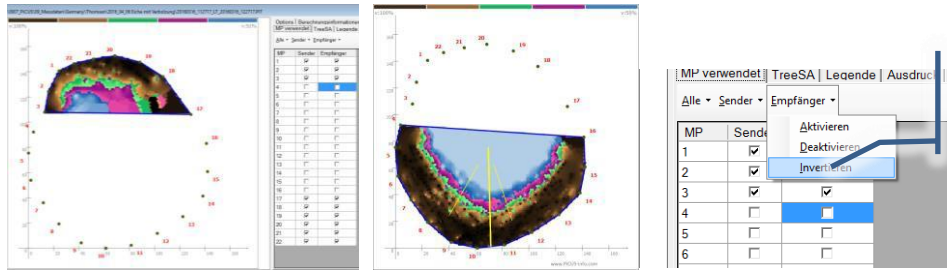
Fast changes possible due to „Invert function".

[4] Data provided by: Baumpflege Uwe Thomsen e.K., Wedeler Weg 178, 25421 Pinneberg

6.9.7 TreeSA

"TreeSA" means "Tree Stability Assessment". These TreeSA calculations are based on the publications by Dr. Wessolly, Günther Sinn and Martin Erb in the book "Handbuch der Baumstatik" (published by Patzerverlag). Because the shape and number of crowns to work with have been expanded in the TreeSA program, there are some minimal differences to the SIA method of Dr. Wessolly.

Both the SIA and TreeSA methods attempt to estimate the minimal residual wall thickness needed to prevent the tree trunk from breaking. The methods incorporate the tree species, tree size, wind load, and the environmental conditions.

The values calculated apply for the cross section of primarily round trees 100 cm above ground level. The closer the measuring level to this height, the more accurate the results are.
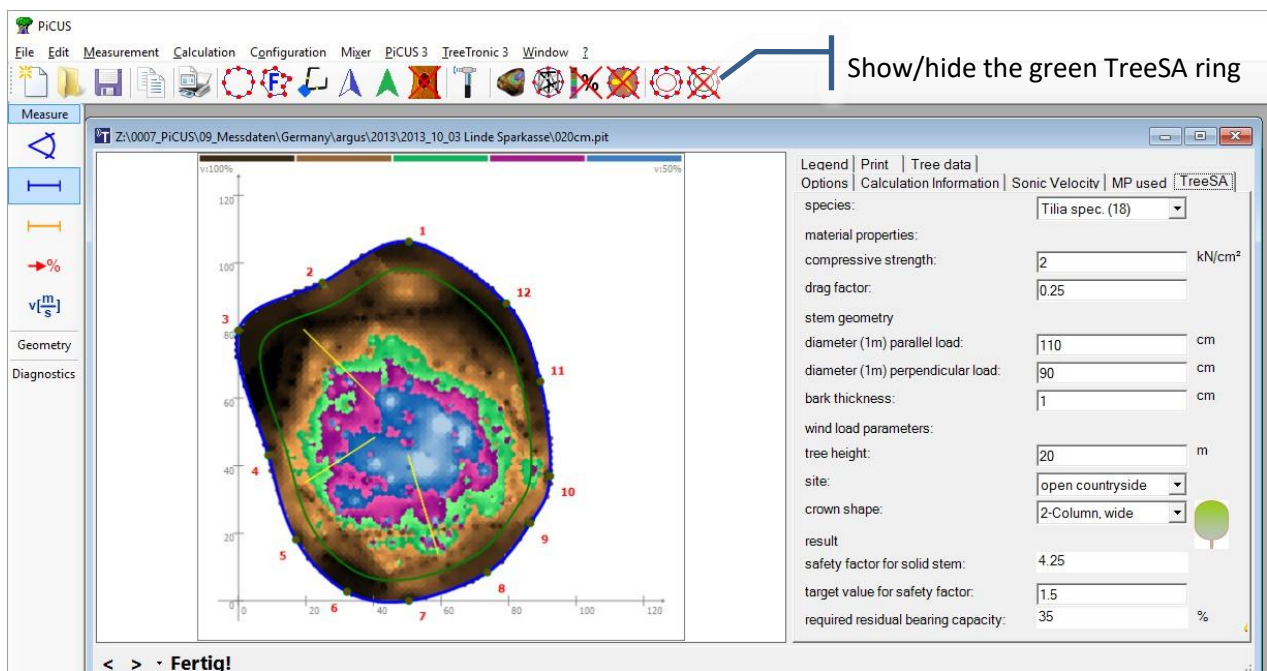
Procedure:

Enter the values for tree species, tree height, etc.

Results:

"Safety factor for solid stem":   "The basic safety of a tree can be calculated if a tree is evaluated statically, not considering its defects. Three factors are most important for the basic safety: (wind) load, (crown) shape and (wood) material." [5] A basic safety of "1" (or 100%) means that the tree trunk can theoretically break at storm-wind speed. A safety factor of 1.5 (150%) is recommended for a tree to be considered to be safe in storm winds. The basic safety is calculated from the values entered.

"Target value for safety factor":   Enter the recommended safety values: 1.5 to 2.0.

---

[5] Translation from "Handbuch der Baumstatik" by Wessolly and Erb, (Patzerverlag).

"Required residual bearing capacity": The bearing capacity of the trunk can be reduced by that value in relation to the non-damaged trunk. In other words:

The bending strength of the trunk must be like this or higher (in relation to the non-damaged trunk) in order to meet the safety factor chosen.

The maximum size of a possible cavity that coincides with the remaining stability calculated is shown by a green line. When no line is shown the data entered the calculation based on the data entered cannot find a solution.

The result will not show residual walls thinner than 5 cm even if it would be theoretically – according to the pure math - possible: a real tree in a real environment exposed to wind and weather having a remaining wall of – say – 1 cm is not save.

For more accurate calculations please refer to the next chapter "TreeCalc.com".

6.9.8   Treedata – TreeCalc

The tree data entered are shown on this tab. Furthermore it is possible to transfer these data to the webservice at www.treecalc.com for more accurate stem breaking calculations. An internet connection is required.

The web site performs tree static safety calculations using the latest technical standards. The tomogram can be rated according to a wind speed that can be chosen by the operator. The service also give pruning recommendations if needed.
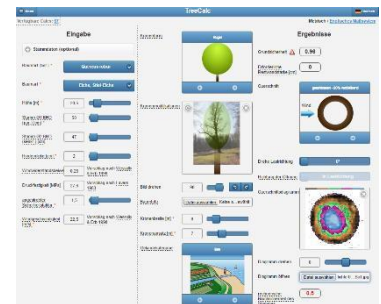
The service operates on a pay-per-calculation basis.

6.9.9   Legend

The tab legend offers to copy the tomogram legend into the windows clip board. So that it can be used in other documents.

6.9.10 Tab Print

Two photos for the print function can be selected here. Both photos will appear in the report printed using the programs print function.

6.10 Calculation options

Calculation options can be adjusted in the "Settings" window that is opened by clicking:

Main menu → "Configuration" → „Settings"

This chapter describes all the parameter of the settings window.

Some options of the calculation can be altered in the *settings* window.

In order to change the calculation options for **a single file** proceed as follows:

1. Open the PiCUS data file (*.pit).
2. Click on the new window to select it.
3. Click on "Configuration" → "Settings" to open the "Settings" window.
4. Select options. Close the "Settings" window with "OK".
5. Run the calculation.

The changes made in the setting window DO NOT affect other files. A data file can be opened several times, so it is thus possible to apply different options to the same data file.

In order to change calculation options for **all files** proceed as follows:

1. Close ALL data files.
2. Click "Configuration" → Settings" to open the "Settings" window.
3. Select options. Close the "Settings" window with "OK".
4. Open the PiCUS data file(s)
5. Run the calculation(s).

The calculation options will affect all files opened AFTER the changes were made. When you end the PiCUS program, the majority of these changes are automatically set back to the standard parameters.

6.10.1 Tab "General"

- Set residual wall reference value

  "t/R" positions a red line, parallel to the circumference, that is shown when this button is pressed. The value of "0.3" shows the red line at 1/3 of the radius

- Set standard height of tree diameter reading

  "Measure circumference at.." determines the height at which the tree's diameter was measured for inventory purposes. (Note: this is NOT the height of the measuring level.)

- Configuration of the legend

  By setting the checks the user can determine what values are displayed in the window.

- Activate voice messages

  Turn ON/OFF voice messages of the sonic scan window.

- Save calculated data

  This option determines whether the "*.pit" file contains the sound-data only (file size 10-20 kB) or if both the sound-data AND the calculated tomogram (file size 200-300kB) should be saved.

6.10.2 Tab "Owner"

Here you can enter your own data as owner/operator of a PiCUS unit. The checkbox specifies whether the information is to be printed or not.

6.10.3 Tab "Data checking"

The Expert version of the program provides access to some of the data checking algorithms. They can be accessed at this tab. All settings of this window only take effect in the active PiCUS ".pit" window.

Hint: the expert version allows to open multiple files. One file can be opened several times to see the impact of different calculation options.

- Absolute value check

  When active very low or high readings will be ignored.

- Correlation check

  Testing for similarity of readings at one measuring point: when tapping at the same point all readings must give very similar values.

- Velocity limits (new in Q74)

  Standard setting Maximum: **2300 m/s**

  Standard setting Minimum: **400 m/s**

  Limits of the velocity used can be set here. This option helps to ignore erroneous readings caused by incorrect operation. Velocities of in wood of more than 2000 m/s have not yet been recorded. In the tapping window the incorrect values will be marked according to the settings in this section. Red markers indicate values exceeding the maximal velocity. Yellow markers show values lower than the minimum.
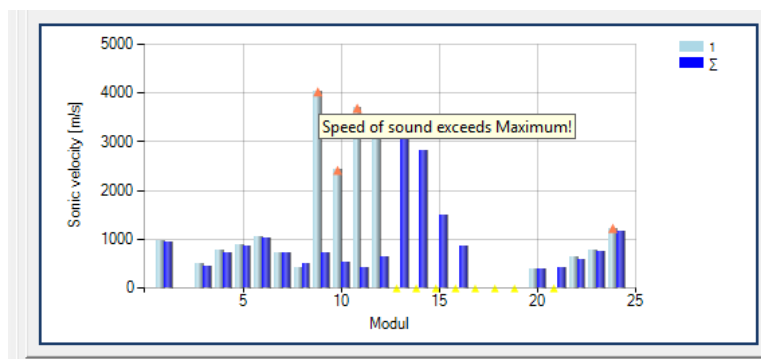
Using this option may help to uses files containing allot of incorrect readings without the need of re-doing the test or deleting false readings by hand.

Recommended procedure:

1. Determine the likely maximal velocities by using the absolute velocity bar graph of the tapping window. Go to every MP and try to identify a value that is likely to be correct. The following screen shots show the velocity bar graphs at 4 different MPs.
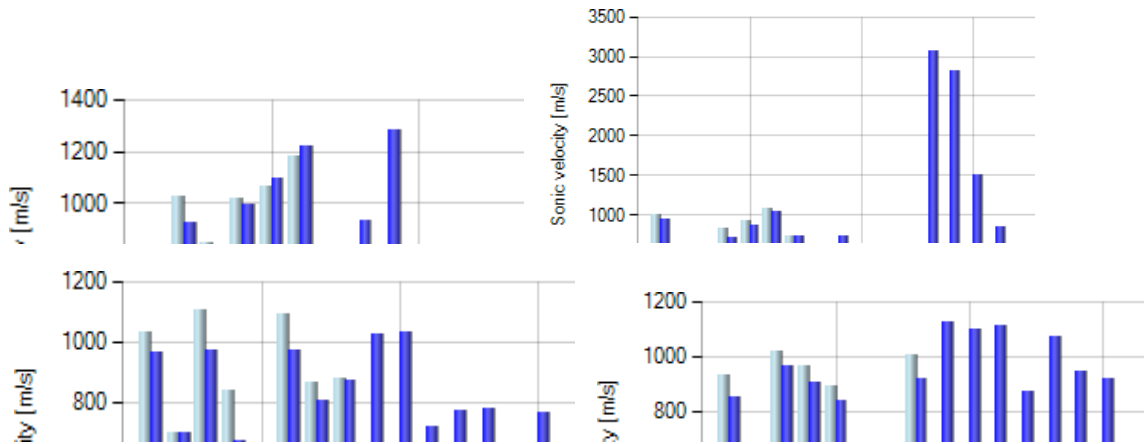
In this example the maximal velocity of correct readings is around 1100-1200 m/s.

2. Enter the value of 1200 m/s in the "maximal velocity" text box and close the config window with OK.

☑ Velocity limits

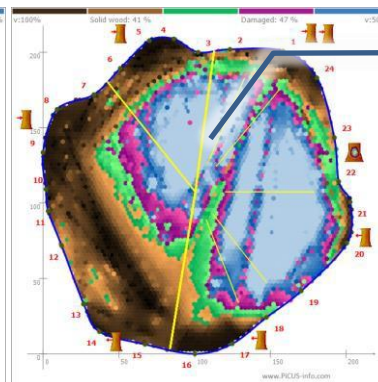| 300 | minimum velocity [m/s] | 1200 | maximum velocity [m/s |
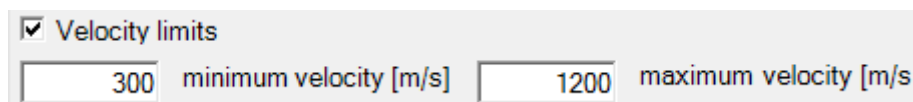
3. Re-calculate the tomogram.

The result should show the new tomogram in which the values exceeding the limit have been removed.

Incorrect readings disturb the tomogram
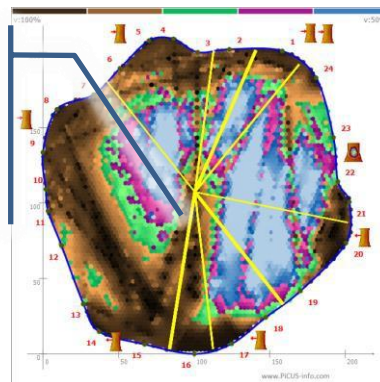
Most of the too fast velocities have been ignored.

Max velocity =3000 m/s   Max. Velocity = 1200 m/s

- Improve contrast (new in Q74)

Standard setting: **activated**

This option helps to mitigate the effects of naturally occurring variations of the wood quality such as reaction wood versus "normal" wood. The option often leads to more precise colours. The outcome of this option is not visible in every tomogram.

The example below shows a tomogram with no defect. At the left side of the, right at the dark brown area, a branch was attached. The dark colours in that area indicate higher acoustic velocities and, thus, a higher MOE of the material. The "normal" wood at the right side is not as hard and therefore the

velocity is slower and the colour is a light brown. The "improve contrast" option reduces the effect of those naturally occurring variations of MOE that we normally do not want to see.

Hint: Turn off this option to see the raw data file.
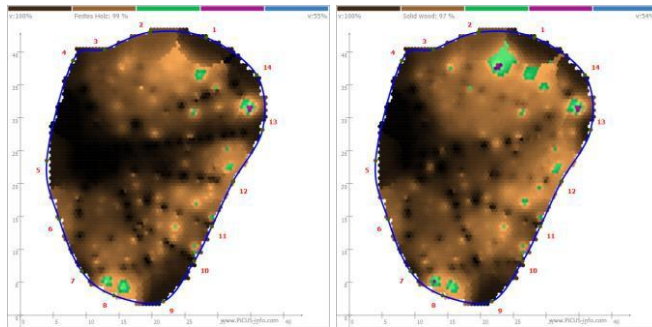
Tomogram <u>with</u> and   <u>without</u> "improve contrast" option

6.10.4 Tab "Calculation 1"

- Resolution of the tomogram

  Standard setting: **100**

  sets the number of pixels in the tomograms. The standard is 100 but some screens require 120 to show the tomogram correctly.

- Smooth tree shape

  Connects the measuring points using a smooth line to show the outline more naturally.
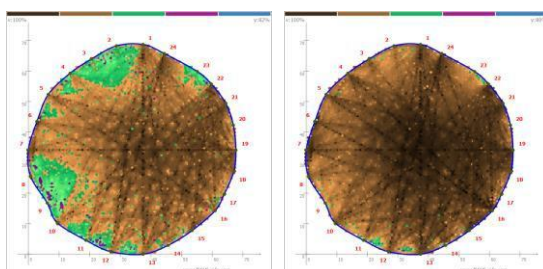
- Set minimal colour space

  Standard setting: **activated**

  Determines the minimal velocity range across which the colour scale is spread. The scale ranges from the slowest velocities (light blues) to the highest velocities (100% = browns). In rare cases – usually in sound trees – these two velocity boundaries are close together. The option sets the minimal velocity range to make sure that the tomogram is not too sensitive. Especially in healthy trees, this results in more comprehensive tomograms. The bar graph to the right shows a case of very similar reading at all MP. Consequently the lowest

  velocity would be assigned to 90% and the tomogam would be very "noisy".
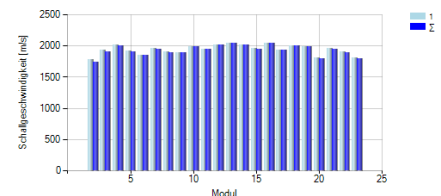
The left tomogram was calcualted usign the origional colour space of 82 – 100%. Small variations of the velocity are shown very clearly because of the small colour space. The tomogram to the right was calcualted with minimal colour space activated and the option "improve contrast".

.

„Raw"-Tomogram   Tomogram in Q74

- Set maximal colour space

  Standard setting: **activated**

  The colour space is automatically stretched between slowest and fastest velocities like explained before.

  In case there are large variations of velocities in the file (for instance at trees with open cavities defects) damaged parts of the trunk can be shown in greens or even light brown colours.

  The example shows a beech tree with an open cavity. The damage reaches approximately 50 cm into the trunk. The left tomogram was calculated using the full colour space: the damage (colours blue, purple and green) is pictured a little too small. However, the light brown colours do indicate a loss of velocity and therefore the defect. The right tomogram was calculated by limiting the colour space to 50% maximal extension. The defect is shown more precisely.

  Colour space not limited: 23-100%   Colour space limited: 50-100%

  The „maximal colours space" limit might be turned off at trees with very large defects. Some tomograms might look more complaisant when the colours are distributed over the full range of velocities.
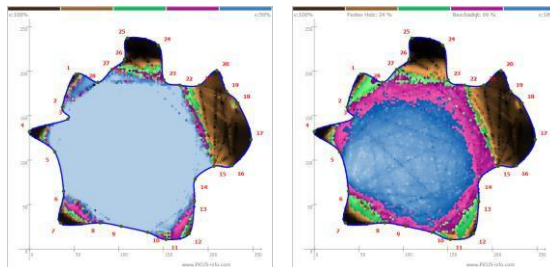
  Colours space: limited   full range used

- Offsets

  Standard setting: **0**

  "Offset" can be used in those rare cases (special tree species, old measuring hardware) where it might be useful to add or subtract a value from the data measured. Using this option requires expert knowledge and is usually unnecessary.

- Zero value correction (new in Q74)

  Standard setting: **off**

  Tomograms recorded at tree with extensive damages do often have bad acoustic wave propagation and the data file can contain many zero readings. Those missing values can lead to incorrect tomograms. The example shows the scan of an oak with an open cavity in-between MP 1-2. The "old" calculation misleadingly determines brown colours in-between MP 1 and 2 because of missing lines in

that area. No lines mean no intersections of theoretical travel pathways. And since intersections are needed to calculate finally the velocities the tomogram gets incorrect in that part.
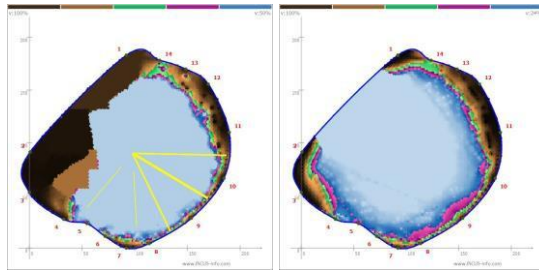

Q73 tomogram   Q74 tomogram using zero value correction.

- Blind   area

Standard setting: **0**

In some rare instances, the cog wheel data constellation will hide smaller defects in the centre of the tree. In situations like this, it can help to exclude the neighbouring sensors from a tapping point when running the calculations, as these are the MP that cause the cog wheel.

The tomogram on the left was calculated using the standard settings. The tomogram shows a cog wheel, but the light brown centre of the tree is not typical for a cog wheel data constellation in healthy trees.
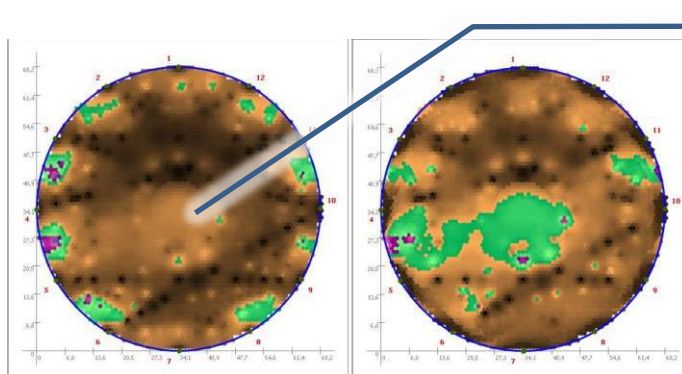
Centre of the tree does not have the highest velocities.

Normal calculation   Blind area = 2

The tomogram on the right was calculated without the two neighbouring sensors on either side of the tapping point.

Example 2[6]:

The bar graph in the tapping window show the same situation: the neighbours of the tapping point have slower velocities than the "shadow" of the defect at the other side of the tree.

---

[6] Data provided by Lesy hl.m. Prahy, Czech Republic

The reduction of the velocity caused by the defect in the centre.

Slow sonic speed to the neighbours.
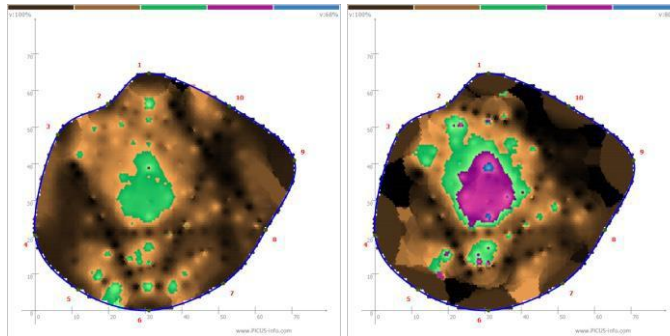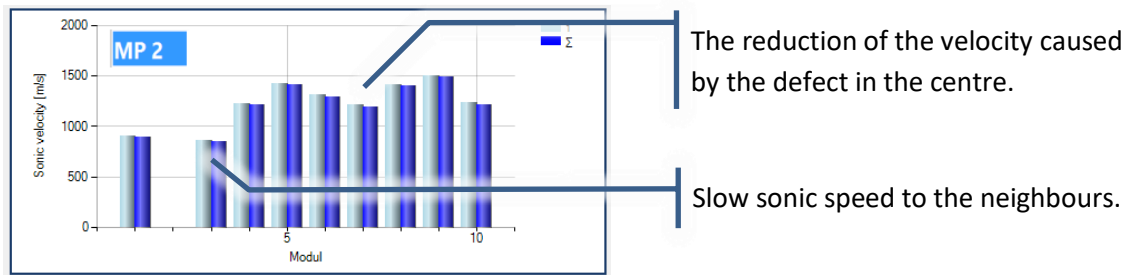
Normal calculation   Blind area = 2

The "blind" parameter can be set to "1" or "2". Larger values will result in inaccurate border areas.

6.10.5 Tab "Calculation 2"

- Maximal velocity supervision

Like discussed before this function monitors the maximal velocities that occur at every point. Measuring points should be normally placed at locations that have direct links through good wood to at least one other measuring point. That is not always possible, in particular at trees with large defects on the surface. If velocities recorded on a specific measuring point do not keep up with roughly the average of all the other points then the nail has no good contact to the wood or the location of that MP is isolated from the rest of the trunk. In case the nails is correctly installed the supervision function applies some compensation methods

In the example[7] below MP 7 and 8 have been placed in decay. From those points there is no link through sound wood to any other point. Consequently the local maximal velocity does not represent the 100% sound wood reference and needs to be replaced.
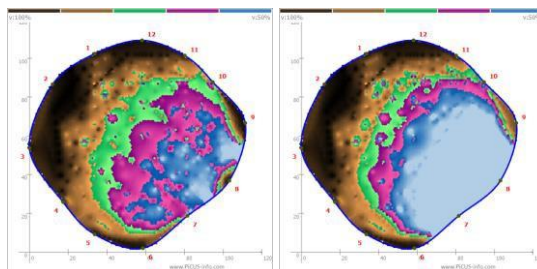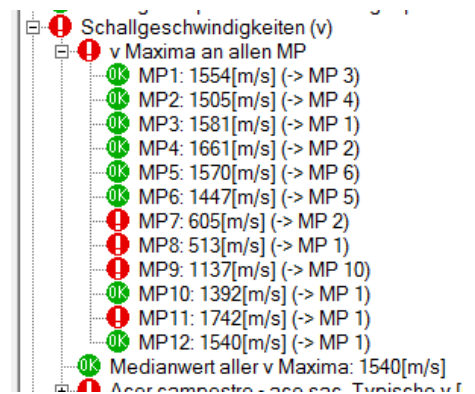
Without -   with maximal velocity supervision

---

[7] Data provided by John Harraway, UK

6.10.6 Tab "Cog wheel"

The technical and wood related background of this function has been discussed before. At this tab the cog wheel compensation can be activated in order to make the tomogram easier to explain to clients.

If the PC program identifies a cog wheel constellation, the colour scale of the tomogram is shifted to hide this effect if the cog wheel compensation is active.

Select the option "DETECT…. and APPLY"…" to activate and re-run the calculation. The following tomograms show the result when the cog wheel compensation is on and off.
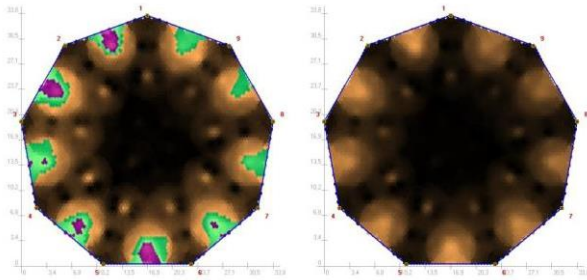
Compensation OFF   Compensation ON

6.11 Criteria for tomogram interpretation

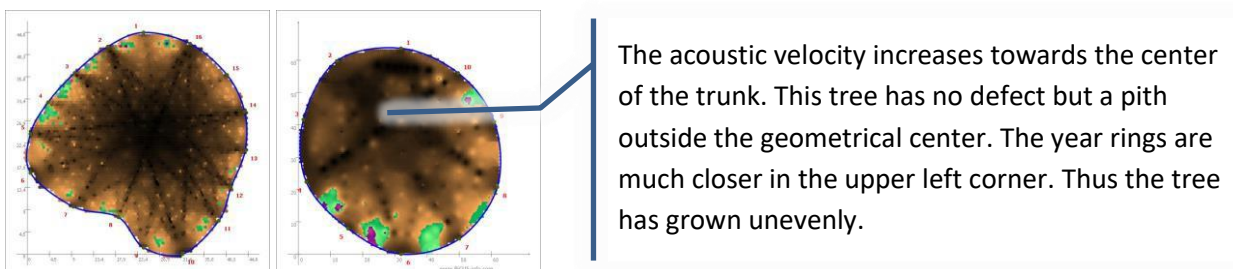When analysing tomograms the following questions should be answered.

- Where are the highest velocities?

- Where are fast and slow velocities and are they closed to each other?

- Is there a typical pattern of colours?

- Watch legend: which variation in velocities do occur?

- Analyse calculation information (data checking, absolute velocities)

- Should a compensation algorithm be applies (cog wheel)?

- How is the density of lines in the line-graph (formerly calculation C)?

- Are there any crack warnings? (CrackDect Funktion)

- Do we need to turn off sensors or add more measuring points?

6.11.1 Velocity distribution – where are the highest velocities?

Since virtually all of tree species we are usually working with belong to SoT type 1 (radial velocity is higher than tangential) the centre of a sound trunk does have the highest velocities shown in dark brown colours.

Tomograms of defect free trees may look like this:

The acoustic velocity increases towards the center of the trunk. This tree has no defect but a pith outside the geometrical center. The year rings are much closer in the upper left corner. Thus the tree has grown unevenly.

In contrast to this, trees that do not have highest velocities in their centre, do have a defect!

Example:

Beech[8] with early defect, likely Kretschmaria.

The center of the tree does not have the highest velocities.
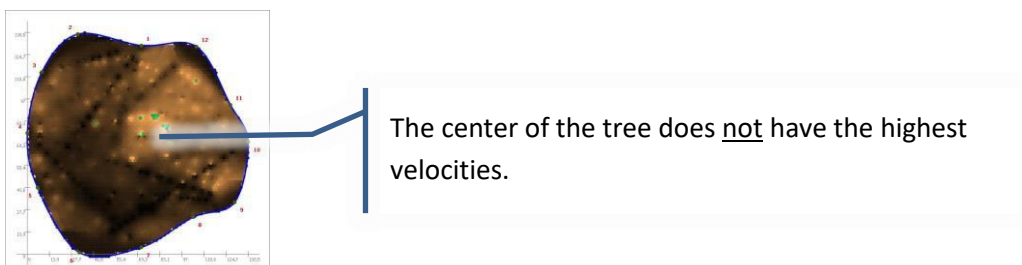
Beech[9] with Kretschmaria:

---

[8] Data provided by : Christian Knaus, Germany
[9] Dat provided by: Aernout Theunissen, BoomOntzorging, The Netherlands
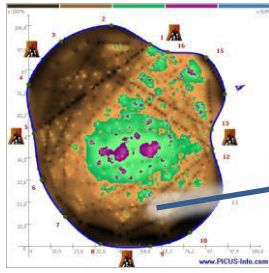
Sonic velocity decreases towards the centre. The small dark brown ring only represents sound wood.

6.11.2 Where are fast and slow velocities and are they closed to each other?

In case the distance between browns (= fast) and purple (= slow) areas are close to each other – this means the green area is small – the reaction zone between defect and wood seems to work well. An example is given in the left tomogram[10]: the abrupt change from slow to high is an indication for a well encapsulated defect.
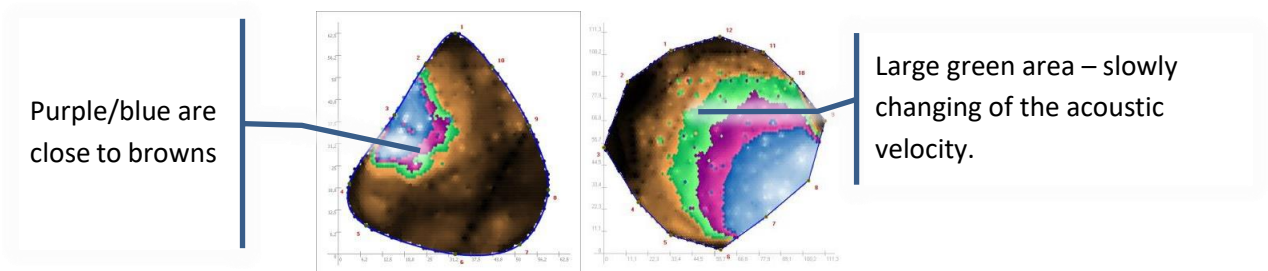
Purple/blue are close to browns

Large green area – slowly changing of the acoustic velocity.

The tomogram[11] to the right is the opposite example: the apparently damaged area is not clearly separated from the good wood. This is typical for fungi infections. The example shows an acer with *ganoderma* infection at different stages.

6.11.3 Is there a typical pattern of colours

At some tree species certain types of defects create specific colour patterns in the tomogram. An example is given by *kretschmaria deusta* infections in beech trees.

Differently to cavities the acoustic velocity does not raise and decrease constantly from one side to the other side of the cross section.

The example shows a typical *kretschmaria deusta* infection on a beech tree. The ERT is on the right.

Typical *kretschmaria deusta* Tomogramm of a beech
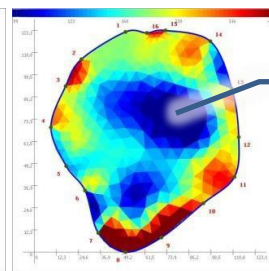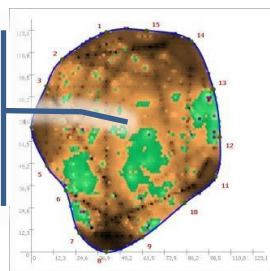
The blue colour in the ERT clearly shows the infection.

SoT   ERT

---

[10] PiCUS data provided by Dr. Hendrik Weiß, Germany
[11] PiCUS data provided by: John Harraway, Great Britain

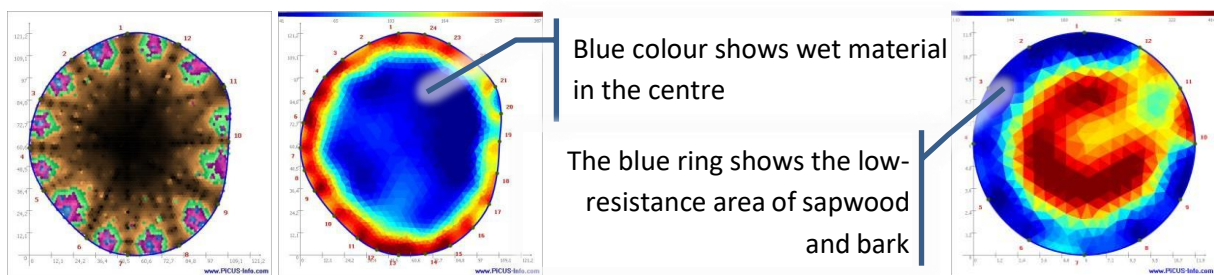The SoT shows a brown / green patterned area in the trunk centre. Because of that pattern it very likely the defect is <u>no</u> hollow and <u>no</u> crack. This defect is fungi infection. The size of the infection can be estimated by encircling the brown/green patterned are. Almost all the cross section is infected.

6.11.4 Wet wood

"Wet wood" appears in the tomogram in blues and purples, the "slow" colours, depending on the age and extent of the damage. This example shows the SoT and ERT of a *populus* tree with early stages of wet wood.

The SoT (on the left) does NOT show any defects. Thus, the mechanical properties of the wood are still good. The ERT in the middle shows the high electric conductivity of the wood in the centre of the tree. The conductivity is even higher than in the bark/sapwood.

The ERT on the right shows a healthy populus tree with no wet wood: The blue ring on the outside shows bark and sapwood.

Blue colour shows wet material in the centre

The blue ring shows the low-resistance area of sapwood and bark

Populus with early wet-wood: SoT, ERT   ERT of sound populus

This photograph of the early-wet-wood populus tree after it was cut down shows brown wood. The brown area was dripping wet.

### 6.11.5 Defect-reconstruction at reaction wood

Reaction wood on old wounds has significantly better acoustic properties because of a high MOE than "normal" wood on a defect-free trunk.

Sonic scans at those areas show often very dark colours indicating high velocities. It may happen that these very good areas cover/hide smaller defect nearby: the wave simply travel through the very stiff reaction wood outside of the measuring level.

When defects are shown too small in such a situation it means the following:

- The defect is surrounded by very good wood, also in vertical direction. That means the tree is strongly working on compensating and demarcating the defect.

- The defect does usually not go far into the tree. Otherwise the central beams of the sonic scan would pick it up.

The example shows a beech tree with a man-made opening. The opening is just above MP1-2. The hollow is not visible in the tomogram.
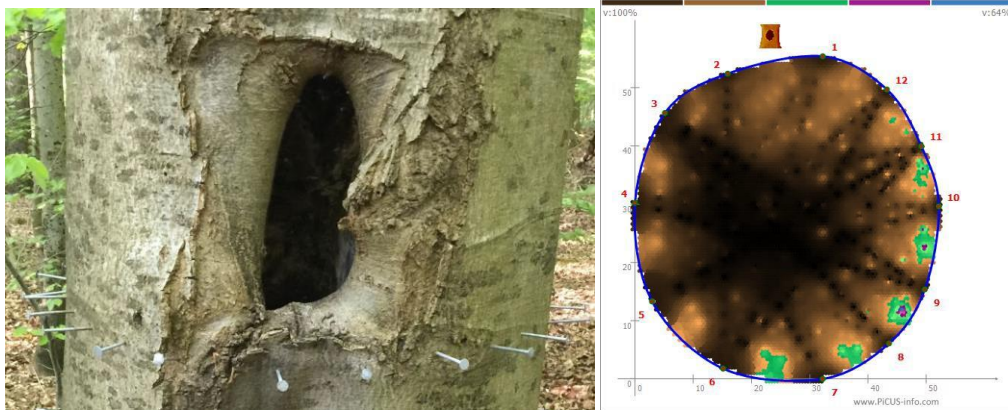
6.12 3D presentation of tomograms

One or more SoT or TreeTronic tomograms can be displayed in 3D views.

Q74 also offers the option to merge the perspective tomograms into photos of the tree.

The photo should be taken from above like shown in the sketch in order to have a better view on the actual test result. Otherwise the tomogram must be tilted and details are not as good visible.
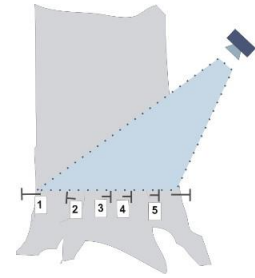
The ERT tomogram (left) and SoT (Right) are easy to see because the photo was taken from a higher position.
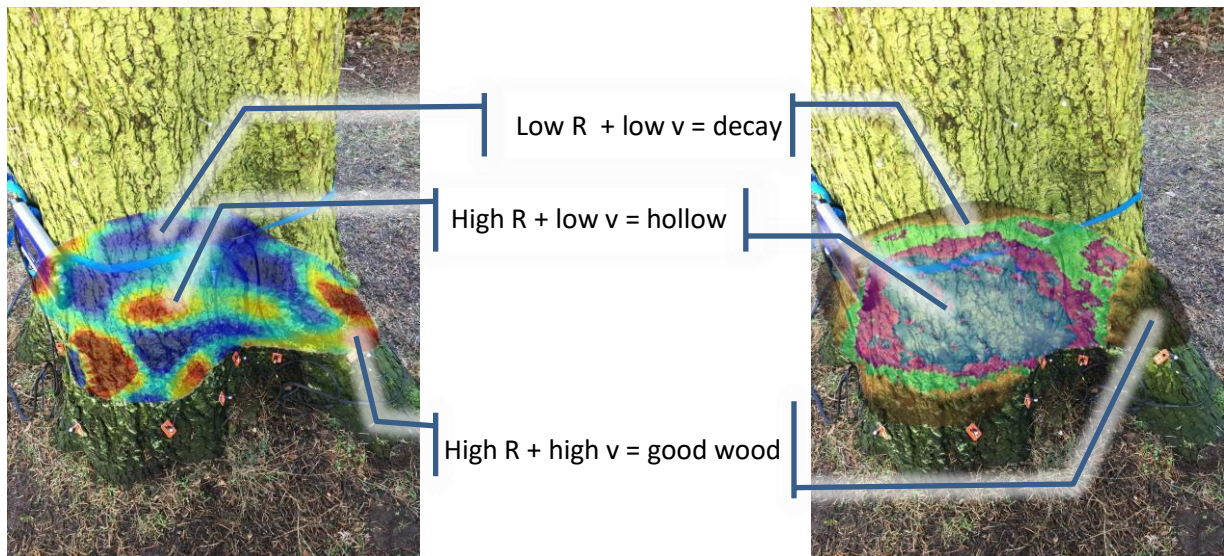
Tomograms and Photo of an *Abis grandis* tree with cavity and decay.

Procedure

1. *Main menu → "File" → „New" or use the new icon to start the wizard*.
2. Select sonic tomogram SoT (or ERT) and check „3D view".
3. 3D window will open.
4. Click „+" to add at least one file.
5. Optional: Click „load left picture" in order to load a photo in which the tomogram shall be merged.
6. Click the „Tomogram" icon to re-calculate the tomogram.
7. Click the „3D" icon to start the 3D view in the 3D window.
8. When only one file is used the 3D window may appear empty. This is because the camera position is exactly at the tomogram level. To change the camera angle hit the "k" key. More camera option are given help window – hit "F1".

The twisting tomogram can be moved around and transferred into the photo using the „← ↑ → ↓" keys. Let the computer work for a second before you hit a key again.

Options

These options are available in the active 3D window. Hit F1 to see the min an extra window.

g/t	- Distance camera tomogram
i, k	- Change vertical angle of the camera
q	- Rotate the tomogram horizontally by 90°
← ↑ → ↓	- Shift position of the tomogram (camera)
p	- Copy current graphic into the right site of the 3D main window (in the back).

s   - Stop/start rotation of the tomogram

a   - save the rotation as animated Gif

Hint: In case the tomogram requires special calculation options then these settings can be done like normal in the settings window. Select the file in the list before by left-clicking. Re-run the calculation.

Meaning of the icons in the 3D window

Left menu

1. Add files to the list

2. Remove files from the list

3. Calculate tomogram(se)

4. Load photo of the tree in which the tomogram is to be merged.

5. Start 3D Graphic. (Terminate 3D calculation with ESC-key)

6. Switch between Photo – Tomogram at the left side. Is available after a photo was loaded.

7. Save left image.

8. Change transparency of the tomogram laying over the photo. Available after running the 3D function.

9. Re-size (larger – smaller) the merged tomogram. Is available after the 3D window was closed.

Transparency level: 0%   50%   70%

Right menu

1. Toggle between cut-view and 3D view of the tomograms. Hit "p" before to copy the 3D vies as an image into the right side of the window..

2. Save image on the right as *jpg.

3. Select a rectangular selection in the right image.

4. Transfer the right image, or the selected part of it, into the photo on the left side.

6.13 Time lines

The time-line functions helps to display the development of a defect in the tree over the cause of the years when tomograms have been recorded on a regular basis.

The underlying idea is to apply the same colour scale to all the tomograms recorded.

The calculation can be performed in both directions: "old" towards "new" and "new" towards "old".

Which means that the colour scale of the oldest scan is applied to all other tomograms or the other way around.

Procedure

1. *Main menu → "File" → „New"* or hit the new icon to start the wizard.
2. Select SoT (or ERT) set check at „Timeline".
3. Timeline window will open.
4. Add at least two files using the "+" key. Same tree recorded at different dates.
5. Enlarge window eventually to see all files. Get a 34" monitor in case the screen is too small.
6. Click „Calculate"
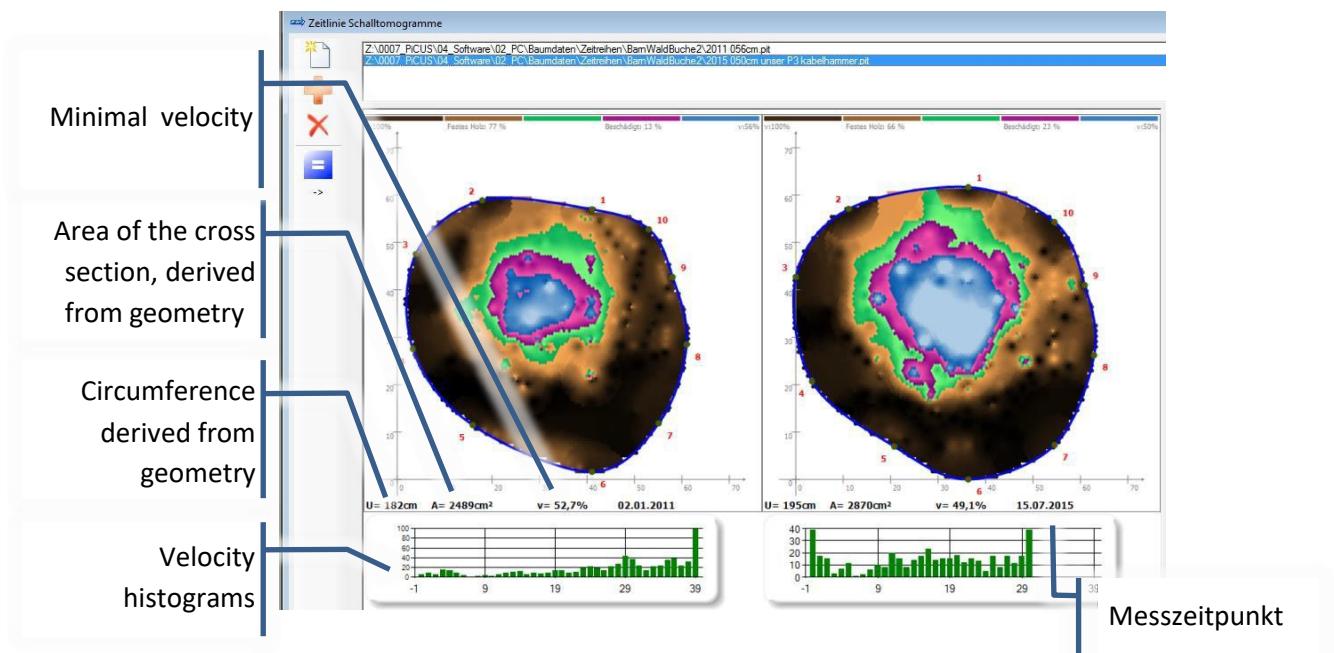
Velocity histograms

The tomogram that was (time wise) calculated first determines the partitioning of the velocity classes in the histogram. The histogram has 40 classes (= velocity range). All the absolute velocities, every connection from any point to any other point, are classified and put into the histogram. The histogram shows how many readings of a certain speed have been recorded.

Example:

The first scan at the tree was measuring velocities of up to 1406 m/s like shown in the calculation information of that file. Roughly 100 readings were recorded at this speed class. Low speed reading – classes 0 to 19 – did not occur so often.
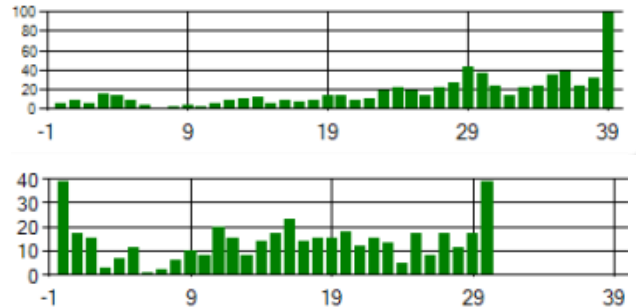
In the second scan the highest velocities occurring are only 1194 m/s. That is why classes 31 to 40 are unmanned. The number of very slow readings (class 0..) has increased.

Menu

1. Create new list. (The current list is cleared).

2. Add files to the list.

3. Remove files from the list.

4. Start the calculation.

5. Set direction of the calculation.
   a. „->" means: colour scale of the oldest scan is applied to all newer scans.
   b. „<-" means: colour scale of the most recent scan is applied to all older scans.

Hint: The position of all the measuring points must be kept the very same from scan to scan. Record the geometry of each scan precisely again.

When comparing the velocity of the scans in the histogram) bear in mind that not only variations in the wood quality affect the readings. Apart from this

- seasonal variations (temperature, moisture) and

- variations in tapping power

do have an impact.

Meaningful timelines are more easily calculated when the time wise distance between the scans is long, one year or more. Variations within a month will be dominated by the reasons mentioned above.

6.14 Questions about tomograms

If you have questions about tomograms that are not answered in this manual then you should not hesitate to contact us. We are interested to learn about your experiences and test results of trees from all over the world.

In order to be able to help in understanding your tomograms we require to get the following information:

1) If you intend to send data of more than one tree, please create an extra folder for each tree.

2) Digital photos of the tree. We need a photo of the total of the tree and photos showing all measuring points (MP). Every MP should be in at least one photo. The MP's must have numbers that can be read in the photos. The photos should be taken from at least three different perspectives.
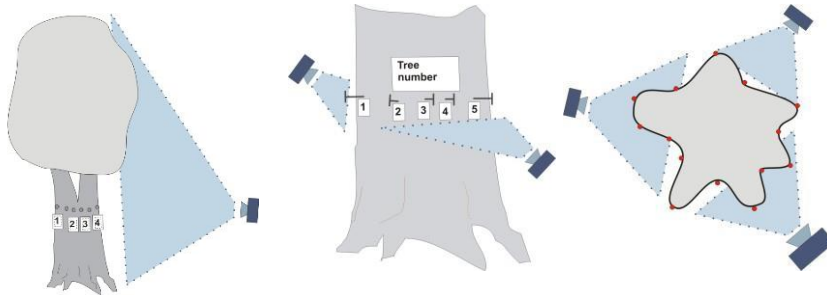
3) A photo of the stump in case the tree was cut after the scan. Please clean the surface and mark the positions of MP's before the photo is taken. Take the photo from directly above.

4) Send photos and PiCUS Datafiles ("name_of_tree.pit" + „name.trt" if available) to our email address: contact@iml-electronic.de. Please use self-explanatory file names like:

Example:

- Oak nr 123 at 23 cm.pit   - PiCUS data file, measuring level 23 cm above ground.
- Oak nr 123 total view.jpg   - Photo of the standing tree
- Oak nr 123 Fungi at MP3.jpg   - Photo of the fungi near MP 3
- Oak nr 123 Stump.jpg   - Photo of the stump

5) Write a brief summary containing the following information

- Tree species
- Reason for the scan (visible defect / decay / fungi etc.). Scan underneath branch fork etc.
- Date of scan (winter or summer), Weather condition (Temperatur of the last days, moisture/rain estimate of the past days …)

7 PiCUS Rootfinder

7.1 Introduction

The PiCUS hardware can also be used for other measurements, one of which involves obtaining information about a tree's roots. To do this, the PiCUS sensors need to be placed on the trunk of the tree just above ground level. Sonic impulses are generated using a small metal plate and/or a metal pole and hammer at set positions around the tree, and the PiCUS unit measures the travel times of these impulses. By analysing these times, the system can give us limited information about the larger roots. This method only works in certain situations.

Best results can be obtained with solitary trees which are not too close to buildings, cellars, pipes, or other solid constructions. The measurements can be greatly influenced by soil compression, water content, and by large objects in the ground (such as rocks). Due to the limitations of such influences, the reliability of measurements should be treated with care and you should apply results with caution.

It is much more difficult to generate and measure sonic waves between soil and trees than to make sonic measurements on trees alone. This is because the waves must overcome many different materials as they travel from the sender to the receiver:

hammer → metal plate or pole → soil → root(s)→ nail → receiving sensor.

Every time the signal leaves one material and enters another, the amplitude and frequency of the signal are changed. Such measurements obscure information about the condition of roots, so it is not possible to state whether they are healthy or not. In some cases, we can obtain limited information about the soil content or about the connection between the roots and the soil.

7.2 How to find large roots

1. Mount the sensors on the tree close to ground level. If you are using an older Y-cable, please refer to earlier versions of the manual.
2. To generate signals, use a hammer and a metal plate, a disc of >= 10cm diameter and >= 1 cm thick). In some cases it is best to generate sonic signals below ground level by using a metal pole – as seen here in the left of the picture. The measuring site should look like this:
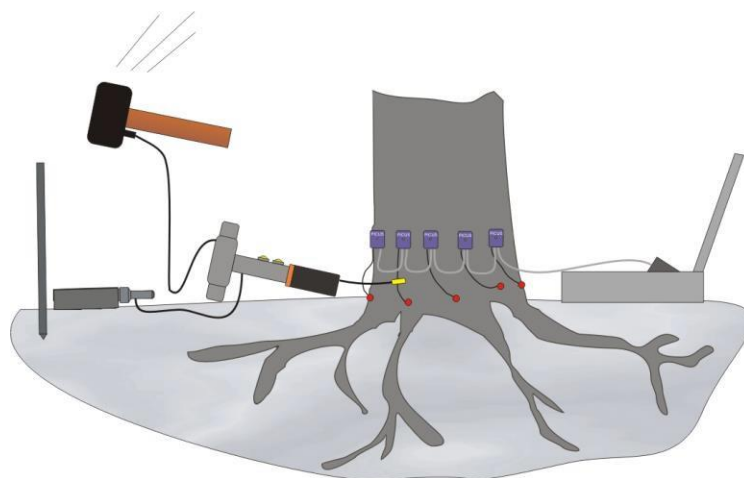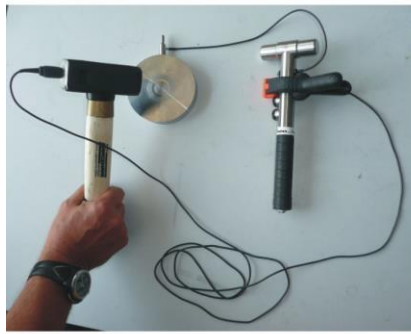
Connect rootfinder cable set as shown above. Do not use the PRH or PEH directly to hit on the metal plate or pole.

3. Open a new "Root" – File:
      "File" → "New Root file"

4. Enter the positions of the sensors on the trunk, just as you would with other PiCUS Sonic Tomograph measurements:
      "Measurement" → "Tree Geometry" → "Free shapes Calliper"

5. Enter the positions of the points on the ground where you wish to generate the sonic signals. Use the following window:
   "Measurement" → "Root Point Geometry" → "Free Shapes"

Space out the points to be tapped on the ground in even circles. For each circle, enter the distance to the tree and set the number of measuring points. If you are working with measuring points below the surface, you can also type in the "tapping depth" for each circle here. You will need to use the metal pole for tapping (see image). The positions of all root-points are displayed in the table after pushing the "Generate" button. Proceed as follows:

a)   Determine the number of circles (1) and "root-points"
b)   Select the current circle (2)
c)   Set the distance to the tree (3)
d)   Enter the depth you will tap (4)
e)   Click "Generate"
f)   Create 2-5 circles and enter all data required (steps a-e).

6. Start sonic measurement:

"Measurement" → "Measure Sonic"
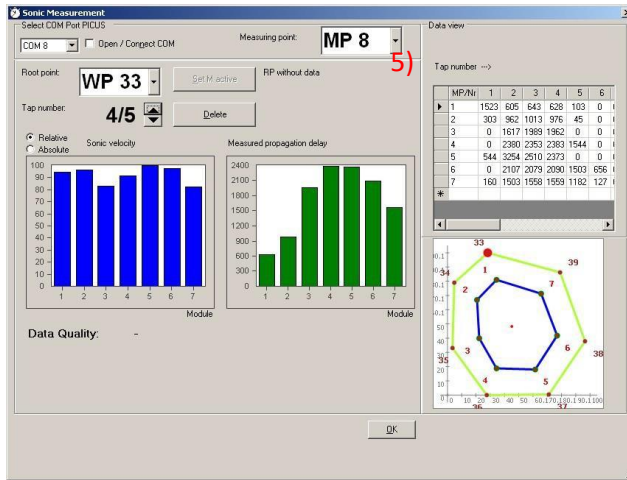
When using an electronic hammer (PRH/PEH), selecting the tapping-module (5) is not necessary.

7. Open the COM port.
8. Select the root-point you intend to start with (in this example it is "WP 33") by pushing the buttons of the PRH/PEH.
9. Strike the metal plate / pole. Use a sledgehammer for tapping. Connect tapping pin of the PRH/PEH to the metal plate. Connect the hammerhead of the PEH/PRH to the head of the sledgehammer using an electric wire. Use the metal pole to generate signals below ground level.
10. Repeat on all root points and circles

7.3 Presenting the results

The presentation of the results is similar to Calculation C in tree trunks.

The velocities measured are shown for each circle using a different colour – which is actually a combination of one colour and black. The darker the colour is, the faster the sonic signal has travelled between the points.
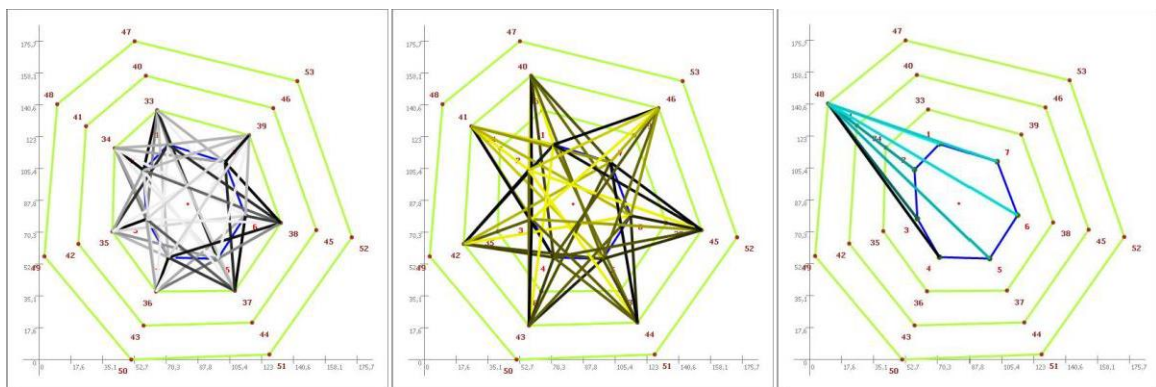
The example shows a tree that was examined using three circles.

8   Contact information

IML Instrumenta Mechanik Labor Electronic GmbH

Erich-Schlesinger-Straße 49d

18059 Rostock
Germany

Phone: +49-381 / 49 68 14 40
E-Mail: contact@iml-electronic.de

www.iml-electronic.com

With Passion and Precision