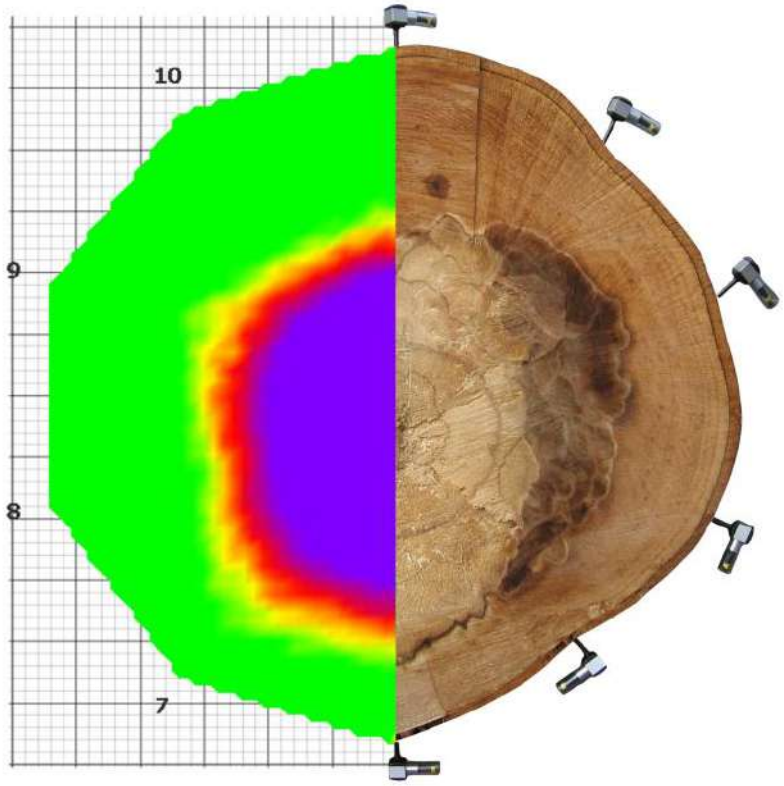


Manual for the ArborSonic3D acoustic tomograph

2025.

ArborSonic 3D



User's Manual

January 28, 2025

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Introduction

Welcome as a new ArborSonic 3D owner. ArborSonic 3D is designed to detect hidden holes and decay in trees by non-destructive acoustic testing.

Manufacturer information

ArborSonic3D is manufactured by:

Company:	Fakopp Enterprise Bt.
EU tax number:	HU22207573
Address:	Fenyo 26.
City:	Agfalva
ZIP:	9423
Country:	Hungary
Web:	http://www.fakopp.com
E-mail:	office@fakopp.com
Phone:	+36 99 330 099

Principle of operation

- Several Sensors are placed around the trunk, which are coupled to the tree by steel nails.
- Each Sensor is tapped by a hammer.
- The unit measures the travel-time of the sound wave generated by the hammer tap between each sensor.
- If there is a hole, then the sound waves have to pass around the hole and therefore it requires longer time to reach the opposite sensors.



Hardware – System parts

SD02 Piezo Sensors



Amplifier Boxes (black)



Battery Box (gray) containing the Bluetooth transmitter



Link Cables



Caliper (optional)

Sensor Remover



Tape measure

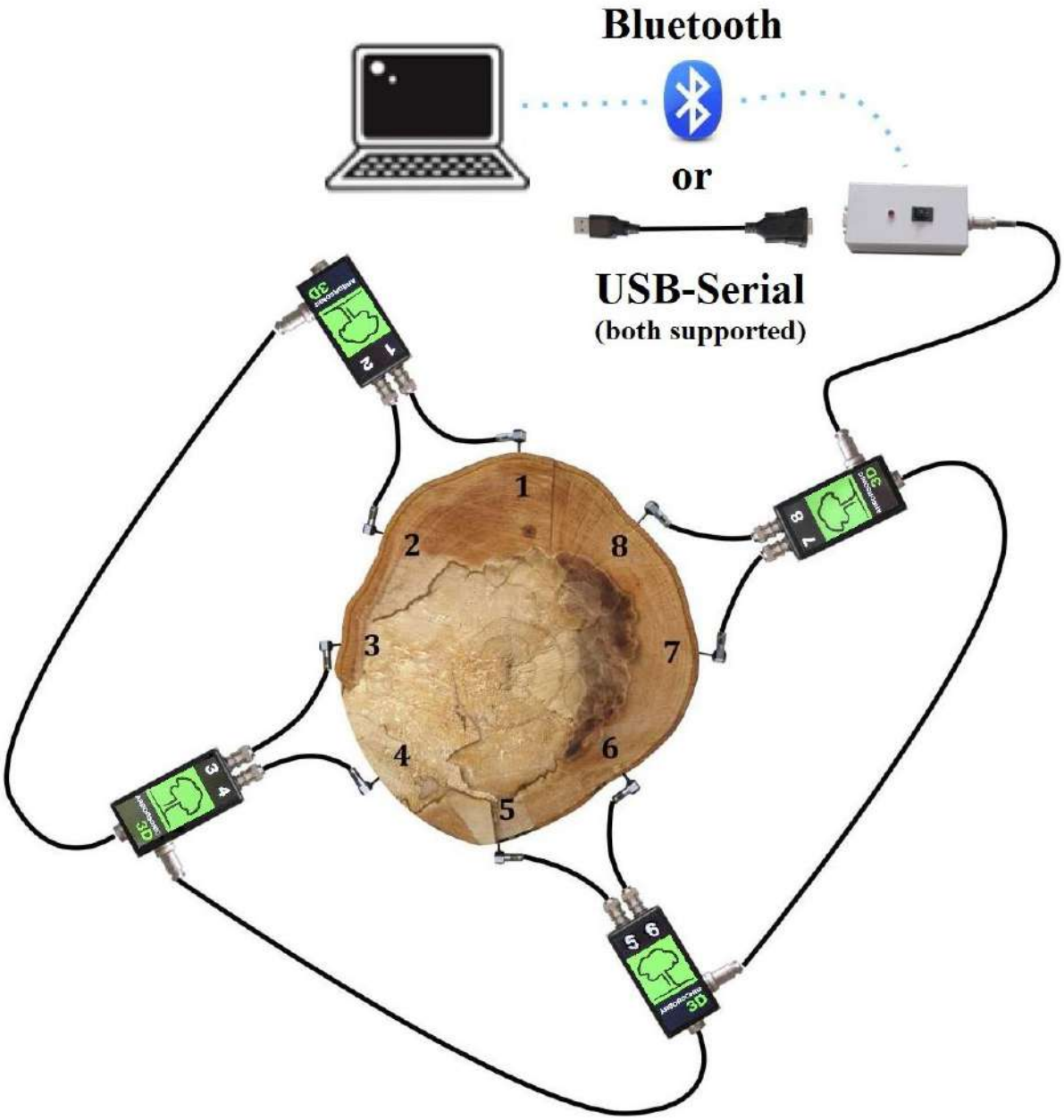
Steel and rubber hammers

Case



Hardware

Hardware – Setup



- Drive the Sensors into the trunk, perpendicular to the direction of the growth in a counter-clockwise order as seen above.
- Connect the Sensors to the Amplifier boxes.
- Connect the Amplifiers in a line. The side connector goes to the bottom connector of the next box.
- Connect the Battery Box to an Amplifier on any end of the line.
- Establish cable or Bluetooth connection to the PC

Hardware – Handling the Piezo Sensors

Maintenance

- Always keep the nails, sensor head and the hammer clean, because dirt influences the coupling and time reading.
- The numbers on the sensors are just decoration, you can change them freely, however the numbers on the amplifier boxes are important.

Fixing

- Use the rubber hammer to fix the sensors
- The sensors need to go through the bark into the wood
- Good coupling between the nail and the wood is essential. The coupling is good if the sensor head can't be rotated with 3 stretched fingers. If the sensors can rotate additional hammering is needed to couple the sensors well.
- The sensors need to be in intact wood material, not in decayed material.
- The software requires the penetration depth (PD parameter on the Sensor Geometry tab) of the sensors. This parameter is very important in case of small diameter trees.
- The sensor nails need to point to the center of the trunk; however, this is also not very critical.
- The sensors need to be placed in the same plane. However, this plane doesn't necessarily have to be horizontal. The plane should be perpendicular to the growth direction. In case of tilting trees, the plane will be tilted as well.

Measurement

- Use the steel hammer for generating the readouts by tapping on the sensor heads.
- Remove the tape measure before tapping because it may cause an acoustic short-circuit.
- Always tap on the center of the sensor head in the nail direction. If you accidentally tapped the side of the sensor, remove the data and tap again.
- Tap with uniform strength. Apply more power for large trees. Tapping power is not very critical, but similar power is recommended. Tap with loose wrist.
- Never tap on the cable connection part of the sensor.

Removal

- First disconnect the sensor cable from the amplifier box. Then disconnect the cables. For removing the sensors use the sensor remover tool if possible.
- When removing by hand, first rotate the sensors and then pull. Always pull in nail direction.
- Never pull the cable.
- Never use any support to remove the sensors because it may break or bend the nails.

Hardware – Amplifier boxes



- When building up, first fix the sensors, then the amplifier boxes and finally the link cables
- Make sure to apply correct connector orientation when connecting the link cables. Don't force them.
- Amplifier numbering is essential. Don't cross the cables because it will mess up the whole measurement.
- Connect the bottom connector of an amplifier box to the side connector of the next amplifier box.
- Never move the sensors with attached amplifiers because it may damage the cable connectors.
- When taking apart, first remove the cables, then the amplifiers and finally the sensors



Hardware – Battery Box

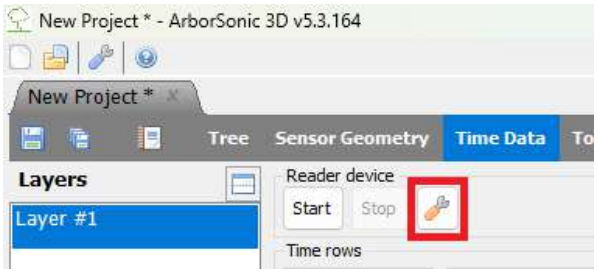


- Contains the 9V battery and the Bluetooth transmitter.
- Keep the Battery Box turned off while connecting the Amplifier Boxes.
- The Battery Box can be connected to any amplifier box.
- Make sure to apply correct polarity when changing battery.
- Any regular or rechargeable 9V battery can be used.
- The LED blinks for 5 seconds after turning on. This is the time required for the Bluetooth module to warm up.
- If the battery is low, the LED blinks continuously.
- The battery should be charged well (8V is the recommended minimum, it can be checked during measurement on the Time Data tab in the program, next to the green area indicating the used COM port).
- It is recommended to turn on the battery box only for the measurement (and keep it turned off during the rest of the time).
- The Bluetooth connection drains the battery faster than the cable connection.
- The battery should be in the proper position.

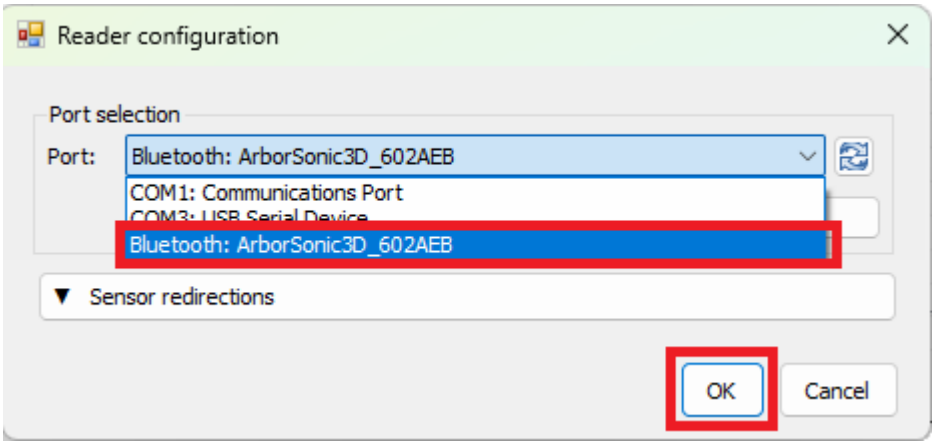


Software

Bluetooth Low Energy (BLE) connection



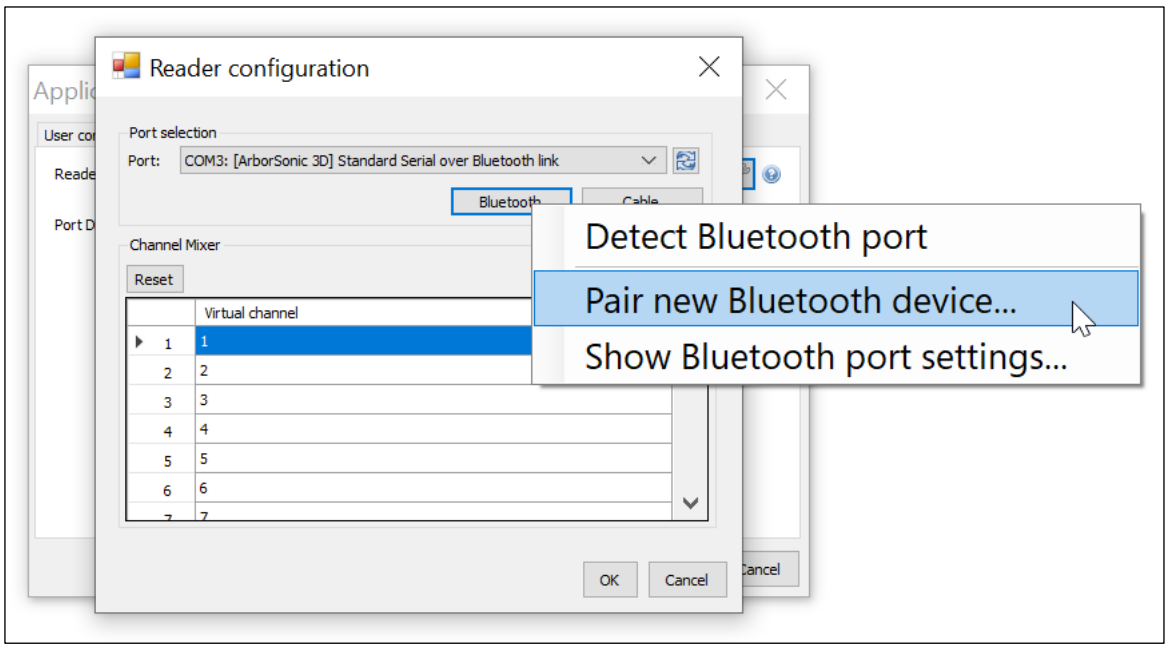
- Select the wrench icon on the “Time Data” panel.
- The BLE devices will appear on the bottom of the device selection list.



- The BLE devices will appear on the bottom of the device selection list, with the “Bluetooth” prefix. Please note that this only applies to BLE devices.

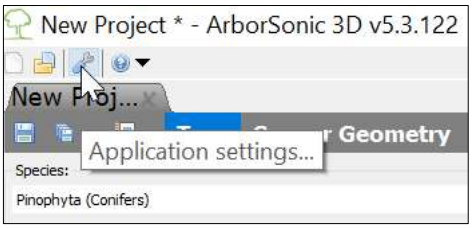
Bluetooth Classic (COM) and serial connection

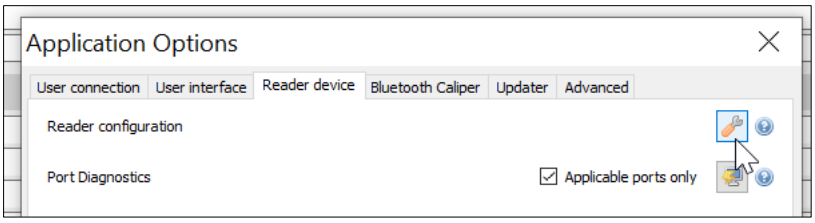
- The Battery Box of the device is responsible for transmitting data to the PC (or to an Android smartphone). There are two ways to establish connection with PC: over a Serial-USB cable or using Bluetooth module (for the smartphones only Bluetooth connection is possible).
- To set up the connection follow these steps: plug in the USB cable or pair the Bluetooth device in Windows. In either way a COM port is assigned to the connection with a specific name (e.g. COM1, COM2, ...). Afterwards set this COM port in the software.
- ArborSonic3D can help you with detecting ports and pairing Bluetooth devices. Clicking “Pair new Bluetooth device…” pops up the Bluetooth pairing wizard. See details in the next chapter.



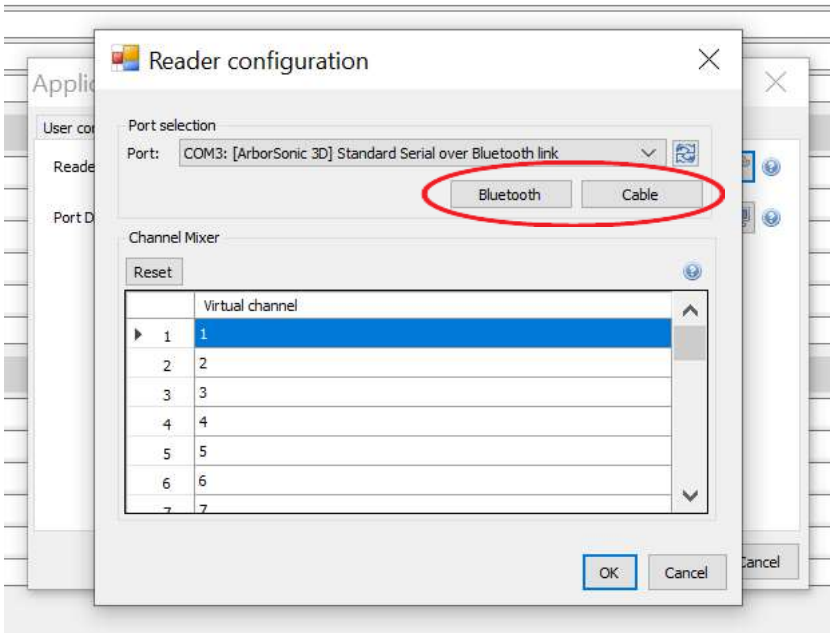
Establishing connection to the Battery Box

- Turn on the Battery Box.
- Start ArborSonic3D, click “Application settings” in the right top corner.
- A new window pops up, go to the “Reader device” tab.
- Here, choose “Reader configuration” wrench.

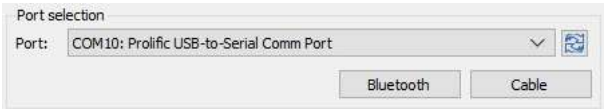




- It will open the “Reader Configuration” window.

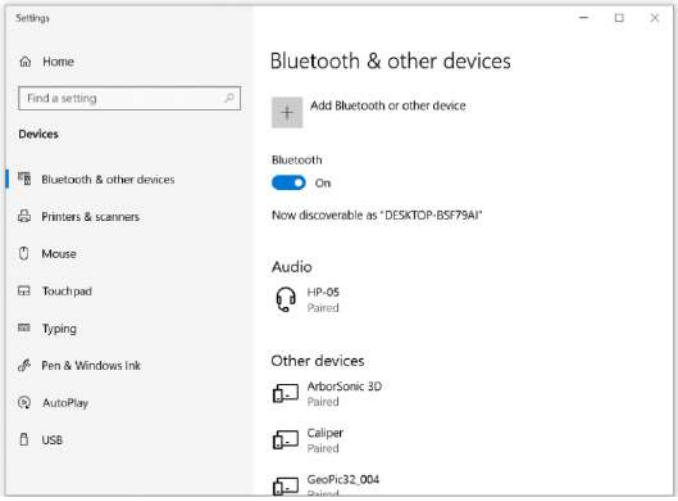


- Cable
  - Connect the Battery Box using the USB-Serial cable to the computer. Wait a few seconds while Windows installs the drivers. Afterwards click “Cable” to let the software find the correct Port.
  - In the port selection area the selected port will be shown in the following format, for example: COM10: Prolific USB-to-Serial Comm Port



  - It is recommended to always connect the Serial-USB cable to the same USB port.

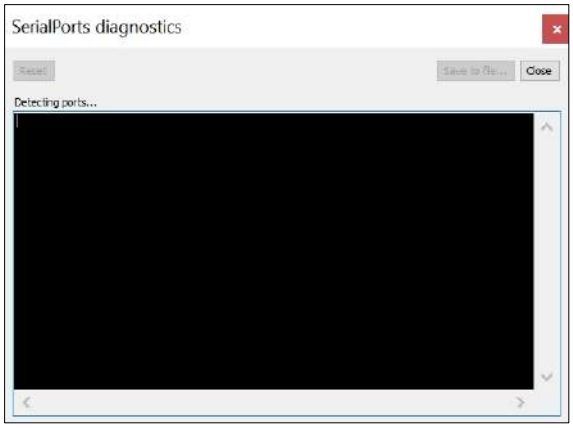
- Bluetooth
  - **Detect Bluetooth port**: finds an already paired device. When successful, “COM…: [ArborSonic 3D] Standard Serial over Bluetooth link” will appear.
  - **Pair new Bluetooth device**: starts pairing a new Bluetooth device. This has to be done only once and before clicking “Detect Bluetooth port”. If a PIN code is needed, it will be 1234. Please keep in mind that the maximum Bluetooth range is 30 feet / 10 meters. If you need extended range, longer cable can be used between the Amplifier Box and the Battery Box



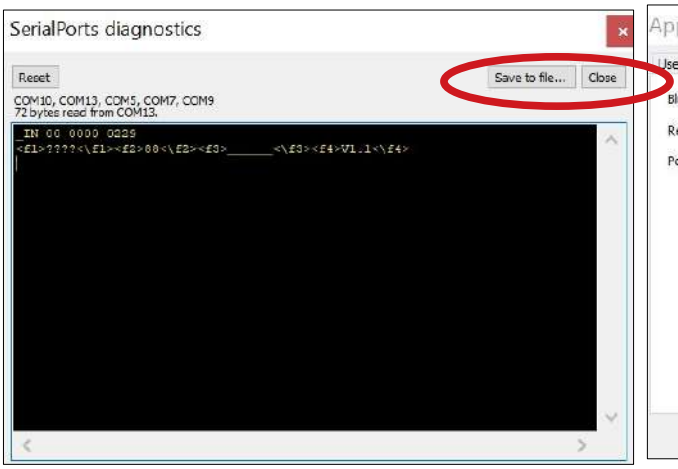
  - **Show Bluetooth port settings**: lists paired Bluetooth COM ports
  - If you are using an external USB Bluetooth Module (i.e. a Bluetooth Dongle), it is recommended to always connect it to the same USB port

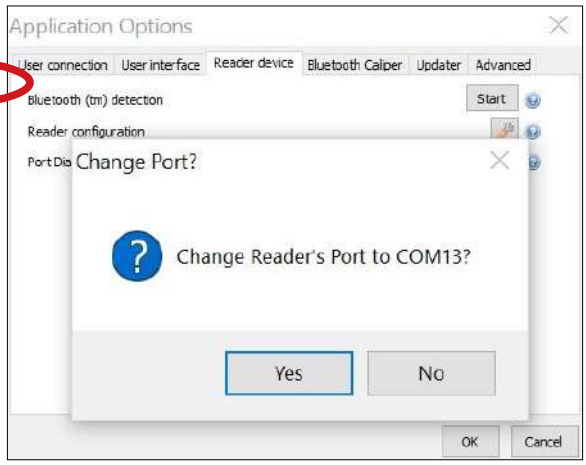
Selecting COM port – other possibility

- These steps are necessary only if somehow the Reader Device did not find the proper COM port.
- There is also a possibility is to use the Port Diagnostics on the same panel (on the Reader device tab of the Application Options). Click to this  button.
    - It opens the SerialPort diagnostics window. The program automatically looks for the used COM ports. (It can take a few minutes.)
    - Connect at least one Amplifier Box and two sensors to the Battery Box, get a piece of wood.
    - Generate data by tapping the connected sensors.
    - The COM ports are listed on the top and if any data could be received it is shown in the window. The raw data can be saved if it is needed.



    - By clicking Close the window will close. If the COM port set in the program is not same which sent the last data, the SerialPort diagnostics will ask if the COM port can be changed. Push Yes if the last received data was from the ArborSonic device.
    - The information sent by ArborSonic starts with IN (referring to incoming data), followed by two numbers which refers to the Amplifier Box which sent the data (00 is for the Amplifier Box with 1st and 2nd sensors, 01 is for the Amplifier Box with 3rd and 4th sensors, 02 is for the Amplifier Box with the 5th and 6th sensors and so on). The following 2 four-digit numbers are the time data detected by the proper sensors.
      For example a line can be IN 03 0205 0311 which means the Amplifier Box with the 7th and 8th sensors sent the data 205µs from the 7th sensor and 311µs from the 8th sensor.





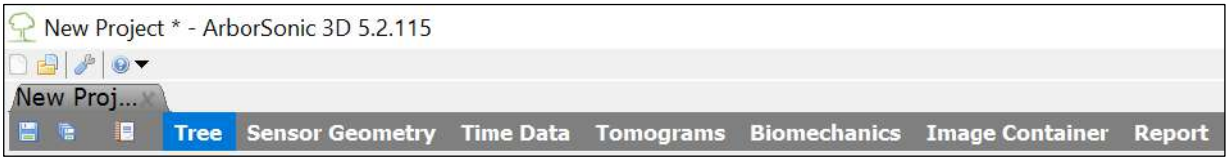
- To check if everything is fine, restart the program, create a dummy layer with some dummy geometry parameters (the simplest is to choose a circle), and go to the Time Data page. (You may have to push „Start".) If the connection is set up successfully, a green "Reading device (COM_)" message should appear. Start tapping the sensors and you should see rows of numbers arriving in the table below.

Software – Basics

- The latest version of the software can be downloaded at http://www.fakopp.com.
- The software can be installed to any PC with Windows 7 or higher.
- The software includes the following:
  - Selecting parameters of the tree (species, ...)
  - Registering the geometry of the sensors
  - Collecting the time data from ArborSonic 3D over Bluetooth or via USB cable
  - Computing the internal cross-sectional tomogram
  - Performing biomechanical calculations
  - Generating a report file for customers
  - Saving and opening previous projects

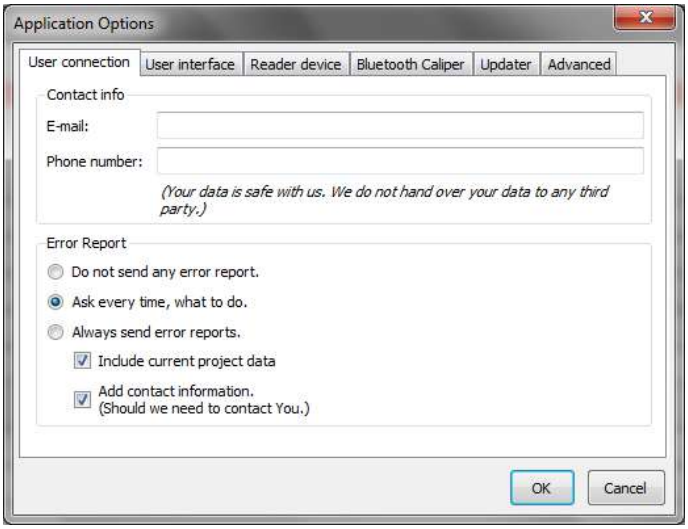
- The steps of a measurement are:
  1. Choosing the measurement Layer on the trunk.
  2. Starting the software and selecting the tree species.
  3. Placing the sensors (to the proper positions calculated by the software when using circle, elliptic or rectangular geometry) and registering the sensor geometry manually or with the Bluetooth Caliper (in case of irregular geometry).
  4. Collecting time data by tapping on each sensor.
  5. If measurements at several layers are required, choose the next layer and repeat the previous two steps.
  6. Evaluating the cross-sectional maps, tomograms.
  7. Performing stability computations. (For this step a photo made from the tree including the whole canopy area is needed as well.)
  8. Saving the data and exporting data to the report file which can be printed later.

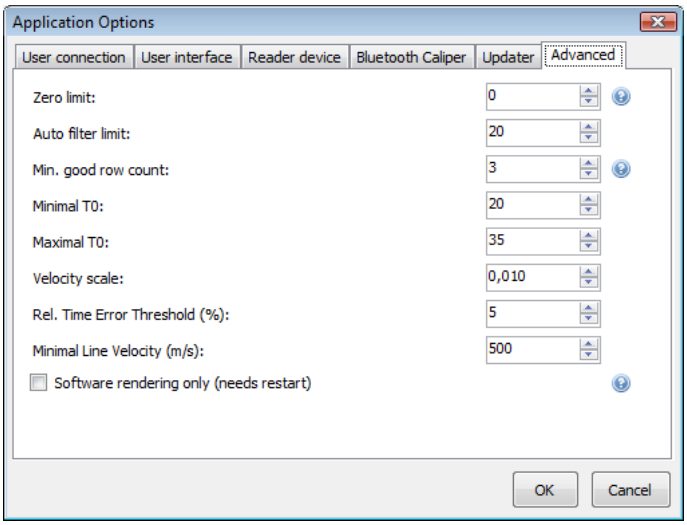
- The main menu of the program contains “New project”, “Open project…”, “Application settings” and “Click here if, You need Help!” where you can check the manual and about the program.
  Every project has it’s name which is displayed on the tab of the project while the active’s project’s name is displayed next to the program’s name in the head.



The project’s menu starts with saving and saving as functions and you can immediately generate a report by clicking onto . The rest of the line are the different functions of the program which will be detailed in the proper chapters.

Software – Application Settings

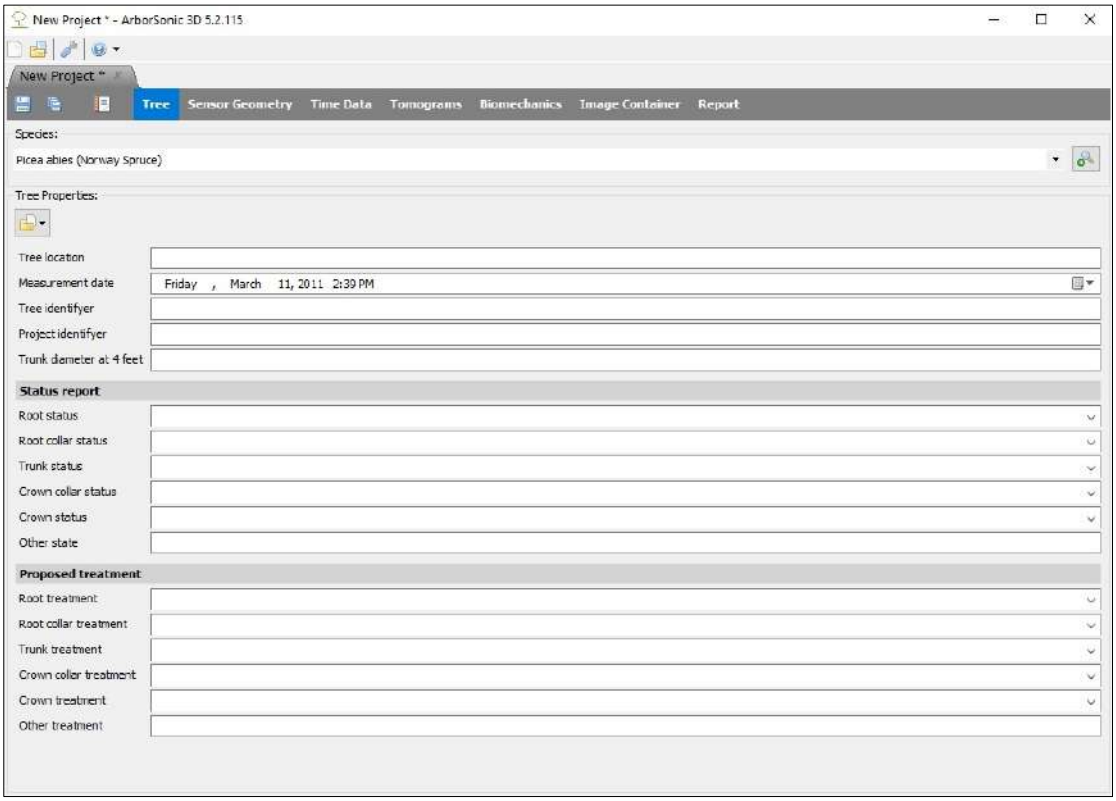




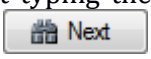
- To access the application settings, click . This panel is divided into several tabs for changing different settings of the software.
- On the User Connection tab, you can leave your contact details which will only be used in case of software problems, so we can get in touch with you and help with the solution. In case of a software problem an error report is sent to us in email. You can select whether this email should be sent automatically or not and whether it should contain your contact information and the current project.
- On the User Interface tab, you can select the software language and the measurement system which can be Metric or American Standard.
- The Reader Device tab can be used to set up and configure the connection settings with the ArborSonic 3D device.
- The "Reader Configuration" button opens the same window as the same button on the Time Data page of the software. This window is responsible for selecting the COM port which is explained in the "Establishing connection to the Battery Box" section. The channel mixer tool lets you assign different numbering for the physical channel numbers as printed on the Amplifier Boxes. This is useful if you lose one of the boxes, let's say 5-6, but still want to perform measurements with 8 sensors using boxes 1-2, 3-4, 7-8, 9-10. (Detailed in chapter Testing and Troubleshooting.)
- Port diagnostics is a tool that is useful for monitoring the raw data received from the device. Actually, it is a simple telnet application. It opens all the ports and listens to any data that is received. Using the Save button the data can be saved to an external file.
- On the Bluetooth Caliper page, you can select the COM port of the Bluetooth Caliper.
- On the Updater page you can disable or enable automatic software updates over the internet. By default, this feature is turned on, so you will receive updates automatically when starting the software.
- On the Advanced tab Zero limit is the number under which a measured time value is considered as zero. The default and recommended setting is 0 which in fact turns this function off.
- Auto filter limit value determines the limit of acceptable variance of proper measurements, per sensor. The default setting is 20.
- Min. good row count is the number of required good time measurements from each sensor. The default setting is 3.

- Minimal and maximal T0 are internal time correction limit parameters which are out of the scope of this manual. The default settings are 20 and 35. You have to change these values if you are using long (e.g. 12 cm / 4.7 inches) nails. In this case T0 min should be 45 while T0 max should be set to 60.
- Velocity scale controls the scale (height) of the 3D map in the z axis.
- Rel Time Error Threshold controls the level above which the values in the time matrix on the Time Data panel are shown as red, if the relative error exceeds this limit. The default is 5%.
- Minimal Line Velocity is an internal minimum value for any measured line velocity, default is 500 meter/sec.
- Software rendering should be used if you experience problems with the tomogram images. The program must be restarted if this setting is changed.

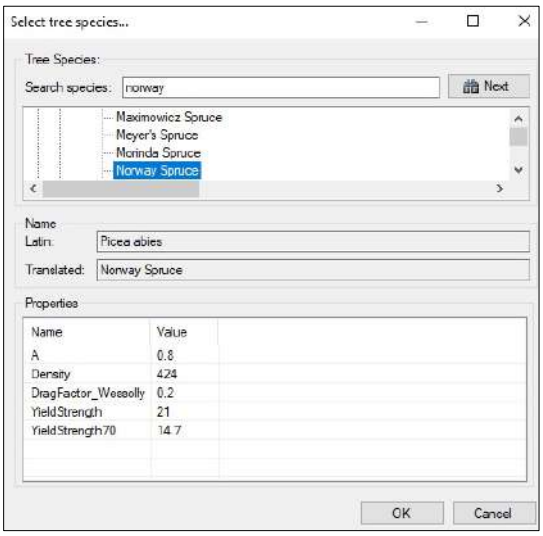
Software – Tree Properties



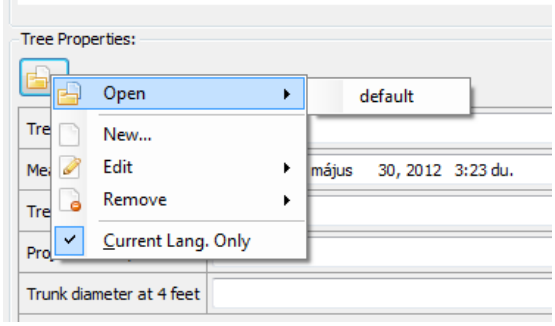
- The first page contains the general properties of the tree. Tree species must be selected before you can move to the next page! The species can be selected from the top list. This is a quick list which contains maximum 20 of the recently used species. To select a species which is not in this list, click the  button. A new window pops up where you can navigate

in the taxonomical list of tree species. This list contains above 3000 species. To speed up the search process, you don't need to click through the whole list to find a species, but you can simply start typing the English or Latin name of the species. To jump to the next candidate, click 

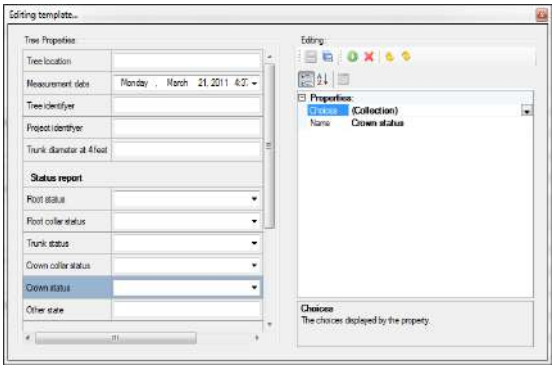
or hit the enter button. After selecting the desired species, click OK to close this window.



- The rest of this page contains various fields for describing different properties of the tree. The software comes with a default tree property template, but it is possible to create custom templates which may be used to register different properties. All this will go into the report that is generated by the software, so a well-designed template can save you a lot of time. Of course, changing this template is optional and you can start working with the default template.
- Click the  button to open the tree properties menu. Select Open for opening another template, New for creating a new one, Edit to modify an existing one or Remove to delete. The default template that comes with the software can't be deleted. (If Current Lang. Only option is active, templates only in the current language of the program are available. If this is unchecked all templates are visible and useable.)

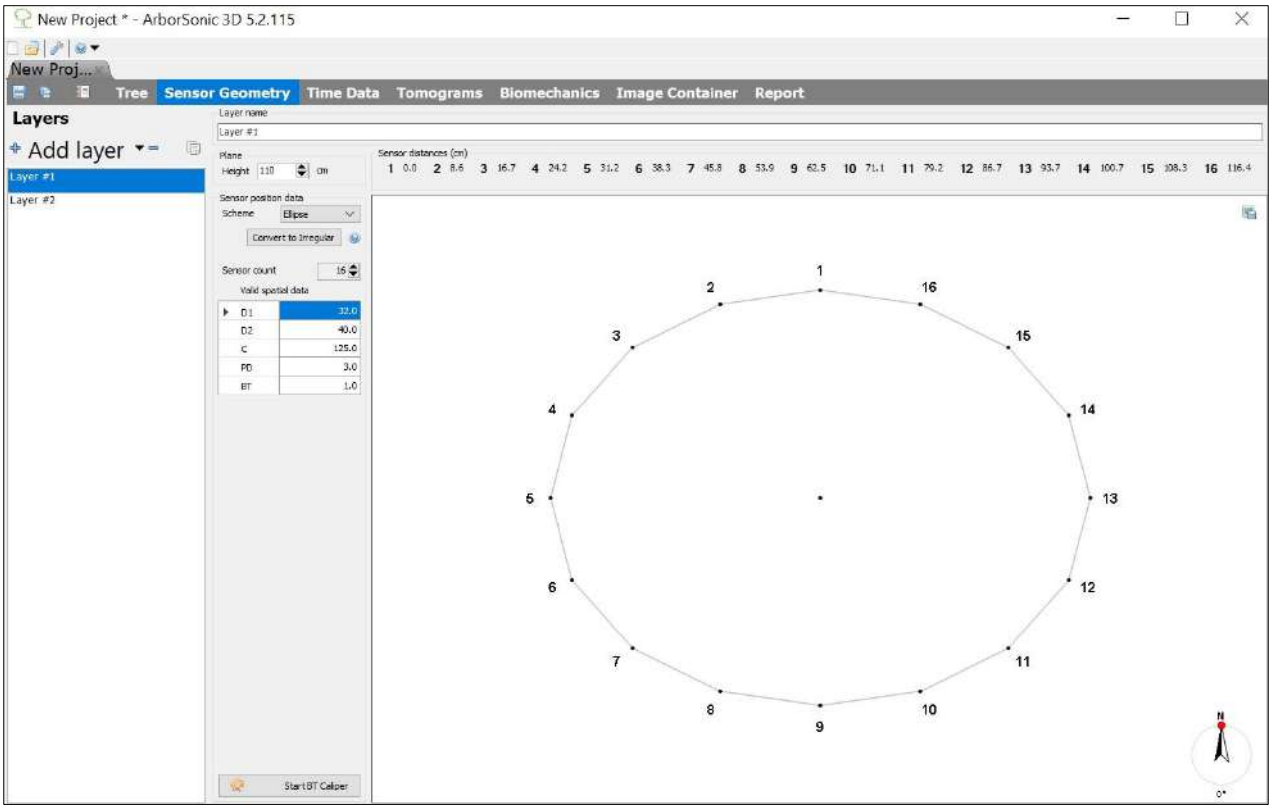


- When selecting New or Edit, the template editor window pops up. The left side of this window shows the preview of the template while the right side can be used to add, remove and modify distinct fields in the template.
- By clicking the  button a new field can be added to the template. The type of the new field and its position relative to the current selection must be selected. After clicking OK the properties of this field can be set. For example, each field type has a Name property which is the display name of this field.



- The  buttons can be used to change the relative position of the selected field and the  button can be used to remove it. The  buttons can be used to save the modifications to the template or to save it under a new name. After this the template is ready to be opened for use.

Software – Sensor Geometry – Basics



- The software can handle measurements at several (different) heights. These are the so-called Layers. The sensors can be placed at one Layer at a time and need to be moved between the Layers after collecting the Time Data. Please disconnect the cables when moving between Layers, otherwise the connectors may be damaged.
- Use the ✚ button to add a new layer and user the ▬ button to remove one.
- "Add layer" can also handle files from previous program version with "Add f2d files as layer…"
- It is also possible to copy an entire layer.
- The name of each layer can be changed in the Layer name field.
- The height of a layer from the ground should be defined in the Height field.
- The length units (cm or inch) can be changed in Application Settings / User interface (the program does not keep the numbers but converts them).
- There are four geometry schemes: Circular, Ellipse, Irregular and Rectangular. These can be selected in the Scheme field. Please use the proper geometry. (For example, do not use circular geometry if the trunk is concave.)
- Circular, Ellipse and Rectangular geometries can be converted to Irregular scheme. This can be useful if the trunk is almost circular or elliptic with only one outgrowth or dent.
- The number of sensors used for the measurement can be set in the Sensor count field. Usually it will be the same number for each layer, but it is possible to use more or less sensors for a layer.

- PD is a parameter required for all schemes. It is the penetration depth of the nail tip from the bark surface. It is critical parameter in case of smaller trees.
- BT is another parameter required for all schemes and denotes the Bark Thickness. This parameter is should be set carefully for small trees.
- For measurements physical penetration depth should always be more than the bark thickness, the nail should go through the bark.
- In Circular, Ellipse and Rectangular the software tells you where to put the sensors.
- In Irregular first you place the sensors and then you tell the software where they are.
- Different layers can have different schemes.
- Sensors need to be placed in a counter-clockwise order when seen from above. Therefore, previous sensors need to be on the left side while next sensors on the right side.

Software – Sensor Geometry – Circular, Elliptical, Rectangular and Irregular

Circular



- Use this scheme if the trunk is circular.
- Place sensor no. 1 anywhere and use it as a support to hold the tape around the trunk. (The north direction is included in the program. The layer can be rotated by the red/green dot on the top of the compass (the arrow in corner) indicating north direction. It can become important if the sensors are not at the same directions in the different layers. Detailed in chapter Software – Sensor Geometry – Compass.)
- Measure the circumference with the tape and type it into C.
- Place the other sensors around the trunk at the positions displayed:

Sensor distances (in):
[1] 0; [2] 4.49; [3] 9.02; [4] 13.5; [5] 17.99; [6] 22.52; [7] 27.01; [8] 31.5;
[9] 35.98; [10] 40.51; [11] 45; [12] 49.49

- Provide the estimated penetration depth of the sensor nail tip from the bark surface as the PD parameter. (The nails' lengths are usually 6 cm.)
- Provide the estimated bark thickness as the BT parameter.
- By pressing the "Convert to irregular" button, the scheme will be converted to Irregular (see below) which might be useful when the tree is almost circular, but the positions of one or two sensors need to be adjusted.

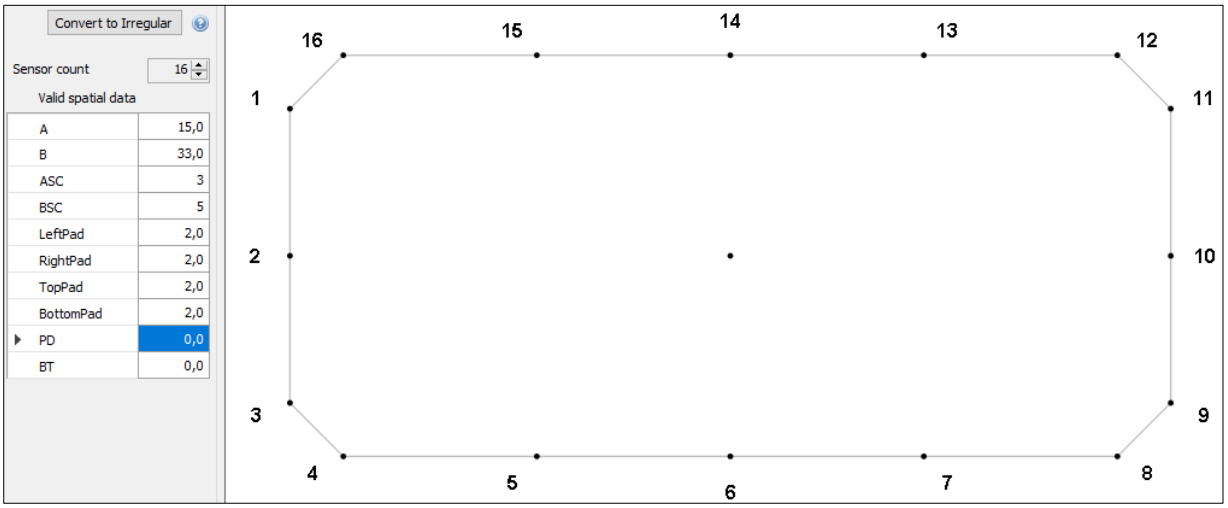
Elliptical

- Use this scheme if the trunk is elliptical.
- Place sensor no. 1 at the end of the larger diameter and use it as a support to hold the tape around the trunk.
- Measure the circumference with the tape and type it in parameter C.
- Measure the larger diameter (major axis) with a caliper and type it in D1. Measure the smaller diameter (minor axis) and type it in D2.
- Place the other sensors around the trunk at the positions displayed:

  Sensor distances (in):
  [1] 0; [2] 4.49; [3] 9.02; [4] 13.5; [5] 17.99; [6] 22.52; [7] 27.01; [8] 31.5;
  [9] 35.98; [10] 40.51; [11] 45; [12] 49.49
- Direction, PD and BT can be adjusted the same as detailed above for circular geometry.
- By pressing the "Convert to irregular" button, the scheme will be converted to Irregular (see below) which might be useful when the tree is almost elliptical, but the positions of one or two sensors need to be adjusted.

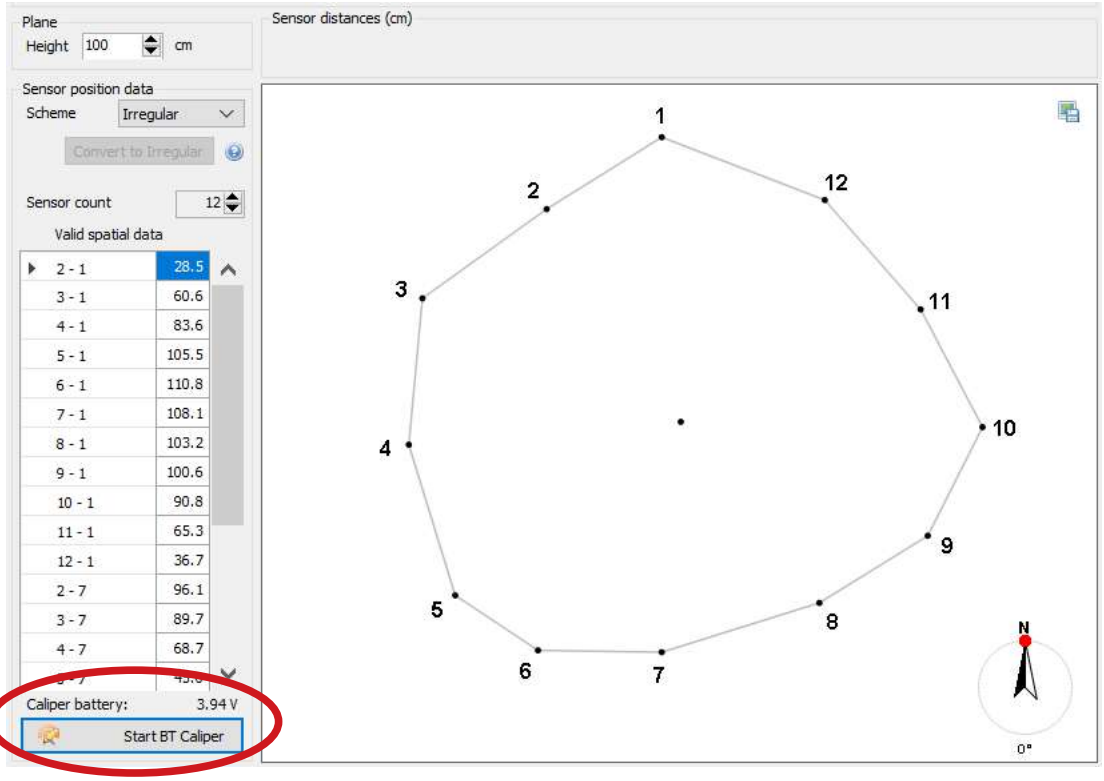
Rectangular

- Use this scheme if you are investigating rectangular wood.
- A is the width of the rectangle and B is its depth.
- ASC and BSC are the number of sensors on the A and B side. 2*(ASC+BSC) must equal the total number of sensors, otherwise you get a sensor count mismatch.
- LeftPad, RightPad, TopPad, BottomPad are the spacings between the corner and the first sensor from the given direction. These must be smaller than A or B.
- By pressing the "Convert to irregular" button, the scheme will be converted to Irregular (see below) which might be useful when the shape is almost rectangular, but the positions of one or two sensors need to be adjusted.
- Direction, PD and BT can be adjusted the same as detailed above for circular geometry.



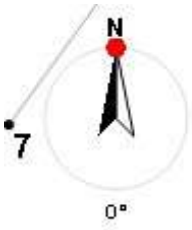
Irregular

- Use this scheme if the trunk shape is irregular.
- Place the sensors around the trunk in counter-clockwise order.
- Make sure that the sensors are in one plane. The tape measure can be used for this.
- After placing the sensors use the caliper to measure distances between sensor pairs. For example, distance between sensor no. 1 and no. 2 needs to be entered in the field `1 - 2`.
- The Bluetooth caliper can be used to transmit the data automatically. Just start the caliper and measure the appropriate distances.
- The Bluetooth caliper works properly if the battery is at least 3.5V. The charge can be checked above the Start / Stop BT Caliper button. Please charge the caliper if the battery is under 3.5V.
- Direction, PD and BT can be adjusted the same as detailed above for circular geometry.
- The other shapes can be converted into irregular. Change the distances of the sensor(s) which is not fitting the previously used shape.



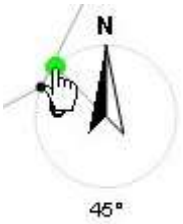
Software – Sensor Geometry – Compass

Description



- The compass is the graphic in the lower right corner.
- Using the compass is optional.
- It can be used to specify a direction of interest, relative to north. (E.g. it can be used to specify the positions of the trees, of the sensors.)
- It rotates all views of the selected layer (except the multilayer view). (Therefore, it can be used to rotate the layer according to your viewing angle of the tree.)
- The specified angle is saved, when you save your project.

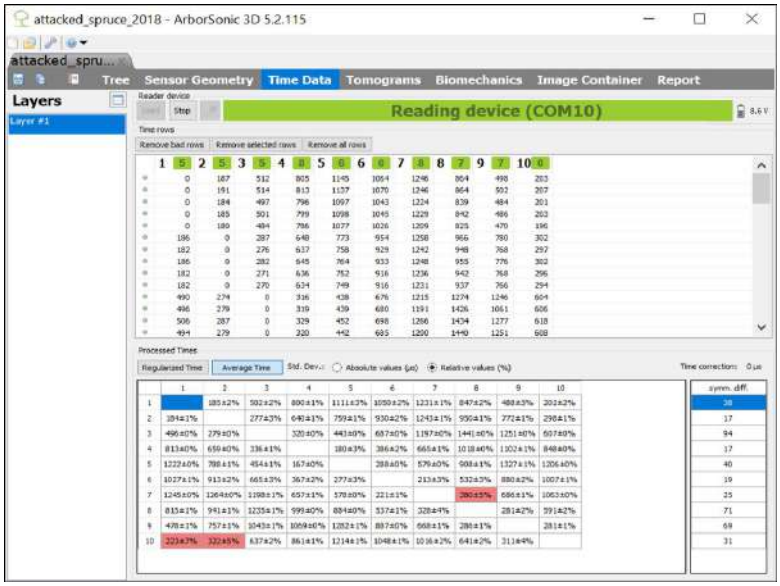
Usage



- The angle needs to be set separately for each layer.
- The angle is represented by a dot on the circle. The exact value is displayed at the bottom, in degrees.
- The angle can only be changed on the Sensor Geometry page. This is indicated by its red color.
- When on the Sensor Geometry page, hover your mouse over the dot, and press down the left mouse button while you move it to its new place. While this is done, the color of the dot will be green.
- On all other pages the dot will be colored black, to indicate that it cannot be edited.
- On Sensor Geometry tab the default position of the first sensor on the top (facing to north). You may measure different layers with the sensors facing to different directions and rotate them to proper positions. You can check the relative positions of the layer in the multi-layer mode.

Software – Time Data

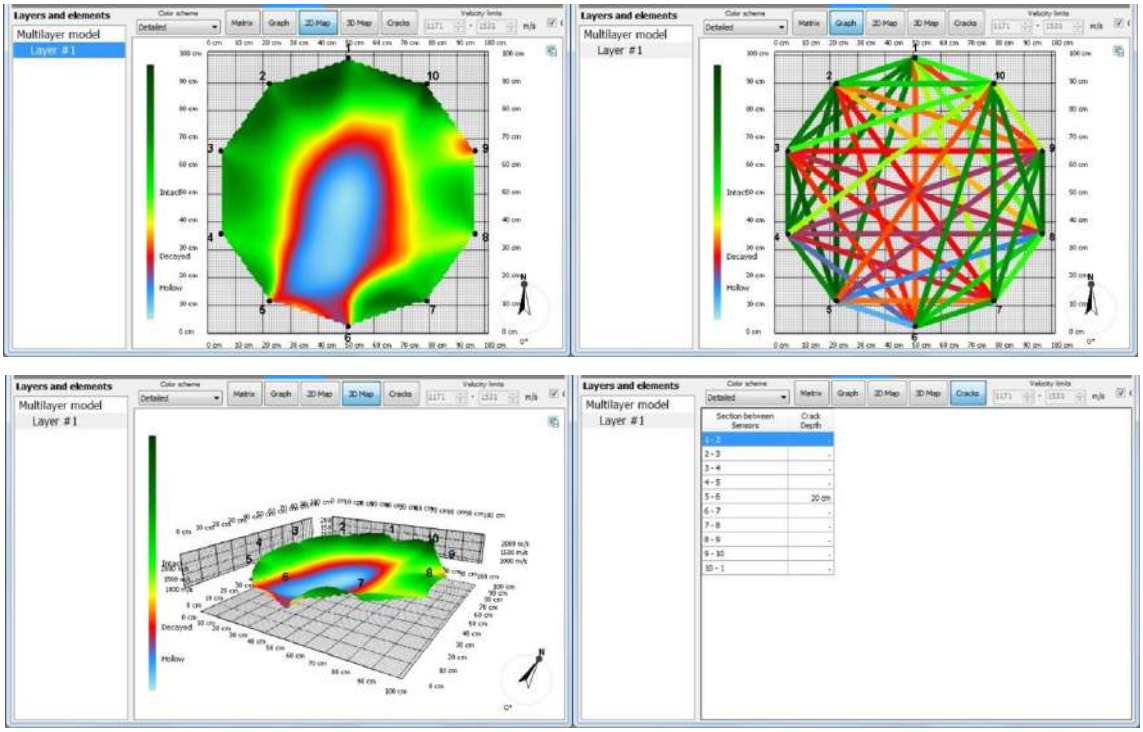
- Time data are the shock-wave travel-times measured by ArborSonic 3D between the sensors in microseconds.
- After placing the sensors and registering the geometry, go to the Time Data tab. If the connection is already configured and the Battery Box is turned on, the Reading device message appears which shows that the connection was opened successfully. ("Reading device" means only that the COM port is found and could be opened. This is necessary. Yet there are cases when having this sign is not enough for starting the measurement, the COM port might need to be changed.)



- Otherwise you will need to configure the connection. This process is described in the "Hardware – Bluetooth and serial connection" section earlier.
- On the right side of the green area 8.6 V a battery icon can be seen if there is communication with the Battery Box. The voltage can be checked as well. Please note that measurements done while the voltage is lower than 8 V can be incorrect.
- Make sure to select the correct Layer on the left side, i.e. where the sensors are actually placed. Change this selection when sensors are moved to the next Layer.
- Tap each sensor at least 3 times. (5 taps are recommended.)
- The measured time data appear in the Time rows table.
- One line of this table contains the measured travel-times from the tapped sensor to all the other sensors. Therefore, the value belonging to the tapped sensor is always 0.
- The numbers near the column labels show the number of correct taps from each sensor. If the number if below 3, the color is red 2 which means, that additional taps are required from that sensor. Otherwise the number is green 4.
- The small dots in the columns show the correctness of the time row. If the row is correct, a green dot is shown. It is not a problem if not every row is correct, because the software uses the correct rows only.
- Please make sure to tap always on the center of the sensor head with approximately uniform strength. If the side of the sensor is tapped or the strength is too low, the measured time data row is incorrect. The software has a built-in filter for these data, however it is better to remove them manually by the „Remove bad rows" or „Remove selected rows" button.
- If there is enough time data from every sensor, the Processed Times section contains the averaged times between the sensor pairs. Most of this data is just for monitoring.

- The standard deviation of the average of the times measured between each sensor pair is shown after the ± signs. The standard deviations can be displayed in microseconds or in relative values. If the relative error is above 5%, then the corresponding cell is shown as red and it is advised to check the Time rows table, remove rows far from the average or simply collect some more data for the affected sensors.
- When tapping on each sensor, the time between each sensor pair is measured in two different ways: when one of the sensors is tapped and the other is the receiver and in the reverse direction. The symm. diff. table contains the average differences between the times measured in both directions for all sensors. This table is a handy tool for finding bad sensors: if the value for one sensor is unusually high (above 100), then the sensor may be in a bad position (the tip is in decayed wood or in a hollow), broke or the tape measure was not removed from the trunk.

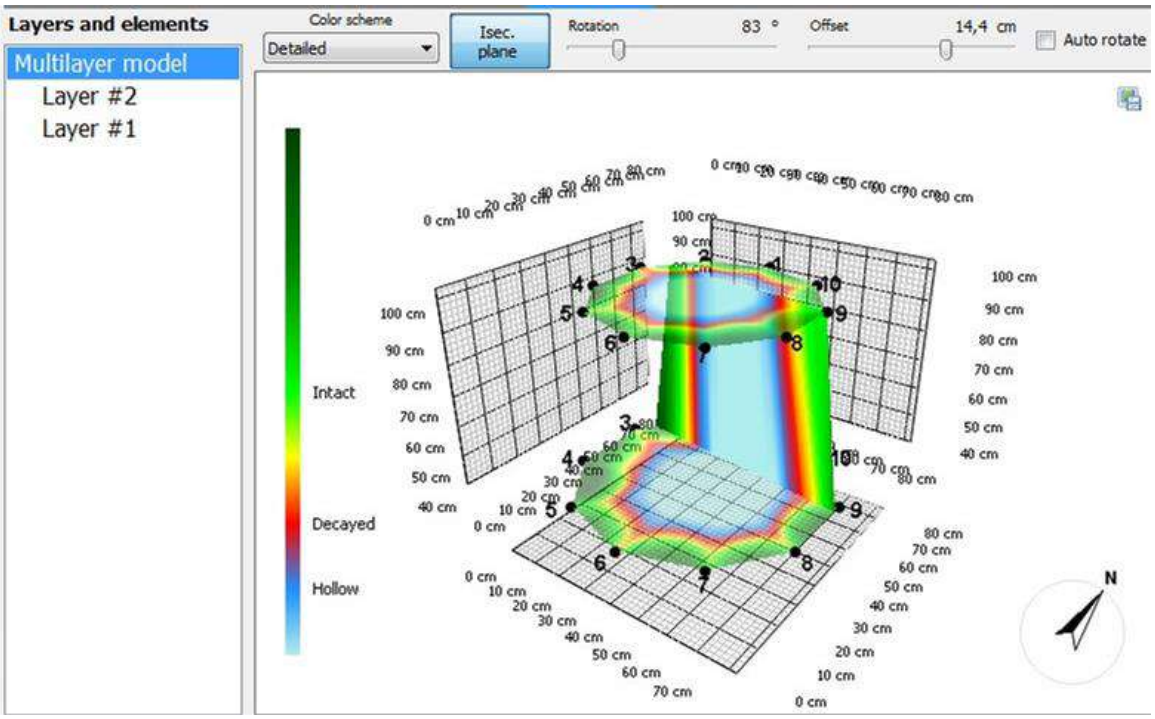
Software – Tomograms – Single-layer mode



- After registering the geometry and collecting enough time data, the tomograms are visible on the Tomograms tab.
- Selecting only one Layer from the Layer list shows the tomogram for that specific Layer only.
- A color scheme can be selected for visualization, the recommended scheme is Detailed. The legend and the meaning of colors are on the left side of the figure.
- In Graph mode the measured average velocities are represented as colored lines on the figure. The average velocities can also be displayed by clicking Matrix.

- In 2D Map mode the tomogram can be seen. Moving the mouse over the area shows the velocity below the cursor point.
- In 3D Map mode the tomogram is represented as a 3-dimensional surface.
- The Cracks mode tries to estimate crack depths which start from the surface. The estimated crack depth between each sensor is displayed in the list. However, this tool does not detect internal cracks.
- By checking the Calculate automatically checkbox, the velocity limits which set the colors are calculated automatically and this is the recommended setting. However, by un-checking this checkbox allows for manual modification of the velocity limits.
- Use the icon on the top right corner to save a view to the Image Container.

Software – Tomograms – Multi-layer mode



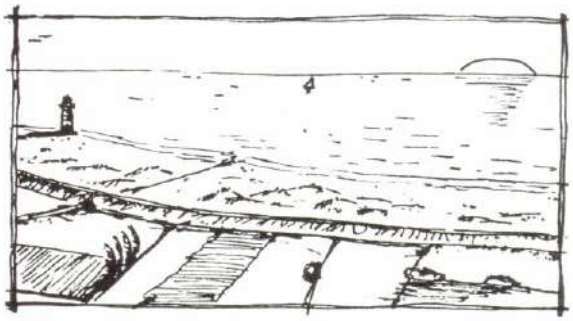
- If there are at least two layers, the 3-dimensional representation of all the tomograms measured at all the layers can be seen by selecting Multilayer model on the left side at the Tomograms tab.
- Use the left mouse button to rotate the figure.
- Click the Isec. plane button to show the vertical interpolation plane between the layers.
- By checking Auto rotate to face You the plane will always face you.
- Otherwise the plane can be rotated and moved by the rotation and offset controls.

Software – Biomechanics

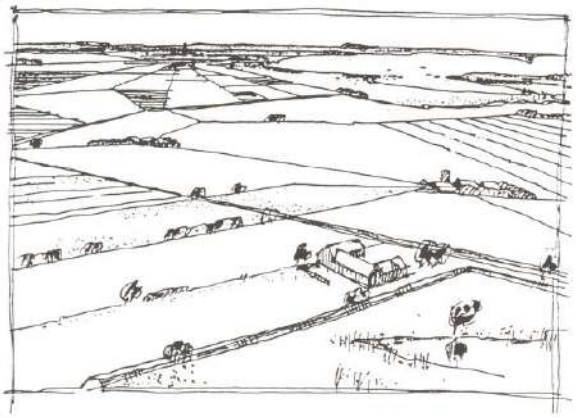
- The Biomechanics page allows you to evaluate the Safety Factor of the tree trunk using the obtained cross-sectional tomograms at the specified wind load.
- The process gives an estimate for the trunk safety. Please note that only the tomograms at the measurement Layers are used, therefore the software is not aware of any parts outside the measured region.
- As evaluation of wind loads are not simple the program offers you two different models.
    - "Uniform" wind load model uses a relatively simple model to estimate the load, force and torque caused by wind. This model usually calculates higher wind load and lower Safety Factor for trees below 20 m.
    - "EN1991" wind load calculations are based on the EUROPEAN STANDARD EN 1991-1-4 (also known as EUROCODE). The wind load calculation and the approach of the standard were applied to the trees.
- The data requested for the evaluations have overlaps and some similarities. The settings of the models are detailed in the following subchapters by subjects in the same order as it is in the program.

Wind

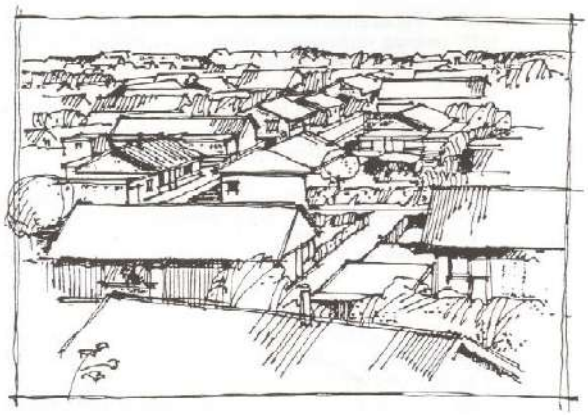
- For the uniform wind load calculations, the expected highest wind velocities are needed.
    - Wind velocity must be set to the highest expected wind gust speed, which is usually 33m/s or 75 mph but can be even higher like 45 m/s in coasts, mountain areas and so.
    - Set the data properly. Try to estimate the real wind which will reach the tree. Consider if the tree stands windward or leeward.
- Using EN1991 wind load evaluations first terrain category should be chosen. These categories refer to the exposition of wind.
    - "City" is the category where there are high buildings around and not all the load of the wind will reach the tree. "Villages" refers to lower surroundings, more load (in similar wind situations). As switching to "Agriculture", "Lakeside" and "Seashore" the surroundings become lower while the wind load increases.
    - Note that according to the description in EN1991 the wind load is calculated for 1, 2 or 6 layers of the tree and their moments are summed up at the end. (This is the reason why entering the crown area manually for EN1991 in the next part is not supported by the software. The software cannot figure out the crown areas in the layers.)
- Base wind velocity is a value recommended by the standard. See the following pages for help.
- Dry air temp. is the temperature of the air in dry conditions. This value effects the calculated wind load.

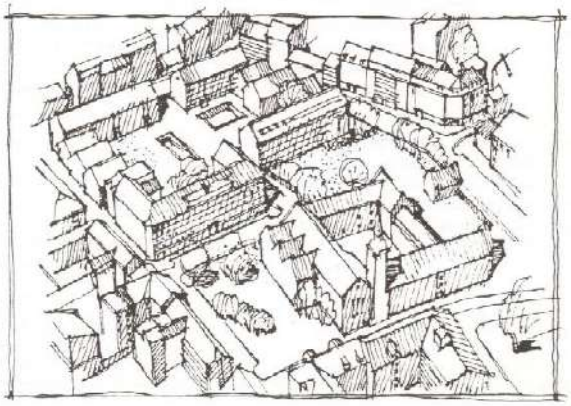


Drawings which can help determining the terrain categories; seashore, lakeside, agriculture, village and city.[1]









[1] S. O. Hansen, Svend Ole Hansen: EN 1991-1-4. Presentation on Common standards to improve competitiveness of construction industry IP/08/259, 19 February 2008; available: https://eurocodes.jrc.ec.europa.eu/doc/WS2008/EN1991_4_Hansen.pdf at 29.03.2019.

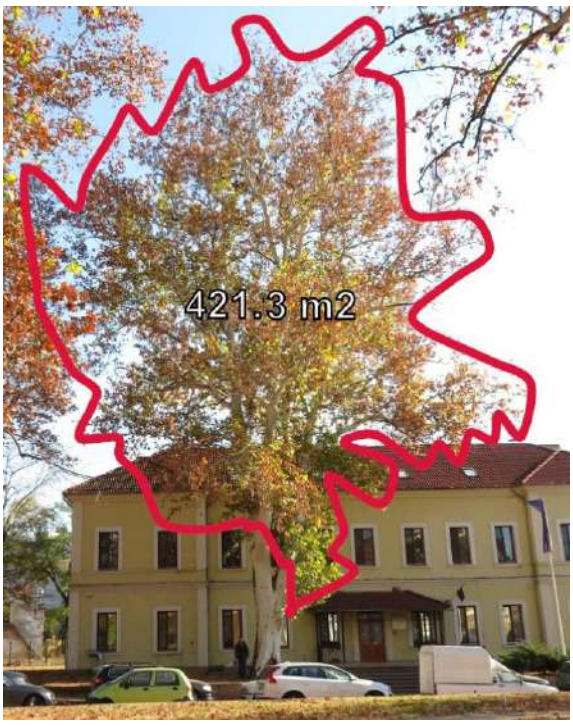
Base wind values in m/s. [2]



[2] S. O. Hansen, Svend Ole Hansen: EN 1991-1-4. Presentation on Common standards to improve competitiveness of construction industry IP/08/259, 19 February 2008; available: https://eurocodes.jrc.ec.europa.eu/doc/WS2008/EN1991_4_Hansen.pdf at 29.03.2019.

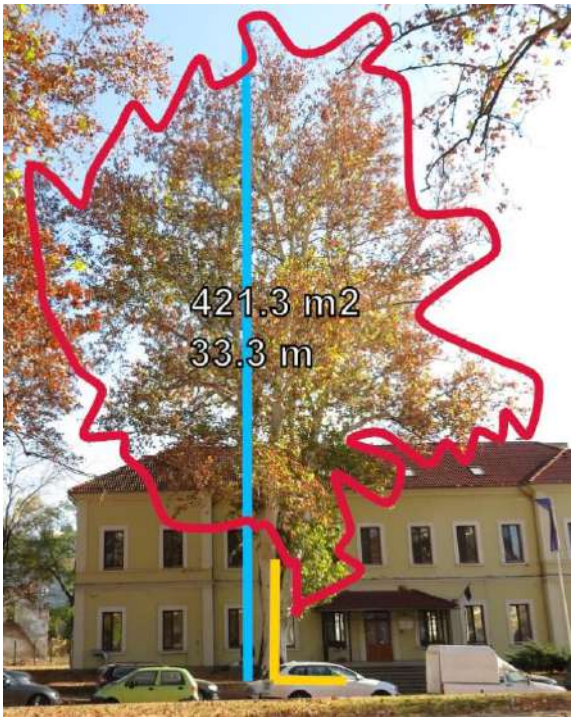
Crown

- The crown should be given for the load calculations. Using UNIFORM wind load model there are three possibilities to enter this data; “Manual”, “Calculator” and “Drawn”. The option “Manual” is available only for the UNIFORM calculations.
    - Choosing “Manual” data entering, the area, top height and center of height and bottom height (where the crown starts) should be given. All these data are needed and influences the calculated safety.
- “Calculator” is available for both models and work similar.
    - Click the  icon. This tool requires the width, height of the crown and a shape factor. The calculated area is simply width times height times factor. Predefined factors can be selected by choosing the assumed crown shape. (Using a custom factor is also possible for the UNIFORM model.)
    - Center of height should be given in UNIFORM model (when using the EN1991 this is automatically calculated from the shape data). This height is the height of the crown’s center, not the center of the whole tree.
    - Bottom height is the height of the bottom of the crown, where the crown starts.
- “Drawn” is the option which uses a photo with the tree. The photo should include the whole tree. It is recommended to take the photo from a distance of at least the height of the tree to avoid distortions. After opening a photo, it is needed to mark the crown area, a reference height and the lean of the trunk.



    - Click the  button in the Image Editor tab under Image Container section and load a photo of the tree. If the tree has substantial inclination, then it is recommended to take the photo from a direction where this inclination can be seen. After loading and selecting the photo you can use the  button to collapse the image container to gain more space on the screen. (Note: that you can enter all the necessary parameters without a photo as well, marking dimensions on a photo is an option to make the process more convenient.)
    - Use the  button to mark the shape of the **crown**. Please mark the area of the crown only. (The area of the trunk will be calculated from the layers diameter and heights by the software.) Click once for each point. Closing the curve and finishing marking can be achieved by clicking the same button again.
    - The reference length can be marked with the  button. Two clicks place a blue line with a “???” text on the line. Click the text to enter the reference length (in meters if using metric system) of this line. This line should mark a person or some reference object on the photo, placed at the distance of the tree. If the height of the tree itself is known, it is better to use it as reference.

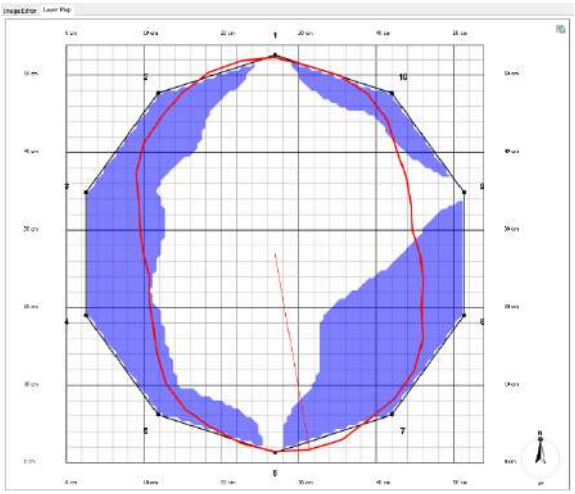
- The button can be used to measure the degree of tilting (lean) of the trunk. It can place a yellow line of two-line segments defined by three points. The middle point marked by a square should be placed **at the bottom of the trunk**, one of the endpoints marked by a circle should point in the direction of the trunk and the other one should point to the horizontal direction. Click the same button again to finish marking. This marks the tilt angle of the tree. (The points can be moved by mouse. If it is impossible to predict the actual tilting from the photo you can modify the data manually. The program usually can handle rotated images as well but be very careful in these cases. It is recommended to rotate the imaged into standing position before opening them in ArborSonic program.)



- Crown area, reference height and direction of trunk should be marked to make the software able to calculate. If any of these are missing, Safety Factor can not be estimated.
- The buttons in the right down corner can be used to zoom in and out the photo, and recolor the image (for example for black and white printing).

Trunk

- The next parameter is the tilt angle which can also be taken from the photo. 90 degrees mean a completely vertical trunk.
- The tilt of the trunk can also be set.
- The direction of lean should be set as well. Tilt direction cannot be taken from the photo and always needs to be provided manually. Choose from the options (North, North East, East,…) or the direction can be given manually with the resolution of 1 degree. Zero degree means North, 90 degrees means East.
- On the top of the right area, next to “Image Editor”, there is the “Layer map” tab. Here a simplified map of the selected layer can be found.
  - The areas where the sound velocity is under the average of minimum and maximum values (see on Tomograms tab, at Velocity limits) are shown as white areas. This refers to damaged, decayed wood which lost its load bearing capacity.
  - Blue color refers to wood capable to hold the loads.



- As the program can not predict from which direction will the wind arrive, the appearing mechanical stresses are calculated for every 5° This is shown as a red contour. The red line from the center to the edge shows the highest stress. (Safety Factor is the estimated for the weakest direction.)
- This image gives informative information about how the stress depends on wind directions.
- Layer maps and stresses are different for the different layers.

Interpretation of the displayed data – Tree, Layers and Details of the selected layer

- Wind load is the force acting on the crown, calculated by the software.
- Center height is a simplification, Uniform model uses this height as the attack height for the wind's force to calculate the load. Similar height is calculated back from the wind load in EN1991 as well.
- Drag factor is the drag coefficient of the crown, taken from the tree species database.
- Yield strength is the yield strength of the trunk wood, also taken from the species database.
- The table lists all the layers. The first column is the name of the layer, the second column is the layer height as provided on the Geometry page. The third column is the Decayed area regarding the cross-sectional area in the given height. It is the percentage of the decayed region of the selected layer compared to the total layer area. Safety Factor is in the fourth column and the fifth column is the Risk Rating.

Safety Factor	below 50%	50% - 100%	100% - 150%	above 150%
Risk Rating	**Extreme Risk**	**High Risk**	**Moderate Risk**	**Low Risk**

- Details of the selected layer shows some more details.
- Avg T/R is the average ratio of the intact wall thickness to the trunk radius. Some scholars recommend that the trunk is safe if this value is above 0.3. However, the Safety Factors doesn't consider this parameter and in this implementation it is shown just as a distinct piece of information. The exact formula is: $AvgT/R = 1 - \sqrt{DecayedAreaRatio}$.
- Tree weight above layer is the estimated total weight of tree that is above the selected layer.
- M is the torque resulting from the wind.
- Max stress is the maximal stress resulting from the torque and mass of the tree, taking into consideration the tomogram.
- Safety factor is the ratio of the wood strength from the species database as shown at YieldStrength and this computed maximal stress. The formula is SF=YieldStress/MaxStress. The rationale behind this approach is that given all the parameters above the software tries to estimate the stress in the wood and if this exceeds the maximum limit the material can resist, then the trunk would break.
- In UNIFORM wind model Safety Factor is calculated for a tree standing alone and exposed to the total effect of wind. Trees standing next to each other, close to buildings, in parks and so on can be protected against wind and the calculated Safety Factor might be lower than real one. Still the tree might be safe. While if the tree stands in a wind tunnel the calculated safety factor can be higher than the real one.
- EN1991 model considers the surroundings as well while calculating the Safety Factor. Experiences show that the Safety Factor calculated by UNIFORM model is usually about the one calculated for Village terrain.

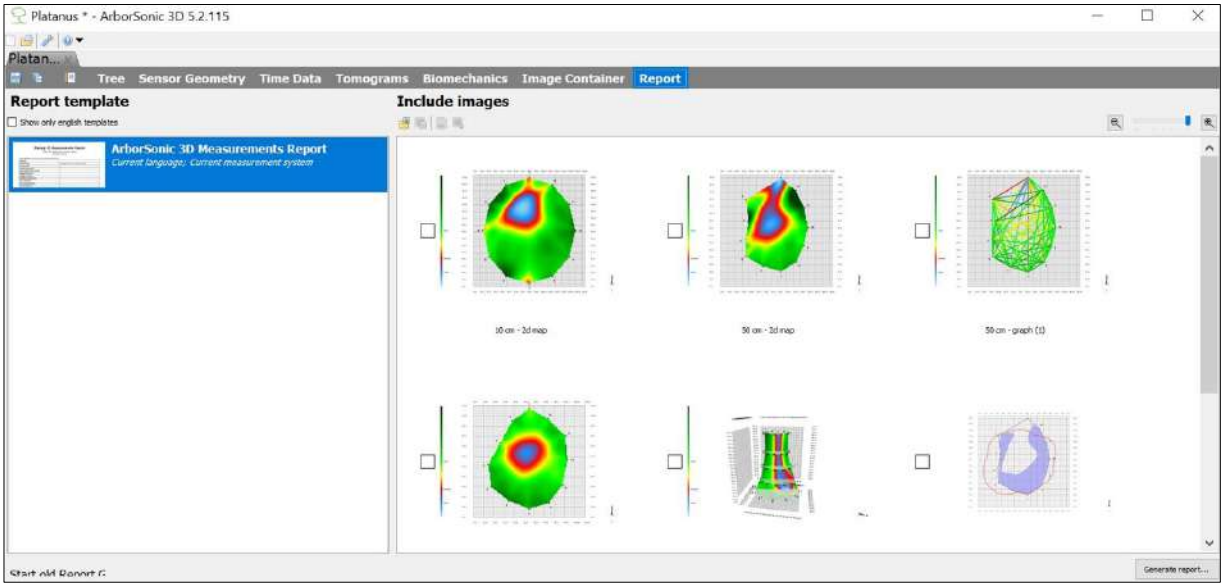
- If the trunk has a tube-like shape and the trunk is split the calculation overestimates the safety factor. The tree may even be extremely unsafe, and the cut can be necessary.
- The software takes the minimum of all the safety factors and displays it at the bottom. A tree might be considered safe if Safety Factor is above 150%, using an additional 50% for overestimation. In this case the text appears in green. Otherwise, if the value is between 100% and 150%, the tree is in the gray zone and the text is shown as light yellow. If the value of below 100%, the tree might be considered unsafe and the text is shown as red. The weakest layer can be seen in the list where the corresponding safety factor is the lowest.
- WARNING! Special care needs to be taken at all times. Although the software tries to overestimate the risks, the computation of the safety factor contains simplifications and even the input data might be disrupted. You are solely responsible for ensuring that the System is appropriate for the use you put it to, and you understand that is only one part of what is needed to assess the health of trees and similar green assets. Please understand that the System is just one tool to be used, along with your experience and training in assessing these living organisms, that the System cannot be relied upon as the sole source of evaluations, and that all hardware and software is subject to failure or misuse.

Software – Image Container

- The image container is the place where the images are stored. This is to where you can export your tomograms from any view in the software with the  button and these will be exported later into the generated report. This is the same container as the one you can access from the Biomechanics page.
- You can open an external image with the  button and export an image from this container to an external file with the  button. The  button can be used to remove an image from the container.
- Use the,  buttons (or the slider between them) to change what size the images are shown at. This does not change however the actual size of the images.
- Clicking the title of an image or using  button allows you to change it.

Software – Generating reports

- The built-in report generator makes creating reports for customers quick and easy.
- Go to the Report page, select a report template and the list of images you wish to include in the report and that's is. By clicking the Generate report… button, the report will be created in .docx format which is ready to be further edited or it can be printed immediately.



ArborSonic 3D Android Application

Basics

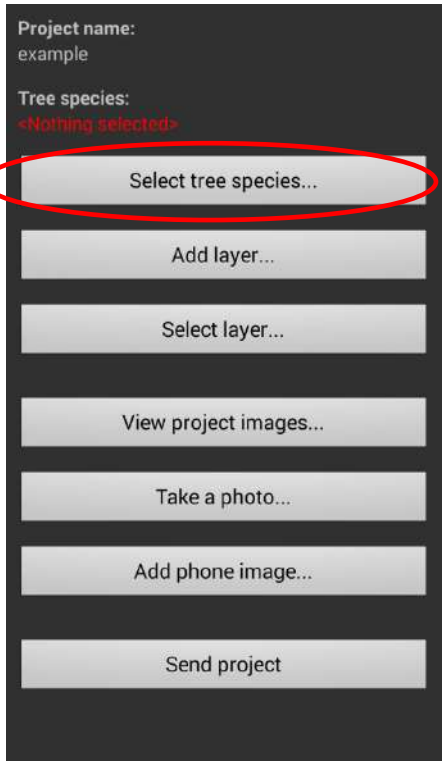
- An Android application version of the ArborSonic 3D program is available in the Google Play Store. You can download and install it for free. After installation you can find the ArborSonic 3D icon.

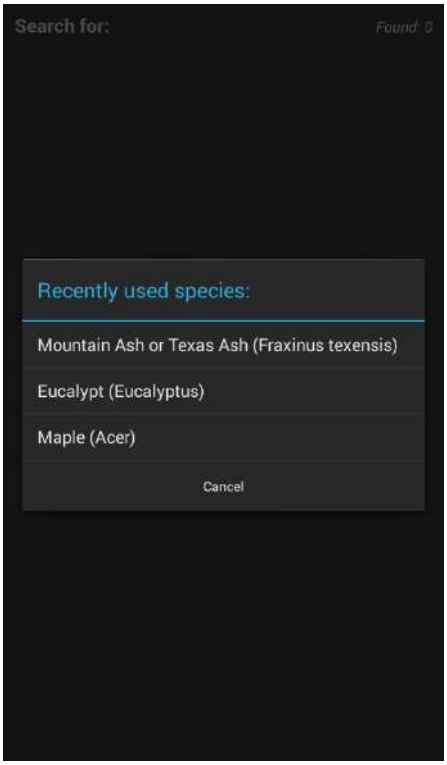


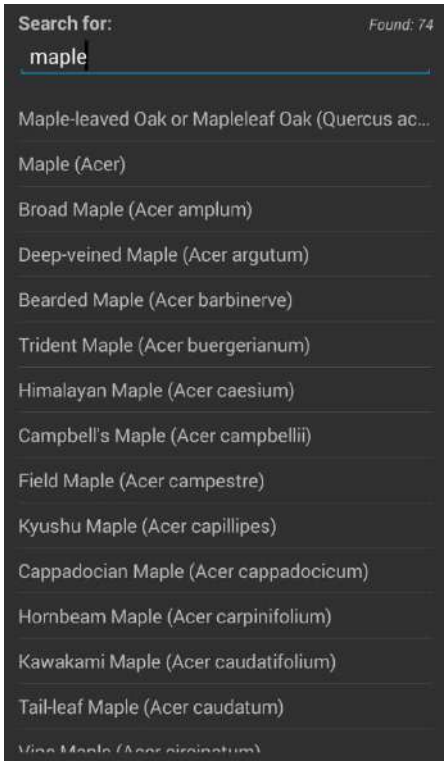
  - Measurements can be performed by the application and photos can be added to the project. The 2D tomogram of the layer can be previewed as well.
  - 3D model, biomechanical analysis and report generation works only in ArborSonic software for PC.
  - On the main screen you can select from "New project…", "Load project…", "Settings…" and "Show online manual…"
- At "Settings" you can choose the language (English, German and Hungarian are available), set an e-mail address (this is where the program will send the projects), open the folder of the program (if it is supported by your phone) and send log files, which can help us resolve any issues you might have..

Measuring

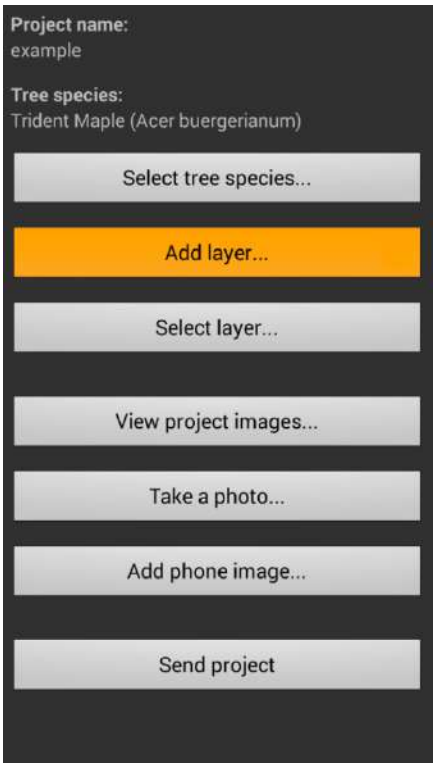
- If you start a new measurement with “New project…”, you have to name the project first. You will not be able to change this name in the ArborSonic application. (You can rename the project in your file manager or on your computer if it is needed.)
- The species of the tree must be selected.

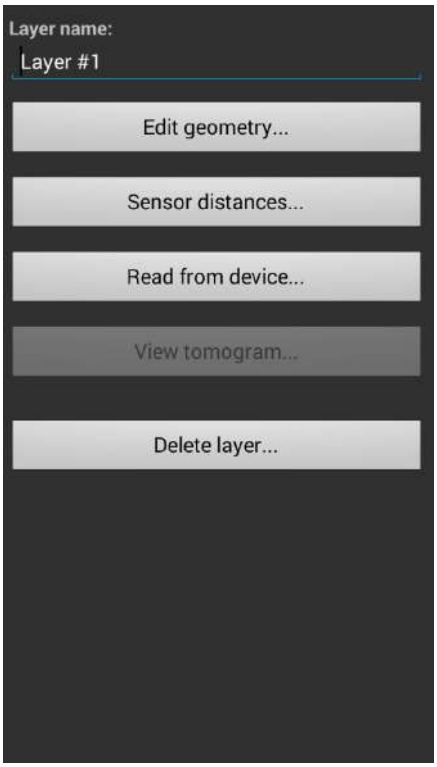


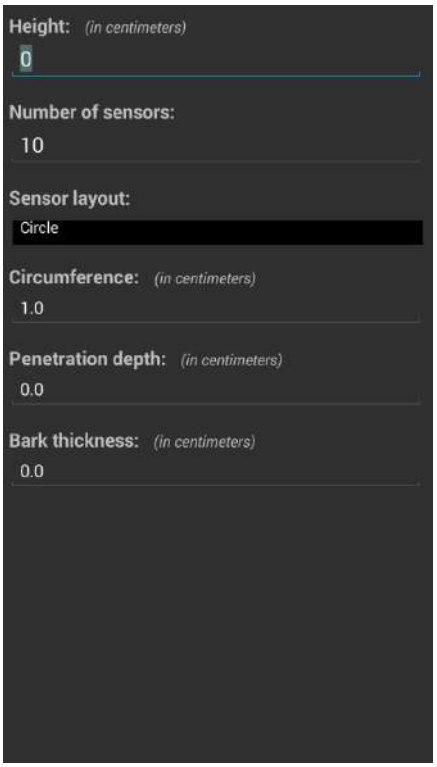




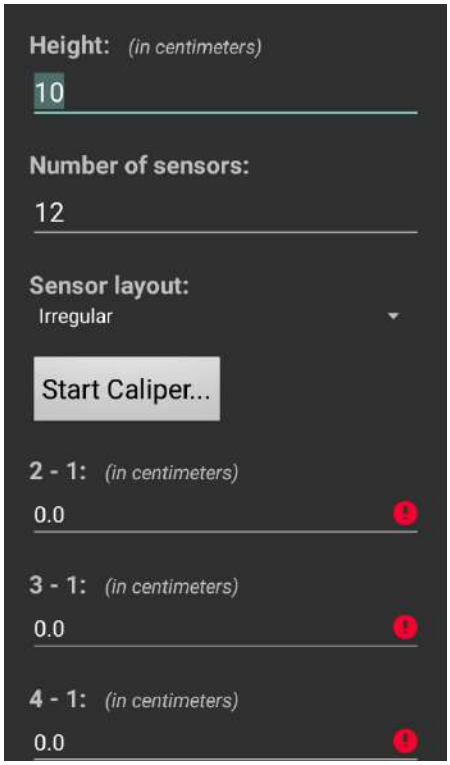
- The list of the recently used species pops up. If the list does not include the species you need, push “Cancel” and search for the proper one. Select it and the application returns to the project page.

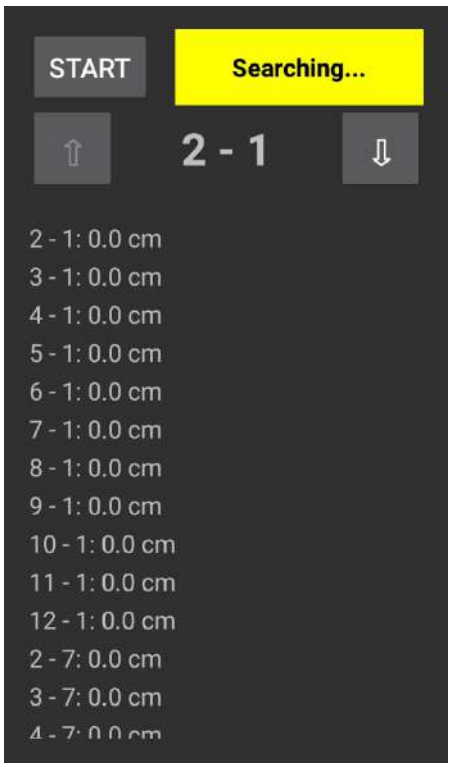


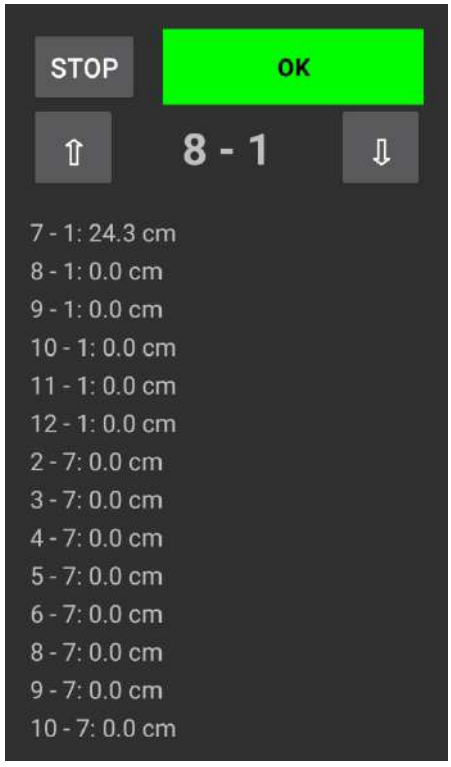




- The species appears on the top. Now you can add a layer. You can name the layer or just leave it as Layer #1 (the app automatically counts the layers).
- Editing geometry is similar to the PC software's geometry page. Here you can give the details of the layer.
    - The height of it in centimeters, the number of used sensors.
    - The layout of the sensors can be circular, elliptic and irregular (rectangular geometry is not available in the application).
        - Using circular geometry, the required data is circumference (in cm)
        - If you choose ellipse, the required data are D1 (major axis), D2 (minor axis) and circumference, all in centimeters
        - In case of irregular geometry, first place the sensors to the selected positions. Then fill the distances of the proper sensors (depending on the number of used sensors). The Bluetooth Caliper is integrated into the application.
            - Push "Start Caliper…" and start the caliper as well by pushing the yellow button on the right arm of the caliper. Push "Start" and pair the caliper with your phone.
            - Push the yellow button on the caliper a few times. Your phone will read aloud the next distance to measure, and it will appear on the top of the screen as well.
            - Push the yellow button on the arm of the caliper when you are in the proper position. Measure the next sensor pair, once notified. Continue until you finish with the last pair of sensors, and then push "Stop" to return to the geometry of the layer.

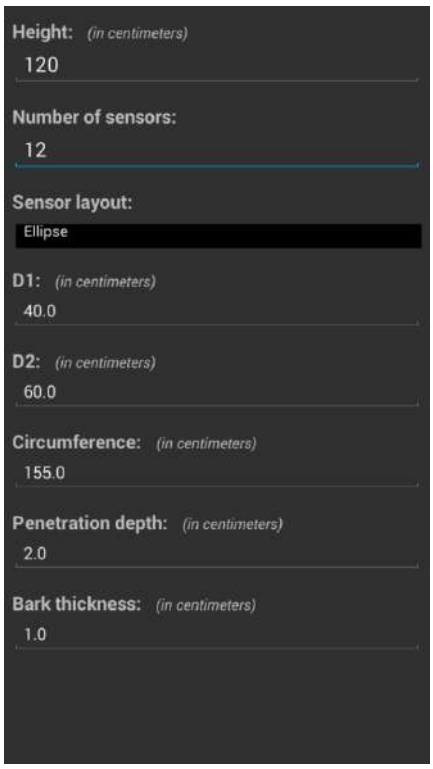


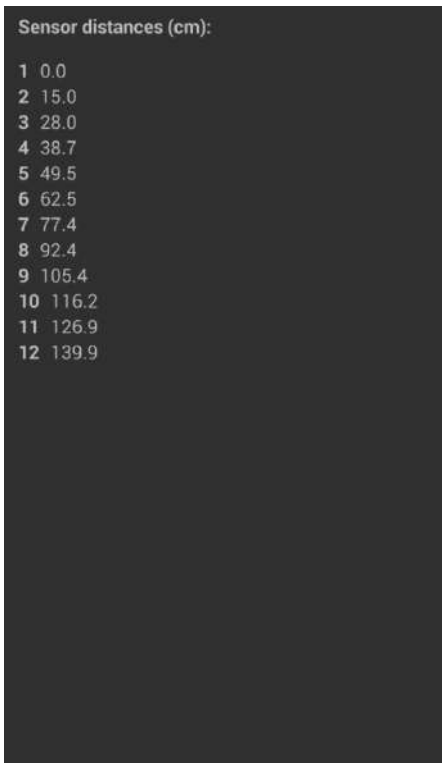




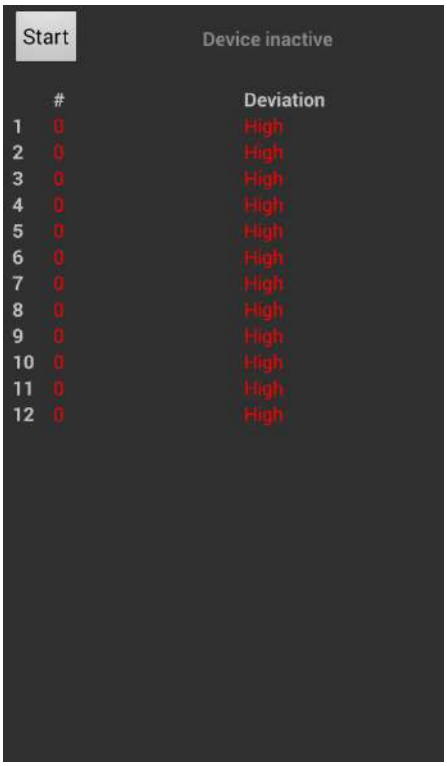
    - Penetration depth (how deep the sensors penetrated) and bark thickness are of course unaffected by the layout of the sensors.

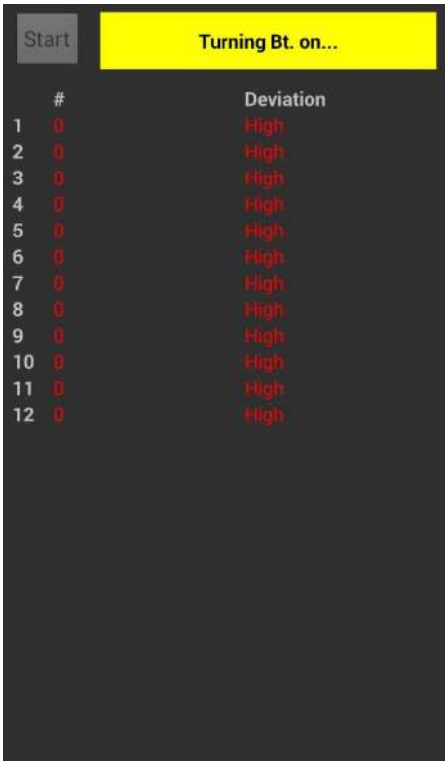
- Using circular or elliptical geometry the sensors' positions can be seen if you go back to the layer's page and select "Sensor distances…"

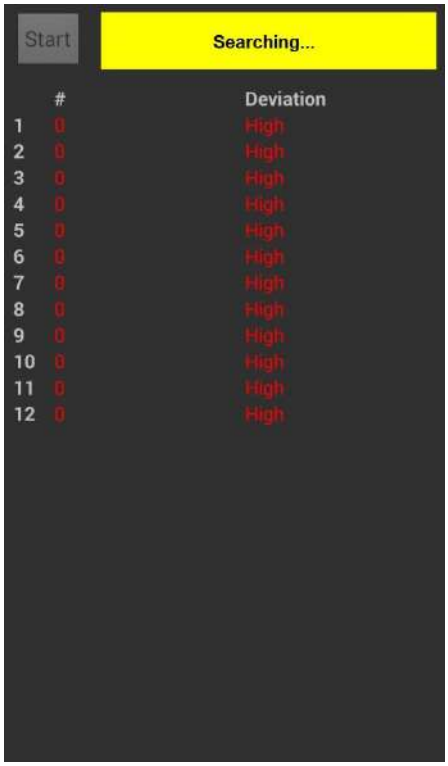




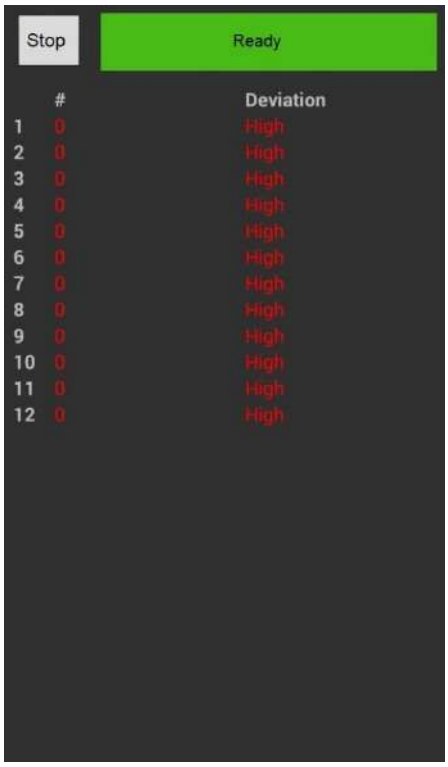
- Please place the sensors to the proper positions.
- When you are ready, turn the Battery Box on and turn on Bluetooth on your phone as well. Pair ArborSonic 3D to your device.
- Go to "Read from device…" on the layer's page.

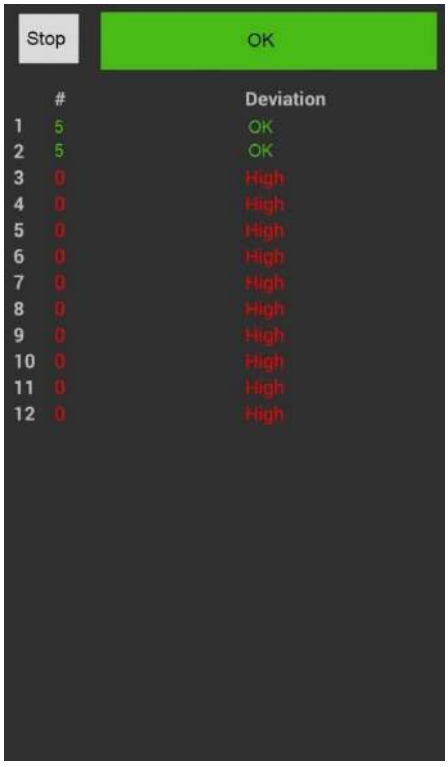


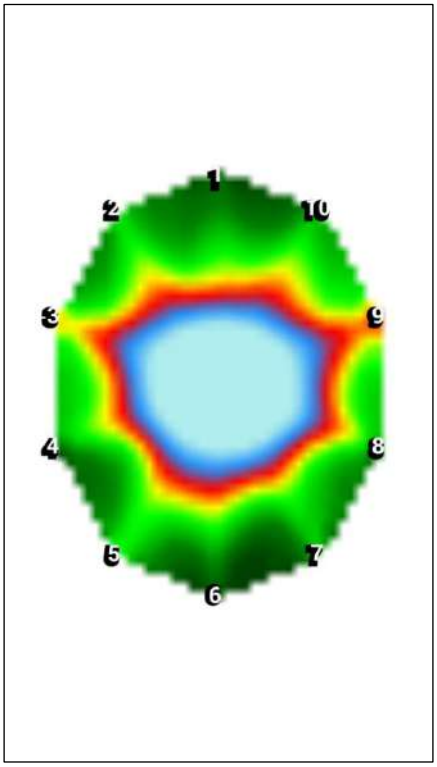




- Push start and wait until the searching and pairing progress is finished. You may be asked by the application which Bluetooth device to pair to. Select ArborSonic 3D.
- A green area with “OK” appears when the connection is established.
- The device is ready for measuring. Please grab the hammer and hit the sensors for measuring. You can check if your hit was the successful.





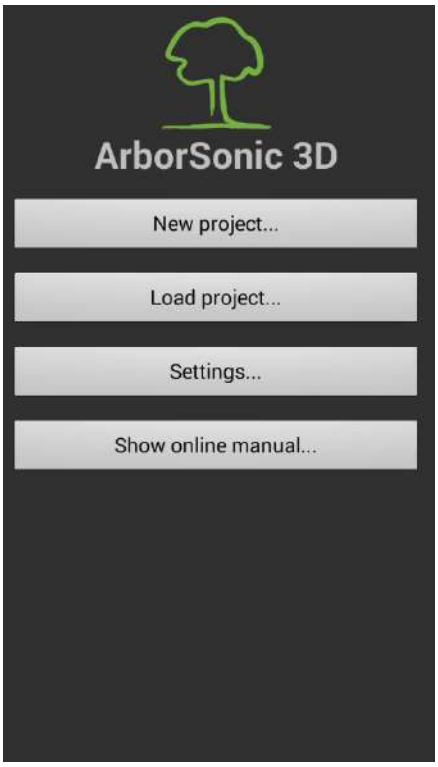


- Collect data form all the sensors.
- Sometimes Deviation stays high for one or a few sensors. You can hit these sensors a few more times but deviation probably will stay high. It is not a serious problem if only one of a few sensors are involved.
- When you have collected at least 3 data from all the sensors, you can go back to the layer’s page and check the tomogram. The calculation takes a little time, but you can follow the progress.

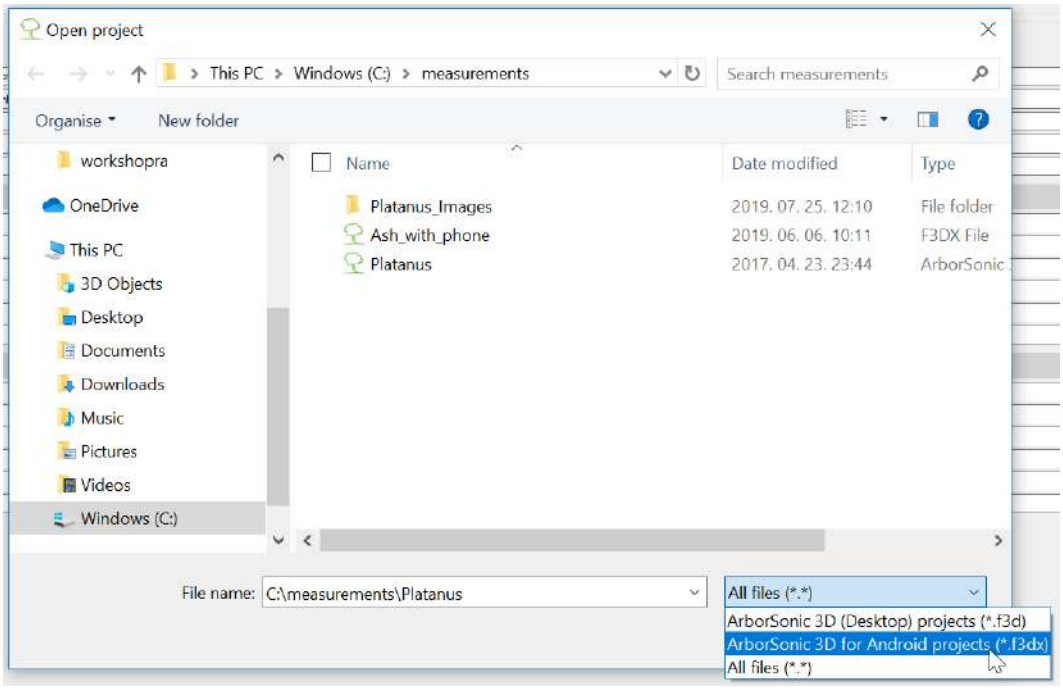


- The tomogram is similar to the tomogram you can see in ArborSonic 3D PC software when you use color scheme “Detailed”. Healthy parts are presented with the shades of green.
- Data is saved automatically by the application. File name is identical with the project name.
- You can also delete a layer.
- If you measure several layers of the same tree, add them to the same project.
- Photo also can be added to a project on the main page of the project by “Take a photo…” (your camera will be opened and you can make a photo) or by “Add phone image…” if you already have a photo from the measured tree.
- The photo should include the whole tree. It is recommended to take the photo from a distance of at least the height of the tree to avoid perspective distortion.
- You can check and delete the photos in “View project images…” page.
- These images can be used by the ArborSonic PC software for further analysis.

Others



- The ArborSonic application saves the data as .f3dx files. These are different from the .f3d files used by the PC software while they contain similar information.
- If you return to the main menu you can load a project as well. You can choose from all the previous projects.
    - A project page opens with the same options as with new projects. You can continue measuring on the same tree.
    - It is recommended to save all the layers of the same tree into the same project.
- Note that if you measure again on the same layer the previously measured data will be lost.
- To be able to open the projects in ArborSonic PC software, you have to send or copy the files to your PC.
    - "Send project" attaches the current project to an e-mail and sends it from your phone to the e-mail address set in "Settings…". The email will be sent using the email app of your phone (e.g. GMail, Viber, ... etc.).
    - Files may be copied directly to your computer via USB connection. This option is not available for all smart phones and different models can have different ways of enabling it. Please read the manual of your phone for more information.
- For opening the .f3dx files in the PC software you may have to switch the file format in the "Open project" window.
- Once opened, you can work with .f3dx files similarly to how you would with .f3d files.



Testing and troubleshooting

This chapter describes how to test your equipment. Please read this chapter carefully if you did not use your device for more than 3 months and you are planning to go to the field.

The most common troubles, errors and misuses are also described with the most probable solutions.

Testing before going to the field

- Please check if the battery is well charged. The Bluetooth connection needs much charge. (Sometimes even new and unused batteries don’t have enough charge.)
- Hammer two sensors to any piece of wood if it is possible. No tree is needed only a piece of wood.
- Connect the two sensors to one Amplifier Box and connect it to the Battery Box.
- Start the program on your computer and turn on the Battery Box.
- Check the COM port connection (as in the chapter Hardware – Bluetooth and serial connections).
- Go to the Time Data tab of the program and hit one of the sensors. If time data is arriving, these parts of the device are ready to work.
- If you cannot find any piece of wood, you can gently tap the sensor nails to each other and see if you get any new row on the Time Data tab.
- You may check all the Amplifier Boxes and sensors.
- The best is to have a tree nearby (in a garden or park) or a testing log and make a whole measurement similar to measurements done on field.

Most common troubles and solutions

Trouble	Solution
Battery Box is not turning on.	Check the battery, charge or replace it with a new and/or charged one. Switch on and off the unit several times. (It is recommended to turn off the battery after each measurement and turn it on only for the duration of the measurement.)
There is no signal from one sensor or sensor pair.	Check the cables and their orientations.
There is no signal after hitting any sensor.	Check if you are using the proper COM port. Check the Battery Box. Check the serial cable if you are using cable connection. If you are using Bluetooth check if the Battery Box is shielded by the tree. If the Battery Box cannot see the computer / smartphone relocate the computer, the phone or the Battery Box. (You can connect the Battery Box to any Amplifier Box, just be sure that all other Amplifier Boxes are connected to their neighbors.) If you have used cable connection try it via Bluetooth. If you have used Bluetooth try it with cable connection.
There is the green “Reading device (COM__)” on the Time Data tab, but there is no data coming from any of the sensors.	Please check if you are connected to right COM port. (See sub-chapter “Selecting COM port” for more information.)
 Time row without ‘zero’.	It is just a bad measurement row. You can delete it by “Remove bad rows” or leave it there (the calculation will not use these data). You may have to hit some sensors again.



Time row with 28 or 29 if
the tree's diameter is above 30 cm
and the sensors are more than 3 cm-s from each other.

If the sensors are too close to each other (less than 3 cm) this time data can be realistic.

Otherwise, when a time value is 28 or 29, this may refer to noise in the system. Such rows should be deleted, and you may have to hit some sensors again. If the issue persists after repeated tests, then the Amplifier Box may be faulty. Please contact Fakopp Enterprise, or your local dealer, about the issue.

‘ -1 ‘ appears in the time row.

-1 is indicating that no signal has arrived from the sensor. It indicates battery, virtual channel, sensor or Amplifier Box trouble. (If all the cables are connected properly.)

First please check the battery voltage on Time Data tab on the right side of the green are. If the voltage is lower than 8 V please charge the battery or replace the battery with a proper one. Next you may check the if the virtual channels are defined correctly. (Go to Application Options / Reader Device / Reader configurations.) If battery and channel problems are out of question, please follow these steps.

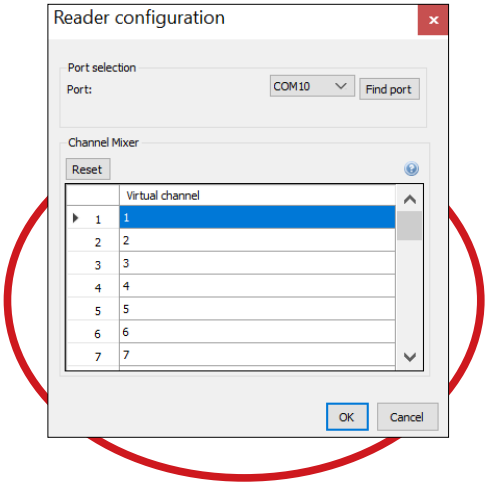
1) Deciding if there is a problem with a sensor or an Amplifier Box.

1.1) Shift the Amplifier Boxes (for example replace each of them with the one used to be on their right)
1.2) Hit a sensor or several sensors to check if the -1 stays at same place or not.
If the -1 stood at same position the problem may be with the Amplifier Box.
If the -1 appears in another column then the problem may be with that sensor.

2.) Continuing / finishing measurements

If you would like to continue / finish the measurement, you have to go on with a reduced number of Amplifier Boxes and sensors.

Renewing the sensor geometry (and replacing the sensors) is necessary.



2.1.) If there was a problem with an Amplifier Box, look for the number of the column in which the -1 appeared. Look for the Amplifier Box with that number (all Amplifier Boxes have 2 numbers on them referring the 2 sensors they are connected to). Disconnect the wrong Amplifier Box. Open Application Options go to Reader Device tab and click onto  for Reader configurations. Here at Channel Mixer you can change the Virtual channels (the channels known by the program) of the physical ones. For example, if the Amplifier Box 3-4 is wrong set 1 to 1, 2 to 2, 3 to for example 31, 4 to for example 32 (higher than the sensor count you will use), 5 to 3, 6 to 4 and so.
When you set the acting Amplifier Boxes be very careful about their positions because the numbering is shifted.

2.2) If there was a problem with a sensor, disconnect and remove the last Amplifier Box. In this way you have extra 2 sensors. Replace the bad sensor with a good one. (The sensors are identical, numbers are decorations only.)

3) Long-term solution

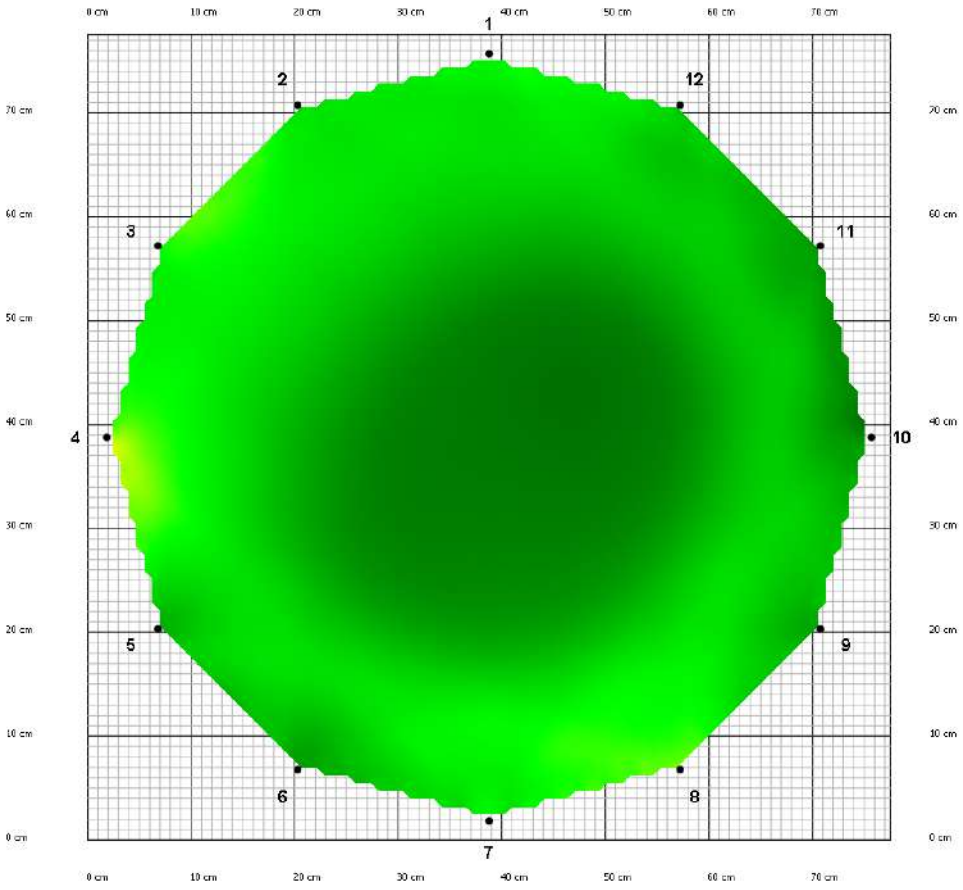
3.1.) If there was a problem with an Amplifier Box, please contact Fakopp company or our dealer in your area.

3.2) If there was a problem with a sensor you may replace the BNC connection on the end. It helps in most of the cases. Otherwise please contact Fakopp company or our dealer in your area.

Common setup issues illustrated with resulting tomograms

Device setup or program setting can cause strange tomograms. We collected the most typical cases. Note that some of the strange tomograms CAN refer to real decayed, damaged situations as well. The errors demonstrated were measured on a healthy tree and may look different on decayed trees.

A correct measurement looks like this:

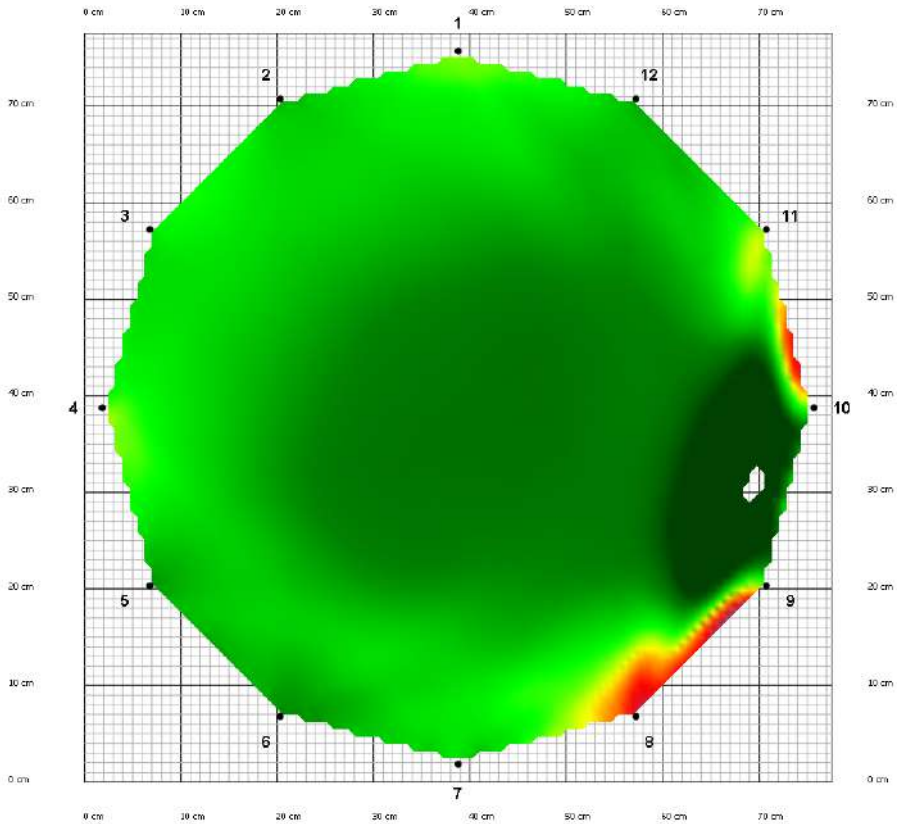


Interchanged cables





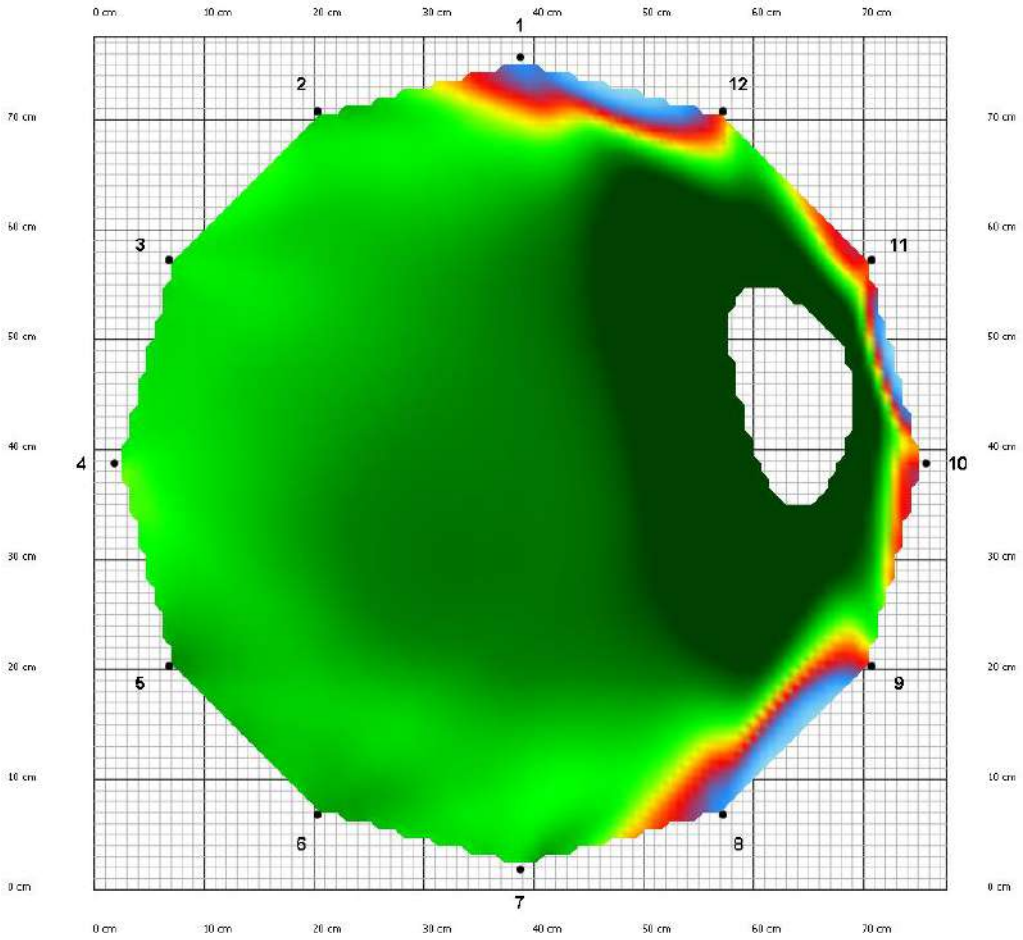
As the sensor in the ninth position's cable was connected to the tenth connection on the Amplifier Box and the sensor in the tenth position was connected to the ninth connection. The tomogram contains a hole and red side areas.



Interchanged Amplifier Boxes



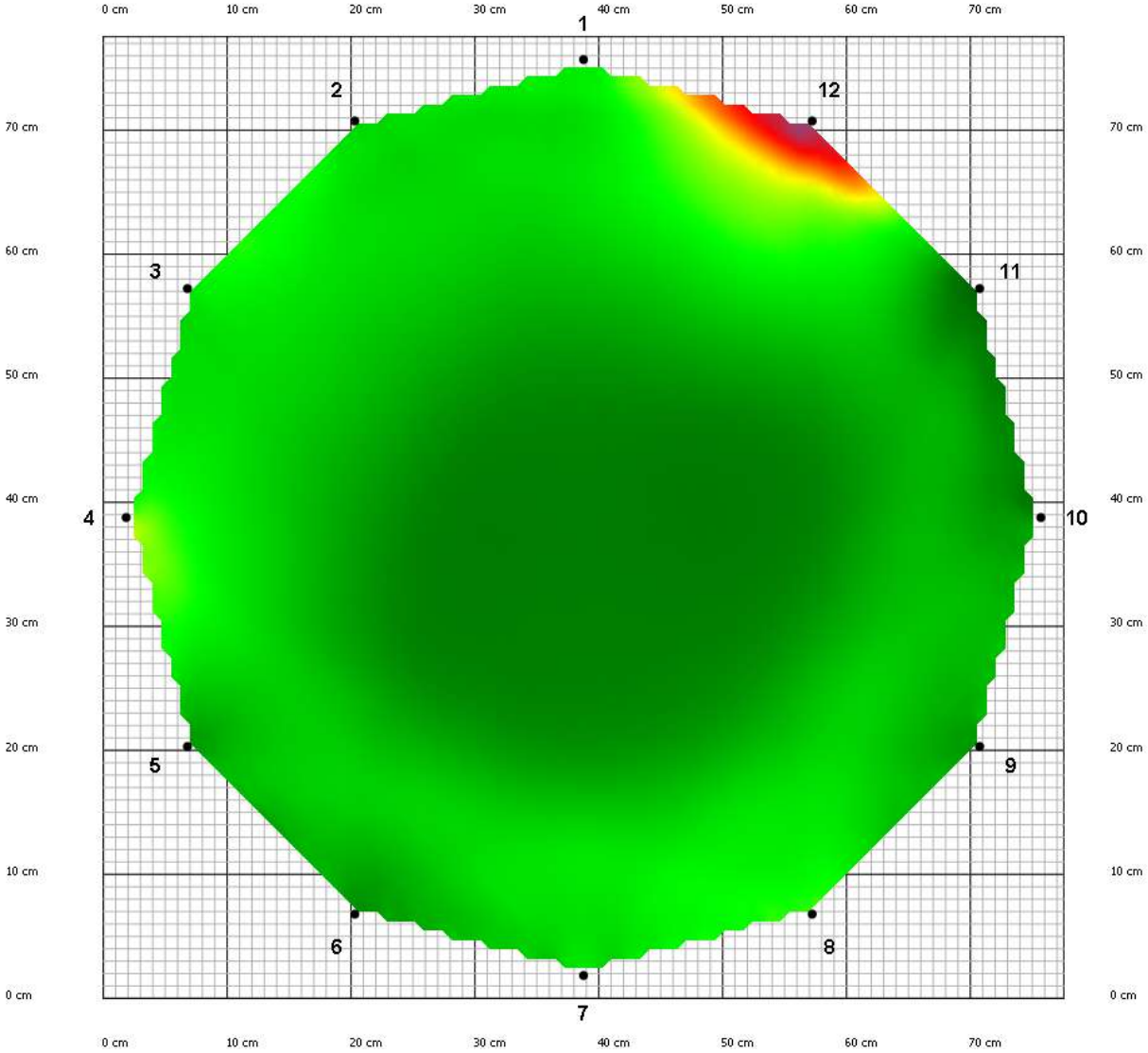
The Amplifier Box for sensors 9 and 10 was exchanged with the Amplifier Box for sensors 11 and 12. The tomogram has a hole and strange areas on the side.



A loose sensor

Sensor 12 didn't penetrate through the bark. The sensor was very loose.
A damage-like area appears on the tomogram.
Note that a tomogram like this could also indicate decay or other issues.

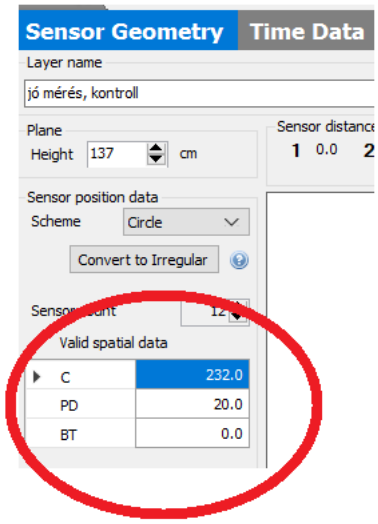


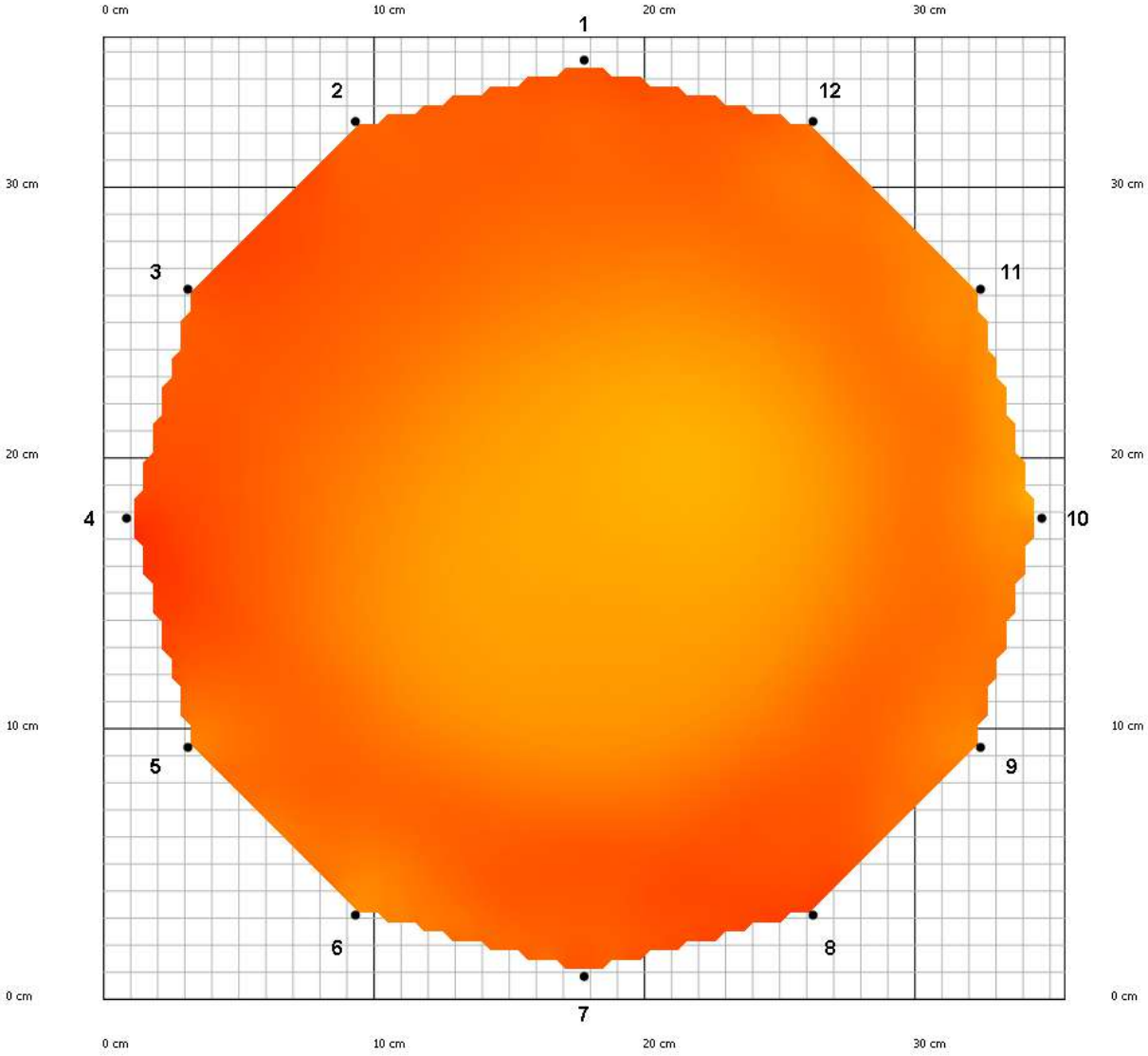


Extreme penetration depth

The penetration depth was set to 20 cm instead of 2 cm.

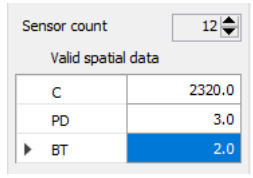
Even the tomogram of a healthy tree looks like if it was all decayed.

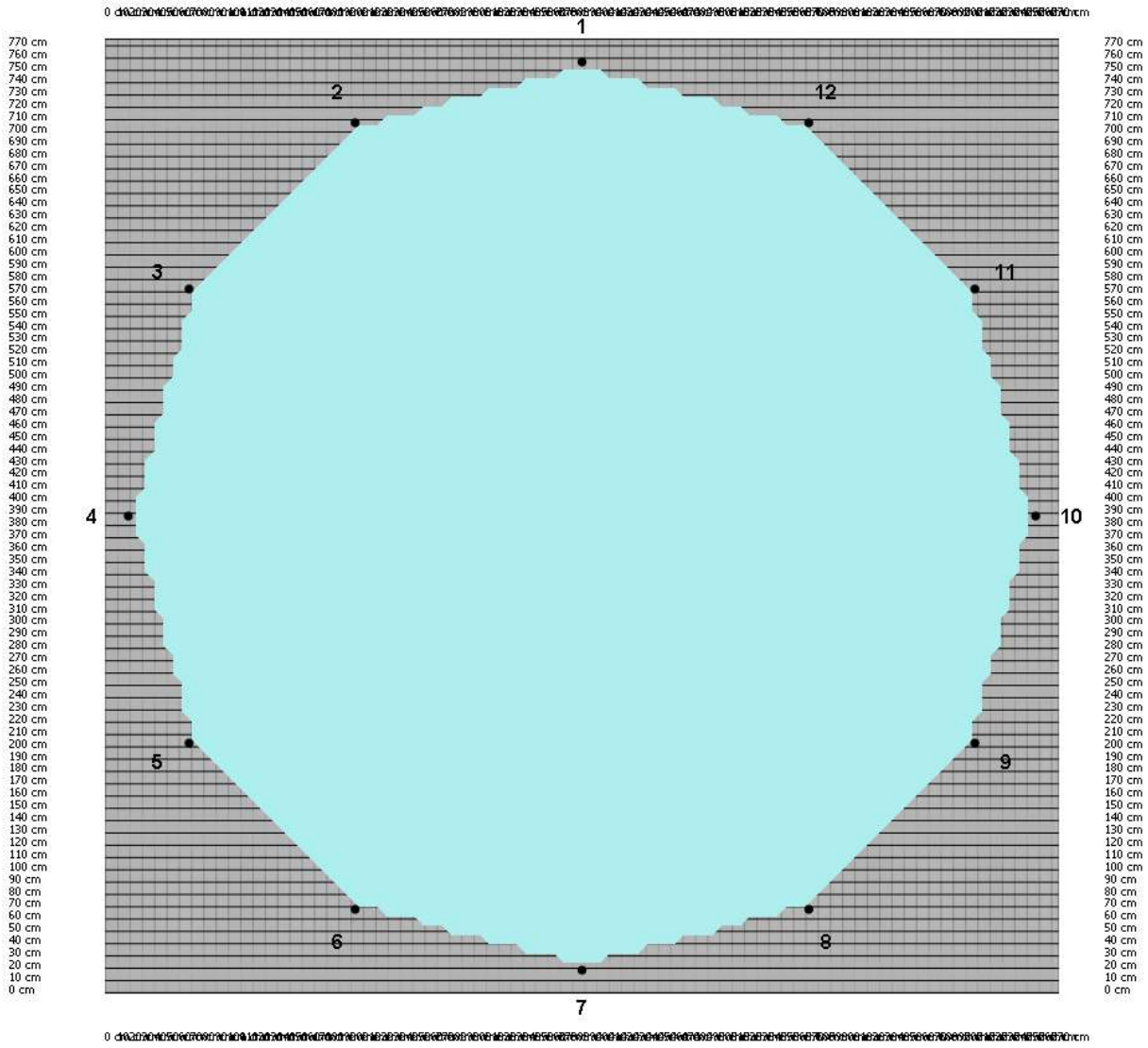




Extreme circumference

The circumference was set to 2320 instead of 232 cm.
The tomogram becomes light blue while the values on the axes become high.



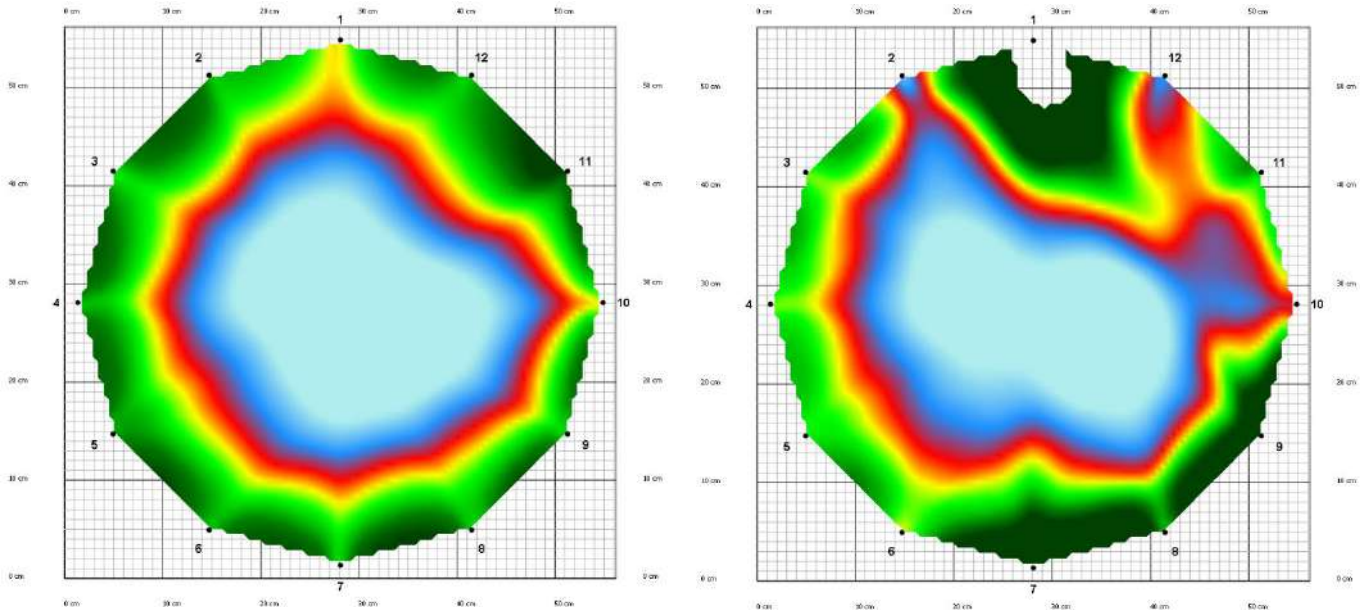


Tape measure left on tree

In this case an acoustic shortcut can appear. This trouble was measured on a decayed tree to highlight the differences.



Measurement without tape measure (left) and with tape measure (right).



The image of the decayed are is screwed-up and it can even contain a hole.

Advice and safety regulations

Be aware, the sensors' tips are pointed.

Clean the device after measurement. Sterilize the sensors if there is a risk of infection.

Check the batteries before going to the field.

Do not break the cables, sensors, boxes, any part of the device.

Take care of your fingers, toes,… while placing the sensors onto the tree and during measuring, hitting the sensors with the hammers.

Fix the sensors with the rubber hammer and generate sound signals for measurement with the steel hammer.

Do not start acoustic and resistivity measurements at the same time on the same tree.

If you expect to measure trees with elliptic or irregular trunk shape, it is recommended to bring a caliper as well.

Do not use the acoustic tomograph if the temperature is below 0 °C / 32 °F or more than 40 °C / 100 °F.

Do not use the device in heavy storms, raining or in foggy conditions.

Bringing a folding table with yourself to the measurement is recommended for holding the computer.

This device is for measuring living trees and some wooden structures. Do not use it for any other purpose.

Do not open the amplifier boxes or the sensors. If there is a problem with the device, please contact us. Opening the parts cancels all guarantee.

The device includes sensitive parts as well, do not drop it, step onto it, put it under water. (Sensors specialized for underwater measurements are available.)

Always save the data after the measurement.

Maintenance

Keep the device in a dry place in room temperature.

If you have to clean it, please use a lightly wet towel.

If resin got to the sensors you can clean them with benzine. Take care of the handling of the chemical.

If any of the parts are broken please contact us.

It is recommended to switch off the device after measurement.

Do not break the cables and keep them coiled up to avoid tangle.

FAKOPP

LONGNAILS APPENDIX



Longnails

Introduction

This appendix is for the users of ArborSonic 3D who measure with the long nailed sensors. Normal sensors have 6 cm / 2.36 inch nails which are suitable for the most of the tree species, where the nails can reach the wood material. However, some species have thicker barks and longer nails are needed. The longer nails are 12 cm / 4.72 inch long.

Regarding the most of the usage the long nailed sensors can be handled similar to the normal ones. This appendix contains and highlights only the cases when there is a difference.

Hardware

The maintenance, fixing, measuring and removing are the same as for the normal nailed sensors. Amplifier and Battery boxes are the same as are the cables.

Please do not mix normal and long nailed sensors for the same measurement.

The case is higher (and little heavier) to have enough space for the long nails to fit in.

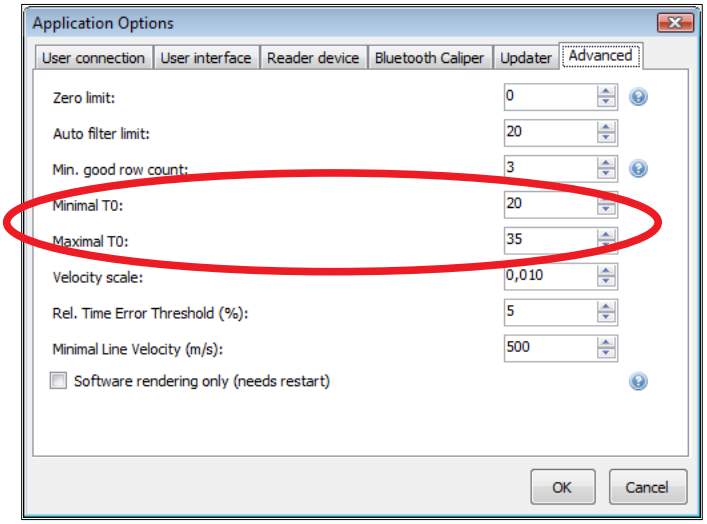


For measuring the proper acoustic signals, the nail has to go through the bark and reach the wood material. You may have to hammer the sensors 10-11 cm deep.

Software – Application Options

The ArborSonic3D program can handle the long nailed sensors as well, there is no need for other software. Some time corrections HAVE to be changed according to the fact that the sound signal travels in the nail for a longer time.

Open Application Options with button on the left top of the program window. Go the Advanced tab.



Minimal T0 and the Maximal T0 values are time correction parameters for calculation of the tomograms.

Change Minimal T0 to 45 and Maximal T0 to 60.

(The default values are 20 and 35, these should be used when measurements are done with normal, 6 cm nails.)

The program remembers these parameters. You should set these parameters only once if you don't switch between normal and long nailed sensors. If you use different nails for different measurements, you should always change these parameters.

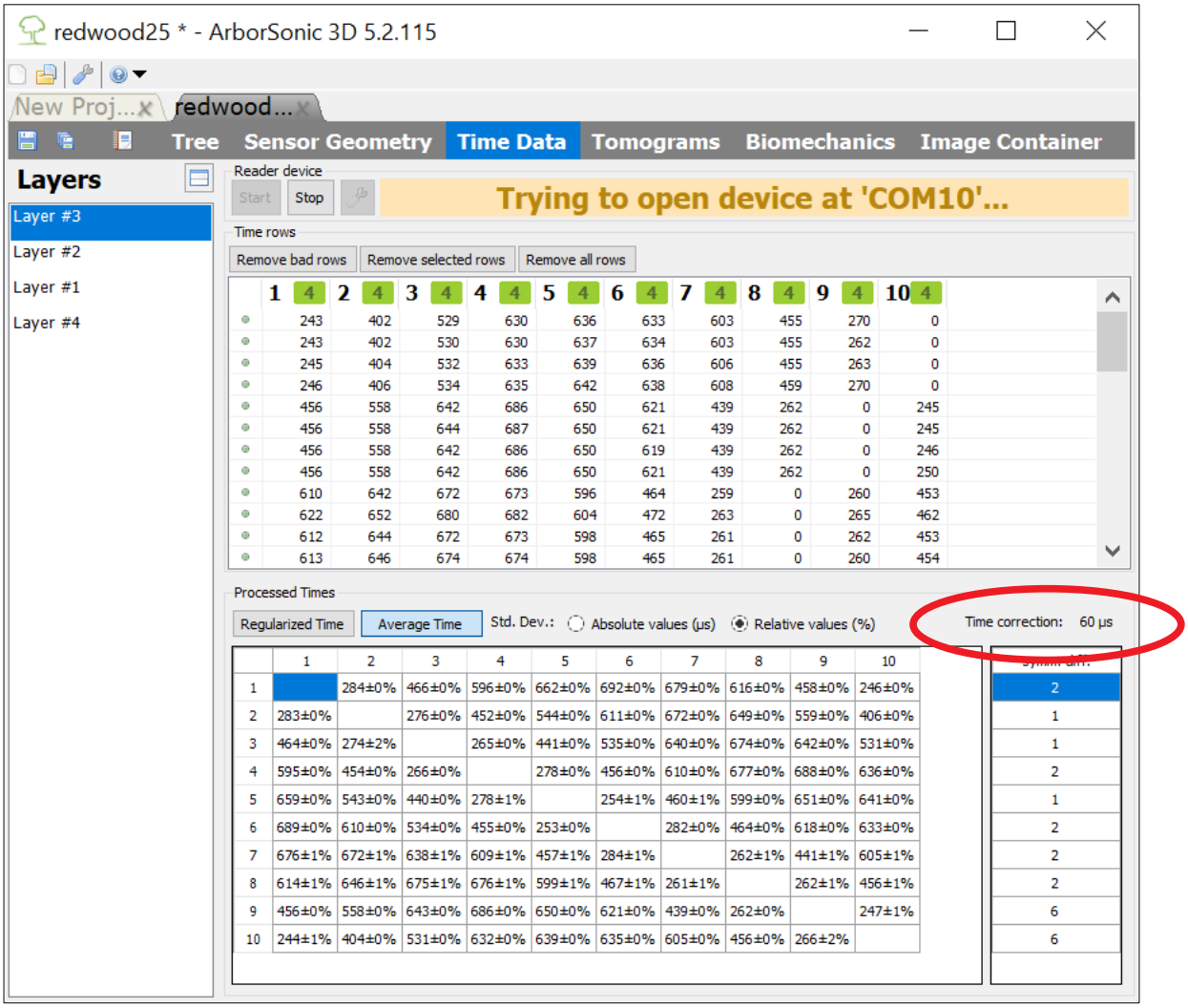
The program is installed with the default values and if you open your (long nailed) measurement on a different computer the calculated data and safety evaluation can be different.

Software – Time data

The program calculates the tomograms after measuring. The program always recalculates the tomograms from the saved time data when opening an .f3d file. Recalculation happens only during the opening but not after changing Minimal or Maximal T0.

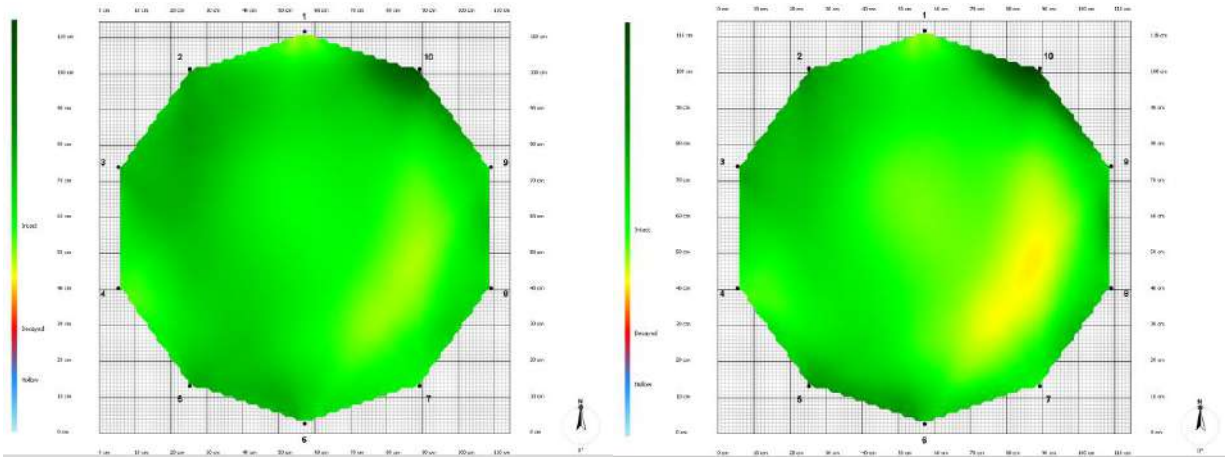
Reopening the .f3d file is necessary if the Minimal and/or Maximal T0 were not at the proper values.

You can check the used time correction on Time Data tab. When long nails are used it is usually around 60µs. If the time correction is around 30µs you may check the Minimal and Maximal T0 values.



Software – Tomograms and Biomechanics

The calculated tomograms are different according to the time correction used.



Tomograms for redwood (measured with long nails) calculated with min T0 20 and max T0 35 on the left, min T0 45 and max T0 60 on the right.

Using wrong time corrections lead to false tomograms. (In the example above the tomogram on the left shows less decay there actually is.)

As the extent of the decayed area and the rating of the decay are different in these cases the safety calculations on the Biomechanics tab will be different as well.

(Similar effects appear if a normal spiked measurement is calculated with wrong time correction.)

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LUDWIG SENSORS APPENDIX



Ludwig Sensors

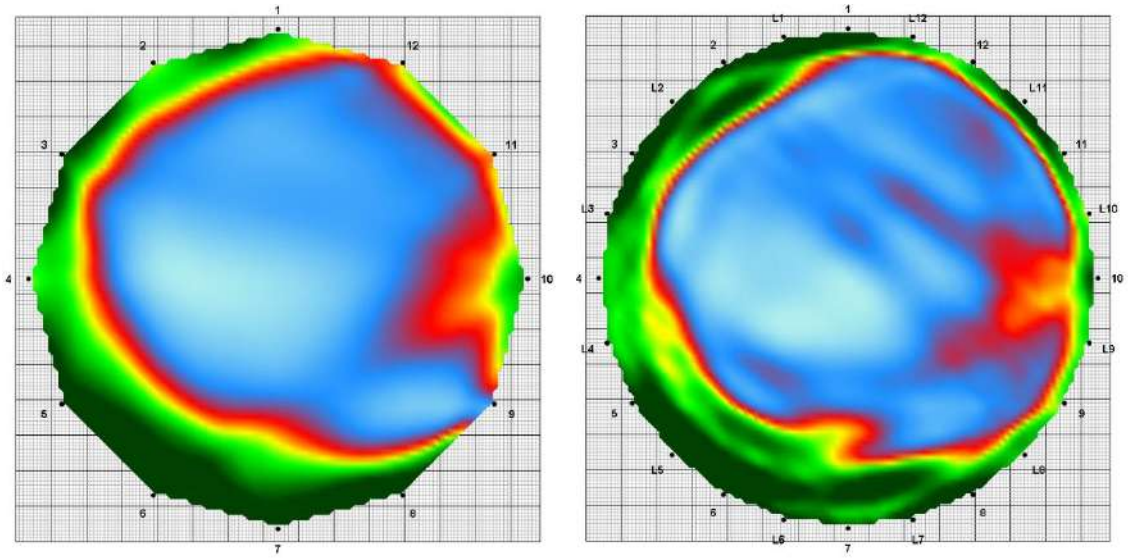
Introduction



Ludwig sensors

- make more detailed measurements
- let you enter more precise geometry
- provide tomograms closer to the real situation

This appendix is for the users of ArborSonic 3D who measure with Ludwig sensors. Ludwig "sensors" are nails without sensors. They can be hit like sensors, making them signal sources, but they can not receive any signal. (They are "deaf", still making perfect sounds.) Using Ludwig sensors can show a more accurate picture of the selected layer (if the number of sensors was not changed).



Same measurement with sensors only and with Ludwig sensors as well.



On the geometry page, there is a checkbox under the number of sensors. If you check it, Ludwig sensors are added to geometry and they behave like extra sensors. Going on to Time data, normal sensors should be measured like during a usual measurement. After the sensors, the Ludwig sensors should be measured in order (L1, L2, L3…).

The tomogram is calculated by the program and can be used for biomechanical calculations or for reports and so on. The steps are detailed in the chapters of this appendix.

Accurate evaluation is possible only if the 'blind' sensors are the same in both shape and material to the ArborSonic3D sensors. In case of using any other nails or using less than 10 Ludwig sensors, the time data is misleading the tomogram is unreliable.

Hardware and set up



Ludwig sensors are special nails (both in shape and in material) with a 6 cm long spike and a rounded head. The maintenance, fixing and removing are almost the same as for the normal sensors. Ludwig sensors can be easily removed with the remover tool.

As Ludwig sensors are supplements only, they can NOT be used on their own, they have to be used together with normal sensors.

When measuring with Ludwig sensors, use the same number of Ludwig sensors as normal sensor. Always put one Ludwig sensor between 2 normal sensors (and one sensor between 2 Ludwig ones).

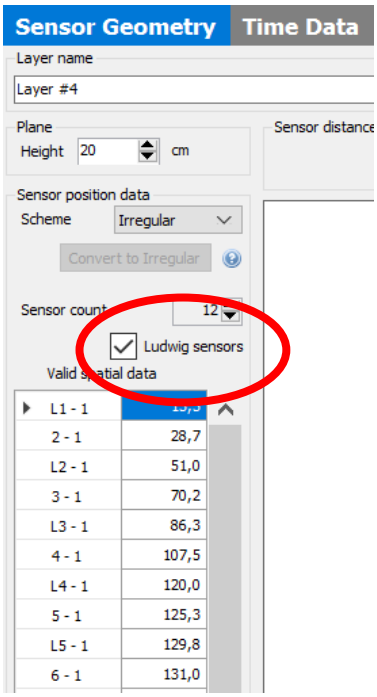
Hit the Ludwig sensors to the same depth as the normal ones are.



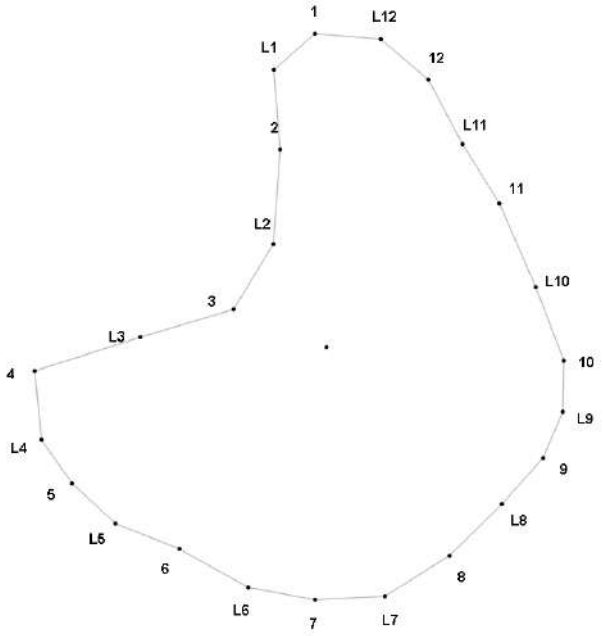
Geometries

- Check in the “Ludwig sensors” on the Geometry page
- If you use circular, elliptic or rectangular geometry, the software will show you where to place the Ludwig sensors. They will be L1, L2, L3,… on the geometry page





  - Distances will start with 1 for the first sensor, then L1 for the first Ludwig sensor, 2 for the second sensor and L2 for the second Ludwig one, and so on.
  - The Ludwig sensors are numbered as which sensor is on their left side (on the tree).
  - Ln is always between sensor n and n+1. (Except the last one, which is between the last and the first sensors.)
  - Otherwise you will need the usual data, circumference, major and minor axis (for ellipse), penetration depth, bark thickness, …
- When using irregular geometry, you will have to measure the distances similarly like when you have normal sensors, just, of course, you will have to measure the Ludwig ones too. The software will tell you which distances to measure (if you turn the speakers on).

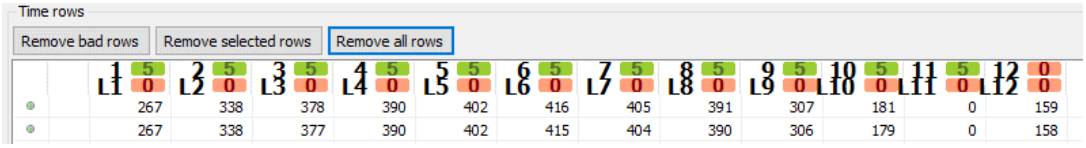


An example for irregular geometry with 12 sensors and 12 Ludwig sensors

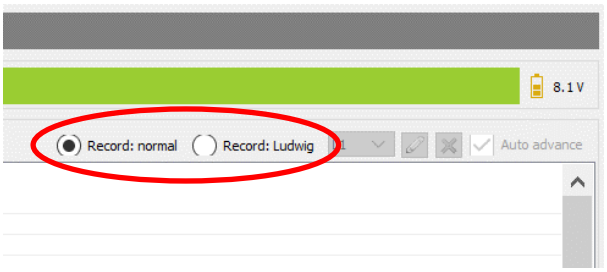
Measurement – switch between usual and Ludwig sensors

After setting the proper geometry, click to the “Time data” tab for executing the measurement. The measurement starts similarly to a usual measurement, the tomogram should be set up (Amplifier Boxes, linking cables, Battery Box), the proper COM port should be set and found. Turn the Battery Box on.

At the “Time data” tab there will be an extra row.



First do the measurement using **only** the normal sensors, just as you usually would.



In the right top corner “Record: normal” should be chosen. (The program chooses it automatically.)

When all the sensors were hit (at least as many as the minimal row count in set – see in the subsequent chapter), you can switch to “Record: Ludwig”.

The software needs to be told, which Ludwig sensor you are going to hit next. The easiest way to do this, is to make sure that "Auto Advance" is checked. This way once you've made enough good hits on a Ludwig sensor, the software will automatically "advance" to the next Ludwig sensor. You will hear the name of the next Ludwig sensor to be hit, when this happens."

The Ludwig sensors should be hit in order, starting with L1. Hit the Ludwig sensors’ heads similarly to the normal ones, with a loose wrist.

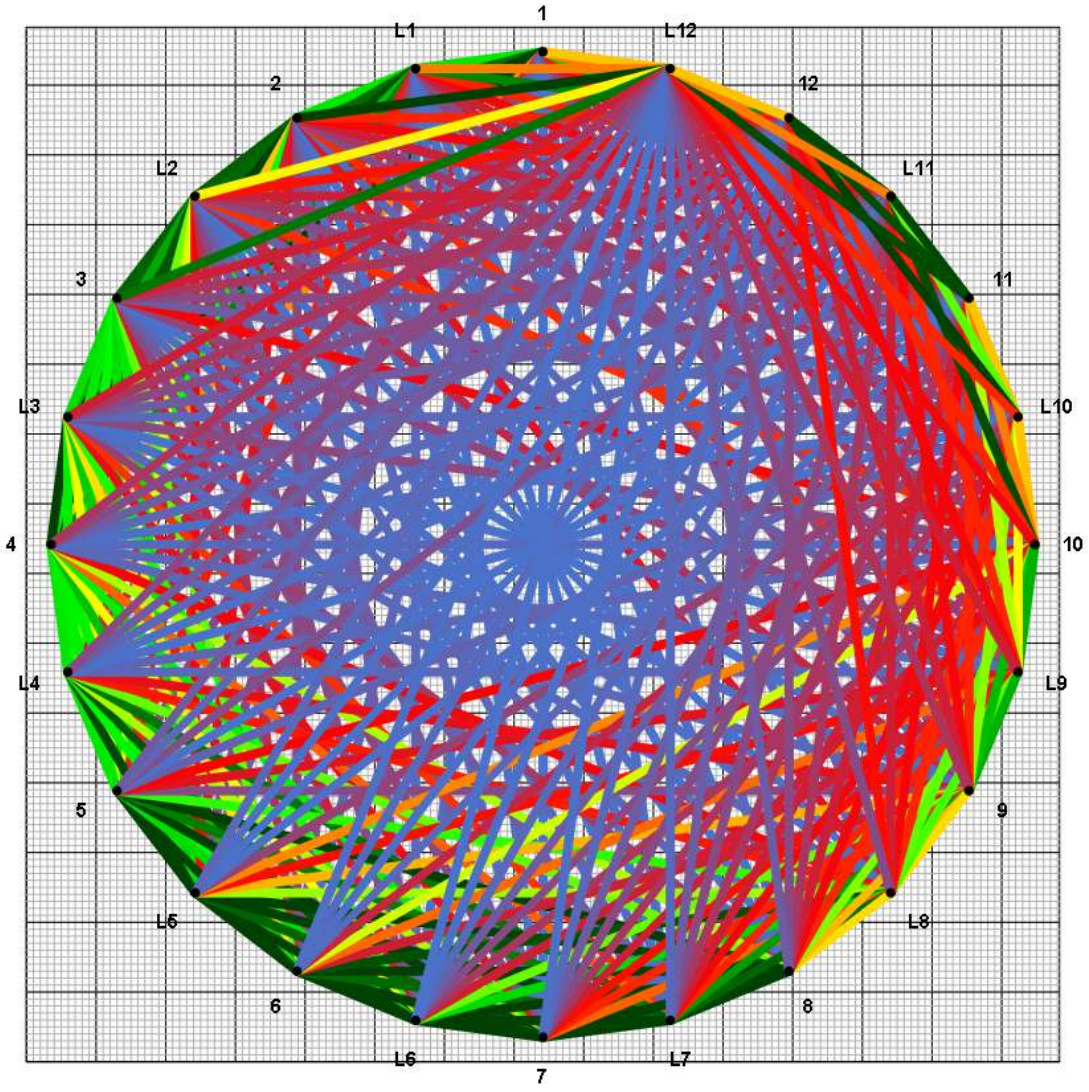


When you hit enough on the Ludwig sensors, the measurement is finished. (Turn off the Battery Box for saving battery.) All the areas next to the sensors’ and Ludwig sensors’ numbers will be green containing the number of correct hits.

If you hit a Ludwig sensor badly, you will hear the usual sound indicating this. If you however hit a normal sensor instead of a Ludwig one or reverse, the same sound will be played. (A normal hit can be turned into a Ludwig hit, and vica versa. See chapter: “Time data corrections – what to do with a bad hit?”.)

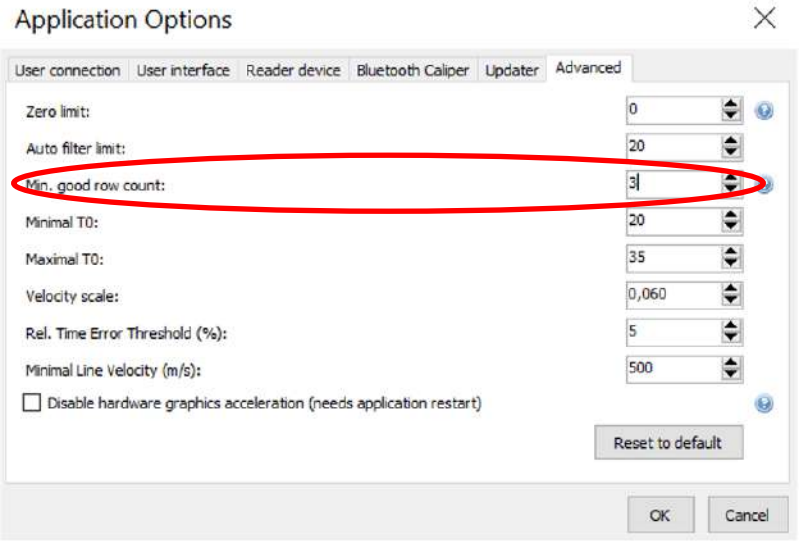
Tomogram

The tomogram(s) is calculated by the software and the only difference is that Ludwig sensors are shown as L1, L2 and so on. Otherwise the tomograms can be used as usual, the functions are the same.



The maximal number of sensors are 32 while the maximum number of Ludwig sensors are the same. Together the 32 sensors and 32 Ludwig sensors can make measurements via about a thousand “lines” like the ones you can check in graph view.

Software – Number of (required) hits

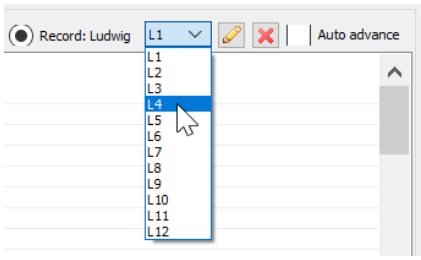


For both normal and Ludwig sensors, there is a minimum number of good hits required per sensor. When you reach this, the number in the column header turns green, and if this was a Ludwig sensor and Auto Advance is checked, you automatically advance to the next Ludwig sensor.

It is recommended to set this number between 3 and 6.

This can be set in Application Options, which is  button on the left top of the program window. Here the Advanced tab is used.

If you want to measure more with one Ludwig sensor, you can do it manually with unchecking “Auto advance” and setting the proper Ludwig sensor.



Time data corrections – what to do with a bad hit?

If a measurement is bad, you can delete the time data row as you normally would.

If the measurement itself is good, but it indicates the wrong Ludwig sensor being hit, you can reassign the Ludwig hit: select the correct Ludwig sensor that was hit from the combo box, select the time row to be fixed, and then click the  button.

You can do the same thing, to turn a normal sensor hit into a Ludwig sensor hit (in case you might forget to click "Record: Ludwig ").

You can also turn a Ludwig sensor hit into a normal sensor hit, by selecting the affected time rows, and clicking the  button (in case you forgot to click "Record: normal").

Extra possibilities

If you are interested how the tomogram would look like if the measurement was done with normal sensors only, you can go to the Sensor Geometry page and uncheck the Ludwig sensors check-box.

This hides the Ludwig sensors, and you can see how the tomogram and biomechanical calculations would do without the Ludwig sensors. You can always check " Ludwig sensors" to bring the Ludwig sensors back. You do not lose any data, by hiding them.

Go to the Tomograms page to see the tomogram from the sensors only.