ArborSonic 3D

User's Manual

v5.1.66

June 5, 2012

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

ArborSonic 3D 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 99 510 996
Fax:	+36 99 330 099

Principle of operation

- Several Sensors are placed around the trunk, which are coupled to the wood 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 more time to reach the opposite sensors.

Hardware – System parts

Piezo Sensors	
Amplifier Boxes (black)	
Battery Box (grey) containing the Bluetooth transmitter	
Cords	
Caliper	
Sensor Remover	
Tape measure	
Steel and rubber hammer	
Case	

Hardware - Setup
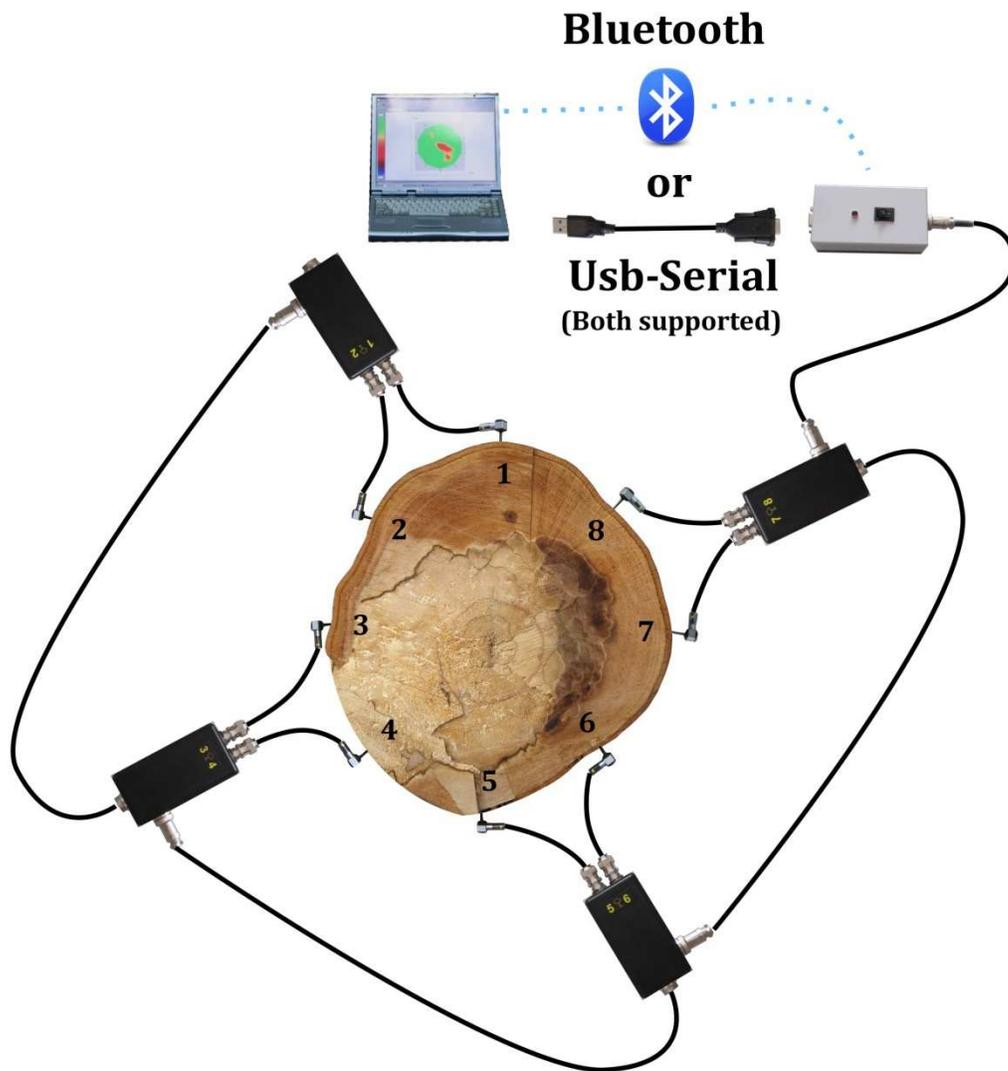
- Drive the Sensors into the trunk in a counter-clockwise order when seen from above.
- Connect the Sensors to the Amplifier boxes.
- Connect the Amplifiers in a line. The bottom connector goes to the side connector of the next box.
- Connect the Battery Box to the Amplifier on any end of the line.
- Establish cable or Bluetooth connection to the PC.

Hardware – Handling the Piezo Sensors

Maintenance
- Always keep the nails and the head clean because dirt influences the coupling.
- 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 penetrate the bark
- Good coupling between the nail and the wood is essential. The coupling is good if the sensor head can't be rotated with 3 <u>stretched</u> fingers.
- The sensors need to be in intact wood material, not in decay.
- The software requires the penetration depth (PD parameter on the Spatial Data tab) of the sensors. This parameter is only important in case of small diameter trees and the value is not critical in case of large trees.
- The sensor nails need to pint in 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.

Measurement
- Use the steel hammer for generating the readouts by tapping on the sensor heads.
- Remove the tape measure while tapping because it may act as 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.
- Never tap on the cable connection part of the sensor.

Removal
- Use the sensor remover 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 amplifiers and finally the cables
- When breaking down, first remove the cables, then the amplifiers and finally the sensors
- Never move the sensors with attached amplifiers because it may damage the cable connectors.
- Make sure to apply correct connector orientation when connecting the cables.
- Amplifier numbering is essential. Don't cross a cable because it will mess up the whole measurement.
- Connect the bottom connector of an amplifier box to the side connector of the next box.

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.

Hardware – Bluetooth and serial connection

- The Battery Box of the device is responsible for collecting and trasmitting data to the PC. There are two basic ways to establish connection: over a Serial-USB cable or over the built-in Bluetooth module.
- There are two steps in setting up the connection. The first is to install the USB cable or the Bluetooth device in Windows. In either way a COM port is assigned to the connection with a specific number. The second step is to set this number in the software. The software provides support for both steps.
- The part below deals with setting up the connection over Bluetooth and does not apply if you choose to use a Serial-USB cable. Please keep in mind that the maximum Bluetooth range is 20 feet. If you need extended range, longer cable can be used between the Amplifier Box and the Battery Box.

Establishing Bluetooth connection to the Battery Box

- If the automatic method does not work for any reason, the device needs to be installed manually in the Control Panel. The final goal of the installation is to set up and find the COM port number of the device and later set it in the software.
- Turn on the Battery Box, start adding a New Bluetooth device in the Control Panel. The device name is ArborSonic 3D.
- The PIN code of the device is 1234.
- The device should be installed by Windows and one or two COM ports should be detected. Remember the number of the installed COM port.
- Start the software.

Selecting COM port

- The second step is to select the correct COM port in the software. This applies regardless of using the device over Bluetooth or Serial-USB cable.
- Start the software, click 🔧 to go to the settings and choose the Reader Device tab. Click the 🔧 icon to open the reader configuration window.
- Wait until all the available COM ports are listed, this can take **up to a minute**.
- If you have remembered the COM port when you Bluetooth or Serial-USB cable device was installed, just select it and close the panel by clicking OK.
- Otherwise, if you don't know the number of the COM port, there is a useful support to find it out. Turn on the Battery Box and connect at least one amplifier box with at least one sensor. You can do this in the office with any piece of wood, no real tree is needed.
- Click the Find Port button. This will open all the available COM ports and start listening to any data that can be received. Tap on any sensor to generate some data.
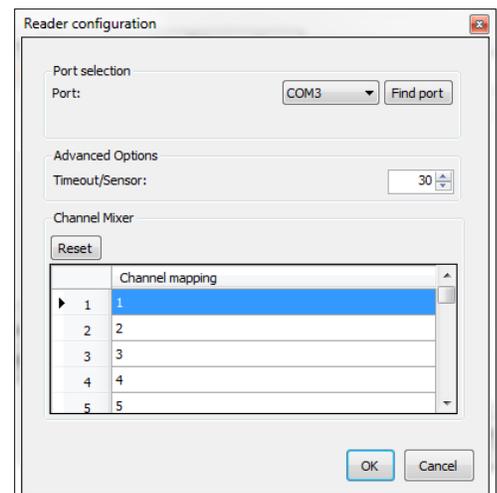
- If any data could be received, the software selects the COM port where it was received and you get a notification. At this point everything is set up for the connection. Now you can click OK to close this panel.
- To check if everything is fine, restart the program, create a dummy layer with some dummy geometry parameters (the simplest is to choose a circle), and go to the Time Data page. If the connection is set up successfully, a green "Reading Device" 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 XP or higher.
- The software is responsible for:
  - Selecting parameters of the tree (species, ...)
  - Registering the geometry of the sensors
  - Collecting the time data from ArborSonic 3D over Bluetooth
  - Computing the internal cross-sectional tomogram
  - Performing stability calculations of the whole tree
  - 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 and registering the sensor geometry manually or with the Bluetooth Caliper.
  4. Collecting time data by tapping on each sensor.
  5. If measurements at several layers are required, choose the next layer and repeat step 2.
  6. Evaluating the cross-sectional maps
  7. Performing stability computations
  8. Saving and exporting data to the report file which can be printed later.

Software – Application Settings

- To access the application settings, click 🔧 . This panel is divided into several tabs for changing different setting 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 Bluetooth settings with the ArborSonic 3D device. The effect of the Start button is described earlier in the "Establishing Bluetooth connection to the Battery Box – Automatic Method" part above.
- 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 "Selecting COM port" section above. The Timeout/Sensor value controls the general timeout value for the communication, the default setting is 30 which is fine for most of the cases, however if you experience some problems with the connection, for example some of the data arriving and the other not, it would make sense to increase this value to 50 or maybe even 100, but not higher. 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, lets say 5-6, but still want to perform measurements with 8 sensors using boxes 1-2, 3-4, 7-8, 9-10.
- Port diagnostics 🖥 is a tool that is useful for moitoring 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.
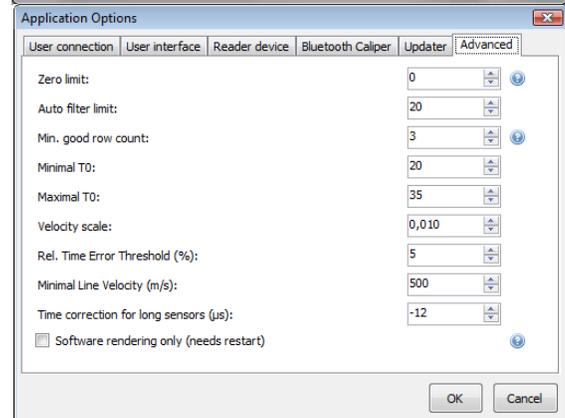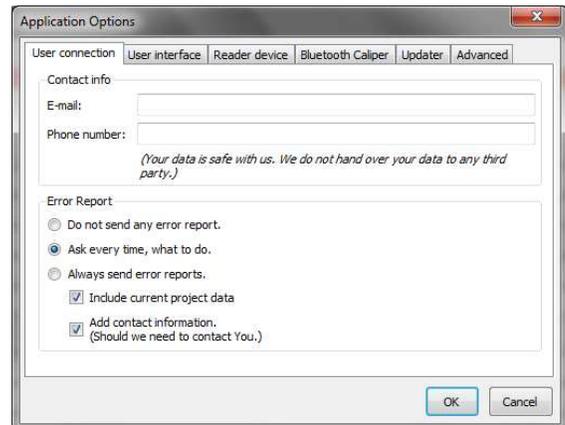
- Auto filter limit is the difference limit in time which if reached results the measured time row to be filtered out. The default setting is 20.
- Min. good row count is the number of required good time measurements from each sensor. The default setting is 3.
- Minimal and maximal T0 are internal time correction limit parameters which are out of the scope of this manual. The default settings are 20 and 35.
- Velocity scale controls the scale 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.
- Time correction for long sensors should be set to -12, this value is used only if you are using long sensors.
- 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 the last 20 species you used. 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 tree 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
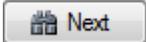
⬚ **Next** or hit the enter button. After selecting the desired species, click OK to close this window.
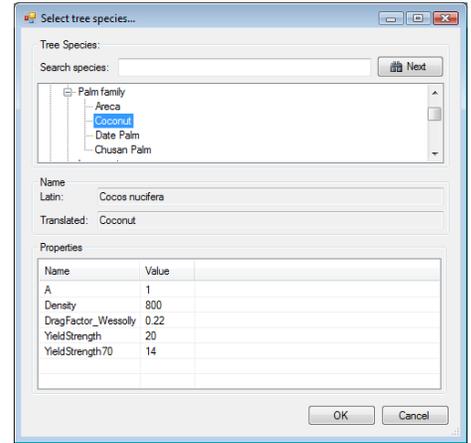
- The rest of this page contains various fields for describing different properties of the tree. The software comes with a default tree property template, but it is possible to create custom templates which may be used to register different properties. All this will go into the report that is generated 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 modified or deleted.
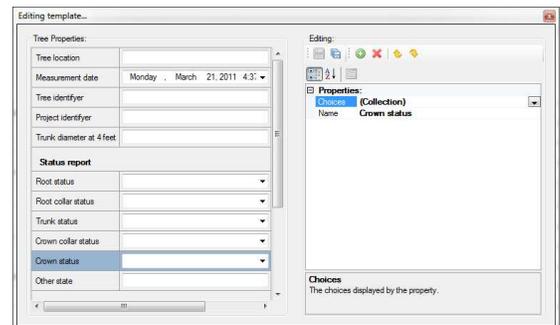
- When selecting New or Edit, the template editor window pops up. The left side of this window shows the preview of the template while the right side can be used to add, remove and modify distinct fields in the template.
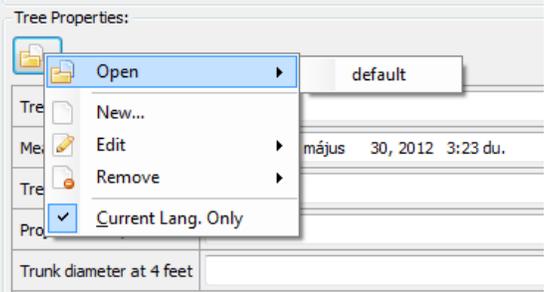
- By clicking the ⬚ button a new field can be added to the template. The type of the new field and its position relative to the current selection must be selected. After clicking OK the properties of this field can be set. For example each field type has a Name property which is the display name of this 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.

13

Software – Sensor Geometry – Basics
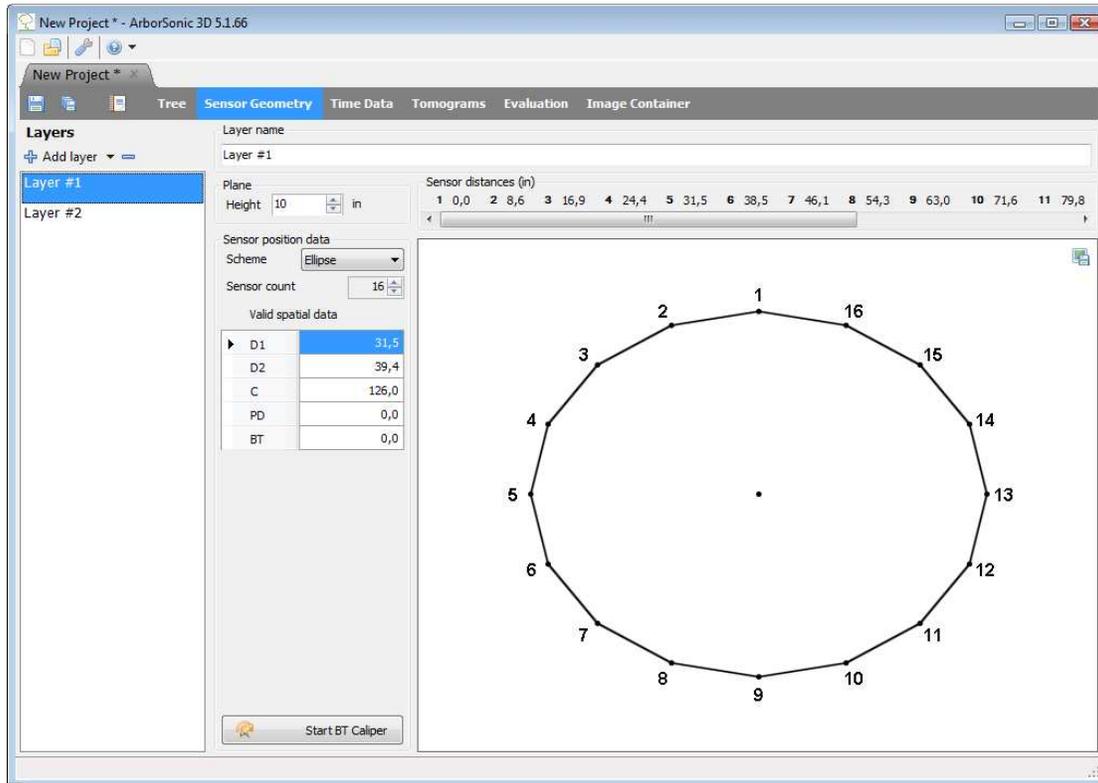
- The software can handle measurements at several different heights. These are the so-called Layers. The sensors can be placed at one Layer at a time and need to be moved between the Layers after collecting the Time Data. Please disconnect the cables when moving between Layers, otherwise the connectors may be damaged.
- Use the ➕ button to add a new layer and user the ➖ button to remove one.
- The name of each layer can be changed in the Layer Name field.
- The height of a layer from the ground can be defined in the Height field.
- The length units (cm or inch) can be changed in the Measure in: cm/inch field.
- 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.
- There are four geometry schemes: Circular, Ellipse, Irregular and Rectangular. These can be selected in the Scheme field.
- PD is a parameter required for all three schemes. It is the penetration depth of the nail tip from the bark surface. It is not a very critical parameter, especially in case of large trees.
- BT is another parameter required for all schemes and denotes the Bark Thickness. This parameter is not very critical in case of normal sized trees and should be set carefully for small trees only.
- 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, Irregular and Rectangular

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.
- Measure the circumference with the tape and type it in C.
- Place the other sensors around the trunk at 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.
- Provide the estimated bark thickness as the BT parameter.

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 with a caliper and type it in D1. Measure the smaller diameter and type it in D2.
- Place the other sensors around the trunk at 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.
- Provide the estimated bark thickness as the BT parameter.

Rectangular

- Use this scheme if you are investigating rectangular wood.
- A is the width of the rectangle and B is its height.
- 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 forst sensor from the given direction. These must be smaller than A or B.

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.
- Provide the estimated penetration depth of the sensor nail tip from the bark surface as the PD parameter.
- Provide the estimated bark thickness as the BT parameter.

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.

- Otherwise you will need to configure the connection. This process is described in the "Hardware – Bluetooth and serial connection" section above.

- 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.

- 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 is 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 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 $\pm$ 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, then the sensor may be broke.
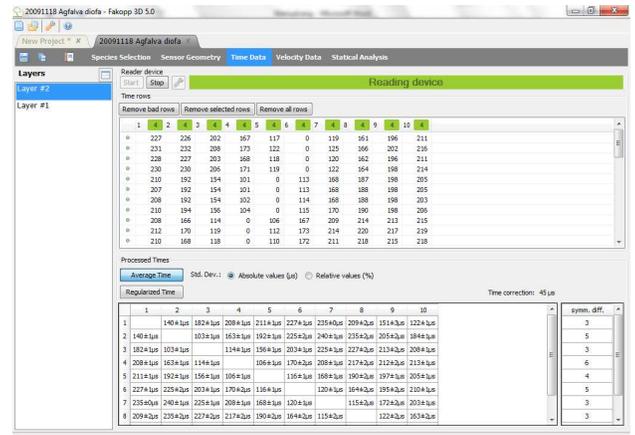
Software – Tomograms – Single-layer mode
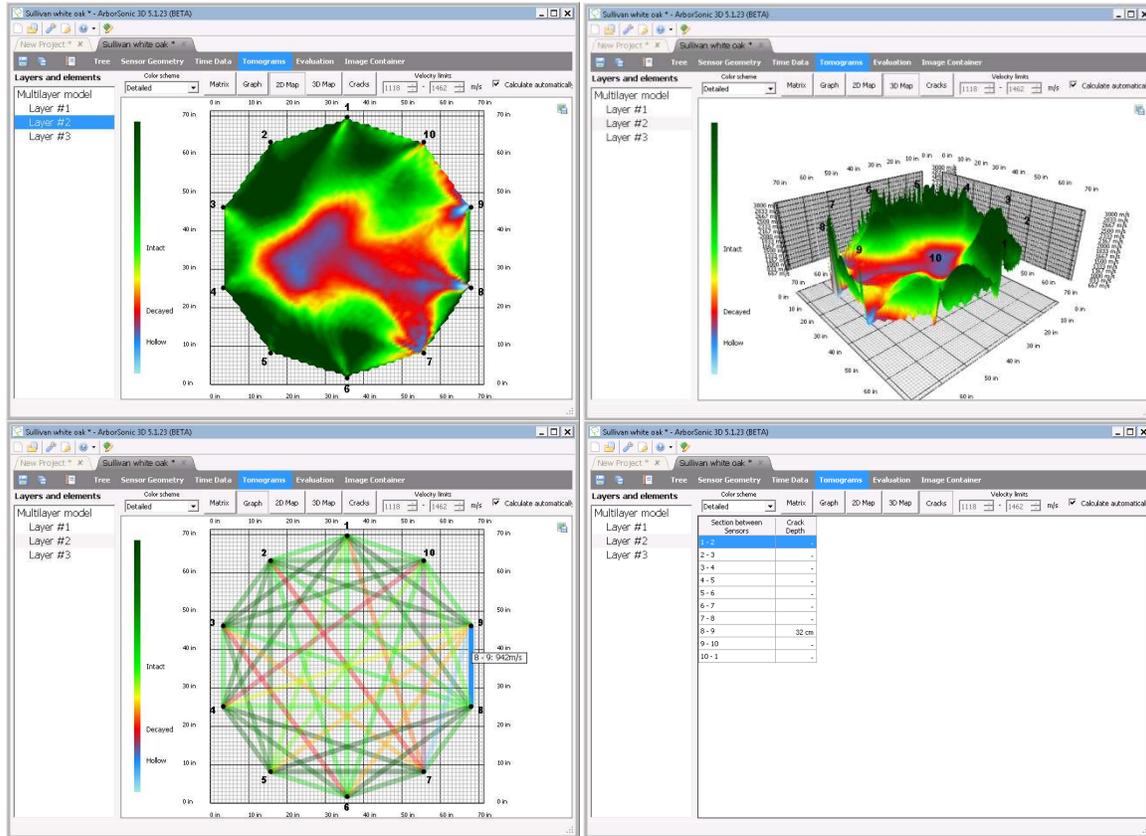
- After registering the geometry and collecting enough time data, the tomograms are visible on the Tomograms tab.
- A color scheme can be selected for visualization, the recommended scheme is Detailed . The legend and the meaning of colors are on the left side of the figure.
- Use the icon on the top right corner to save a view to the Image Container.
- Selecting only one Layer on from the Layer list shows the tomogram for that specific Layer only.
- 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.
- 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 account for internal cracks.

Software – Tomograms – Multi-layer mode
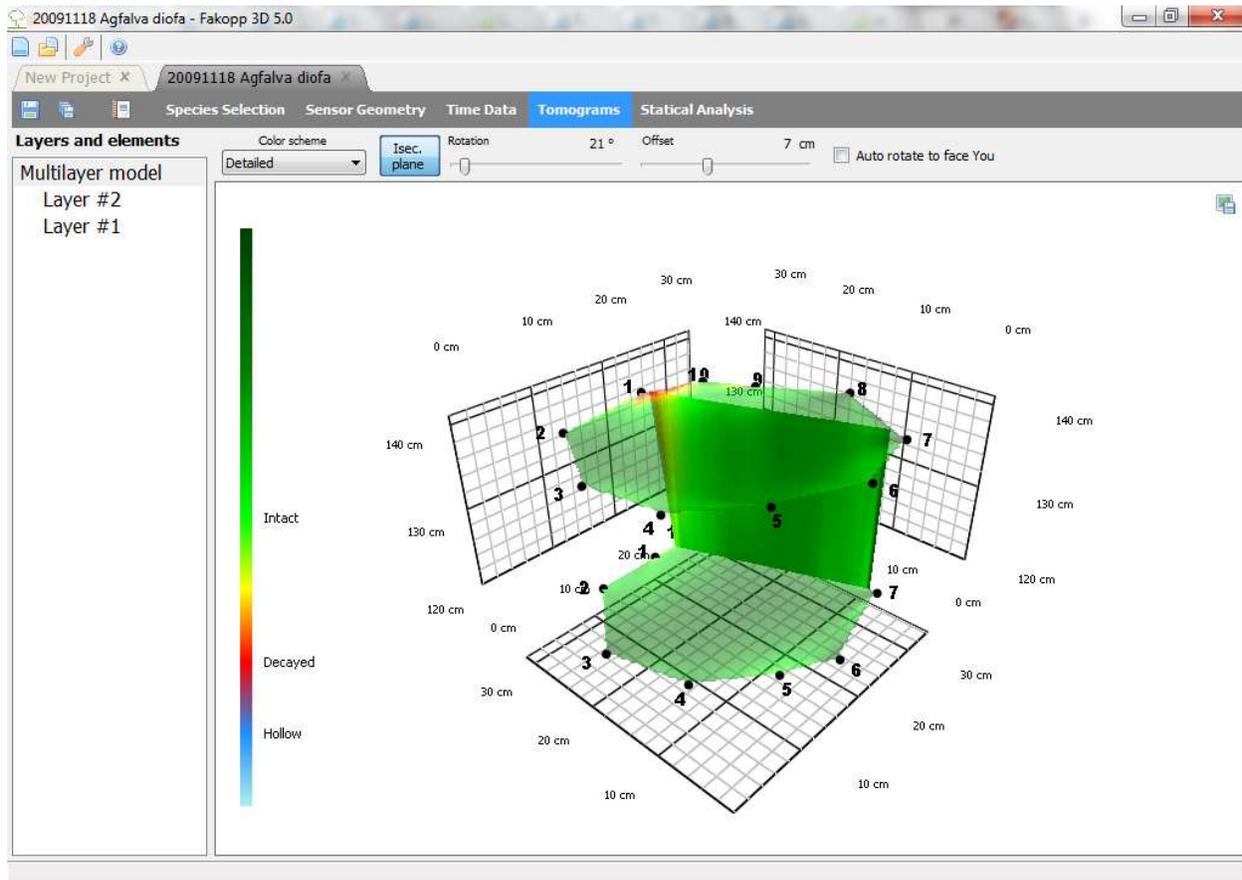
- If at least two layers are present, the 3-dimensional representation of all the tomograms measured at all the layers can be seen by selecting Multilayer model on the left side.
- Use the left mouse button to rotate the figure.
- Click the Isec. plane button to show the vertical interpolation plane 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 – Static Analysis

- The **Evaluation** 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 measurement region.

- It is possible to measure different parameters of the tree from a photo. Click the button on the Image Container section and load a photo of the tree. It is recommended to take the photo from a distance of at least the tree size to avoid distortions. 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. Please 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. 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 of this line. This line should mark a person or some reference object on the photo, placed at the distance of the tree.

- The button can be used to 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 tree height and the tilt angle of the tree.

- The first parameter is the Crown Area. This can be entered either from the photo as described above, or manually, or using the crown area calculator by clicking . 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.

- The distances from the trunk bottom to the crown center and crown top need to be provided. These parameters are also taken from the photo if everything is marked appropriately.

- The next parameter is the tilt angle which can also be taken from the photo. 90 degrees mean a completely vertical trunk.
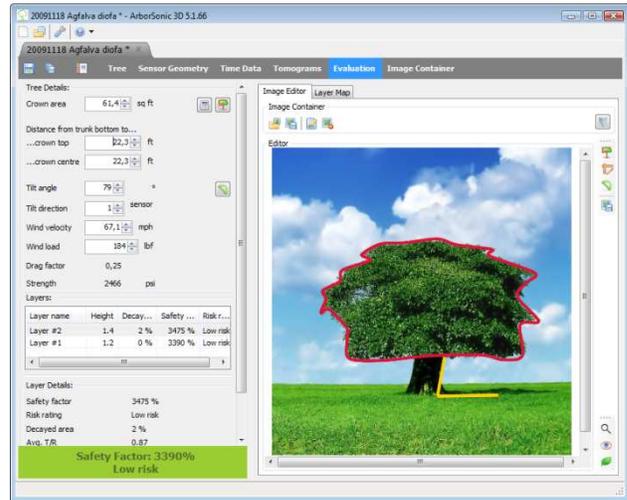
- Tilt direction is not taken from the photo and needs to be provided manually at all times. This is the number of the sensor at the bottom Layer in which direction the trunk tilts.
- Wind velocity must be set to hurricane wind speed which is 33m/s or 75 mph.
- Drag factor is the drag coefficient of the crown, taken from the tree species database.
- Strength is the yield strength of the trunk wood, also taken from the species database.
- Wind force is the calculated force acting on the crown center at the given wind speed and crown size.
- The table lists all the layers. The second column is the layer height as provided on the Geometry page. The third column is the Safety Factor and the fourth 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

- The Layer Details section shows the details for the selected layer. Decayed area is the percentage of the decayed region on the selected layer compared to the total layer area.
- 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 don'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 and gravity forces.
- 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 "Strength" and this computed maximal stress, multiplied by a correction factor of 70%. The formula is: $SF = 0.7 \frac{Strength}{MaxStress}$. 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.
- 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 over-estimate 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 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 Evaluation 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.

- Clicking the title of an image allows you to change it.
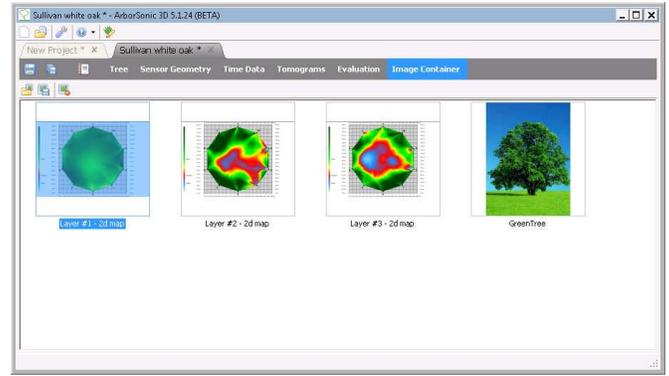
Software – Generating reports

- The built-in report generator makes creating reports for customers quick and easy.

- After the measurement use the 🗒 button to generate a report.

- The generated report will be an external .rtf file which contains the data of the measurement and which can be opened with a text editor for further editing. The format of the generated file is RTF.

- Use the checkbox tree on the left side to select the data which should be included in the report.

- Header contains the title of the document and the time of creation.

- Species Selection contains the selected species.

- Sensor Geometry contains the parameters of the geometry. Individual layers can be selected or de-selected.

- Time data contains the measured time data.

- External images can be included in the Tomograms section. To include an image, first go to the Tomograms page and save the view to an external JPG file using the 🖫 icon in the top right corner. After saving the file, use the Load Image... button to load and include it in the generated document.

- If everything is fine, click the Save As... button to save the report to an external document.