Articulate Assistant Advanced™

AAA User Guide

Version 221_12

Address:

Articulate Instruments Limited

Queen Margaret Campus,

Queen Margaret University Drive,

Musselburgh EH21 6UU

UK

Phone:0131 474 0000

Email:support@articulateinstruments.com

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Preface

To cope with many different data streams recorded at different sample rates and allow complex annotation queries, a Articulate Assistant Advanced uses a database structure.

AAA can load any number of databases, one at a time. Each database is located in a separate folder and consists of a core database file (Data.aa0) containing records smaller than 4 bytes such as annotations, prompts, client details etc. Records larger than 4 bytes such as audio, video, ultrasonic and EPG recordings are held in separate files (Chunk_1.aa0, Chunk_2.aa0, etc). Every frame or sample of data is time stamped to the nearest 100,000th of a second (10microseconds). The software can therefore cope with data that does not have a regular sample rate. The only exception to this is audio data; audio data is the ground truth for all other data streams. Audio data must have regular sample intervals and has a nominal sample rate associated with it which is received from the recording device. Even if this rate is inaccurate, it becomes the clock to which all the other streams are synchronised. **A recording must have an audio track**. i.e. other data streams cannot be recorded by AAA without audio.

The AAA software allows you to

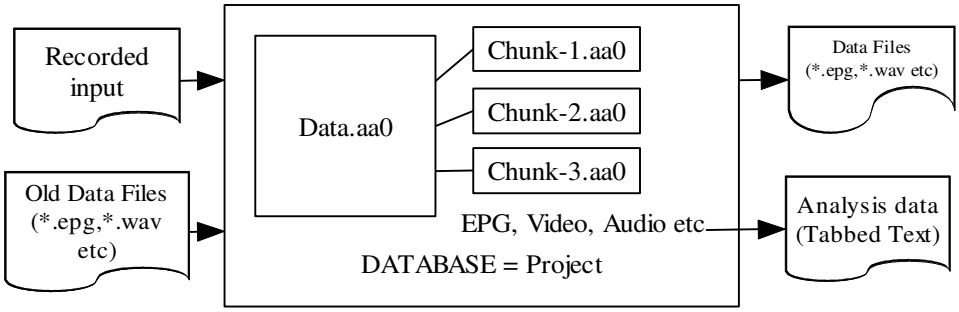
- create as many databases as you wish
- transfer data between databases
- import data in standard file formats (*.wav, *.epg, PRAAT textgrid, *.avi,,EMA pos.* etc)
- export data to those standard file formats
- calculate values from data and export those values and/or plot them.
- create publishable quality graphics from the data.

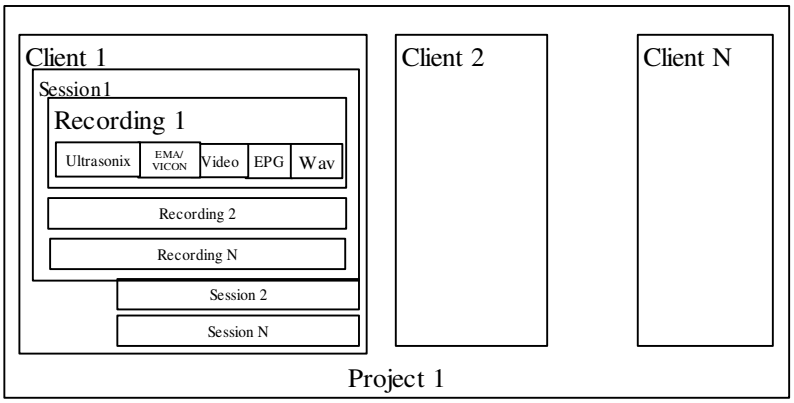
Each database is called a *project*. All data within a *project* can be compared and analysed as a group. Each recorded data channel can be filtered, smoothed, differentiated, combined with other data channels, etc. Key features like peaks, valleys, midpoints etc can be found automatically and labelled.

Data values, durations of labelled regions and many other pieces of information can be exported to Excel or R for charting or statistical analysis. Sophisticated queries can be carried out on labelled data to extract only the information that is required.

Movies of articulatory data can be created for use in presentations and played in slow motion if required. High quality charts suitable for 600dpi journal and book publication can be generated from the various displays.

AAA provides a powerful tool for multichannel speech analysis but we are always on the lookout to improve the utility of the software. So if you have ideas for new features please get in touch and we'll see what we can do.



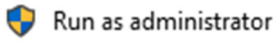


WARNING: Don't copy or move subsets of files in project folders. When using AAA, data gets deleted and rewritten. The associated chunk files get deleted and can be reassigned to a different data type as new annotations or analysis values are created. It is very risky to save time when moving projects between machines to copy only parts of a database based on date as some chunks whose date shows as old may nevertheless have been modified. Windows has a bad habit of showing the creation date and not the modification date. The result can be a corrupted database.

System Setup

Installing Articulate Assistant Advanced™ Software

1. Download the latest revision of AAA from http://www.articulateinstruments.com/downloads/ or install from the USB drive provided with the USB licence key.

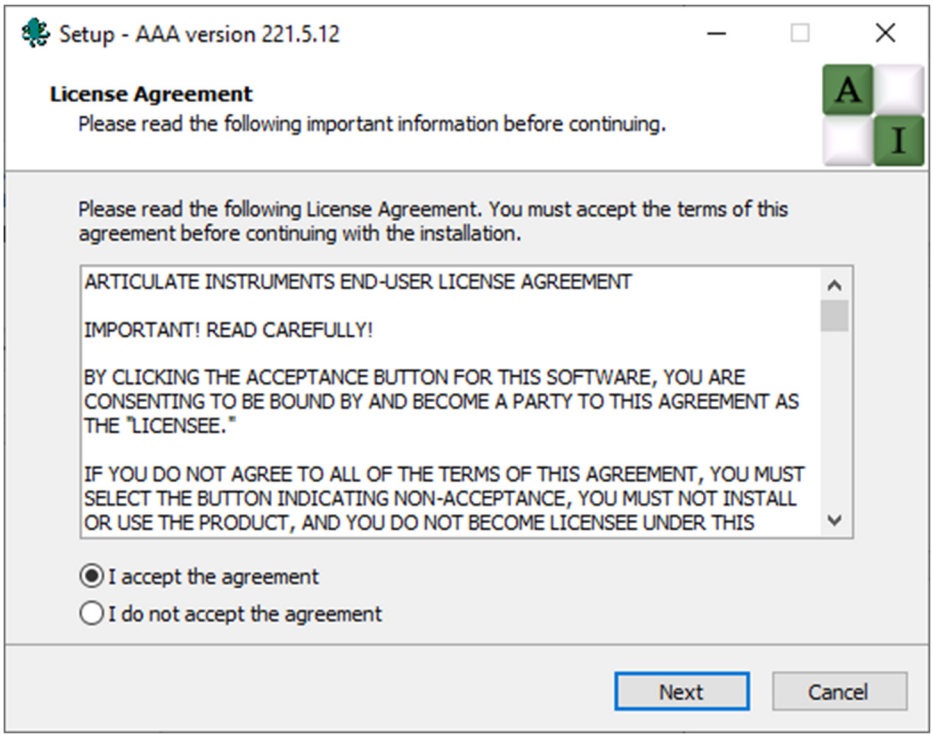
2. Right-click  on the 'Setup_AAA_<version>.exe' installer and run as administrator 

. Run as administrator is only required the first time AAA is installed.

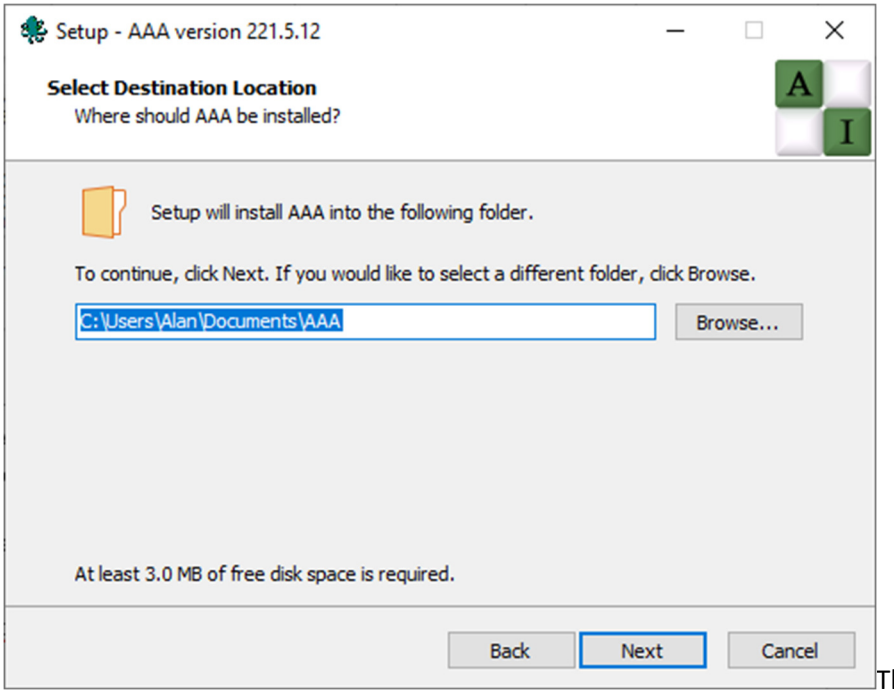
3. This screen may appear. Click More info then 'Run anyway'.

Then allow the app to make changes to your computer

4. Read the agreement. Then accept the agreement and click Next.

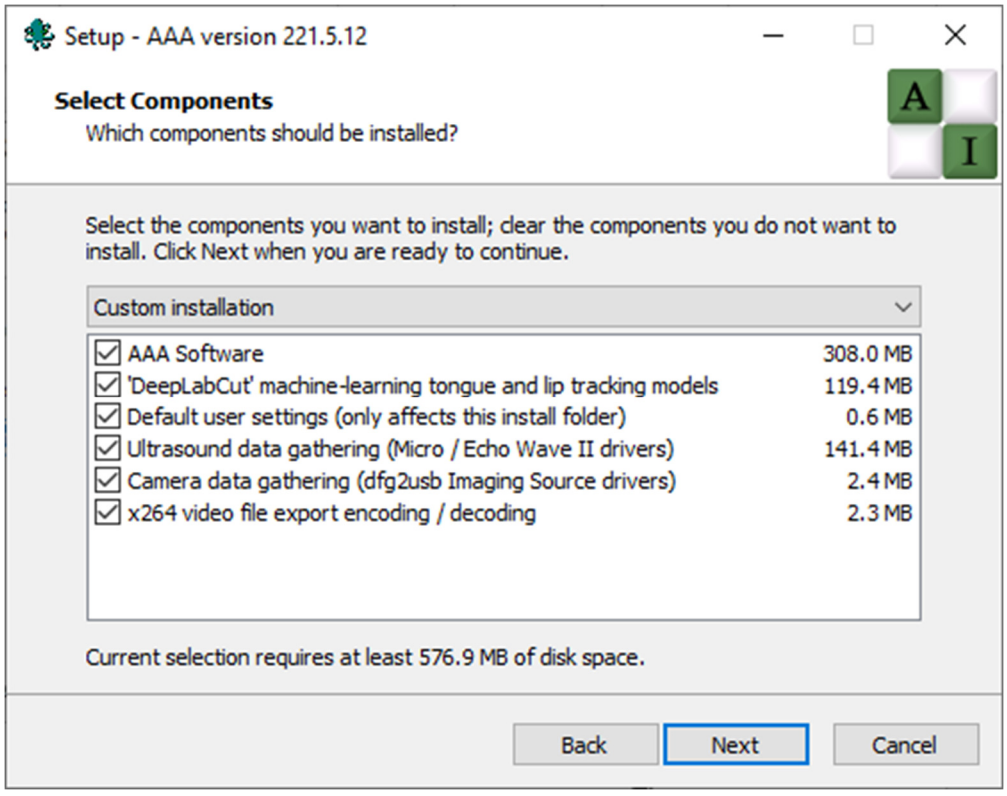


5. Newer versions of AAA (221_3 onwards) install the app into the user's documents folder. This avoids folder permission problems where the user does not have full administrator rights. In all versions it is possible to choose a different application folder. Click Next.

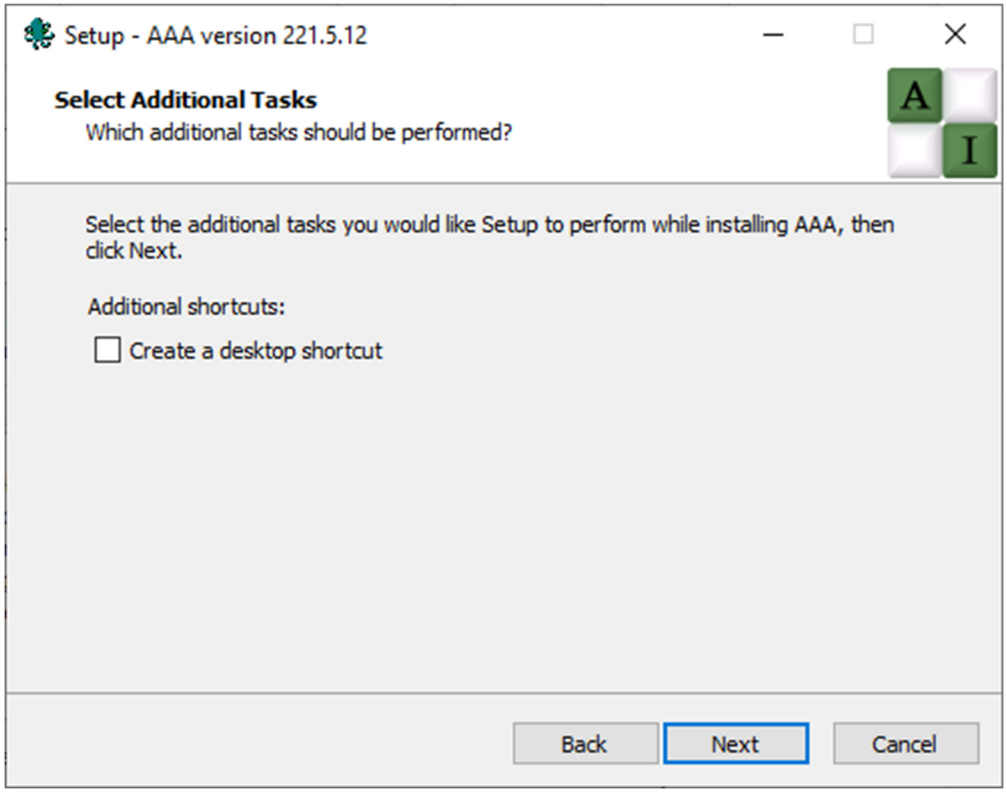


The program can be run from the Windows Taskbar Start Menu ('**Start:Programs:ArticAsst:AAA**') or a desktop icon.

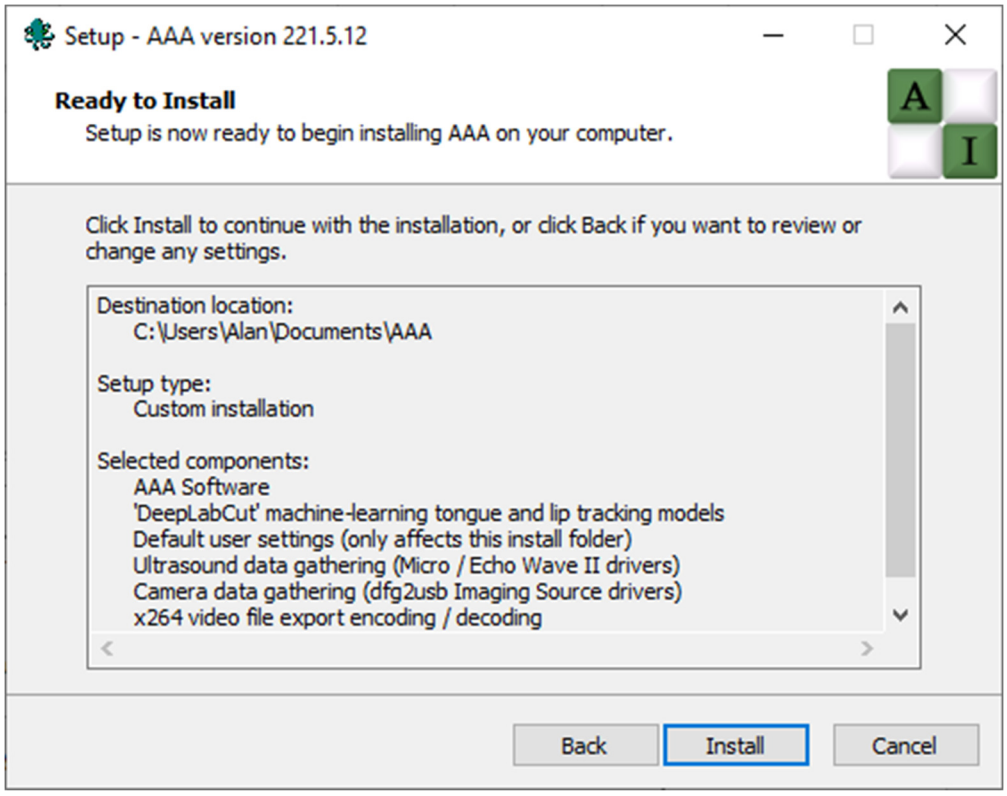
6. The components to be installed should be left checked. Click Next.

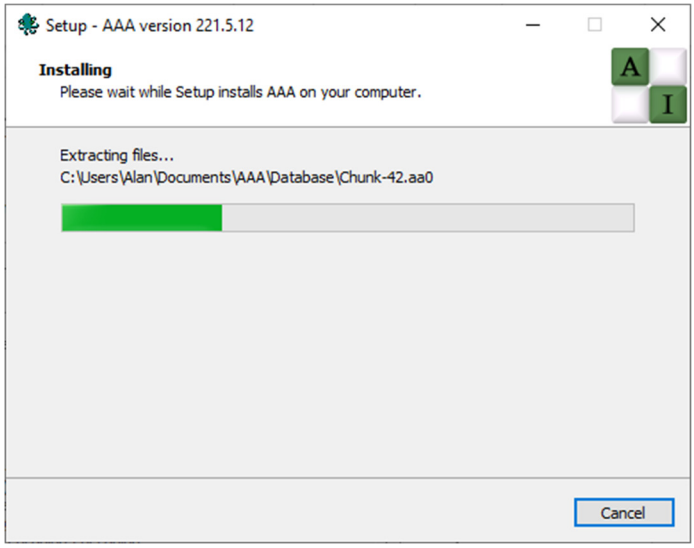


7. Choose whether to have a desktop shortcut. Cliick Next



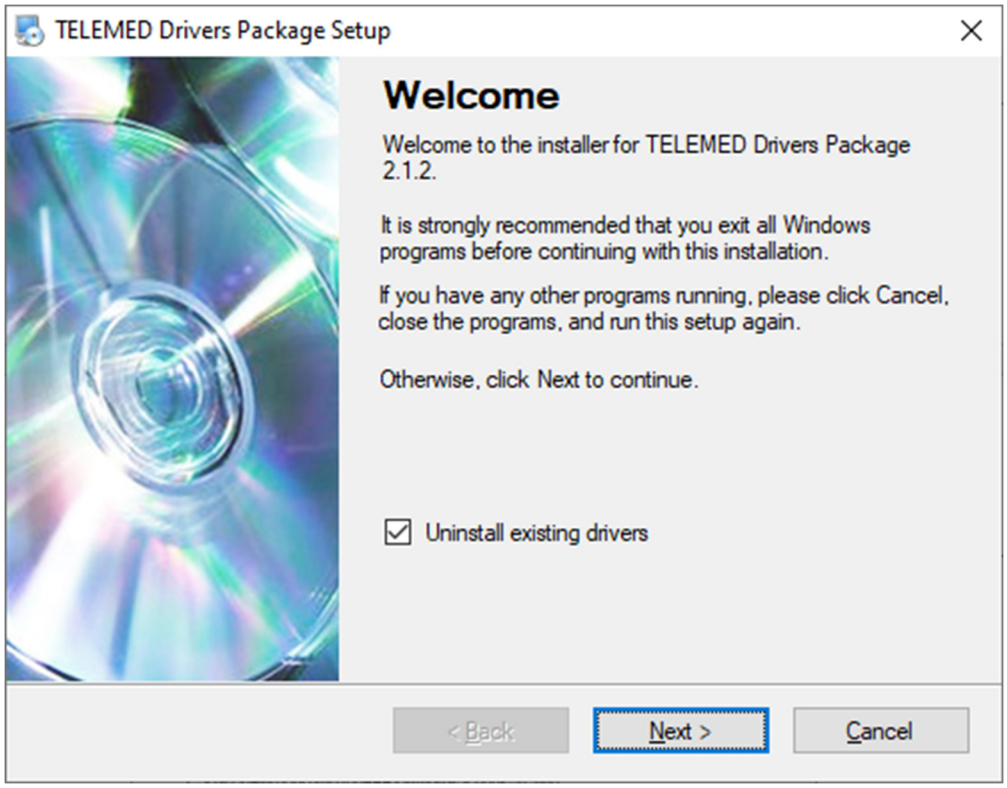
8. Click Install. The files will be extracted



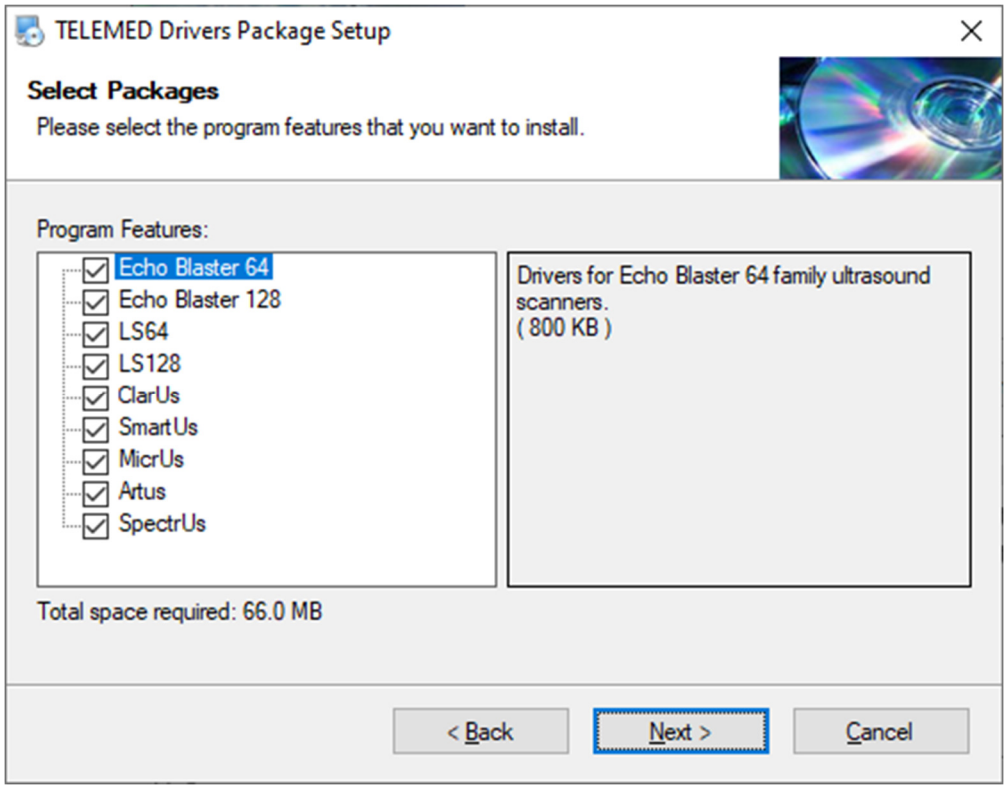


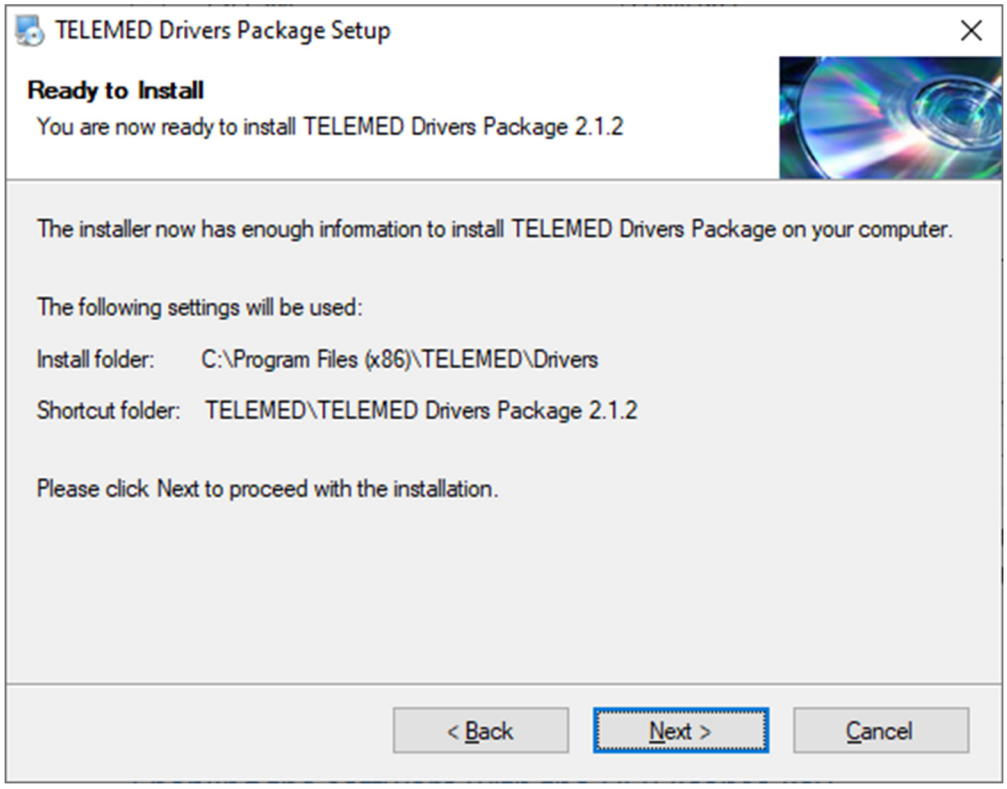
Telemed drivers (32-bit version) installation.

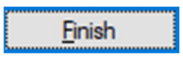
Telemed drivers ill be installed automatically as part of the AAA installation. Click Next. DO NOT close programs and run again.

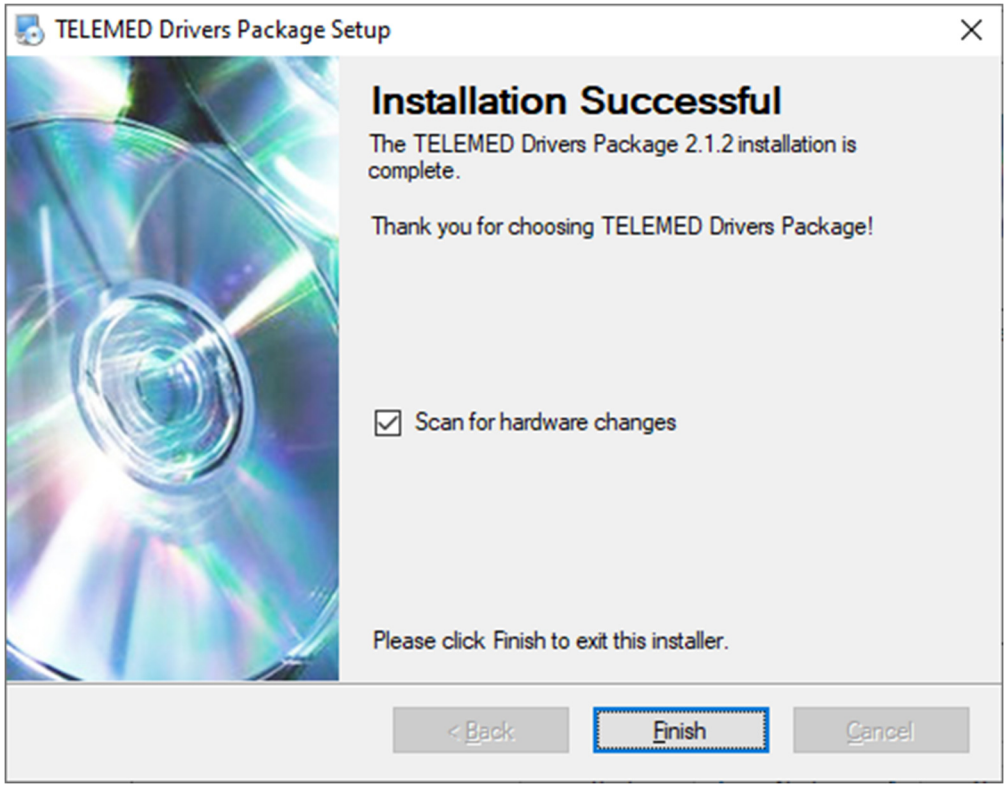


Click Next. Optionally, to save a little time and space, uncheck all options except MicrUs and Echo Blaster 128





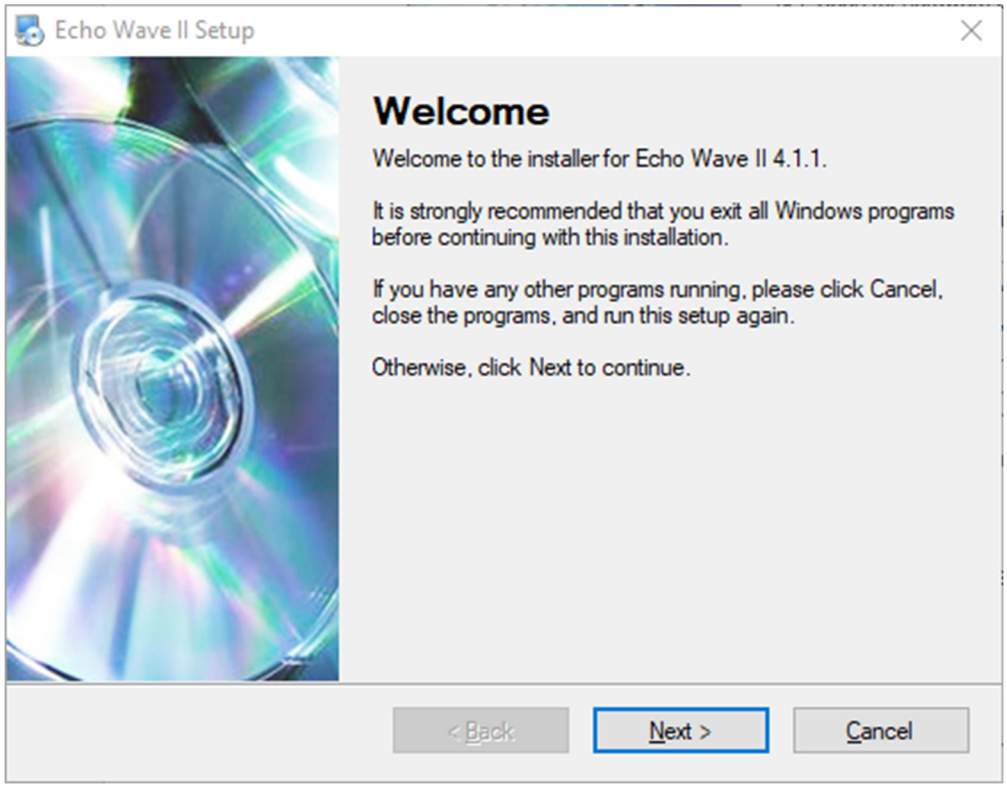
Click 



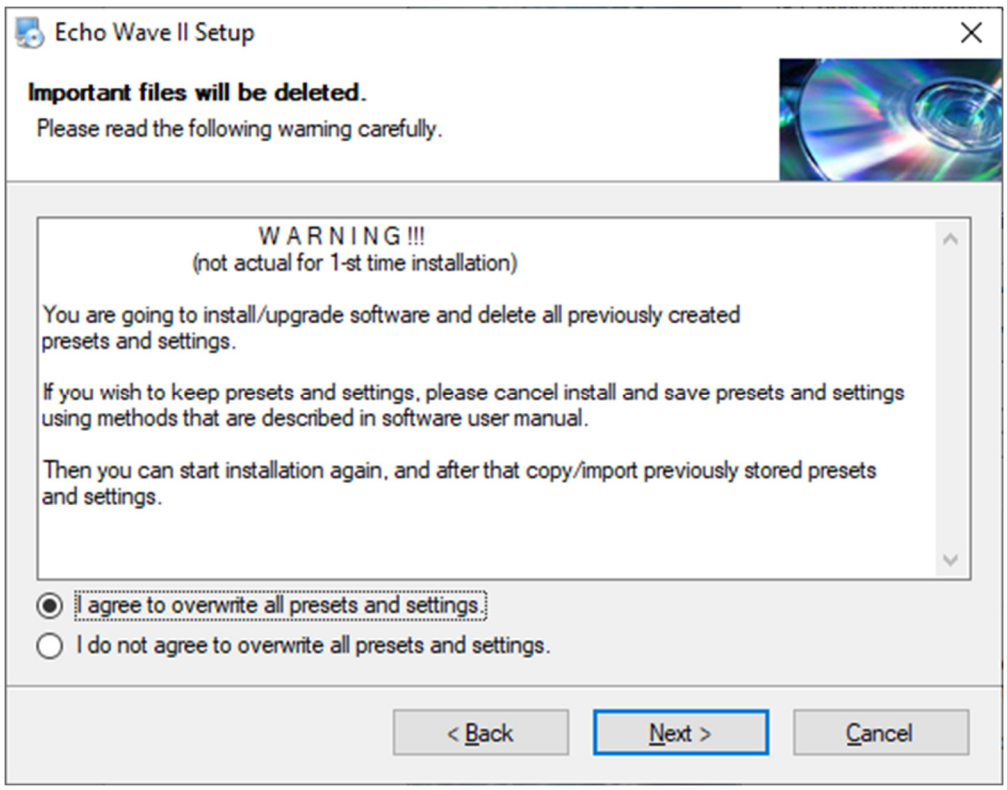
Echo Wave II software (32-bit version) installation.

Echo Wave II will be installed automatically as part of the AAA installation. Click

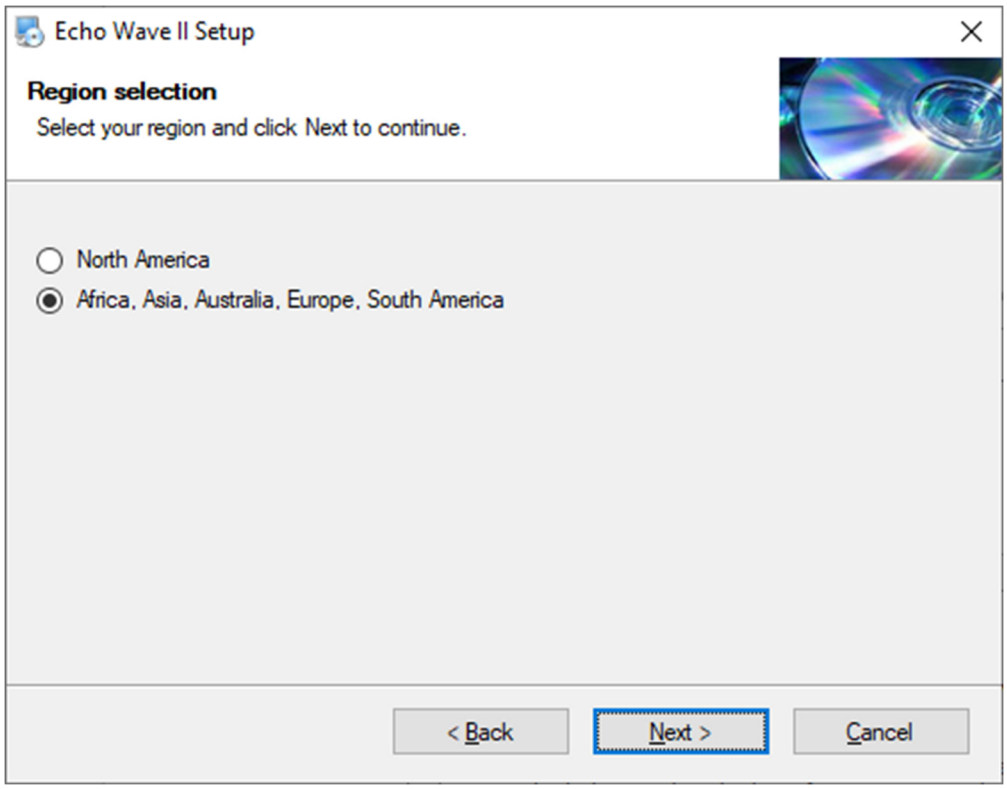
Next

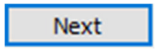


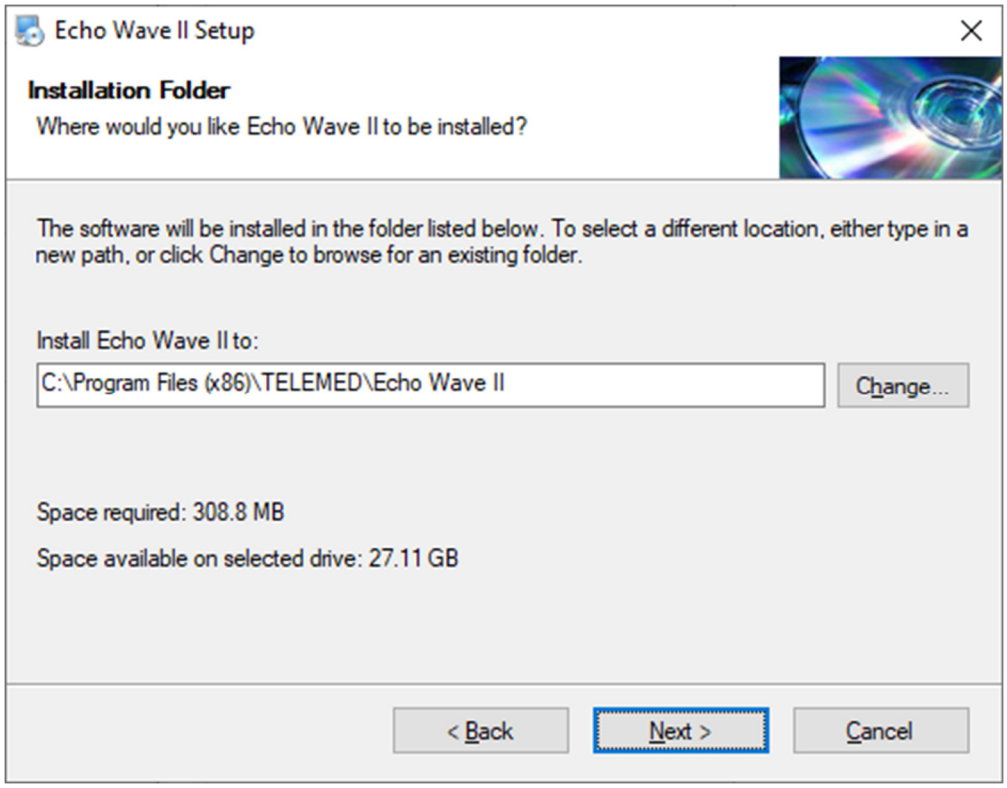
Select I agree to overwrite all presets and settings and click Next

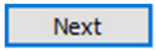


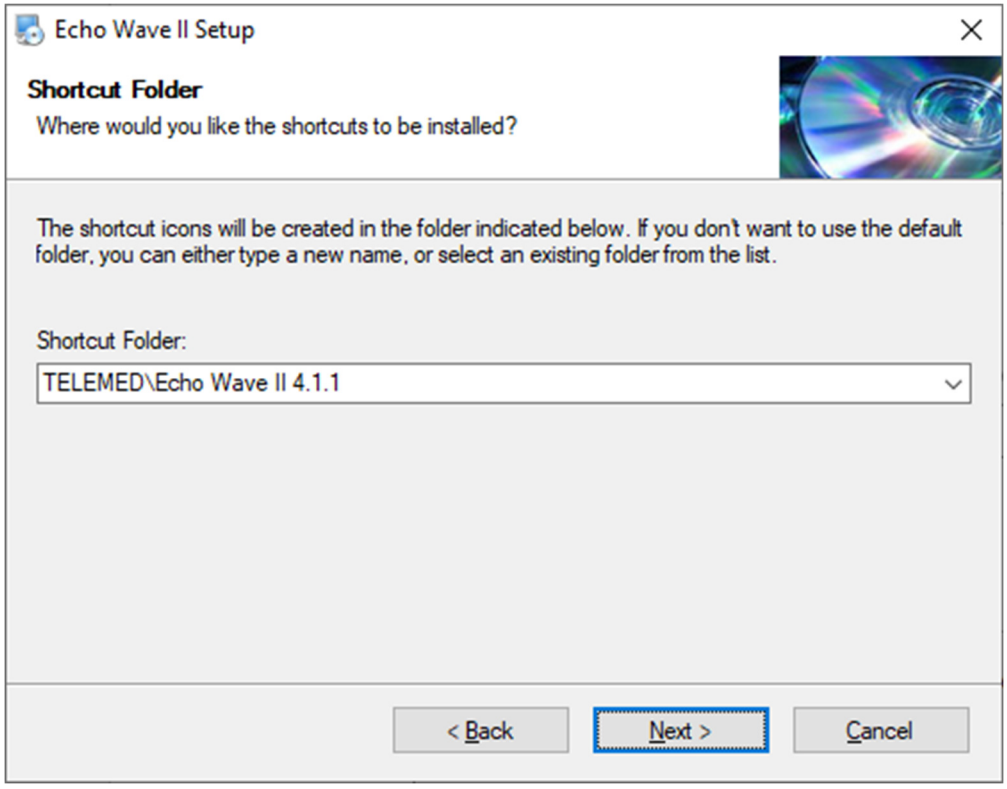
Select region and click Next

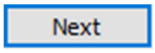


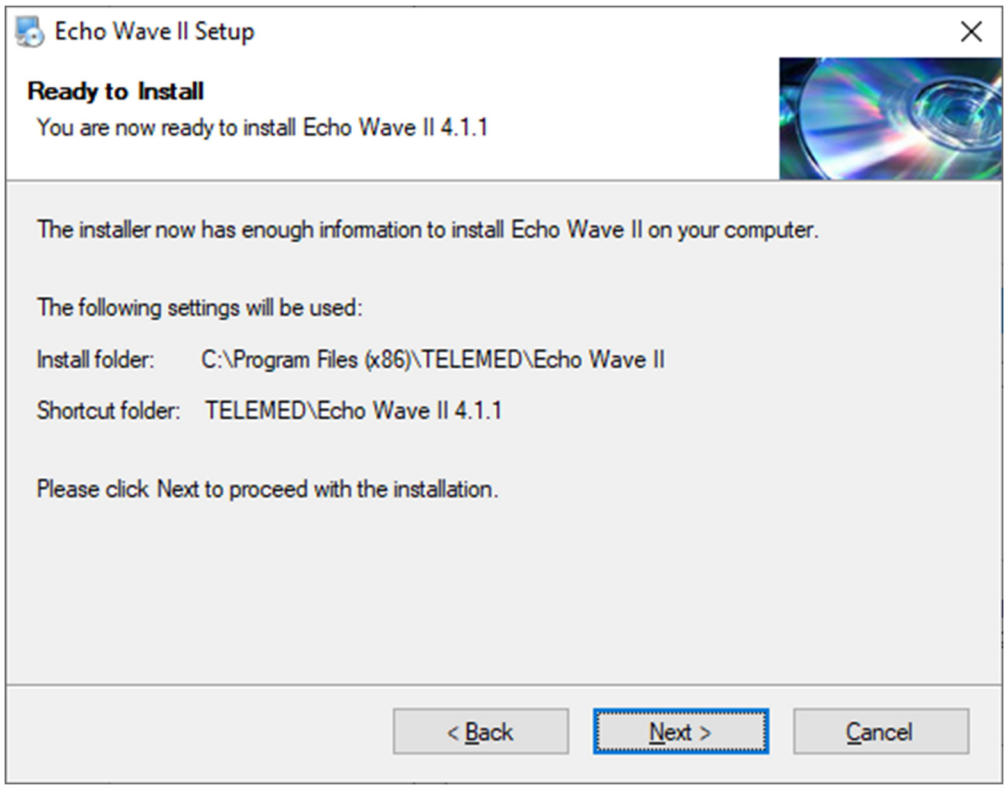
Click 

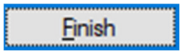


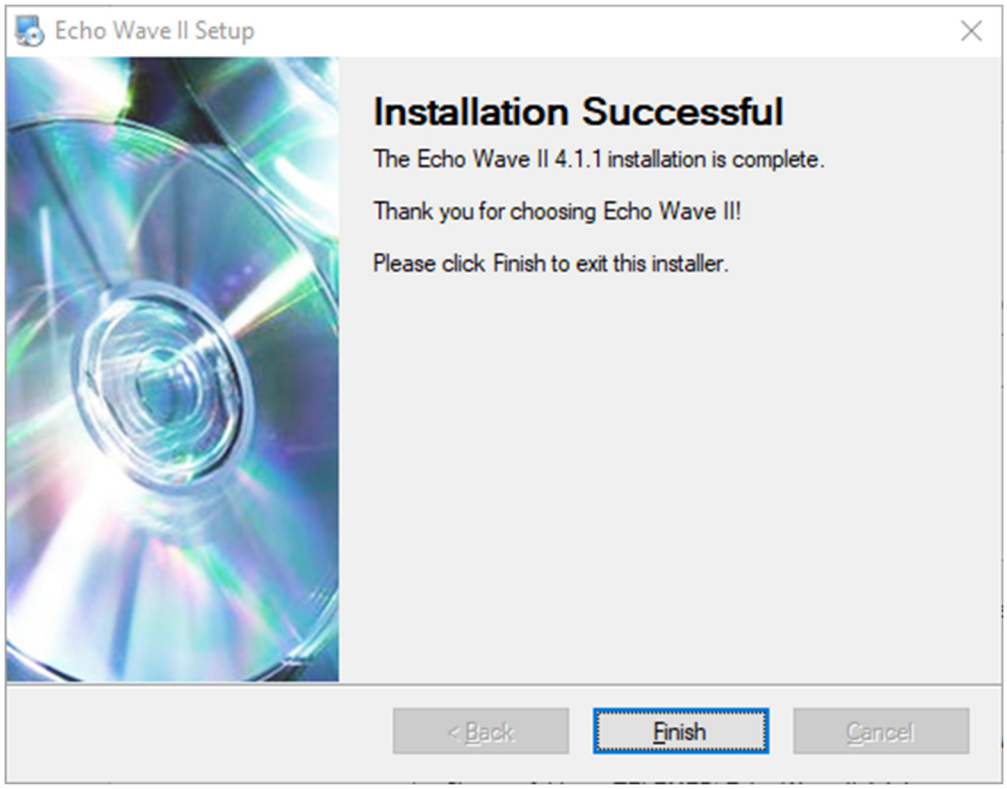
Click 



Click 

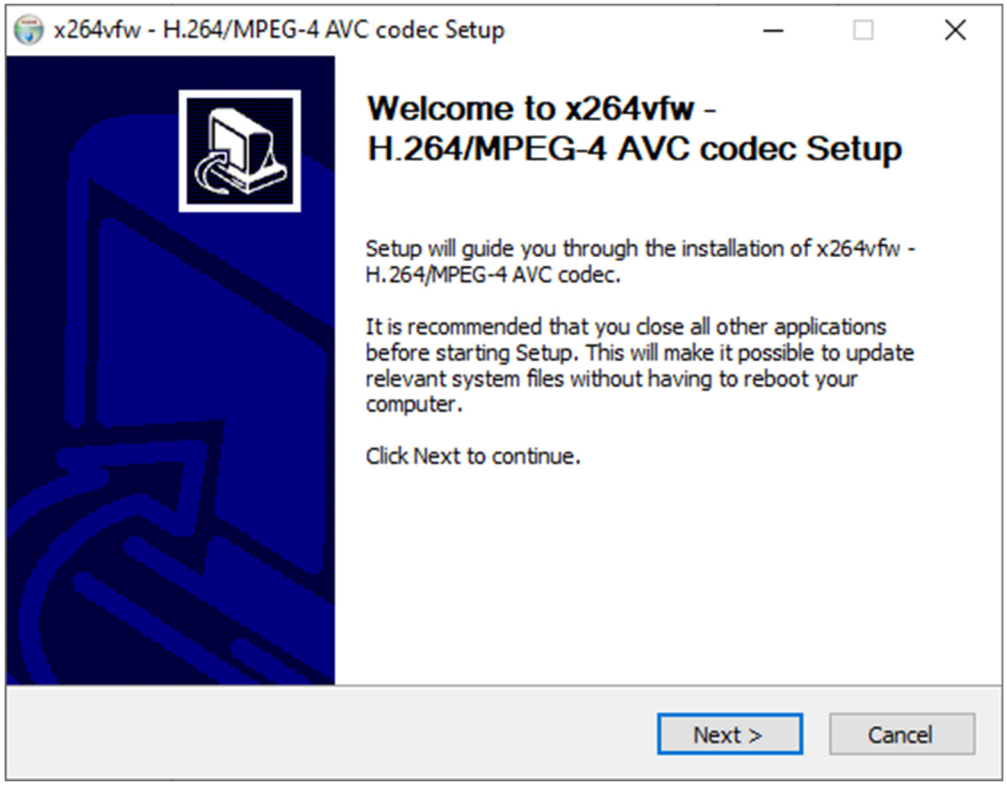


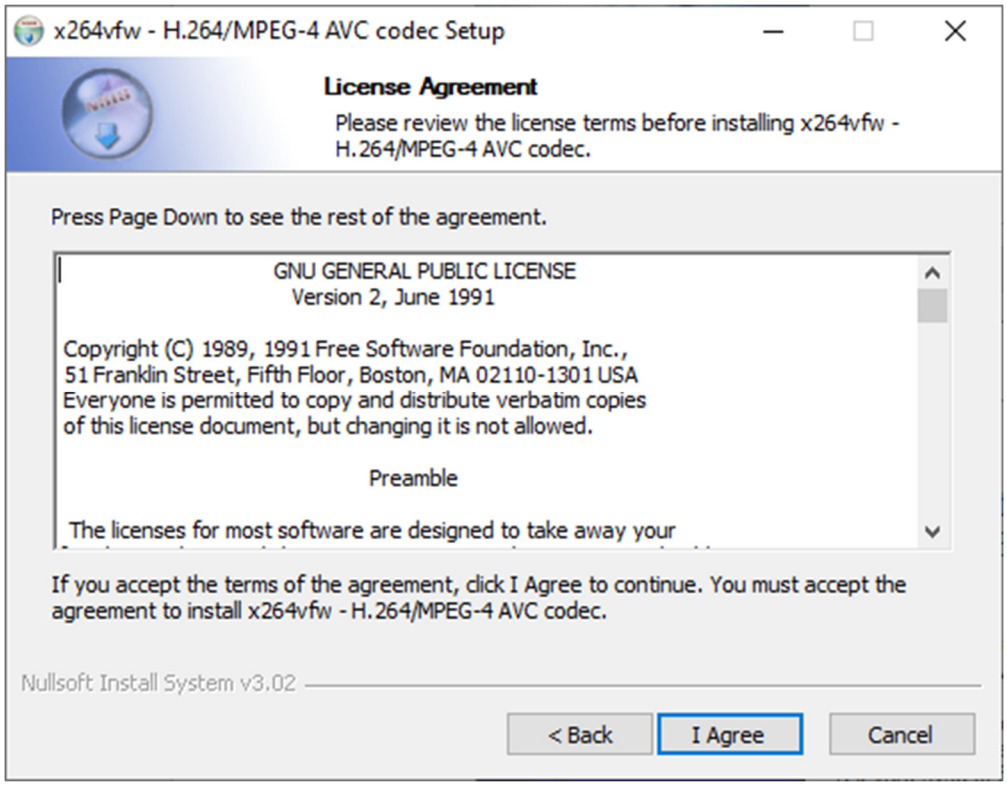
Click 

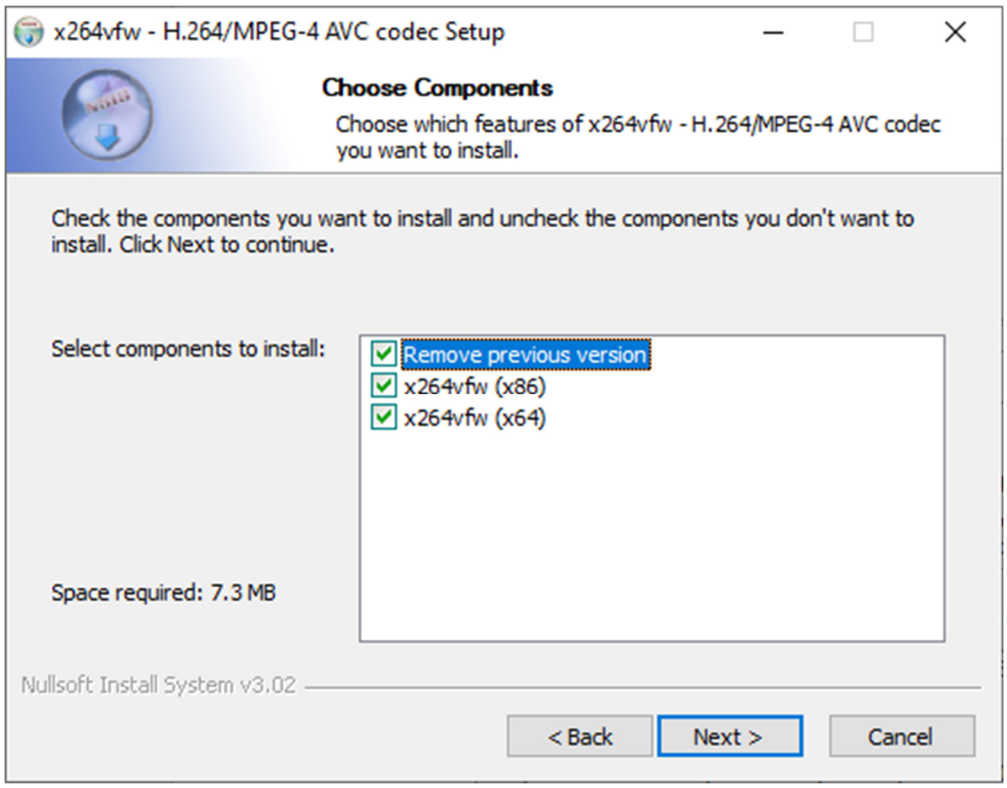


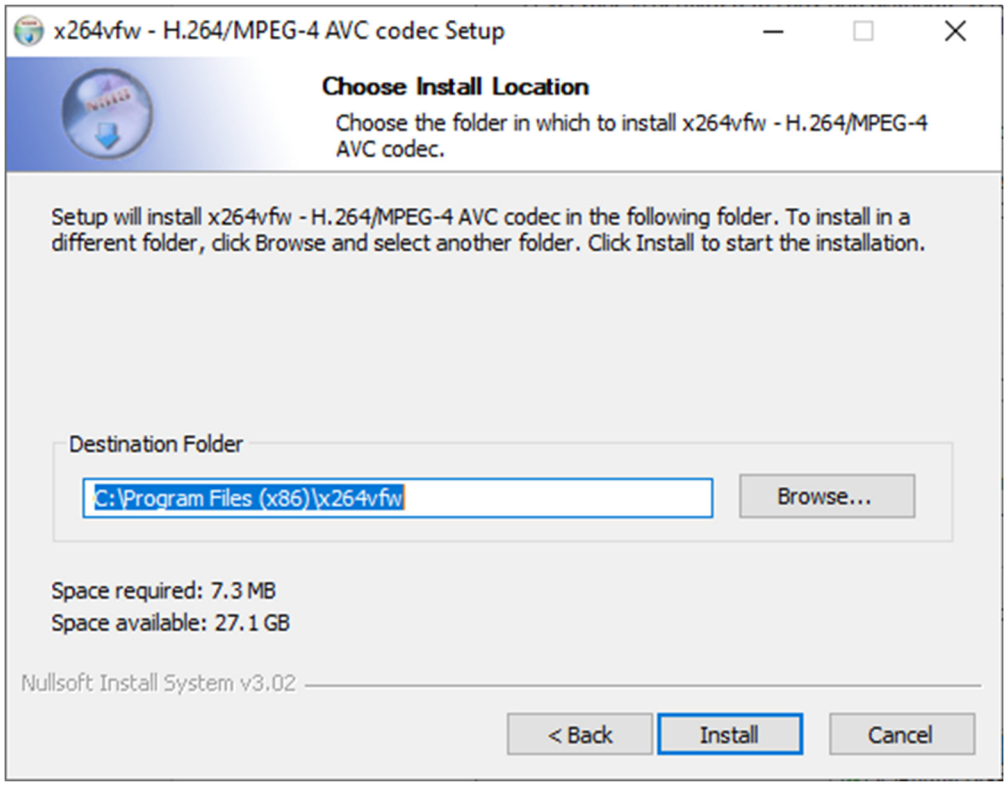
H.264 image codec installation

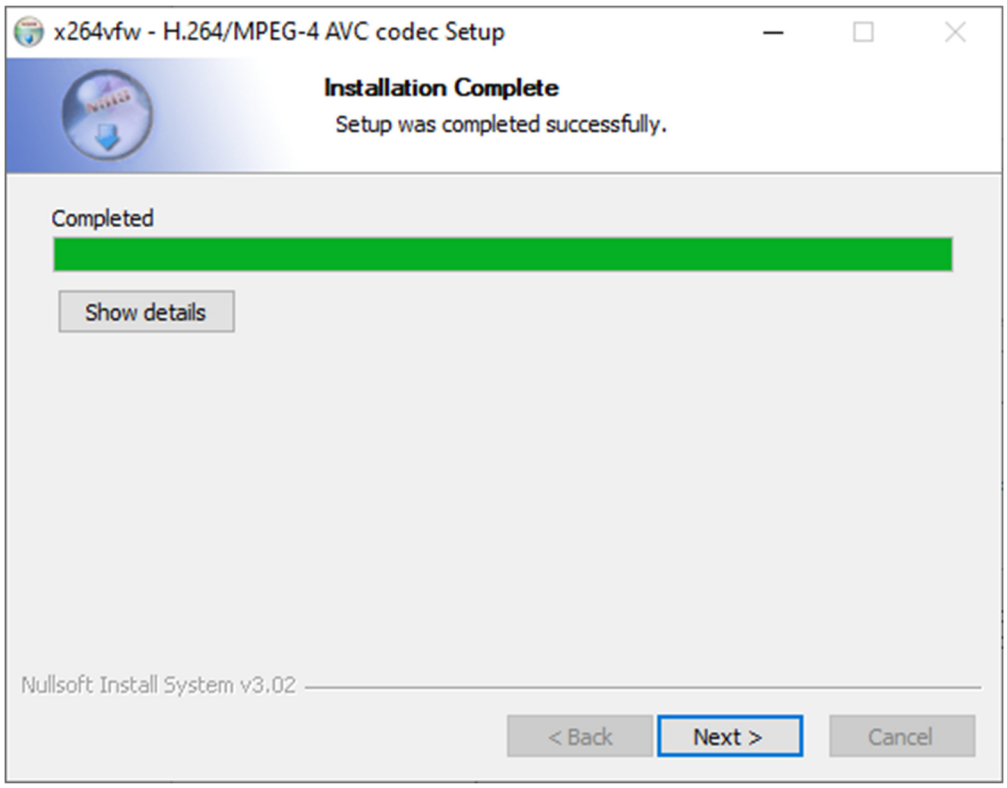
This codec saves space when exporting videos from AAA

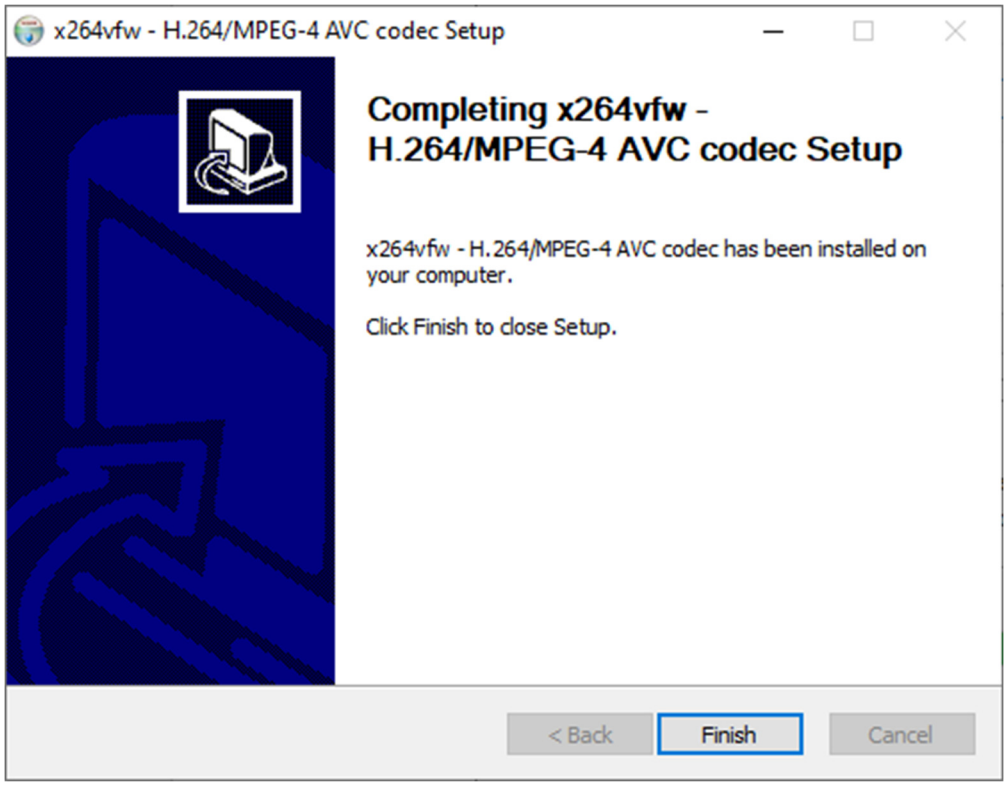






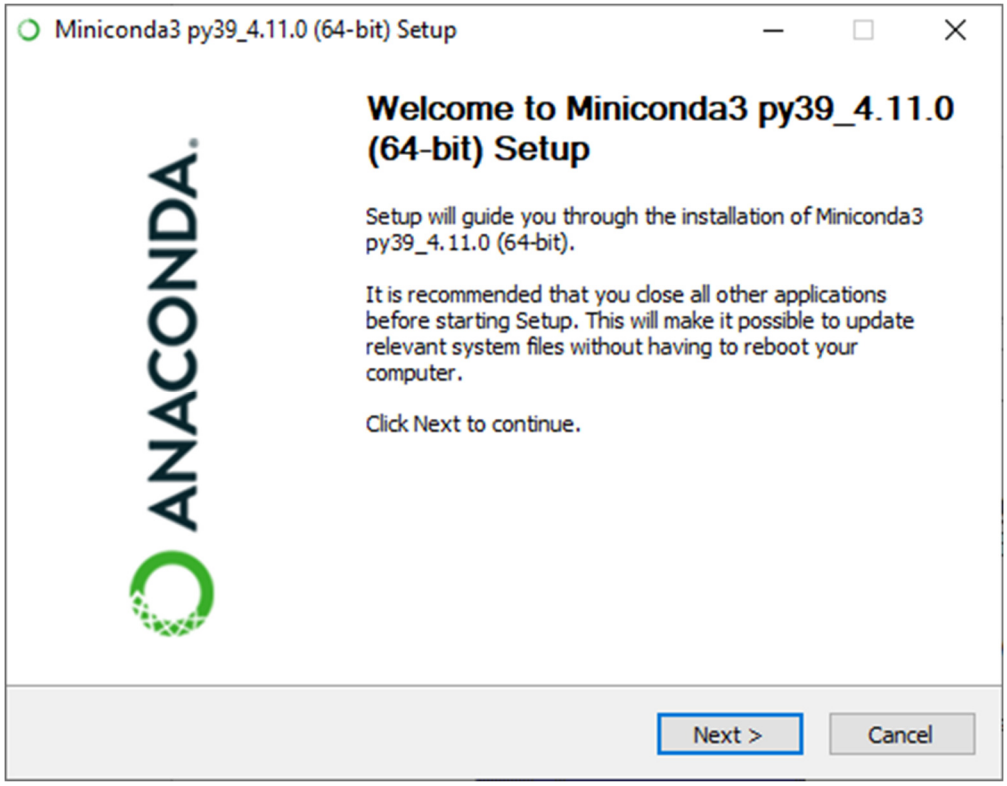


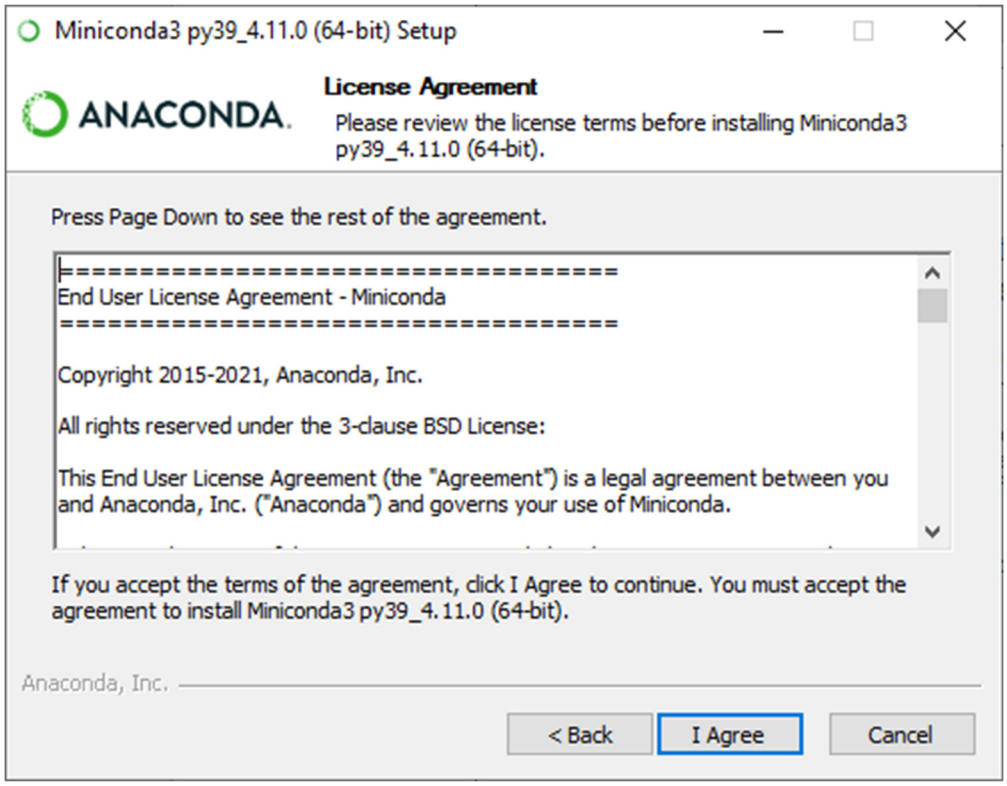


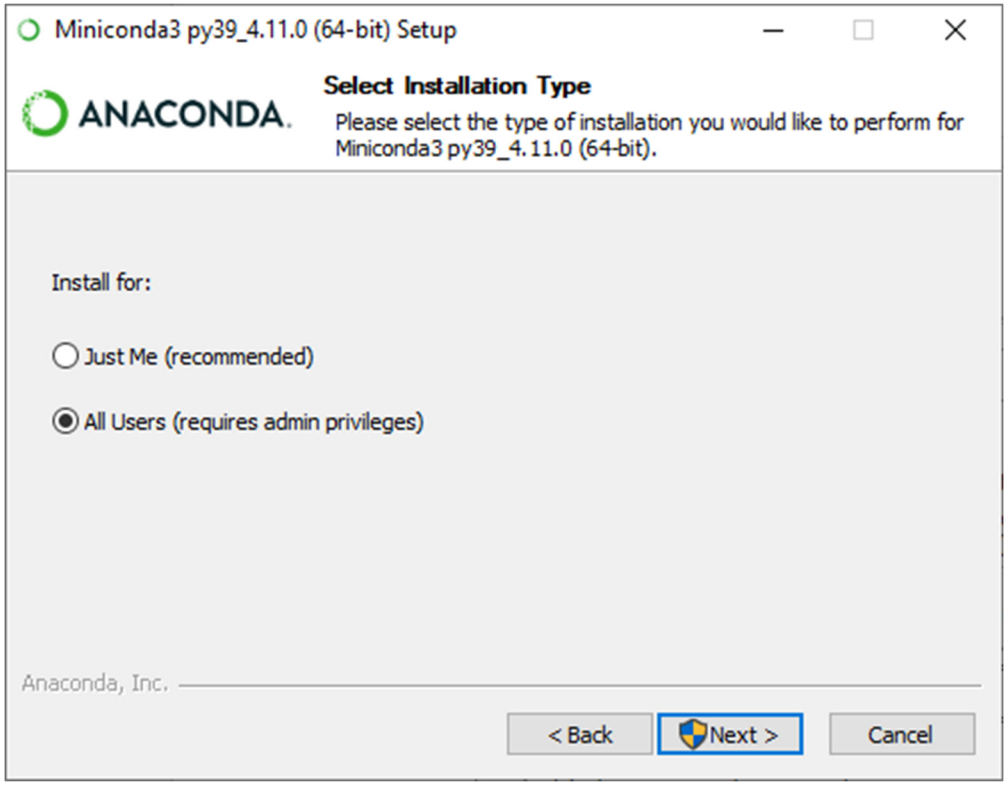


Miniconda installation

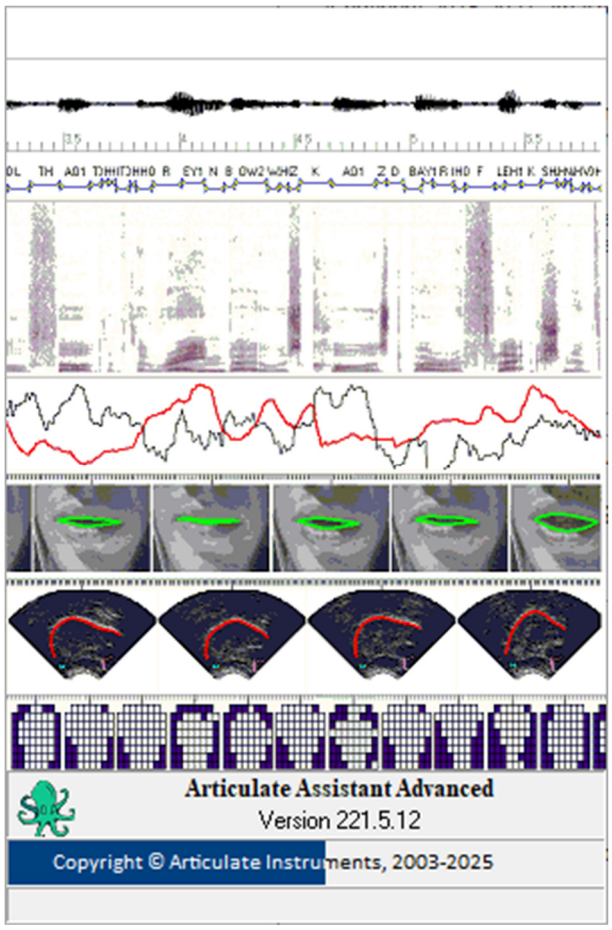
This should only be done once. The first time AAA is installed.



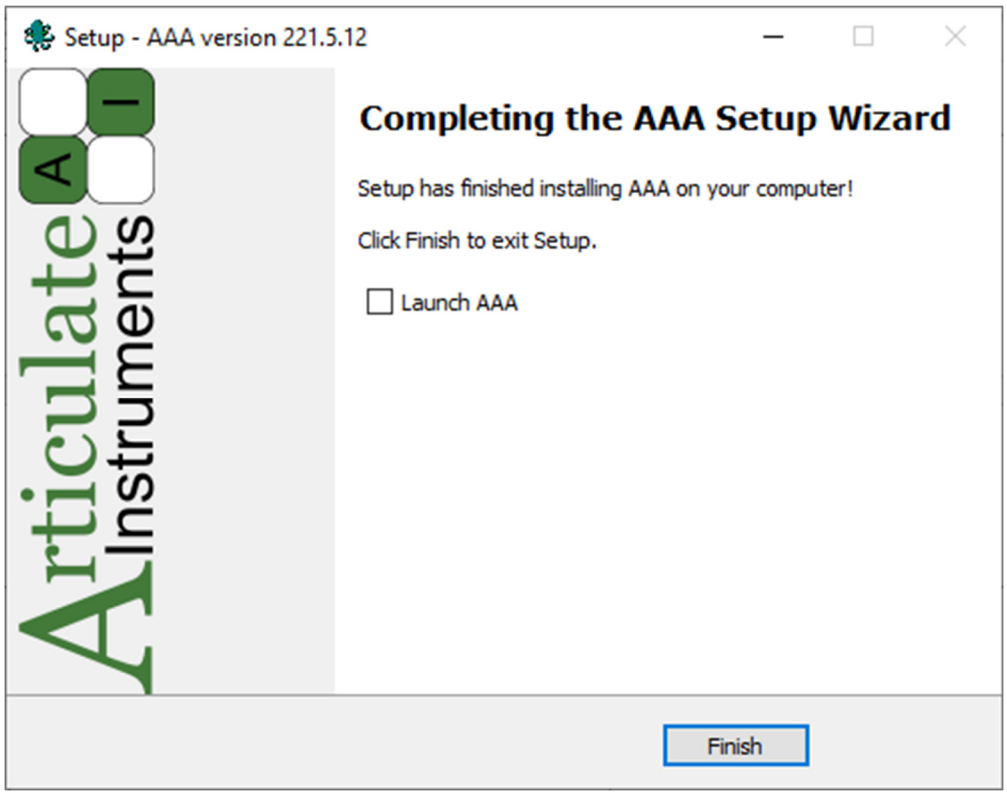




AAA will then automatically run and install deeplabcut



Installation will then be complete



Initialising Telemed ultrasound

It is necessary to run Echo Wave II once as administrator after the system is installed for the first time. This initialises a number of settings.

1. Connect the Telemed probe to the scanner and the scanner to the PC via USB.
2. Right-click on C:\Program Files (x86)\TELEMED\Echo Wave II\EchoWave.exe and run as administrator Run as administrator
3. Close Echo Wave II.

Installing DFG2USB driver.

To install the driver for the Imaging Source video capture card, the DFG2USB unit must be connected via USB to the PC.

Installing Focusrite Scarlett pre-amp/soundcard drivers

Focusrite update their models every couple of years. Each new model is given a generation ID (Gen2, Gen3, Gen4 etc). Each model has unique drivers and care must be taken to install the driver that matches your model.

Articulate instruments supplies Focusrite Scarlett Solo and Scarlett 4i4 models. The following pictures show the appearance of each model and the location of the driver.

Match the image below to your Focusrite Scarlett and download and install the corresponding driver.

https://downloads.focusrite.com/focusrite/scarlett-2nd-gen/scarlett-solo-2nd-gen

Focusrite Scarlett Solo Gen2 https://downloads.focusrite.com/focusrite/scarlett-2nd-gen/scarlett-solo-2nd-gen

Focusrite Scarlett Solo Gen3 https://downloads.focusrite.com/focusrite/scarlett-3rd-gen/scarlett-solo-3rd-gen

Focusrite Scarlett Solo Gen4 https://downloads.focusrite.com/focusrite/scarlett-4th-gen/scarlett-solo-4th-gen

FocusriteScarlett 4i4 Gen3 https://downloads.focusrite.com/focusrite/scarlett-3rd-gen/scarlett-4i4-3rd-gen

FocusriteScarlett 4i4 Gen4 https://downloads.focusrite.com/focusrite/scarlett-4th-gen/scarlett-4i4-4th-gen

Enabling the AAA app with the USB licence key

Articulate Assistant Advanced requires a USB licence key plugged into the usb port of the PC in order for the software to function fully. Without the licence key it is not possible to record or import data nor view data that has been previously recorded.

A USB key embodies each issued licence. Red licence keys, issued from 2003-2025, are now obsolete. Red AAA dongles require a driver to be installed and Windows Core Isolation Memory Integrity blocks this driver. If you are having problems with your licence key, please check if a Windows update has turned ON Core Isolation Memory Integrity. To do this, please use your Windows Start menu to search for “Core Isolation”, then in that settings page please ensure that Memory Integrity is disabled.

Since August 2025 we have issued green usb licence keys which do not require dedicated drivers. If you wish to replace your red dongle with a green one then you will need to return the red dongle to us or show photographic evidence that the red dongle has been destroyed. We will then ship a green dongle to you at a cost of £30 +shipping + import customs charges (payable to courier).

IMPORTANT: Keep your USB key safe when not in use. **It is valuable**.

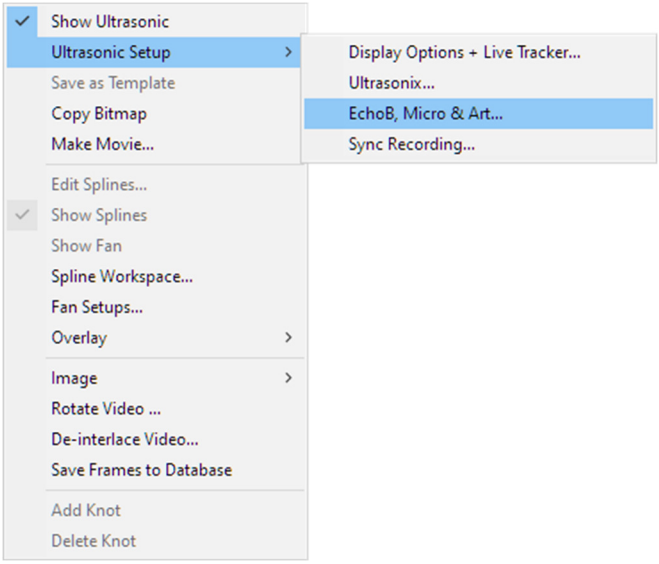
Note: The red USB license key should be plugged in AFTER Articulate Assistant Advanced has been installed because the installation process sets up the USB key drivers. If the USB key is plugged in before Articulate Assistant Advanced is installed then windows will detect a new device and ask for the drivers.

Recording video sync signal and ultrasonic pulses on the same channel Focusrite Scarlett Solo

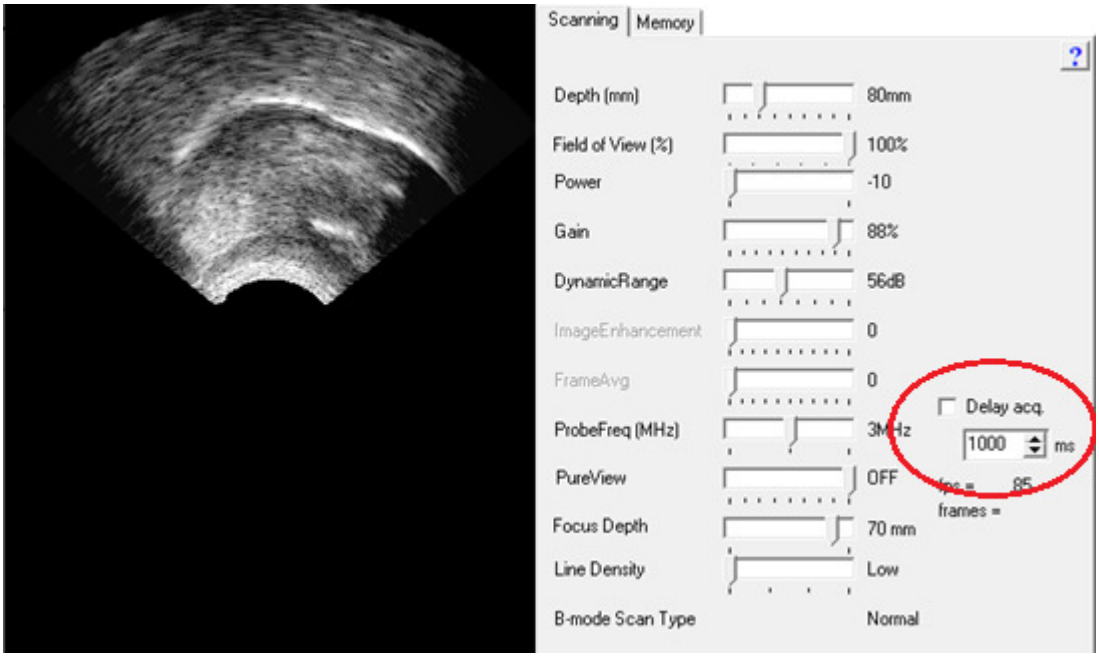
When recording the video sync signal and ultrasonic frame sync pulses on the same channel, it is necessary to delay the start of the ultrasonic recording to ensure separation. It is also necessary to set the automatic ultrasonic syncronisation so that it ignores the video sync signal.

Follow these steps:

1. Right-click on the ultrasound display and select “ultrasonic setup… -> Micro, Echob & Art”

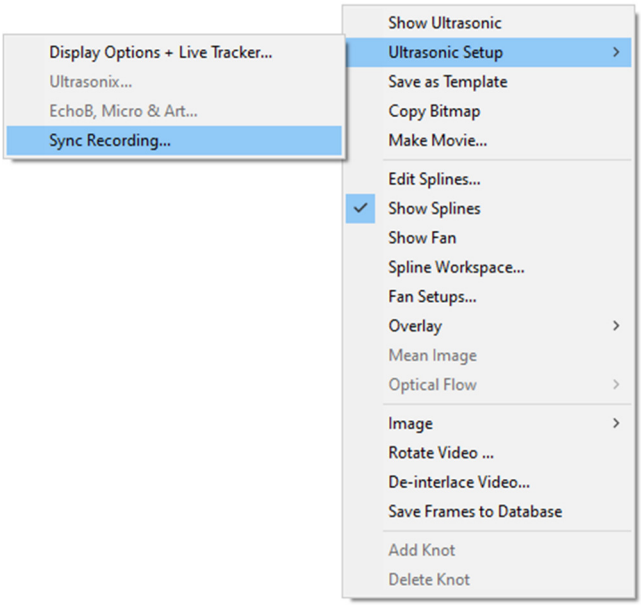


2. This opens the ultrasonic settings dialog. Check the box Delay acq. And set to 1000ms. This will delay the start of ultrasound recording for one second.



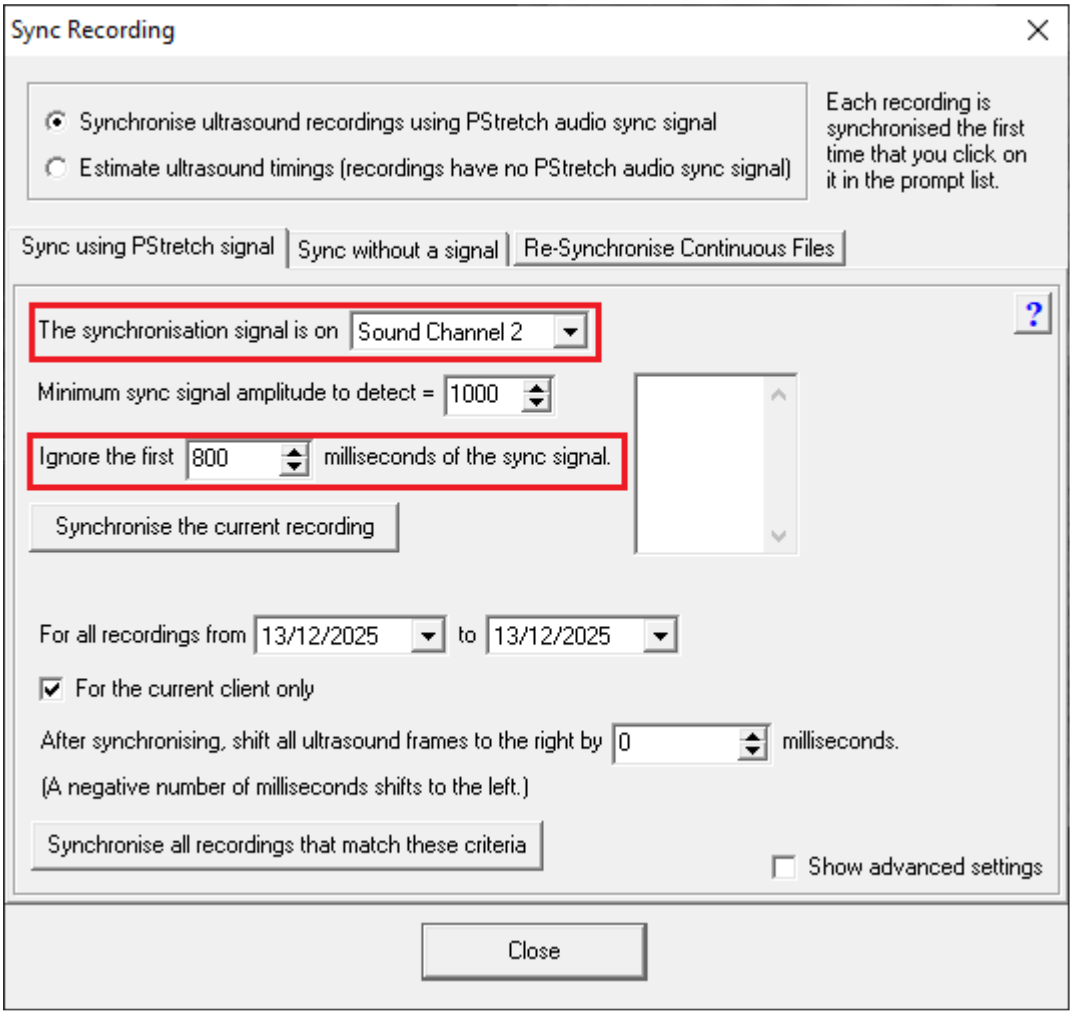
3. Close the dialog

4. Right-click  on the ultrasound display and select “ultrasonic setup… -> Micro, EchoB & Art”



5. In the sync ultrasonic dialog, make sure the channel is set to the Focusrite Scarlett channel with the ultrasonic pulses.

6. Set ignore the first 800 milliseconds of the sync signal



See video synchronisation section for processing the video.

Recording Speech audio, ultrasonic frame pulses and video sync signal on separate channels (Focusrite Scarlett 4i4)

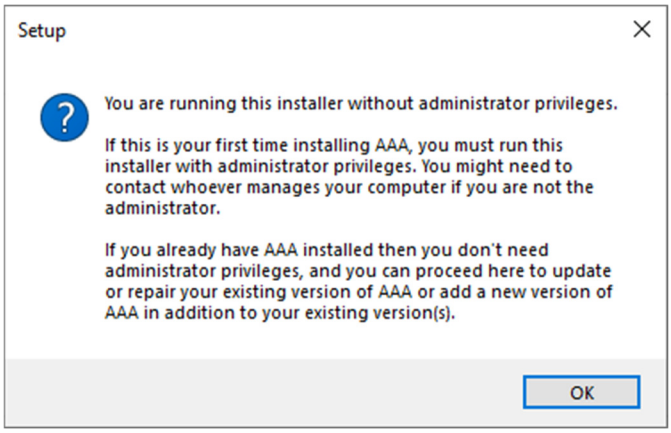
If recording the video sync signal on a separate third channel then simply ensure that the Ultrasonic sync channel setting matches the channel with the ultrasonic frame strobe pulses.

See video synchronisation section for processing the video.

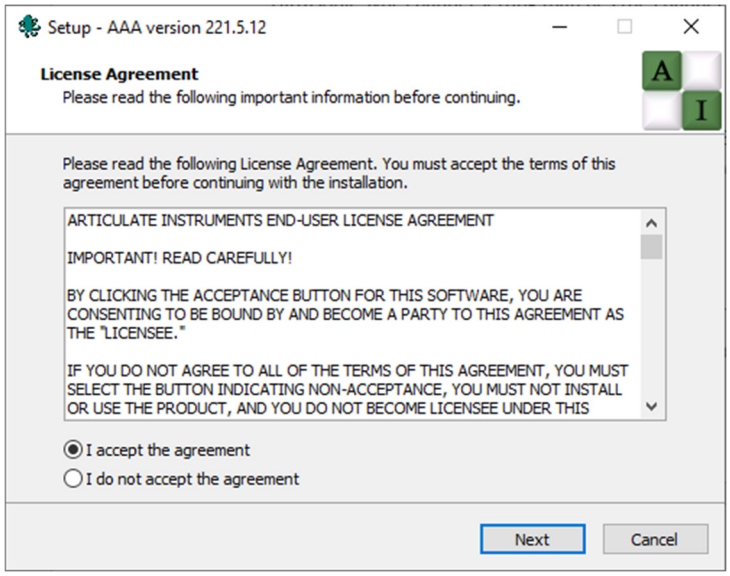
Updating your AAA software to the latest revision

DO NOT uninstall the old version of AAA

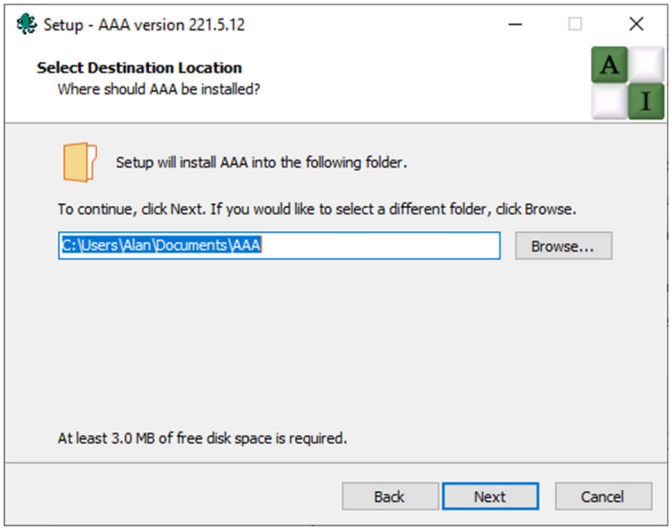
1. Double click on the AAA setup installer for the latest revision. DO NOT run as administrator.



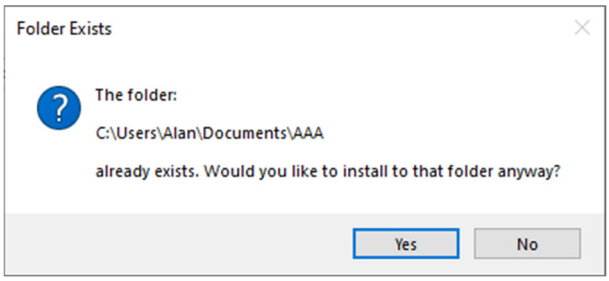
2. Select I accept the agreement and Click Next



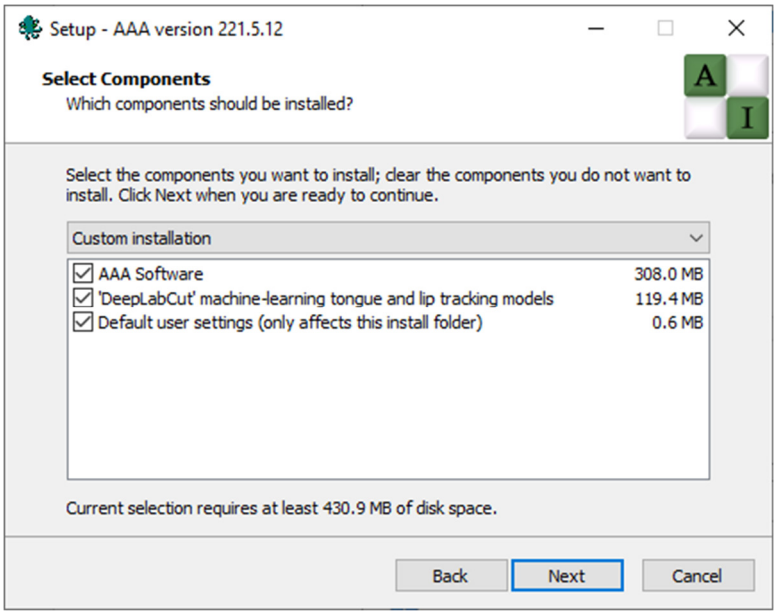
3. Click Next unless you have reason to install the new revision elsewhere. This will overwrite the old version.

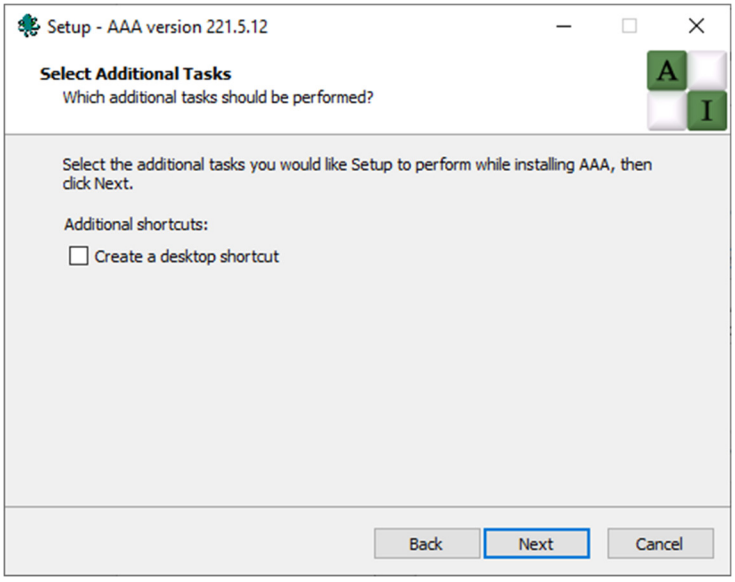


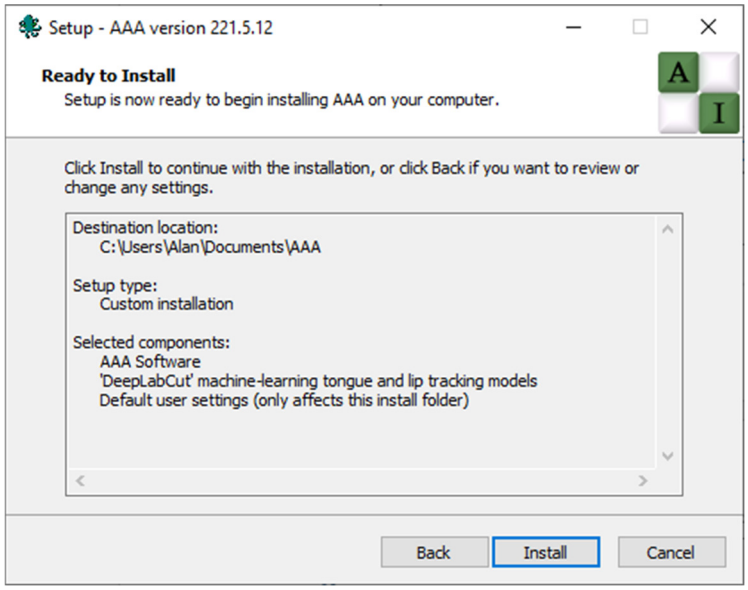
4. Click Yes unless you have reason to install the new revision elsewhere. This will overwrite the old version.



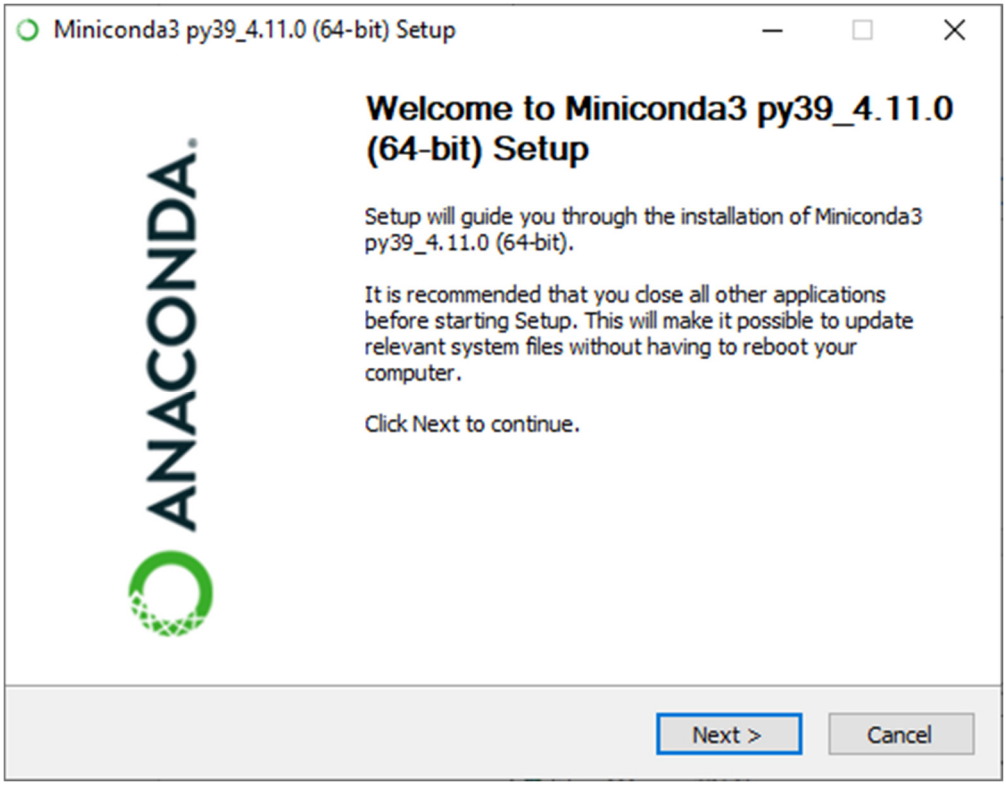
5. Click Next to install the revised version of AAA, up-to-date tongue and lip models, and default AAA settings for this revised version.



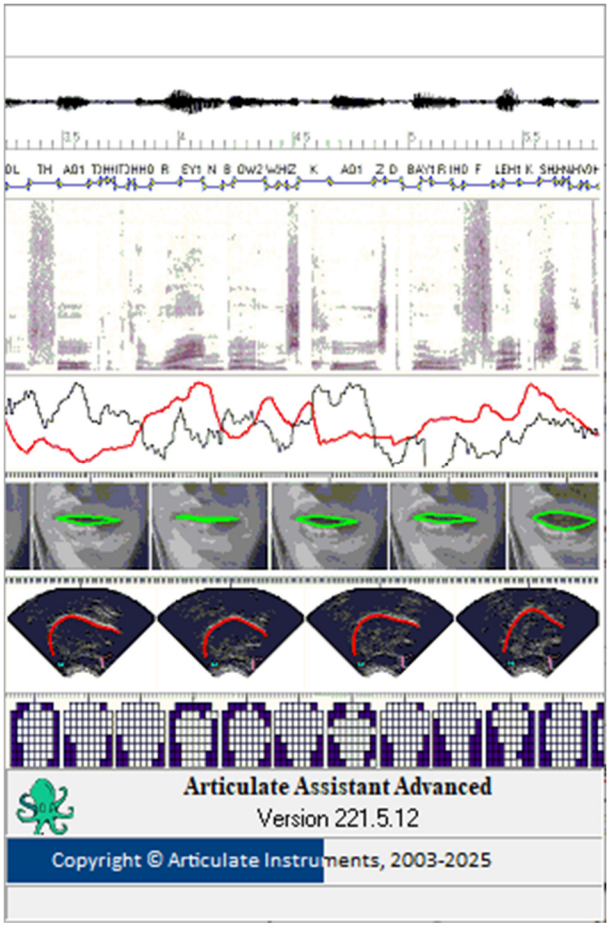
6. 

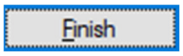
7. Click Install 

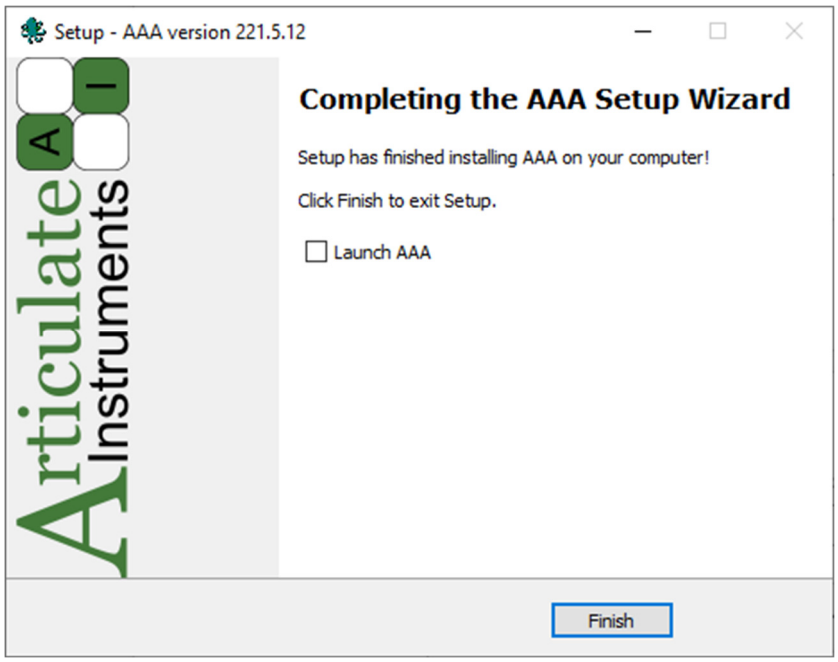
8. CLICK CANCEL as Miniconda has already been installed.



9. AAA will automatically start to check that DeepLabCut is installed.


Articulate Assistant Advanced
Version 221.5.12
Copyright © Articulate Instruments, 2003-2025

Click 
Finish


Setup - AAA version 221.5.12
Completing the AAA Setup Wizard
Setup has finished installing AAA on your computer!
Click Finish to exit Setup.
Launch AAA
Finish

Overview

The Articulate Assistant Advanced (AAA) application runs under Windows 10 and 11.

Instrumentation

AAA is designed to allow speech scientists to synchronously record and analyse data produced by a wide variety of articulatory instrumentation such as:

- Speech acoustics
- EPG (WinEPG system)
- Laryngograph, airflow, and other analogue signals recorded with multichannel soundcard
- Ultrasound (raw data from Telemed and ultrasonix systems)
- Lip camera video and video based output from ultrasound systems
- Electrophotoglottograph (measures glottal abduction, adduction and phonation)
- Electromagnetic Articulograph (Carstens EMA)
- Vicon (camera tracking system)

Design philosophy

AAA is designed to work on 2 levels.

- We attempt to make the default settings appropriate for best results.
- Advanced settings allow control over parameterisation.

The goal

The goal of AAA is to improve productivity of articulatory analysis in the speech lab. 20 years ago a researcher could spend months hand drawing tongue contours on single frames representing a phone target. Today a computer can fit contours to hours of data overnight and more accurately than many human labellers. We continue to strive for greater accuracy. Analysing data has advanced too. AAA has brought together many tools for quickly running different tongue shape comparisons and significance tests. We continue to work on developing methods for cross speaker analysis and other challenges.

Quick Start: Prepare to record

Articulate Assistant Advanced™ starts up in a demonstration project containing data that can be analysed but it is not possible to record new data in this project. The 

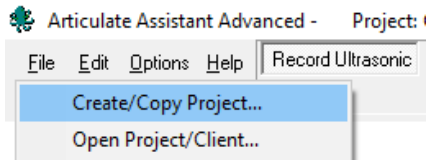
button will be inactive. To be able to record and activate the record button you must do four things

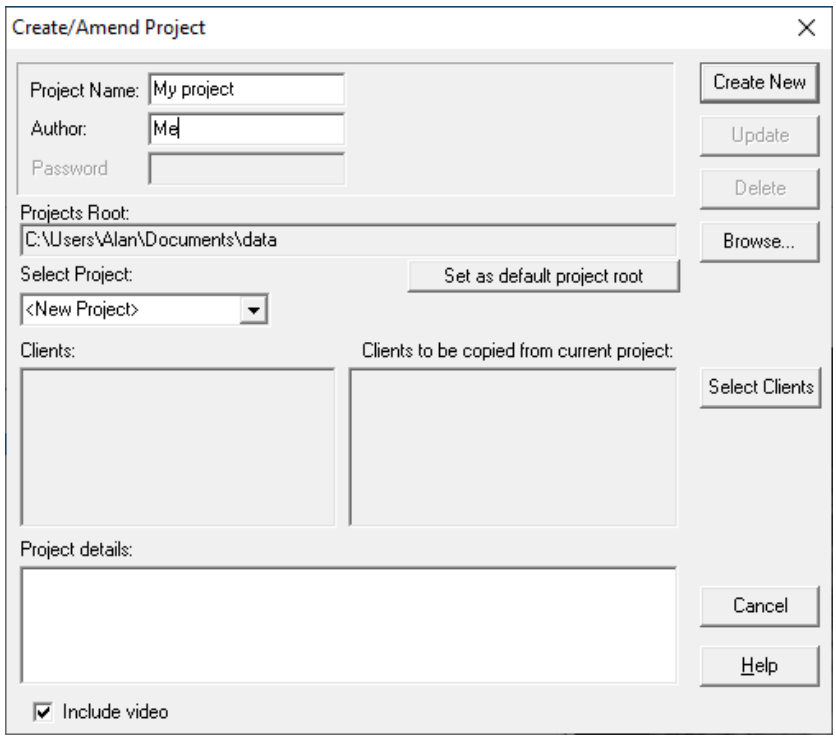
1. Either create a new project or open a project that you previously created.
2. Either copy prompts from the current directory or create your own promptlist
3. Create a Client/participant

4. Make sure an audio recording device is enabled.

Create a project, a prompt list, and a client

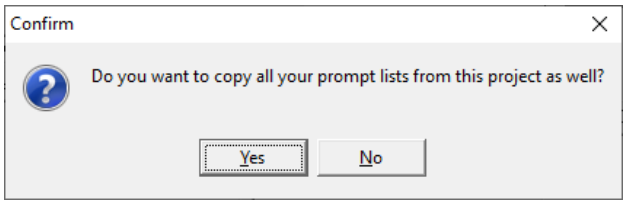
To create a new project select the “File” menu and select Create/Copy project…



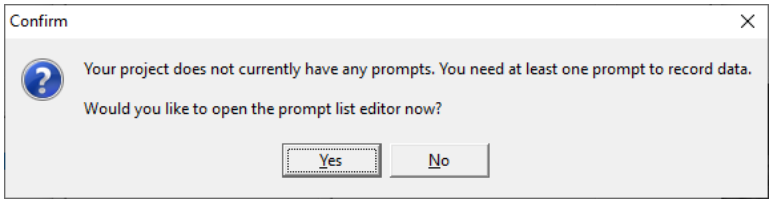


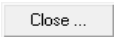
1. By default the projects root directory is the directory from which the application is run. However, you may prefer to specify a separate location for data storage, perhaps in another folder or on another disk drive, dedicated to storing data.
2. Browse... to select the Project root or type or paste the path into the Projects Root edit box.
3. To remember this location the next time you create or open a project, click the Set as default project root button.
4. After setting the Project root, complete the ‘Project Name’ using alphanumeric characters. This will also be the name of the folder in which all the project data is stored. You may also specify the author and any details describing the project.
5. Click Create New You will be asked if you want to copy the promptlist from the current project. It is easiest to click OK the first time you create a project. The

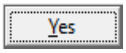
prompts from the demo project will be copied to your new project.



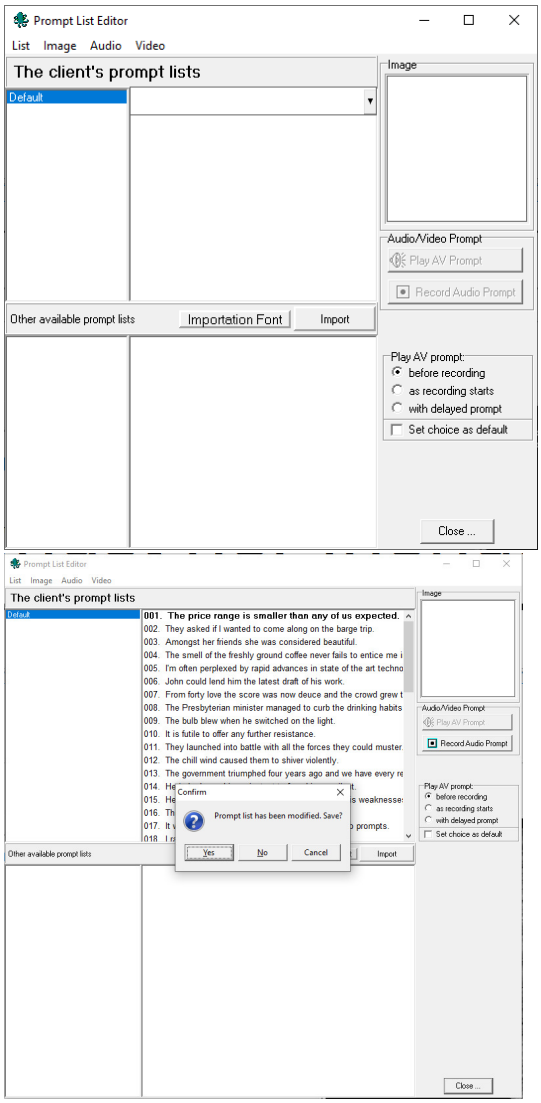
6. However, if you prefer not to add unwanted prompts to your new project and prefer to create your own promptlist, click No. Then click Yes when asked if you want to open the promptlist editor. IMPORTANT: You must have at least one prompt to be able to make a recording.



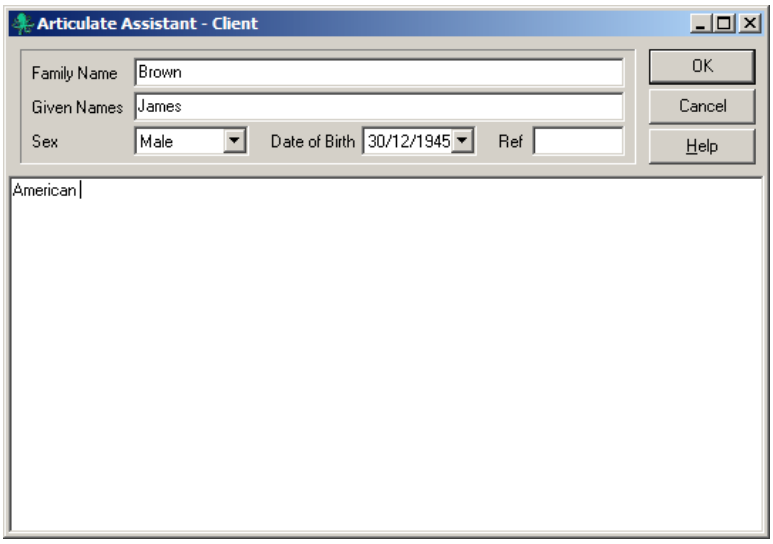
7. To quickly create a promptlist either type or paste text into the top right panel corresponding to the default promptlist, click 

and then 

when prompted to save. See following section for more advanced promptlist options.



8. After importing or creating a promptlist you will be prompted to create the name of the initial client in this project. As a minimum you must enter text in the “family Name” box or the Ref box. Other information is optional.



Select audio recording and playback devices

9. You **must have a soundcard enabled** to enable recording. Every AAA recording must have an audio data stream as it provides the time base for all the other data streams. If you are recording from a laptop you will have a choice of the built-in soundcard and microphone and the external soundcard (e.g. Focusrite Scarlett Solo). Usually the external soundcard will be selected by Windows automatically but it is good practice to confirm that the recording and playback is set to the external soundcard if you are intending to record with it.

Important
If you are using the external soundcard to record you **MUST use the external soundcard to playback otherwise ultrasonic data will not synchronise correctly**. If the laptop is used to playback then the system will temporarily halt recording while it swaps soundcard to playback. This results in critical loss of initial ultrasonic pulses which results in mis-assignment of ultrasound images relative to the audio.

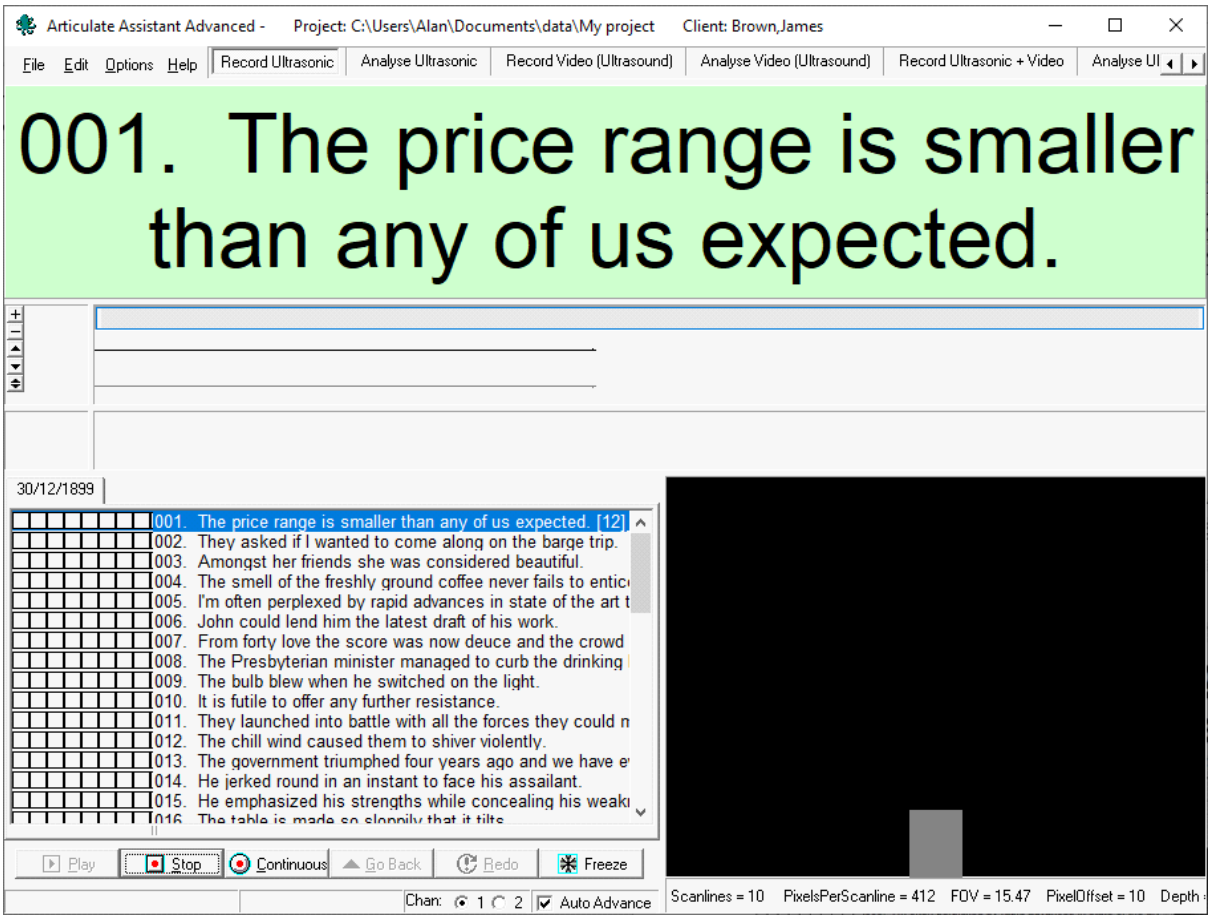
Start and stop recording

10. To start a recording, select a prompt text by clicking on an empty box or the prompt text in the list bottom left. The 

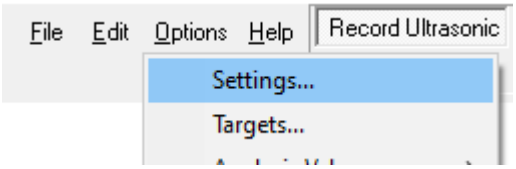
button should now be active. Click 

to start recording. You will hear a beep and the prompt screen will turn green. When the speaker has finished speaking you can click the 

button to stop the recording before the default duration.



11. The settings dialogue defines the **Maximum Duration** of the recording which defaults to 6 seconds. i.e After 6 seconds the recording will automatically stop and save. If you need to record for longer you can change this timer.



12.

In the Settings dialog, **Maximum Attempts** defines the maximum number of recordings that can be made for a single prompt for a client across all sessions. It defaults to 256. i.e. more than 4 hours of 6 second recordings.

Play WAV file defaults to playing a BEEP at the start of the recording. This is a useful indicator for the participant to start speaking. **It is recommended to use the default BEEP.wav** as this file is optimised for triggering the SyncBrightUp unit used for synchronising video.

Projects

AAA does not use filenames to store recordings. Instead they are uniquely referenced withing a database called a project by three pieces of information

1. Client name
2. Prompt
3. Date/time of recording

A recording may consist of a collection of several data streams. For example a recording may consist of speech acoustics and ultrasonic data from the Micro. But a recording can also contain Splines generated from the ultrasound data, analysis values generated from the splines, annotation labels. All of these data streams are time-tagged and managed by the AAA software.

You may wish to create one project per client/participant so that each project is a manageable size or a group of clients can be stored in a project. This will allow comparisons to be performed between clients within the software but take care that the project does not become unmanageably large particularly in the time required to back It up. If your project does become larger than you would like, you can use the copy project option to transfer a subset of clients or recordings to another project.

Typical storage requirements

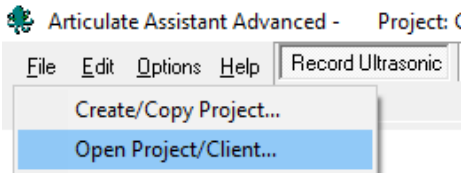
22kHz 16-bit stereo audio	0.09Mb/sec	317Mb/hr
44kHz 16-bit 4-channel audio	0.35Mb/sec	1.27Gb/hr
Micro ultrasonic data	5.85Mb/sec	2.1Gb/hr
Greyscale Video	9.2Mb/sec	3.32Gb/hr
24bit Colour	27.6Mb/sec	82.8GB/hr

Create a new project

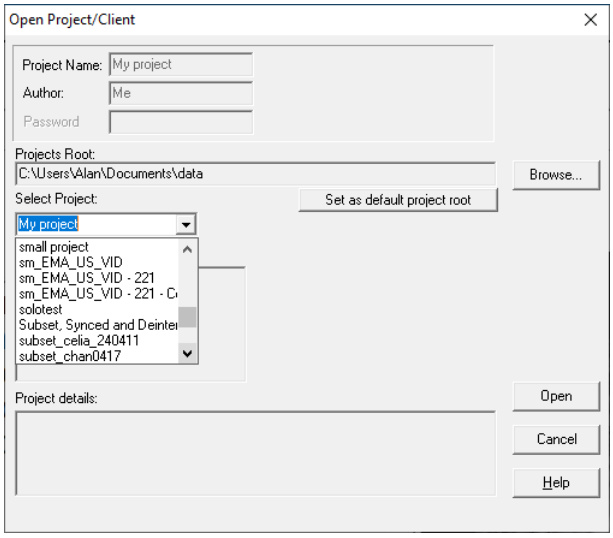
See previous section on preparing to record.

Open an existing project

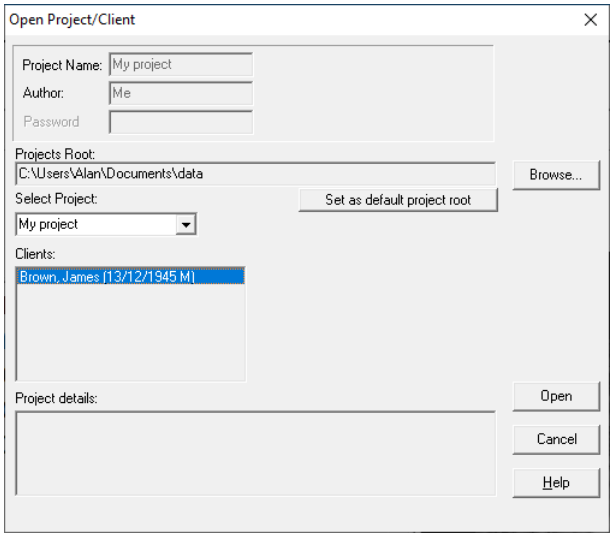
To open an existing project select the “File” menu and select Open project/client…



1. If the project you are looking for is not in the current Projects Root then select Browse... to find the project folder or type the path into the "Projects Root" edit box.
2. Select a project from the list of available projects in the projects root.



3. Select a client from the selected project and click Open.

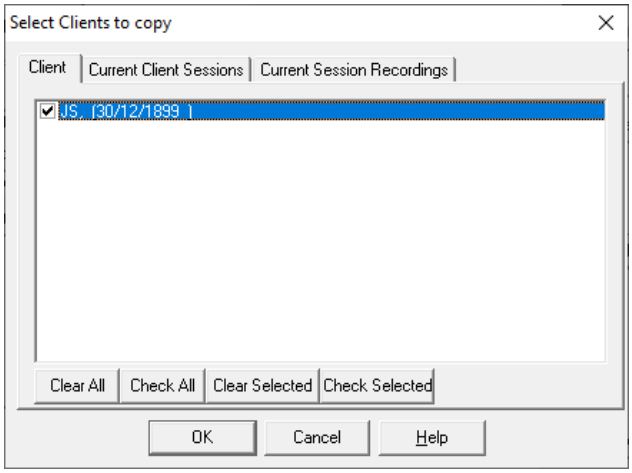


Copy recordings from one project to another

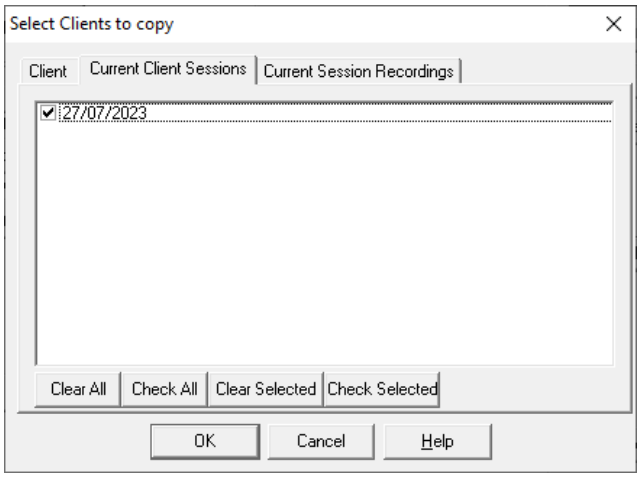
It is possible to copy data from the currently open project to another project. The data can be appended to an existing project or a new project can be created specifically for the files to be copied. You may wish to do this to create a subset of data for a particular analysis or to allow a subset of data to be given to another researcher using AAA.

1. Use “File | Open project/client…” dialogue to open the project and the client that you wish to copy data **from.**
2. Use the ‘File | Create/Amend Project…’ dialogue to select the project you want to copy the data **to**. This can be a new project you create or an existing project you wish to add clients and recordings to.
3. Click the 

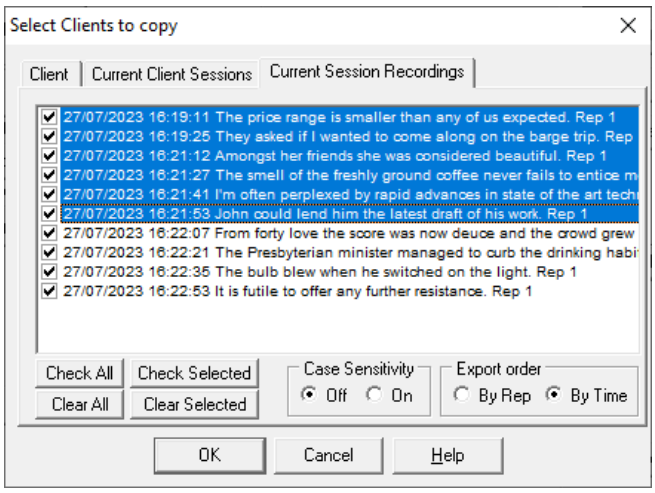
button to open the ‘Clients to Copy’ dialogue.
4. From the ‘Client’ tab window in the dialogue select the client or clients you wish to copy to the new project.

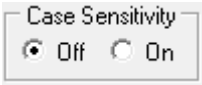


5. From the ‘Current client sessions’ tab window in the dialogue select the session or sessions you wish to copy to the new project. You can only access sessions from the currently loaded client.

6. 

7. From the 'Current Session Recordings' select individual recordings from the current client. You can click and drag or <cntrl> click to multiselect recordings and then check or uncheck the selected recordings.



8. 

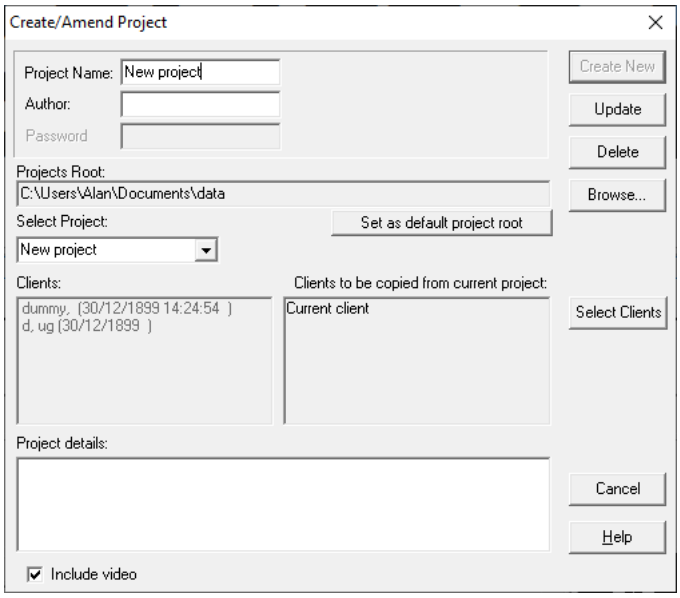
If you have separate prompts that deliberately differ because the target word has a upper case character in one prompt and lower case in the other then switch case sensitivity on.

9. 

'By rep' lists the recordings according to the order of the prompts. 'By time' lists them according to the time they were recorded.

10. After selecting the data to be copied, click OK to close the 'Clients to Copy' dialogue. The name(s) of the clients to be copied in full or in part will be entered in the clients to be copied listbox in the 'Create/Amend Project' dialogue.

11. Finally, to add this data to the new or existing project click Create New or Update as appropriate.



Backing up projects

It is strongly recommended to back up your projects to an external drive, network drive or cloud repository. You must back up ENTIRE project folders. DO NOT BACKUP PART OF A PROJECT FOLDER.

The Data.aa0 file in the project folder contains the database and small pieces of data less than 4 bytes. Larger data chunks of data such as audio, ultrasound, video recordings are stored as Chunk???.aa0 files.

Prompts

A promptlist MUST be selected in order to enable a recording to be made. Each recording is then automatically saved and associated with a selected prompt from the promptlist. If the The PromptList window is empty then use the PromptList Editor to edit existing prompt lists or add new ones or select a different one.

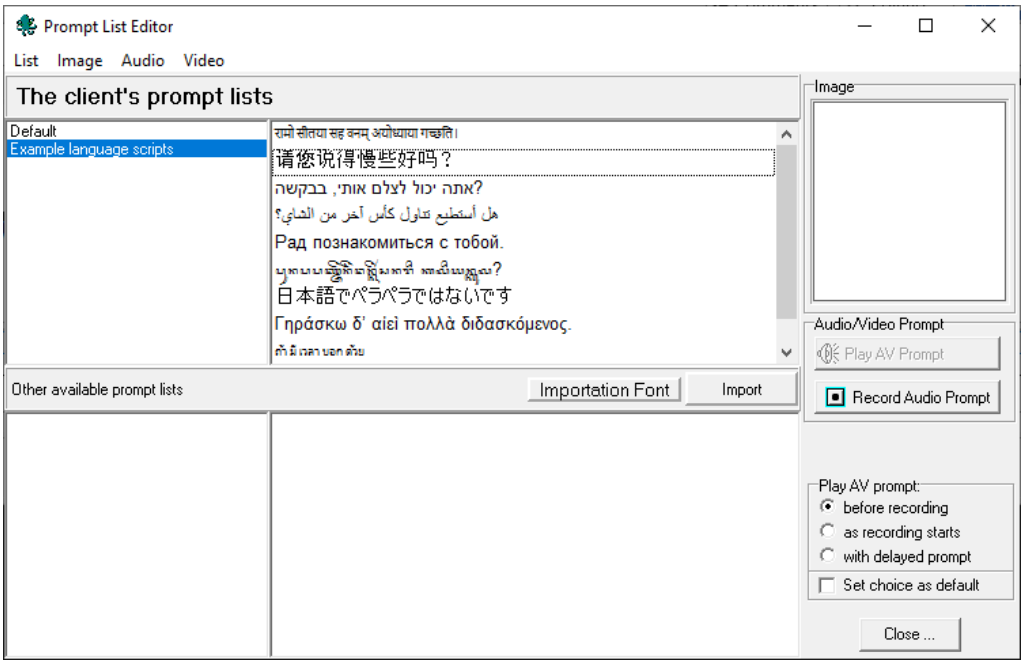
A prompt consists of a line of text terminated in a carriage return linefeed. It may be a single word or a passage of text.

They asked if I wanted to come along on the barge trip.

TIP

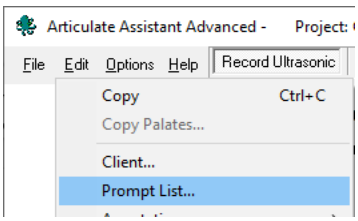
Optionally you can add a number in square brackets at the end of the prompt. AAA will read this number and stop the recording automatically after this number of seconds.
e.g. The following prompt will stop recording after 3 seconds.
025. I always seem to follow my instincts rather than reason. [3]
The [3] overrides a default duration for stopping recording which is set in Options|Settings Utterances.

Since version 220_x AAA has been able to read and display Unicode prompts. In previous versions it was necessary to use fonts or present pictures of prompt texts in languages unrepresented in the basic ASCII character set.

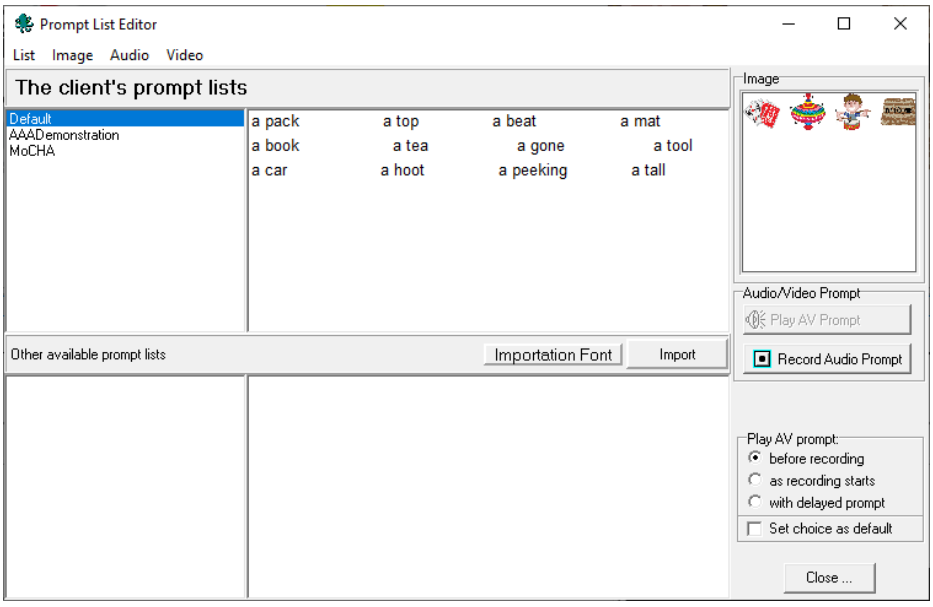


PromptList Editor

The list of prompts can be edited or a new list created with the '**Edit:Prompt List…** dialogue.



On startup, the AAA demo project has sample prompt lists default, AAA demonstration and MoCHA.



When you create a new project you can choose whether to copy these lists into the new project. If you choose not to copy them, this will reduce the size of the project but you must then create your own list with at least one prompt.

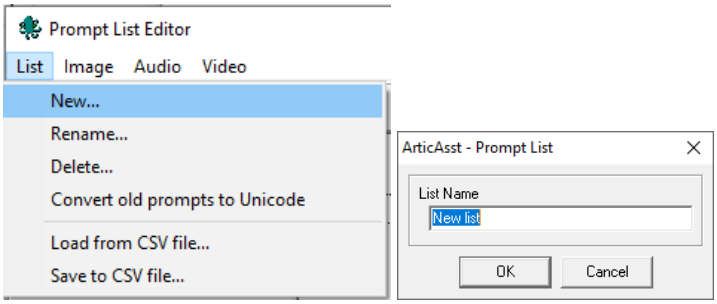
The easiest way to create a list is to **cut and paste** a set of prompts that you have prepared in word or excel or found on the internet into the **default** list. Each recording can be prompted by text, an image, an audio or a video clip.

TIP

If you already have a list of prompts in a text file. Simply copy the list to the clipboard using <Ctrl>-C in your text editor and paste into the Prompt List Editor using <Ctrl>-V

To create a new list click the List menu item

'New' sets up a Title and opens a new blank list.



'Rename…' allows the currently selected list to be renamed.

'Delete' allows the currently selected list to be deleted. This may save space especially if the list has audio, video or image prompts.

'Convert old prompts to unicode' allows prompt lists which were stored in special fonts in previous version of AAA to be converted to unicode. See following section.

Load and save prompt lists

Promptlists are stored within the database but they can be exported or imported in csv format. The benefit of this format over cut and paste is that it records associated bitmaps and audio. Exporting the default promptlist exports the associated bitmaps as well as the csv file.

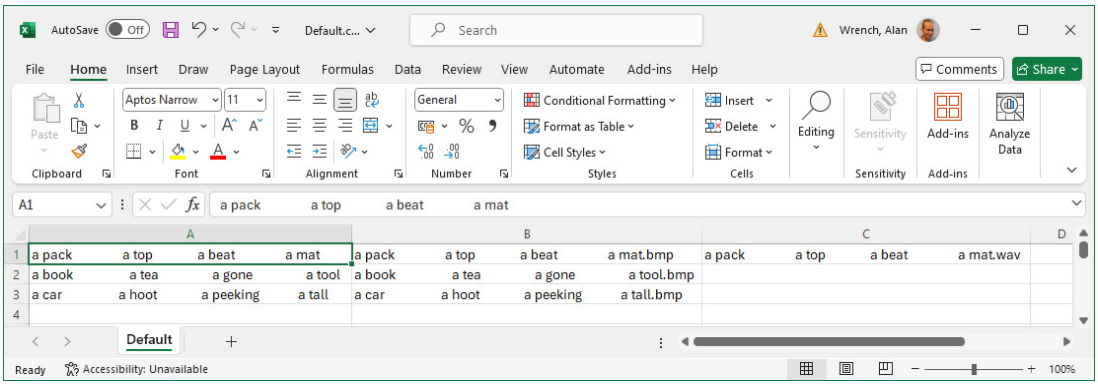
In the csv file

Column 1 contains the prompt text

Column 2 contains the name of any image bitmap

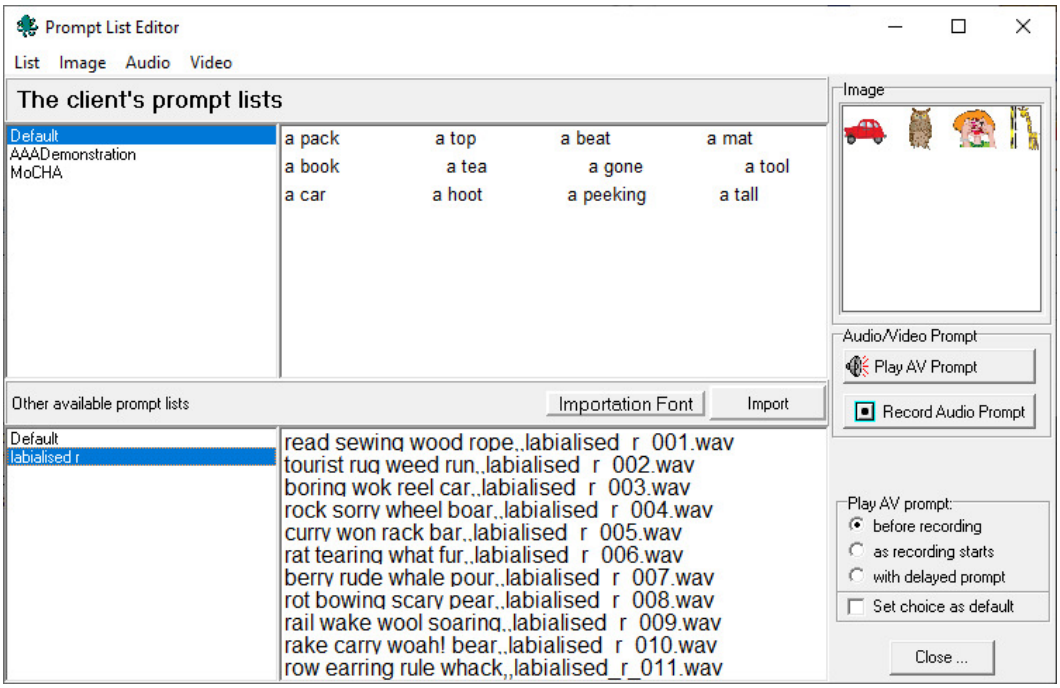
Column 3 contains the name of any audio wav

Currently video avi files are not saved – but will be in column 4 in future versions.



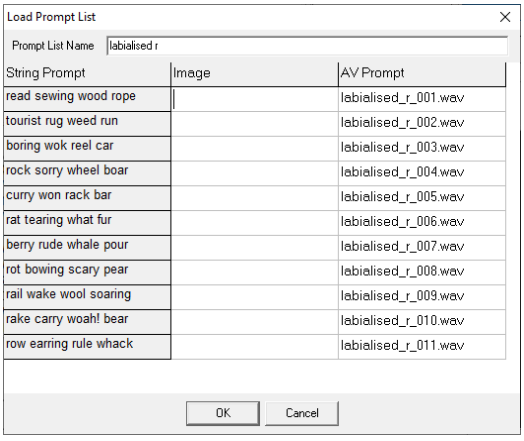
	A				B				C				D
1	a pack	a top	a beat	a mat	a pack	a top	a beat	a mat.bmp	a pack	a top	a beat	a mat.wav	
2	a book	a tea	a gone	a tool	a book	a tea	a gone	a tool.bmp					
3	a car	a hoot	a peeking	a tall	a car	a hoot	a peeking	a tall.bmp					
4													

Csv files will be shown in the bottom panels of the promptlist editor if they are present in the **Prompts folder** under the application folder.



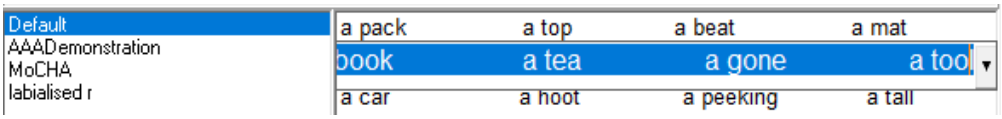
Click the 

button to import the prompts and associated images and audio into the current project. An editor will appear. You can use the editor to change the name of the list and delete any media files you don not wish to import.

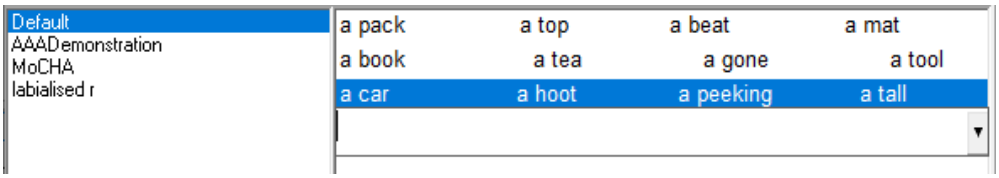


Edit the currently selected prompt list

To select an existing prompt for editing double-click or click on it and then click again. Edit

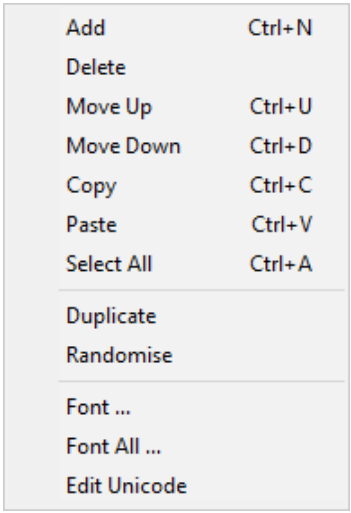


To add a new prompt to the end of the list, click below the bottom entry or  right-click and select **add** from the menu.



TIP
Lines can be multiselected using click and drag, <shift>click or <cntrl> click . Use cut<cntrl>x and paste <cntrl>v options to move groups of prompts to different positions in the list.

 Right-click for a menu of options.



'Add' – adds a new line to the bottom of the list

'Delete' – deletes the currently selected line or lines from the list

'Move Up' – moves the currently selected line up the list

'Move Down' – moves the currently selected line down the list

'Copy' – copies the selected lin or lines to the clipboard

'Paste' – pastes the conents of the clipboard above the currently selected line

'Select All' – select all lines

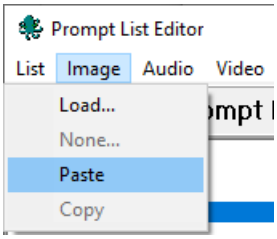
'Duplicate' – copies the selected line to the end of the list

'Randomise' – randomly re-orders the list

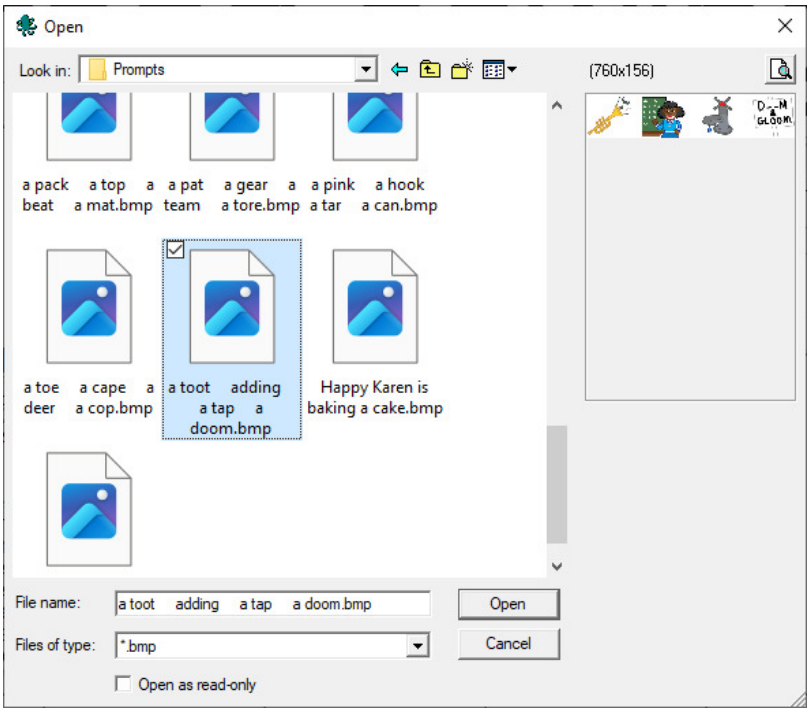
TIP
To randomise 5 reps of a list. <cntrl>A to select all prompts, then <cntrl>V five times to duplicate the prompts. Then  right-click and select randomise.

Picture Prompts

An image can be associated with each prompt. First create the image using your favourite program (e.g. Paint, Boardmaker, Adobe Photoshop etc.). This can be a drawing or a photograph. Copy the image to the clipboard from within that program. Then, from the Prompt List Editor menu, select '**Paste**'.



Select '**load...**' to browse for an image file. Only *.bmp files are currently accepted It brings up a dialogue where the file can be selected and previewed.



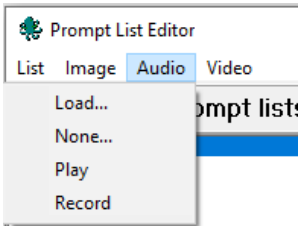
Select **'Copy'** to copy the image from the currently selected prompt. If the current prompt doesn't have an image associated with it then this option will be disabled.

Select **'None...'** to remove the image from the currently selected prompt. If the current prompt doesn't have an image associated with it then this option will be disabled.

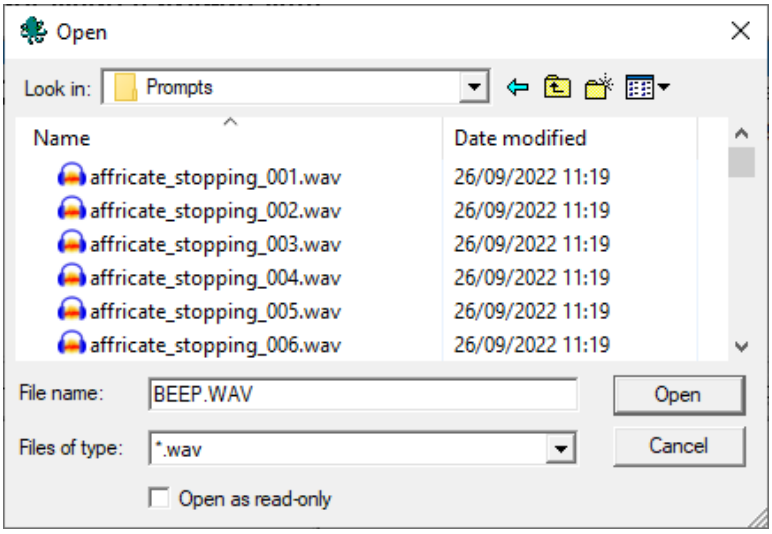
WARNING: If you change a prompt that has an image associated with it, that association will be lost (even if you make as simple a change as adding a space or a comma). This is because the image is associated with the precise text. This also means that if the exact same text is placed in another promptlist the picture will automatically be linked to it.

Audio Prompts

A prerecorded utterance or sound can be associated with each prompt. To associate a wav file with a prompt simply click on the line in the prompt list that contains the prompt you want to link audio to then use the audio menu to:



'Load' – to browse for a prerecorded audio file. It opens a dialogue. You can use any windows (wav) file as an audio prompt.



'Play' – to verify the audio associated with the selected prompt. Also can click 

button.

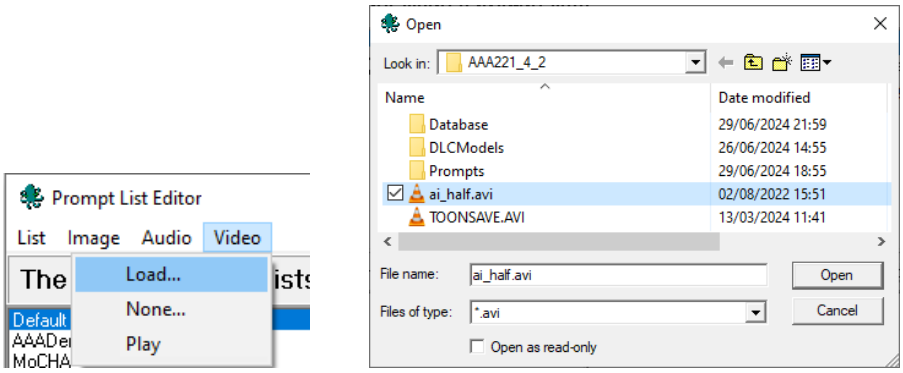
'None…' – remove the audio associated with prompt from the project.

'Record' – not functioning. Also click the 

button.

Video Prompts

Read the instructions above for Audio prompts. Video prompts must be prepared in separate video editing software and be in *.avi format.

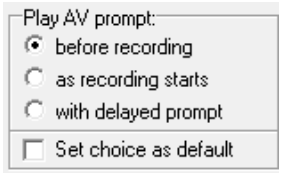


Select a prompt in the list and then use the 'Video' menu option to load the video and associate it with the recording.

WARNING: As with images if you change a prompt that has a wav associated with it, that association will be lost (even if you make as simple a change as adding a space or a comma). This is because the image is associated with the precise text. This also means that if the exact same text is placed in another promptlist the audio will automatically be linked to it.

Choose when to play audio or video

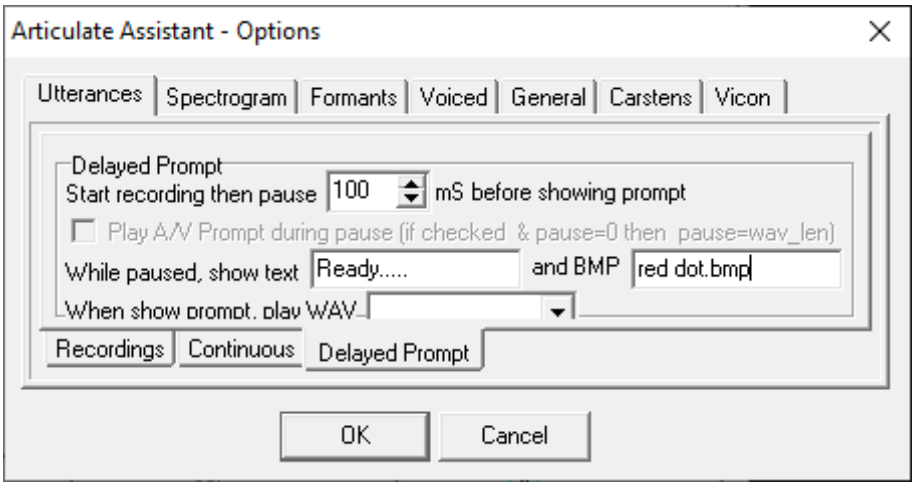
Audio/video prompts default to playing before recording starts. Options are available in the Prompt Editor to start playing the audio or video prompt at the same instant that the audio recording starts. Alternatively, it can also be set to start with a delayed text/image prompt after the recording starts.



Delay presentation of text/image prompt

For studies of anticipatory articulation and reaction times AAA can delay presentation of prompts until some time after recording starts.

Select Options|Settings from the main menu. Select the Utterances tab and the delayed prompt subtab.



1. Specify the wait time after recording starts and before the prompt text/image is displayed.
2. During the waiting time choose to present some text e.g. “Ready…” and/or an image
3. At the instant the prompt appears, specify an audio file to play. E.g. Play a beep.

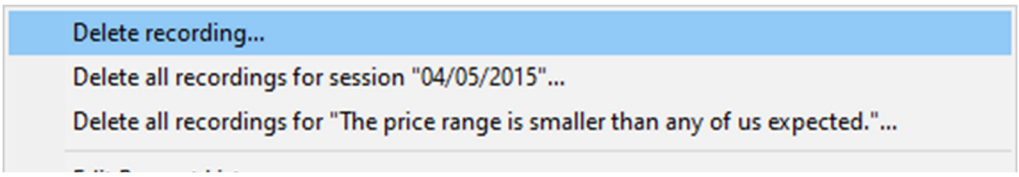
If these options are blank they will be ignored.

The PromptList window

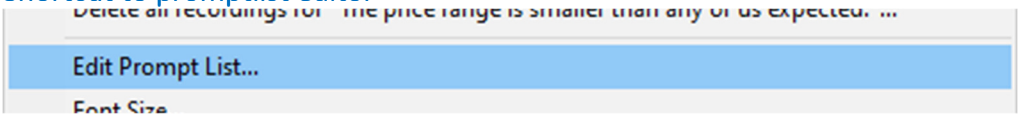
The list of prompts will appear in the promptlist window. The window has boxes on the left. Empty boxes are holders for new recordings. Boxes with crosses have recordings associated with them. Click on a box with a cross to load the recording. Click on an empty box or the prompt to enter live mode ready for recording. On the right side are the prompts. These include prompts from the currently selected promptlist and any recordings previously recorded with a different promptlist. At the top there are tabs. Each tab corresponds to a “Session” of recordings made on a given date.

Deleting a recording

Right-click  for a dialog that allows the currently selected recording (box with a cross with green background) to be deleted. Alternatively, all recordings wit the same prompt may be deleted or all recordings in the current session (i.e date) can be deleted. Be careful as this deletion cannot be undone.

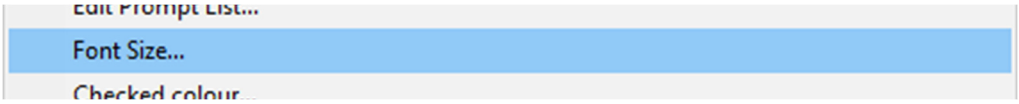


Shortcut to promptlist editor



Font size

Change the font size of the prompts in the promptlist if they are too small and difficult to read. This will also enlarge the boxes.

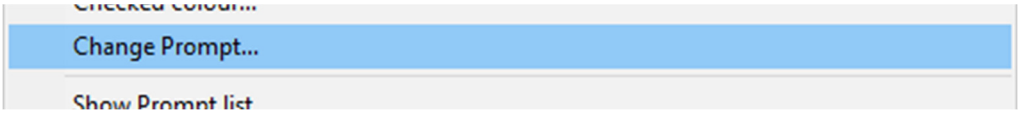


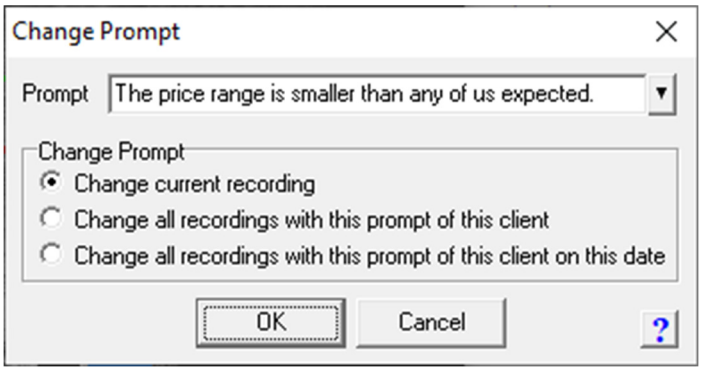
Change colour of box with cross when selected

The default colour of a box with a cross is green but you may choose any colour.

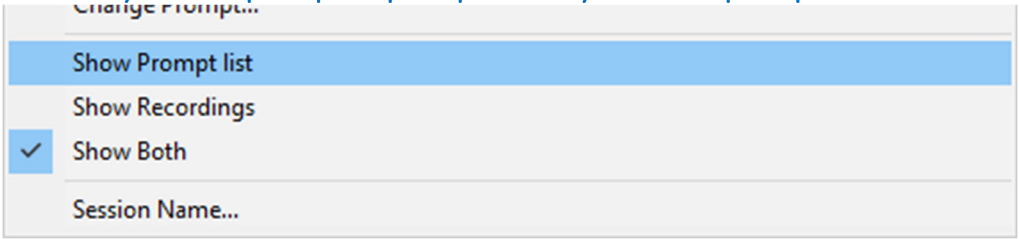
Change the text of a recorded prompt

It is possible to change the text associated with a recording after it is recorded. This can be useful if you have accidentally recorded speech that doesn't match the prompt.



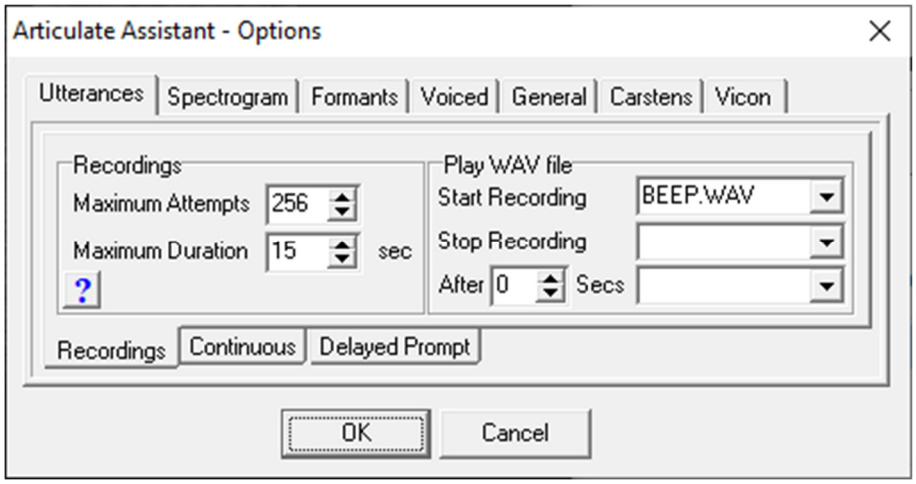


Show only current promptlist prompts or only recorded prompts.

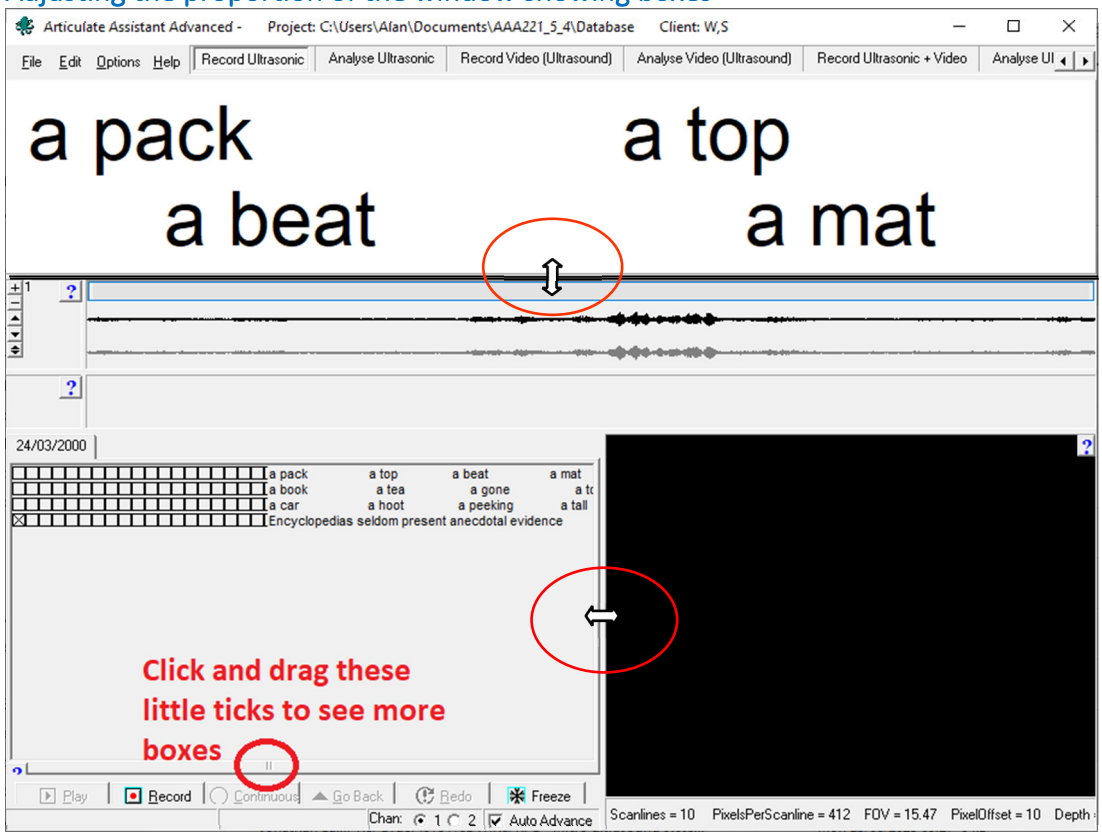


Set the total number of recordings that can be made for a prompt

In the main menu, select Options|Settings and then the "utterances" tab. Alter the maximum number of attempts.



Adjusting the proportion of the window showing boxes



The prompt window

The prompt will appear in the prompt window.

WARNING: If the delay prompt option is selected then the prompt won't be visible in this window until the specified period after recording starts.

Right-click for Promt display options.

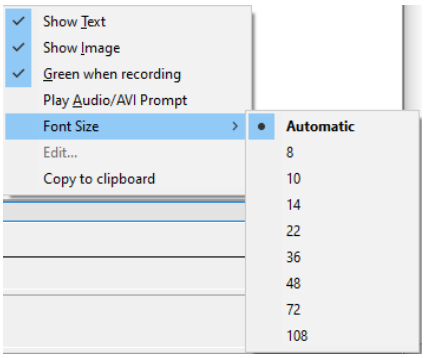
'Show text' – show or hide the prompt text. By default the text is shown.

'Show Image' – show or hide the associated image. By default the image is shown.

'Green when recording' – Sets the prompt display background green when the recording starts.

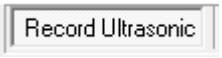
'Play Audio/AVI Prompt' – Plays the associated audio/video prompt. Off by default.

'Font size' – Font size can be fixed. By default the font size adjusts automatically to fill the prompt screen.

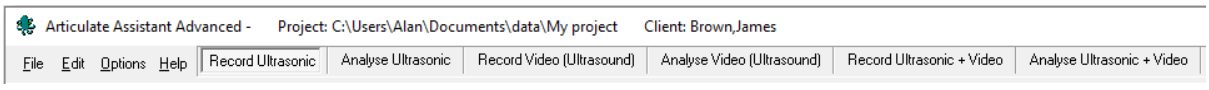


Task Windows

There are too many signal analysis windows to fit on one screen. AAA provides **Task Windows** configured to present a subset of windows appropriate for a particular task.

When AAA starts the default **Task window** is 

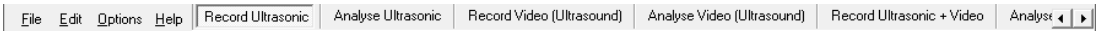
suitable for recording speech audio and ultrasonic (Telemed Micro or EchoB) data. Other task windows are configured for recording different combinations of data and for analysis of different kinds.



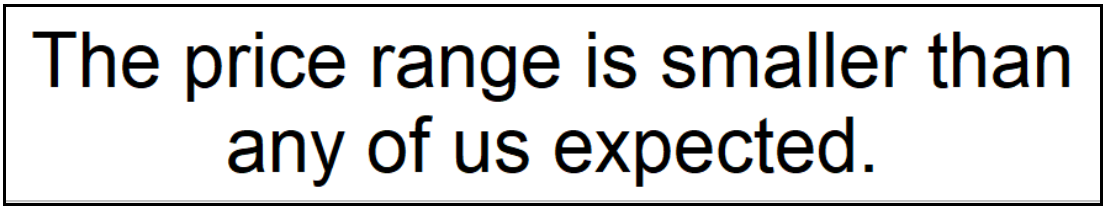
Adjust an existing Task window

Task windows consist of subwindows. For example, the Record Ultrasonic task window is made up of the following:

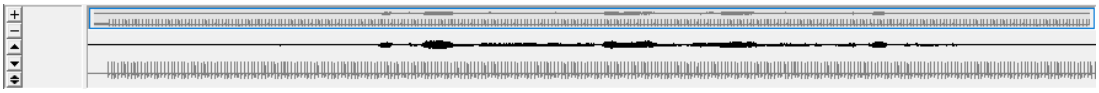
Menubar - Main menu bar and task bar



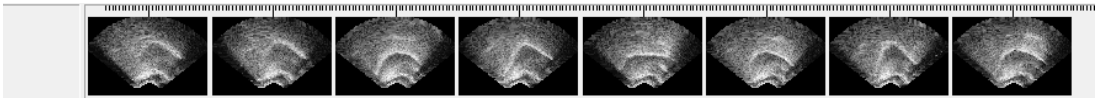
Prompt display



Waveform Chart



Ultrasonic Chart

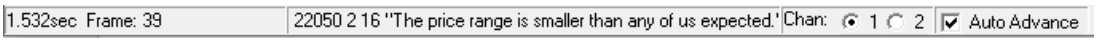


Prompts/recordings selection window

Ultrasonic display

Menubar – Button bar

Status bar



The size of each subwindow can be adjusted by clicking and dragging on the boundary between subwindows. Any adjustments are not saved unless performed in design mode (next section). The next time the design window is opened it will revert to the designed layout.

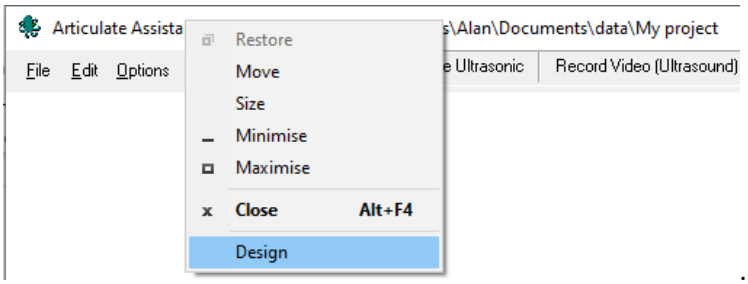
Design your own Task window

Designing a new task window or permanently adjusting subwindow sizes in an existing task window is done in design mode. Because this is an advanced function access to this function is concealed as a  right-click menu option in the application caption bar.

WARNING: A task window intended to record ultrasonic data must have an Ultrasonic Chart. A task window intended to record video must have a Video Chart.

Entering and Exiting Design Mode

In order to enter design mode click on the caption bar at the top of the AAA application with the  right mouse button. Then select the 'Design…' option in the popup menu.



Note: If there is more than one window with a caption bar (e.g. The '2-screen Ultrasound + Video' Task Window) then only the Caption bar with Articulate Assistant Advanced - written in it has the 'Design' option.

The 'Design Dialogue' list will then appear.

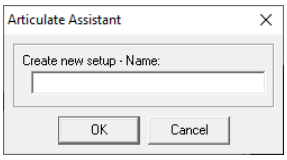
To exit design mode without saving any changes simply close the 'Design Dialogue by clicking on the ☒.

Save Design Change and position Task Window button

Saving changes must be done before exiting design mode. To save changes made in design mode, click the right mouse button anywhere in the Task Bar to reveal the popup menu

Click '**Save "<Task name>"**' ('Save "Record Ultrasonic"' in this example). Saving always applies to the currently selected task window regardless of where you right-click.

Click **'Save as New Setup'** to copy the current Task Window configuration to a new task window and leave the current task window unchanged. You will be prompted to give this new Task Window a name.



The new task window button will appear at the far right of the Task bar.

Click **'Move "<Task name>" left'** to shift the button position left in the bar

Click **'Move "<Task name>" right'** to shift the button position right in the bar

Note: AAA will always open displaying the leftmost Task Window

Delete a Task Window

To delete a Task Window, first left-click to select the Task Window to be deleted. Then

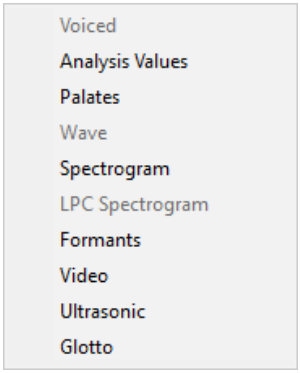

right-click to bring up the menu.

Click **'Delete "<task window>" '** (e.g. 'Delete EPG "Feedback" ').

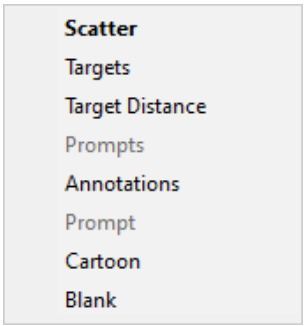
Subwindows - Charts, Panels, Bars and Displays

Task windows are made up of subwindows that dock together and can be resized and positioned to create an ensemble suited to a particular task. Modules fall into 4 categories as follows:

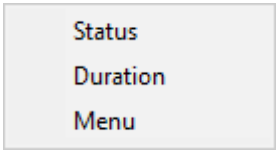
Charts. Any subwindow which has a display with a time axis .



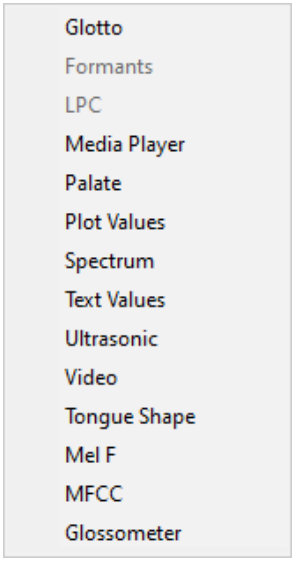
Panels. Subwindows that do not fall into the other 3 categories



Bars. Subwindows that cannot be resized in normal operation



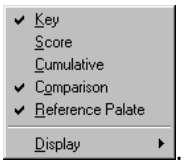
Displays Any module with a graphical display, which doesn't have a time axis



To create a new module, simply select it from the menu in the 'Design Dialogue'.

The 'Menu Bar' can be configured further by  right clicking in it to bring up the popup dialogue (**Error! Reference source not found.**). The top three options in this popup menu control the visibility of 'Menu', Task 'Setup Buttons' and 'Buttons'. There is a submenu

allowing each of the buttons to be enabled or disabled.

The 'Palate Display' also has a popup dialogue to control the visibility of elements of the display 

. The elements consist of:

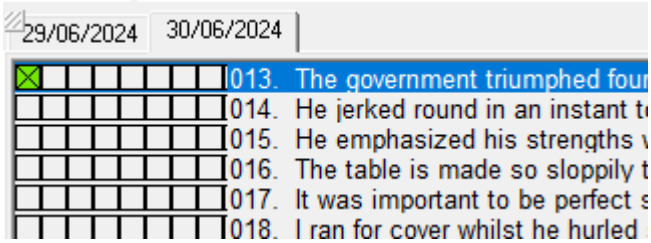
- **Key**. Colour scale

- **Score**. Variability Index
- **Cumulative**. Cumulative contact check box
- **Comparison**. Palate comparison gauge

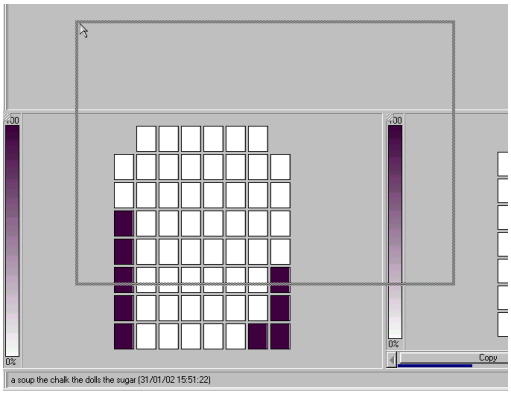
It is also possible to specify whether the 'Palate Display' is a '**Reference Palate Display**'. Note: Only one 'Reference Palate Display' permitted per 'Task Window'.

Repositioning a module in a Task Window

To rearrange the modules in a Task Window, click and drag the in the top left corner of the window (or the at the left edge in the case of 'Bar' type modules).



A grey outline that will move about the screen and 'dock' in positions relative to other modules. When you are happy with the position release the mouse button. The relative size of the module can be adjusted as described in Adjust an existing Task window



It is also possible to move a module so that it exists in a separate window on its own. In fact this is the state of a new module created by selecting a menu option from the 'Design Dialogue'. To get a module to be separate from the main window , click and drag until the grey outline is not aligned with the other modules (as shown above) then release the mouse button.

Repositioning modules is an art that improves with practice.

Deleting a Module from a Task Window

To delete a module from a Task Window move the module so that it exists in a separate window on its own (as described in the previous section) then close that window by clicking on the  .

Ultrasound / Video module

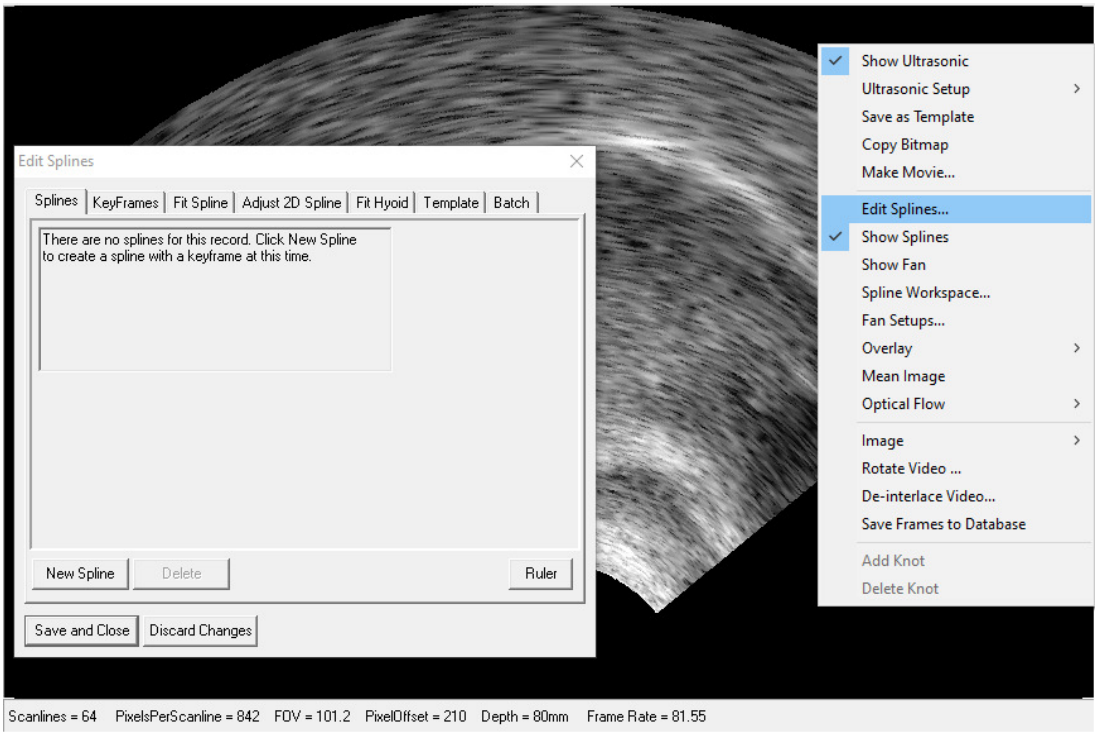
The Ultrasonic/Video module is a standard addition to the basic (Audio and EPG only) Articulate Assistant Advanced (AAA) software that enables the recording and analysis of Ultrasonic (high frame rate, raw pre-scan ultrasound) data and is compatible with Micro, Art and legacy EchoB systems (and SonixTouch or SonixTablet Ultrasonix machines running Exam version 5.7). This module also enables the recording of lip camera or ultrasound video output through the dfg2USB video capture card (and legacy cards, Adlink Angelo RTV, Imperx VCE Expresscard|54), or by importing pre-recorded ultrasound video.

The ultrasound module enables the following functions:

- Record ultrasound synchronously with audio (hardware required)
- Import AVI format ultrasonic/video files
- Review and play back ultrasonic/video sequence
- Add splines and set conversion scale for mm measurements
- Calculate and display analysis values based on spline distances and shapes
- Export spline data in Euclidean or Polar co-ordinates
- Export analysis values for labelled time points
- Export ultrasonic and video movies in AVI format
- Provides a workspace for superimposing, averaging and comparing tongue curves which have been extracted from different time points or recordings
- Export raw Ultrasonix/EchoB/Micro data for further analysis
- Carve vocal tract boundaries from tracked contours.
- Perform live tracking of lip or tongue contours up to 40 frames per second

QuickStart: Automatically spline recordings

The Edit Splines dialog is the interface for creating and editing splines based on either ultrasonic or video data. To access the Edit Splines dialog,  right-click on the ultrasonic display in any task window or the video display.



Note

Ultrasonic and video data streams are stored and processed separately and when splines are generated they are associated with either video or ultrasonic. This prevents lip video splines appearing on an ultrasonic tongue image and vice versa.

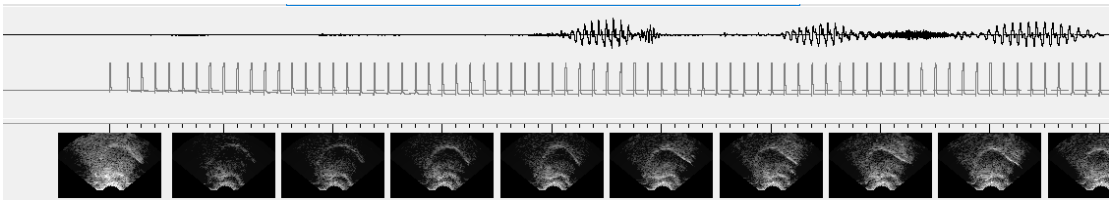
DeepLabCut Batch Process

It is recommended to use the fully automatic DeepLabCut Batch processing to spline every frame for every recording in the session that has just been recorded. There are different models for splining tongue contours or front facing lip camera. If you have an ordinary CPU processor then this might take as long as 20 times real time (i.e. 30 minutes of recorded might take 10 hours to process). For a faster processor more like 8 x real-time (i.e. 4 hours for 30 minutes of data) and if you have an NVIDIA GPU configured then more like 2 x real-time (i.e. 1 hour for 30 minutes of data). This process will estimate the contour at the timepoint when the ultrasonic/video frame is generated and the spline will be linearly interpolated for time points in between.

1. Use the batch sync process (see separate section) to make sure all your recordings are synchronised for audio-video and audio-ultrasonic.

Note

Ultrasonic data is only synchronised when viewed for the first time and video data is not automatically synchronised. Both require explicit batch synchronisation to be sure.

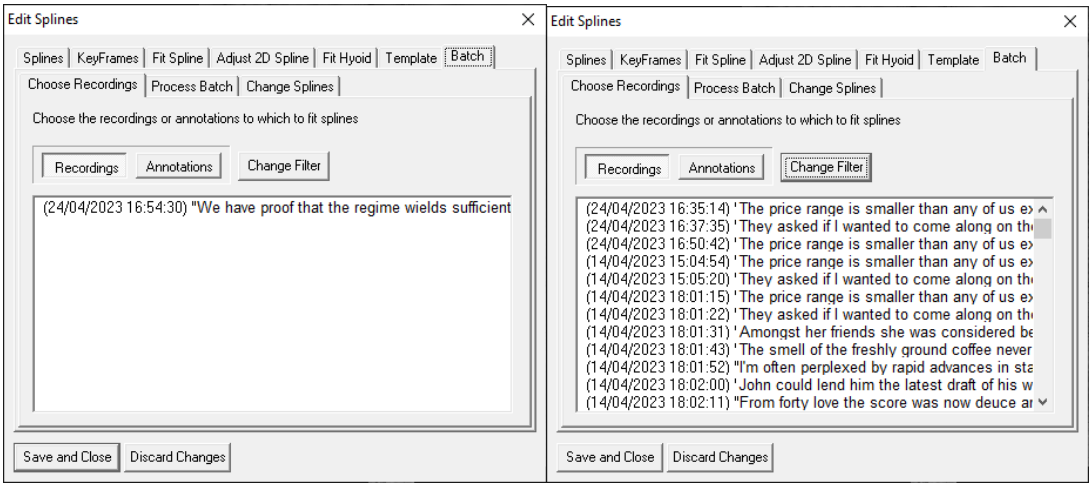


Tick marks above ultrasonic chart should line up with pulses on channel 2.

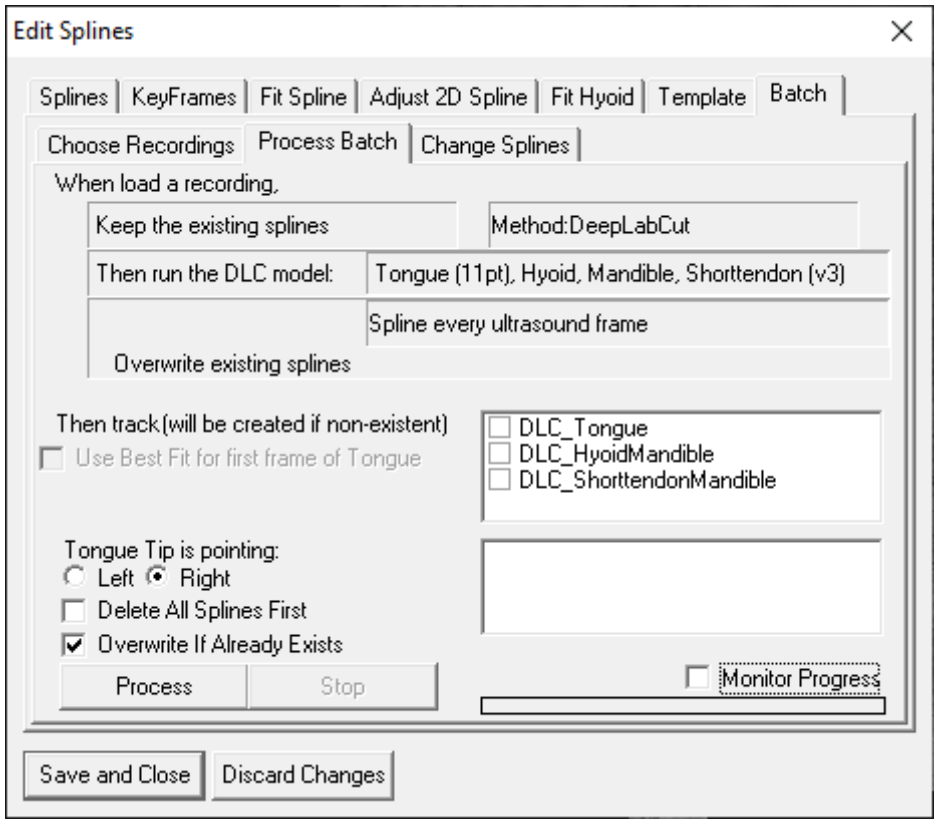
2. Select the **Fit Spline** tab

   By default the Autofit method should be set to **DeepLabCut** and the keyframes region should be set to **All of recording**. The DeepLabCut Settings button will take you to a dialog to select the appropriate model. It defaults to the best tongue model so if you want to estimate lips you need to click this and change the model. Click Go to Batch DeepLabCut Settings or click the Batch tab.

3. Under the Choose Recordings subtab make sure the Recordings button is selected and click the Change Filter button. Then set the filter to Current client and **All recordings.** The box will then show all the recordings for the current client.

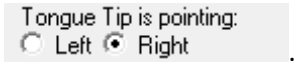


4. Select the Process Batch subtab.



Check that the specification at the top confirms

- you are using the DeepLabCut method
- You are using the Tongue model if ultrasonic or Lip model if lip video
- It is set to spline every ultrasound frame.

If you have recorded the ultrasonic data with the tongue tip pointing left then change the radio button 

. Check all the spline options DLC_Tongue, DLC_HyoidMandible, DLC_ShorttendonMandible.

If you check 

The ultrasonic display will show the estimate for every frame as it is calculated. This will slow down the splining hugely but you can switch this off while the splining is in progress so it can be useful to check that the estimation is working as you expect.

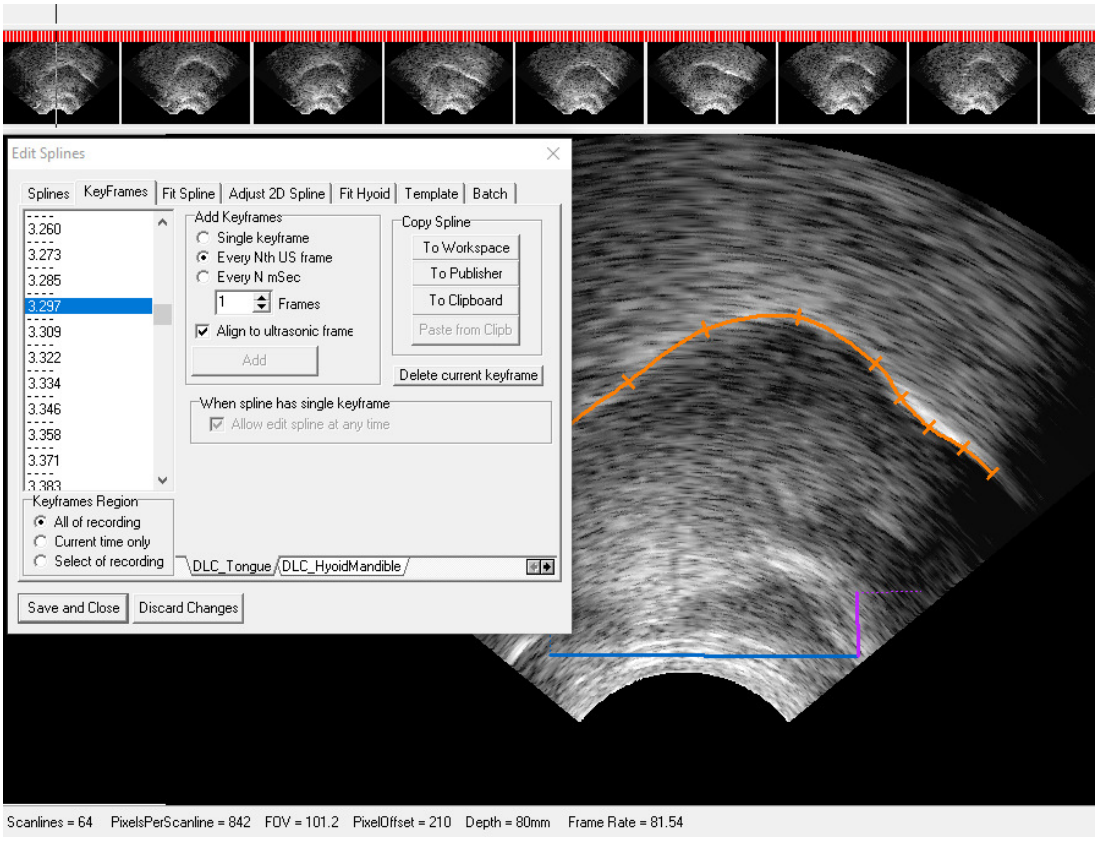
Click 

to start the automatic fitting.

Hand correcting 2D (DLC) splines

DLC splines are freeform splines with no restriction in shape. They are referred to as 2D splines in AAA.

After automatic splining is complete, every ultrasound frame or video frame will have a spline **keyframe** with a unique spline. It is possible to manually edit these from the **keyframe** tab.



To select a single keyframe:

1. Make sure the DLC_Tongue spline tab is selected. Use the buttons if it is not visible.
2. Click on a time in the list on the left. The spline will then turn orange to indicate that it has been selected.
3. The DLC_Tongue spline is controlled by 11 **knots** (control points) represented by ticks along the contour. Click near a tick and drag to move it around.

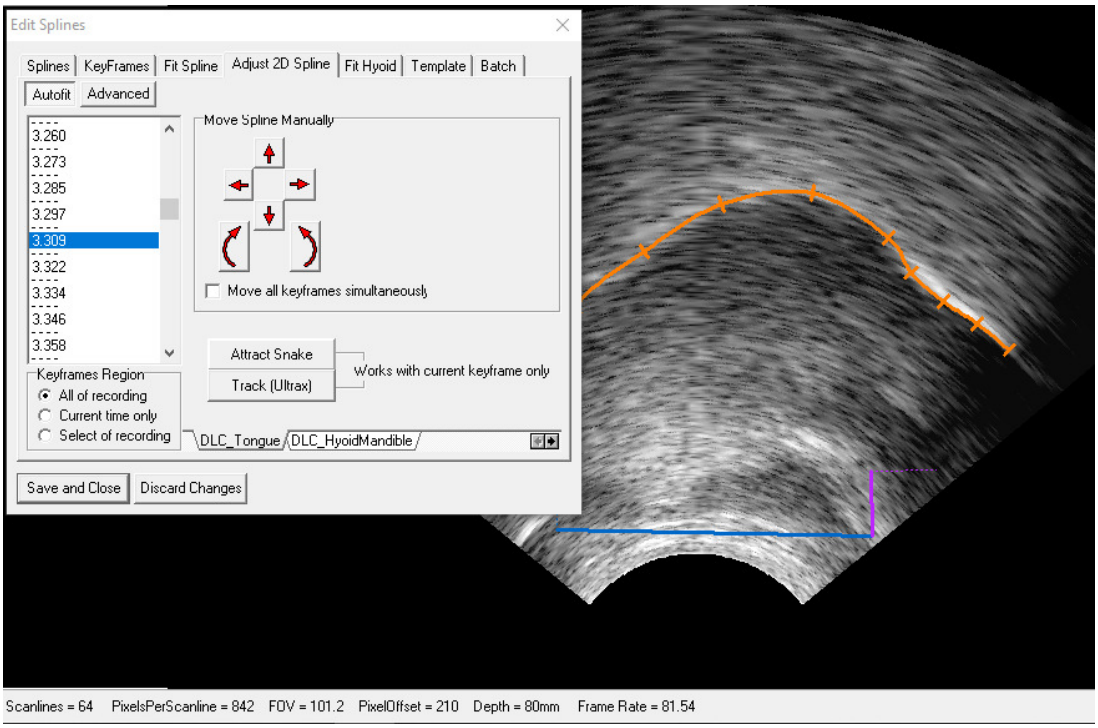
Tip

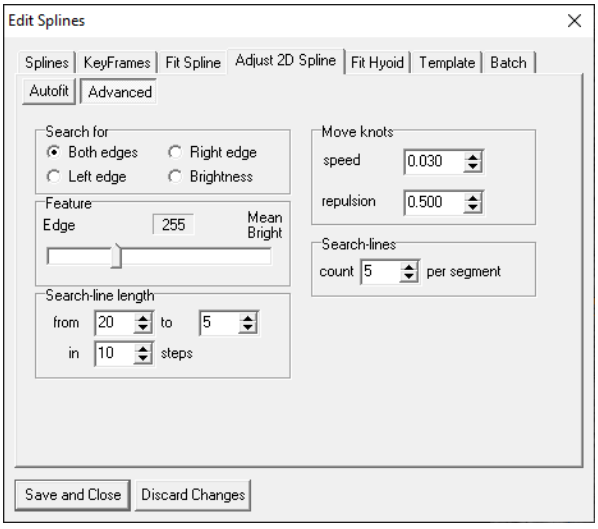
If you hold down the <ctrl> key, then click and drag on the ultrasonic display, a contour will be drawn with the same number and relative spacing of knots, starting where you first click and ending where the drag ends. You can use this to hand draw the entire contour.

Moving and rotating 2D splines

The **Adjust 2D Spline** tab offers controls to translate and rotate whole splines. This is not very useful for tongue or lip splines and more often applied to fiducials (see Fiducial Spline

section). There is also a snakes algorithm. This is intended to iteratively adjust the selected 2D spline to fit to the nearest bright edge. This function is not recommended. Used sparingly (clicked a couple of times) it may move the spline closer to a bright edge but extended use will distort the spline shape. See Appendix B for description of Algorithm. The Advanced button reveals the parameters for adjusting the Snake algorithm behaviour. But this bright edge hunting algorithm is inferior to DeepLabCut and discouraged. The Track Ultrax button has been deactivated.

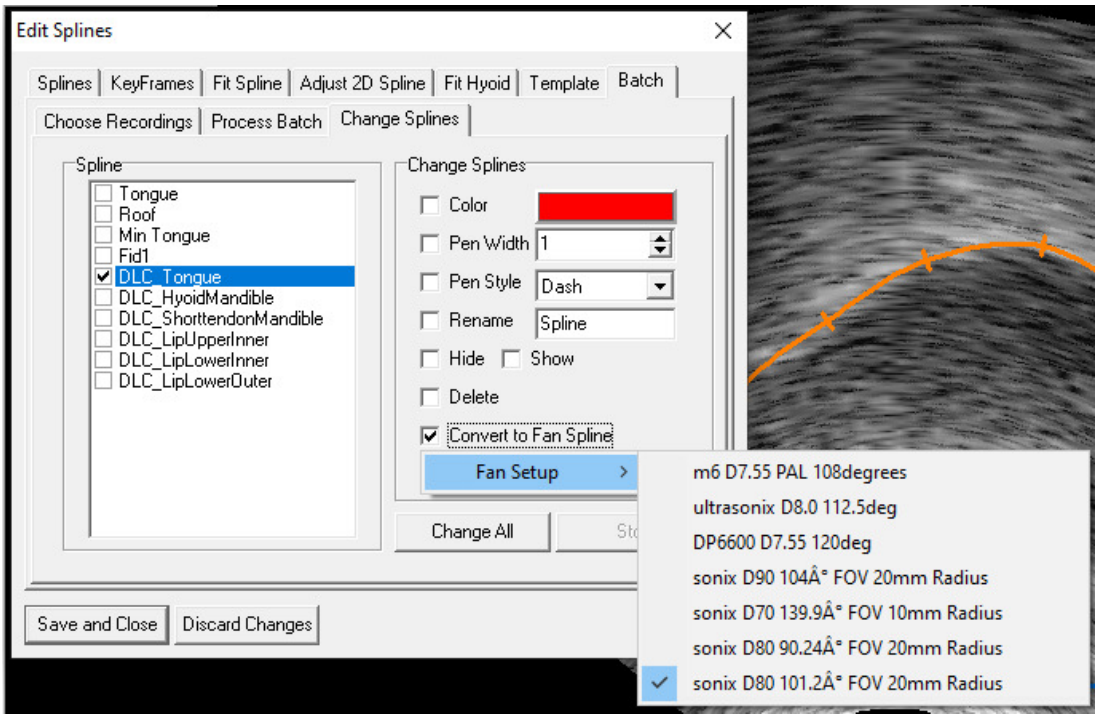




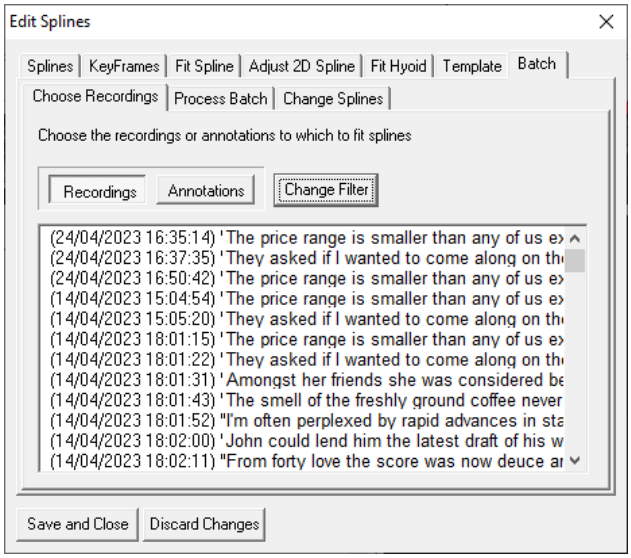
Converting 2D splines to fan splines

This is not a recommended process as there are better ways to analyse splines but it provides a route to exporting polar coordinates.

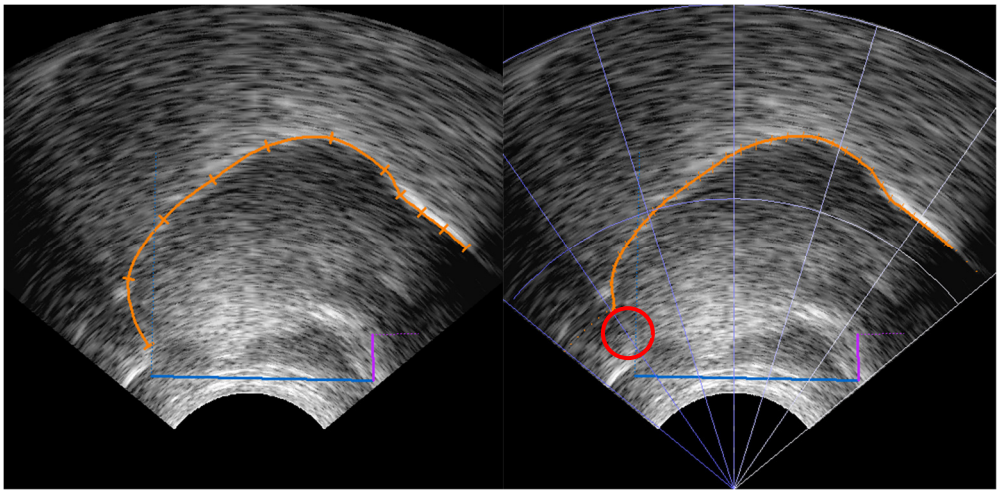
1. Click on the **Batch** tab then the **Change Splines** subtab
2. Select the DLC Tongue spline
3. Select Convert to Fan Spline
4. A submenu will appear with preformed fans with different origins and extents. The fan designed to fit the ultrasonic data with origin at the probe origin.



5. Check the Choose recordings tab has selected the recordings that you want to convert. Use the  to change the selection.



6. Return to the **Change Splines** subtab and click 

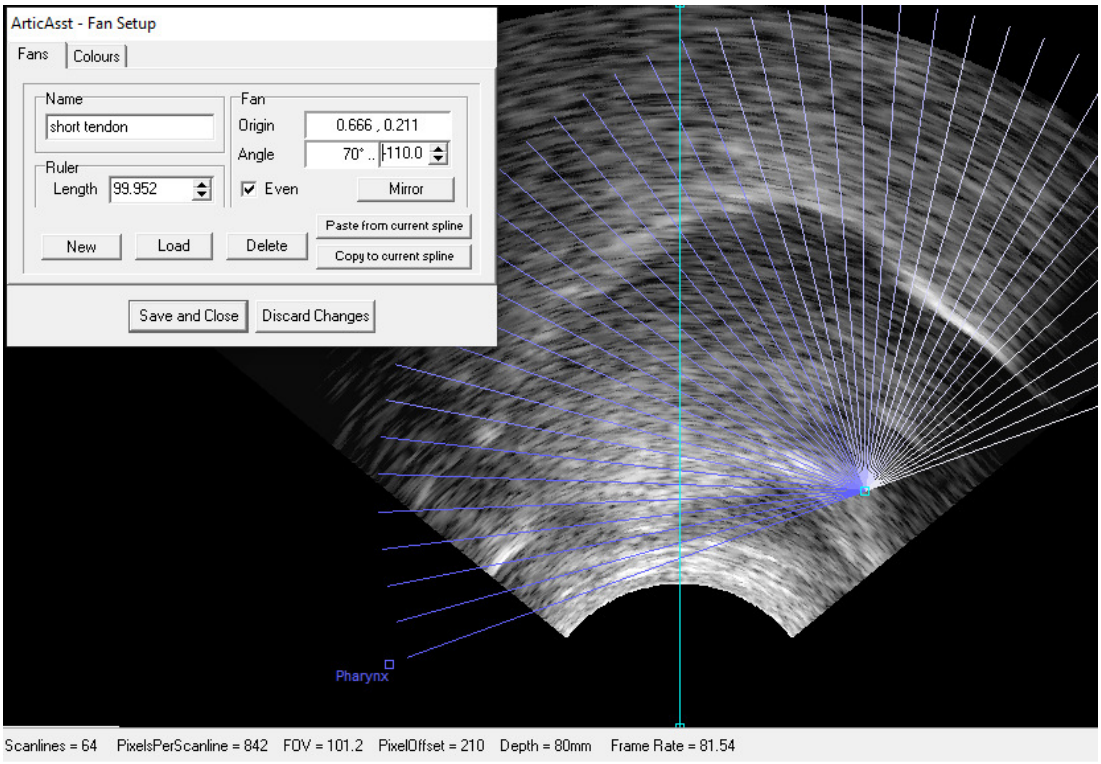


Note that choosing this fan origin can result in loss of tongue contour where it is parallel to the fan axis (red circle above).

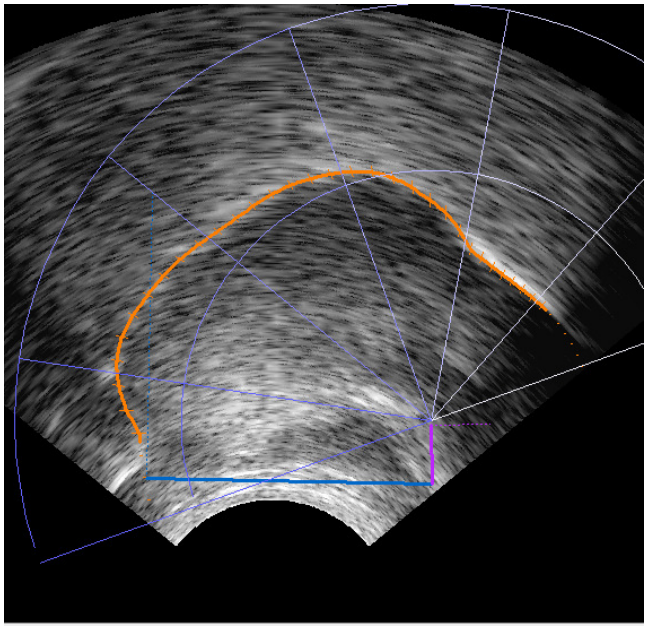
7. Instead, create a new fan with its origin at the short tendon. This will guarantee the whole contour to be converted.  Right-click and choose **fan setup.**

8. Change the fan name to Short tendon. Set the cyan length measure from top to bottom of display and set length to ultrasonic depth + probe radius. Make sure the pharynx and dental labels are the right way round. If not, use 

button. Click and drag the fan origin to the short tendon.



9. Run **Convert to fan spline** but select the short tendon fan that you have just created. The resulting converted spline completely matches the original Tongue spline. It is also based on an anatomical origin which will be consistent across sessions rather than a probe origin which may be in a different position.

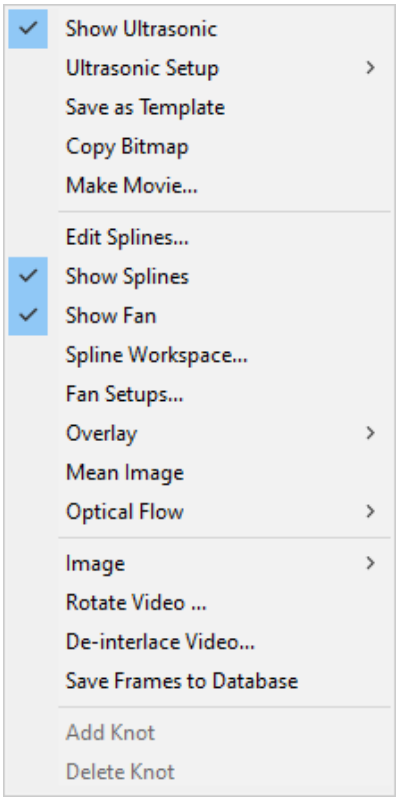


Exporting splines

While there are many spline analysis options within AAA, splines may also be exported for analyses in R such as GAM

Ultrasound Display

Appearance and functions associated with the ultrasonic display are accessed via a  right-click popup menu. It looks very slightly different depending on whether a recording is loaded or it is in live mode ready to record. In live mode the Mean Image and Optical flow settings are not present.



Controlling appearance of the ultrasonic display

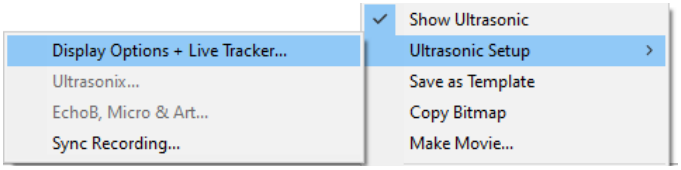
The ultrasonic image can be controlled to adjust the brightness and contrast, elements such as splines, fan grids or the ultrasound image itself can be made visible or invisible and background colour can be changed to suit publication requirements

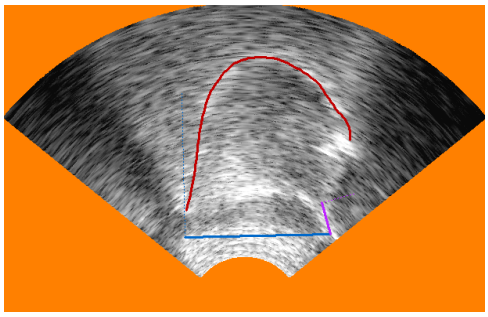
Show ultrasonic, splines, fan

Click these menu entries to toggle visibility in the ultrasonic window. Ultrasonic windows in other task windows will not be affected. If there are no fan splines associated with the current recording then no fan will be shown regardless of the “Show fan” setting.

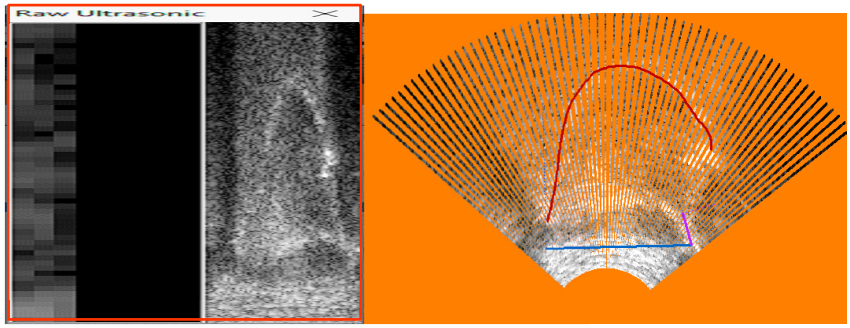
Display options dialog

The background colour can be changed using the Display Options subdialog





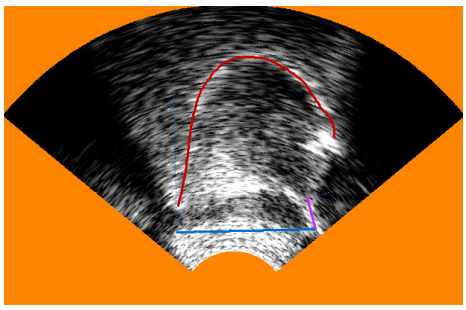
The **Interpolate scanlines (default)** option can be switched off to view the scanlines that are interpolated to fill the gaps in between. It is representative of the raw data from which the image is created.



The **Show raw ultrasonic display** option shows a floating display of the raw scanline data before it is fanned out.

The **Draw ultrasound faster** option only affects the live display and is explained in the section on recording data.

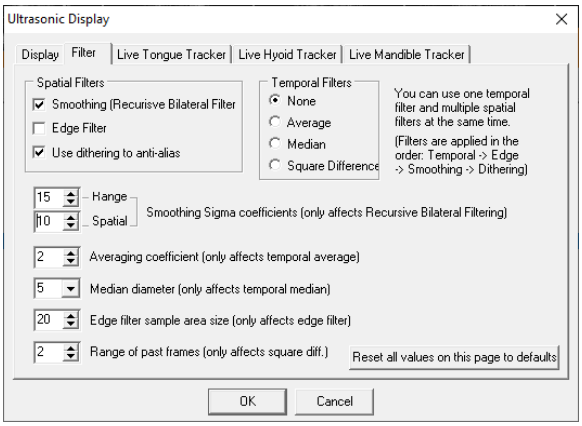
The Brightness and contrast controls adjust the image appearance. They change the image that is sent to DeepLabCut and so the settings can have an effect on the accuracy of the spline contour estimation. Medium values for **Brightness**, **contrast** and **Enhance contrast** are recommended. As is a low rejection value. Enhance contrast shifts the contrast to apply to the region near to or far from the probe surface.

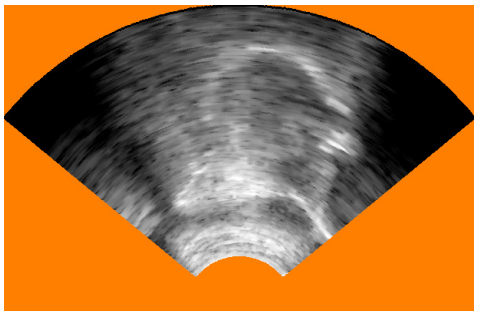


The above image shows high contrast and rejection. These settings are not recommended due to a loss of information in the image.

The **Apply dynamic resolution** function is not recommended. It was introduced as a means to speed up drawing and consequently speed up live spline fitting but it has an undesireable effect on image scaling.

The Filter tab offers a range of image filtering techniques. They were introduced to provide options for reducing speckle and creating a subjectively more pleasing image. However we recommend not using any of the options for analysing data with the exception of **Use dithering to anti-alias** which improves the interpolation of the raw data. All of the other filters distort the image data and, as with the brightness and contrast controls, they will affect the performance of DeepLabCut.





The above application of smoothing reduces speckle but spreads pixels and can reduce DeepLabCut accuracy.

EchoB Micro & Art

Image (Zoom)

The image submenu allows the ultrasound image to be zoomed in or zoomed out.

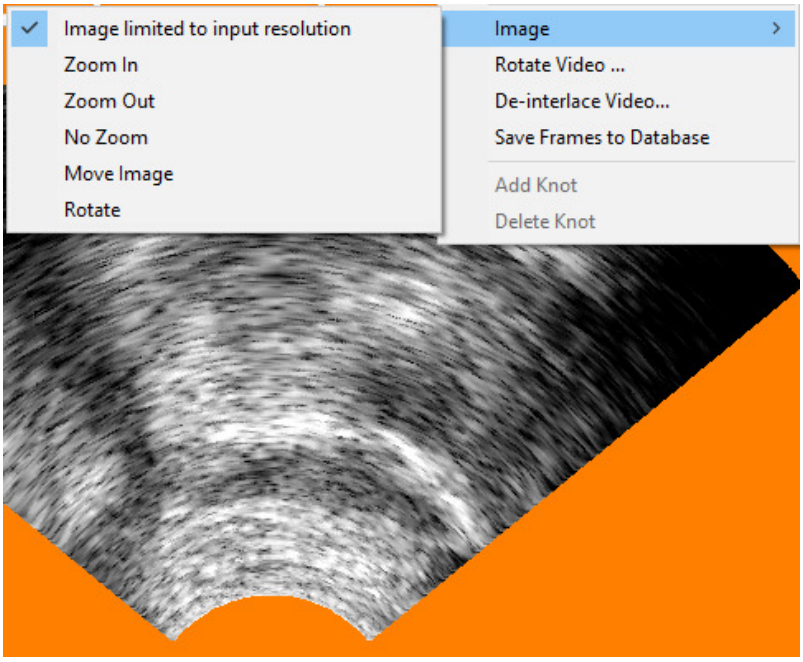


Image limited to input resolution (Fit to window) limits the image so that the image is never stretched to fill the display window. Checking this setting, the image is shrunk to fit the window or if the window is larger than the image, it will be padded with white space. If the option is unchecked then the image can be stretched beyond its true size to fill the window. In practice, Micro ultrasound images have around 900 pixels per scanline and so will nearly always fill the window without stretching the image. i.e. the image is nearly always shrunk to fit the display window.

Each time **Zoom In** is clicked the image will zoom in by 20%

Each time **Zoom Out** is clicked the image will zoom out by 20%

No Zoom *resets the image to unzoomed standard view*

Once zoomed in, select **Move Image** then click and drag on the image to change the part that is visible. It only activates one-shot click and drag. Click on **Move Image** again if further adjustment is required.

Zoom will be remain set while a recording is being analysed but defaults back to unzoomed when a new recording is selected. If a different behaviour is preferred, please contact Articulate Instruments and we can adjust.

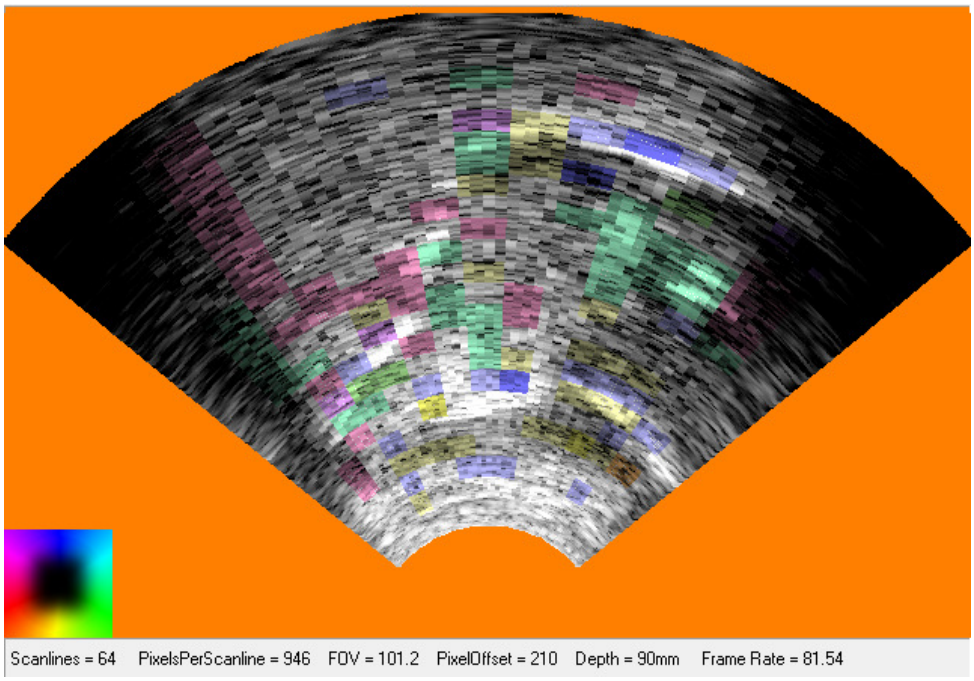
Rotate and **Rotate video…** – currently do not do anything. Please contact Articulate Instruments if this function is desired.

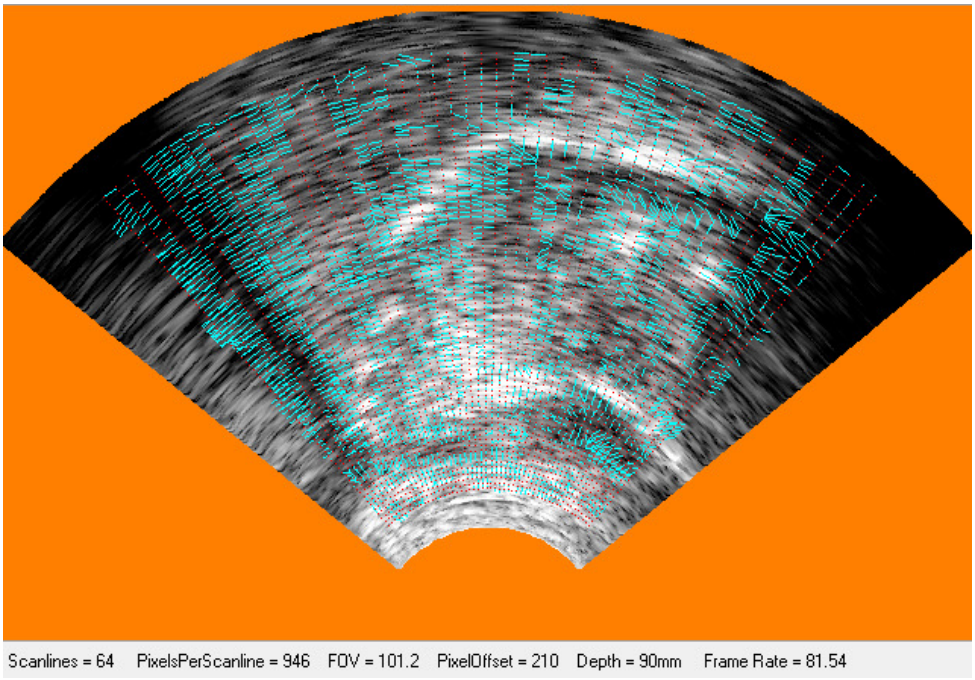
Mean image

The **Mean image** option was intended to provide an averaged ultrasound image for the selected region but has not been implemented. Please contact Articulate Instruments if this function is desired.

Optical flow

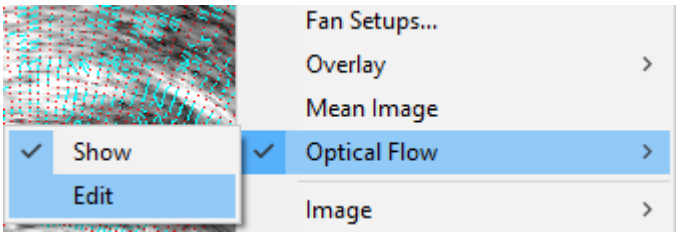
Optical flow is intended to indicate the frame-to-frame shift in pixel direction and so might be expected to indicate internal as well as surface tissue movement. There are two ways to display this movement, either by vectors or by colour.



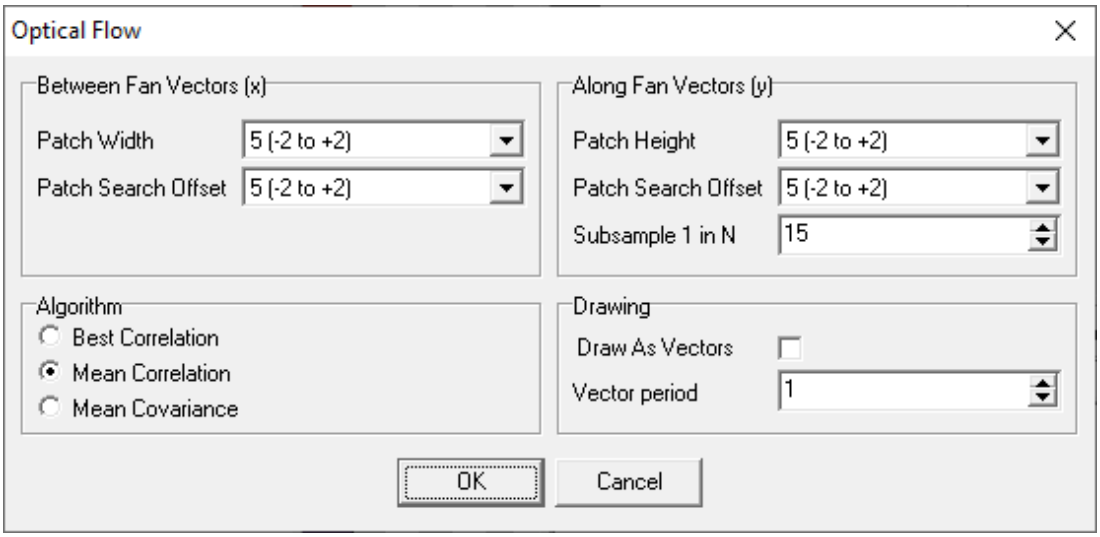


Note

In practice this function is not considered to be very useful as speckle can be generated by internal reflections. Speckle artifacts of this type do not directly correspond to movement of internal tissue structure. Optical flow has therefore not been extended to allow the export or analysis of flow values. Please contact Articulate Instruments if extension of this function is desired.

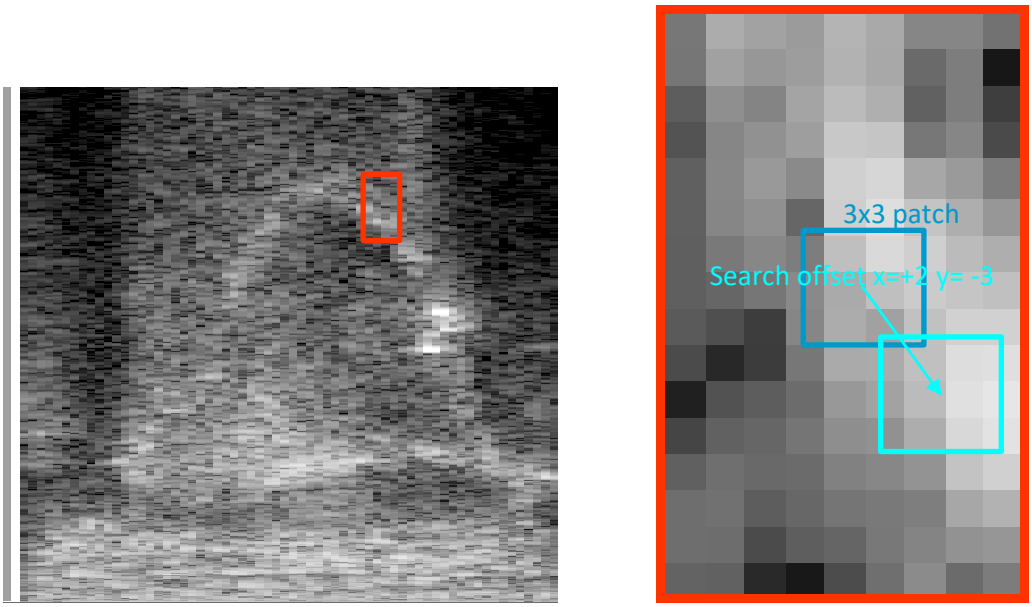


The Optical flow **Edit** dialog provides control of the algorithm.



The algorithm works as follows. The analysis is not performed on the interpolated image but instead it operates on the matrix of raw ultrasonic scanline data of size *Scanlines x PixelsPerScanline*. Typically with the Micro this is a 64x946 matrix of pixel values. Because the number of pixels along the scanlines is 14.7 times the number of scanlines, it is recommended to decimate the number of Y pixels by 15 so that the image is represented by a 64x63 matrix of pixels. i.e. set **Subsample 1 in N** to 15. This also speeds up the calculation. Scanlines are referred to as “Fan Vectors” in the dialog. The size of the patch is defined by ***Patch Width x Patch Height***. A 5x5 patch is recommended. A patch iin the previous frame is then correlated with all the patches in the current frame within the range of relative positions **Patch Search Offset (x)** and **PatchSet Offset (y)**. In the example below the patch is 3x3 and the offset shown is (2,-3). The the "best" patch is the one with the

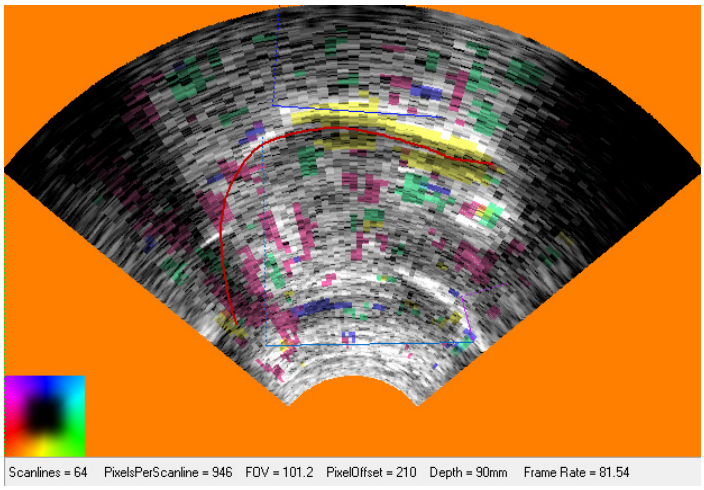
- **Best Correlation** – Finds the offset with the highest correlation and sets the flow vector according to the direction and distance of this offset.
- **Mean Correlation** – Sums vectors for all possible offsets with magnitude defined by their correlation values, then divides by the sum of all the correlation values to find the direction and magnitude of the mean of all possible offsets.
- **Mean Covariance** – as previous but using covariance rather than correlation



The **vector period** sets how densely the arrows/colour blocks are plotted. Set vector period = 1 for best coverage. Set vector period to a higher value for sparser drawing of arrows.

The approach implemented here doesn't deal with the problem of edges. If you have a moving edge, correlation will only show movement perpendicular to the edge. It won't indicate movement parallel to the edge.

In the image below with the settings in the dialog example image above it shows yellow indicating anterior tongue is lowering and purple indicating the posterior tongue and hyoid are retracting. Arguably, short tendon to tongue keypoint distance measures show this more clearly and measurably than optical flow.



Copy Bitmap

This function copies the visible ultrasonic or camera video image as it appears on screen at the screen resolution and places in on the clipborad.. For a higher resolution, use the grab bars to enlarge the footprint of the ultrasonic/video window within the task window, then click copy bitmap. To copy into a document or powerpoint simply click paste.

Note

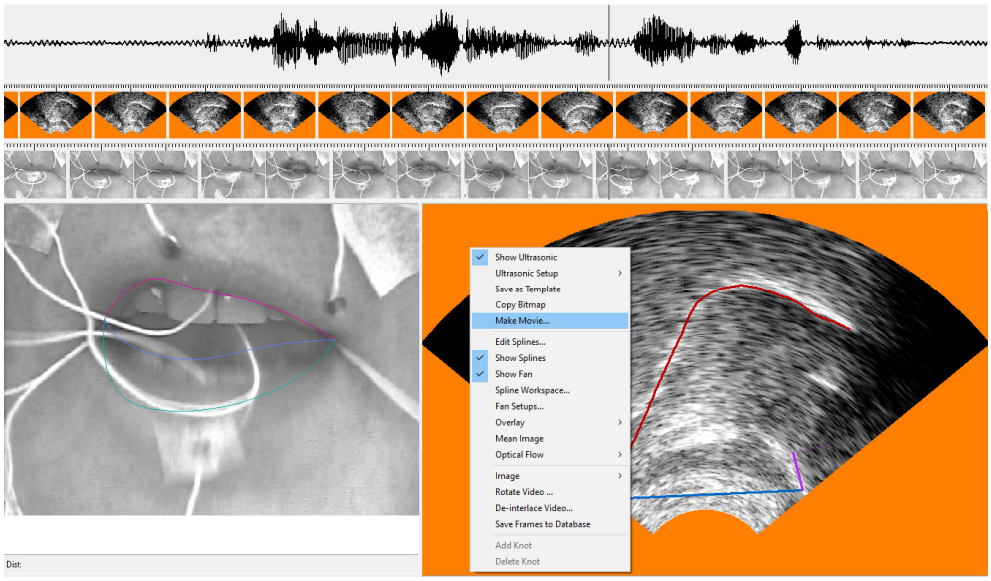
Copy Bitmap does not copy Optical flow or Overlays. It only copies the image and any visible splines.

Make Movie

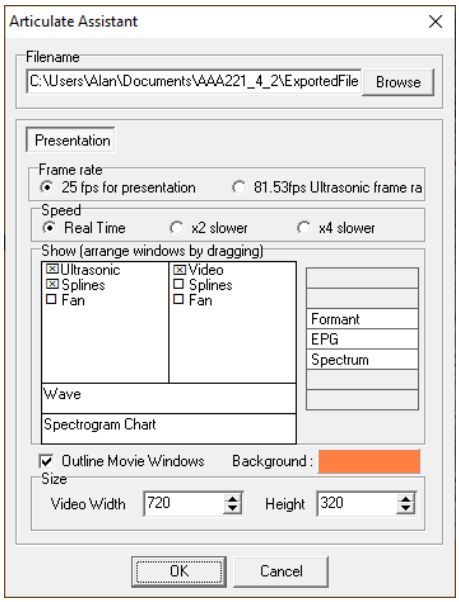
The make movie dialogue allows the whole or selected part of the currently loaded recording to be exported as a movie (with sound) in avi format. This function is intended for creating movies with combined data streams e.g. ultrasonic and lip camera together, to add to a presentation. There is a separate export files dialogue for batch exporting whole files of ultrasonic or camera video and a separate export data dialogue for batch exporting annotated regions of ultrasonic or camera data as videos.

QuickStart: Make movie

1. To save the entire recording, make sure the cursor in the wave window is selecting a single point in time. To save a region of the utterance, select that region by clicking and dragging in the waveform window.



2. Next,  right-click in the ultrasonic or video (or EPG) window and select **Make Movie** from the popup menu to show the dialog.



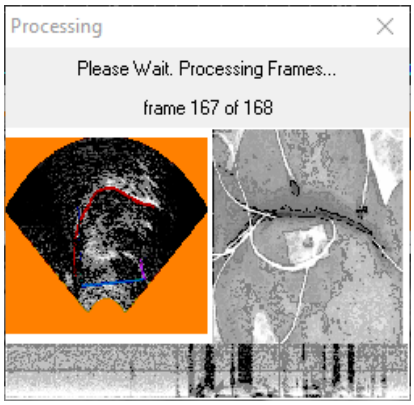
3. The **filename** will default to <AAA folder path>\ExportedFiles\AVI.avi.
4. The **Frame rate** will default to 25 which is sufficient for a presentation video and saves space but you can choose to export at the frame rate of the data stream you clicked on to bring up the dialog. In this example we clicked on the ultrasonic display so the frame rate option is every ultrasonic frame.
5. You can configure the layout of the movie image by clicking on a panel and moving it to a different position. Or to remove it from the layout, drag it to the list on the right. To add a display type drag it from the list on the right onto the layout in the position you want it.
6. Set the resolution of the output. 720x540 is most reliable for good detail in a 4x3 aspect ratio. Or 320x240 is the size of the video needs to be smaller.

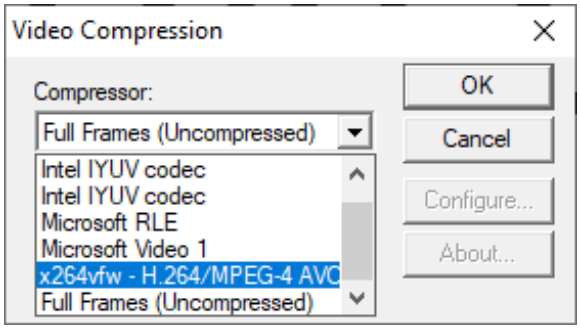
Note

AAA uses Video for Windows to export videos and it refuses to export some resolutions sometimes. For example 640x480 often generates a MEMORY error. IN such cases, try a different resolution.

7. Click 

. The processing subwindow will appear and process every frame. Then a window will appear where you should select **x264vfw codec** for exporting the video as this generates smaller files without losing detail.

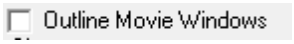




8. Click 

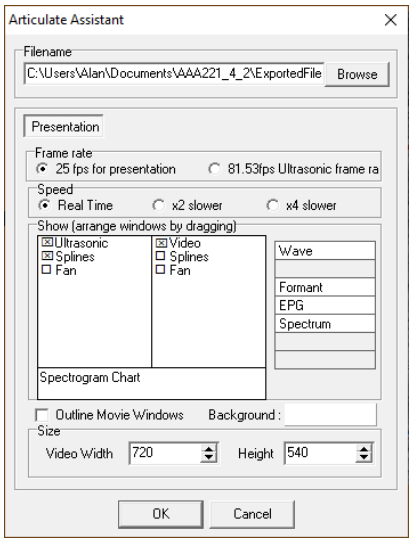
in the Video Compression widow and the file should save to the location specified in step 1. If you get an error, try a different resolution in step 6.

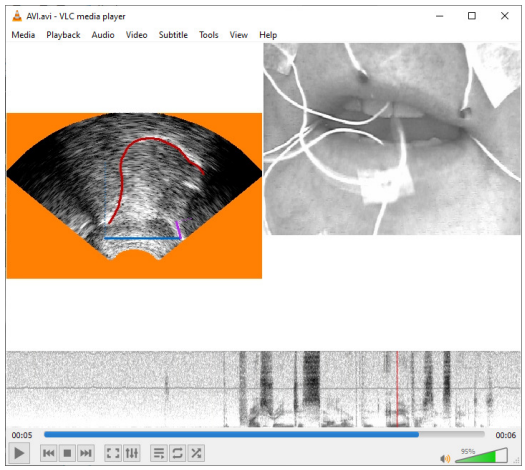
Refining the Movie



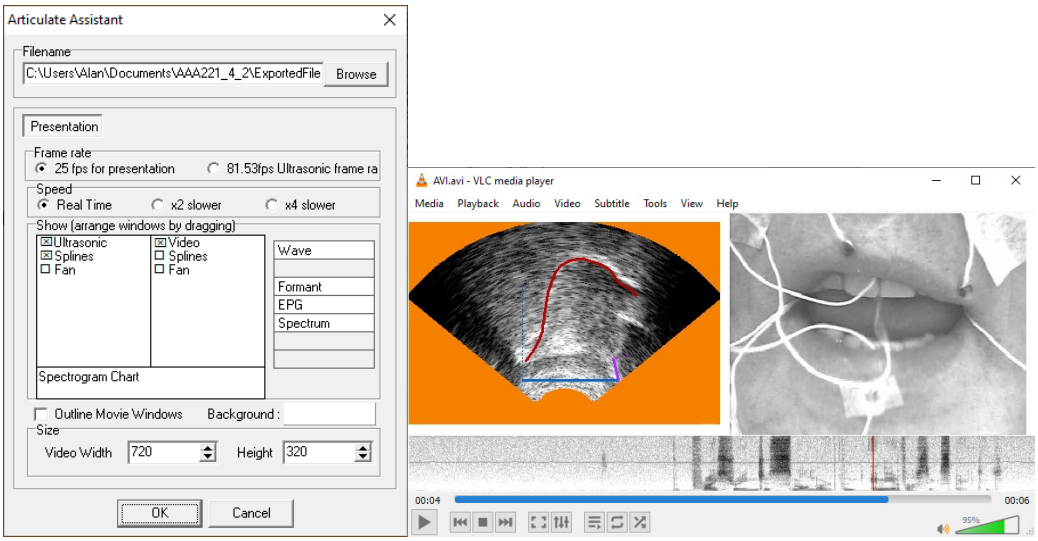
does not do anything. If you would like this feature then contact us.

A default 4x3 aspect ratio may result in an untidy arrangement of windows in the resulting movie.

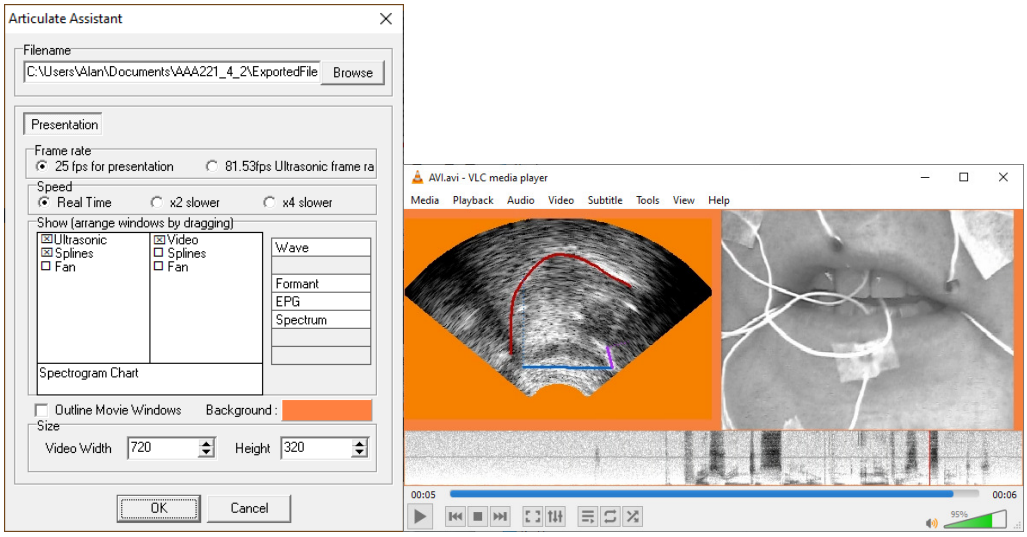




4x3 Aspect ratio looks untidy with ultrsound an lip video not in line.



Change aspect ratio to for example 9x4 so the ultrasound and lip video fill the screen



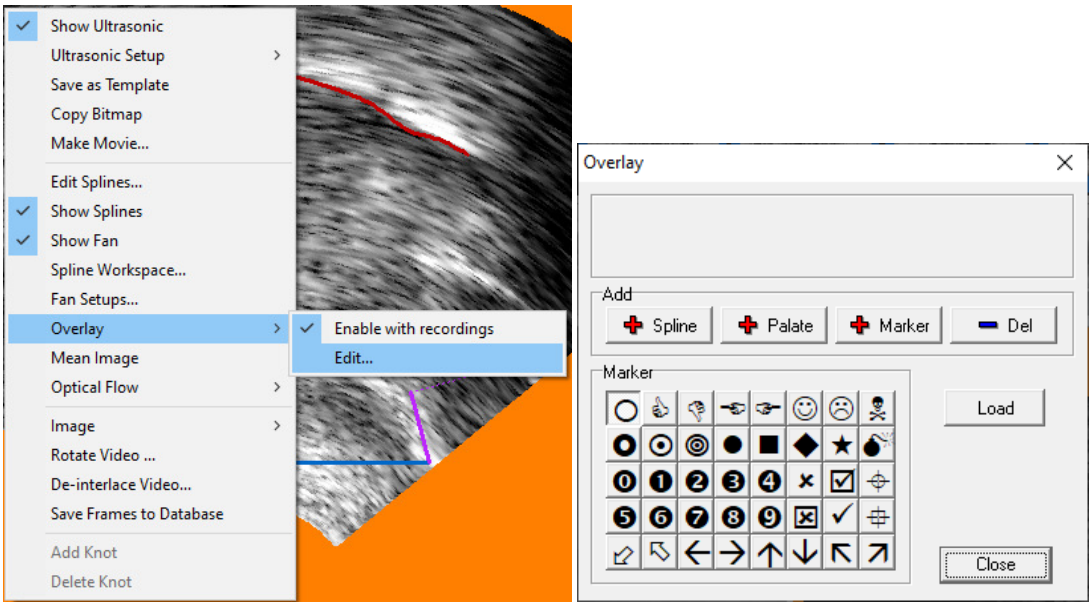
Change the background colour to match the ultrasound background.

Overlays

An **overlay** is a curve or marker that can be drawn on top of a live video or ultrasonic image stream and is primarily intended for facilitating the use of ultrasound as a speech therapy tool. Our sister application **SonoSpeech is much better for this purpose** so we no longer recommend using it in AAA. However, it is fully functional.

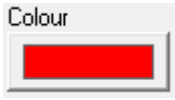
It works as follows.

If you have a live display, Select **Edit** from the submenu. If you are applying overlays to recorded data for the purpose of creating an image for a presentation then check the **Enable with recordings** option first. Then the **Edit** option will appear.

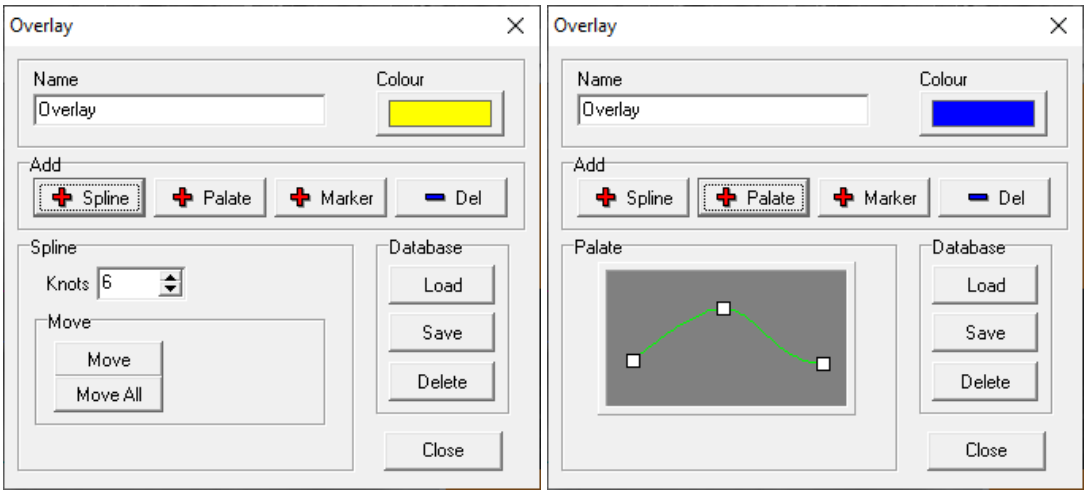


Click on 

. This will immediately add a marker symbol to the ultrasonic display. Click and drag the marker to where it is required. To change the marker, clik on it in the ultrasound window and then click in the dialog on a different marker symbol.

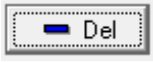
Click on the 

button to change the colour.

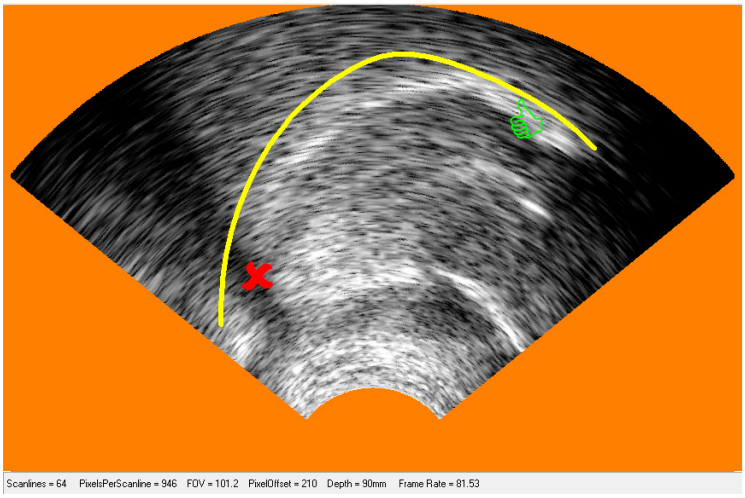


Click on 

to add a freeform spline. It defaults to having 6 knots (control points) Click near a knot to move that knot position and change the local shape.

To remove a marker or spline click on the titem in the ultrasonic wingow then click 

.



Fan Setups

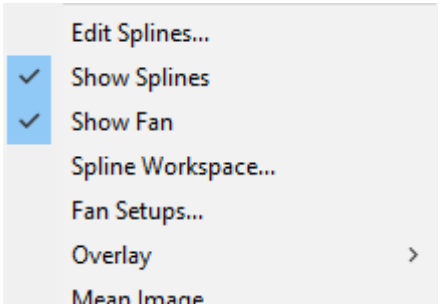
As well as freeform “2D” splines used by DeepLabCut, AAA has, for two decades, based ultrasound analysis on splines that are tied to a fan (polar) grid. The AAA fan grid has a fixed number of 42 radial axes and the shape of the “fan” spline is controlled by 42 points that are constrained to lie on these axes.

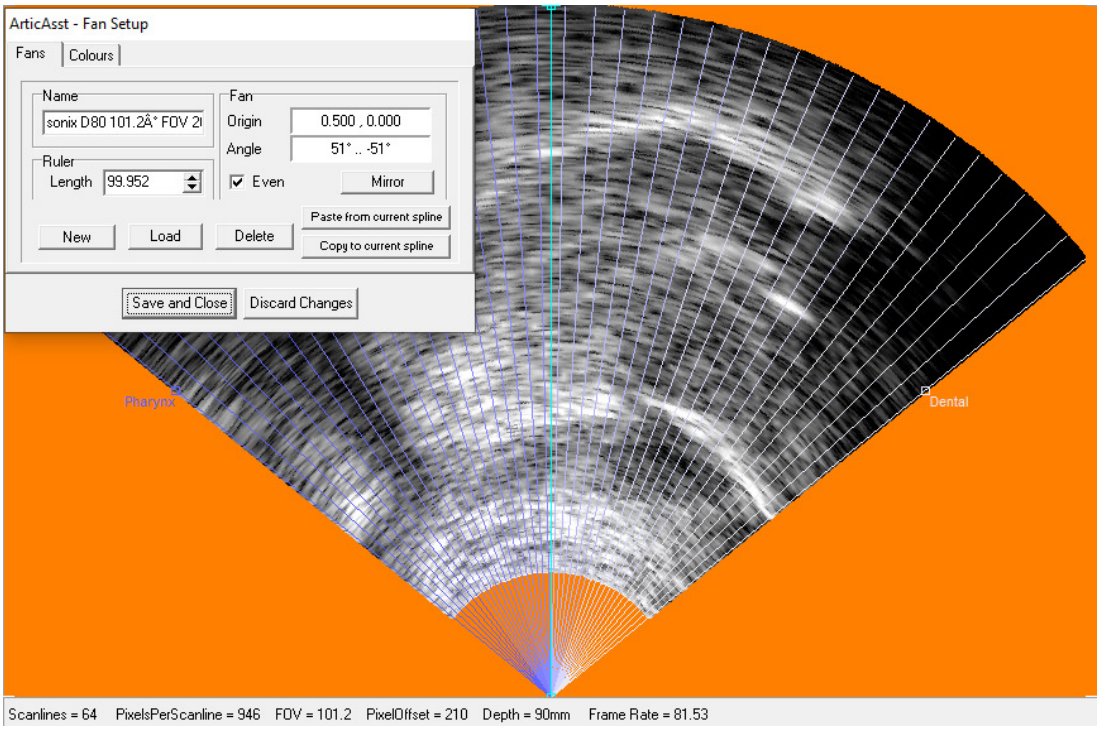
If you use the Art, Micro, EchoB or ultrasonix systems then *AAA automatically generates a fan grid* with origin at the probe origin; an angular range that matches the set field of view; and a pixel-to-mm scale derived from the depth setting.

The fan Setup dialog also permits a fan grid to be configured manually. This is necessary if the ultrasound data is video based. It is also useful, as previously described, if you wish to convert DeepLabCut 2D splines to fan based splines so that polar co-ordinates can be used for further analysis.

Different fan grids and scales will be required for each new ultrasound machine and even for the same ultrasound machine with different depth settings and field of view (fan angles). The fan setup dialog allows any number of different setups to be created and saved.

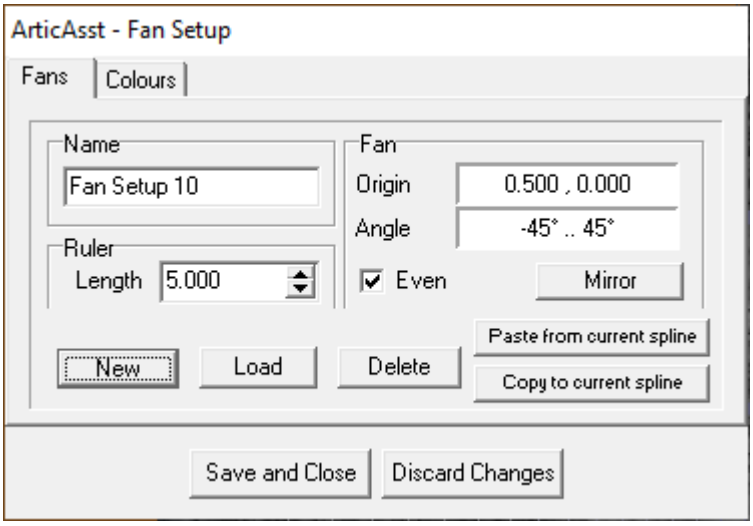
The **Fan Setups…** dialogue can be initiated from the video display popup menu or from the ultrasonic display popup menu.





For Video data (or ultrasonic data recorded with revision 214 or earlier of AAA) the following steps are required.

Click  to create a new fan setup. Then type the name of the fan setup, replacing the default name which has the form 'Fan Setup #' with something more informative. It is advisable to include info on the model of ultrasound, the depth and the sector angle.



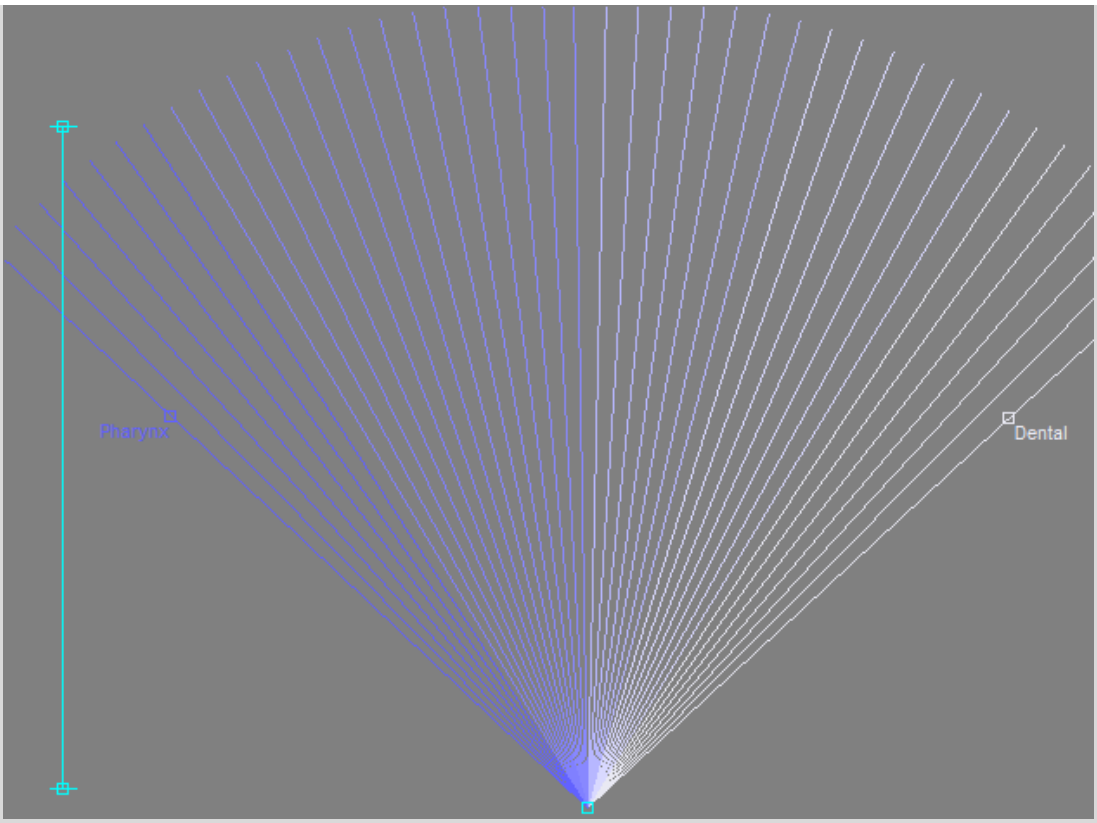
Click on  to change the side of the fan marked "Dental" to match the orientation of the tongue in the image.

The fan angles can be adjusted by clicking and dragging the control points 

or by typing values in the “origin” and “Angle” edit boxes. The origin of the fan can also be moved by clicking and dragging its control point.

Note

The co-ordinate system is normalised. x is always 0 at the left of the image and 1.0 at the right. Y starts at 0 at the bottom of the image. The y value at the top of the image will vary depending on the aspect ratio of the image but it retains the same scale conversion from pixels as defined by the x-axis. i.e if the image is 640 pixels wide and 480 pixels high then the top of the image will be 480/640 = 0.75.



Note

The probe origin in ultrasonic data is always [0.5, 0.0] but in video based ultrasound images it can be in a different position. When converting DeepLabCut splines we recommend using the short tendon as the origin rather than the probe origin.

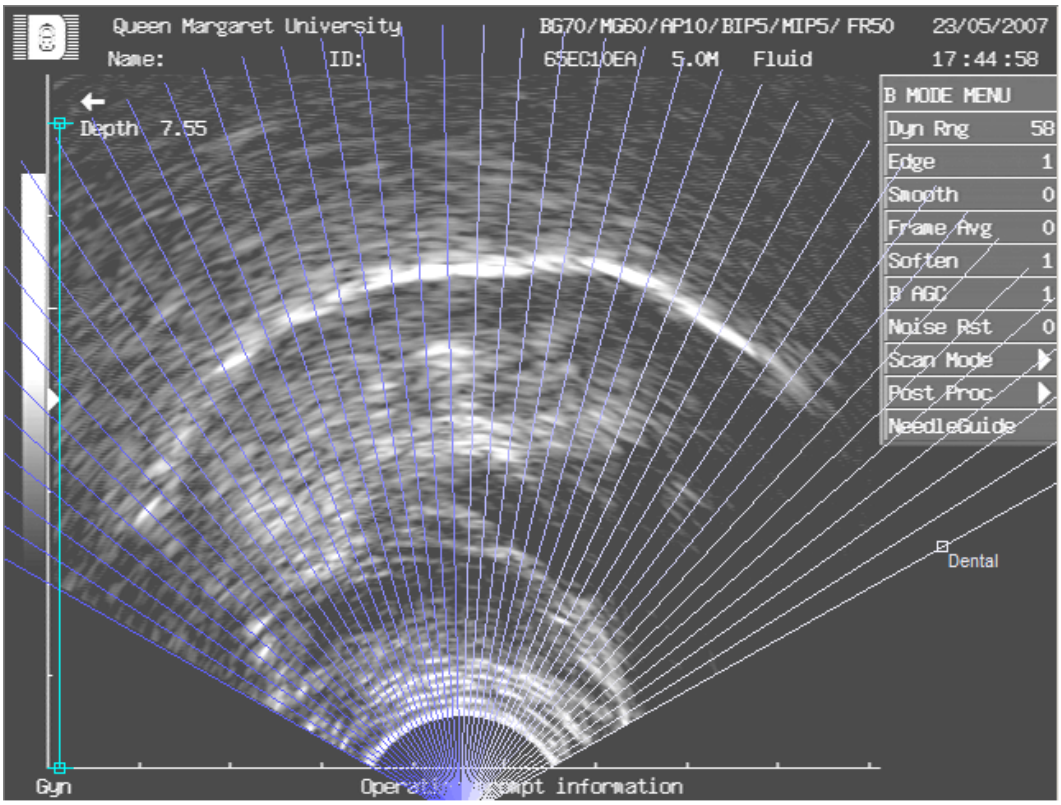
Creating fans for video-based ultrasound

The **ruler** (vertical cyan line on left of image) and **Length** value combine to define the scale in mm. In video based ultrasound the cyan line should be adjusted so that the top and bottom align with scaling tick marks that usually appear down the side of the Video ultrasound image and indicate the depth in centimetres. Once aligned, count the number of ticks and enter the length of the ruler in mm in the ruler length edit box in the fan setup dialogue.. This sets the scale for any measurements made within, or exported from, AAA.

Once complete, click 

to save the setup. You can also edit setups but be careful if you have already used a setup to create fans for analysis of some recordings then changing it will obviously change the basis upon which further recordings are analysed.

The colours tab permits the appearance of the fan to be changed.

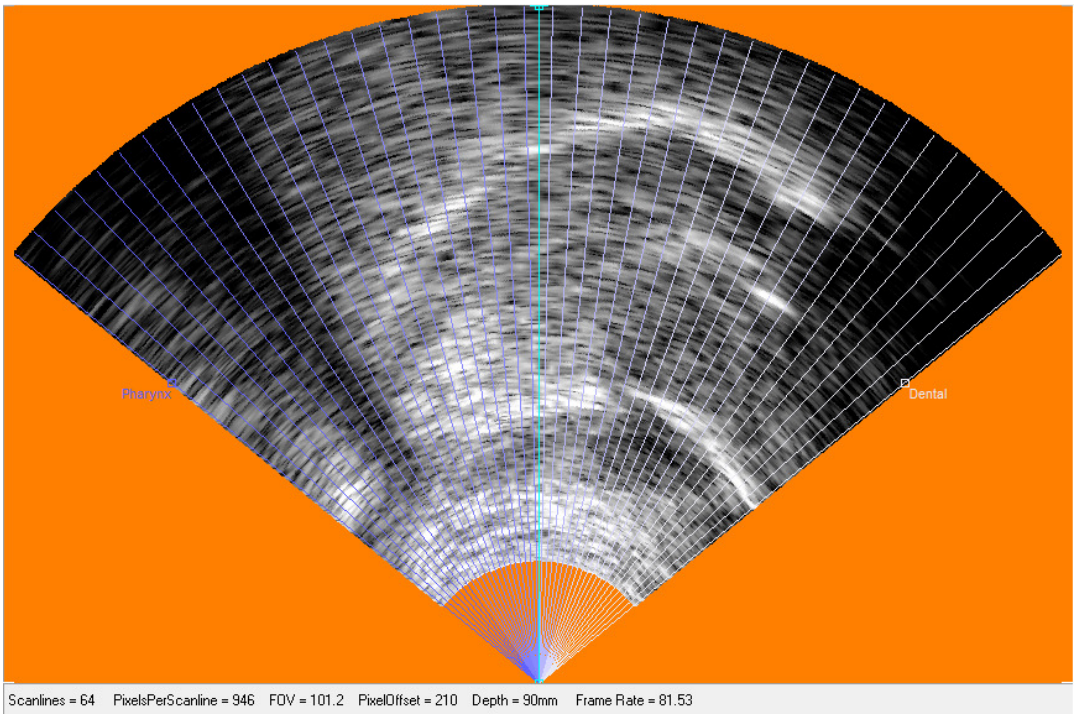


Note:

It is only necessary to create one fan setup for all recordings if the ultrasound setup is not changed but if you change the depth setting remember to create a new setup with and adjusted scale for your real world measurements to remain correct

Creating fans for Art, Micro, EchoB or Ultrasonix data

In ultrasonic data, the easiest way to set the scale manually is to set the cyan line from top to bottom of the image and set the **length** to depth+probe radius.

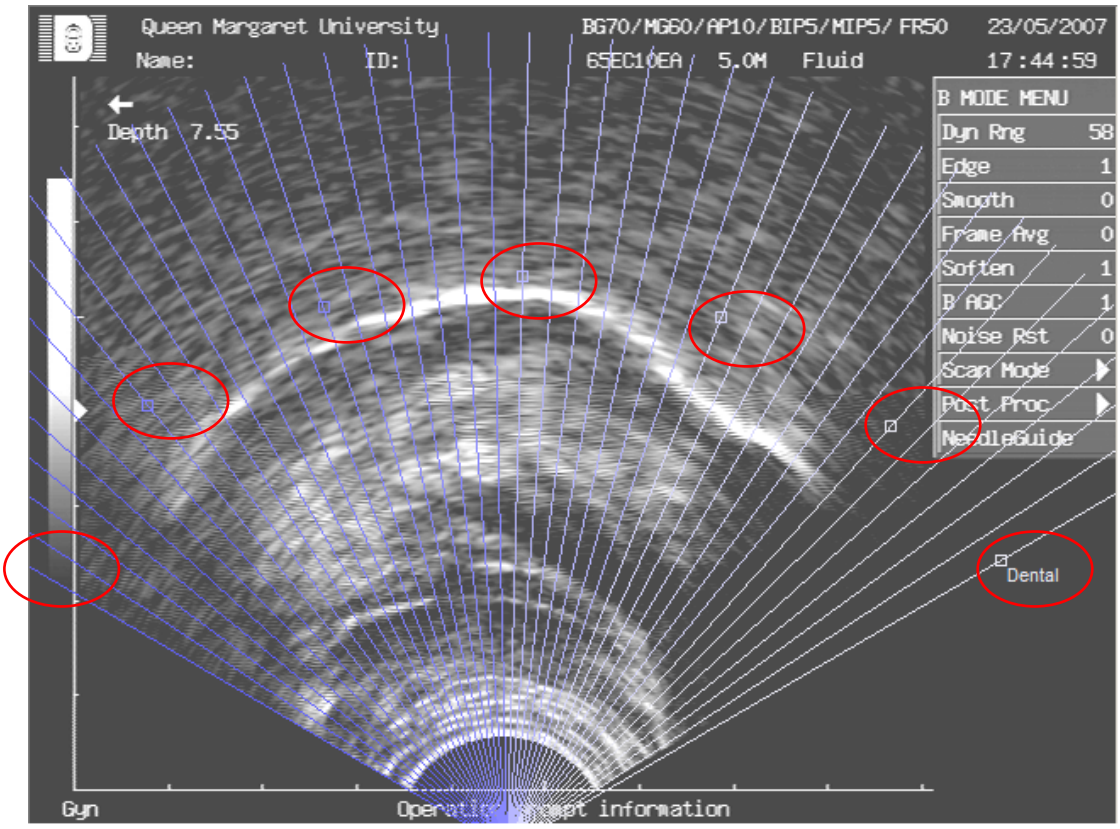


Creating fans with unevenly spaced axes

There is a facility to have an unevenly spaced fan grid. The thinking behind this is that specific fanlines could be assigned to align with palatal regions such as dental, palatal, velar etc. A higher density of fanlines could be assigned in the alveolar and post alveolar region allowing more closely defined curves in this region where the tongue tip is very flexible.

If the ☐ Even checkbox is unchecked then the Video display will appear with seven control points appear rather than the default two (Dental,Pharyngeal).The “Angle” edit box will change from showing a pair of values defining the start and end of the fan to showing a single angle value associated with whichever of the 42 axes is selected. The angle can be changed by editing this value or by clicking and dragging on the display.

IN PRACTICE THIS OPTION HAS NEVER BEEN USED.



FAN GRID SECTOR ADJUSTMENT

In ultrasonic data, the easiest way to set the scale manually is to set the cyan line from top to bottom of the image and set the length to depth+probe radius.

Copying to and pasting from existing fan splines in the current project

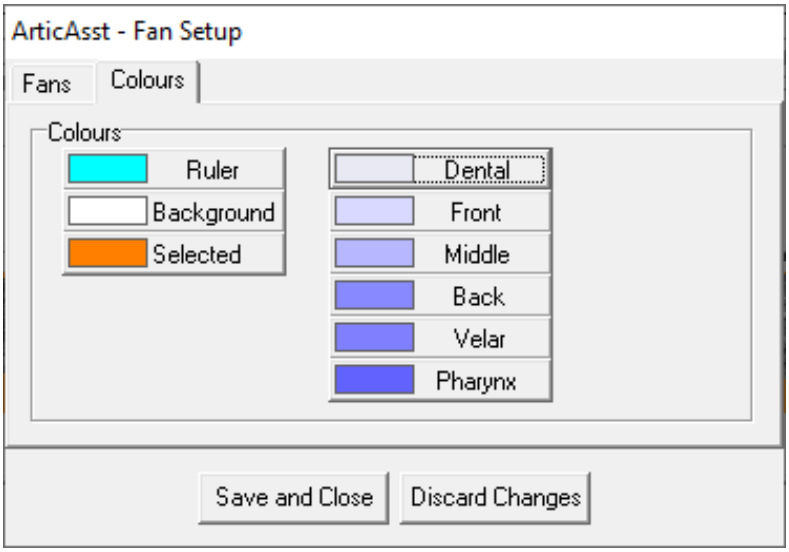
If you have an existing project that has had fan splines fitted, perhaps on a different computer by someone-else, and you wish to use exactly the same fan and ruler so that your data is comparable then you can copy the fan from a spline in that project.

First, load the project that contains the fan you wish to copy. Then open the Edit splines dialogue (see following section) and select a fan spline based on the fan you wish to copy. If the fan setup dialogue s not already open, open it and click the Paste from current spline button. This will create a new setup with a default name like "Fan Setup 5". Change this default name to something that will describe the fan setup and click Save and Close. This fan setup will now be available for any new project that is created or loaded.

Similarly, once a setup is stored, it is possible to transfer it to a spline that has already been drawn. Open the Edit Spline dialogue and select the spline whose fan and ruler you wish to modify. Then use the Copy to current spline in the fan setup dialogue to transfer the fan

selected in this dialogue to the spline selected in the Edit Splines dialogue. Note that this should be done for all of the splines for a given recording in turn. It will also need to be done for every recording. Take care, as changing the position and angle of the fan will change the position and angle of the spline that is already drawn. [In future it may be possible to correct for this and keep the spline in the same position but not in this current version of AAA.]

Fan and spline background colour specification

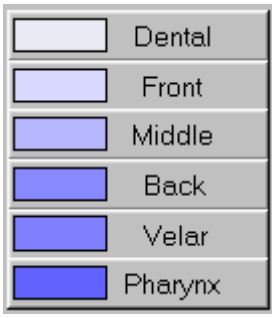


It is not usually necessary to change these colours. They are for aesthetic preference. For example, when creating presentation videos of tongue splines, the background colour can be changed from white to something more colourful. It has the following options:

The colour of the ruler in the setup dialogue

The background colour for spline drawings if the video is switched off and, in the case of ultrasonix, around the scan image

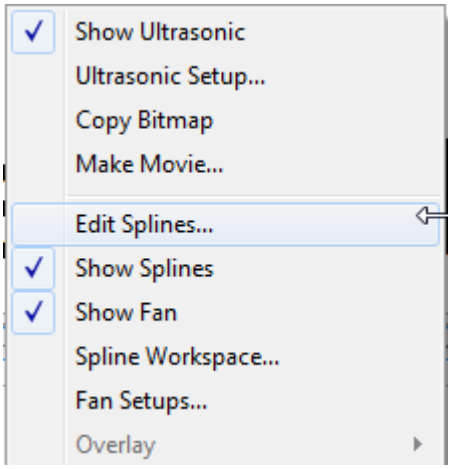
The colour a spline changes to when selected in the Edit Splines dialogue.



The colour of the fan lines in the 7 major regions.

Edit Splines Dialogue

The Edit Splines dialogue is the engine-room of the ultrasound/video data analysis. It facilitates the creation and adjustment of splines that define key structures such as the surface of the tongue, hyoid, mandible and the roof of the mouth. Or in the case of lip videos they can define upper an lower lip boundaries.



Splines

Splines are curves defined by a mathematical (cubic B spline) function that are constrained to pass through specified control points referred to as **knots**.

AAA has two different implementations of splines:

Fan Splines

In AAA a fan grid has 42 axes. A fan spline is defined by the 42 control points where the curve crosses these axes. Essentially what this means is that the once all of the crossing points of these 42 axes are defined the software draws a smooth line that passes through all of them. Using 42 splines provides a slightly smoother result than joining the 42 points with straight lines.

The use fan splines for ultrasound images is justified because the ultrasound image is created from beams of ultrasound that fan out in straight lines from ultrasound probes with convex arrays, typically used in speech analysis. The restriction of the fan grid therefore matches the way the data is created. One advantage of using fan splines when

they were introduced to AAA in 2003 was the associated automatic edge detection/tracking algorithm that speeded up spline fitting. A second advantage was the opportunity it provides to calculate the average of several splines and find the regions of significant difference between two such average splines.

More recently with the introduction of DeepLabCut which operates on 2D splines, the conversion of these 2Dsplines to fan spline format is favoured by some reseachers as they provide a polar co-ordinate representation that is useful for GAMMS analysis.

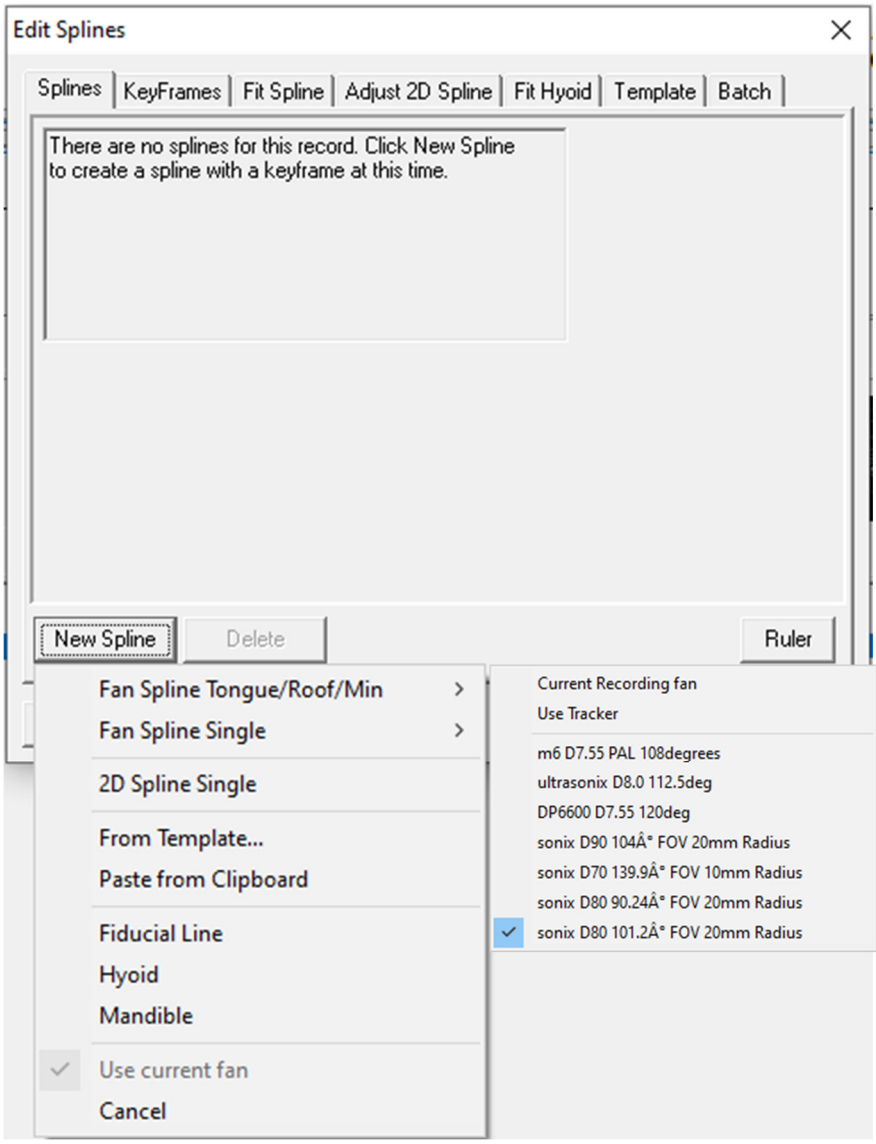
2D splines

Unlike fan splines, 2D splines are not restricted to having 42 control points that lie along 42 axes. 2D splines can have any number of control points in any position. The crucial difference is that unlike fan splines it is possible to draw curves that bend back on themselves. So for example in MRI images a curve can be drawn that continues from the upper surface of the tongue around the tip and along the underside of the tongue tip. Or, if a camera image of a facial profile is being drawn, a spline can follow the contour of the upper lip and/or the lower lip.

2D splines with only two points are special. Two point splines define a **Fiducial** line. A dotted axis will appear at one end to define the origin and orientation of the line and this line can then be used to define a plane and rotate exported co-ordinates or analysis values. The origin of the Fiducial can be used to define the origin of the exported co-ordinate space. It can also be employed as a user defined axis along which measurement can be taken.

New Spline : Creating splines manually

Open the Edit Splines dialogue by clicking on the option in the Video display window popup menu. The first time this is done for each recording the dialogue will look like Figure 9. Subsequent calls to the edit splines dialogue will look like this.



To manually create a spline, click 

. However, note that tongue contours are most often and most simply generated using the DeepLabCut Batch process.

Fan Spline Tongue/Roof/Min

To create a new fan spline select “Fan Spline Tongue/Roof/Min” and then choose one of the fan setups named in the submenu. The one which matches the ultrasound display in the current recording is automatically generated and indicated with a  . If there is no suitable setup then follow the guidance in the previous section to create an appropriate fan setup. When the submenu option is selected, a fan and three default splines will be created. These three splines are named Tongue, Roof and Min Tongue.

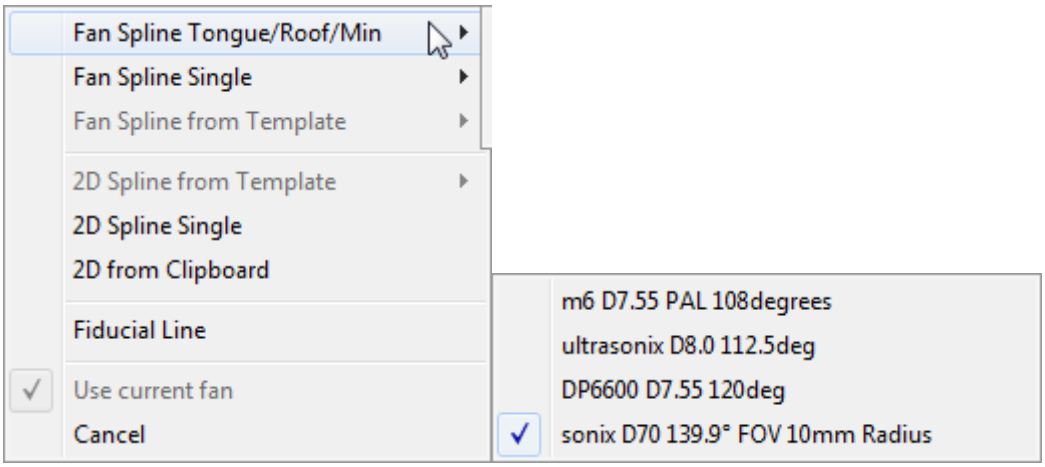


FIGURE 8 FAN SPLINE SELECTION WITH FAN SETUP SUBMENU TO THE RIGHT WITH AUTOMATICALLY DETERMINED FAN SPECIFICATION SUGGESTED BY TICK

Tongue spline – used to highlight the surface of the tongue

Roof Spline – has a dual purpose to highlight the shape of the palate and/or provide an upper limit to the range over which the tongue surface may be found. This latter purpose is necessary for the automatic spline fitting to work. Note that even if a palate contour is not needed it is useful to adjust the roof spline to isolate non ultrasound graphics such as menus, scales and axes from the search space.

MinTongue – This spline is used to provide a lower limit to the automatic search for a tongue contour. This spline should be drawn as high as possible to isolate the bright reflections caused by the sublingual tongue muscles but bearing in mind that, for some articulations, the tongue root can advance forwards and, for others, the tongue tip can lower. Once a you think you have a good minimum position defined. It is worth running through the whole recording to make sure by observation that the tongue surface never crosses it.

Fan Spline Single

This option is provided for completeness but in practice should probably not be used.

Fan Spline from Template

The default three splines (Tongue, roof and Min) are created as simple arcs. Once the roof and min splines have been redrawn to suit the data in one recording it is recommended to save all three splines as a template (see later section for how to create templates). This provides the opportunity to load this template for all the other recordings in the same session (or indeed by any speaker in any session).

2D Spline Single

This option will create a single curve with seven knots (control points). A good option for drawing outlines of facial features or MRI tongue contours.

2D Spline from Template

As with Fan splines, once a set of 2D splines has been redrawn, perhaps with extra knots added to some of them and spacings between knots altered, it is possible to save them as a template and then load this template into other recordings.

2D Spline from Clipboard

This is a similar function to templates but on a temporary basis. Splines can be copied from the spline workspace (se later section on Spline workspace)

Fiducial Line

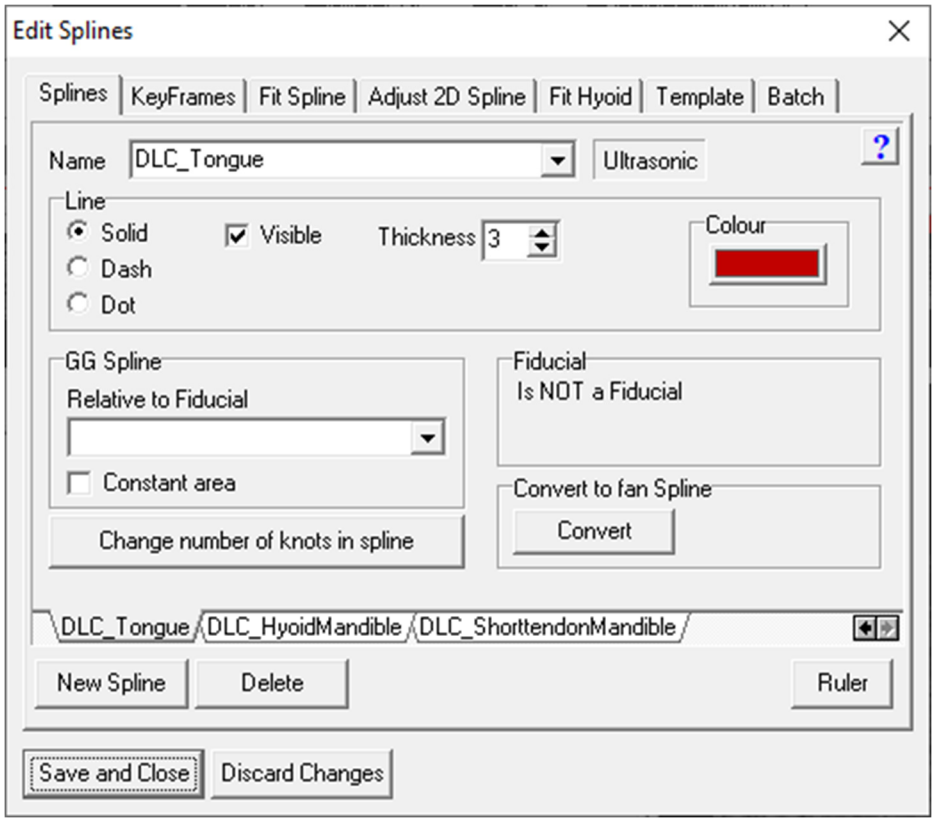
A 2D spline with only 2 knots is created. This is termed a Fiducial and has special properties. Note: if knots are added to a fiducial line it becomes an ordinary 2D spline.

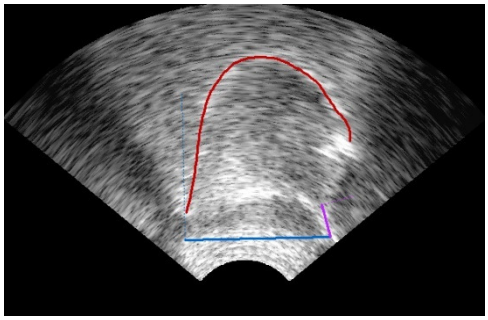
Use current fan

If a fan is already selected for the current recording and additional splines are required for any reason then, with “use current fan” checked, fan setups will not be displayed and clicking on “single spline” or Tongue/Roof/Min will add a spline with the same fan setup as is already loaded. If the “use current fan” is unchecked then a different fan setup can be selected. It is not clear why you would ever want to e two different fans for one recording.

Editing spline appearance and name

As well as manually adding splines, the Spline tab allows the colour, boldness and visibility of individual splines to be controlled.





Spline appearance

The appearance of splines once drawn is controlled by the Splines tab settings Each spline appearance is controlled separately.

Line style

The line appearance options include:

- **Line type** – solid, dotted or dashed
- **Visible** – or not (HOTKEY <Ctrl>S also toggles this setting)
- **Thickness** – of the line
- **Colour** – of the line

GG Spline

This is an old obsolete experimental option for fitting 2D splines to tongue contours. It restricts the 2D points to lie on vertices of a fan originating from a point defined by a related fiducial. May be removed in future.

The 

button will delete the selected spline.

Important: Changes to splines additional keyframes etc are ONLY SAVED WHEN THE SAVE AND CLOSE BUTTON is clicked. If fitting splines to several keyframes in a recording it is advisable to save and close regularly.

Keyframes

KeyFrames are a central concept in the creation of splines. Keyframes are points in time for which a spline can be defined (drawn). Keyframes can be produced at any point in time (although it makes most sense to link them to video/ultrasonix frames). Different keyframes exist for the tongue, roof, min_tongue splines and any other fan or 2D splines. Typically you only need one keyframe for the roof and Min_tongue splines as these are normally unchanging over the course of a recording and even across recordings. It does not matter which time points you choose for such keyframes.

There are three methods for creating keyframes.

Single Keyframe – Create a single keyframe for the selected spline at the timepoint indicated by the waveform cursor.

Every Nth video frame – N is specified by the “Frames” counter. When Frames is set to 1 then keyframes are placed at every video/ultrasonix tickmark in the region highlighted in the waveform window. If the waveform cursor indicated only a single point in time then the keyframe will be placed at the tickmark corresponding to the current video frame.

Every N millseconds – N is specified by the “Frames” counter. Included for completeness but this not normally used.

The software will always interpolate between keyframes to ensure continuous spline values throughout the recording. i.e. if there is one keyframe at the start of the recording

and one at the end then the spline will linearly morph each spline control point from the start shape to the end shape as the cursor moves through the recording.

IMPORTANT: When analysis values based on splines are exported, the values will not necessarily be the keyframe values but rather, they will be the interpolated value at the specific time point that is labelled.

Confidence – the confidence values generated for the spline are based on the algorithm error measure which is in turn based on the brightness of the image. The value can therefore be very small for dark images. The multiplier is a fiddle factor to better reflect the true confidence as reflected by a solid line appearing where a clear edge is present. This is admittedly unsatisfactory and more development of the algorithm is required to remove the need for this multiplier which is related to brightness and contrast levels.

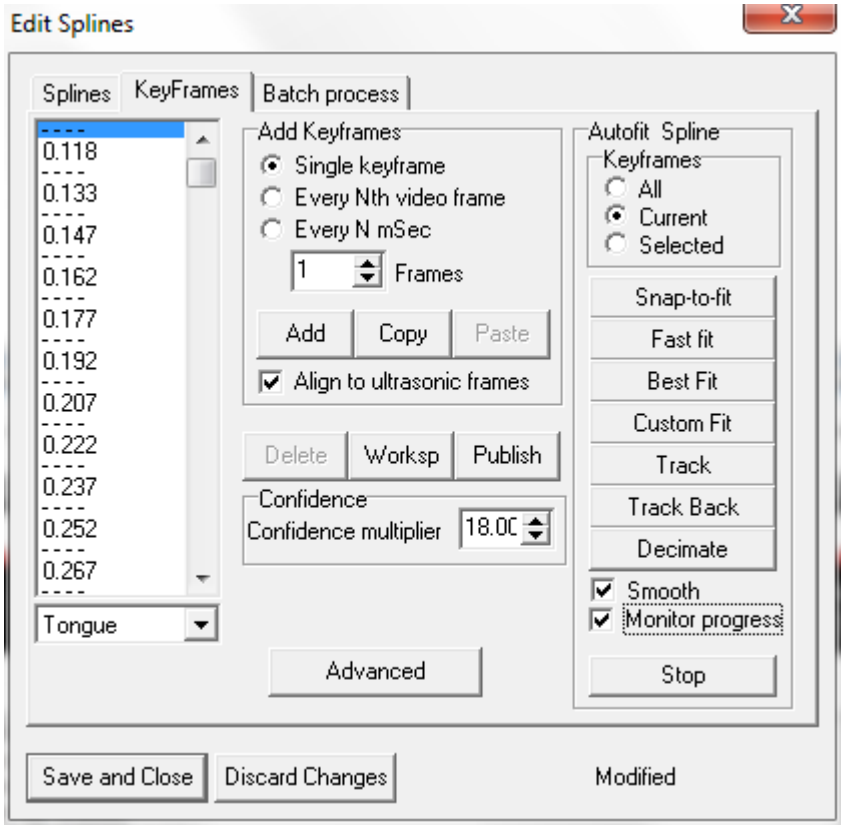


FIGURE 10 EDIT SPLINES DIALOGUE – KEYFRAMES TAB AS IT LOOKS FOR FAN SPLINES

Monitor progress – If checked then the ultrasound image updates and the newly fitted spline is shown for every keyframe. Drawing each frame in this wayprovides useful

feedback but slows the fitting process. Uncheck this to speed up batch processing by a factor of 10 or more.

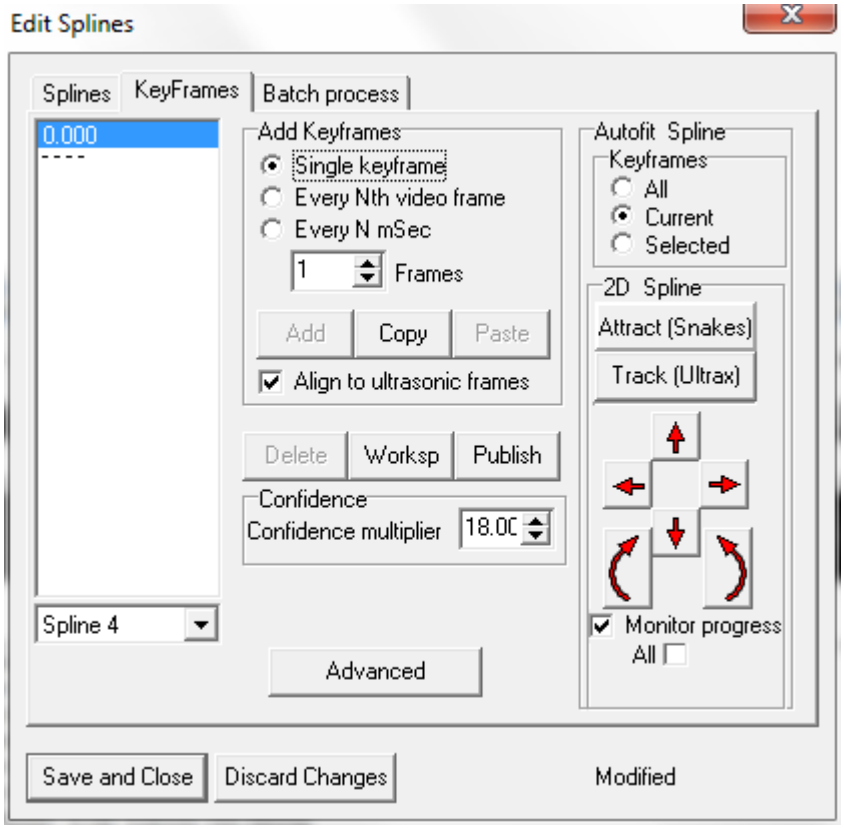


FIGURE 11 EDIT SPLINES DIALOGUE - KEYFRAMES TAB AS IT LOOKS FOR 2D SPLINES

Several keyframes can be highlighted at one time by clicking and dragging on the list on the left. When highlighted, the selected splines can be deleted with the delete button or copied to the Workspace or the Publisher. See later sections for more details.

Note: There must always be at least one keyframe. To be able to delete a single keyframe, first a new keyframe must be added.

The - - - - is highlighted when the waveform cursor selects a timepoint that does not have a keyframe associated with it.

The “Autofit Spline” options on the righthand side of the Keyframes dialogue provide automatic spline fitting functions. These are discussed in the *Fittting Splines* section of this manual.

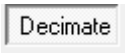
Batch Process

Batch Process allows groups of recordings or annotations to be splined with one button click. This allows splining to be done without time-consuming manual interaction. Use the filter function to select a set of recordings or a set of annotated regions and then process them all in one go.

There are two variants of spline fitting algorithm.

Snap 

Snap is the same bitmap based algorithm that is described in the spline fitting section of this manual. It will work with Video based ultrasound images (e.g. Mindray DP6600 and DP2200) as well as ultrasonic data from Echo B , Ultrasonix and Micro. Since revision 217_02 the algorithm work on the raw data rather than the image data speeding up the process by 100x. It provides the usual selection of tracking as well as localised “snap-to-fit” and more global “best fit”. See following section for details). A template with Tongue Roof and Min Tongue splines must be provided to seed this method and results will vary depending on the suitability of this template.

Decimate 

Decimate is still in development and so the accuracy is less than for snap at the moment. However, it does not need a template to be created for it to work. Parameters for the decimate algorithm are set in the “Ultrasonic Setup | Options” dialogue.

Drawing Splines manually

Fan Splines

A spline can be drawn by clicking and dragging on the video display window when the Edit Splines dialogue is open and a keyframe is selected. When a keyframe is selected the specified spline will change from the designated colour to an orange line with tick marks through it corresponding to each of the 42 radial axes (Figure 12)

If the **control key** is held down while clicking and dragging then the tickmarks will become dots and the line will disappear. This can be used to indicate regions where the tongue surface disappears. It actually invokes another important concept, that of **Confidence (**see following section).

EXAMPLE PROCEDURE:

STEP 1: Add Tongue, roof,min toungue

STEP 2: Draw roof and min tongue limits for the session

STEP 3: Draw a typical tongue position

STEP 4: Save this as a template (name according to client and session)

STEP 5: Run batch tracking using this template

STEP 6: Run batch snap-to-fit using this template

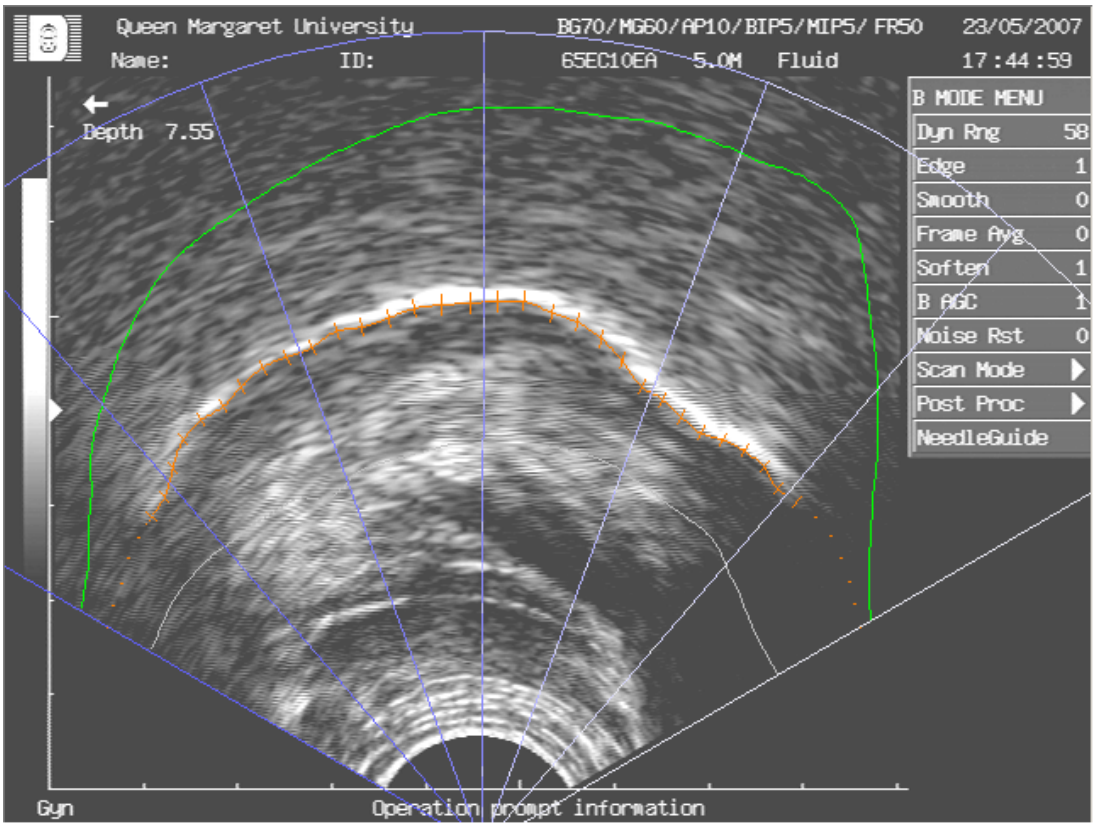


FIGURE 12 TONGUE KEYFRAME (ORANGE) DRAWN TO FIT THE TONGUE CONTOUR.

2D Splines

The technique for drawing 2D splines is different to fan splines. It is possible to click and drag each knot individually to any location on the screen. It is also possible to add knots or delete knots by right-clicking and selecting “Add knot” or “Delete knot” from the pop-up menu.

The number of knots and their spacing should be selected to match the contour being traced. For example Figure 13 has 17 knots to define the tongue contour with the spacing between knots reduced at the tip to account for tighter curvature in that region.

Tip: Hold down the <cntrl> key and click and drag to draw a contour. The relative spacings of the knots will be preserved so it will make a difference if the drawing is done from left to right and from right to left.

FIGURE 13 DRAWING 2D SPLINES

Confidence

Confidence is a way of indicating how confident the experimenter (or the automatic edge detector) is, that a given bit of spline (represented by the tickmark) is correctly positioned. A hand drawn spline has a 100% confidence level associated with it but when the control key is held down the confidence is set to 0%. The confidence can be used later in analysis or to determine which parts of a spline are exported as x-y co-ordinates.

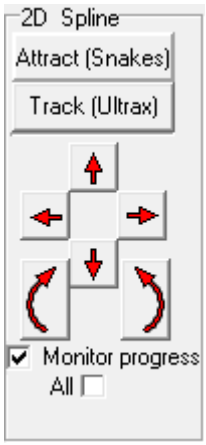
Confidence has not yet been implemented for 2D splines and is always 100%.

Confidence is linked to the brightness and contrast of an image. If the brightness or contrast settings are changed then the confidence levels will change and the confidence gain factor may need to be altered to compensate.

When applying autofit functions the confidence value will be automatically assigned and is related to the "goodness" of the edge found at each of the 42 control points. Goodness is dependent on the overall brightness and the relative shift from dark to light at the boundary. There is a manual adjustment that can be made to this confidence by changing the value of the confidence multiplier. Typically this value will be in the range 2-20. Adjust it and then click "Snap-to-fit" until the spline appears as solid line in the parts of the contour that have a good edge.

Moving 2D Splines

When fitting 2D splines to MRI images or other images where there is a feature, such as the hard palate, which has a fixed shape but moves position from frame to frame, it is useful to be able to move the spline without having to redraw it. The keyframes tab for 2D splines has a a set of buttons with arrows which allow rotation and translation of the selected spline (shown below). If the “All” box is checked then all 2D splines for the recording will be moved together.



Ruler adjustment

The 

button provides a safety net to be able to adjust the ruler in the case where an error was made when setting up the fan and a means to set the ruler for 2D splines. When the dialogue is opened, the ruler for the currently selected spline will appear on the video/ultrasonic display.

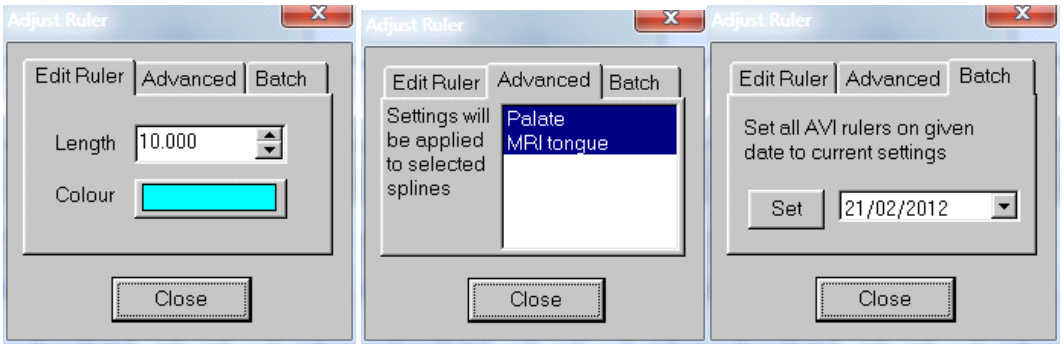
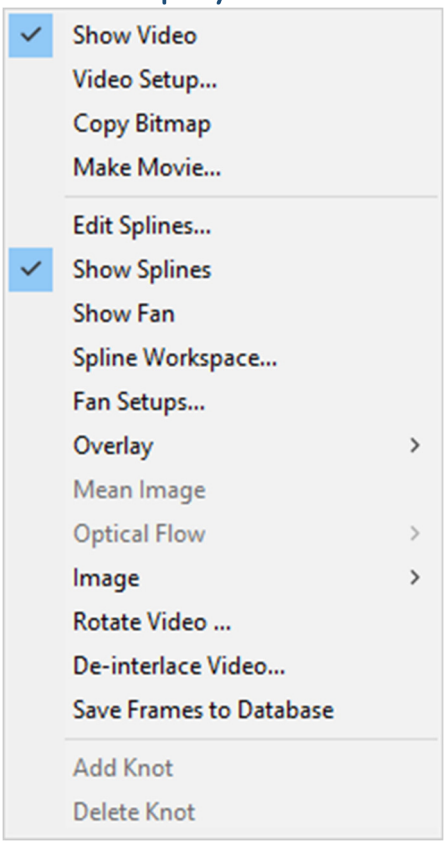


FIGURE 15 RULER ADJUSTMENT DIALOGUE

The "Advanced" tab can be used to select which splines the adjustment will be applied to. By default it will be applied to all splines in the current recording.

The "Batch" tab provides a means to apply the ruler change to every recording by the current client made on a specific date.

Video display



Controlling appearance of Video display

Show video, splines, fan

Video setup dialog

Copy bitmap

See Copy Bitmap in Ultrasound display section

Make movie

See Make Movie in ultrasound display section

Overlays

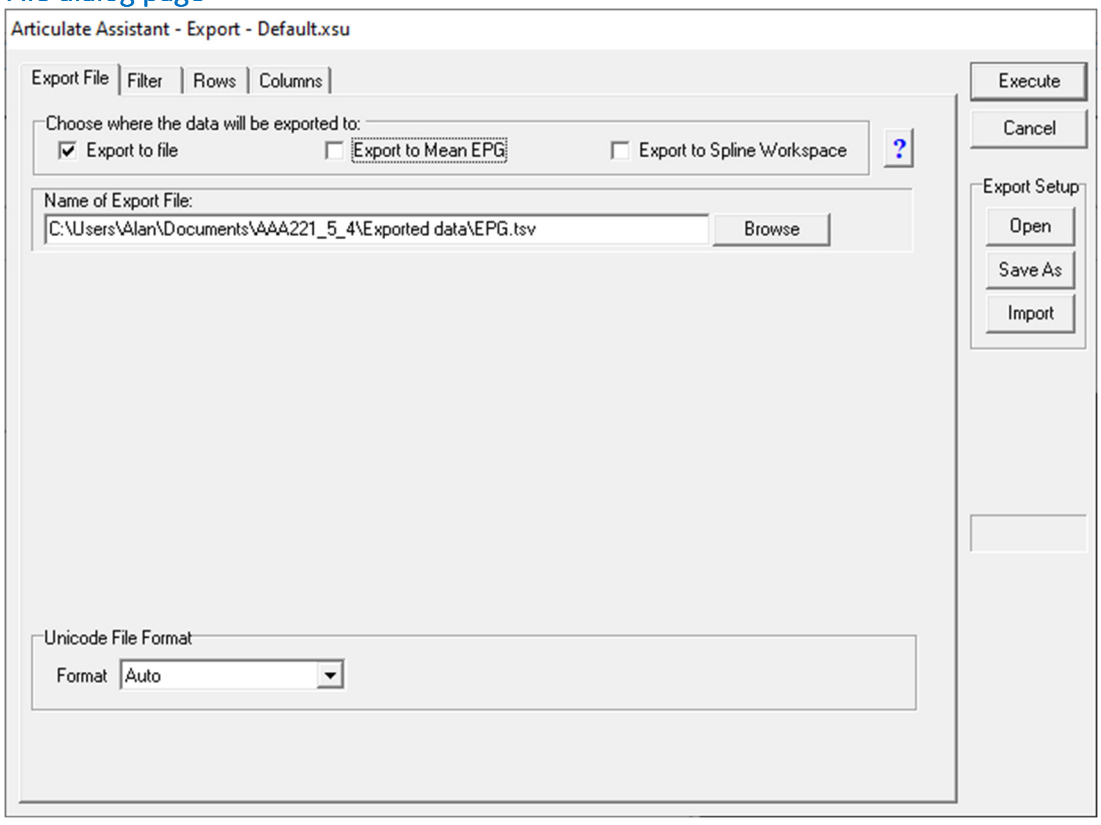
See Overlays in ultrasound display section

Exporting files and data

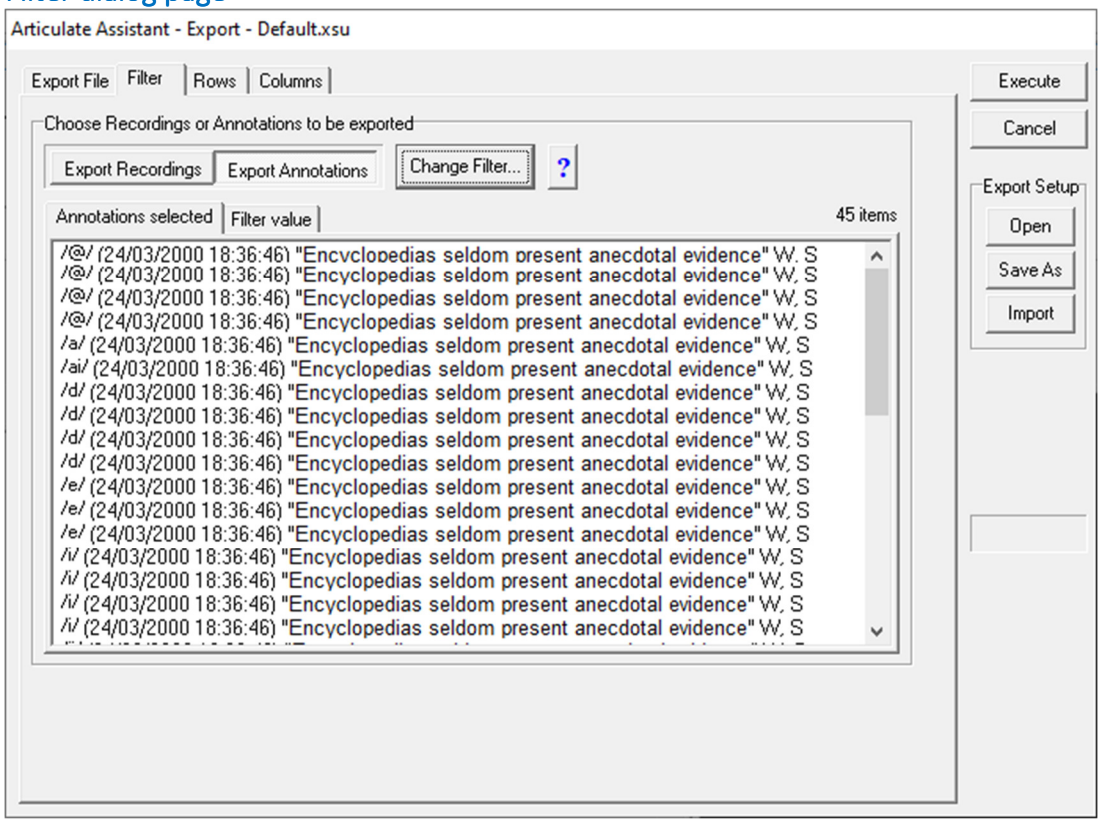
Export Data

AAA provides many options for processing and analysing data. Once the data is analysed the Export Data dialog allows the results of the processing and analysis to be exported

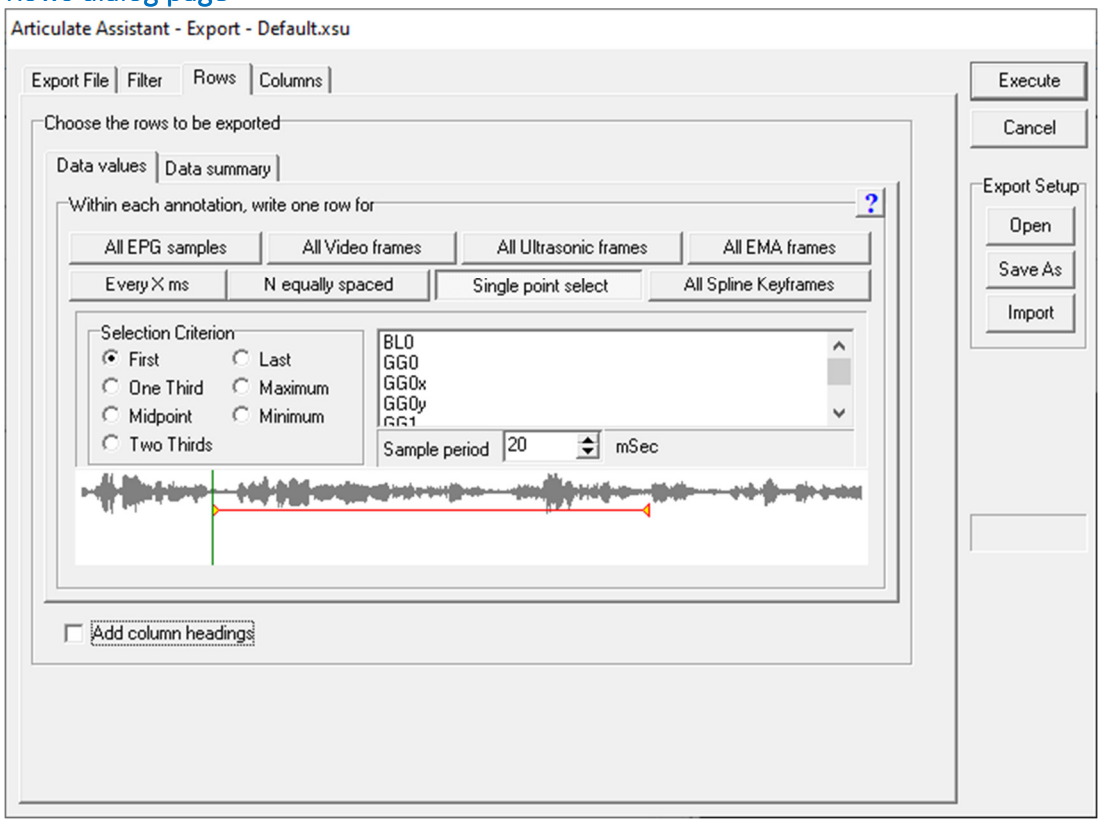
File dialog page



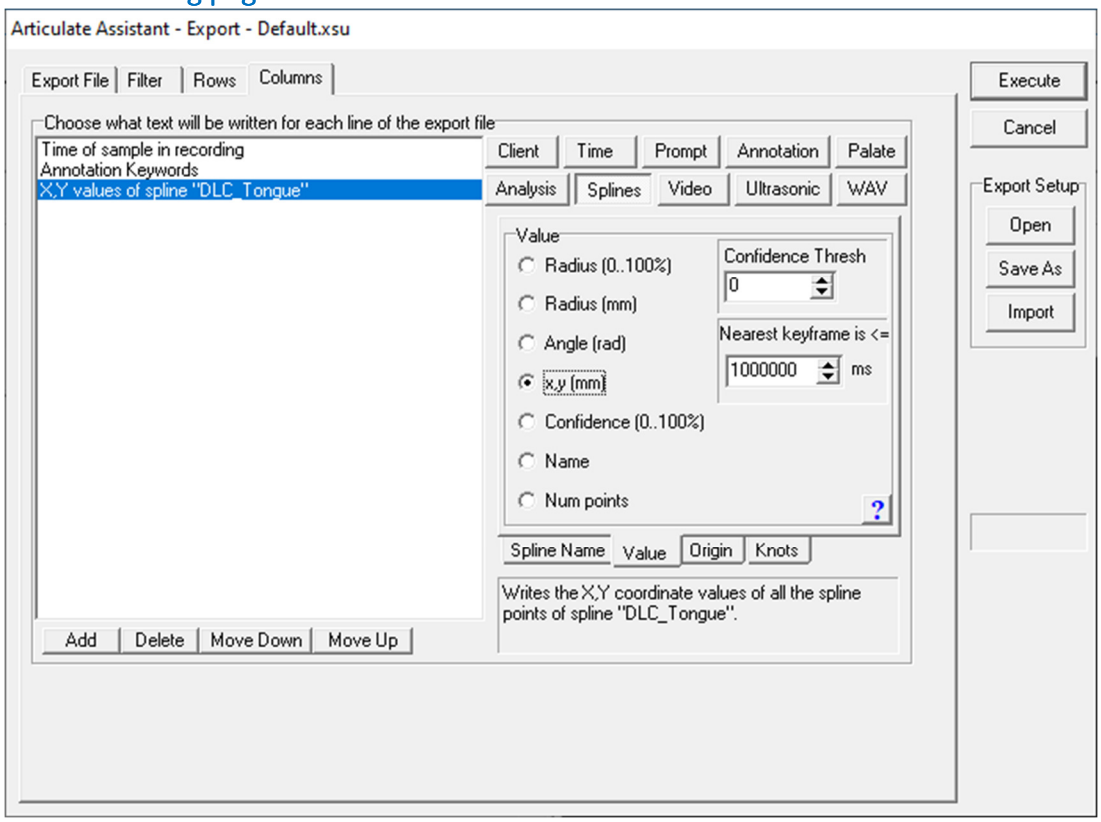
Filter dialog page



Rows dialog page

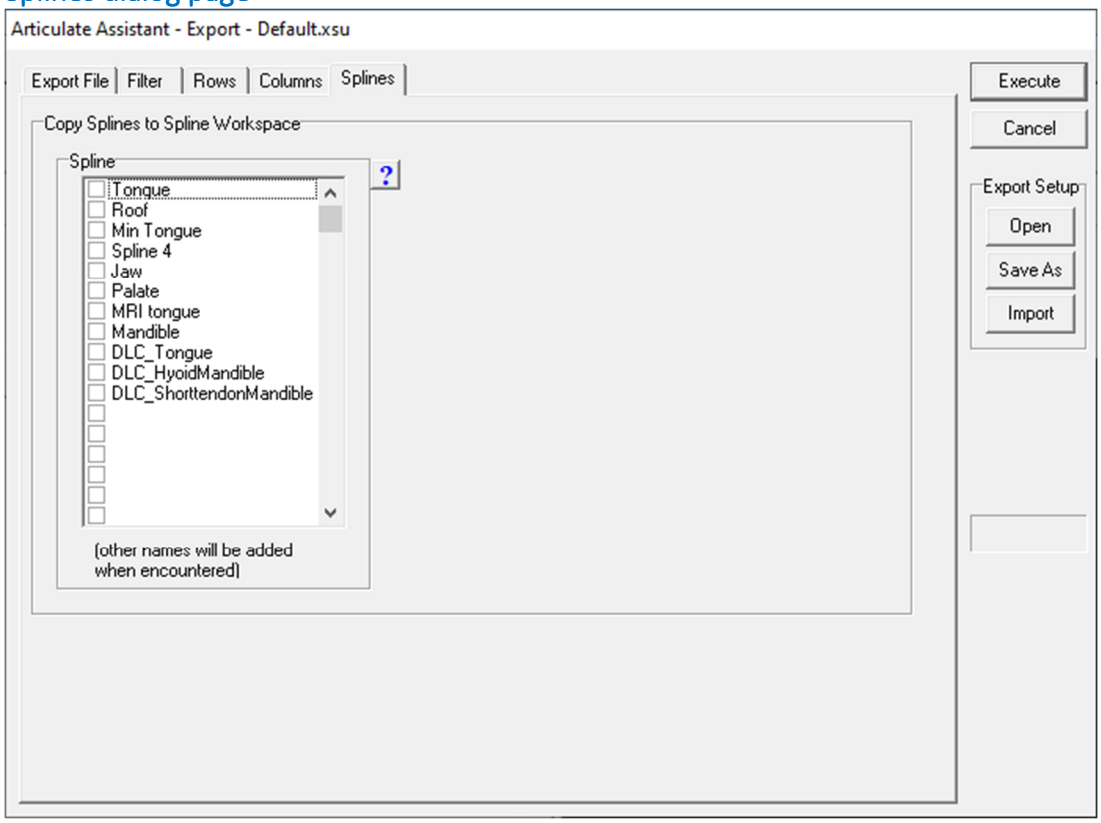


Columns dialog page



There is no standard format for splines. They are typically stored as a sequence of points specified in Euclidian or Polar co-ordinates. The number of points can vary. Splines are generated from a small number of control points extrapolated using a cubic formula. However, some software expects tongue contours to be stored using a large number of points (e.g. 100) that represent the shape without needing to be interpolated .

Splines dialog page



Examples of how to use export data

Copying selected splines to spline workspace

Exporting labelled clips of video, audio or ultrasonic data/video from recordings

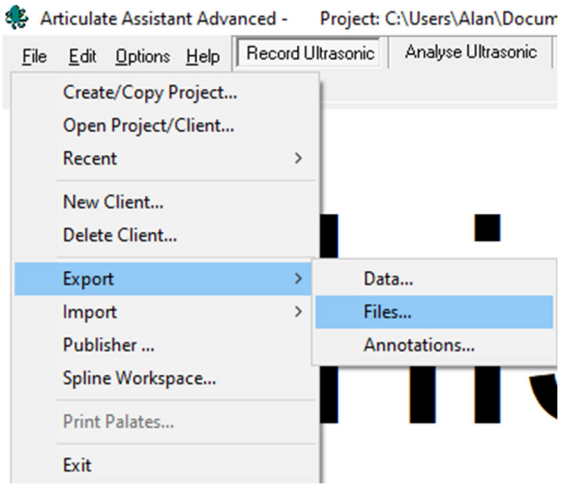
Exporting spline co-ordinates while rotating and translating based on a bite plane fiducial

Exporting time normalised segments

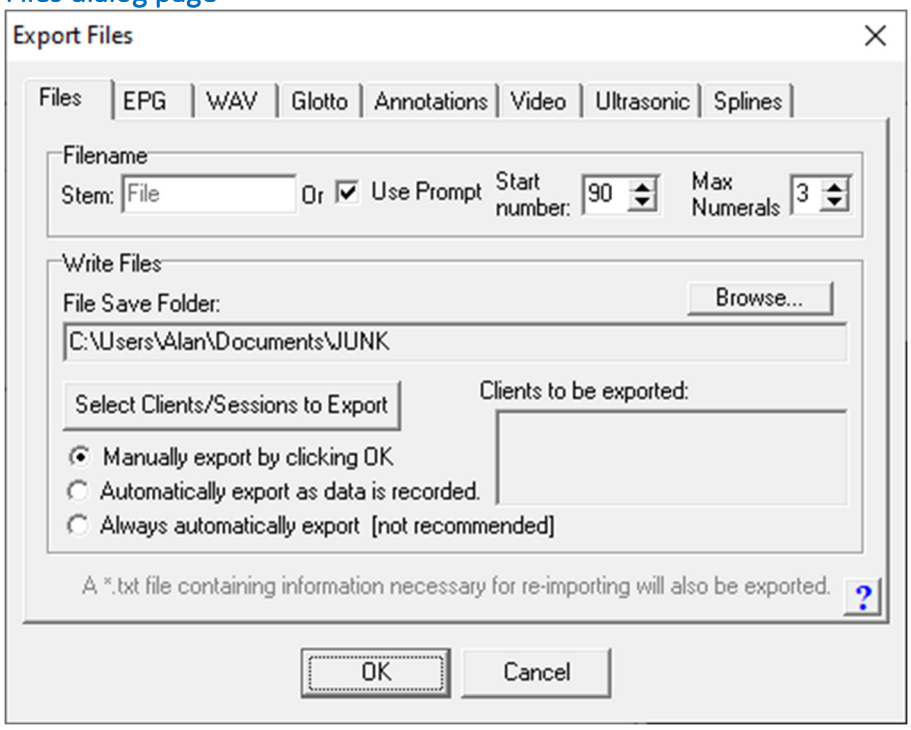
Export Files

The purpose of the export files dialog is to allow data streams recorded in the project to be converted to file formats that may be read by other analysis applications such as Excel, “R”, Matlab, PRAAT etc. The Export Files dialog is designed to export entire recordings. To export labelled regions of recordings see Export Data. The following sections describe how file export works and the different types of data that can be exported. Files of most types can be imported back into AAA (see Import section). To allow a file to be imported into the correct recording, a *.txt file is always exported along with selected data streams. The test file contains three pieces of data that together define the source recording

- `Client name`
- `Date/time of recording`
- `Prompt text`



Files dialog page



The File dialog defines the naming format for the exported files, the destination folder where they are to be saved and the recordings to be exported.

Filename: <stem><number with max Numeral digits>.wav or <prompt><number>.wav

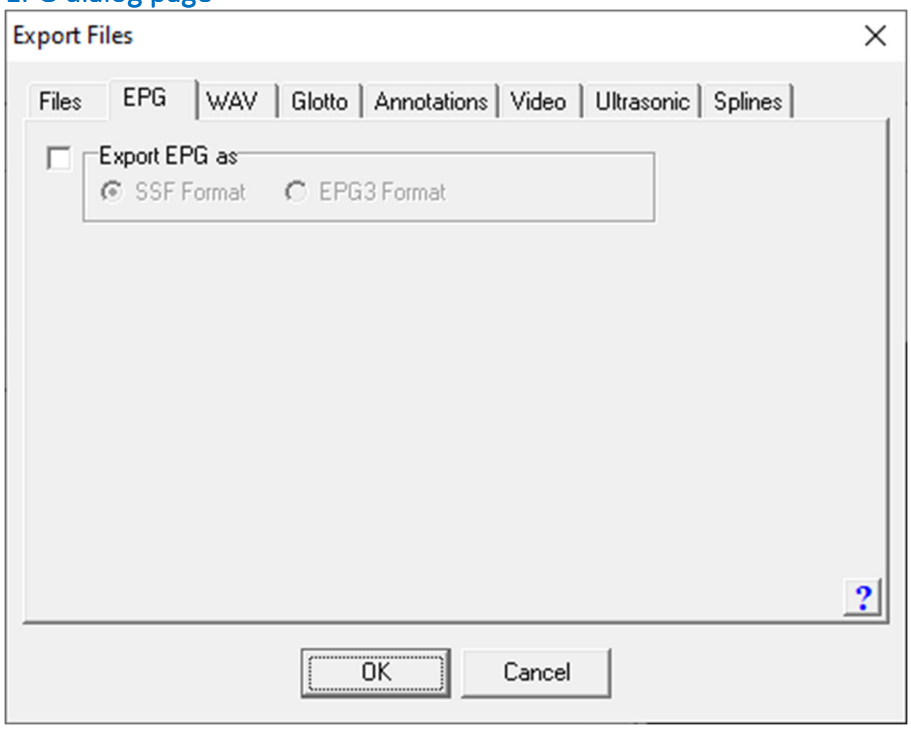
- **Stem** – This text will form the initial characters of every exported file
- **Use prompt** – Alternatively each file will be named using the prompt text with any illegal filename characters removed.

```
< (less than)
> (greater than)
: (colon – sometimes works, but is actually
NTFS Alternate Data Streams)
" (double quote)
```

```
/ (forward slash)
\ (backslash)
| (vertical bar or pipe)
? (question mark)
* (asterisk)
```

- **Start number.** – the stem is followed by a number starting at this index.
- **Max Numerals.** – Number o decimal places. E.g if 3 and start number = 5 then the first exported file name will be <stem>005.wav or <prompt>005.wav
- **File save folder.** – Full path of folder where exported files will be saved. This can be an external drive. Use the browse button to open a windows explorer dialog to find and select the folder on your computer.
- **Select clients/sessions to export.** – Opens the subdialog described in the earlier section of this manual *Project | Copy recordings from one project to another* allowing whole sessions or individual files from the current client to be selected for export.
- **Manually export by clicking OK.** – the default and recommended way to export files by clicking the OK button in this Export files dialog.
- **Automatically export as data is recorded.**- If this option is set then the next time a recording is made then all the file formats checked in this dialog will be exported when the recording stops. This will slow down the recording process and so is not recommended. As it is not recommended, this option is rest to off when AAA is closed so that it is not active the next time AAA starts up.
- **Always automatically export (not recommended).** – disables the safety feature described above so that the next time AAA starts automatic export remains active.

EPG dialog page



The EPG dialog exports electropalatography data recorded by AAA consisting of 62 electrodes arranged in an 8x8 matrix.

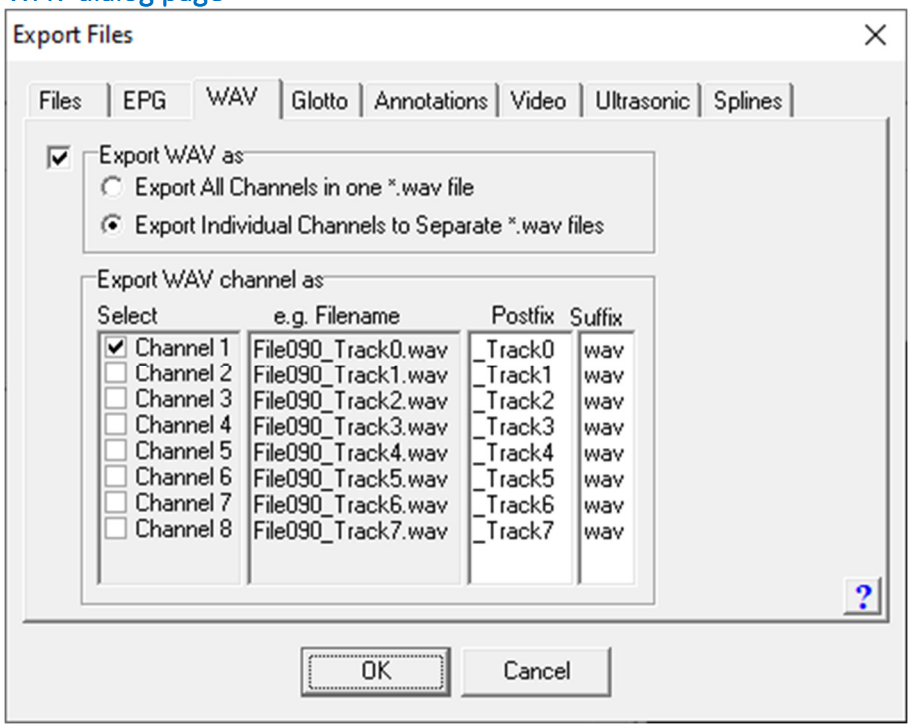
- **SSF format.** – Speech sound file, a format designed by Kiel university which comprises of binary data preceded by an ascii header that defines the frame rate and the number of bytes per frame as follows:

```
SSFF -- (c) SHLRC
Machine IBM-PC
Start_Time 0.0000
Record_Freq 100.0000
Column epg BYTE 8
```

- **EPG3 format.** - A raw binary with no header .

Reading EPG palates have 62 contacts which can be ON or OFF It is easy therefore to specify a single palate pattern by a set of 8 x 8 binary bits. These are coded and stored as 8 palate rows from posterior to anterior. Each row consists of 8 binary bits (1 byte).

WAV dialog page

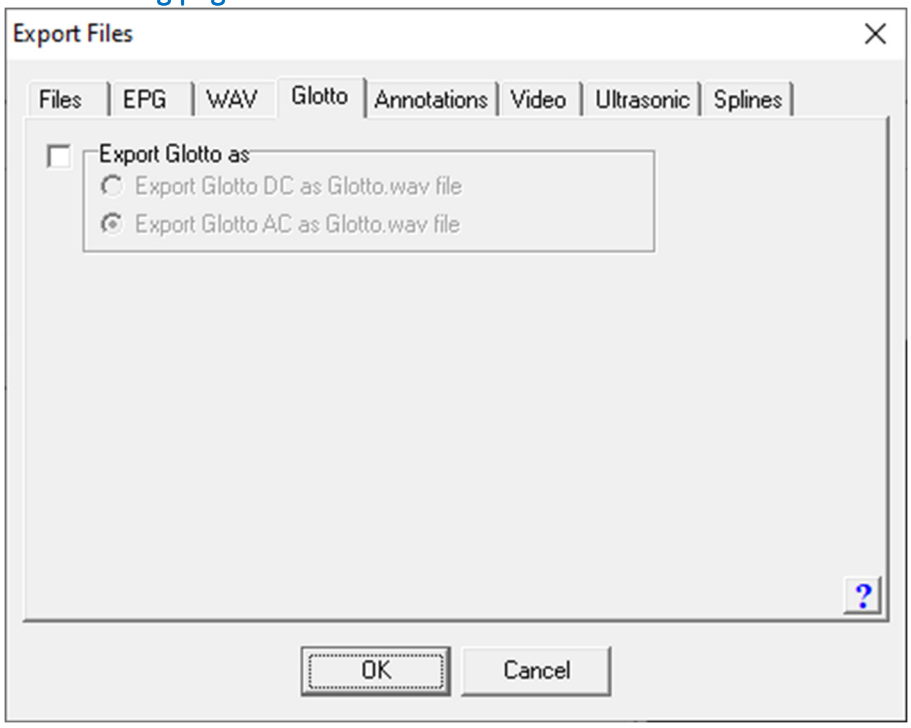


The wav dialog exports the audio recording as a wav format file.

- Export all channels in one *.wav file – self explanatory. AAA may have up to 8 channels but more typically a recording will have 2 channels, a speech audio and a synchronisation channel. More then two channels permits more synchronisation signals on separate channels.
- Export individual channels to separate *.wav files. – check as many channels as desired. The postfix can be edited if a different channel indicator is preferred.

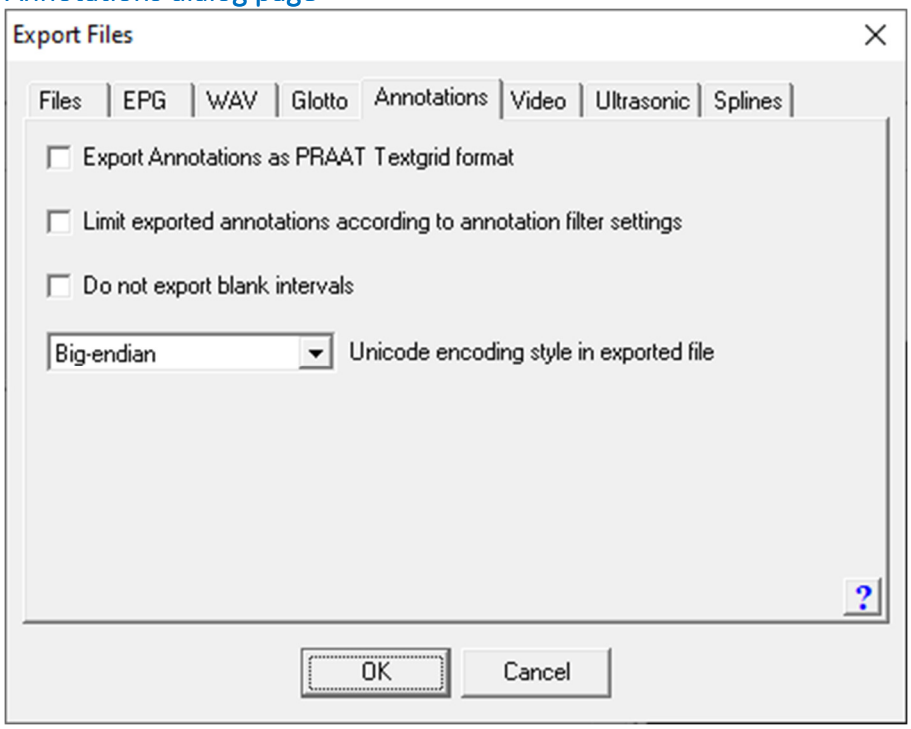
The dialog does not permit selected channels to be combined in a single wav file.

Glotto dialog page



Dialog for exporting data from a prototype ElectroPhotoGlottoGraph (ePGG). This product is unique in measuring the slow glottal opening and closing gesture as well as fast vocal fold action. This device is not yet in production.

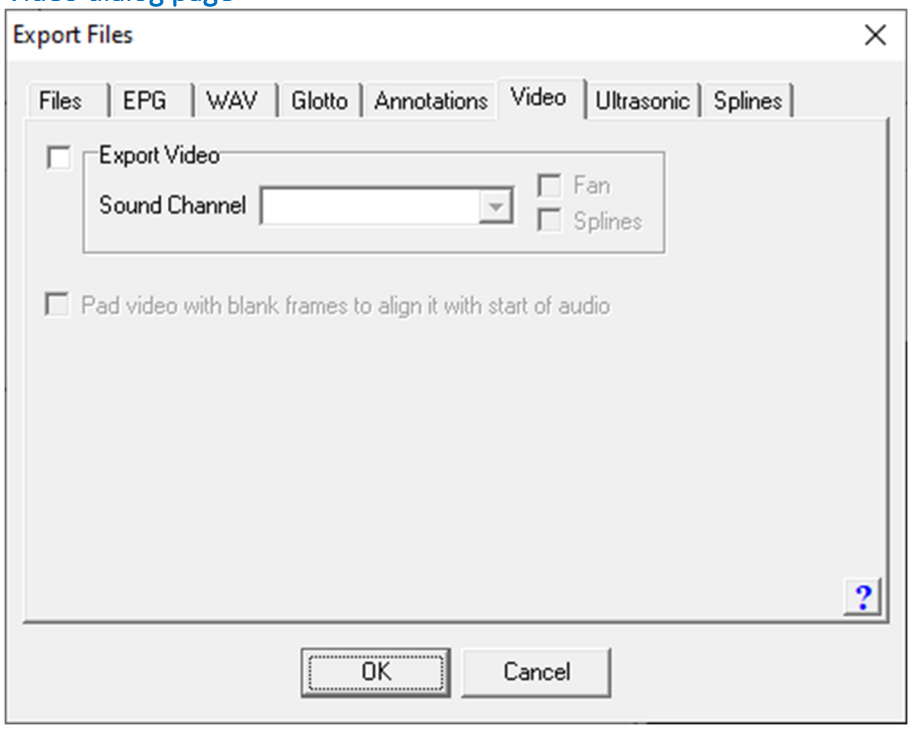
Annotations dialog page



The annotations dialog exports PRAAT textgrid files. After exporting they can be loaded into PRAAT (along with a wav file exported using the WAV dialog page) or they can be imported into a copy of the same project being worked on by a collaborator.

- **Export Annotations as PRAAT textgrid format**. – If not checked then annotations are exported in a legacy AAA format with file extension *.ann. This is less versatile and is not recommended.
- **Limit exported annotations according to annotation filter settings.** – If unchecked then all annotations associated with a recording are exported. If checked then the dialog obeys the current filter dialogue settings and exports only the annotations determined by those settings.
- **Do not export blank intervals.** – PRAAT segment tiers assign unlabelled temporal regions a segment with no label. AAA in contrast allows temporal regions to have no annotation. If the intended use of the exported textgrid is to import into a copy of the same project then check this box to avoid lots of annotations with no label.
- **Unicode encoding style in exported file –** Unicode is encoded in two bytes. The expected order of those bytes may depend on the computer operating system. The default for Windows is big-endian.

Video dialog page

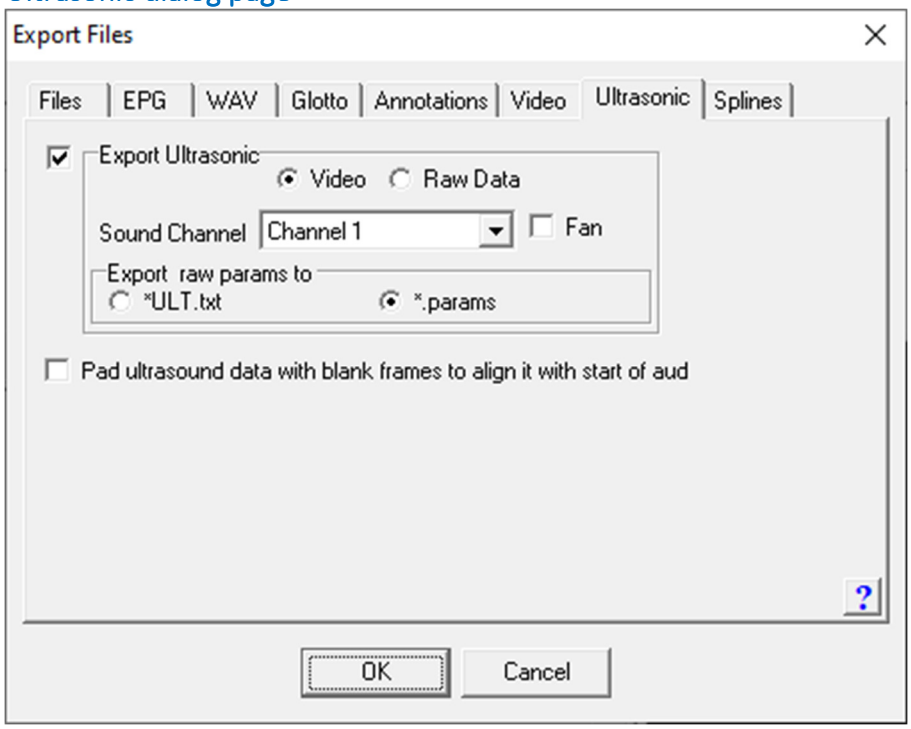


The Video dialog exports the video stream in AAA as *.avi. When exporting video sub-dialogs will pop up allowing the video resolution to be specified and the codec to be specified. These options appear once. Thereafter, for all the recordings selected for export, the videos will be created using those selected options. See **Make Movie** for more details on exporting videos and limitations in setting output resolution.

Dialog options include:

- **Sound channel** <Allows a single audio channel to be added to the image sequence when creating the video> Typical value = the audio channel recording the speech signal.
- **Fan** <If fan splines have been applied to the recording then the associated fan grid can be superimposed on the image> Typical value = unchecked.
- **Splines** < Superimposes any visible splines onto the exported video> Typical value = unchecked
- **Pad ultrasound data with blank frames to align it with the start of audio** < This option is essential to offset the ultrasound images from the start of the audio using the alignment determined by the synchronisation process applied within AAA. If not checked, the image sequence will start at the same time as the audio.> Typical value = checked.

Ultrasonic dialog page



Ultrasonic data is not video data. It is recorded and stored within AAA as 2D matrix of scanline vectors each with a number elements which correspond the time at which the ultrasound echo was received. The value of each element 0-256 represents the strength of the echo for each time element. Associated parametric data specifying the depth setting, the number of scanlines, the number of elements, the radius of the convex probe and the angle between each scanline is also recorded and stored. With this information it is possible to construct an image based on the raw scanline matrix.

Raw data

The ultrasonic dialog page offers the option of exporting the **raw data** matrix along with the associated parameters **(*.param**) that allow the data to be reconstructed as an image. This form of ultrasound data is often preferred by engineers for machine learning as it is more compact and does not include the interpolated data values that are added when generating an image. The *.param file contains the following information:

- NumVectors <number of scanlines. This will vary if the field of view setting is reduced from 100%> Typical value for 100% field of view = 64
- PixPerVector <number of elements (aka pixels or time points) in each scanline.> Typical value = 946
- ZeroOffset < distance from the origin of the convex probe to the first scanline element measured in number of elements> Typical value for 210.
- BitsPerPixel < number of bits assigned to each element to specify the echo strength (pixel brightness.> Typical value = 8 (0-255 brightness levels)
- Angle (angle measured in radians between each scanline used to reconstruct an image.>Typical value = 0.028

- Kind < Specifies if the data was recorded by an Ultrasonix (0) ultrasound system or a Telemed (1) system.> Typical value = 1
- PixelsPerMm < Scaling defines how many scanline elements correspond to one millimetre.> Typical value = 10.511.
- FramesPerSec < frame rate > Typical value = 81.543
- TimeInSecsOfFirstFrame < Offset in seconds of the time of the first ultrasound frame from the start of the audio recording> Typical value = 1.00327.

The *ULT.txt option includes the same information as the *.param option but in an earlier proprietary format. The param file format is the most widely accepted format and should be used.

When exporting in raw ultrasonic format, the audio channel, fan checkbox and Pad ultrasound data with blank frames are ignored. The exported files are:

- *.ULT <raw ultrasound data in binary format>
- *.param <parameters as described above>
- *.txt < text file with client, date/time of recording and recording prompt, together specifying the recording from which the data was exported.

Video

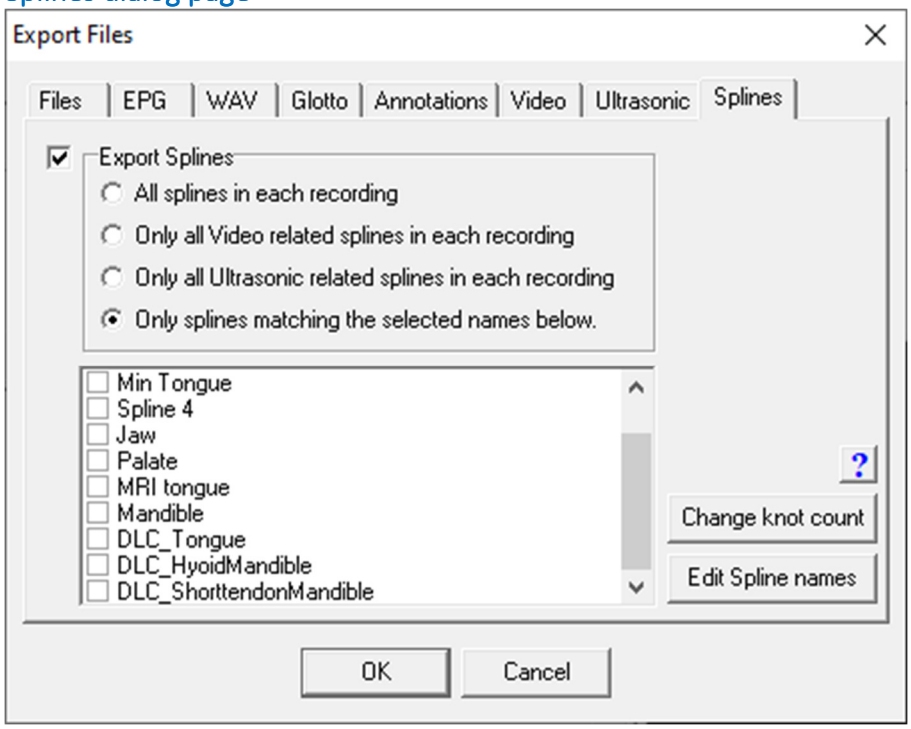
Users may wish to analyse ultrasonic data in other software that expects ultrasound in a video format. The **Video** option allows, if necessary, all the ultrasonic recordings in one project to be exported as video with a single click. This opteration takes longer that exporting the raw data as each frame needs to be converted into an image. Options include:

- **Sound channel** <Allows a single audio channel to be added to the image sequence when creating the video> Typical value = the audio channel recording the speech signal.
- **Fan** <If fan splines have been applied to the recording then the associated fan grid can be superimposed on the image> Typical value = unchecked.
- **Pad ultrasound data with blank frames to align it with the start of audio** < This option is essential to offset the ultrasound images from the start of the audio using the alignment determined by the synchronisation process applied within AAA. If not checked, the image sequence will start at the same time as the audio.> Typical value = checked.

See Export data if only labelled sections of files are required.

If more than one audio channel is required, use the WAV tab to export more audio channels as wav files.

Splines dialog page



The Splines dialog is not intended to export splines as Euclidean or Polar co-ordinates. See Export Data and **Spline Workspace** for means to do that. The Splines dialog exports tongue contours in a proprietary text format intended to permit, if necessary, for the spline to be imported back into AAA. This is useful if two people are working on separate copies of the same project and one wants to have the splines without compromising other work that they have done, such as labelling. The format is as follows:

2DSplineKeyframes <Type of Spline which may be Fan Spline or 2D spline>
ssUltrasonic <type of data steam that the splines were derived from and should be imported back into, which may be ultrasonic or video>
100327
Spline2D
DLC_Tongue <Spline name>
<text end>
Rulerp1x <scaling ruler consisting of a start point (RulerP1) and an endpoint (RulerP2)
0.500 <co-ordinates defined by
Rulerp1y
0.000
Rulerp2x
0.500
Rulerp2y
0.647
Rulerlen <length of ruler in mm>
109.979
Color <colour of the spline>

193
LineStyle <Linestyle (solid, dotted dashed etc) used to draw the spline in AAA>
0
LineWidth <width of the line used to draw the spline in AAA>
3
Points
11 <Number of spline control points.>
0.36884880 < x-co-ordinate of 1st control point (aka knot)>
0.21795702<y co-ordinate of 1st control point (aka knot)
100 <confidence on scale of 0-100 that the point is accurately estimated>
0.38196936 <2nd control point>
0.29921082
100
0.40625018 <3rd control point>
0.37896824
100
0.44555146 <etc>
0.45498317
100
0.50085509
0.52352208
100
0.58252007
0.53801638
100
0.66429871
0.49736014
100
0.69371825
0.47163340
100
0.72137231
0.44719329
100
0.75626290
0.43669757
100
0.78702390 <11th control point>
0.41837409
100

Dialog options allow for selection of splines according to various criteria.
There are also options to:

- **Change the knot count** <increase or decrease the number of control points using interpolation. This option has no obvious advantage> Typical (recommended) value = leave unchanged.
- **Edit Spline names** < This actually allows new spline names to be added to a list of spline names. It does not allow existing spline names to be changed. If the list of

splines shown in the dialog does not contain spline names you expect to see then edit spline names allows you to refresh that list. See elsewhere in the user guide for a fuller description of Spline Name list> Typical value = Leave unused.

Examples of how to use Export Files

Exporting Wav files for annotation in PRAAT and re-importing those annotations.

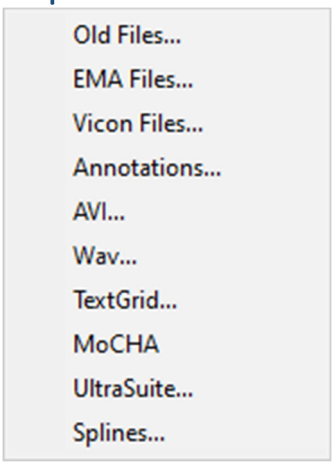
1. In the files dialog, select the recordings to be annotated in PRAAT
2. In the wav dialog export the audio. All audio channels can be exported in one file but it does mean that during playback a buzz will be heard if there is a sync signal on channel 2. Alternatively export the channel with the speech audio only.
3. If the recordings already have annotations in AAA these can be exported using the annotations dialog if the intention is to modify them.
4. Create and save a textgrid file in PRAAT. The textgrid MUST have the same stem as the *.txt file that was exported by default with the wav file from AAA and must be saved to the same folder as the *.txt file.
5. Use the Import | textgrid dialog to import the textgrid back into AAA.

Exporting Ultrasonic data as video or raw format for processing in other software.

This is covered in the section above on the Ultrasonic dialog.

Prompts Recordings Window

Import files



Old files
EMA files
Vicon files
Annotations
AVI
Textgrid
MoCHA
Ultrasuite
Splines

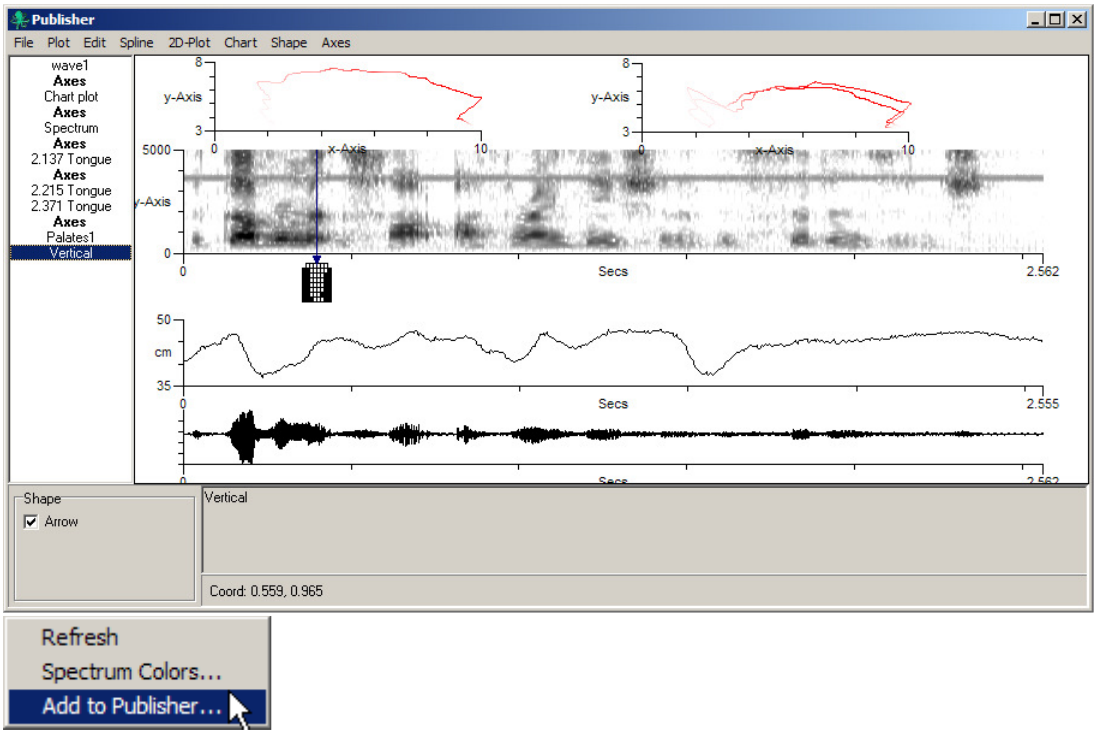
Publisher

Create publishable quality diagrams from AAA data.

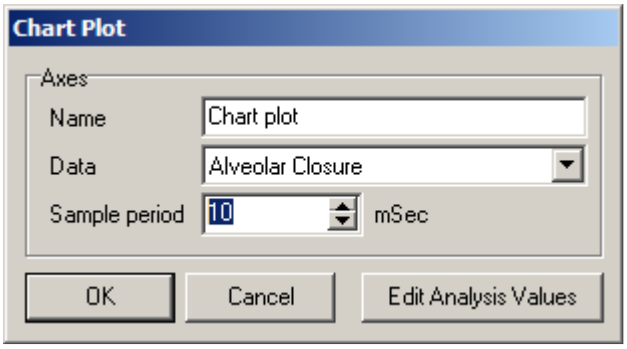
Although it is possible to capture bitmaps from the screen the quality is not adequate for Journal publication. The Publisher facility within AAA allows high resolution (e.g.600DPI) images to be created. With the ultrasound module comes the ability to export 2D spline contours to the publisher. Using the Publisher image importing function in combination with the Video Display window “Copy Bitmap” function, ultrasound video frames can also be incorporated.

AAA provides a versatile function in order to create combinations of charts and plots suitable for publication. It is however currently rather time consuming to create images with multiple charts and scheduled for improvement.

To publish a time-based chart such as a waveform, a spectrogram, EPG sequence or an analysis value, right click in the appropriate window and select “**Add to Publisher…”**.



Charts of analysis values



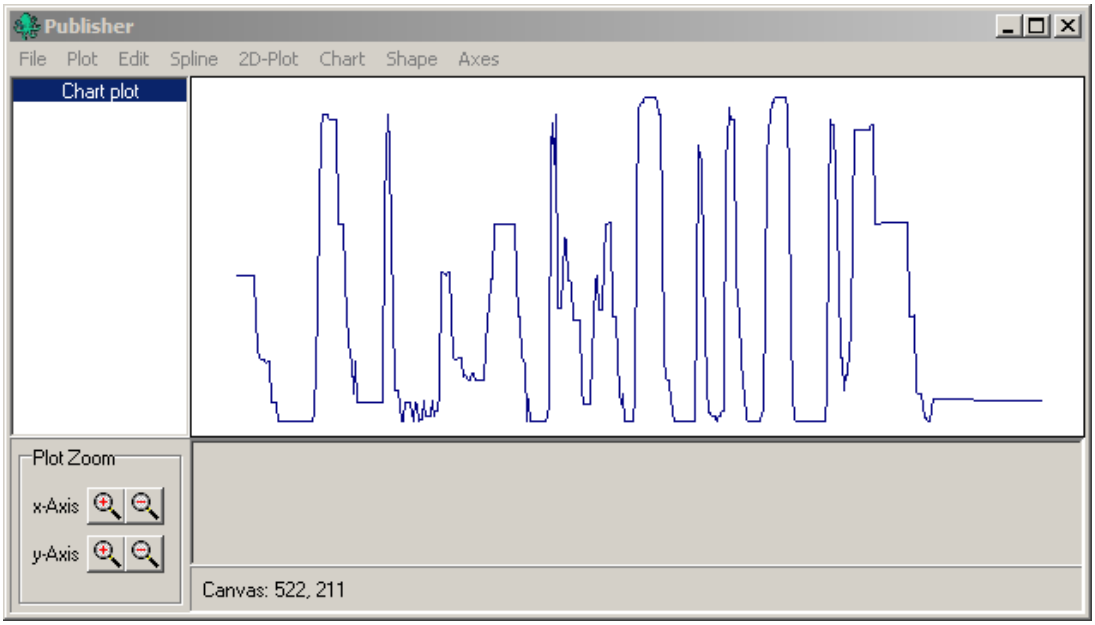
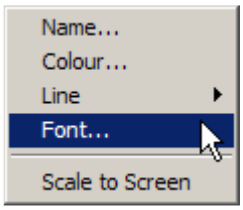


Figure 1 Adding a Chart to Publisher

Then, select the **Axes** menu option and **Create Axis**. Then hold down the ctrl key and click on the axis and the chart in the lefthand plot list so that they are both highlighted, select the **Axes** menu again and this time select "**Tie Plots to Axes**". The choices are tie to one of the axes or both. The process of tying links the scale on a given axis to the data so when you change the range on the axis the plot will expand or contract to correspond with the chosen scale. If the axes are not tied then values can be changed independently of the axis. For example, it may not be desireable to have the waveform y-axis tied as it will range from +32768 to –32768.

Axes may be named and max and min values changed. The size and type of font used for the axes can be changed by selecting" **Font…"** from the "**Plot"** menu.



To move the plot around the screen use the shift key in conjunction with the mouse. The cursor will change to a  symbol

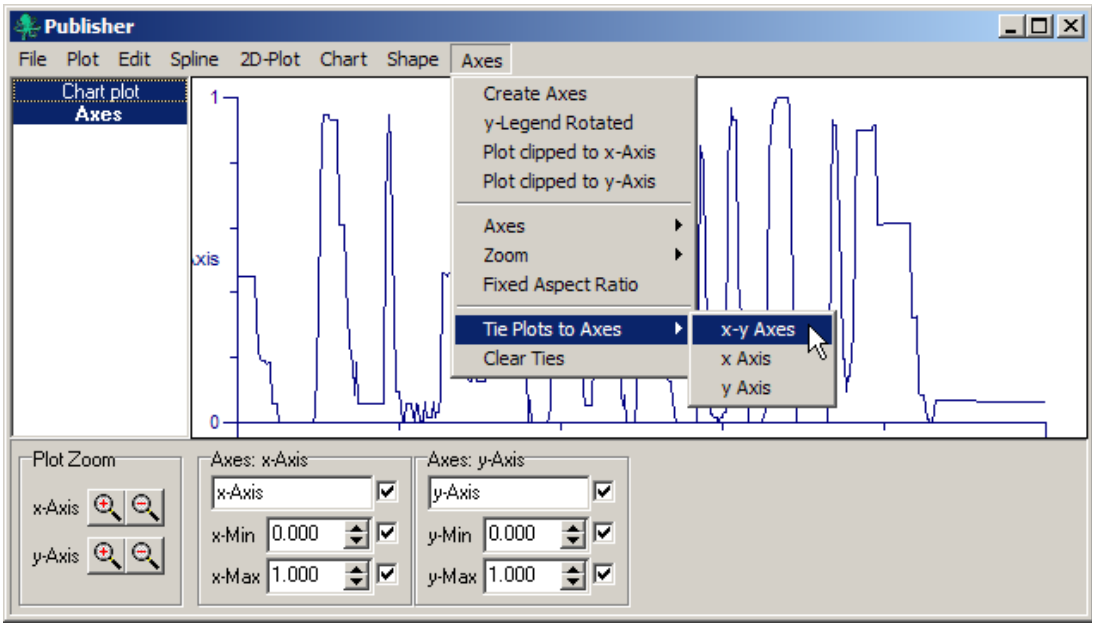


Figure 2 Tying the Axes

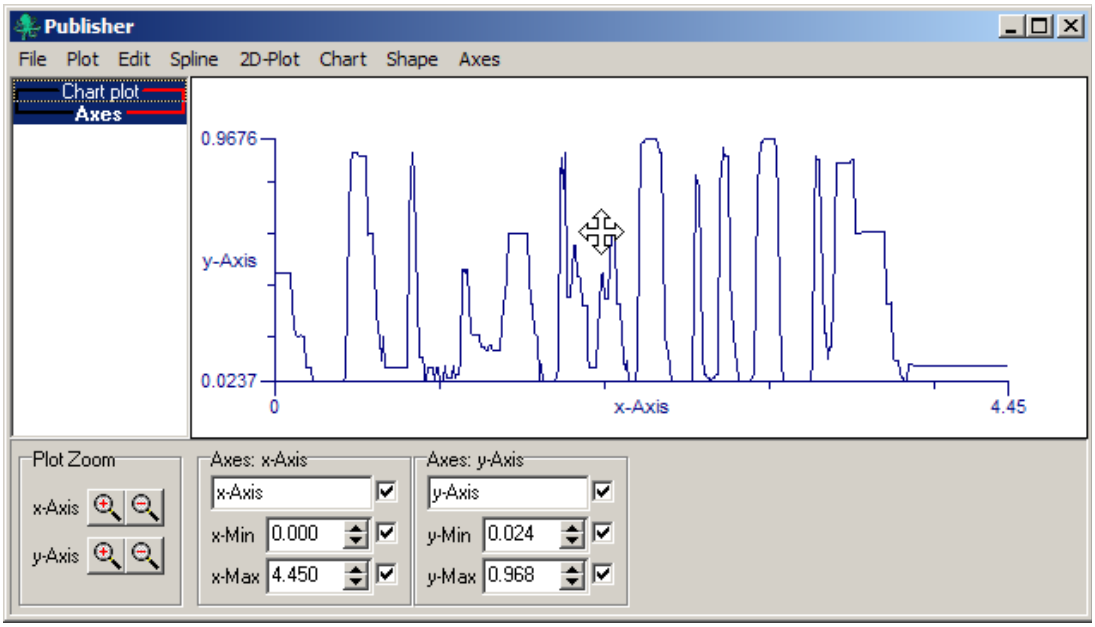


Figure 3 Chart with Tied Axes

It is possible to clip the data so that it does not extend beyond the axes. This is useful if you wish to show only part of the range of a spectrogram or a shorter period of time.

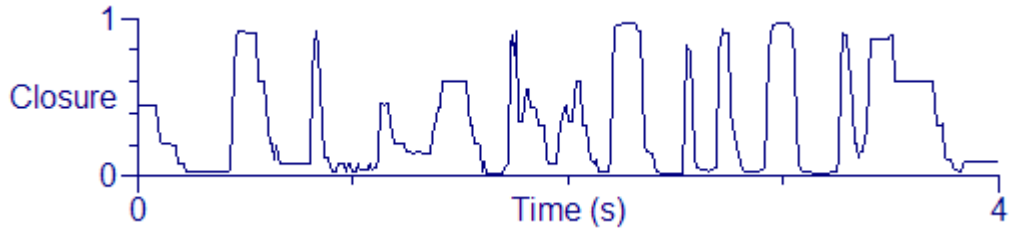


Figure 4 Plot with larger font, clipped to 4 seconds

Waveform

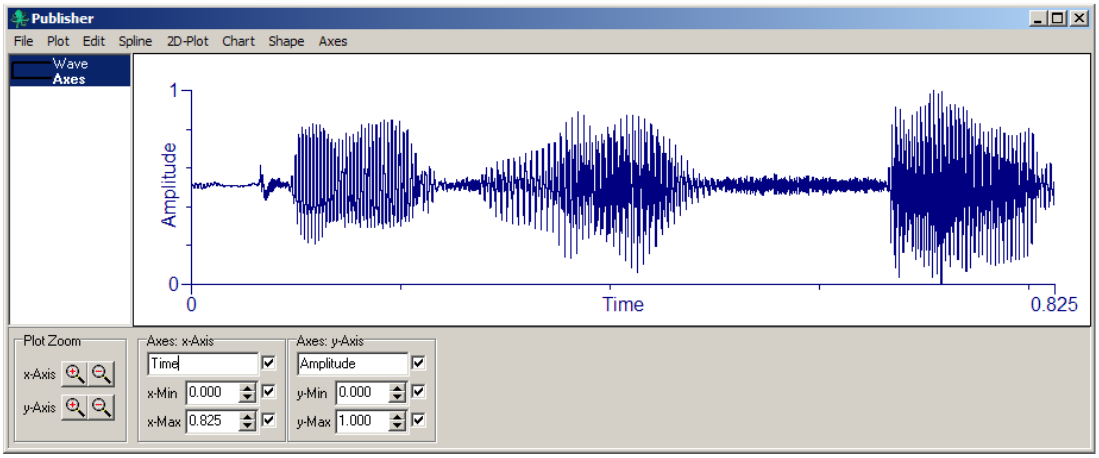


Figure 5 Waveform plot

Spectrogram

A spectrogram can be created in the same way. Note that there is also an option to change the greyscale levels.

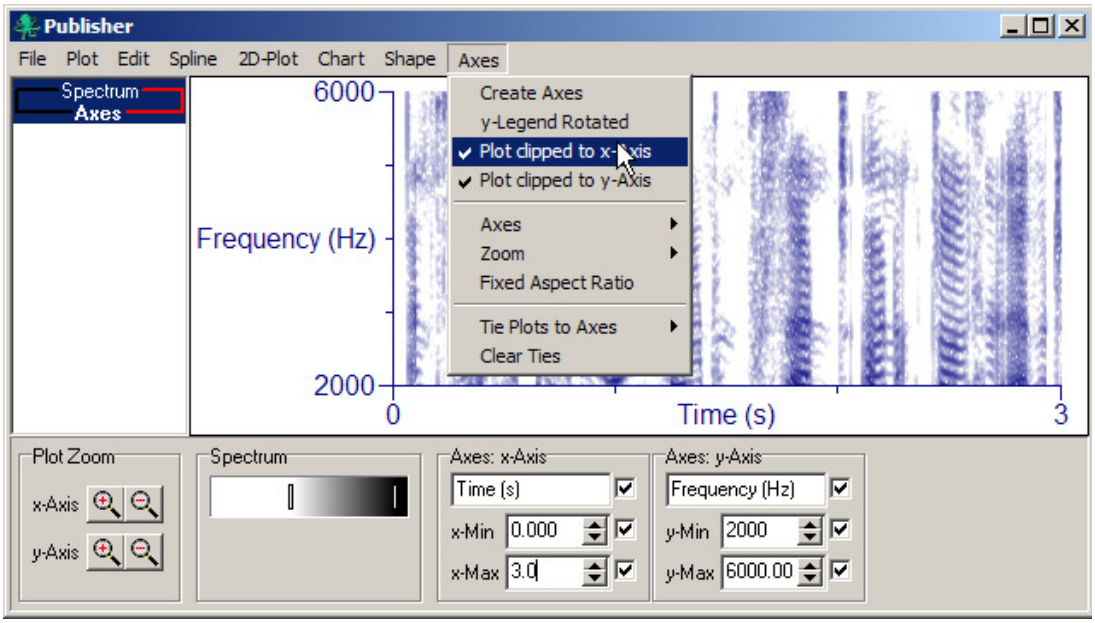


Figure 6 Spectrogram with frequency clipped between 2kHz and 6kHz

EPG sequences

As well as the Copy Palates function, it is possible to publish EPG sequences in the publisher.

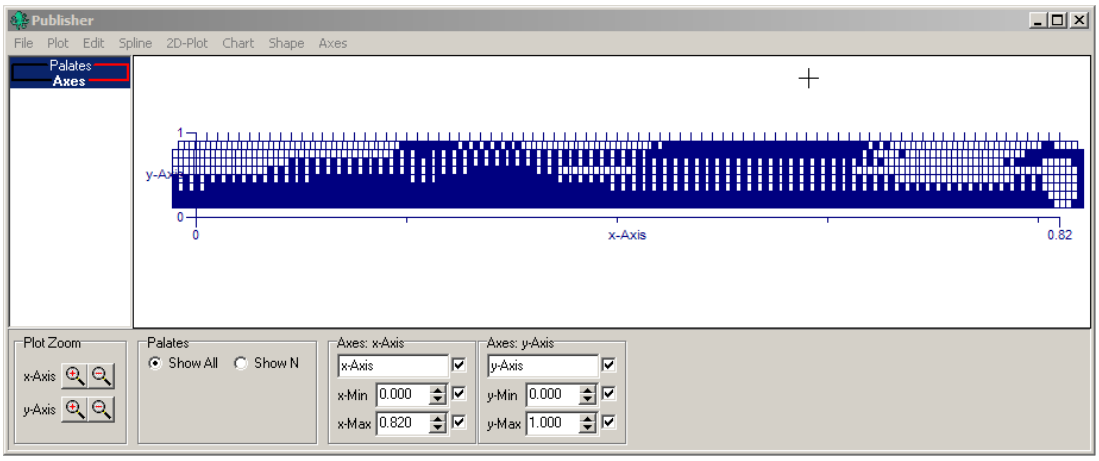


Figure 7 EPG sequence with tied axis (too many to view)

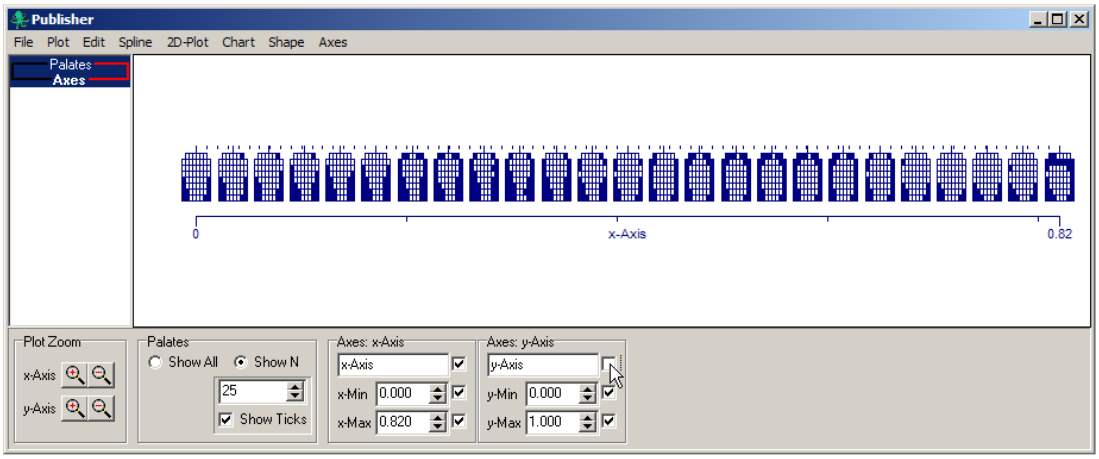


Figure 8 EPG sequence showing 25 out of 80 palates (tick marks above show timings of all 80 palates)

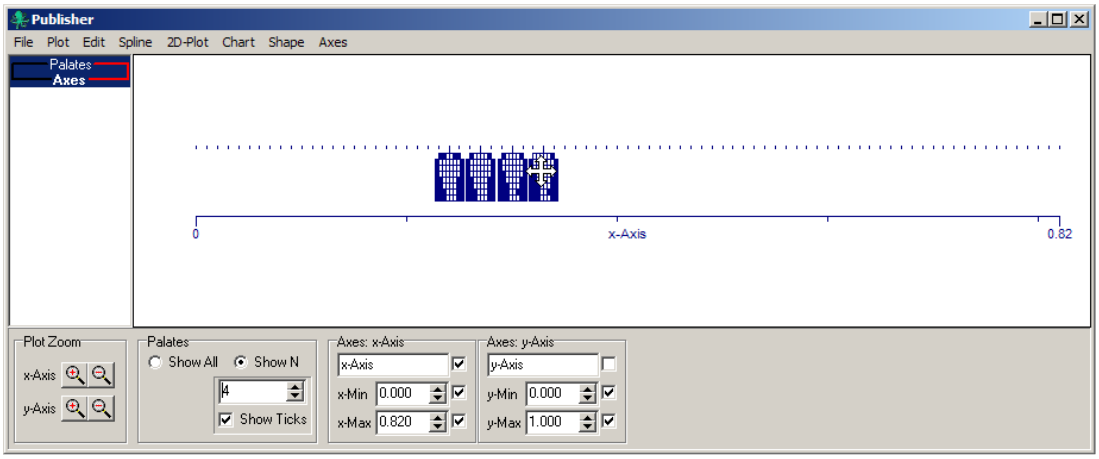


Figure 9 Click and drag a palate and the pattern changes to match the data at any time point

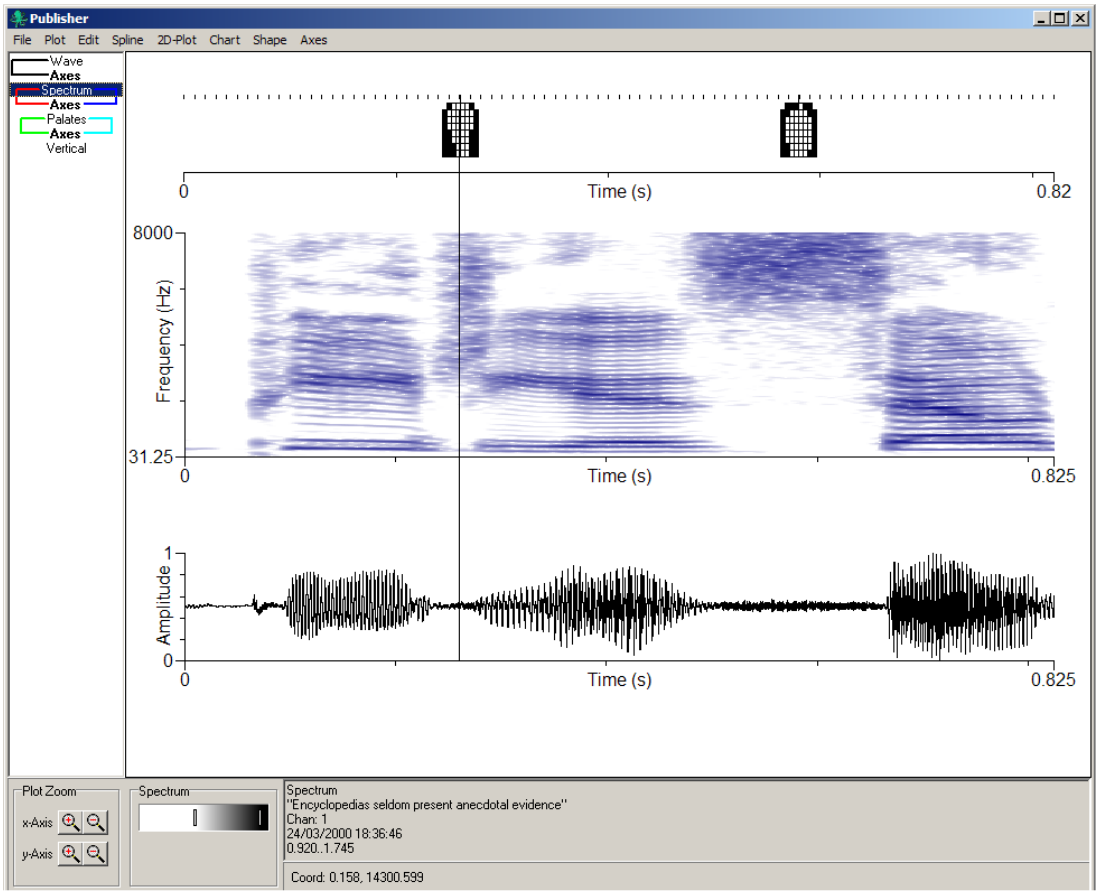
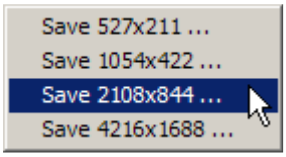


Figure 10 Combined plots including extra graphics such as text, lines, arrows, boxes, etc.

To publish the plot it is possible to copy to the clipboard (**Edit | Copy** menu) or to save as a bitmap file (**File | Save Bitmap…** Menu). Note that the clipboard may have a size limit that prevents the higher resolution images from being stored. If this is the case then use the Save Bitmap option. The size and shape of the plot depends on the size and shape of the publisher window. However, the resolution can be improved by up to a factor of 8.

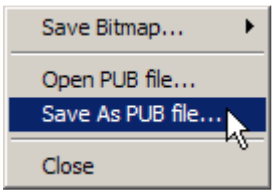


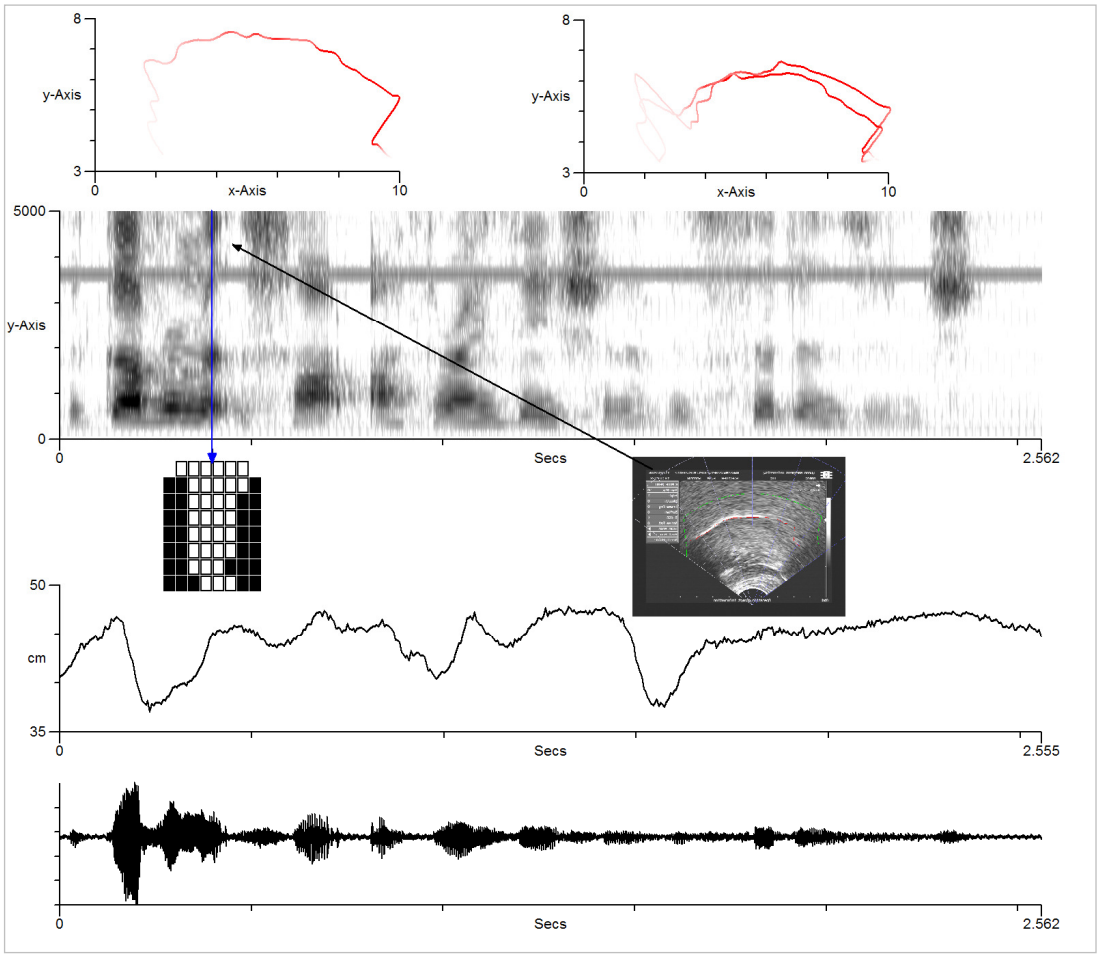
Publisher stores and manipulates copies of the data, not just the images

so when higher resolutions are selected the whole plot is redrawn to that resolution before being output.

The contents of publisher are retained while AAA is running but are lost when the application is closed. In order to save a plot that may have taken some time to create, it is

possible to save the plot in a *.pub file using the "**File | Save As PUB File…**" menu.





Spline workspace

Print palates

Fitting Fan splines (Custom Fit parameters)

The fit splines tab (Figure 16) provides parameters to modify the behaviour of the Edge detector for the "Custiom Fit" button.

Important: Changes to “smooth within keyframe” now affect the performance of snap-to-fit, best fit and track. If the tracking is too high try lowering this value. A value in the range 4-25 is typical.

The edge detector automatically fits splines to the tongue surface contour for a single frame or indeed multiple frames within a recording. Details of the algorithm can be found in Appendix A.

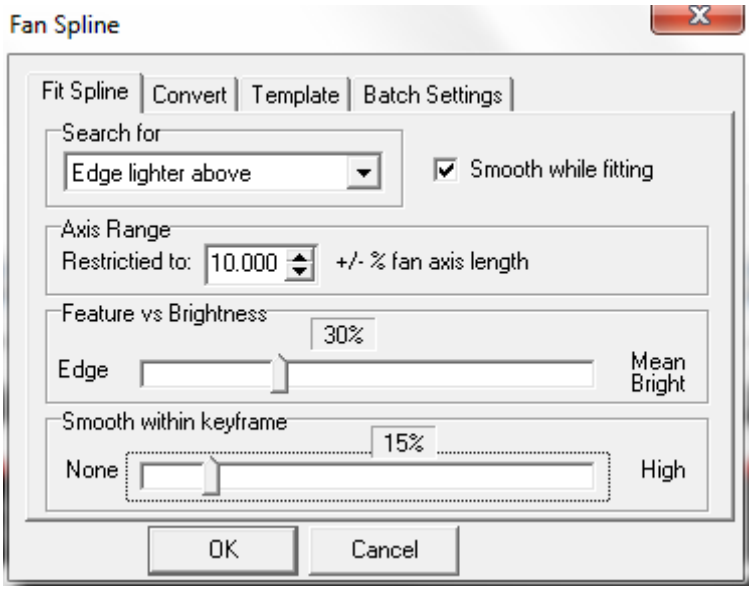


FIGURE 16 EDIT SPLINES DIALOGUE - FIT SPLINE

Search for – should usually be set to “Edge lighter above”

Axis range +/- % grid axis length – determines the maximum search distance away from the current tongue spline position expressed as a proportion of the fan grid axis length. Note that the search limit cannot be greater than the upper (roof) and lower (Min tongue) limits but this imposes a further constraint. If a small value is chosen then the spline will not move from the current position but the confidence values will be updated. See Snap–to-fit below.

Feature vs brightness – tells the algorithm to pay attention to the contrast of the light to dark edge regardless of the overall brightness (0%) or Overall brightness regardless of how good an edge there is (100%) A value of 30% usually gives good results but it can be adjusted if necessary.

calculation (see Appendix A for further clarification)

Smooth within keyframe – determines the penalty for consecutive axis crossing points (edge values) being at different radial distances. This is a crude smoothing function which will be improved in future versions. A typical value would be 75% but if the tongue contour jumps to bright spots away from the true contour it should be set higher. Conversely, if the tongue contour drifts away from the image keeping a similar radial distance it is set too high.

Smooth while fitting – check this to activate the within keyframe smoothing – recommended

In the keyframes tab there are several preset spline-fitting options

Snap-to-fit NumSearchLines:=2 EdgeVsBright:=0.30

Increment:=0.001;

WindowSize:=10

SmoothWithinKeyframe:= slider value

Smooth while fitting:=true

+/- Grid axis length:=2.0 %

Confidence:= as set in Edit Splines and under Fit Spline tab

Fast fit NumSearchLines:=2

EdgeVsBright:=0.30

Increment:=0.005

WindowSize:=10

Smooth Within Keyframe:= slider value

Smooth while fitting:=true

+/- Grid axis length:=50.0 %

Confidence:= as set in Edit Splines and under Fit Spline tab

Best Fit NumSearchLines:=3

EdgeVsBright:=0.30

Increment:=0.002

WindowSize:=10

SmoothWithinKeyframe:= slider value

Smoothwhilefitting:=true

+/- Grid axis length:=30.0 %

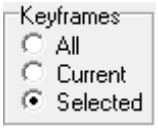
Confidence:= as set in Edit Splines and under Fit Spline tab

Custom Fit Uses the values set in the Fit Spline tab

Track Applies snap-to-fit but uses the spline from frame n-1 as the starting point except for the first frame when the current spline is used. For this to work well, the first frame should be fitted to the image, then this frame plus following frames can be tracked.

Track Back Same as "Track" but works back from the last selected frame.

Stop Halts the automatic fitting while in progress. Use this if you see that tracking is inaccurate.



All – will run the fitting process on all keyframes in the current recording.

Current - will run it on the closest keyframe to the waveform cursor.

Selected - will run it on all the keyframes selected by clicking and dragging in the waveform display

Fitting 2D splines

2D splines have a different method of spline fitting. A snakes algorithm is implemented. This adjusts the position of the knots to fit the spline to a nearby boundary. Unlike the fan splines algorithm which searches the whole image space and then provides the best answer, the snakes algorithm is iterative nudging the knots a small distance on each iteration. It may find a suboptimal solution, particularly if it is allowed to run for a large number of iterations.

Click the Attract (Snakes) button for a single iteration or hold it down to keep iterating. **Best results seem to be achieved with one or two clicks**. If the spline seems to be moving away from the edge that it is supposed to model, it may be that the algorithm is looking for a dark-light boundary instead of a light-dark boundary. There are two ways to resolve this. One is to draw the 2D spline in the opposite direction (i.e. if it was drawn from left to right, try drawing it from right to left). Alternatively (if the drawing needs to be done in a particular direction) try changing the "Search for" option in the "Snake" tab of the 2D spline – Advanced dialogue (Figure 17) to search for "Left Edge" rather than "Right Edge".

To open the "2D Spline - Advanced" dialogue, click the Advanced button in the "Spline" tab of the Edit Splines dialogue

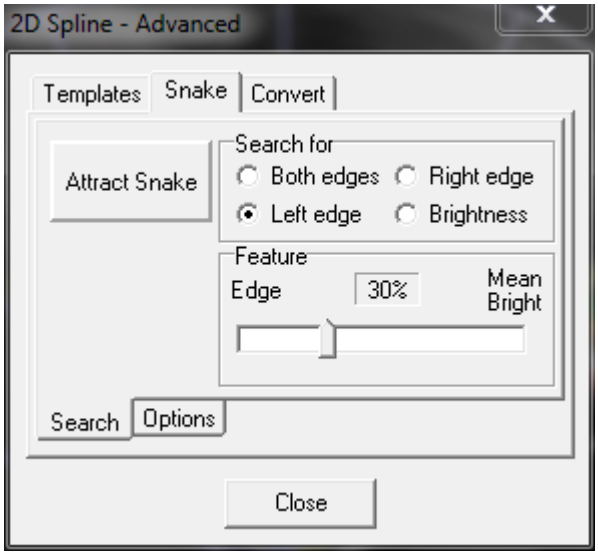


FIGURE 17 2D SPLINE ADVANCED DIALOGUE – SNAKE – SEARCH

Feature – determines the weighting given to whether the snake is attracted to the brightest feature or to regions with the biggest difference between light and dark. The default 30% mix is recommended.

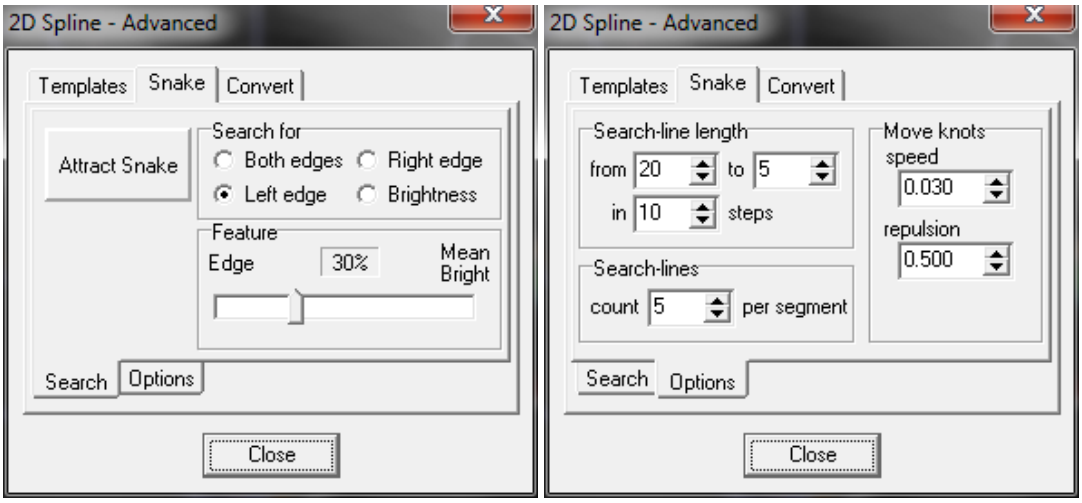


FIGURE 18 2DSPLINE ADVANCED DIALOGUE - SNAKE – OPTIONS

Search-line length – For each knot (and additional points on either side of every knot see "Search lines" below), the algorithm searches the underlying image in a direction perpendicular to the tangent of the curve. For each click of the "Attract" button the algorithm will carry out a set of iterations determined by the "steps" value. With reference to Figure 18, the "from" value determines that the algorithm will start by looking 20 pixels either side of the spline. For each successive iteration it will start looking from the new knot position, searching shorter distances until after 10 "steps" it will search only 5 pixels either side of the spline.

Search lines – The Snake algorithm doe not just extend search lines from the knots themselves. Points along the spline on either side of each knot have searchlines extended from them. These additional points are equally spaced between the knot in question and its neighbour. A value of 5 for example will extend search lines from an additional 5 points on each side of a given knot in order to estimate how far to move that knot.

Speed – Speed determines the percentage of distance towards the best edge that a knot is moved on each iteration. 3% (0.030) seems to be a reasonable value.

Repulsion – Repulsion determines how easily knots move along the spline towards each other. This can be tricky to balance.

For more information on the Snakes algorithm see **Appendix B**

Batch Fitting Fan splines

Use the batch processing tab to add a Tongue, Roof and Min Tongue spline to a set of recordings, create keyframes for the Tongue spline at every video or ultrasonic frame and

then fit the Tongue spline to the contour all with one click. Come back the next day to have all of your data splined.

Once you have recorded your video or ultrasonic data (and synced it if it is video data), the first step is to create a Fan Spline Template with a Tongue , Roof and Min Tongue spline. The roof and Min Tongue splines need to be carefully positioned to exclude as much of the image from the edge search without excluding the maximum and minimum extent of the tongue surface movement. In particular, the Min Tongue spline should try to exclude the floor of mouth region and leave room for an advanced root position in the /i/ vowel. The Roof spline should be just above the estimated position of the hard palate. See following section for more information on **Saving fan spline(s) as a template**.

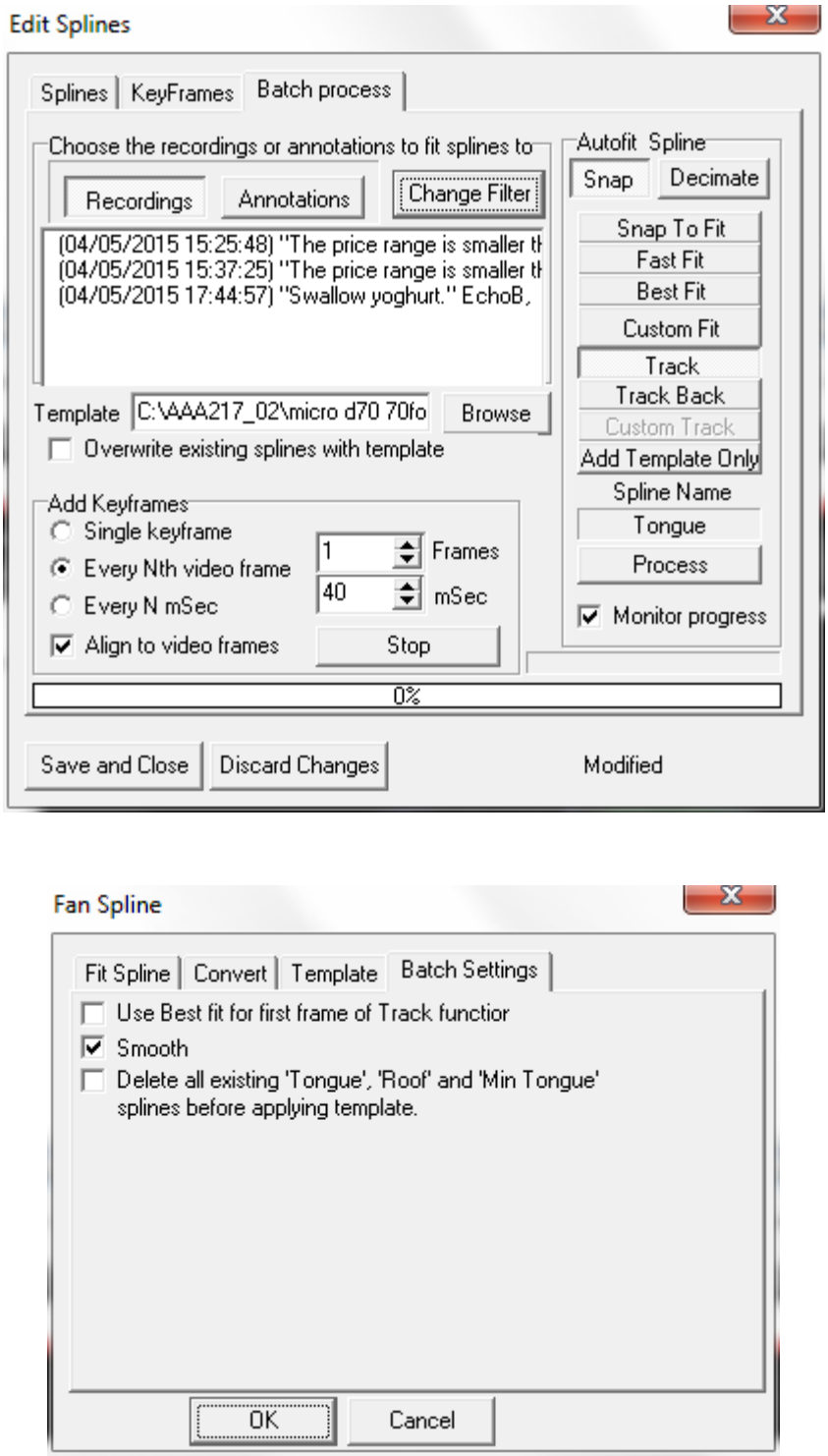


FIGURE 19 BATCH SPLINING A SET OF NEW RECORDINGS WITH RECOMMENDED DEFAULT ADVANCED OPTIONS.

1. Create a template by manually fitting Roof and Mon Tongue splines to define the upper and lower limits for automatic tracking of the Tongue spline. Set the tongue spline to an average shape for the data being tracked.

2. Once the optimum template has been created and saved, select the “Batch Process” tab in the Edit Splines dialogue and set the template name in the box provided.
3. Use the filter option to select a set of recordings or a set of annotated regions. Since this will run unsupervised in most cases it can be applied to every frame of recording in a session.
4. It is recommended to leave all the defaults as shown in Figure 19. The Track option works best. [tracking is a snap-to-fit based on the position of the spline in the previous frame].
5. If there is a valid template file (an *.fst file with a Tongue , Roof and Min Tongue spline) then the Batch process button should be enabled. Click to start the process. It will work through every file. Each recording can take a couple of minutes, so a whole session can take a few hours.
6. If there is a problem click the Stop button. The process will halt but everything created up to that point will be automatically saved.

Converting fan splines to 2D splines

It is possible to convert a fan spline to a 2D spline using the “Convert” tab in the dialogue.

To open the advanced dialogue, click the Advanced button in the “Spline” tab of the Edit Splines dialogue

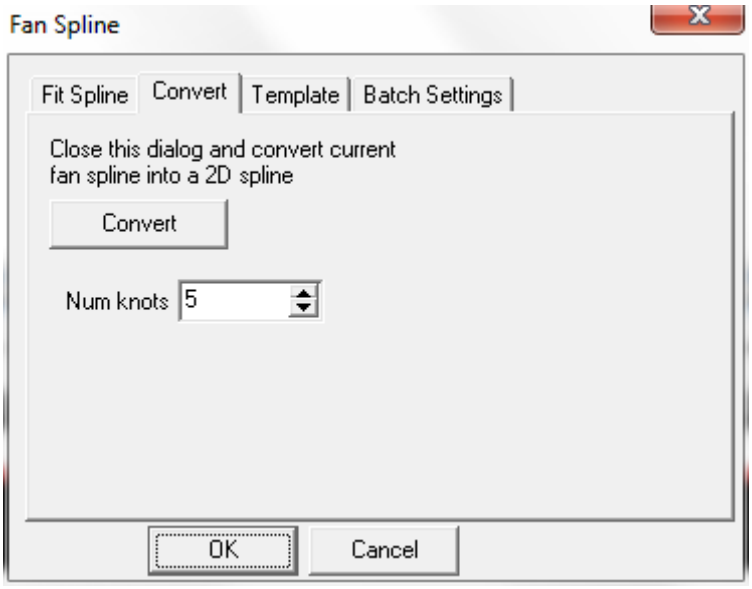


FIGURE 20 FAN SPLINE - ADVANCED : CONVERT TO 2D SPLINE

To convert, select a fan spline in the edit splines dialogue then use the convert dialogue (Figure 20) to convert it into a 2D spline with the specified number of knots. The 2D spline will match the shape of the fan spline as well as possible given the number of knots.

Converting 2D splines to fan splines

If a 2D spline is selected in the Edit Splines dialogue then a "Convert" tab is available in the Advanced dialogue, similar to that which is available for Fan Splines (see Figure 21). Select the appropriate fan setup then click the 

button to convert the 2D spline to a fan spline.

Note that parts of the 2D spline that lie outside the fan will be lost. If the 2D spline does not cross a given fan axis then a value will be made up with the same axis magnitude as the nearest axis that the 2D spline crosses and it will be given a confidence value of zero.

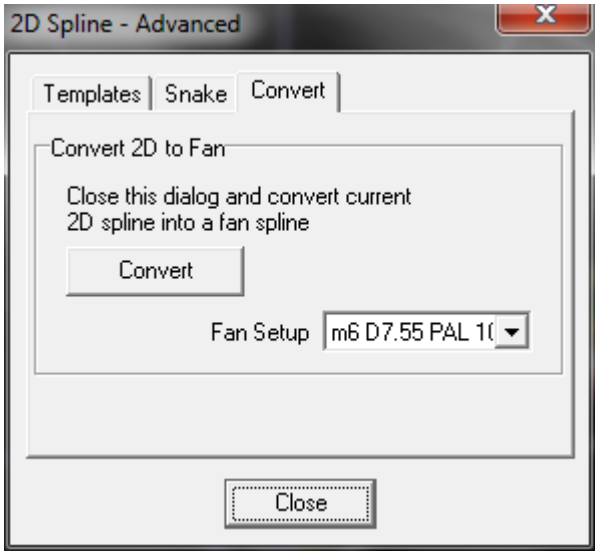


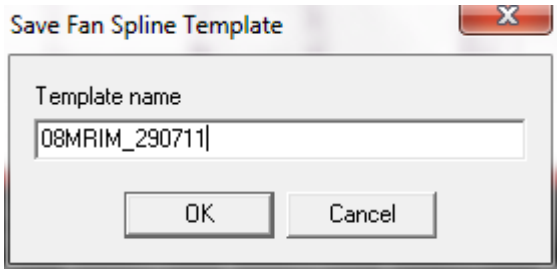
FIGURE 21 2D SPLINE - ADVANCED - CONVERT TO FAN SPLINE

Saving fan spline(s) as a template

Once the "Roof" and "Min Tongue" splines have been set for one recording in a session, it is possible to save three fan splines as a template so that this task does not need to be repeated for every recording. First, open the advanced dialogue by clicking the 

button in the "Keyframes" tab of the Edit Splines dialogue. Then select the "Template" tab. You may need to click the  buttons to see this tab. The dialogue is shown in Figure 22.

To Save all three fan splines as a template (recommended) click the second Save button. The following edit box will appear.



Give the template a name that relates to the speaker and session and possibly the project. Fan templates are stored in the application folder as *.fst files and are not tied to projects. This means that they are available for use across projects but if analysis is to be carried out on a different PC then it is necessary to copy these *.fst files to the application folder on the new PC as well as copying the project to be analysed.

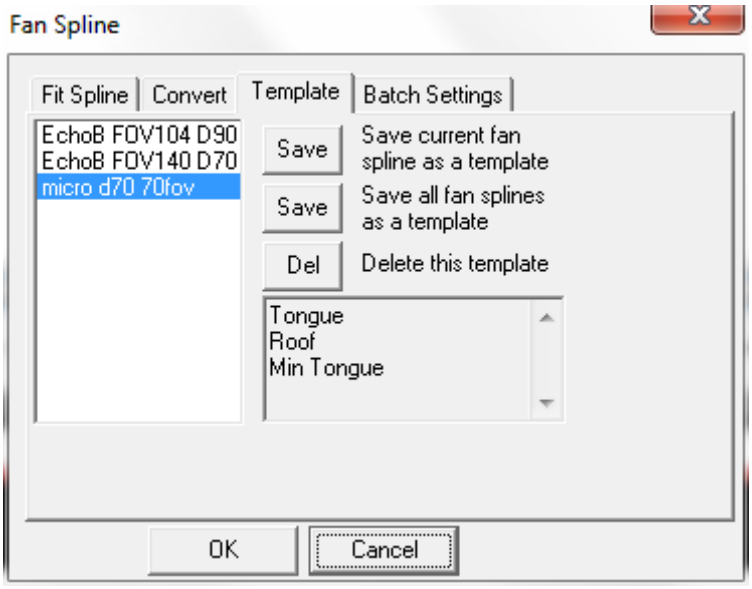
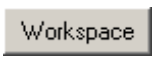


FIGURE 22 FAN SPLINE TEMPLATE DIALOGUE

Saving 2D spline(s) as a template

If a 2D spline is selected in the Edit Splines dialogue then a “Templates” tab is available in the Advanced dialogue, similar to that which is available for Fan Splines (see above). The only difference is that 2D spline templates are saved with the postfix *.2st.

Spline Workspace

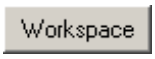
The spline workspace can be invoked by clicking the 

button in the spline or keyframe tabs of the Edit splines dialogue. It can also be invoked from the application “File” menu by clicking “Spline workspace…”.

The workspace is a depository for accumulating splines from different time points, different recordings or even different projects and superimposing them on top of one another. It is possible to create “average” fan splines (averaging is not implemented for 2D splines) and calculate distances between splines within the workspace. Splines can be rotated and translated in the workspace to compensate for frame to frame movement. Splines from different sources are scaled using the ruler from each source so that all splines in the workspace are at a uniform scale and can be compared

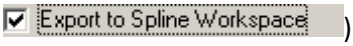
There are two ways to copy splines into the workspace.

Copy to Workspace Method one:

Use the 

button in the Edit Splines dialogue to copy all the currently highlighted keyframes in the current recording to the workspace.

Copy to Workspace Method two:

If you have annotated (labelled) segments throughout your dataset and fitted splines to this data then it is possible to use the “Data export…” (Page) dialogue to copy splines (

) from selected time points across your dataset in one go. See the Export Splines section for more details. For example, you may have labelled all the /l/ segments in your dataset and specified syllable position. It would then be possible for example to export all of the tongue splines from midpoint of /l/ segments in a syllable final position. It is then possible to create an average and compare that average to, say, the /l/ segments in syllable initial position. Or, instead of the midpoint, you could export the time point determined by an analysis value such as EPG contact pattern with the minimum tongue-palate area in the alveolar region.

Spline selection list – to the left of the Workspace dialogue. There is a list with one entry for each spline that has been added to the workspace. Click on one to highlight it in the display or click and drag to select more than one spline. The ➔ symbol will point to the last spline that is selected (see later section on moving splines)

Spline information – Every time a spline is added to the worksapce, information about the recording and timepoint it came from is gathered and held with it in the worksapce. This data is displayed on at the top right of the workspace dialogue.

Cursor Co-ordinates – When the mouse is moved over the workspace it changes it appearance to a cross (┼) . The position of this cross is diaplayed on the righthand side of the display as x-y values in centimetres.

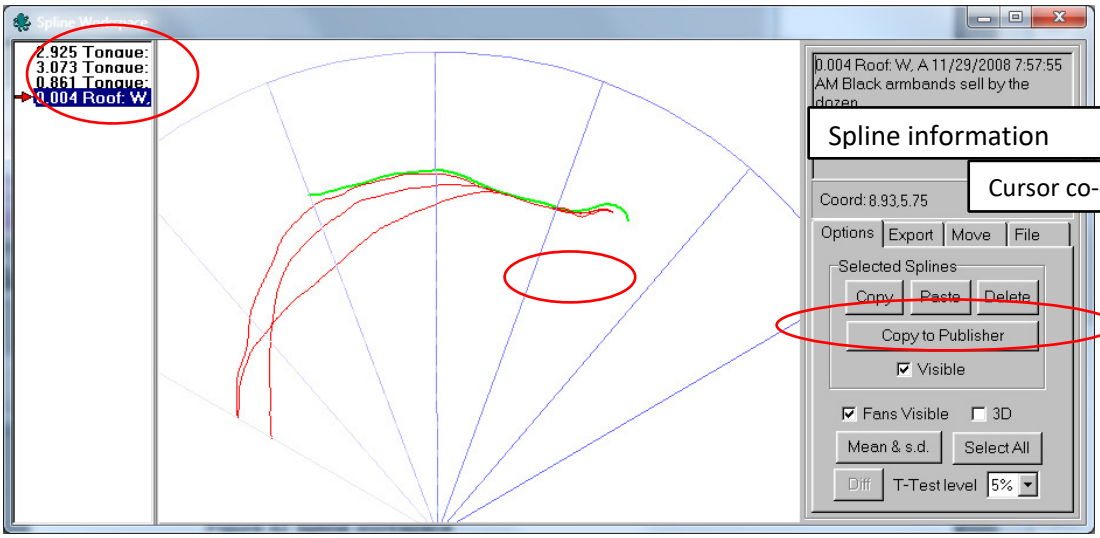


FIGURE 23 SPLINE WORKSPACE

There are three tabbed windows at the bottom right of the workspace dialogue controlling different aspect of the workspace.

Spline workspace Options tab

This control determines the following aspects:

Visible – makes the selectes splines in the workspace visible or hidden

Fan Visible – makes the fan associated with each spline visible or hidden (deactivated currently)

Copy –Copies a selected spline ready for it to be pasted into a recording or into the workspace as a duplicate

Paste – pastes a copied spline or set of splines into the workspace.

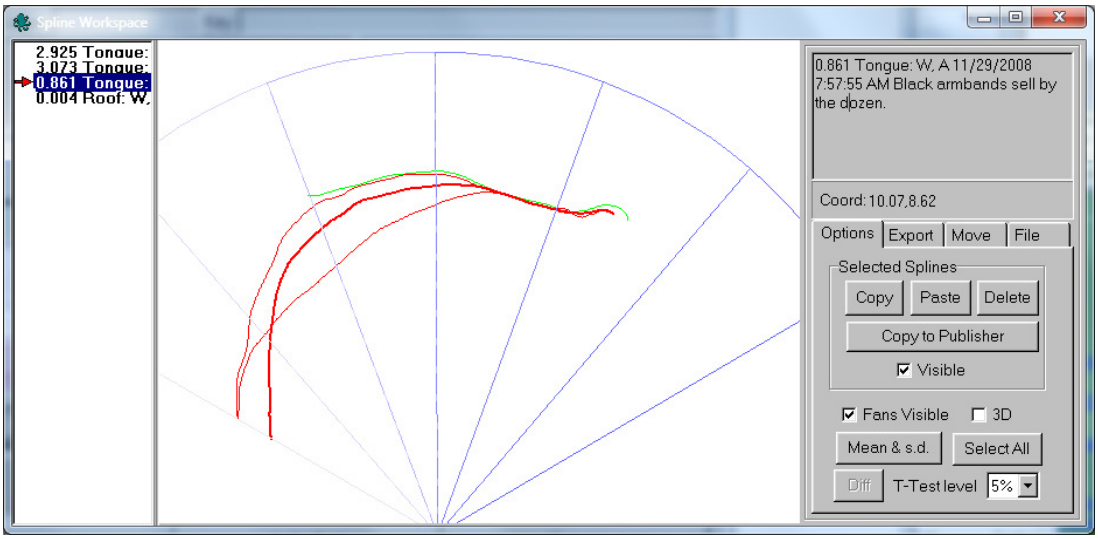


FIGURE 24 SPLINE WORKSPACE WITH LIST OPTION SELECTED PROVIDING A SELECTABLE LIST OF SPLINES ON THE RIGHT. MAKES SELECTING SETS OF SPLINES FOR MOVING OR DELETING EASIER.

Delete – Deletes the currently selected spline

> **Tip**: To delete all the splines and clear the workspace. Select the rightmost spline, click on delete, then hold the <return> key down.

Copy to publisher – copies all of the currently highlighted spllines to the publisher facility.

Fans Visible – quick way to hide all of the fans associated with each spline. (deactivated currently)

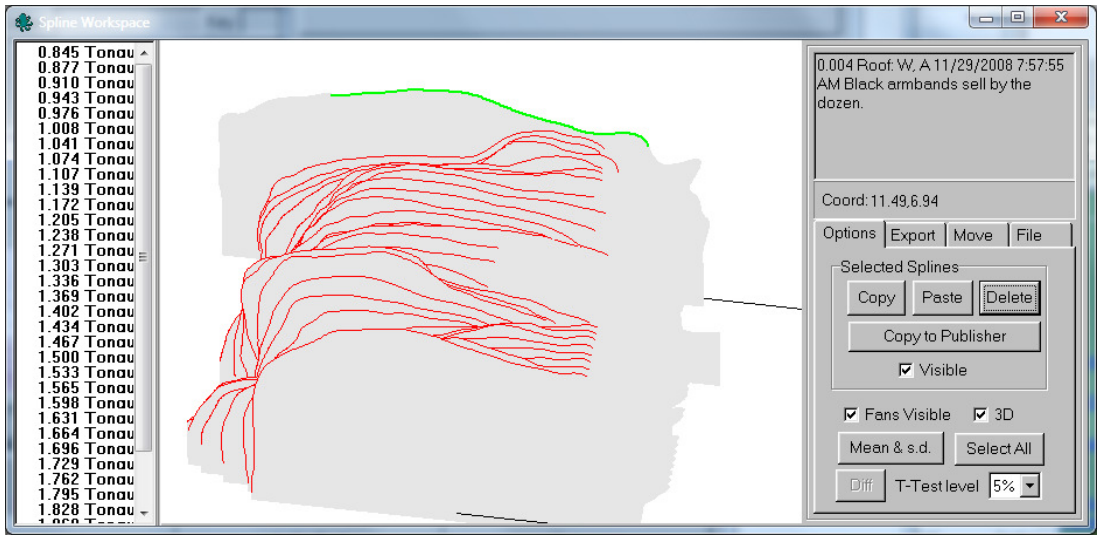


FIGURE 25 SPLINE WORKSPACE WITH 3D OPTION SELECTED SHOWING A CASCADED SEQUENCE OF SPLINES.

Calc Means & s.d. - This function creates a mean spline from the subset of splines that are selected in the workspace. A mean value is calculated for each of the 42 fan-lines. The 42 means are calculated independently and the mean tongue contour is drawn based on those 42 points. It is possible to do it this way because each spline is defined by points that lie on exactly the same 42 axes.

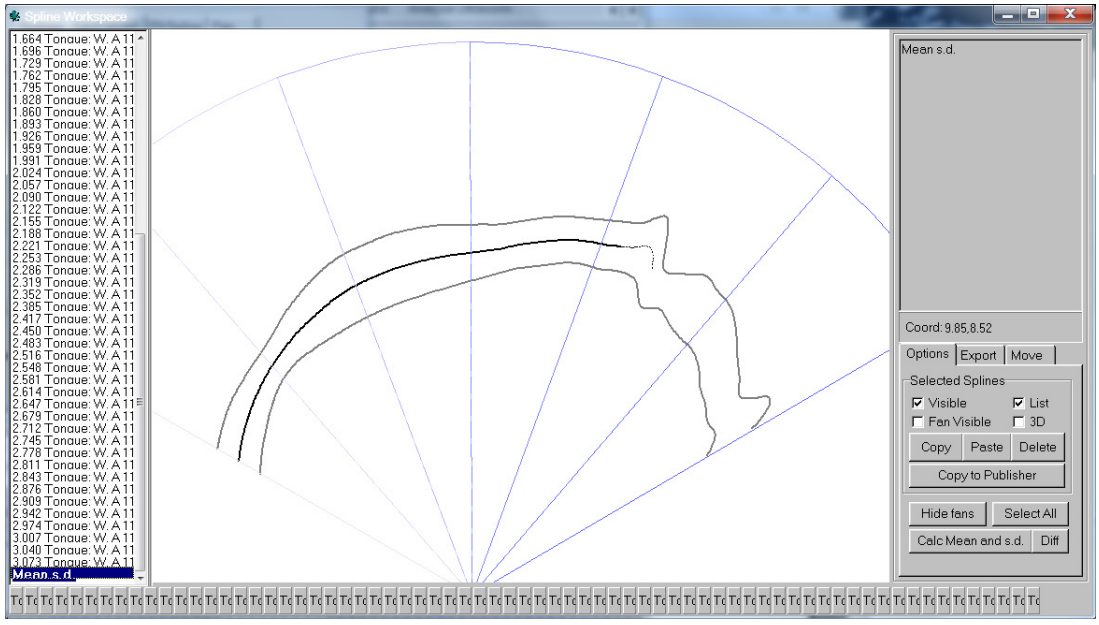


FIGURE 26 MEAN AND STANDARD DEVIATION OF A GROUP OF SPLINES.

Diff – Select two splines and click “Diff”. It's shown as a "zero" line with

spokes to the "difference" line.

If it's a difference between two Mean/SD splines then it calculates a T-test

for each spoke. At the moment, the software just draws a thicker spoke if the T-Test is significant at 2%. It uses a 2-tailed test assuming unequal variances and unequal sample sizes and uses the Welch-Satterthwaite equation.

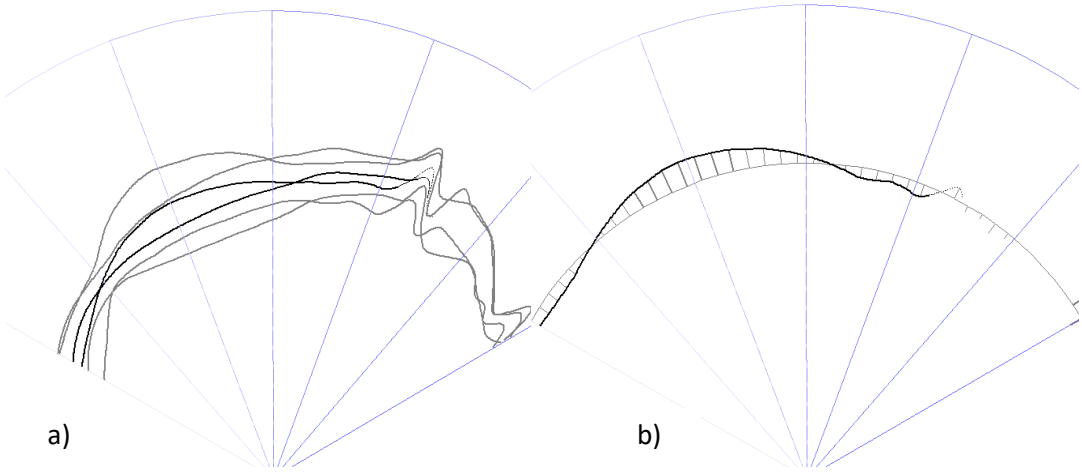


FIGURE 27 A) TWO MEAN TONGUE SPLINES (BLACK)WITH +/- 1 S.D. (GREY LINES)

B) THE DIFFERENCE CURVE WITH THICK SPOKES SHOWING SIGNIFICANT DIFFERENCE IN A T-TEST AT 2%

Spline workspace Move tab

Allows selected splines to be moved and rotated within the workspace relative to unselected splines.

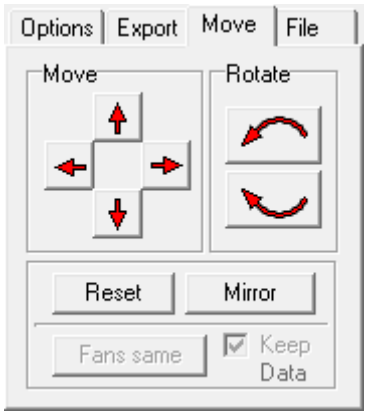
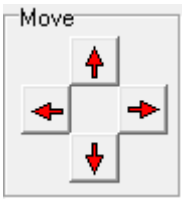


FIGURE 28 THE SPLINE WORKSPACE MOVE CONTROL



Translate all selected splines up down left or right a discrete amount for each click or hold button down to continue to move

Rotate all selected splines anticlockwise or clockwise a discrete amount for each click or hold button down to continue to rotate

Return all selected splines to their initial position.

Flip all selected splines with respect to the workspace Y-axis.

If the keep data checkbox is NOT CHECKED then this will reset all fan splines back so that they lie on top of each other, undoing any rotation and translation.

If the keep data check box is CHECKED then this merges all rotated and translated fan splines so that they remain in the altered positions but are referenced to a single fan grid determined by the spline in the list with the symbol next to it.

NOTE: In order to average splines that have been rotated and translated, they MUST BE MERGED.

Spline workspace export tab

The export control provides a means for exporting the splines in the workspace to a text file as sets of 42 or more co-ordinates. These can then be read into excel or Matlab and plotted or analysed further. This is an alternative to the more common "Export data.." option with the advantage that the data in the workspace can be from several projects.

Choose to export all the splines in the workspace or only the ones that are selected.

Choose to export the splines as x-y (cartesian co-ordinates in an x y <newline> x y <newline> x y format. Or as magnitude angle (polar co-ordinates) in a M θ <newline> M θ <newline> M θ format.

Interpolate the spline curve to output more than th 42 control points 1 = 84 points; 2 = 166 points; 3 = 248 points

Select the cofidence value above which the co-ordinates are exported as numbers. Points along the spline with confidence value lower than the threshold will be exported as asterisks (*)

Spline Workspace File Tab

A workspace can be saved to a *.wsp file. This is a text file with the information about all splines in the workspace. **It is recommended to save the workspace at regular intervals**. This is not done automatically.

Merging roof splines from one recording to another

It is often the case that Palate traces are made in a separate recording from the actual speech data. Palate traces can be done by filling the mouth with a liquid or paste such as water or yoghurt. Traces can also be made by drying the tongue and pressing it against the roof of the mouth (the dry tongue traps air between the papillae so an air boundary is retained which shows up well). Regardless of how the trace is obtained, it will be desirable

to trace the shape of the roof and merge it into all the other recordings that have speech data so that distances and areas between the tongue and the roof can be calculated.

Merging can be done in the following way:

1. Draw the roof spline in the palate trace recording and copy it to the workspace.
2. Save and close the palate trace recording then open up a recording with speech data and add splines
3. Select the roof spline. (IMPORTANT)
4. Then click the 

button in the Edit splines dialogue (keyframes tab option)
5. The roof spline curve will then be merged into the current roof keyframe of the current recording, replacing what was there before.

Publisher

Create publishable quality diagrams from AAA data.

Although it is possible to capture bitmaps from the screen the quality is not adequate for Journal publication. The Publisher facility within AAA (See AAA manual for more details) allows high resolution (e.g.600DPI) images to be created. With the ultrasound module comes the ability to export 2D spline contours to the publisher. Using the Publisher image importing function in combination with the Video Display window “Copy Bitmap” function, ultrasound video frames can also be incorporated.(See Figure 29 for an example).

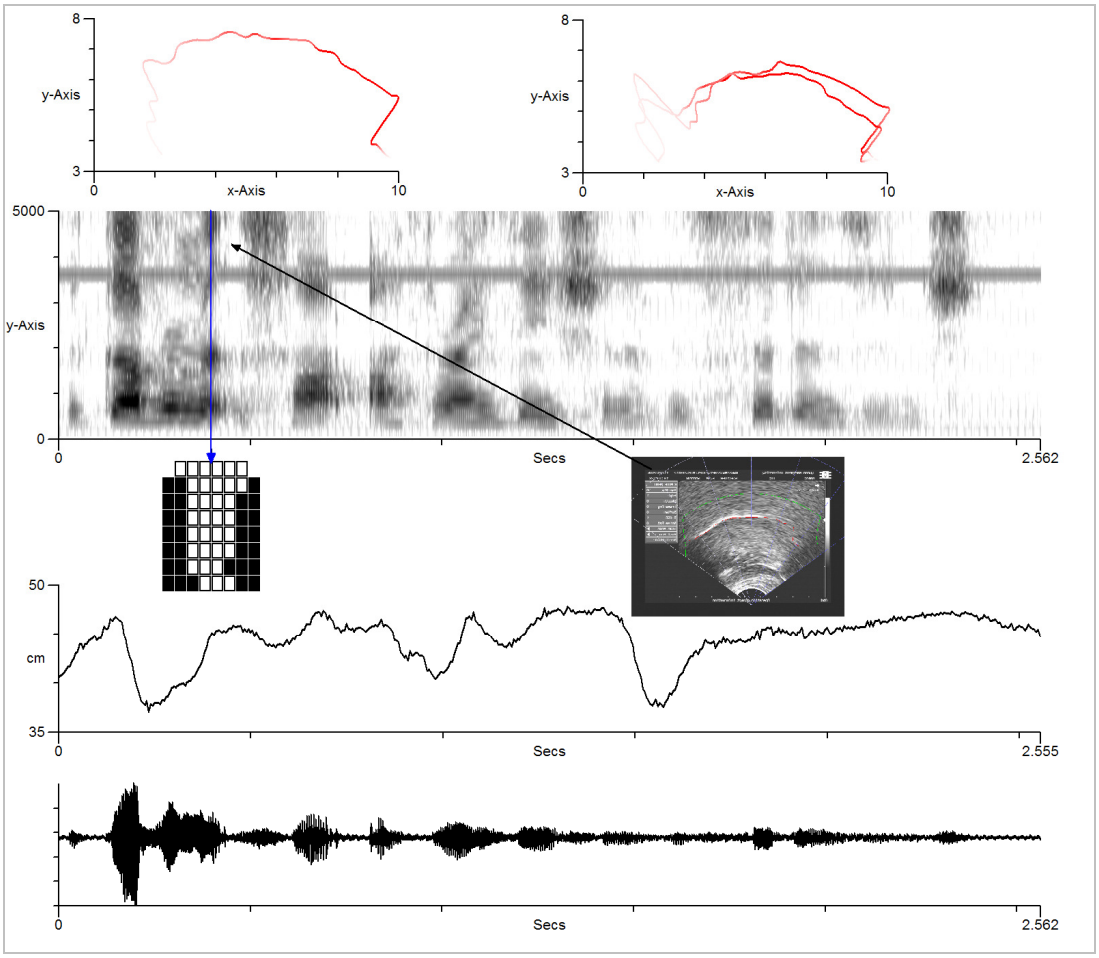


FIGURE 29 AN EXAMPLE PUBLISHER OUTPUT WITH SPLINES

Spline Analysis Values

As with EPG, it is possible to create analysis values derived from the spline curves. The values are based on either the absolute distance from the fan origin to the spline or on the relative distances between splines along the fan grid axes. In all cases regions can be constrained to lie between fan lines

Analysis values based on fan splines

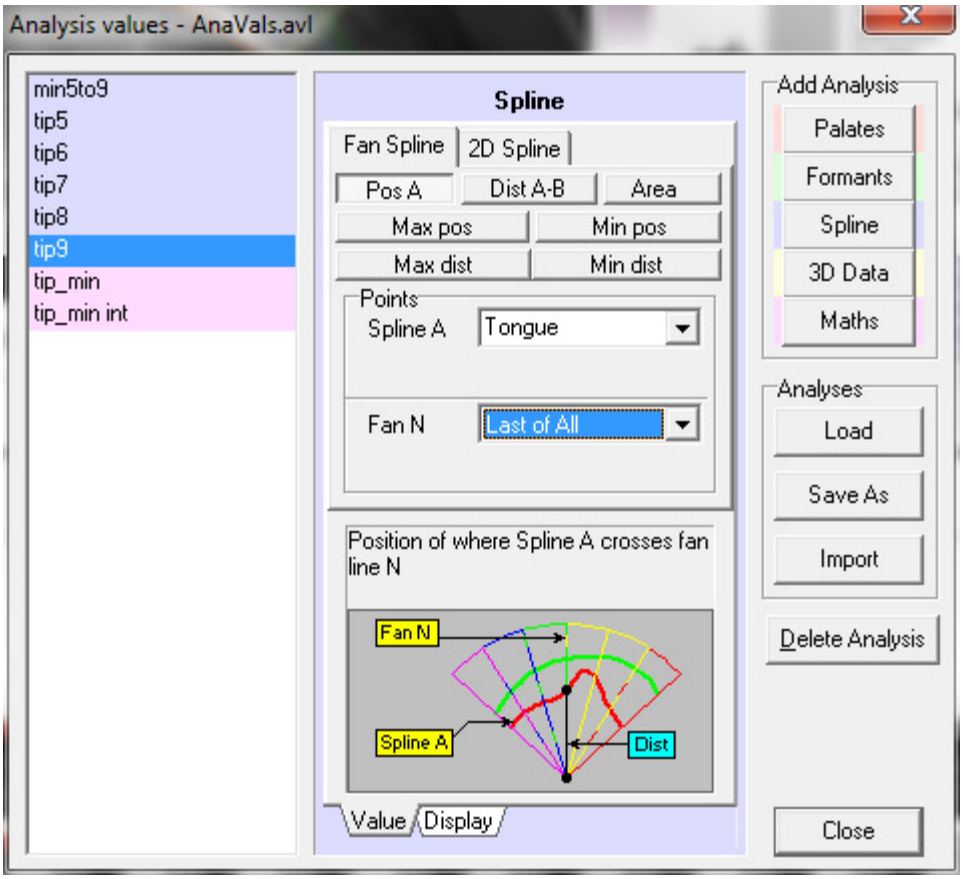


FIGURE 30 ANALYSIS VALUE: POS A. INTERSECTION OF SPLINE AND FANLINE

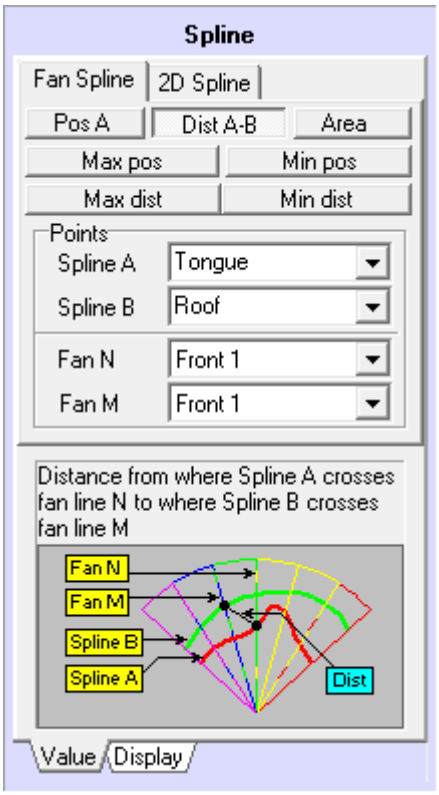


FIGURE 31 ANALYSIS VALUE DISTANCE BETWEEN TWO SPLINES

Pos A

The radial distance from the origin of where Spline A crosses fan axis N.

Dist A-B

Measures the distance from where Spline A crosses fan axis N to where Spline B crosses fan axis M. Most often N and M will be set to the same value and Spline A will be Tongue while Spline B will be Roof.

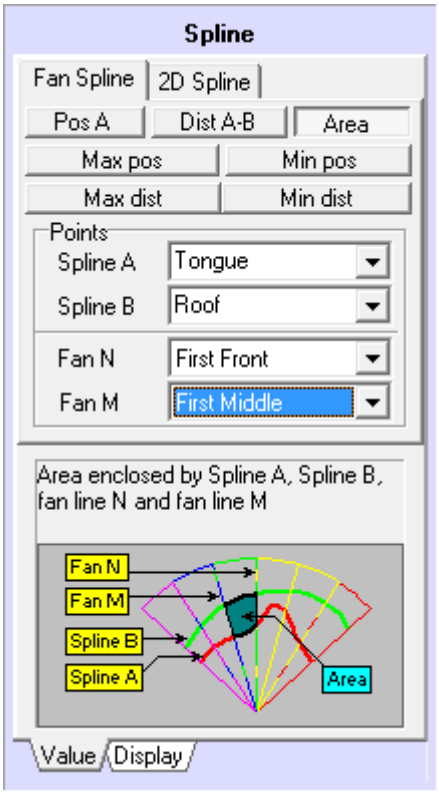


FIGURE 32 ANALYSIS VALUE: AREA BOUNDED BY FANLINES AND SPLINES

Area

Measures the area between Spline A and Spline B, bounded by fan axes N and M on either side. For example Spline A and B are usually Tongue and Roof respectively. The alveolar area might be bounded between fan 7 and fan 13 but this can be determined by observation for any given recording.

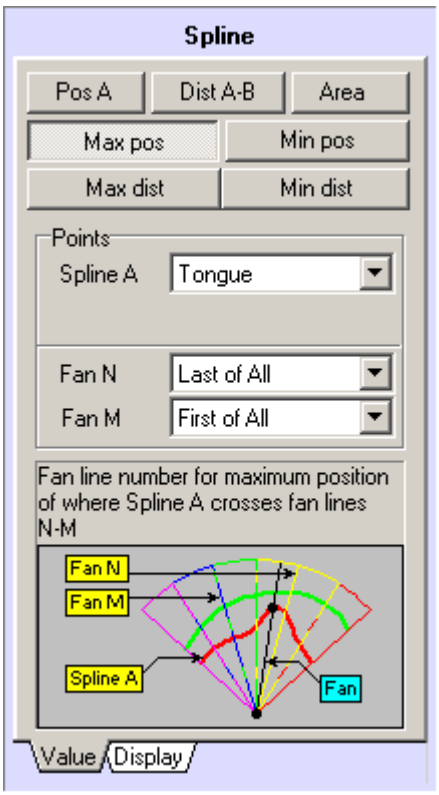


FIGURE 33 ANALYSIS VALUE: FANLINE MAXIMUM POSITION

Max Pos

Determines the fan axis index (0-41) corresponding to the Spline A crossing point with the highest radial distance from the fan origin.

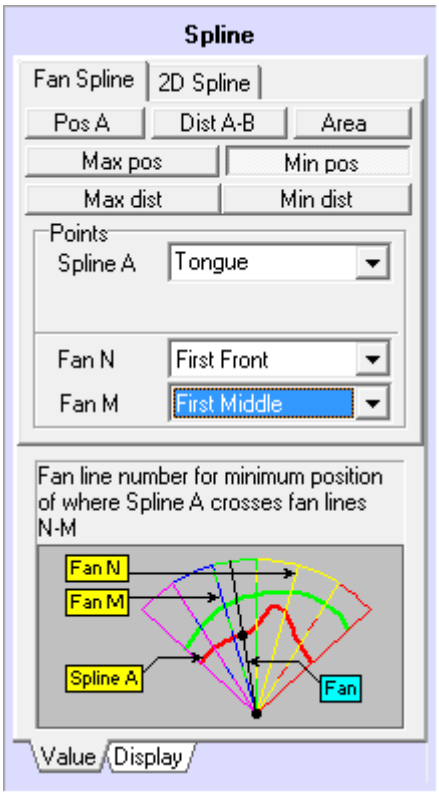


FIGURE 34 ANALYSIS VALUE: FANLINE MINIMUM POSITION

Min Pos

Determines the fan axis index (0-41) corresponding to the Spline A crossing point with the lowest radial distance from the fan origin.

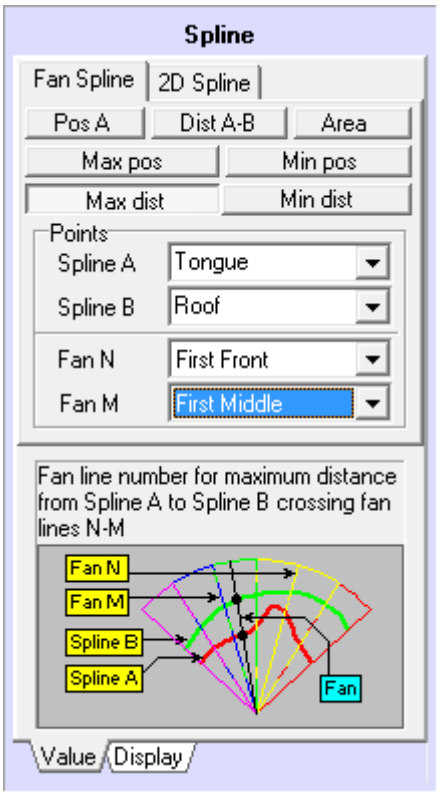


FIGURE 35 ANALYSIS VALUE: FANLINE MAXIMUM DISTANCE

Max Dist

Measures the distance between Spline A and Spline B along each fan axes in the range N to M and determines which axis has the largest relative distance.

Included for completeness – no obvious application

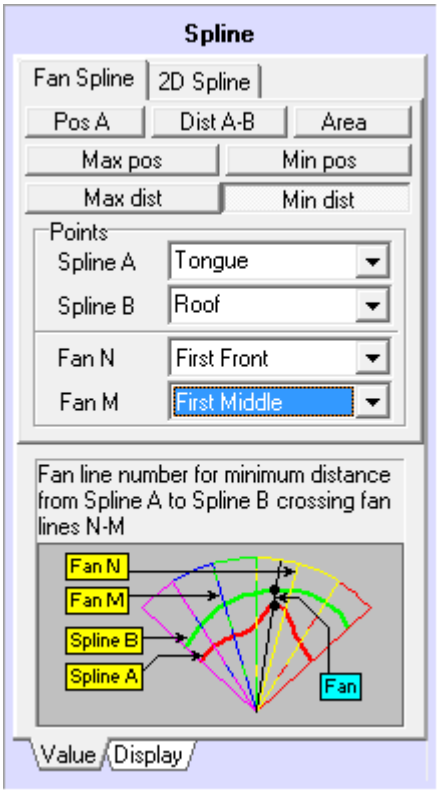


FIGURE 36 ANALYSIS VALUE: FANLINE MINIMUM DISTANCE

Min Dist

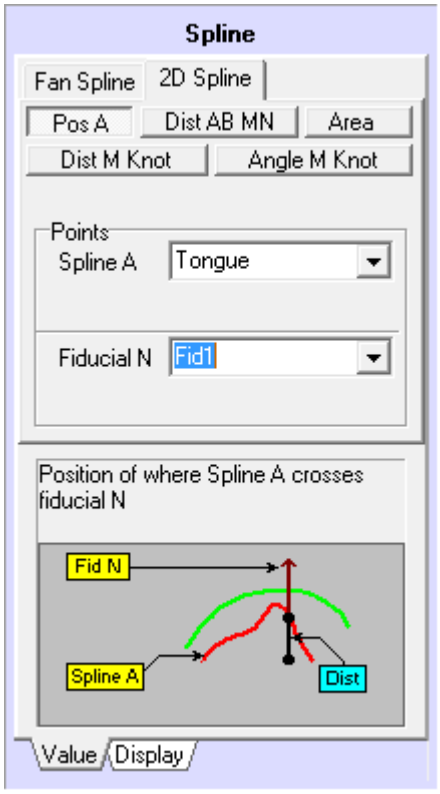
Measures the distance between Spline A and Spline B along each fan axes in the range N to M and determines which axis has the smallest relative distance.

For example Spline A and B would normally be the Tongue and Roof splines respectively and

N and M may be 7 and 24 corresponding to the position of the first and last rows of an EPG palate. In this way the constriction point can be identified.

Analysis values based on a Fiducial

Crucially this allows distance measures to be made for 2D splines. e.g. lip aperture can be measured on lip video. A fiducial also has the advantage that it can be oriented in any direction and start at any origin. It is not constrained to follow radial lines from the centre of the probe but can be positioned relative to some visible anatomical landmark.



Pos A

The radial distance from the origin of where Spline A crosses the specified Fiducial.

FIGURE 37 ANALYSIS VALUE: POS A. INTERSECTION OF SPLINE AND FIDUCIAL

Dist AB MN

Measures the distance between spline A and spline B along fiducial N.

Most often Spline A will be Tongue while Spline B will be Roof and Fiducial M and N will be identical. i.e. measure the distance between two splines along one fiducial.

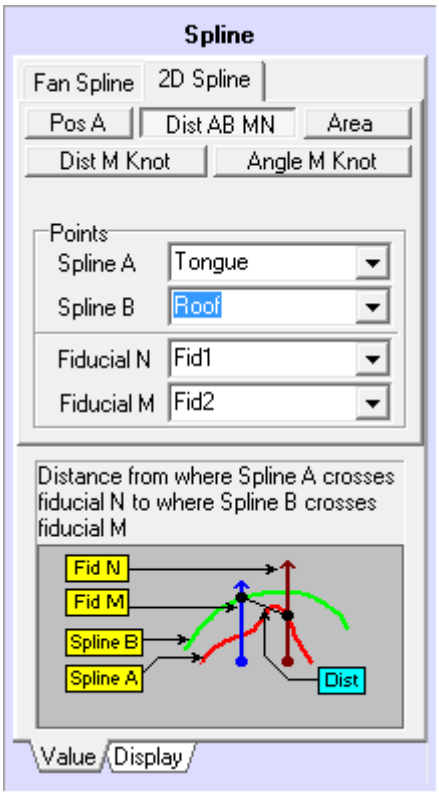
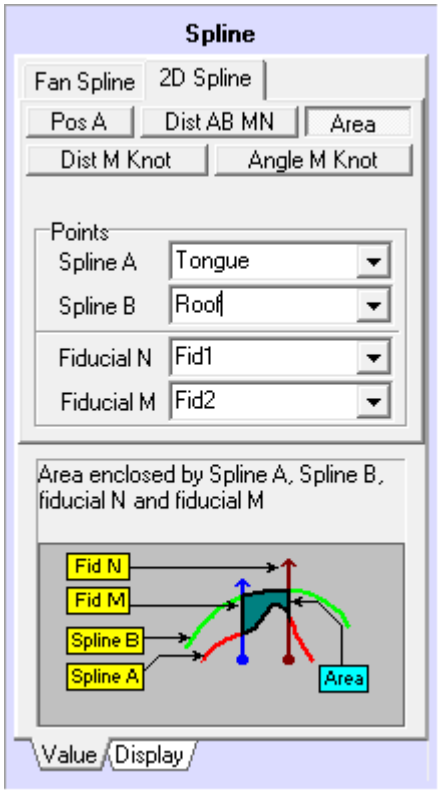


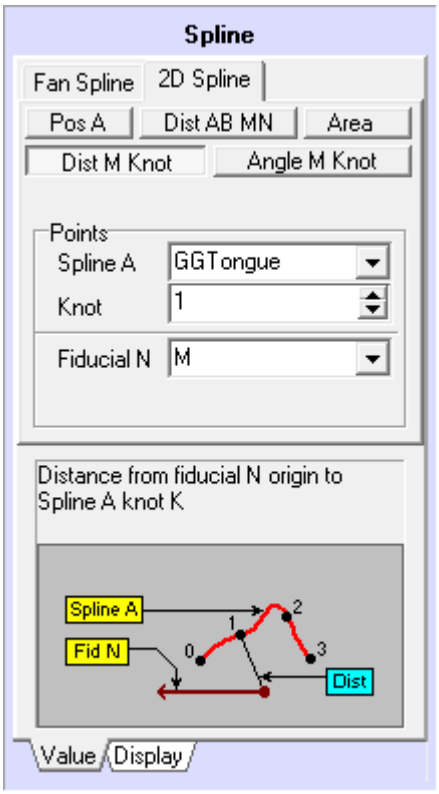
FIGURE 38 ANALYSIS VALUE: DIST AB. DISTANCE BETWEEN TWO SPLINES ALONG FIDUCIAL



Area

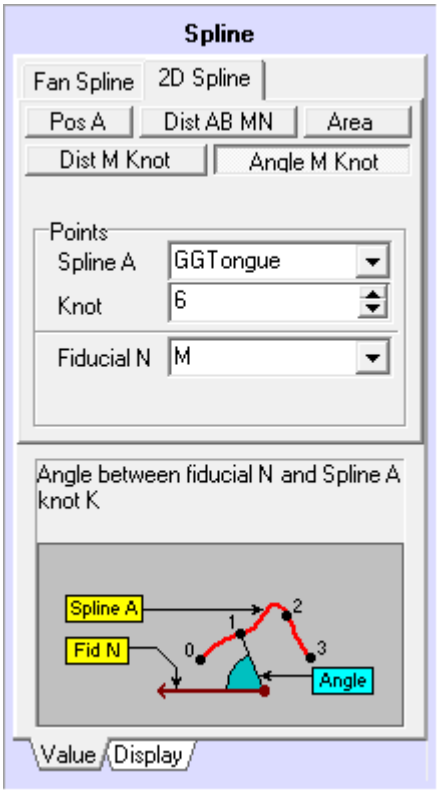
Measures the area bounded by spline A , spline B ,fiducial M and fiducial N.

FIGURE 39 ANALYSIS VALUE: AREA. AREA BOUNDED BY TWO SPLINES AND TWO FIDUCIALS.



Dist M Knot

Measures the distance from the origin of Fiducial N to the specified knot on the 2D GG Spline.



Angle M Knot

Measures the angle between the specified Fiducial and a line defined by the Fiducial origin and the specified knot on the GG Spline.

Spline Export

Spline data can be exported either as analysis values or as x-y values. To export the co-ordinates it is best to check the Export to Spline Workspace box under the Export file tab (See Figure 40). All the selected splines will then be exported to the spline workspace from where they can be exported as co-ordinates. An extra Splines tab appears (Figure 41) which provides the option to select either the tongue spline or the roof spline or both for each time point.

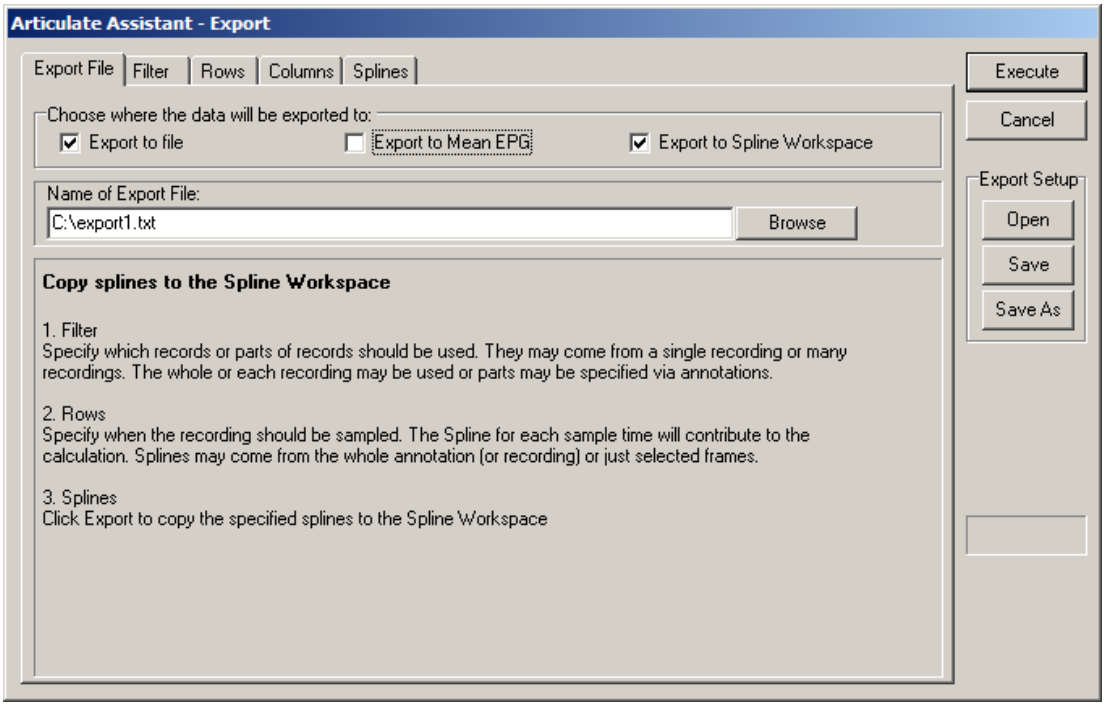


FIGURE 40 EXPORT DATA: EXPORT TO SPLINE WORKSPACE

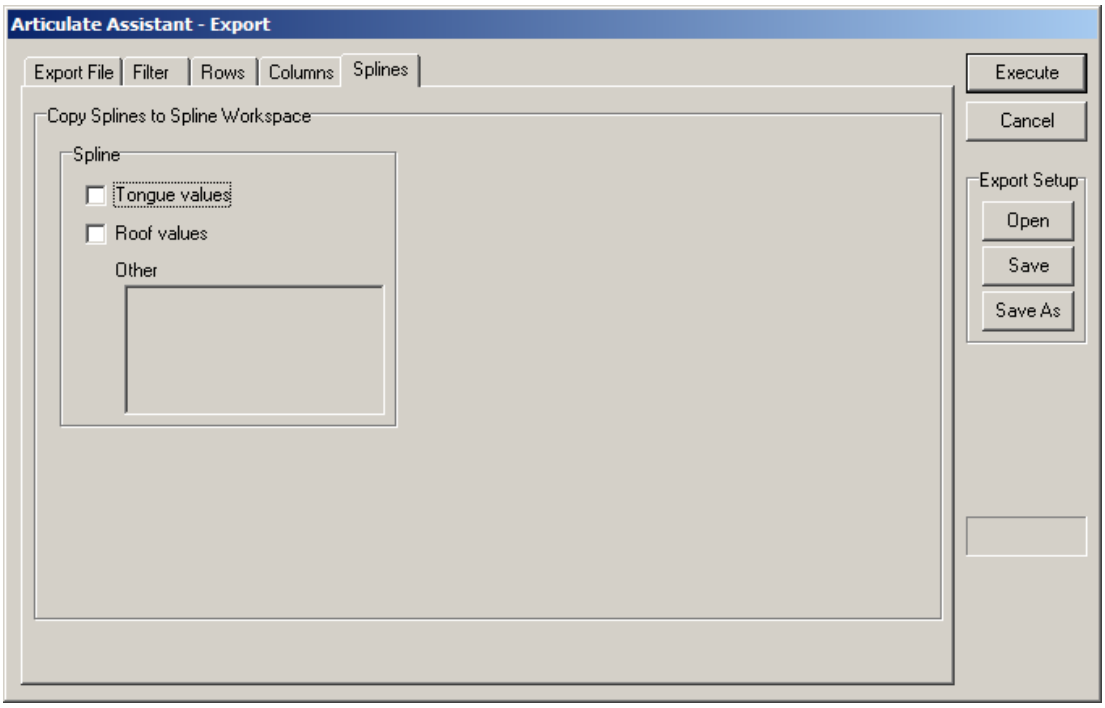


FIGURE 41 EXPORT DATA: SPLINES TAB APPEARS WHEN EXPORT TO SPLINE WORKSPACE IS CHECKED

Alternatively, the 

button under the Columns tab (See Figure 42) provides the option to export the 42 polar co-ordinates (radius in millimetres or % length of fan axis and angle in radians) or to export the 42 Cartesian co-ordinates (x-y) directly to the export file. Only the 42 radial axis crossing points can be exported with this direct option. The confidence values can also be exported in this way.

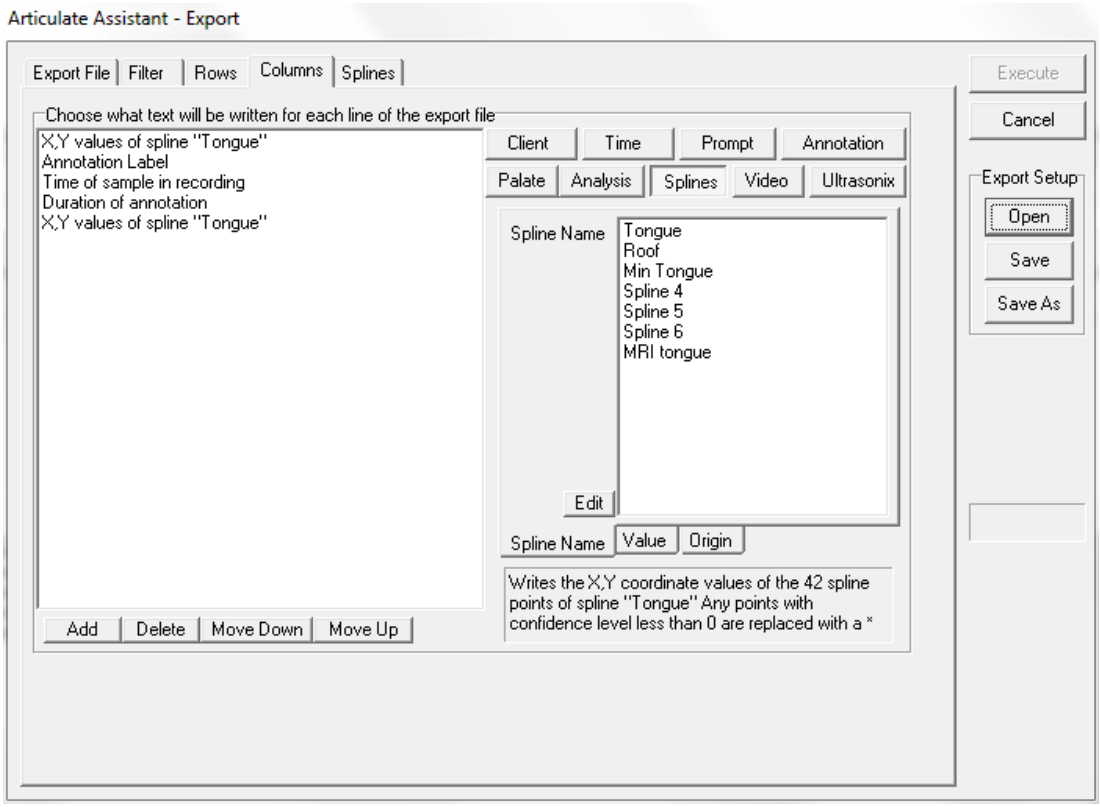


FIGURE 42 EXPORT DATA: COLUMNS DERIVED FROM SPLINES

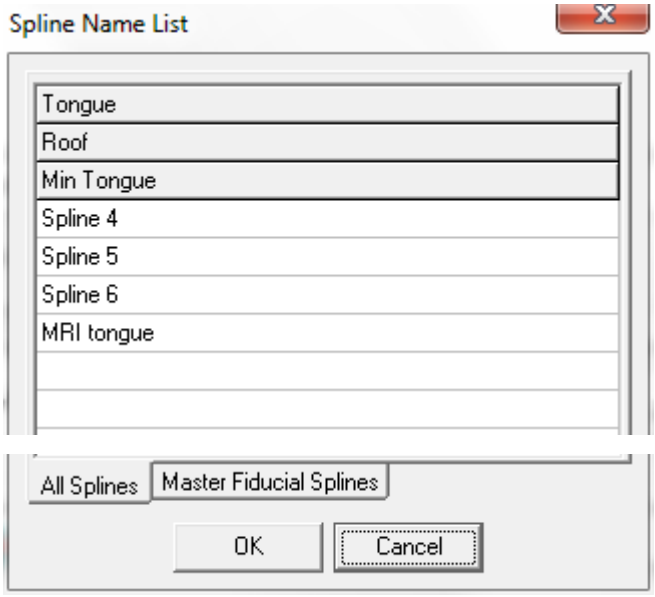


FIGURE 43 SPLINE NAME LIST EDITOR

Spline Name Editor

The list of spline names is automatically populated from by searching the current project for unique spline names. There is a maximum limit of 32 names that can be listed. This is because AAA needs a fixed index to carry out searches.

If there are more than 32 spline names in the project then the list can be edited to include the names of the splines that are required for export.

Master Fiducial

It is possible to rotate and translate exported data relative to a fiducial. That fiducial can either be a single "Master" fiducial or, if no master fiducial is specified then it will look for a fiducial in each recording from which data is exported. " A "Master" fiducial is useful if a single recording is made with a bite plane at the start of a session and the master fiducial is aligned to that bite plane. The other recordings in that session can be rotated to that bit plane. Then is the same speaker returns for a second session with a slightly different headset position then a new master fiducial can be set to the new bite plane and data exported so that it lies in the same co-ordinate system as the first session. Rotation and translation could be used within a session to correct for head movement for instance if lip data is exported and the fiducial is based on fixed cranial features such as the bridge of the nose that are visible in every frame.

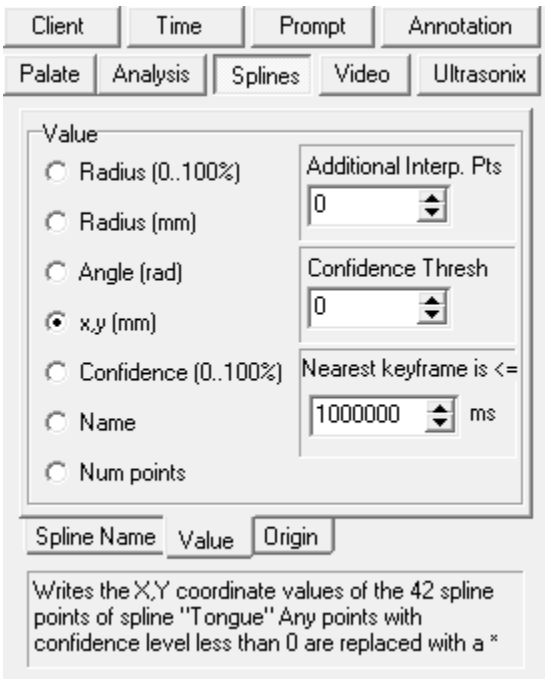


FIGURE 44 SPLINE EXPORT: VALUE TAB

Value

Select the co-ordinates to be output.

Additional Interpolation Points

Splines are interpolated between keyframes. If the nearest keyframe to

Spline analysis values can be exported using the 

button under the columns tab.

Confidence Threshold

Every control point of every keyframed spline has a 0-100% confidence value associated with it. When exporting spline co-ordinates it is possible to only export the co-ordinates when the confidence is above a set threshold value. By default the threshold is set to 0% which means that ALL values are exported regardless of the confidence. Confidence above 80% is shown on the display as a solid line, so by setting the Threshold at 80%, only those co-ordinates which look solid on the image will be exported as numbers. Vlaues below 80% will be exported as Asterisks "*". Any threshold value between 0 and 100 can be selected.

Nearest keyframe is <=X ms

If all the time points being exported are supposed to be close to keyframes then this threshold value can be set to a low value. For example if the ultrasound frame rate is 60Hz then a value of 17ms could be chosen. In this case, if the nearest ultrasound frame does not have a keyframe associated with it then the values will be replaced by a Hash "#" and it will be apparent that the data needs to be reviewed and a keyframe added near that point.

By default the value is set to 100seconds to ensure that ALL values are exported.

Origin

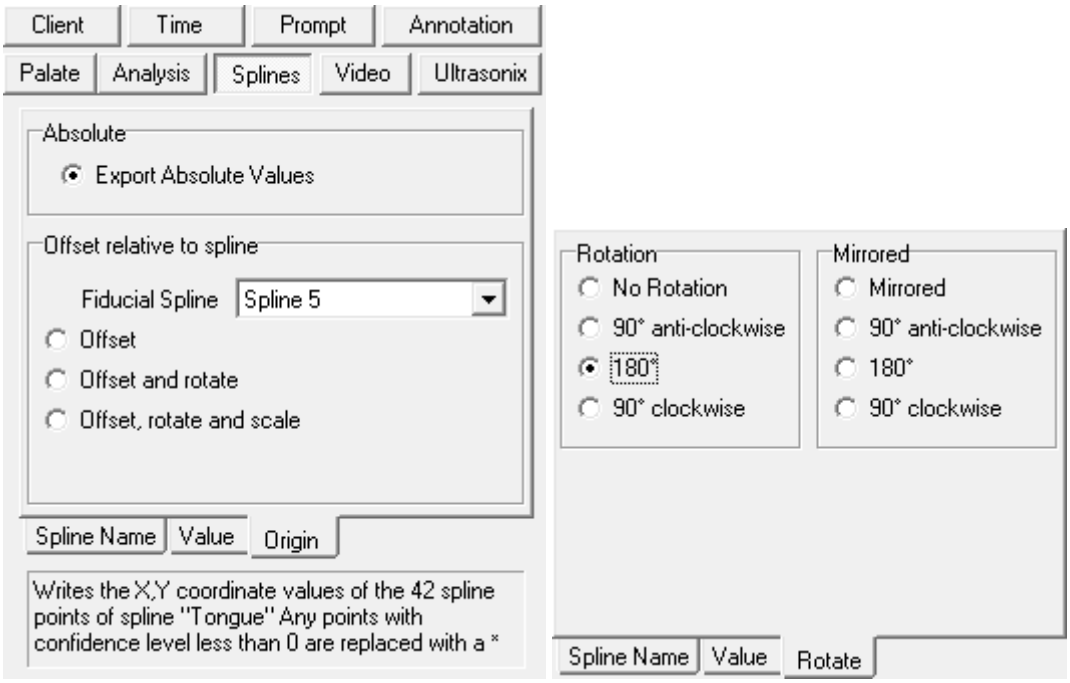


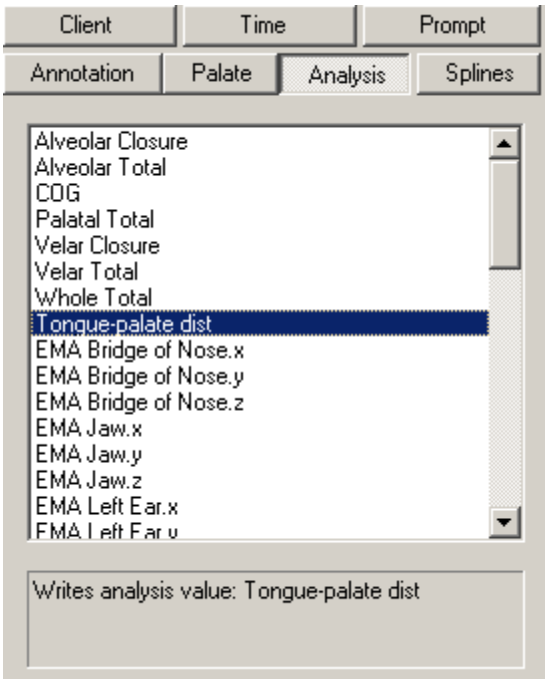
FIGURE 45 EXPORT SPLINES: ORIGIN, OFFSET AND ROTATION.

A Fiducial has an origin, an angle and a scale associated with it. The Origin tab permits the exported data to be normalised by one or all three of these factors.

Note that if polar co-ordinates are exported then radius values have no option to rotate or translate as this makes no sense. If angle values are exported then these can only be rotated or mirrored by 90 or 180 degrees (see Figure 45). If other options are required then please contact Articulate Instruments to discuss this.

Analysis tab

The Analysis values created from splines can be exported using the analysis tab.



Select the desired spline-based analysis value (e.g. tongue-spline distance) previously created using the Analysis Values dialogue.

Under the rows tab there is an extra option to allow export time points to be based on video tick marks (See Figure 46)

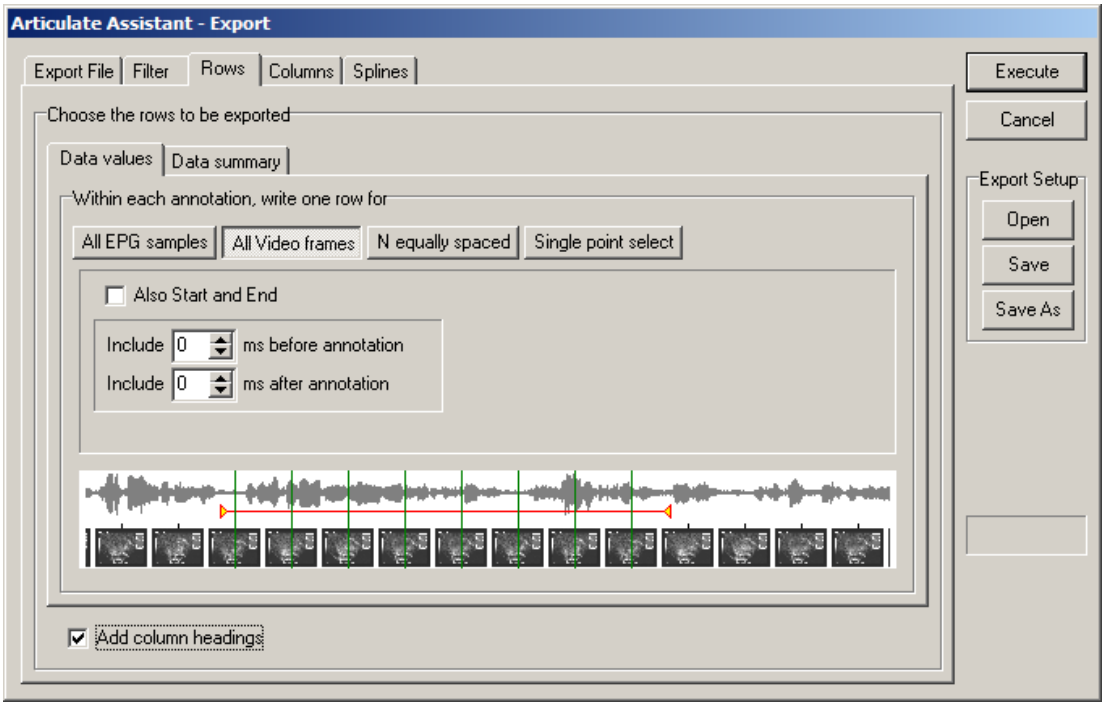


FIGURE 46 EXPORT DATA: ROWS BASED ON VIDEO FRAMES

Ultrasonic tab

Raw ultrasonix data and ultrasonix parameters can be exported using the ultrasonix tab.

Single raw pre-scan frame - for each exported time point, a binary file consisting of a single frame of ultrasonix data is created and the filename added as a column in the exported text file. File format is single byte integers corresponding to each pixel of each scanline ordered by scanlines. i.e. scanline1 scanline2 scanline3 .... scanline N Filemname is in format Clientname_Datetime_frameNum.ult

Whole raw pre-scan - as above but the whole recording is ouput and the filename format is Clientname_Datetime.ult If more than one time point is exported from the same timepoint the file is only written once. The values *frame number, Number of pixels per scanline* and *Number of scanlines* can be used to reference the appropriate frame of binary data.

Whole avi recording – converts ultrasonic data to movies. The make movie dialogue will pop up once to allow the movie layout to be designed, thereafter every export row will produce a movie with those specifications.

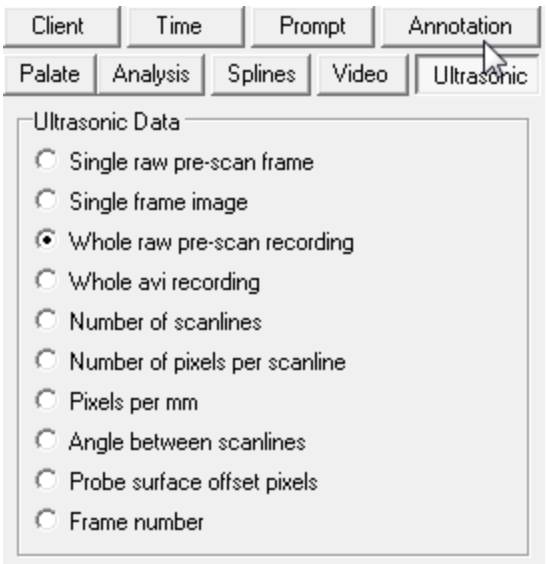


FIGURE 47 EXPORT: ULTRASONIC DATA

Shortcut Keys

Help	F1
Playback	F2

Record	F3
Select visible region of waveform	Click waveform then Ctrl+A
Adjust selected region/ selected annotation	Ctrl + drag mouse
Select region in Palates or Analysis values windows	Shift + drag mouse

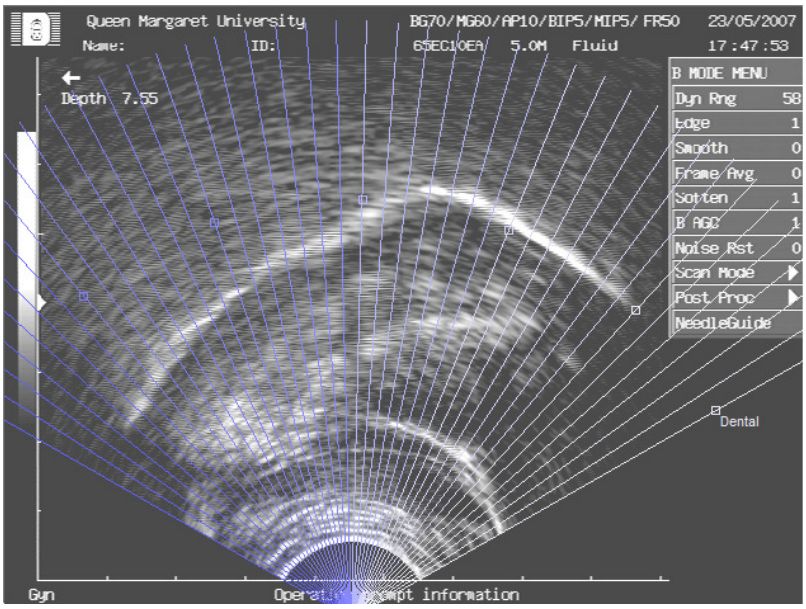
Revision	Date	Notes
2.10	04/11/10	Added Imperx Expresscard54 video capture capability
2.14	03/02/12	Overlays, 2D splines,
2.15	06/04/14	Spline Export, Fiducials, Dfg2Usb card, Ultrasonix recording setup and support for Exam 5.7.*
2.16	03/10/15	Ultrasonic data type expanded to include EchoB: Anavals(*.avl) and Data Export configuration (*.xsu) now stored separately for each project; recalculation of analysis maths values revised.
216.11	02/06/15	Batch splining added. New “Make movie” dialogue replaces “Video avi export”. Frame averaging display option for ultrasonic data.
216.12	18/07/15	Batch splining improved. Make Movie dialogue bugs fixed. Export from spline workspace changed to matrix format.
216.13	25/11/15	Comm bug fixed. “Unable to write” export data bug fixed. Post acquisition frame averaging option added to EchoB storing tab.
217.01	05.09/16	New real-time edgetracker. Complete rewrite of ultrasound display code. Automatic detection of EchoB or Micro probe or machine connection. Continuous record of audio and EchoB/Micro.Faster ultrasonic file save.
217.02	24/05/17	Offline edgetracker now works on raw data making it 100x faster. Several bugs have been fixed.
221.12	??/??/25	Major rewrite of whole manual.

Appendix A

Fan Spline fitting algorithm

- Based on a fan grid with 42 axes (ultrasonic data uses the raw data vectors)
- Set search upper limit (palate) and lower limit
- Search along each axis for best edge

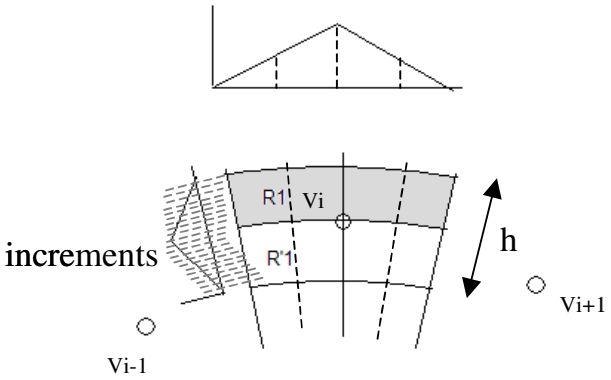
- Find the 3 consecutive axes with the best edge and use as an anchor for second pass
- Search out from the anchor with a penalty for being a different radial distance (smoothing function).
- Note the edge error value and use as “confidence” measure of edges

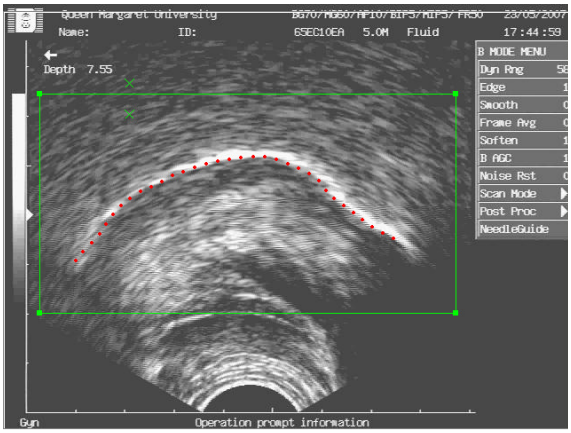


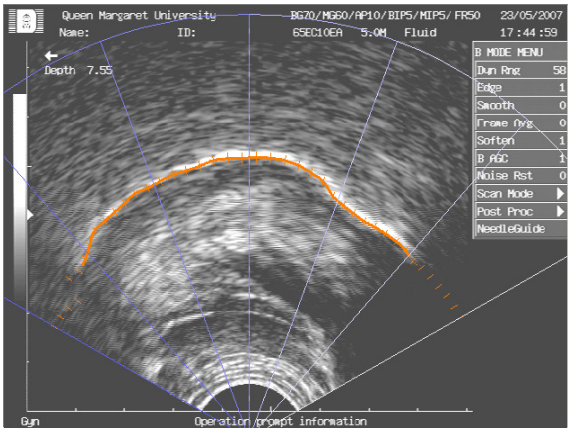
The edge detection algorithm

- Triangular weighting function
- Not all pixels sampled
- Edge confidence = 30% brightness (R1+R`1)+70% brightness(R1-R`1)
- h = approx 20 pixels
- Increments = 0.2% of axis (about 1 pixel)

Comparison of algorithm (right image) with Edgetrak (left image)







Appendix B

SNAKE spline fitting algorithm

2D splines

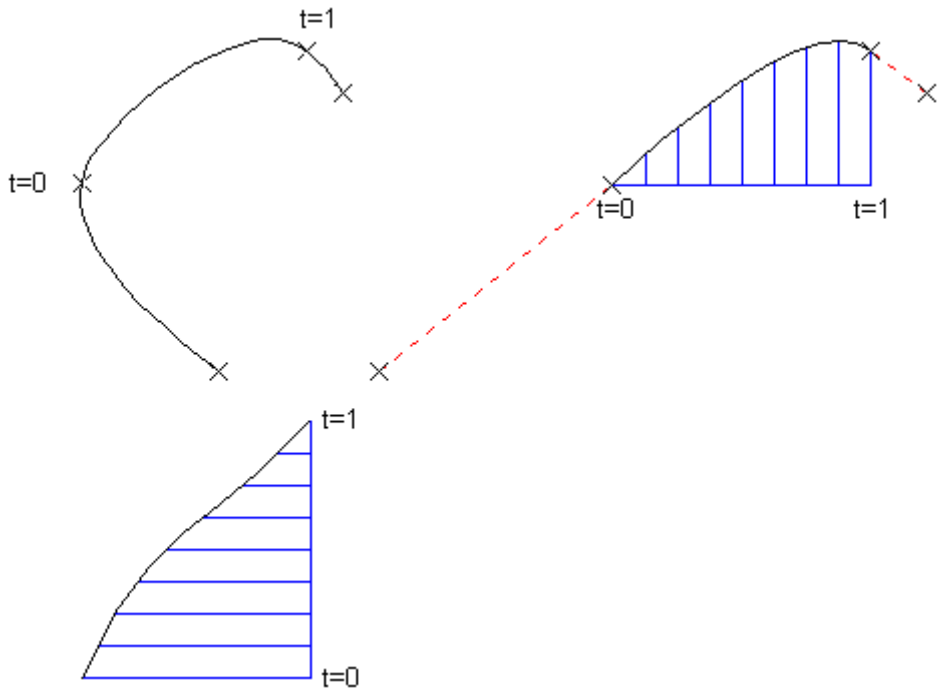
A *cubic spline* passes through several knots. There are no extra control points (as with *B-Splines*) - we feel that controlling the spline simply by the positions of the knots is more intuitive for users (who set the initial position of the spline) and is easier for any Snake algorithm.

The line is composed of several segments - each segment runs between two adjacent knots. The segment is drawn with "time" t running from 0 to 1

$$x = ax*t3 + bx*t2 + cx*t + dx$$

$$y = ay*t3 + by*t2 + cy*t + dy$$

The coefficients (a,b,c,d) for the line between knot N and knot N+1 are calculated independently for the x-coordinates of the line and the y-coordinates.



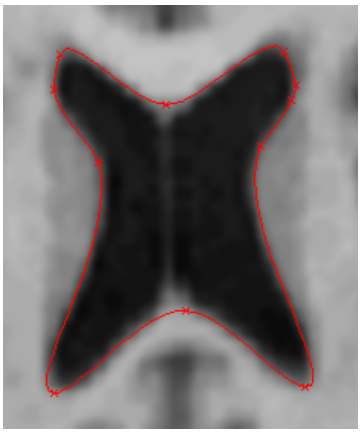
The coefficients are calculated so that:

1. the line passes through the two knots N and N+1
2. the slopes at knots N and N+1 are specified

The slope at knot M (dx/dt or dy/dt) is the slope of a quadratic which passes through knots M-1, M and M+1

If two knots have no neighbour to the left or right then a quadratic expression is used for the segment. If two knots have no neighbours to both the left and right then a linear expression is used for the segment.

This form of spline has been found to be well behaved and is intuitively easy to use. It is not completely rotationally invariant but the variation is negligible.



(11 knots)

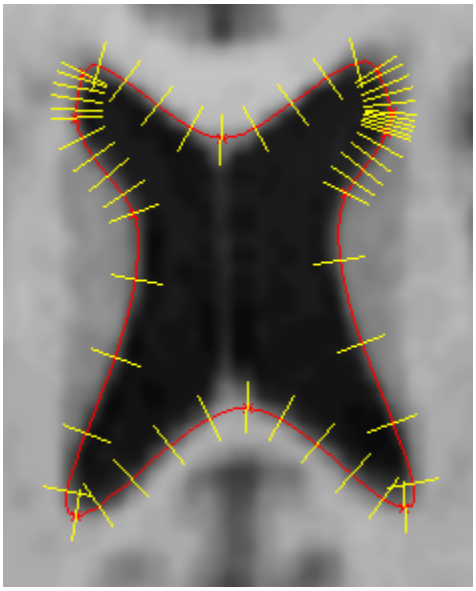
There are several advantages to using this form of spline to represent a Snake. The coefficients and the line are quick to calculate. There are only knots, not knots and control points. If the snake "knows" that a line segment should increase its curvature and move up, then which way should it move the knots and the controls points or a B-spline or Bezier? We have only knots and the line reacts sensibly to changes in the position of a knot.

Snake

A Snakes algorithm moves the knots so that the line gets closer to a "feature". We are interested in edges so a "feature" is an edge. It could equally well be a particular brightness, a dot, the end of a line or a combination of features.

The algorithm is iterative. In each iteration, the algorithm must decide where to move each knot: how far and in which direction.

To move knot N, search-lines are drawn normal to the tangent to the spline. A search-line is drawn through the knot and w search-lines are drawn on either side equally spaced between knot N and knots N-1 and N+1. In this example, w is 5 and the search-lines extend h = 20 pixels on either side of the spline.



The pixels lying under each search-line are examined working from one end of the search-line to the other:

p is the brightness of the pixel being examined

q is the brightness of the previous pixel

We are looking for edges so we calculate a number which is bigger if there is an edge near the the spline:

left-rising	c := + (p-q)*sign(ay)
right-rising	c := - (p-q)*sign(ay)
either	c := abs(p-q)*sign(ay)

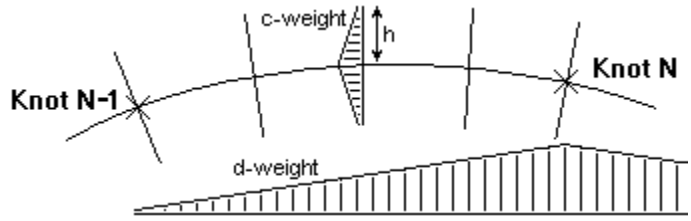
ay is the distance along the search-line from the central spline

If p is different from q then there is an edge. The edge can be "left-rising", "right-rising" or either. The snake will hug "internal" boundaries, "external" boundaries or both.

We calculate a weighted value of c

weight = (h-abs(ay))/h;

the weight is 1 on the spline and decreases linearly to zero at the ends of the search-line.



The image does not have to be smoothed. The above calculation automatically smooths the contributions from different pixel-pairs.

Each (weighted) value of c contributes to the movement of Knot N. If the sum of c is positive, it implies shifting the line to the "left". So the origin of the search-line should move "left" along a vector d. The length of d is given by c, the direction of d is the direction of the search-line.

The d values are vector-summed to give an overall movement for Knot N. This is a weighted sum: the weight falls off linearly with distance from Knot N and is zero at Knots N-1 and N+1.

The weighted sum of d is scaled by a "speed" factor which controls how fast the Knot moves in each iteration. Typical values range from 0.005 to 0.05.

The algorithm is iterated several times (typically 10 to 100). At first, the search-lines are long (h = 20) which gives a coarse movement of the knots but has a large capture distance. Later iterations have smaller search-lines (h = 5).

Knots move along the spline

With successive iterations, the knots move around. They move the spline from side to side and they move along the spline. You may require several iterations of the above (iterated) algorithm to see the effect.

If two knots get too close to each other (within one or two pixels) then the spline goes crazy. A term can be added to force pixels apart. This force should only act over small distances and should be negligible above (say) 10 pixels. A suitable force involves moving each knot away from each neighbour (N+1, N-1) by a distance k/d (d is the distance to the neighbour; k is a speed constant, e.g. 0.3).

You could restrict each knot only to move along the search-line that passes through the knot: so the spline moves from side to side but the knots don't move along the spline. The knots then tend to stay spaced-out as they were originally placed. The knots generally, move along the spline to sensible positions, so it usually isn't neccessary to force them to retain their original spacing. However, if the spline is not closed then the end-points can occasionally wander off. We have restricted the movement of the endpoints of the spline so that they can only move along their searchlines and not move so as to extend or shrink the overall

distance between the endponts.

Some snake algorithms introduce other internal forces into the snake:

- tension: pulls the knots together like a rubber band

- stiffness: straightens the spline

For our application, both tension and stiffness do more harm than good.

Rather than search for edges, we can search for pixels of a particular brightness:

brightness c := -abs(r-p) *ay/h /10

r is the "required" brightness

(the "/10" constant brings the value of c into the same range as the edge calculation)

A combination of 70% edge detection and 30% brightness detection seems to work well. (The required brightness is the mean of the pixels under the spline.) The snake follows a strong edge but where the edge becomes ill-defined, it follows the mean brightness.

Appendix C

File formats

Ultrasonic

<stem>.ult is a binary file consisting of a sequence of N vectors. Each vector represents a scanline.

<stem>US.txt is the associated text file with values needed to read and reconstruct image from binary data

Reading parameters

'NumVectors ‘= <number of vectors>

'PixPerVector’ = <number of elements in each vector>

'BitsPerPixel’ = <number of grey levels (usually one byte = 8 bits i.e. 256 levels)

Image reconstruction parameters

'ZeroOffset’ = <distance in pixels from the fan origin to the first element of the vector

'Angle’ = < the angle of separation between each pixel>

'Kind’ = < echoB or Ultrasonix>

'PixelsPerMm’ = < scale used to allow real world measurements>

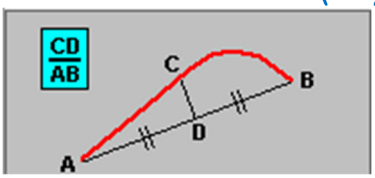
'FramesPerSec’ = < frame rate>

'TimeInSecsOfFirstFrame' = < time of first image relative to start of audio>

Appendix D

Ultrasound tongue SHAPE measures

Dorsum excursion index (DEI) (Zharkova,2013)



Defined as - length(CD)/length(AB) where A is the posterior of the tongue and B is the anterior. D is the midpoint. C is the crossing point of the tongue spline with a line arising from D and perpendicular to line AB.

Typical value range – positive values usually less than 1

Purpose – intended to differentiate /k/ from other articulations particularly /t/

Weaknesses - requires establishing the length of the line between two curve ends. The length of this line is dependent on assessing the location of the ends of the tongue curve.

Reference - Zharkova, N. (2013). Using ultrasound to quantify tongue shape and movement characteristics. *The Cleft Palate-Craniofacial Journal, 50*, 76–81.

Tongue Constraint Position Index (TCPI) (Zharkova,2013)

Defined as – (C-B)/(B-A) where A is posterior tongue and D is anterior. B is the midpoint of line AB. C is the crossing point on line AD corresponding to a perpendicular with maximum distance between line AB and the tongue spline

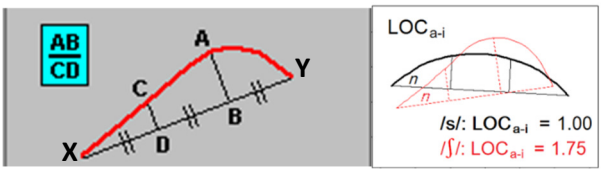
Typical value range - -1 to +1 (This assumes that C is within the range of A to B which is not guaranteed). A positive value indicate anterior constriction and a negative value indicates posterior constriction.

Purpose – Intended to detect if a tongue dorsum is responsible for the primary vocal tract constriction

Weaknesses - requires establishing the length of the line between two curve ends. The length of this line is dependent on assessing the location of the ends of the tongue curve.

Reference - Zharkova, N. (2013). Using ultrasound to quantify tongue shape and movement characteristics. *The Cleft Palate-Craniofacial Journal, 50*, 76–81.

Location of constriction (LOCa-i) (Zharkova, 2015)



Defined as – length (AB)/length(CD) Where point D and B are the 1/3 and 2/3rd the distance from posterior tongue point X to anterior tongue point Y. Point A is where a perpendicular to line XY from point B (anterior 3rd) intersects with the tongue curve and point C is where a perpendicular to line XY from point D (posterior 3rd) intersects with the tongue curve.

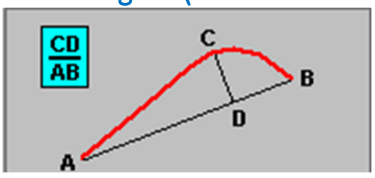
Typical value range – 0 to infinity where values > 1 indicate anterior constriction (more like /i/) and fractional values indicate posterior constriction (more like /a/)

Purpose – To quantify coarticulatory difference between consonant tongue curves across two different vowel contexts, /a/ and /i/

Weaknesses – Despite the authors claiming it does not "directly" depend on the assessing the ends of the tongue curve, Points D and B are still derived from their estimated position. The values are not linear and are better represented on a log scale.

Reference - Zharkova, N., Gibbon, F. E., & Hardcastle, W. J. (2015). Quantifying lingual coarticulation using ultrasound imaging data collected with and without head stabilisation. *Clinical linguistics & phonetics*, *29*(4), 249-265.

Curve degree (Aubin & Menard,2006)



Defined as – length(CD)/length(AB). Where A is the posterior tongue and B is the anterior. C is the point of maximum distance from line AB measured perpendicularly.

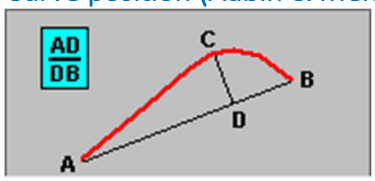
Typical value range – 0 to 1

Purpose – unspecified tongue curvature metric

Weaknesses - requires establishing the length of the line between two curve ends. The length of this line is dependent on assessing the location of the ends of the tongue curve.

Reference - Aubin, J., & Ménard, L. (2006). Compensation for a labial perturbation: An acoustic and articulatory study of child and adult French speakers. In *7th International Seminar on Speech Production* (pp. 209-216).

Curve position (Aubin & Menard,2006)



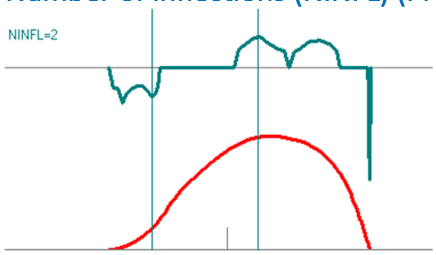
Defined as - length(AD)/length(DB). Where A is the posterior tongue and B is the anterior.

Typical value range – 0 to infinity. Note that point D can be outside the range AB but will give values tat reflect a position within the range AB.

Purpose – To determine if the point of curvature is more anterior or posterior

Weaknesses - requires establishing the length of the line between two curve ends. The length of this line is dependent on assessing the location of the ends of the tongue curve. The values are not linear and are better represented on a log scale. Midpoint has value 1, more posterior positions are fractions between 0 and 1; more anterior positions have values 1 to infinity

Number of Inflections (NINFL) (Preston et al, 2019)



Defined as - $$k = \frac{x'y'' - y'x''}{(x'2 + y'2)^{3/2}}$$k .

where primes denote derivatives with respect to offset along the curve, with any curl-over points (non-monotonic values of x with associated higher y values) deleted. The Number of INFLections (NINFL) is the count of nonzero sign changes in trimmed curvature (values whose associated radius is < thresh times the distance along the curve from the first to the last point, where thresh was a heuristically determined value of 0.3). NINFL values greater than 5 may be removed from the analysis (n=4 instances). Matlab code for the procedure is freely available at https://osf.io/xzdb7/

Typical value range – positive integer values. If the tongue curve is smooth then values should be in the range 0 to 5.

Purpose – To determine if the tongue shape is simple (low value) or complex (high value)

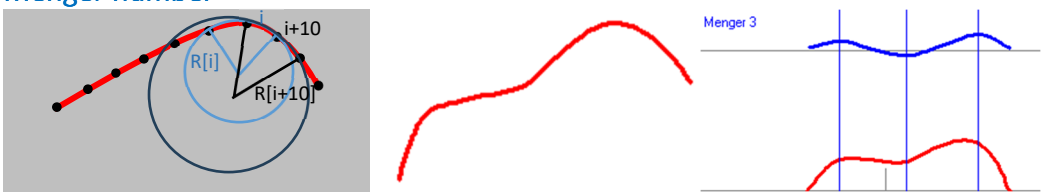
Weaknesses – If the tongue contour is not smooth then NINFL values will be higher. Tends to work OK for DLC_Tongue splines (based on 11 control points) but values are higher for fan-based tongue splines (based on 42 control points).

Note: NINFL is related to a similar reference-free metric, the Modified Curvature Index (MCI) described in Dawson, Tiede and Whalen (2016), which computes the integral of

unsigned filtered curvature, but Preston et al found that the NINFL metric outperformed MCI in distinguishing between targeted groups.

Reference - Preston, J. L., McCabe, P., Tiede, M., & Whalen, D. H. (2019). Tongue shapes for rhotics in school-age children with and without residual speech errors. *Clinical Linguistics & Phonetics*, *33*(4), 334-348.

Menger number



The Menger curvature of a triple of points along a curve is the reciprocal of the radius of the circle that passes through the three points. It is named after the Austrian-American mathematician Karl Menger.

Defined as – Menger curvature(A, B,C)

=4*triangleArea/(length(AB)*length(BC)*length(CA))

for points A, B and C on the curve

The tongue curve is represented by a series of xy points i= 1 to 100. A Menger curvature value is calculated for each point as

for i=11 to 90 Menger curvature($Point_{i-10}$, $Point_i$, $Point_{i+10}$)

for i=2 to 10 Menger curvature($Point_1$, $Point_i$, $Point_{i+10}$)

for i=91 to 99 Menger curvature($Point_{i-10}$, $Point_i$, $Point_{100}$)

The array of Menger values is smoothed then all the inflection points (where the sign of the Menger value changes) are found.

Finally the peak Menger values between each inflection point are counted if the value is grater than a threshold (0.05).

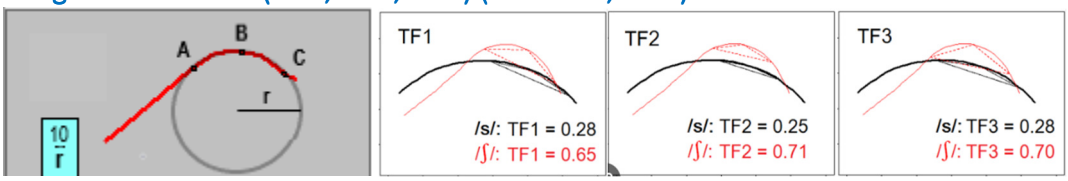
The results are very similar to the NINFL value

Typical value range – positive integer values. If the tongue curve is smooth then values should be in the range 0 to 5.

Weaknesses – Similar weakness to NINFL as it depends on threshold values to determine if an inflection should be counted or not.

Reference – Although the Menger curvature calculation is widely reported, the above algorithm for counting the number of inflections is not reported anywhere else. It is offered here as a option but provides no great advantage over NINFL.

Tongue Front Index (TF 1, TF 2, TF 3) (Zharkova,2020)



Defined as – 10/(radius of circle whose circumference passes through ABC)

TF1 points as % distance along the curve from posterior A=50% B=72.5% C=95%

TF2 points as % distance along the curve from posterior A=50% B=66.6% C=83.4%

TF3 points as % distance along the curve from posterior A=43.2% B=66.6% C=90%

Typical value range – 0 to 100 Higher values indicate tighter curvature.

Weaknesses – Dependent on end points of curve and not generalisable.

Reference - Zharkova, N. (2021). Development of the voiceless sibilant fricative contrast in three-year-olds: an ultrasound and acoustic study. *Journal of Child Language*, *48*(6), 1126-1149.

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