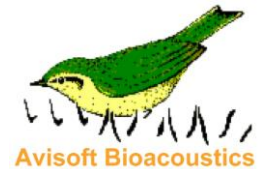


(Automatically) Classifying (Bat) Sound Recordings



This document describes how large numbers of .wav files (that have been produced by automated acoustic monitoring systems) can automatically be scanned for specific calls or vocalizations. There are generally two different approaches: multiparametric or template-based procedures. For further details see also the descriptions of the corresponding commands in the manual or the online help system (**Help...** buttons on the dialog boxes).

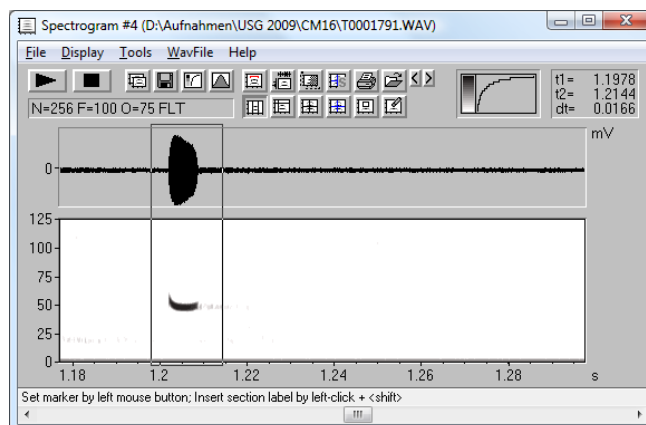
1. Template-based Approaches

There are two different option options for the template-based approach. Correlating either the entire spectrogram images or just the (fundamental) frequency contours:

1.1 Spectrogram image cross-correlation (using Spectrogram Templates)

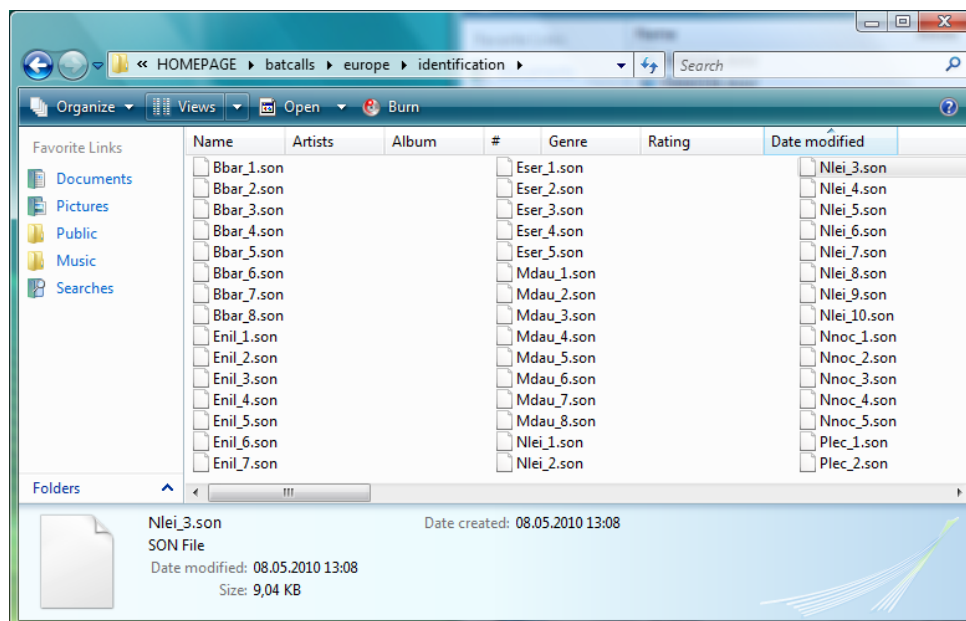
The spectrogram cross-correlation first requires to save the spectrograms of the template calls as .son files, which can be done as follows:

Create a spectrogram of the reference recording (select appropriate spectrogram parameters in order to get meaningful spectrograms) and select the desired call by using the marker cursor:



Then save this subsection from the spectrogram window command File/Save Spectrogram (ASCII/ Binary...) and select the "Save as type" "Binary File (*.SON)". If there are any disturbing noise components, echoes or vocalizations of other species, these should be removed before by using the eraser cursor.

This must be done for all call classes and preferably for all the different call variants that should be assigned to the same class. Template spectrograms that belong to the same class must receive the same filename prefix (filename format: classname_xxxx.son), which must be terminated by an underscore character ("_") followed by the individual name of the file (this could be an index). So, a typical template spectrogram repertoire would look like this:



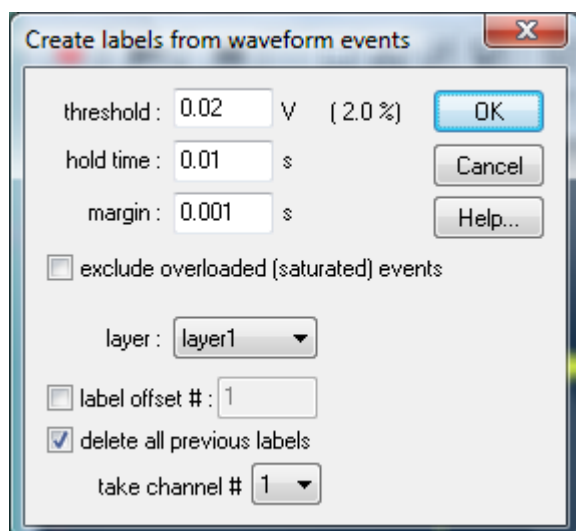
In case there were frequent undesired signals such as insect noise, it might also be useful to additionally include templates for these unwanted signals, which would increase the success of the final classification procedure.

Once the template spectrograms have been prepared, the classification tool can be set up (the settings should first be optimized interactively). There are two different classification tools:

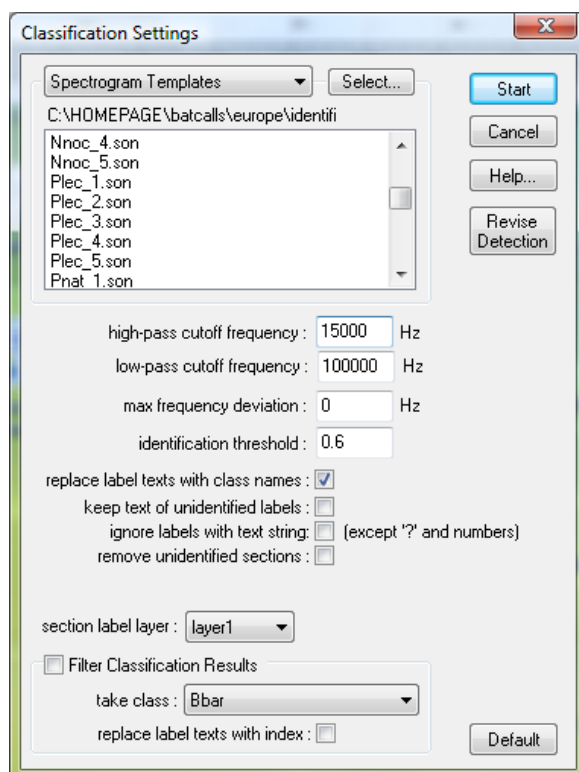
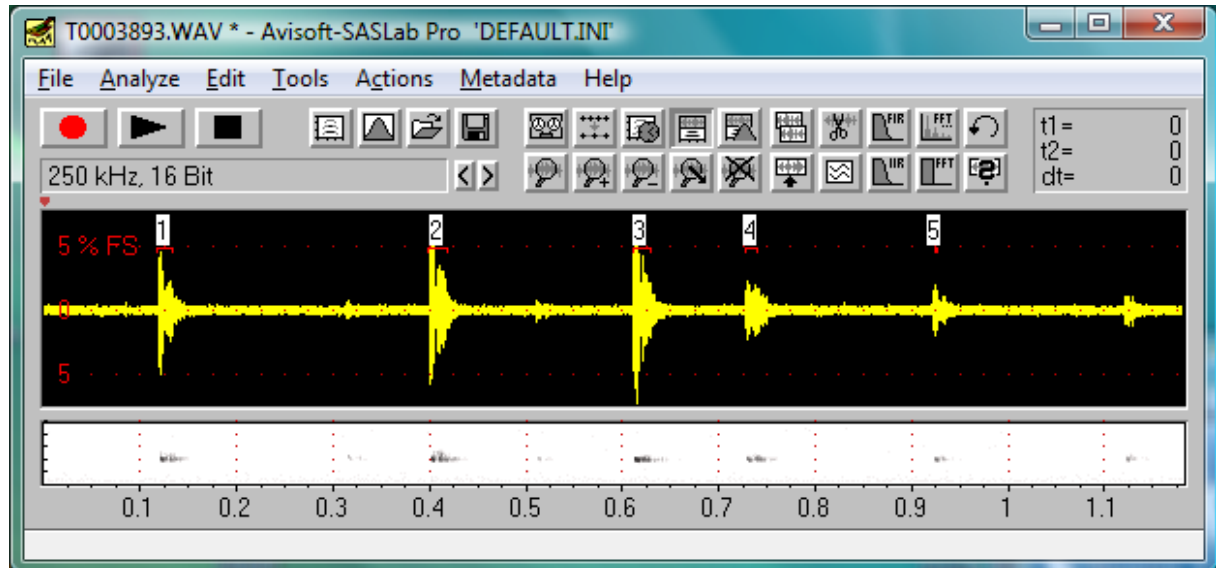
1.1.1 Event-based analysis

The event-based analysis option (command **Analyze/Specials/Detect and classify waveform events...**) limits the spectrogram-cross correlation to sound events that exceed a predefined amplitude threshold, which will execute faster than the continuous analysis option.

The software first creates section labels that represent the individual sound events (calls). The detection is based on a simple threshold comparison:



The threshold, hold time and margin settings should be optimized according to the specific properties of the sound events. Because the error rate will increase with soft low-quality (distant) bat calls, it is recommended to exclude low-level calls from the automatic classification procedure. This can simply be accomplished by setting the threshold to a higher level.



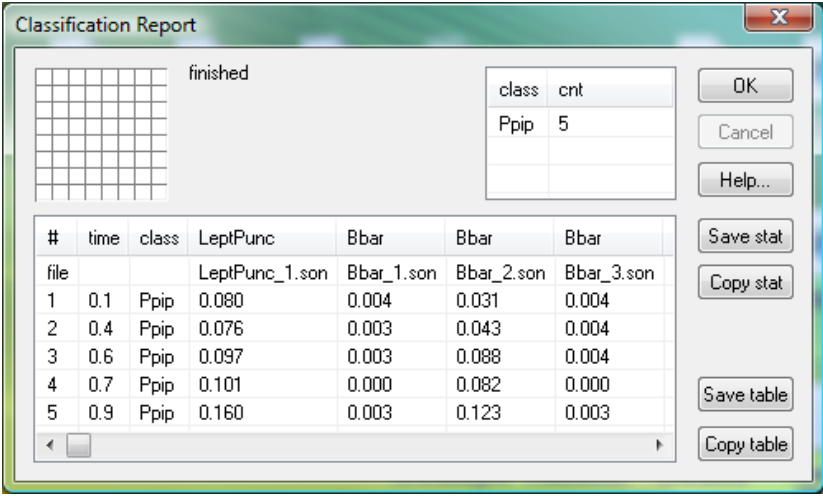
The best settings can be found by repeatedly trying different settings (clicking at the button "Revise Detection"). Once the relevant calls are properly detected, the template spectrograms should be selected and classification settings should be adjusted. The **cutoff frequencies** define which parts of the spectrogram will be analyzed (signal components outside of that range will be excluded from the cross-correlation algorithm). In order to tolerate slight frequency shifts between the templates and the calls to be classified, the

correlation can be repeated at different frequency shifts. The maximum frequency shift that should be allowed can be entered (in Hz) into the edit field titled **max frequency deviation**

The **identification threshold** determines the minimum correlation coefficient that a comparison must provide in order to enable the assignment to one of the predefined classes.

The option **max duration difference between template and section label** allows to limit the template comparison to templates having a duration similar to the duration of the section label to be examined. This can help prevent miss-classifications due to high correlation values between long complex sound elements that would otherwise produce high correlation values when compared to short and less complex templates. The maximum duration difference threshold [unit **ms**] should be selected according to the typical durations (it should be typically in the range of 1 to 2 ms for applications in bats). In order to make it work, it is necessary that the total duration of each template spectrogram reflects the duration of the sound element in it (there should be uniform margins) and that the section labels to be examined exhibit margins similar to those in the templates.

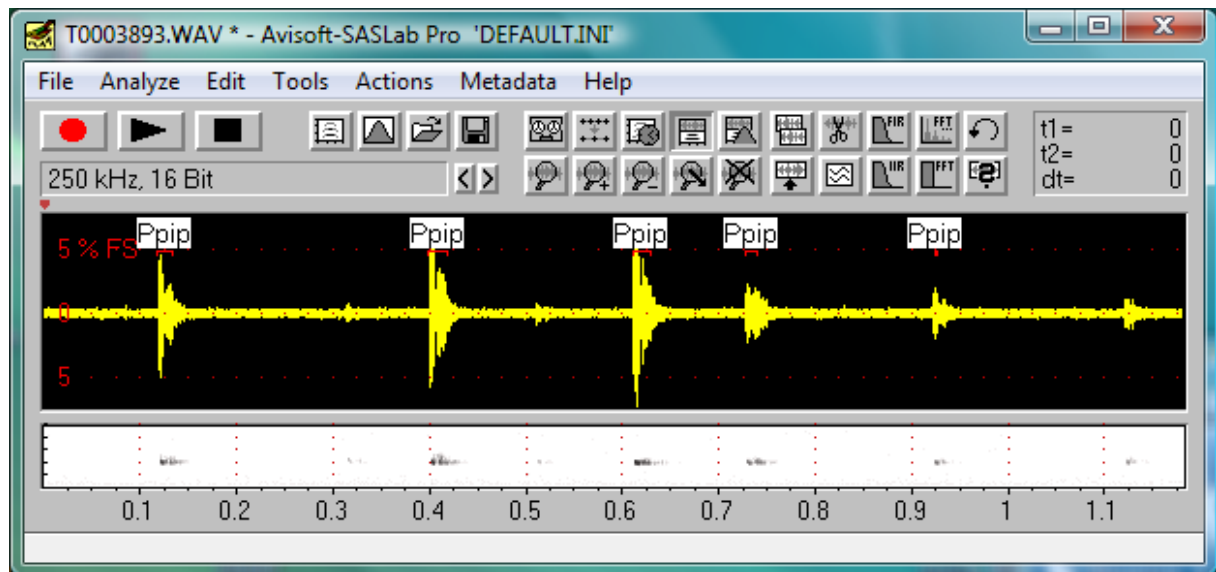
Click at the **Start** button to execute the classification procedure.



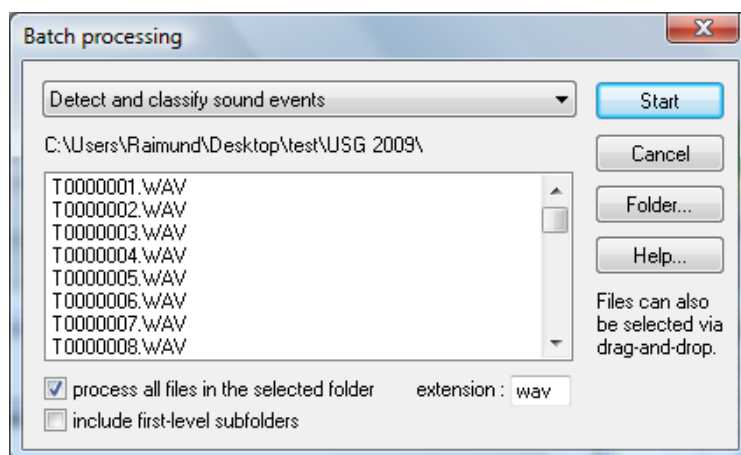
The image shows a 'Classification Report' dialog box. It contains a grid on the left, a 'finished' status indicator, a small table with 'class' and 'cnt' columns, and a larger table with columns for file, time, class, and various correlation coefficients. On the right side, there are buttons for 'OK', 'Cancel', 'Help...', 'Save stat', 'Copy stat', 'Save table', and 'Copy table'.

#	time	class	LeptPunc	Bbar	Bbar	Bbar
file			LeptPunc_1.son	Bbar_1.son	Bbar_2.son	Bbar_3.son
1	0.1	Ppip	0.080	0.004	0.031	0.004
2	0.4	Ppip	0.076	0.003	0.043	0.004
3	0.6	Ppip	0.097	0.003	0.088	0.004
4	0.7	Ppip	0.101	0.000	0.082	0.000
5	0.9	Ppip	0.160	0.003	0.123	0.003

The classified elements will then be displayed as labels on the main window:



It is recommended to test the effectiveness of the settings and templates on a number of .wav files and further optimize the settings until the results are acceptable. Afterwards, the settings can be applied to a batch of files or entire folders by using the batch command **Tools/Batch processing > Detect and classify sound events**.



The detected classes will be displayed in a Class Count Statistics table that summarizes the results:

filename	Ppip	Ppyg	Pkuh	Mnat	Memi
T0000175.WAV					
T0000176.WAV					
T0000177.WAV					
T0000178.WAV					
T0000179.WAV					
T0000180.WAV					
T0000181.WAV					
T0000182.WAV					
total number	1	0	0	0	0

Alternatively, the batch commands **Tools/Batch processing > Detect, classify and save sound events** or **Sort files using template spectrograms (triggered CCF)** could be used, which will additionally copy the classified calls into new .wav files.

The latter option **Sort files using template spectrograms (triggered CCF)** will copy the files according to the detected classes in each file into separate class-specific subfolders.

1.1.2 Continuous analysis

The continuous analysis option (command **Analyze/Specials/Scan for template spectrogram patterns...**) performs the spectrogram-cross correlation continuously through the entire .wav file, which will take longer but can better handle low-dynamic range recordings. Otherwise, the usage of the command is similar to paragraph 1.1.1

The corresponding batch commands are **Scan for template spectrogram patterns**, **Scan for template spectrogram patterns and save** and **Sort files using template spectrograms (continuous CCF)**.

The latter option **Sort files using template spectrograms (continuous CCF)** will copy the files according to the detected classes in each file into separate class-specific subfolders.

1.2 Frequency contour cross-correlation (using Frequency Contour templates)

This option generally functions in the same way as the spectrogram cross-correlation method except that only the frequency contours are being compared. The frequency contour template files (extension “.ft”) must be saved from the Graphic Synthesizer (use the spectrogram window command **Tools/Scan frequency contour and amplitude envelope...** to scan natural calls).

Execute the command **Analyze/Specials/Detect and classify waveform events...** and select the option “**Frequency Contour Templates**”) from the **Classification Settings** dialog box. The corresponding batch command is also **Tools/Batch processing > Detect and classify sound events**.

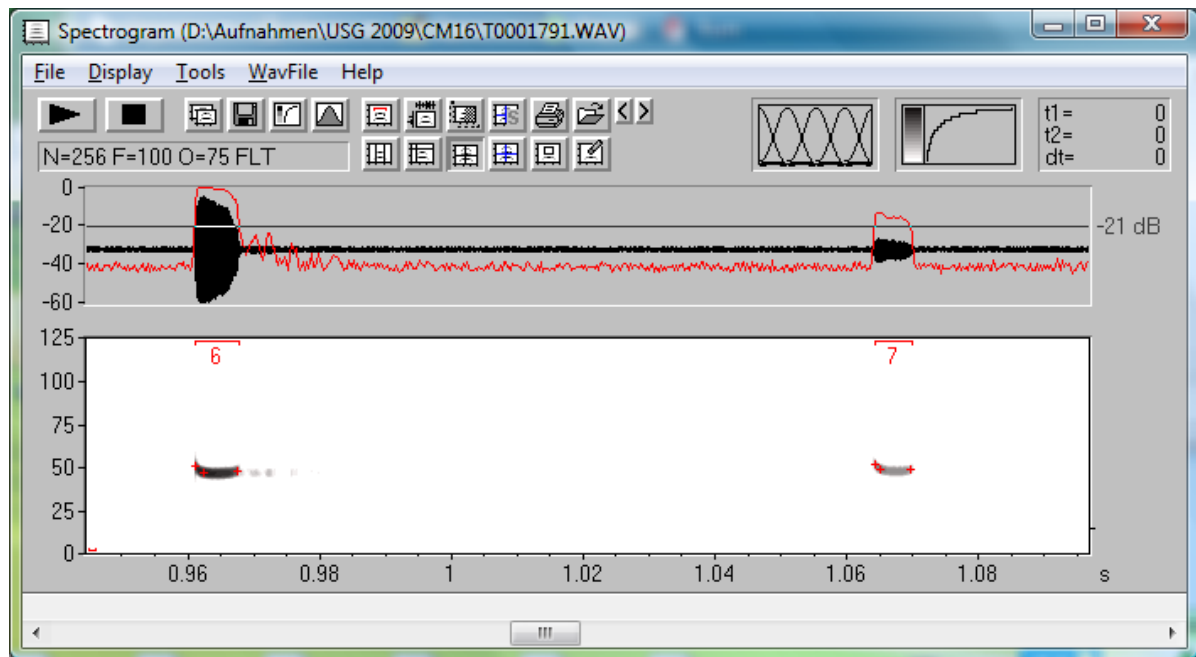
2. Multi-parametric Approach

The multi-parametric approach employs the Automatic Parameter Measurements tool of the spectrogram window.

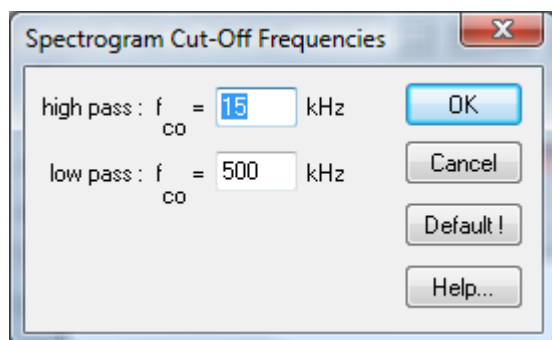
The individual call classes must first be set up from the spectrogram window command **Tools/Automatic parameter measurements/Automatic parameter measurements setup...**

The screenshot shows the 'Automatic Parameter Measurements setup' dialog box. Several settings are highlighted with orange circles:

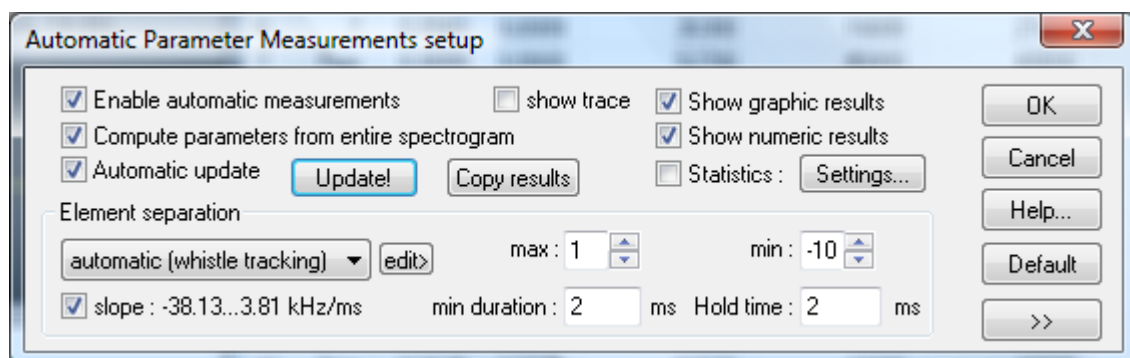
- Element separation:** The dropdown menu is set to 'automatic (whistle tracking)'. The 'max' value is 1 and the 'min' value is -10. The 'slope' is set to -38.13...3.81 kHz/ms. The 'min duration' is 2 ms and the 'Hold time' is 2 ms.
- Temporal parameters:** 'Duration of element' and 'Interval between elements' are checked.
- Sub-elements:** 'Number of elements' and 'Element rate' are unchecked. The 'Hold time' is 5 ms.
- Waveform parameters:** 'rms' and 'dB' are checked. 'energy' and 'peak-to-peak ampl.' are unchecked.
- Spectrum-based parameters:** 'Peak frequency' and 'Peak amplitude' are checked. The 'interpol.' dropdown is set to 'none'. 'Fundamental freq.' is 0 Hz. 'Min frequency' and 'Max frequency' are unchecked. 'Bandwidth' is checked with 'total' selected. 'Quartiles' and 'Entropy' are unchecked. 'Harmonic-to-noise ratio' is 10 bins. 'Number of peaks above' is -20 dB. 'Frequencies of peaks' and 'Amplitudes of peaks' are unchecked. 'Hysteresis for peak detection' is 10 dB. 'uniform parameters for all locations' is checked.
- Locations of measurements:** 'Start of element' and 'End of element' are checked. 'Centre of element' and 'Maximum amplitude of element' are unchecked. 'Mean' and 'Max' are unchecked. 'Min param. of entire element' and 'Max param. of entire element' are unchecked. 'Mean param. of entire element' and 'Relative stddev of entire element' are unchecked. 'Regular intervals of' is 100 ms. 'max entries' is 20. 'Regular intervals of duration/' is 4.
- Post filter on elements:** 'enable' is unchecked. 'min duration' is 100 ms. 'max entropy' is 0.3. 'add filename' is unchecked.
- Classification:** 'enable' is checked. The 'Settings...' button is highlighted.



In order to remove (low-frequency) disturbing noise, it might additionally be necessary to limit the frequency range of the automated measurements to a limited frequency interval. This can be done from the spectrogram window command **Display/Cut-Off-Frequencies...**

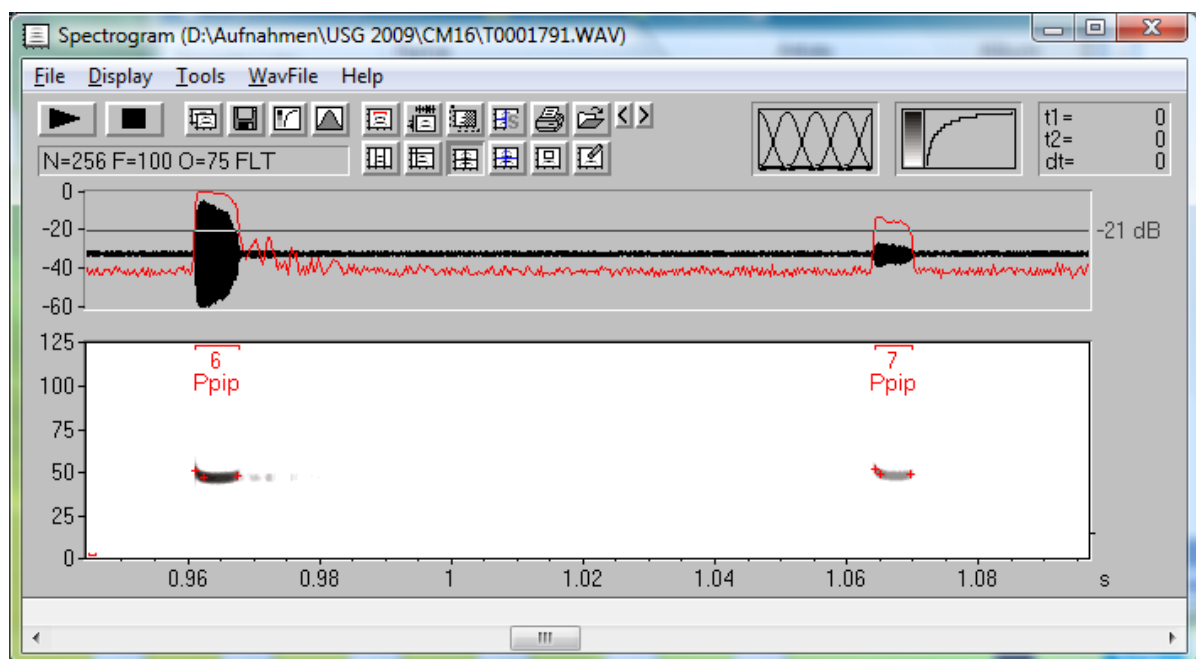
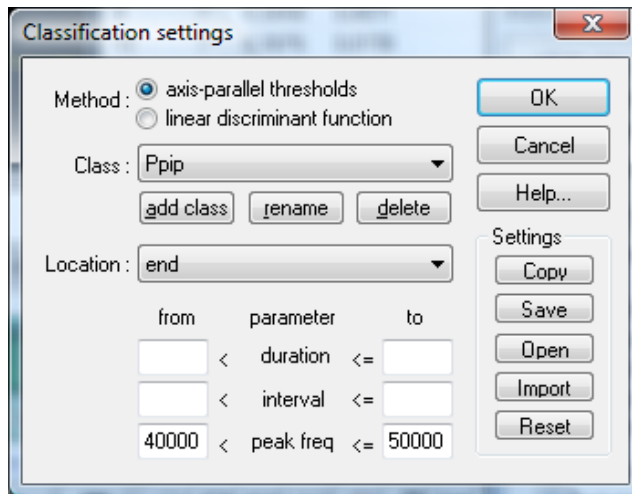


Depending on the structure and quality of the recordings, it is very important to adjust the “Element separation” properly in order to accomplish the best possible results. For bat call classifications in recordings with insect and environmental noise, the option “**automatic (whistle tracking)**” might provide the best results:



Once the time and frequency parameters that are suited to discriminate the various call categories have been selected (the description of the Automatic Parameter Measurements tool can be found in the manual), the axis-parallel thresholds that define the individual

classes must be set up for each desired call class from the **Classification > Settings** button on the bottom of the **Automatic parameter measurements setup** dialog box:



The settings should first be tested on a number of .wav files, which then can be applied to a batch of files or an entire folder by using the batch commands “**Automatic parameter measurements**”, “**Automatic parameter measurements; save labels**” and “**Sort files using APM classes**”.

The latter option **Sort files using APM classes** will copy the files according to the detected classes in each file into separate class-specific subfolders.

The above described batch processing functionality can also be applied in real-time by using the alternative command **Tools/Real-time processing...**

There is a similar tool in the Avisoft-RECORDER software (command **Options/Automated call parameter measurements...**) that can perform some basic classification tasks in real-time or on previously recorded .wav files (Device : **WAV File** or **WAV File Folder**)

3. Visual Approach

In case the structure of the vocalizations to be examined was too complex or if the signal-to-noise ratio of the recordings was poor, then the automated analysis might not work satisfyingly. It is then required to review the data manually.

3.1 Manually browsing through the files in a folder

The keyboard shortcuts <Ctrl+N> and <Ctrl+B> of the commands **File/Specials/Next file** and **File/Specials/Previous file** allow to quickly move through the files in a folder. Use the command **File/Specials/Previous/next file command settings....** to select the desired file order.

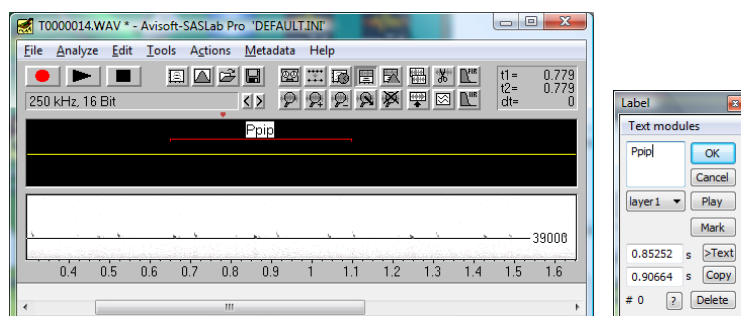
In order to better recognize short calls in long .wav files on the main window overview display, it could be useful to disable the “**fast**” option on the “Analyze”/“Overview Parameters...” dialog box.

Sometimes it may also be useful to limit the initial view to the first few hundred milliseconds, which can be accomplished by checking the option “**limit the initial view to the first xxx seconds**” and entering the desired duration on the “File”/“File Open Settings...” dialog box. Additionally activating the option “**do not create a temporary copy (limited undo!)**” will accelerate the processing speed. In combination with the above described keyboard shortcuts <Ctrl+N> and <Ctrl+B> it is possible to browse extremely fast (beyond 30 files / sec, which is faster than human perception...) through the .wav files in a folder.

While manually moving through the files it would also be possible to add a number of different annotations:

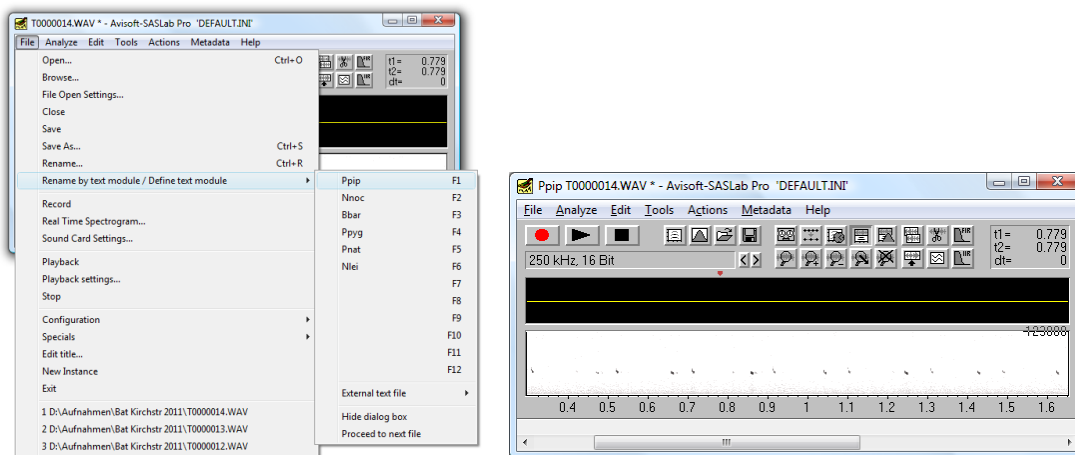
3.1.1 Adding labels

by pressing the Shift key, left-clicking and dragging. Right-click at the newly created section label to enter a text string.

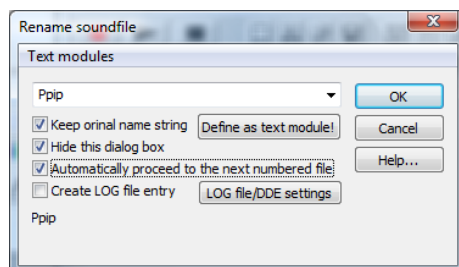


3.1.2 Renaming .wav files

by using species name templates. Define the species names from the command **File/Rename by text module / Define text module:**

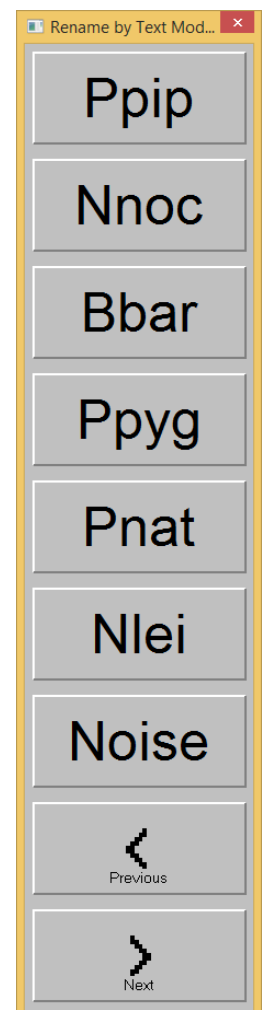
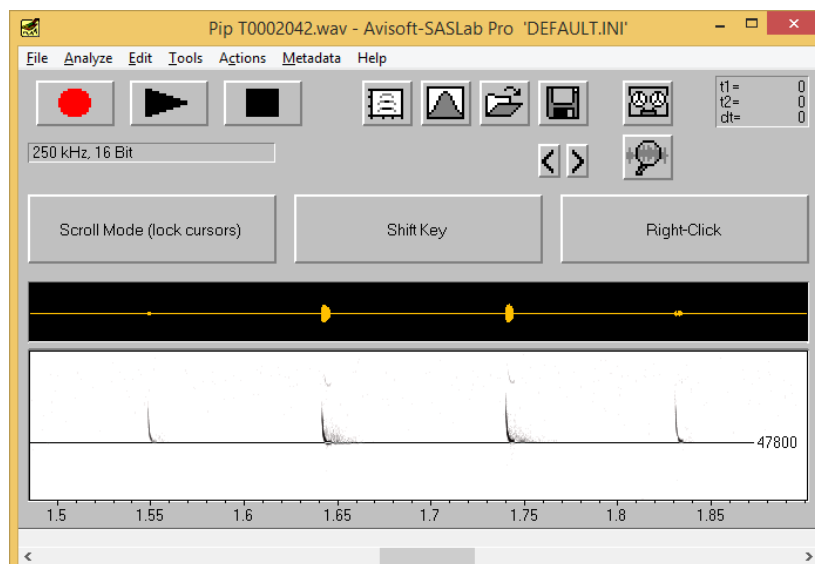


Once the species names have been defined, activate the options **Keep original name string**, **Hide this dialog box** and **Automatically proceed to the next numbered file**. The filename prefixes can then be added simply by pressing the associated function keys.



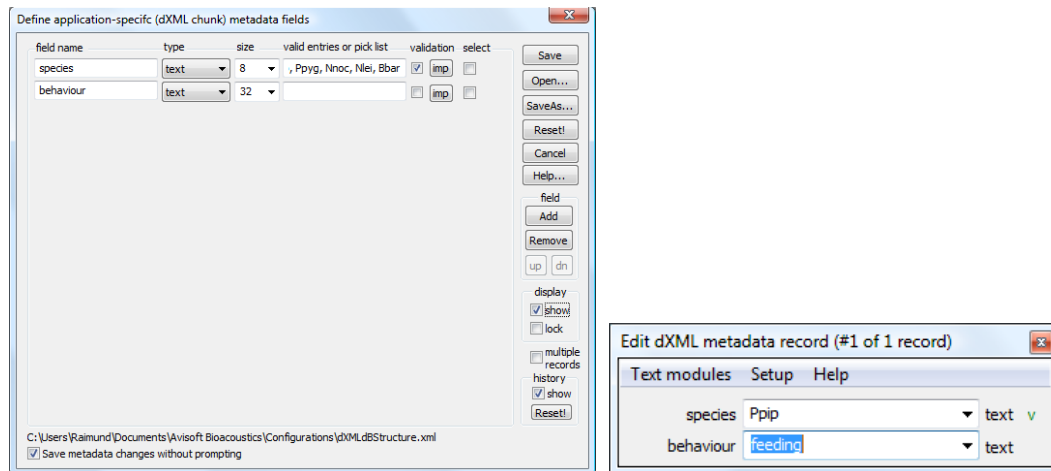
The defined text modules can also be displayed visually on a separate touch panel window, which makes it possible to easily use the rename functionality on a tablet PC. This mode of operation can be activated by checking the option **“File”/“Rename by text module / Define text module” / “Show text modules on touch panel”**.

The operation of the software on a tablet PC can also be simplified by using the Touch Screen Optimizations from the command **“Tools”/“Touch Screen Optimizations...”**



3.1.3 Adding metadata

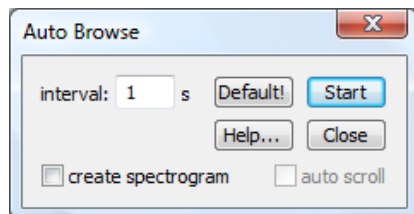
by using the command **Metadata/Define database structure:**



These metadata sets are stored directly into the .wav files and can subsequently be processed through the command **Metadata/Create virtual metabase...** An integrated query command then allows to select .wav files that meet certain criteria.

3.2 Automatically browsing through the files in a folder

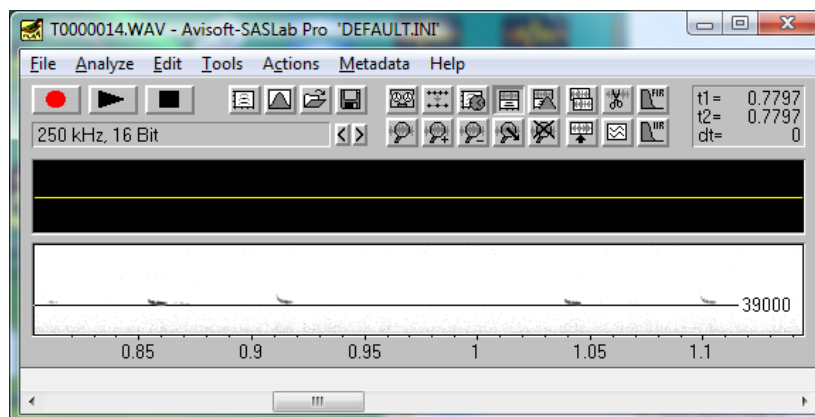
The command **File/Specials/Auto Browse** executes the command **File/Specials/Next file** at the specified **interval**. Click at the **Start** button to start the slide show and click at **Stop** to stop it. The **create spectrogram** option corresponds to the command *Actions/On new soundfile/Create Spectrogram*, which will automatically create a spectrogram of each file. The **auto scroll** option will additionally launch the spectrogram window command *Auto Scroll (Tools/Scroll/auto scroll)*, which allows to move step by step through the entire spectrogram of each sound file.



The Start/Stop button can alternatively also be operated by pressing the space bar.

In case the .wav file names do not contain running numbers, the option “**alphabetic order**” could be selected from the command “**File”/”Specials”/”Previous/next file command settings...**”.

Use the command **Analyze/Frequency cursor** to activate a horizontal cursor for estimating frequencies:

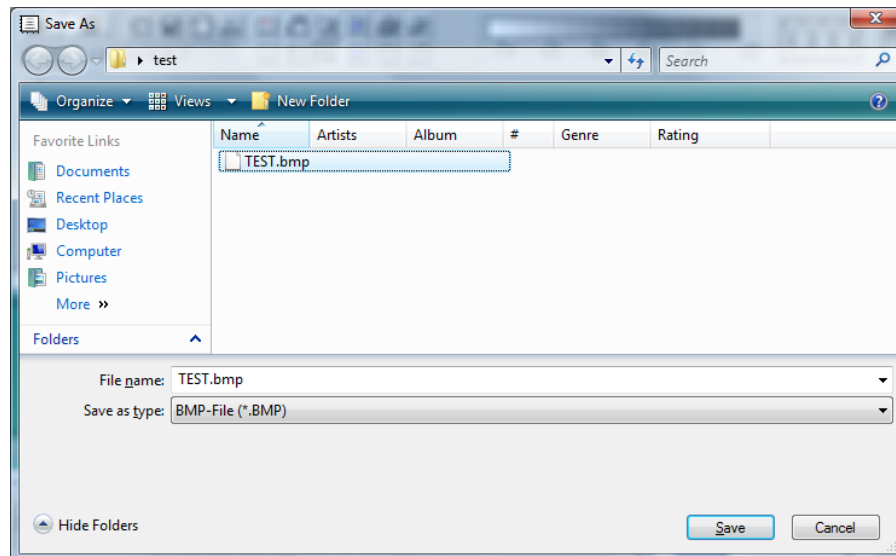


3.3 Creating Spectrogram Images in a batch procedure

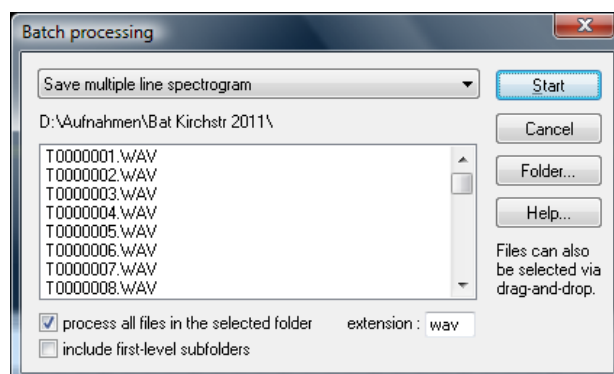
In order to get a quick overview, it might be useful to have spectrogram overview images of the recordings, which could be created by using a batch command in SASLab Pro.

In order to get it work, a number of settings must be adjusted as follows:

1. Create a spectrogram and navigate to the spectrogram window command **File/Save Entire Spectrogram Image...** and select either the **BMP** or **TIF** file format. Click at **Save** in order to save this selection:



2. Navigate to the command **File/Export Parameters...** and activate the option **create multiple (page) files** at the bottom of the dialog box.
3. Go to the main window command **Tools/Batch Processing...**, select the option **Save multiple line spectrogram** and activate **process all files in the selected folder**, then select the desired folder that contains the .wav files (by drag&drop or through the **Folder** button) and click at **Start**. It might now take some time until all the spectrogram images have been created.



4. Navigate to the folder that contains the original .wav files to watch the created spectrograms. On Windows Vista / Windows 7 select the **Extra Large Icons** option from the **Views** menu:

