(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 dilaog 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:

Organize ▼	DMEPAGE ► ba Views ▼ 📾	otcalls 🕨 euro Open 👻 (ope ▶ identifi 8) Burn	cation 🕨	•	4 € Search		× ۵
Favorite Links Documents F Pictures Public Music Searches	Name Bbar_1.so Bbar_2.so Bbar_3.so Bbar_4.so Bbar_4.so Bbar_5.so Bbar_5.so Bbar_5.so Bbar_5.so Chil_1.son Chil_2.son Chil_3.son Chil_3.son Chil_5.son Chil	Artists	Album	# Ge Eser_1.s Eser_2.s Eser_3.s Eser_4.s Eser_5.s Mdau_1 Mdau_2 Mdau_2 Mdau_2 Mdau_2 Mdau_2 Mdau_2 Mdau_2 Mdau_2 Mdau_2 Mdau_1 Mdau_2 Mdau_2 Mdau_2 Mdau_1 Mdau_2 Mdau_2 Mdau_2	nre on on on .son .son .son .son .son .son	Rating	Date modified Niei 3.son Niei 4.son Niei 5.son Niei 5.son Niei 5.son Niei 9.son Niei 9.son Niei 9.son Niei 10.son Nnoc 1.son Nnoc 2.son Nnoc 4.son Nnoc 4.son Piec 1.son Piec 2.son	
Folders Nile SON Dat	i_3.son N File re modified: 08.0 Size: 9,04	111 15.2010 13:08 1 KB	Date c	reated: 08.05.20	10 13:08			•

In case there were frequent undesired signals such 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:

Create labels from waveform events							
threshold :	0.02	۷	(2.0 %)	ОК			
hold time :	0.01	s		Cancel			
margin :	0.001	s		Help			
exclude overloaded (saturated) events							
layer : <mark>layer1 ▼</mark>							
🔲 label offset # : 1							
delete all previous labels							
take ch	annel # [1	•]				

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.



Classification Settings	×
Spectrogram Templates Select C:\HOMEPAGE\batcalls\europe\identifi Nnoc_4.son Nnoc_5.son Plec_1.son Plec_2.son Plec_2.son Plec_4.son Plec_5.son Pnat 1.son	Start Cancel Help Revise Detection
high-pass cutoff frequency : 15000 Hz low-pass cutoff frequency : 100000 Hz max frequency deviation : 0 Hz identification threshold : 0.6 replace label texts with class names : ✔ keep text of unidentified labels : ignore labels with text string: (except '?' and remove unidentified sections :	numbers)
section label layer : layer1 Filter Classification Results take class : Bbar replace label texts with index :	Default

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.

Classifi	cation	Repor	t					×
	finished						cnt 5	OK Cancel Help
#	time	class	LeptPunc	Bbar	Bba	r	Bbar	Save stat
file			LeptPunc_1.son	Bbar_1.son	Bba	r_2.son	Bbar_3.son	Copu stat
1	0.1	Ppip	0.080	0.004	0.03	31	0.004	Copy stat
2	0.4	Ppip	0.076	0.003	0.04	13	0.004	
3	0.6	Ppip	0.097	0.003	0.08	38	0.004	
4	0.7	Ppip	0.101	0.000	0.08	32	0.000	Save table
5	0.9	Ppip	0.160	0.003	0.123		0.003	
•							4	Copy table

Click at the Start button to execute the classification procedure.

_ **D** X T0003893.WAV * - Avisoft-SASLab Pro 'DEFAULT.INI' File Analyze Tools Actions Metadata Help Edit 🖾 🎞 🖻 🗉 🖾 🕷 🎗 🗐 🛆 🖻 日 t1 = 000 **D**eib t2= 250 kHz, 16 Bit < > dt= Ppip Ppip Ppip Ppip Ppip ili. 1225 with 1 1000.3 0.5 0.7 0.2 0.8 0.1 0.4 0.6 0.9 1.1 1

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**.

Batch processing	×
Detect and classify sound events	Start
C:\Users\Raimund\Desktop\test\USG 2009\	Cancel
T0000001.WAV T0000002.WAV T0000003.WAV T0000004.WAV T0000005.WAV T0000005.WAV T0000006.WAV T0000007.WAV	Folder Help Files can also be selected via
T0000008.WAV Image: process all files in the selected folder Image: process all files in the selected folder Image: process all files in the selected folder Image: process all files in the selected folder	drag-and-drop.

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

filename	Ppip	Ppyg	Pkuh	Mnat	Mema	*	OK
T0000175.WAV							Help
T0000176.WAV							
T0000177.WAV							
T0000178.WAV							
T0000179.WAV							
T0000180.WAV							
T0000181.WAV							
T0000182.WAV							Save tab
total number	1	0	0	0	0	Ŧ	

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*..:

Automatic Parameter Measurements setup	8
 Enable automatic measurements show trace Show graphic results Compute parameters from entire spectrogram Show numeric results Automatic update Update! Copy results Statistics : Settings Element separation automatic (whistle tracking) edits max : 1 min : -10 min : -10	OK Cancel Help Default << Group anal. enable 100 ms Settings
Spectrum-based parameters Locations of measurements more Peak frequency interpol.: none Locations of measurements more Peak amplitude V Stat of element 0 ms Fundamental freq. 0 Hz ACF V End of element 0 ms Min frequency Threshold: -20 dB Cent e of element 0 ms Max frequency Threshold: -20 dB V Maxmum amplitude of element Bandwidth V total -10 dB Mean spectrum of entire element	Post filter on elements in enable min duration: 100 ms max entropy: 0.3
 Entropy Harmonic-to-noise ratio average: 10 bins Number of peaks above : -20 - dB Frequencies of peaks Max param. of entire element Regular intervals of 100 ms 	add filename
Amplitudes of peaks max peak entries : 5 max entries : 20 Hysteresis for peak detection : 10 ♣ dB Regular intervals of duration/ 4 Image: State of the stat	Classification enable Settings
Derived parameters : Settings	Response

Spectrogram (D:\Aufnahmen\USG 2009\CM16\T0001791.WAV)	
<u>F</u> ile <u>D</u> isplay <u>T</u> ools <u>W</u> avFile Help	
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0-	,
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50-	<u> </u>
25-	
0.96 0.98 1 1.02	1.04 1.06 1.08 s
4	

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...*

Spectrogram Cut-Off Frequencies	×
high pass : $f = \frac{15}{co}$ kHz	ОК
low pass : f = 500 kHz	Cancel
	Default !
	Help

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:

Automatic Parameter Measurements setup	×
 Enable automatic measurements show trace Show graphic results Compute parameters from entire spectrogram Show numeric results Automatic update Update! Copy results Statistics : Settings 	OK Cancel
automatic (whistle tracking) edit> max : 1 min : -10 Image: slope : -38.133.81 kHz/ms min duration : 2 ms Hold time : 2 ms	Default >>

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:

Classification settings	X	
Method : axis-parallel thresholds linear discriminant function Class : Ppip add class rename delete Location : end from parameter to from parameter to < duration <= < interval <= 40000 < peak freq <= 50000	OK Cancel Help Settings Copy Save Open Import Reset	
Spectrogram (D:\Aufnahmen\USG 2009\CM1	L6\T0001791.WAV)	
File Display Tools WavFile Help		
	<u>. 6 8 8 1</u>	t1=

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		00 🖸 🖻	1 👛 🛄 🖪	음음의	∇		/~~ I	t1 = +2 =	0
N=256 F=1	00 O=75 FLT	. II	日田田田		<u> </u>	LAA [/	dt=	ŏ
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-60 -									
125								_	
100-	Ppip					Ppip			
75-									
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50-	the second se					A			
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0		·			104	1 00	1 00		
	0.96	0.98	1	1.02	1.04	1.06	1.08	S	
4				III					•
	_						_		

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 realtime 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 signalto-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:**

			00 N
T0000014.WAV * - Avisoft-SASLab Pro 'DEFAULT.INI'			×
ile Analyze Edit Tools Actions Metadata Help			
Open	Ctrl+O	🖽 🗶 🕅 ti= 0.	779
Browse			779
File Open Settings			
Close			
Save			
Save As	Ctrl+S		
Rename	Ctrl+R		
Rename by text module / Define text module	•	Ppip	F1
Record		Nnoc	F2
Real Time Spectrogram		Bbar	F3
Sound Card Settings		Ppyg	F4
		Pnat	F5
Playback		Nlei	F6
Playback settings			F7
Stop			F8
Configuration	•		F9
Specials	•		F10
Edit title			F11
New Instance			F12
Exit		External text file	
1 D:\Aufnahmen\Bat Kirchstr 2011\T0000014.WAV		I fishe states in term	
2 D:\Aufnahmen\Bat Kirchstr 2011\T0000013.WAV		Proceed to peet file	
3 D:\Aufnahmen\Bat Kirchstr 2011\T0000012 WAV		Proceed to next file	

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

Rename so <mark>un</mark> dfile Text modules		
Ppip	•	ОК
 Keep orinal name string Hide this dialog box Automatically proceed to Create LOG file entry 	Define as text module!	Cancel Help
Ppip	LOG TIE/DDE settings	

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**..."

Pip T000	02042.wav - Avisoft-SASLab Pro 'DEFAULT.INI'	- 🗆 ×
<u>File Analyze Edit T</u> ools A <u>c</u> tions	<u>M</u> etadata Help	
		t1= 0 t2= 0
250 kHz, 16 Bit		
Scroll Mode (lock cursors)	Shift Key	Right-Click
	·	
		47800
		1.85



3.1.3 Adding metadata

by using the command Metadata/Define database structure:

eld name	type	size	valid entries or pick list	validation sele	ct Saus				
species	text	- 8 -	, Ppyg, Nnoc, Nlei, Bbar	📝 imp 📃	Save				
oehaviour	text	• 32 •		imp 🕅	Open				
					SaveAs				
					Reset!				
					Cancel				
					Help				
					field				
					Add				
					Remove				
					up dn				
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					- multiple	Edit dXML metad	data record (#1 of 1 record)		
					records	Text modules	Setup Help		
					▼ show			_	
					Reset!	species	Ppip	 text 	t

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.

Auto Browse
interval: 1 s Default! Start
Help Close
Create spectrogram auto scroll

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 horiziontal cursor for estimating frequencies:

🛃 T0000014.WAV - A	visoft-SASLab Pro	DEFAULT.	INI'			
<u>F</u> ile <u>A</u> nalyze <u>E</u> dit	<u>T</u> ools A <u>c</u> tions	<u>M</u> etadata	Help			
			III 🐼 🖽		t1= t2=	0.7797
250 kHz, 16 Bit		<>	<u> </u>	🎘 🏝 🖾 🐨	dt=	0
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ni da kale ana mala sa kale a	ana ana isara isa	ana ana				- 39000
0.85	0.9	0.95	1	1.05	1.1	
4		_				+

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:

Save As		ALC I	38.86	42				×	
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🌗 Organize 👻 🏭	🖣 Organize 🔻 🏢 Views 💌 📑 New Folder 🛛 🕖								
Favorite Links		Name	Artists	Album	#	Genre	Rating		
Documents		TEST.bmp							
🖳 Recent Places									
E Desktop									
🖳 Computer									
Pictures									
More »									
Folders	^								
File <u>n</u> ame:	TEST	.bmp						-	
Save as <u>t</u> ype:	BMP-	File (*.BMP)						•	
) Hide Folders							<u>S</u> ave	Cancel	

- 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.

Batch processing		x
Save multiple line spectrogram	•	<u>S</u> tart
D:\Aufnahmen\Bat Kirchstr 2011\		Cancel
T0000001.WAV		
T0000002.WAV		Folder
T0000003.WAV		
T0000004.WAV		Help
T0000005.WAV		<u> </u>
T0000006.WAV		Files can also
T0000007.WAV		be selected via
T0000008.WAV	*	drag-and-drop.
process all files in the selected folder	extension : way	
include first-level subfolders		
include first-level subfolders		

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:

