Package 'baRulho'

Type Package

Title Quantifying habitat-induced acoustic signal degradation

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Description Quantifying habitat-induced degradation of (animal) acoustic signals.

License GPL (>= 2)

Imports pbapply, warbleR, utils, stats, seewave, tuneR

Depends R (>= 3.2.1)

LazyData TRUE

URL https://github.com/maRce10/baRulho

BugReports https://github.com/maRce10/baRulho/issues

NeedsCompilation no

Suggests ggplot2, knitr

VignetteBuilder knitr

RoxygenNote 7.0.2

Repository CRAN

Language en-US

R topics documented:

atmospheric_attenuation

Measure atmospheric attenuation and absorption of sound

Description

`atmospheric_attenuation` measures atmospheric attenuation and atmospheric absorption of signals referenced in an extended selection table.

Usage

```
atmospheric_attenuation(f, temp, RH, p = 101325,
formula = 1, spi = NULL, dist = NULL)
```

Arguments

f	numeric vector of length 1 with frequency (in Hertz).
temp	numeric vector of length 1 with frequency (in Celsius).
RH	numeric vector of length 1 with relative humidity
p	numeric vector of length 1 with ambient pressure in Pa (standard: 101325, default).
formula	1 = Bazley 1976, 2 = Rossing 2007 (p. 116, see details).
spi	numeric vector of length 1 with the initial sound pressure in Pa. Required for calculating atmospheric absorption. Default is `NULL`.
dist	numeric vector of length 1 with distance (m) over which a sound propagates. Required for calculating atmospheric absorption. Default is `NULL`.

Details

Calculate the atmospheric attenuation based on temperature, relative humidity, pressure and sound frequency. The function can applied to formulae based on:

- 1: default. As used by Bazley (1976), Sound absorption in air at frequencies up to 100 kHz. NPL acoustics report Ac 74.

- 2: as used by Rossing (2007), Handbook of Acoustics, Springer.

If 'spi' and 'dist' are supplied the function also returns the atmospheric absorption (in dB).

Value

Returns atmospheric attenuation (in dB/m) of sound based on supplied parameters. If 'spi' and 'dist' are supplied the function also returns atmospheric absorption (in dB).

Author(s)

Marcelo Araya-Salas (<marceloa27@gmail.com>)

References

Araya-Salas, M. (2019), baRulho: a R package to quantify habitat-induced degradation of (animal) acoustic signals. R package version 1.0.0

Examples

```
{
# load example data
data("playback_est")

#' # remove ambient selections
playback_est <- playback_est[playback_est$signal.type != "ambient", ]

# measure atmospheric attenuation formula 1
atmospheric_attenuation(f = 20000, temp = 20, RH = 90, p = 88000, formula = 1)
}
```

---

baRulho   *baRulho: quantifying habitat-induced acoustic signal degradation*

Description

'baRulho' is a package intended to quantify habitat-induced degradation of (animal) acoustic signals.

Details

The main features of the package are:

- Loops to apply tasks through acoustic signals referenced in an extended selection table
- The comparison of signals playback and re-recorded at different distances

Most functions allow the parallelization of tasks, which distributes the tasks among several processors to improve computational efficiency.

License: GPL (>= 2)

Author(s)

Marcelo Araya-Salas

Maintainer: Marcelo Araya-Salas (<marceloa27@gmail.com>)

---

blur_ratio   *Measure blur ratio in the time domain*

Description

blur_ratio measures blur ratio in signals referenced in an extended selection table.

Usage

```
blur_ratio(X, parallel = 1, pb = TRUE, method = 1, ssmooth = 200,
msmooth = NULL, output = "est", img = FALSE, res = 150, hop.size = 11.6, wl = NULL,
ovlp = 70, pal = reverse.gray.colors.2, collevels = seq(-60, 0, 5), dest.path = NULL)
```

Arguments

X	object of class 'selection_table', 'extended_selection_table' created by the function [selection_table](#) from the warbleR package. The object must include the following additional columns: 'signal.type', 'bottom.freq' and 'top.freq'.
parallel	Numeric vector of length 1. Controls whether parallel computing is applied by specifying the number of cores to be used. Default is 1 (i.e. no parallel computing).
pb	Logical argument to control if progress bar is shown. Default is TRUE.
method	Numeric vector of length 1 to indicate the 'experimental design' for measuring envelope correlation. Two methods are available:
	• 1: compare all signals with their counterpart that was recorded at the closest distance to source (e.g. compare a signal recorded at 5m, 10m and 15m with its counterpart recorded at 1m). This is the default method.
	• 2: compare all signals with their counterpart recorded at the distance immediately before (e.g. a signal recorded at 10m compared with the same signal recorded at 5m, then signal recorded at 15m compared with same signal recorded at 10m and so on).
ssmooth	Numeric vector of length 1 determining the length of the sliding window (in amplitude samples) used for a sum smooth for amplitude envelope calculation (used internally by [env](#)). Default is 200.
msmooth	Numeric vector of length 2 to smooth the amplitude envelope with a mean sliding window for amplitude envelope calculation. The first element is the window length (in number of amplitude values) and the second one the window overlap (used internally by [env](#)).

output	Character vector of length 1 to determine if an extended selection table ('est', default) or a list ("list") containing the extended selection table (first object in the list) and all (smoothed) wave envelopes (second object in the list) is returned. The envelope data can be used for plotting.
img	Logical argument to control if image files in 'jpeg' format containing the images being compared and the corresponding envelopes are produced. Default is no images (FALSE).
res	Numeric argument of length 1. Controls image resolution. Default is 150 (faster) although 300 - 400 is recommended for publication/presentation quality.
hop.size	A numeric vector of length 1 specifying the time window duration (in ms). Default is 11.6 ms, which is equivalent to 512 wl for 44.1 kHz sampling rate.
wl	A numeric vector of length 1 specifying the window length of the spectrogram, default is NULL. If supplied, 'hop.size' is ignored.
ovlp	Numeric vector of length 1 specifying the percent overlap between two consecutive windows, as in [spectro](). Only used when plotting. Default is 70. Applied to both spectra and spectrograms on image files.
pal	A color palette function to be used to assign colors in the plot, as in [spectro](). Default is reverse.gray.colors.2.
collevels	Numeric vector indicating a set of levels which are used to partition the amplitude range of the spectrogram (in dB) as in [spectro](). Default is seq(-60, 0, 5).
dest.path	Character string containing the directory path where the image files will be saved. If NULL (default) then the folder containing the sound files will be used instead.

Details

Blur ratio measures the degradation of sound as a function of the change in signal energy in the time domain as described by Dabelsteen et al (1993). Low values indicate low degradation of signals. The function measures the blur ratio on signals in which a reference playback has been re-recorded at different distances. Blur ratio is measured as the mismatch between amplitude envelopes (expressed as probability density functions) of the reference signal and the re-recorded signal. The function compares each signal type to the corresponding reference signal within the supplied frequency range (e.g. bandpass) of the reference signal ('bottom.freq' and 'top.freq' columns in 'X'). The 'signal.type' column must be used to tell the function to only compare signals belonging to the same category (e.g. song-types). Two methods for setting the experimental design are provided. All wave objects in the extended selection table must have the same sampling rate so the length of envelopes is comparable.

Value

Data frame similar to input data, but also includes a new column (blur.ratio) with the blur ratio values. If img = TRUE it also returns 1 image file (in 'jpeg' format) for each comparison showing spectrograms of both signals and the overlaid amplitude envelopes (as probability mass functions (PMF)). Spectrograms are shown within the frequency range of the reference signal and also show vertical lines with the start and end of signals to allow users to visually check alignment. If output = 'list' the output would a list including the data frame just described and a data frame with envelopes (amplitude values) for all signals.

Author(s)

Marcelo Araya-Salas (<marceloa27@gmail.com>)

References

Dabelsteen, T., Larsen, O. N., & Pedersen, S. B. (1993). Habitat-induced degradation of sound signals: Quantifying the effects of communication sounds and bird location on blur ratio, excess attenuation, and signal-to-noise ratio in blackbird song. The Journal of the Acoustical Society of America, 93(4), 2206.

Araya-Salas, M. (2019), baRulho: a R package to quantify habitat-induced degradation of (animal) acoustic signals. R package version 1.0.0

See Also

envelope_correlation, spectral_blur_ratio

Examples

```
{
# load example data
data("playback_est")

# remove ambient selections
playback_est <- playback_est[playback_est$signal.type != "ambient", ]

# using method 1
blur_ratio(X = playback_est)

# using method 2
blur_ratio(X = playback_est, method = 2)
}
```

---

envelope_correlation   *Measure amplitude envelope correlation*

Description

envelope_correlation measures amplitude envelope correlation of signals referenced in an extended selection table.

Usage

```
envelope_correlation(X, parallel = 1, pb = TRUE, method = 1, cor.method = "pearson",
ssmooth = NULL, msmooth = NULL, hop.size = 11.6, wl = NULL, ovlp = 70)
```

Arguments

X	object of class 'selection_table', 'extended_selection_table' created by the function [selection_table](#) from the warbleR package.
parallel	Numeric vector of length 1. Controls whether parallel computing is applied by specifying the number of cores to be used. Default is 1 (i.e. no parallel computing). If NULL (default) then the current working directory is used.
pb	Logical argument to control if progress bar is shown. Default is TRUE.
method	Numeric vector of length 1 to indicate the 'experimental design' to measure amplitude envelope correlation. Two methods are available:

- 1: compare all signals with their counterpart that was recorded at the closest distance to source (e.g. compare a signal recorded at 5m, 10m and 15m with its counterpart recorded at 1m). This is the default method.
- 2: compare all signals with their counterpart recorded at the distance immediately before (e.g. a signal recorded at 10m compared with the same signal recorded at 5m, then signal recorded at 15m compared with same signal recorded at 10m and so on).

cor.method	Character string indicating the correlation coefficient to be applied ("pearson", "spearman", or "kendall", see [cor](#)).
ssmooth	Numeric vector of length 1 to determine the length of the sliding window used for a sum smooth for amplitude envelope calculation (used internally by [env](#)).
msmooth	Numeric vector of length 2 to smooth the amplitude envelope with a mean sliding window for amplitude envelope calculation. The first element is the window length (in number of amplitude values) and the second one the window overlap (used internally by [env](#)).
hop.size	A numeric vector of length 1 specifying the time window duration (in ms). Default is 11.6 ms, which is equivalent to 512 wl for 44.1 kHz sampling rate.
wl	A numeric vector of length 1 specifying the window length of the spectrogram, default is NULL. If supplied, 'hop.size' is ignored.
ovlp	Numeric vector of length 1 specifying the percent overlap between two consecutive windows, as in [spectro](#). Default is 70.

Details

Amplitude envelope correlation measures the similarity of two signals in the time domain. The function measures the envelope correlation coefficients of signals in which a reference playback has been re-recorded at increasing distances. Values close to 1 means very similar amplitude envelopes (i.e. little degradation has occurred). If envelopes have different lengths (which means signals have different lengths) cross-correlation is used and the maximum correlation coefficient is returned. Cross-correlation is achieved by sliding the shortest signal along the largest one and calculating the correlation at each step.. The 'signal.type' column must be used to indicate the function to only compare signals belonging to the same category (e.g. song-types).The function compares each signal type to the corresponding reference signal within the supplied frequency range (e.g. bandpass) of the reference signal ('botom.freq' and 'top.freq' columns in 'X'). Two methods for calculating envelope correlation are provided (see 'method' argument). Use [blur_ratio](#) to extract envelopes.

Value

Extended selection table similar to input data, but also includes a new column with the calculated amplitude envelope correlation coefficients.

Author(s)

Marcelo Araya-Salas (<marceloa27@gmail.com>)

References

Araya-Salas, M. (2019), baRulho: a R package to quantify habitat-induced degradation of (animal) acoustic signals. R package version 1.0.0

Apol, C.A., Sturdy, C.B. & Proppe, D.S. (2017). Seasonal variability in habitat structure may have shaped acoustic signals and repertoires in the black-capped and boreal chickadees. Evol Ecol. 32:57-74.

See Also

[blur_ratio](), [spectral_blur_ratio]()

Examples

```
{
# load example data
data("playback_est")

# remove ambient selections
playback_est <- playback_est[playback_est$signal.type != "ambient", ]

# method 1
envelope_correlation(X = playback_est)

# method 2
envelope_correlation(X = playback_est, method = 2)
}
```

---

excess_attenuation   *Measure excess attenuation*

Description

excess_attenuation measures excess attenuation in signals referenced in an extended selection table.

Usage

```
excess_attenuation(X, parallel = 1, pb = TRUE, method = 1,
bp = NULL, hop.size = 1, wl = NULL, ovlp = 70)
```

Arguments

X	object of class 'selection_table', 'extended_selection_table' created by the function [selection_table](#) from the warbleR package. The data frame must include the following additional columns: 'distance', 'signal.type', 'bottom.freq' and 'top.freq'.
parallel	Numeric vector of length 1. Controls whether parallel computing is applied by specifying the number of cores to be used. Default is 1 (i.e. no parallel computing).
pb	Logical argument to control if progress bar is shown. Default is TRUE.
method	Numeric vector of length 1 to indicate the 'experimental design' for measuring excess attenuation. Two methods are available:

- 1: compare all signals with their counterpart that was recorded at the closest distance to source (e.g. compare a signal recorded at 5m, 10m and 15m with its counterpart recorded at 1m). This is the default method.
- 2: compare all signals with their counterpart recorded at the distance immediately before (e.g. a signal recorded at 10m compared with the same signal recorded at 5m, then signal recorded at 15m compared with same signal recorded at 10m and so on).

bp	Numeric vector of length 2 giving the lower and upper limits of a frequency bandpass filter (in kHz). Default is NULL.
hop.size	A numeric vector of length 1 specifying the time window duration (in ms). Default is 1 ms, which is equivalent to ~45 wl for 44.1 kHz sampling rate.
wl	A numeric vector of length 1 specifying the window length of the spectrogram, default is NULL. Ignored if bp = NULL. If supplied, 'hop.size' is ignored. Note that lower values will increase time resolution, which is more important for amplitude ratio calculations.
ovlp	Numeric vector of length 1 specifying the percent overlap between two consecutive windows, as in [spectro](#). Only used when plotting. Default is 70. Only used for bandpass filtering.

Details

Excess attenuation is the amplitude loss of a sound in excess of that due to spherical spreading. With every doubling of distance, sounds attenuate with a 6 dB loss of amplitude (Morton, 1975; Marten & Marler, 1977). Any additional loss of amplitude results in excess attenuation, or energy loss in excess of that expected to occur with distance via spherical spreading due to atmospheric conditions or habitat (Wiley & Richards, 1978). Low values indicate litle signal attenuation. The goal of the function is to measure the excess attenuation on signals in which a reference playback has been re-recorded at increasing distances. The 'signal.type' column must be used to indicate which signals belonging to the same category (e.g. song-types). The function will then compare each signal type to the corresponding reference signal the supplied frequency range (e.g. bandpass) of the reference signal ('botom.freq' and 'top.freq' columns in 'X'). Two methods for calculating excess attenuation are provided (see 'method' argument).

Value

Extended selection table similar to input data, but also includes a new column (excess.attenuation) with the excess attenuation values.

Author(s)

Marcelo Araya-Salas (<marceloa27@gmail.com>)

References

Araya-Salas, M. (2019), baRulho: a R package to quantify habitat-induced degradation of (animal) acoustic signals. R package version 1.0.0

Marten, K., & Marler, P. (1977). Sound transmission and its significance for animal vocalization. Behavioral Ecology and Sociobiology, 2(3), 271-290.

Morton, E. S. (1975). Ecological sources of selection on avian sounds. The American Naturalist, 109(965), 17-34.

See Also

[spcc_distortion](#)

Examples

```
{
# load example data
data("playback_est")

# using method 1
excess_attenuation(X = playback_est)

# using method 2
excess_attenuation(X = playback_est, method = 2)
}
```

| playback_est | *Extended selection table with re-recorded playbacks* |

Description

Recordings of *Phaethornis longirostris* (Long-billed Hermit) songs from different song types (column 'signal.type') that were broadcast and re-recorded at 4 distances (1m, 5m, 10m, 15m, column 'distance'). The data includes ambient (background) noise selections for each distances. The data was created by the function [selection_table](#) from the warbleR package.

Usage

```
data(playback_est)
```

Format

Extended selection table object in the warbleR format, which contains annotations and acoustic data

Source

Marcelo Araya-Salas

---

playback_est_unaligned

Extended selection table with re-recorded playbacks before alignment

---

Description

The data contains almost the same information than the example data 'playback_est' but some selections are not algined in time with the corresponding reference signals (see spcc_align for more details on aligning signals). This data set is intended mostly for using as an example in spcc_align. The data contains recordings of *Phaethornis longirostris* (Long-billed Hermit) songs from different song types (column 'signal.type') that were broadcast and re-recorded at 4 distances (1m, 5m, 10m, 15m, column 'distance'). The data includes ambient (background) noise selections for each distances. The data was created by the function selection_table from the warbleR package.

Usage

```
data(playback_est_unaligned)
```

Format

Extended selection table object in the warbleR format, which contains annotations and acoustic data

Source

Marcelo Araya-Salas

---

snr_attenuation   *Measure attenuation as signal-to-noise ratio*

Description

snr_attenuation measures attenuation as signal-to-noise ratio of signals referenced in an extended selection table.

Usage

```
snr_attenuation(X, mar, parallel = 1, pb = TRUE, eq.dur = FALSE,
noise.ref = "adjacent", type = 1, bp = NULL, hop.size = 1, wl = NULL)
```

Arguments

X	object of class 'selection_table', 'extended_selection_table' created by the function [selection_table](#) from the warbleR package.
mar	numeric vector of length 1. Specifies the margins adjacent to the start and end points of selection over which to measure ambient noise.
parallel	Numeric vector of length 1. Controls whether parallel computing is applied by specifying the number of cores to be used. Default is 1 (i.e. no parallel computing).
pb	Logical argument to control if progress bar is shown. Default is TRUE.
eq.dur	Logical. Controls whether the ambient noise segment that is measured has the same duration to that of the signal (if TRUE. Default is FALSE). If TRUE then 'mar' and 'noise.ref' arguments are ignored.
noise.ref	Character vector of length 1 to determined if a measure ambient noise segment to be used for measuring ambient noise. Two options are available:

- adjacent: measure ambient noise right before the signal (using argument 'mar' to define duration of ambient noise segments). If several 'ambient' selections by sound file are supplied, then the root mean square of the amplitude envelope will be averaged across those selections.
- custom: measure ambient noise segments referenced in the selection table (labeled as 'ambient' in the 'signal.type' column). Those segments will be used to apply the same ambient noise reference to all signals in a sound file. Therefore, at least one 'ambient' selection for each sound file must be provided.

type	Numeric vector of length 1. Selects the formula to be used to calculate the signal-to-noise ratio (S = signal , N = background noise):

- 1: ratio of S amplitude envelope root mean square to N amplitude envelope root mean square (rms(env(S))/rms(env(N)))
- 2: ratio of the difference between S amplitude envelope root mean square and N amplitude envelope root mean square to N amplitude envelope root mean square ((rms(env(S)) - rms(env(N)))/rms(env(N)), as proposed by Dabelsteen et al (1993))

bp	Numeric vector of length 2 giving the lower and upper limits of a frequency bandpass filter (in kHz). Default is NULL.
hop.size	A numeric vector of length 1 specifying the time window duration (in ms). Default is 1 ms, which is equivalent to ~45 wl for 44.1 kHz sampling rate.
wl	A numeric vector of length 1 specifying the window length of the spectrogram, default is NULL. Ignored if bp = NULL. If supplied, 'hop.size' is ignored. Note that lower values will increase time resolution, which is more important for amplitude ratio calculations.

Details

Signal-to-noise ratio measures signal amplitude level in relation to ambient noise. A general margin in which ambient noise will be measured must be specified. Alternatively, a selection of ambient noise can be used as reference (see 'noise.ref' argument). When margins overlap with another acoustic signal nearby, the signal-to-noise ratio (SNR) will be inaccurate, so margin length should be carefully considered. Any SNR less than or equal to one suggests background noise is equal to or overpowering the acoustic signal. The 'signal.type' column must be used to indicate which signals belong to the same category (e.g. song-types). The function will measure signal-to-noise ratio within the supplied frequency range (e.g. bandpass) of the reference signal ('botom.freq' and 'top.freq' columns in 'X'). Two methods for calculating signal-to-noise ratio are provided (see 'type' argument).

Value

Extended selection table similar to input data, but also includes a new column (snr.attenuation) with the signal-to-noise ratio values.

Author(s)

Marcelo Araya-Salas (<marceloa27@gmail.com>)

References

Dabelsteen, T., Larsen, O. N., & Pedersen, S. B. (1993). Habitat-induced degradation of sound signals: Quantifying the effects of communication sounds and bird location on blur ratio, excess attenuation, and signal-to-noise ratio in blackbird song. The Journal of the Acoustical Society of America, 93(4), 2206.

Araya-Salas, M. (2019), baRulho: a R package to quantify habitat-induced degradation of (animal) acoustic signals. R package version 1.0.0

See Also

excess_attenuation

Examples

```
{
# load example data
data("playback_est")
```

```
# using measure ambient noise reference selections
snr_attenuation(X = playback_est, mar = 0.05, noise.ref = 'custom')

#' # remove ambient selections
playback_est <- playback_est[playback_est$signal.type != "ambient", ]
# using margin for ambient noise of 0.05 and adjacent measure ambient noise reference
snr_attenuation(X = playback_est, mar = 0.05, noise.ref = 'adjacent')
}
```

---

spcc_align   *Align start and end of signal using spectrographic cross-correlation*

Description

spcc_align Aligns start and end of signal in an extended selection table using spectrographic cross-correlation

Usage

```
spcc_align(X = NULL, parallel = 1, pb = TRUE,
hop.size = 11.6, wl = NULL, ovlp = 90, wn = 'hanning')
```

Arguments

X	object of class 'selection_table', 'extended_selection_table' created by the function [selection_table](#) from the warbleR package. The object must include the following additional columns: 'signal.type', 'bottom.freq' and 'top.freq'.
parallel	Numeric vector of length 1. Controls whether parallel computing is applied by specifying the number of cores to be used. Default is 1 (i.e. no parallel computing).
pb	Logical argument to control if progress bar is shown. Default is TRUE.
hop.size	A numeric vector of length 1 specifying the time window duration (in ms). Default is 11.6 ms, which is equivalent to 512 wl for 44.1 kHz sampling rate.
wl	A numeric vector of length 1 specifying the window length of the spectrogram, default is NULL. If supplied, 'hop.size' is ignored.
ovlp	Numeric vector of length 1 specifying % of overlap between two consecutive windows, as in [spectro](#). Default is 90. High values of ovlp slow down the function but produce more accurate results.
wn	A character vector of length 1 specifying the window name as in [ftwindow](#).

Details

The frequency uses spectrographic cross-correlation to align the position in time of signals with regard to a reference signal. In this case the signal with closest distance to the source is used as reference. Precise alignment is crucial for downstream measures of signal degradation. The function calls calls warbleR's xcorr and find_peaks internally to align signals using cross-correlation. The output extended selection table contains the new start and end values after alignment.

Value

Extended selection table similar to input data in which time parameters (columns 'start' and 'end') have been tailored to more closely match the start and end of the reference signal.

Author(s)

Marcelo Araya-Salas (<marceloa27@gmail.com>)

References

Araya-Salas, M. (2019), baRulho: a R package to quantify habitat-induced degradation of (animal) acoustic signals. R package version 1.0.0

Clark, C.W., Marler, P. & Beeman K. (1987). Quantitative analysis of animal vocal phonology: an application to Swamp Sparrow song. Ethology. 76:101-115.

See Also

blur_ratio, xcorr

Examples

```
{
# load example data
data("playback_est")

# method 1
spcc_align(X = playback_est)
}
```

---

spcc_distortion	*Measure spectrographic cross-correlation as a measure of signal distortion*

Description

spcc_distortion Measures spectrographic cross-correlation as a measure of signal distortion in signals referenced in an extended selection table.

Usage

```
spcc_distortion(X, parallel = 1, pb = TRUE,  method = 1,
cor.method = "pearson", hop.size = 11.6, wl = NULL, ovlp = 90, wn = 'hanning')
```

Arguments

X	object of class 'selection_table', 'extended_selection_table' created by the function [selection_table](#) from the warbleR package. The object must include the following additional columns: 'signal.type', 'bottom.freq' and 'top.freq'.
parallel	Numeric vector of length 1. Controls whether parallel computing is applied by specifying the number of cores to be used. Default is 1 (i.e. no parallel computing).
pb	Logical argument to control if progress bar is shown. Default is TRUE.
method	Numeric vector of length 1 to indicate the 'experimental design' for measuring envelope correlation. Two methods are available:

- 1: compare all signals with their counterpart that was recorded at the closest distance to source (e.g. compare a signal recorded at 5m, 10m and 15m with its counterpart recorded at 1m). This is the default method.
- 2: compare all signals with their counterpart recorded at the distance immediately before (e.g. a signal recorded at 10m compared with the same signal recorded at 5m, then signal recorded at 15m compared with same signal recorded at 10m and so on).

cor.method	Character string indicating the correlation coefficient to be applied ("pearson", "spearman", or "kendall", see [cor](#)).
hop.size	A numeric vector of length 1 specifying the time window duration (in ms). Default is 11.6 ms, which is equivalent to 512 wl for 44.1 kHz sampling rate.
wl	A numeric vector of length 1 specifying the window length of the spectrogram, default is NULL. If supplied, 'hop.size' is ignored.
ovlp	Numeric vector of length 1 specifying % of overlap between two consecutive windows, as in [spectro](#). Default is 90. High values of ovlp slow down the function but produce more accurate results.
wn	A character vector of length 1 specifying the window name as in [ftwindow](#).

Details

The spectrographic cross-correlation measures frequency distortion of signals as a similarity metric. Values close to 1 means very similar spectrograms (i.e. little signal distortion has occurred). Cross-correlation is measured of signals in which a reference playback has been re-recorded at increasing distances. The 'signal.type' column must be used to indicate the function to only compare signals belonging to the same category (e.g. song-types). The function compares each signal type to the corresponding reference signal within the supplied frequency range (e.g. bandpass) of the reference signal ('botom.freq' and 'top.freq' columns in 'X'). Two methods for calculating cross-correlation are provided (see 'method' argument). The function is a wrapper on warbleR's [xcorr](#) function.

Value

Extended selection table similar to input data, but includes a new column (cross.correlation) with the spectrogram cross-correlation coefficients.

Author(s)

Marcelo Araya-Salas (<marceloa27@gmail.com>)

References

Araya-Salas, M. (2019), baRulho: a R package to quantify habitat-induced degradation of (animal) acoustic signals. R package version 1.0.0

Clark, C.W., Marler, P. & Beeman K. (1987). Quantitative analysis of animal vocal phonology: an application to Swamp Sparrow song. Ethology. 76:101-115.

See Also

blur_ratio, spcc_align, xcorr

Examples

```
{
# load example data
data("playback_est")

# method 1
spcc_distortion(X = playback_est, method = 1)

# method 2
spcc_distortion(X = playback_est, method = 2)
}
```

---

spectral_blur_ratio *Measure blur ratio in the frequency domain*

Description

spectral_blur_ratio measures blur ratio of frequency spectra from signals referenced in an extended selection table.

Usage

```
spectral_blur_ratio(X, parallel = 1, pb = TRUE, method = 1, ssmooth = 50,
output = "est", img = FALSE, res = 150, hop.size = 11.6, wl = NULL,
ovlp = 70, pal = reverse.gray.colors.2, collevels = seq(-60, 0, 5), dest.path = NULL)
```

Arguments

X	object of class 'selection_table', 'extended_selection_table' created by the function selection_table from the warbleR package.
parallel	Numeric vector of length 1. Controls whether parallel computing is applied by specifying the number of cores to be used. Default is 1 (i.e. no parallel computing).
pb	Logical argument to control if progress bar is shown. Default is TRUE.
method	Numeric vector of length 1 to indicate the 'experimental design' for measuring spectrum correlation. Two methods are available:

  - 1: compare all signals with their counterpart that was recorded at the closest distance to source (e.g. compare a signal recorded at 5m, 10m and 15m with its counterpart recorded at 1m). This is the default method.
  - 2: compare all signals with their counterpart recorded at the distance immediately before (e.g. a signal recorded at 10m compared with the same signal recorded at 5m, then signal recorded at 15m compared with same signal recorded at 10m and so on).

ssmooth	Numeric vector of length 1 determining the length of the sliding window used for a sum smooth for power spectrum calculation (in kHz). Default is 100.
output	Character vector of length 1 to determine if an extended selection table ('est') or a list ('list') containing 1) extended selection table and 2) amplitude values is returned.
img	Logical argument to control if image files in 'jpeg' format containing the images being compared and the corresponding spectra are produced. Default is no images (FALSE).
res	Numeric argument of length 1. Controls image resolution. Default is 150 (faster) although 300 - 400 is recommended for publication/presentation quality.
hop.size	A numeric vector of length 1 specifying the time window duration (in ms). Default is 11.6 ms, which is equivalent to 512 wl for 44.1 kHz sampling rate.
wl	A numeric vector of length 1 specifying the window length of the spectrogram, default is NULL. If supplied, 'hop.size' is ignored. Applied to both spectra and spectrograms on image files.
ovlp	Numeric vector of length 1 specifying the percent overlap between two consecutive windows, as in spectro. Default is 70. Applied to both spectra and spectrograms on image files.
pal	A color palette function to be used to assign colors in the plot, as in spectro. Default is reverse.gray.colors.2.
collevels	Numeric vector indicating a set of levels which are used to partition the amplitude range of the spectrogram (in dB) as in spectro. Default is seq(-60, 0, 5).
dest.path	Character string containing the directory path where the image files will be saved. If NULL (default) then the folder containing the sound files will be used instead.

Details

Spectral blur ratio measures the degradation of sound as a function of the change in signal energy in the frequency domain, analogous to the blur ratio proposed by Dabelsteen et al (1993) for the time domain (and implemented in [blur_ratio](#)). Low values indicate low degradation of signals. The function measures the blur ratio of spectra from signals in which a reference playback has been re-recorded at different distances. Blur ratio is measured as the mismatch between power spectra (expressed as probability density functions) of the reference signal and the re-recorded signal. The function compare each signal type to the corresponding reference signal. The 'signal.type' column must be used to tell the function to only compare signals belonging to the same category (e.g. song-types). Two methods for setting the experimental design are provided. All wave objects in the extended selection table must have the same sampling rate so the length of spectra is comparable.

Value

Data frame similar to input data, but also includes a new column (blur.ratio.spectrum) with the blur ratio values. If `img = TRUE` it also returns 1 image file (in 'jpeg' format) for each comparison showing spectrograms of both signals and the overlaid power spectrum (as probability mass functions (PMF)). Spectrograms are shown within the frequency range of the reference isgnal and also show vertical lines with the start and end of signals to allow users to visually check alignment. If `output = 'list'` the output would a list including the data frame just described and a data frame with spectra (amplitude values) for all signals.

Author(s)

Marcelo Araya-Salas (<marceloa27@gmail.com>)

References

Dabelsteen, T., Larsen, O. N., & Pedersen, S. B. (1993). Habitat-induced degradation of sound signals: Quantifying the effects of communication sounds and bird location on blur ratio, excess attenuation, and signal-to-noise ratio in blackbird song. The Journal of the Acoustical Society of America, 93(4), 2206.

Araya-Salas, M. (2019), baRulho: a R package to quantify habitat-induced degradation of (animal) acoustic signals. R package version 1.0.0

See Also

[blur_ratio](#)

Examples

```
{
# load example data
data("playback_est")

# remove ambient selections
playback_est <- playback_est[playback_est$signal.type != "ambient", ]

# using method 1
```

```
spectral_blur_ratio(X = playback_est)

# using method 2
spectral_blur_ratio(X = playback_est, method = 2)
}
```

---

spectrum_correlation   *Measure frequency spectrum correlation*

Description

spectrum_correlation measures frequency spectrum correlation of signals referenced in an extended selection table.

Usage

```
spectrum_correlation(X, parallel = 1, pb = TRUE, method = 1,
cor.method = "pearson", hop.size = 11.6, wl = NULL, ovlp = 70)
```

Arguments

X	object of class 'selection_table', 'extended_selection_table' created by the function [selection_table](#) from the warbleR package.
parallel	Numeric vector of length 1. Controls whether parallel computing is applied by specifying the number of cores to be used. Default is 1 (i.e. no parallel computing). If NULL (default) then the current working directory is used.
pb	Logical argument to control if progress bar is shown. Default is TRUE.
method	Numeric vector of length 1 to indicate the 'experimental design' to measure frequency spectrum correlation. Two methods are available:
	• 1: compare all signals with their counterpart that was recorded at the closest distance to source (e.g. compare a signal recorded at 5m, 10m and 15m with its counterpart recorded at 1m). This is the default method.
	• 2: compare all signals with their counterpart recorded at the distance immediately before (e.g. a signal recorded at 10m compared with the same signal recorded at 5m, then signal recorded at 15m compared with same signal recorded at 10m and so on).
cor.method	Character string indicating the correlation coefficient to be applied ("pearson", "spearman", or "kendall", see [cor](#)).
hop.size	A numeric vector of length 1 specifying the time window duration (in ms). Default is 11.6 ms, which is equivalent to 512 wl for 44.1 kHz sampling rate.
wl	A numeric vector of length 1 specifying the window length of the spectrogram, default is NULL. If supplied, 'hop.size' is ignored.
ovlp	Numeric vector of length 1 specifying the percent overlap between two consecutive windows, as in [spectro](#). Default is 70.

Details

frequency spectrum correlation measures the similarity of two signals in the time domain. The function measures the spectrum correlation coefficients of signals in which a reference playback has been re-recorded at increasing distances. Values range from 1 (identical frequency spectrum, i.e. no degradation) to 0. The 'signal.type' column must be used to indicate the function to only compare signals belonging to the same category (e.g. song-types). The function will then compare each signal type to the corresponding reference signal. Two methods for calculating spectrum correlation are provided (see 'method' argument). Use spectral_blur_ratio to get spectra for plotting.

Value

Extended selection table similar to input data, but also includes a new column ('spectrum.correlation') with the calculated frequency spectrum correlation coefficients.

Author(s)

Marcelo Araya-Salas (<marceloa27@gmail.com>)

References

Araya-Salas, M. (2019), baRulho: a R package to quantify habitat-induced degradation of (animal) acoustic signals. R package version 1.0.0

Apol, C.A., Sturdy, C.B. & Proppe, D.S. (2017). Seasonal variability in habitat structure may have shaped acoustic signals and repertoires in the black-capped and boreal chickadees. Evol Ecol. 32:57-74.

See Also

envelope_correlation, spectral_blur_ratio

Examples

```
{
# load example data
data("playback_est")

# remove ambient selections
pe <- playback_est[playback_est$signal.type != "ambient", ]

# method 1
spectrum_correlation(X = pe)

# method 2
spectrum_correlation(X = pe, method = 2)
}
```

Index