

Package ‘tuneR’

July 8, 2018

Version 1.3.3

Date 2018-07-03

Title Analysis of Music and Speech

Author Uwe Ligges <ligges@statistik.tu-dortmund.de> with contributions from Sebastian Krey, Olaf Mersmann, Sarah Schnackenberg, Guillaume Guenard, Andrea Preusser, Anita Thiel, Johanna Mielke and Claus Weihs, as well as code fragments and ideas from the former package 'sound' by Matthias Heymann and functions from 'rastamat' by Daniel P. W. Ellis. The included parts of the libmad MPEG audio decoder library are authored by Underbit Technologies.

Maintainer Uwe Ligges <ligges@statistik.tu-dortmund.de>

Depends R (>= 3.0.0)

Suggests pastecs

Imports signal, methods

Description Analyze music and speech, extract features like MFCCs, handle wave files and their representation in various ways, read mp3, read midi, perform steps of a transcription, ... Also contains functions ported from the 'rastamat' 'Matlab' package.

License GPL-2 | GPL-3

NeedsCompilation yes

Repository CRAN

Date/Publication 2018-07-08 04:20:03 UTC

R topics documented:

Arith-methods	3
audspec	3
bind	5
channel	5
deltas	6
dolpc	7
downsample	8
equalWave	9

extractWave	9
FF	11
freqconv	12
getMidiNotes	13
length	14
lifter	15
lilyinput	16
lpc2cep	17
MCnames	18
melfcc	19
melodyplot	21
MFCC	23
Mono-Stereo	23
nchannel	24
normalize-methods	25
noSilence	26
noteFromFF	27
notenames	28
panorama	28
periodogram-methods	29
play-methods	32
plot-Wave	33
plot-Wspec	34
plot-WspecMat	35
postaud	36
powspec	37
prepComb	38
quantize	39
quantplot	40
readMidi	42
readMP3	43
readWave	44
show-WaveWspec-methods	45
smoother	46
spec2cep	47
summary-methods	48
tuneR	48
updateWave	50
Wave	51
Wave-class	52
Waveforms	53
WaveMC	55
WaveMC-class	56
WavPlayer	57
writeWave	57
Wspec-class	59
WspecMat-class	60
[-methods	61

Arith-methods	<i>Arithmetics on Waves</i>
---------------	-----------------------------

Description

Methods for arithmetics on Wave and WaveMC objects

Methods

object = "Wave" An object of class [Wave](#).

object = "WaveMC" An object of class [WaveMC](#).

object = "numeric" For, e.g., adding a number to the whole Wave, e.g. useful for demeaning.

object = "missing" For unary Wave operations.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

For the S3 generic: [groupGeneric](#), [Wave-class](#), [Wave](#), [WaveMC-class](#), [WaveMC](#)

audspec	<i>Frequency band conversion</i>
---------	----------------------------------

Description

Perform critical band analysis (see PLP), which means the reduction of the fourier frequencies of a signal's powerspectrum to a reduced number of frequency bands in an auditory frequency scale.

Usage

```
audspec(ppectrum, sr = 16000, nfilts = ceiling(hz2bark(sr/2)) + 1,  
        fbtype = c("bark", "mel", "htkmel", "fcmel"), minfreq = 0,  
        maxfreq = sr/2, sumpower = TRUE, bwidth = 1)
```

Arguments

pspectrum	Output of <code>powspec</code> , matrix with the powerspectrum of each time frame in its columns.
sr	Sample rate of the original recording.
nfilters	Number of filters/frequency bins in the auditory frequency scale.
fbtype	Used auditory frequency scale.
minfreq	Lowest frequency.
maxfreq	Highest frequency.
sumpower	If <code>sumpower = TRUE</code> , the frequency scale transformation is based on the powerspectrum, if <code>sumpower = FALSE</code> , it is based on its squareroot (absolute value of the spectrum) and squared afterwards.
bwidth	Modify the width of the frequency bands.

Value

aspectrum	Matrix with the auditory spectrum of each time frame in its columns.
wt	Weight matrix for the frequency band conversion.

Author(s)

Sebastian Krey <krey@statistik.tu-dortmund.de>

References

Daniel P. W. Ellis: <http://www.ee.columbia.edu/~dpwe/resources/matlab/rastamat/>

See Also

[fft2melmx](#), [fft2barkmx](#)

Examples

```
testsound <- normalize(sine(400) + sine(1000) + square(250), "16")
pspectrum <- powspec(testsound@left, testsound@samp.rate)
aspectrum <- audspec(pspectrum, testsound@samp.rate)
```

bind	<i>Concatenating Wave objects</i>
------	-----------------------------------

Description

Generic function for concatenating objects of class `Wave` or `WaveMC`.

Usage

```
bind(object, ...)  
## S4 method for signature 'Wave'  
bind(object, ...)  
## S4 method for signature 'WaveMC'  
bind(object, ...)
```

Arguments

`object, ...` Objects of class `Wave` or class `WaveMC`, each of the same class and of the same kind (checked by `equalWave`), i.e. identical sampling rate, resolution (bit), and number of channels (for `WaveMC`, resp. stereo/mono for `Wave`).

Value

An object of class `Wave` or class `WaveMC` that corresponds to the class of the input.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>, Sarah Schnackenberg

See Also

[prepComb](#) for preparing the concatenation, [Wave-class](#), [Wave](#), [WaveMC-class](#), [WaveMC](#), [extractWave](#), [stereo](#)

channel	<i>Channel conversion for Wave objects</i>
---------	--

Description

Convenient wrapper to extract one or more channels (or mirror channels) from an object of class `Wave`.

Usage

```
channel(object, which = c("both", "left", "right", "mirror"))
```

Arguments

object	Object of class Wave .
which	Character indicating which channel(s) should be returned.

Details

For objects of [WaveMC-class](#), channel selection can be performed by simple matrix indexing, e.g. `WaveMCobject[, 2]` selects the second channel.

Value

Wave object including channels specified by `which`.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

[Wave](#), [Wave-class](#), [mono](#), [extractWave](#)

deltas

Calculate delta features

Description

Calculate the deltas (derivatives) of a sequence of features using a `w`-point window with a simple linear slope.

Usage

```
deltas(x, w = 9)
```

Arguments

<code>x</code>	Matrix of features. Every column represents one time frame. Each row is filtered separately.
<code>w</code>	Window width (usually odd).

Details

This function mirrors the delta calculation performed in HTKs 'feacalc'.

Value

Returns a matrix of the delta features (one column per frame).

Author(s)

Sebastian Krey <krey@statistik.tu-dortmund.de>

References

Daniel P. W. Ellis: <http://www.ee.columbia.edu/~dpwe/resources/matlab/rastamat/>

Examples

```
testsound <- normalize(sine(400) + sine(1000) + square(250), "16")
m <- melfcc(testsound, frames_in_rows=FALSE)
d <- deltas(m)
```

dolpc

(Perceptive) Linear Prediction

Description

Compute autoregressive model from spectral magnitude samples via Levinson-Durbin recursion.

Usage

```
dolpc(x, modelorder = 8)
```

Arguments

x	Matrix of spectral magnitude samples (each sample/time frame in one column).
modelorder	Lag of the AR model.

Value

Returns a matrix of the normalized AR coefficients (depending on the input spectrum: LPC or PLP coefficients). Every column represents one time frame.

Author(s)

Sebastian Krey <krey@statistik.tu-dortmund.de>

References

Daniel P. W. Ellis: <http://www.ee.columbia.edu/~dpwe/resources/matlab/rastamat/>

See Also

[levinson](#)

Examples

```
testsound <- normalize(sine(400) + sine(1000) + square(250), "16")
pspectrum <- powspec(testsound@left, testsound@samp.rate)
aspectrum <- audspec(pspectrum, testsound@samp.rate)$aspectrum
lpcas <- dolpc(aspectrum, 10)
```

downsample

Downsampling a Wave or WaveMC object

Description

Downsampling an object of class `Wave` or class `WaveMC`.

Usage

```
downsample(object, samp.rate)
```

Arguments

<code>object</code>	Object of class <code>Wave</code> or class <code>WaveMC</code> .
<code>samp.rate</code>	Sampling rate the object is to be downsampled to. <code>samp.rate</code> must be in <code>[2000, 192000]</code> ; typical values are 11025, 22050, and 44100 for CD quality. If the object's sampling rate is already equal or smaller than <code>samp.rate</code> , the object will be returned unchanged.

Value

An object of class `Wave` or class `WaveMC`.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

[Wave-class](#), [Wave](#), [WaveMC-class](#), [WaveMC](#)

`equalWave`*Checking Wave objects*

Description

Internal S4 generic function that checks for some kind of equality of objects of class `Wave` or class `WaveMC`.

Usage

```
equalWave(object1, object2)
```

Arguments

`object1`, `object2`

Object(s) of class `Wave` or class `WaveMC` (both of the same class).

Value

Does not return anything. It **stops** code execution with an error message indicating the problem if the objects are not of the same class (either `Wave` oder `WaveMC`) or if the two objects don't have the same properties, i.e. identical sampling rate, resolution (bit), and number of channels (for `WaveMC`, resp. stereo/mono for `Wave`).

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>, Sarah Schnackenberg

See Also

[Wave-class](#), [Wave](#), [WaveMC-class](#), [WaveMC](#)

`extractWave`*Extractor for Wave and WaveMC objects*

Description

Extractor function that allows to extract inner parts for `Wave` or `WaveMC` objects (interactively).

Usage

```
extractWave(object, from = 1, to = length(object),  
            interact = interactive(), xunit = c("samples", "time"), ...)
```

Arguments

object	Object of class Wave or class WaveMC .
from	Sample number or time in seconds (see <code>xunit</code>) at which to <i>start</i> extraction.
to	Sample number or time in seconds (see <code>xunit</code>) at which to <i>stop</i> extraction. If <code>to < from</code> , object will be returned as is.
interact	Logical indicating whether to choose the range to be extracted interactively (if TRUE). See Section Details.
xunit	Character indicating which units are used to specify the range to be extracted (both in arguments <code>from</code> and <code>to</code> , and in the plot, if <code>interact = TRUE</code>). If <code>xunit = "time"</code> , the unit is time in seconds, otherwise the number of samples.
...	Parameters to be passed to the underlying plot function (plot-methods) if <code>interact = TRUE</code> .

Details

This function allows interactive selection of a range to be extracted from an object of class [Wave](#) or class [WaveMC](#). The default is to use interactive selection if the current R session is [interactive](#). In case of interactive selection, [plot-methods](#) plot the [Wave](#) or [WaveMC](#) object, and the user may click on the starting and ending points of his selection (given neither `from` nor `to` have been specified, see below). The cut-points are drawn and the corresponding selection will be returned in form of a [Wave](#) or [WaveMC](#) object.

Setting `interact = TRUE` in a non-interactive session does not work.

Setting arguments `from` or `to` explicitly means that the specified one does not need to be selected interactively, hence only the non-specified one will be selected interactively. Moreover, setting both `from` or `to` implies `interact = FALSE`.

Value

An object of class [Wave](#) or class [WaveMC](#).

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>, Sarah Schnackenberg

See Also

[Wave-class](#), [Wave](#), [WaveMC-class](#), [WaveMC](#), [bind](#), [channel](#), [mono](#)

Examples

```
Wobj <- sine(440)
# extracting the middle 0.5 seconds of that 1 sec. sound:
Wobj2 <- extractWave(Wobj, from = 0.25, to = 0.75, xunit = "time")
Wobj2

## Not run:
# or interactively:
Wobj2 <- extractWave(Wobj)
```

```
## End(Not run)
```

 FF

Estimation of Fundamental Frequencies from a Wspec object

Description

Estimation of Fundamental Frequencies from an object of class `Wspec`. Additionally, some heuristics are used to distinguish silence, noise (and breathing for singers) from real tones.

Usage

```
FF(object, peakheight = 0.01, silence = 0.2, minpeak = 9, diapason = 440,
    notes = NULL, interest.frqs = seq(along = object@freq),
    search.par = c(0.8, 10, 1.3, 1.7))
```

```
FFpure(object, peakheight = 0.01, diapason = 440,
        notes = NULL, interest.frqs = seq(along = object@freq),
        search.par = c(0.8, 10, 1.3, 1.7))
```

Arguments

<code>object</code>	An object of class <code>Wspec</code> .
<code>peakheight</code>	The peak's proportion of the maximal peak height to be considered for fundamental frequency detection. The default (0.01) means peaks smaller than 0.02 times the maximal peak height are omitted.
<code>silence</code>	The maximum proportion of periodograms to be considered as silence or noise (such as breathing). The default (0.2) means that less than 20 out of 100 periodograms represent silence or noise.
<code>minpeak</code>	If more than <code>minpeak</code> peaks are considered for detection and passed argument <code>peakheight</code> , such periodograms are detected to be silence or noise (if <code>silence > 0</code>).
<code>diapason</code>	Frequency of diapason a, default is 440 (Hertz).
<code>notes</code>	Optional, a vector of integers indicating the notes (in halftones from diapason a) that are expected. By applying this restriction, the "detection error" might be reduced in some cases.
<code>interest.frqs</code>	Optional, either a vector of integers indicating the indices of (fundamental) frequencies in <code>object</code> that are expected, or one of the character strings "bass", "tenor", "alto" or "soprano". For these voice types, only typical frequency ranges are considered for detection. By applying this restriction, the "detection error" might be reduced in some cases.
<code>search.par</code>	Parameters to look for peaks: <ol style="list-style-type: none"> 1. The first peak larger than <code>peakheight * 'largest_peak'</code> is taken.

2. Its frequency is multiplied by $1 + \text{search.par}[1]$ Now, any larger peak between the old peak and that value is taken, if (a) it exists and if (b) it is above the $\text{search.par}[2]$ -th Fourier-Frequency.
3. Within the interval of frequencies 'current peak' * $\text{search.par}[3:4]$, another high peak is looked for. If any high peak exists in that interval, it can be assumed we got the wrong partial and the 'real' fundamental frequency can be re-estimated from the next two partials.

Details

FFpure just estimates the fundamental frequencies for all periodograms contained in the object (of class [Wspec](#)).

FF additionally uses some heuristics to distinguish silence, noise (and breathing for singers) from real tones. It is recommended to use the wrapper function FF rather than FFpure. If silence detection can be omitted by specifying `silence = 0`.

Value

Vector of estimated fundamental frequencies (in Hertz) for each periodogram contained in object.

Note

These functions are still in development and may be changed in due course.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

[Wspec](#), [periodogram](#) (including an example), [noteFromFF](#), and [tuneR](#) for a very complete example.

freqconv

Frequency scale conversion

Description

Perform frequency scale conversions between Hertz, Bark- and different variants von the Melscale.

Usage

```
bark2hz(z)
hz2bark(f)
hz2mel(f, htk = FALSE)
mel2hz(z, htk = FALSE)
```

Arguments

f	Frequency in Hertz
z	Frequency in the auditory frequency scale
htk	Use the HTK-Melscale (htk = TRUE) or Slaney's Melscale from the Auditory Toolbox (htk = FALSE)

Value

The value of the input in the target frequency scale.

Author(s)

Sebastian Krey <krey@statistik.tu-dortmund.de>

References

Daniel P. W. Ellis: <http://www.ee.columbia.edu/~dpwe/resources/matlab/rastamat/>, Malcolm Slaney: Auditory Toolbox

Examples

```
hz2bark(440)
bark2hz(hz2bark(440))
hz2mel(440, htk = TRUE)
mel2hz(hz2mel(440, htk = TRUE), htk = TRUE)
hz2mel(440, htk = FALSE)
mel2hz(hz2mel(440, htk = FALSE), htk = FALSE)
```

getMidiNotes

Extract note events from objects returned by readMidi

Description

Extract only note events from an object returned by the `readMidi` function.

Usage

```
getMidiNotes(x, ...)
```

Arguments

x	A data.frame returned by the <code>readMidi</code> function.
...	Further arguments are passed to the <code>notenames</code> function for extracting the human readable note names rather than their integer representations.

Value

A data frame with columns

time	start time
length	length
track	track number
channel	channel number
note	note
notename	notename
velocity	note velocity

Author(s)

Uwe Ligges and Johanna Mielke

See Also

[readMidi](#)

Examples

```
content <- readMidi(system.file("example_files", "Bass_sample.mid", package="tuneR"))
getMidiNotes(content)
```

length *S4 generic for length*

Description

S4 generic for length.

Methods

x = "Wave" The length of the left channel (in samples) of this object of class [Wave](#) will be returned.

x = "WaveMC" The length for each of the time series in the [WaveMC](#) will be returned.

object = "ANY" For compatibility.

See Also

For the primitive: [length](#)

lifter	<i>Liftering of cepstra</i>
--------	-----------------------------

Description

Apply liftering to a matrix of cepstra.

Usage

```
lifter(x, lift = 0.6, inv = FALSE, htk = FALSE)
```

Arguments

x	Matrix of cepstra, one sample/time frame per column.
lift	Liftering exponent/length.
inv	Invert the liftering (undo a previous liftering).
htk	Switch liftering type.

Details

If `htk = FALSE`, then perform x^{lift} , $i = 1, \dots, \text{nrow}(x)$ liftering. If `htk = TRUE`, then perform HTK-style sin-curve liftering with length `lift`.

Value

Matrix of the liftered cepstra.

Author(s)

Sebastian Krey <krey@statistik.tu-dortmund.de>

References

Daniel P. W. Ellis: <http://www.ee.columbia.edu/~dpwe/resources/matlab/rastamat/>

Examples

```
testsound <- normalize(sine(400) + sine(1000) + square(250), "16")
m <- melfcc(testsound, frames_in_rows=FALSE)
unlm <- lifter(m, inv=TRUE)
```

lilyinput

*Providing LilyPond compatible input***Description**

A function (*in development!*) that writes a file to be processed by *LilyPond* by extracting the relevant information (e.g. pitch, length, ...) from columns of a data frame. The music notation software *LilyPond* can “transcribe” such an input file into sheet music.

Usage

```
lilyinput(X, file = "Rsong.ly", Major = TRUE, key = "c",
         clef = c("treble", "bass", "alto", "tenor"), time = "4/4",
         endbar = TRUE, midi = TRUE, tempo = "2 = 60",
         textheight = 220, linewidth = 150, indent = 0, fontsize = 14)
```

Arguments

X	A data frame containing 4 named components (columns): <ul style="list-style-type: none"> • note: Integer - the notes' pitch in halftones from diapason (a), i.e. 0 for diapason a, 3 for c', ... • duration: Integer - denominator of lengths of the notes, e.g. 8 for a quaver. • punctate: Logical - whether to punctate a note. • slur: Logical - TRUE indicates to start a slur, or to end it. That means that the first, third, ... occurrences of TRUE start slurs, while the second, fourth, ... occurrences end slurs. Note that it is only possible to draw one slur at a time.
file	The file to be written for <i>LilyPond</i> 's input.
Major	Logical indicating major key (if TRUE) or minor key.
key	Keynote, necessary to set sharps/flats.
clef	Integer indicating the kind of clef, supported are "treble" (default), "bass", "alto", and "tenor".
time	Character indicating which meter to use, examples are: "3/4", "4/4".
endbar	Logical indicating whether to set an ending bar at the end of the sheet music.
midi	Logical indicating whether Midi output (by <i>LilyPond</i>) is desirable.
tempo	Character specifying the tempo to be used for the Midi file if midi = TRUE. The default, "2 = 60" indicates: 60 half notes per minute, whereas "4 = 90" indicates 90 quarters per minute.
textheight	Textheight of the sheet music to be written by <i>LilyPond</i> .
linewidth	Linewidth of the sheet music to be written by <i>LilyPond</i> .
indent	Indentation of the sheet music to be written by <i>LilyPond</i> .
fontsize	Fontsize of the sheet music to be written by <i>LilyPond</i> .

Details

Details will be given when development has reached a stable stage ...!

Value

Nothing is returned, but a file is written.

Note

This function is in development!!!

Everything (and in particular its user interface) is subject to change!!!

Author(s)

Andrea Preußer and Uwe Ligges <ligges@statistik.tu-dortmund.de>

References

The LilyPond development team (2005): *LilyPond - The music typesetter*. <http://www.lilypond.org/>, Version 2.7.20.

Preußer, A., Ligges, U. und Weihs, C. (2002): *Ein R Exportfilter für das Notations- und Midi-Programm LilyPond*. Arbeitsbericht 35. Fachbereich Statistik, Universität Dortmund. (german)

See Also

[quantMerge](#) prepares the data to be written into the LilyPond format; [quantize](#) and [quantplot](#) generate another kind of plot; and exhaustive example is given in [tuneR](#).

lpc2cep

LPC to cepstra conversion

Description

Convert the LPC coefficients in each column of a into frames of cepstra.

Usage

```
lpc2cep(a, nout = nrow(a))
```

Arguments

a	Matrix of LPC coefficients.
nout	Number of cepstra to produce.

Value

Matrix of cepstra (one column per time frame).

Author(s)

Sebastian Krey <krey@statistik.tu-dortmund.de>

References

Daniel P. W. Ellis: <http://www.ee.columbia.edu/~dpwe/resources/matlab/rastamat/>

See Also

[spec2cep](#)

Examples

```
testsound <- normalize(sine(400) + sine(1000) + square(250), "16")
pspectrum <- powspec(testsound@left, testsound@samp.rate)
aspectrum <- audspec(pspectrum, testsound@samp.rate)
lpcas <- dolpc(aspectrum$spectrum, 8)
cepstra <- lpc2cep(lpcas)
```

MCnames

Default channel ordering for multi channel wave files

Description

A data frame representing the default channel ordering with id, descriptive label, and abbreviated name for multi channel wave files.

Format

A data frame with 18 observations on the following 3 variables:

id id of the channel
label full label for the channel
name abbreviated name for the channel

Source

Data derived from the technical documentation given at <https://docs.microsoft.com/en-us/windows-hardware/drivers/ddi/content/ksmedia/ns-ksmedia-waveformatextensible>.

References

Microsoft Corporation (2018): WAVEFORMATEXTENSIBLE structure, <https://docs.microsoft.com/en-us/windows-hardware/drivers/ddi/content/ksmedia/ns-ksmedia-waveformatextensible>.

Examples

```
MCnames # the 18 predefined channels in a multi channel Wave file (WaveMC object)
```

melfcc *MFCC Calculation*

Description

Calculate Mel-frequency cepstral coefficients.

Usage

```
melfcc(samples, sr = samples@samp.rate, wintime = 0.025,
        hoptime = 0.01, numcep = 12, lifterexp = 0.6, htklifter = FALSE,
        sumpower = TRUE, preemph = 0.97, dither = FALSE,
        minfreq = 0, maxfreq = sr/2, nbands = 40, bwidth = 1,
        dcttype = c("t2", "t1", "t3", "t4"),
        fbtype = c("mel", "htkmel", "fcmel", "bark"), usecmp = FALSE,
        modelorder = NULL, spec_out = FALSE, frames_in_rows = TRUE)
```

Arguments

samples	Object of Wave-class or WaveMC-class . Only the first channel will be used.
sr	Sampling rate of the signal.
wintime	Window length in sec.
hoptime	Step between successive windows in sec.
numcep	Number of cepstra to return.
lifterexp	Exponent for liftering; 0 = none.
htklifter	Use HTK sin lifter.
sumpower	If <code>sumpower = TRUE</code> the frequency scale transformation is based on the power-spectrum, if <code>sumpower = FALSE</code> it is based on its squareroot (absolute value of the spectrum) and squared afterwards.
preemph	Apply pre-emphasis filter [1 -preemph] (0 = none).
dither	Add offset to spectrum as if dither noise.
minfreq	Lowest band edge of mel filters (Hz).
maxfreq	Highest band edge of mel filters (Hz).
nbands	Number of warped spectral bands to use.
bwidth	Width of spectral bands in Bark/Mel.
dcttype	Type of DCT used - 1 or 2 (or 3 for HTK or 4 for feacalc).
fbtype	Auditory frequency scale to use: "mel", "bark", "htkmel", "fcmel".
usecmp	Apply equal-loudness weighting and cube-root compression (PLP instead of LPC).
modelorder	If <code>modelorder > 0</code> , fit a linear prediction (autoregressive-) model of this order and calculation of cepstra out of lpcas.
spec_out	Should matrices of the power- and the auditory-spectrum be returned.
frames_in_rows	Return time frames in rows instead of columns (original Matlab code).

Details

Calculation of the MFCCs includes the following steps:

1. Preemphasis filtering
2. Take the absolute value of the STFT (usage of Hamming window)
3. Warp to auditory frequency scale (Mel/Bark)
4. Take the DCT of the log-auditory-spectrum
5. Return the first 'ncep' components

Value

cepstra	Cepstral coefficients of the input signal (one time frame per row/column)
aspectrum	Auditory spectrum (spectrum after transformation to Mel/Bark scale) of the signal
pspectrum	Power spectrum of the input signal.
lpcas	If modelorder > 0, the linear prediction coefficients (LPC/PLP).

Note

The following non-default values nearly duplicate Malcolm Slaney's mfcc (i.e.

```
melfcc(d, 16000, wintime=0.016, lifterexp=0, minfreq=133.33,
        maxfreq=6855.6, sumpower=FALSE)
```

== log(10) * 2 * mfcc(d, 16000) in the Auditory toolbox for Matlab).

The following non-default values nearly duplicate HTK's MFCC (i.e.

```
melfcc(d, 16000, lifterexp=22, htklifter=TRUE, nbands=20, maxfreq=8000,
        sumpower=FALSE, fbtype="htkmel", dcttype="t3")
```

== 2 * htkmelfcc(:, [13, [1:12]]) where HTK config has 'PREEMCOEF = 0.97', 'NUMCHANS = 20', 'CEPLIFTER = 22', 'NUMCEPS = 12', 'WINDOWSIZE = 250000.0', 'USEHAMMING = T', 'TARGETKIND = MFCC_0').

For more detail on reproducing other programs' outputs, see <http://www.ee.columbia.edu/~dpwe/resources/matlab/rastamat/mfcs.html>

Author(s)

Sebastian Krey <krey@statistik.tu-dortmund.de>

References

Daniel P. W. Ellis: <http://www.ee.columbia.edu/~dpwe/resources/matlab/rastamat/>

Examples

```

testsound <- normalize(sine(400) + sine(1000) + square(250), "16")
m1 <- melfcc(testsound)

#Use PLP features to calculate cepstra and output the matrices like the
#original Matlab code (note: modelorder limits the number of cepstra)
m2 <- melfcc(testsound, numcep=9, usecmp=TRUE, modelorder=8,
  spec_out=TRUE, frames_in_rows=FALSE)

```

melodyplot

*Plotting a melody***Description**

Plot a observed melody and (optional) an expected melody, as well as corresponding energy values (corresponding to the loudness of the sound).

Usage

```

melodyplot(object, observed, expected = NULL, bars = NULL,
  main = NULL, xlab = NULL, ylab = "note", xlim = NULL, ylim = NULL,
  observedtype = "l", observedcol = "red", expectedcol = "grey",
  gridcol = "grey", lwd = 2, las = 1, cex.axis = 0.9,
  mar = c(5, 4, 4, 4) + 0.1, notenames = NULL, thin = 1,
  silence = "silence", plotenergy = TRUE, ...,
  axispar = list(ax1 = list(side=1),
    ax2 = list(side=2),
    ax4 = list(side=4)),
  boxpar = list(),
  energylabel = list(text="energy", side=4, line=2.5, at=rg.s-0.25, las=3),
  energypar = list(),
  expectedpar = list(),
  gridpar = list(col=gridcol),
  observedpar = list(col=observedcol, type=observedtype, lwd=2, pch=15))

```

Arguments

object	An object of class Wspec .
observed	Observed notes, probably as a result from noteFromFF (or a smoothed version). This should correspond to the Wspec object. It can also be a matrix of k columns where those k notes in the same row are displayed at the same timepoint.
expected	Expected notes (optional; in order to compare results), same format as observed.
bars	Number of bars to be plotted (a virtual static segmentation takes place). If NULL (default), time rather than bars are used.
main	Main title of the plot.

<code>xlab, ylab</code>	Annotation of <i>x</i> / <i>y</i> -axes.
<code>xlim, ylim</code>	Range of <i>x</i> / <i>y</i> -axis, where <code>ylim</code> must be an integer that represents the range of note heights that should be displayed.
<code>observedtype</code>	Type (either "p" for points or "l" for lines) used for representing observed notes. "l" (the default) is not sensible for polyphonic representations.
<code>observedcol</code>	Colour for the observed melody.
<code>expectedcol</code>	Colour for the expected melody.
<code>gridcol</code>	Colour of the grid.
<code>lwd</code>	Line width, see par for details.
<code>las</code>	Orientation of axis labels, see par for details.
<code>cex.axis</code>	Size of tick mark labels, see par for details.
<code>mar</code>	Margins of the plot, see par for details.
<code>notenames</code>	Optionally specify other notenames (character) for the <i>y</i> axis.
<code>thin</code>	Amount of thinning of notenames, i.e. only each <i>thin</i> th notename is displayed on the <i>y</i> -axis.
<code>silence</code>	Character string for label of the 'silence' (default) axis.
<code>plotenergy</code>	Logical (default: TRUE), whether to plot energy values in the bottom part of the plot.
<code>...</code>	Additional graphical parameters to be passed to underlying plot function.
<code>axispar</code>	A named list of three other lists (<code>ax1</code> , <code>ax2</code> , and <code>ax4</code>) containing parameters passed to the corresponding axis calls for the three axis time (<code>ax1</code>), notes (<code>ax2</code>), and energy (<code>ax4</code>).
<code>boxpar</code>	A list of parameters to be passed to the box generating functions.
<code>energylabel</code>	A list of parameters to be passed to the energy-label generating mtext call.
<code>energypar</code>	A list of parameters to be passed to the lines function that draws the energy curve.
<code>expectedpar</code>	A list of parameters to be passed to the rect function that draws the rectangles for expected values.
<code>gridpar</code>	A list of parameters to be passed to the abline function that draws the grid lines.
<code>observedpar</code>	A list of parameters to be passed to the lines function that draws the observed values.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

[noteFromFF](#), [FF](#), [quantplot](#); for an example, see the help in [tuneR](#).

MFCC

*DEFUNCT: Mel Frequency Cepstral Coefficients***Description**

DEFUNCT: Computation of MFCCs — this has been replaced by [melfcc](#) already and is just a wrapper! Will be removed shortly.

Note

This function was always documented to be in development and highly EXPERIMENTAL!!!

See Also

[melfcc](#)

Mono-Stereo

*Converting (extracting, joining) stereo to mono and vice versa***Description**

Functions to extract a channel from a stereo Wave object, and to join channels of two monophonic Wave objects to a stereophonic one.

Usage

```
mono(object, which = c("left", "right", "both"))
stereo(left, right)
```

Arguments

object	Object of class Wave .
which	Character, indicating whether the “left” or “right” channel should be extracted, or whether “both” channels should be averaged.
left	Object of class Wave containing monophonic sound, to be used for the left channel.
right	Object of class Wave containing monophonic sound, to be used for the right channel (if missing, the left channel is duplicated). If <code>right</code> is missing, <code>stereo</code> returns whether <code>left</code> is stereo (TRUE) or mono (FALSE).

Details

For objects of [WaveMC-class](#), a mono channel can be created by simple matrix indexing, e.g. `WaveMCobject[,2]` selects the second channel.

Value

An object of class [Wave](#).

If argument `right` is missing in `stereo`, a logical values is returned that indicates whether left is stereo (TRUE) or mono (FALSE).

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

[Wave-class](#), [Wave](#)

Examples

```
Wobj <- sine(440)
Wobj
Wobj2 <- stereo(Wobj, Wobj)
Wobj2
mono(Wobj2, "right")
```

nchannel

Number of channels

Description

Get the number of channels from a [Wave](#) or [WaveMC](#) object

Usage

```
nchannel(object)
## S4 method for signature 'Wave'
nchannel(object)
## S4 method for signature 'WaveMC'
nchannel(object)
```

Arguments

`object` Object of class [Wave](#) or class [WaveMC](#).

Value

An integer, the number of channels given in the object.

See Also

[Wave-class](#), [WaveMC-class](#)

normalize-methods	<i>Rescale the range of values</i>
-------------------	------------------------------------

Description

Centering and rescaling the waveform of a `Wave` or `WaveMC` object to a canonical interval corresponding to the `Wave` format (e.g. [-1, 1], [0, 254], [-32767, 32767], [-8388607, 8388607], or [-2147483647, 2147483647]).

Usage

```
normalize(object, unit = c("1", "8", "16", "24", "32", "64", "0"),
         center = TRUE, level = 1, rescale = TRUE, pcm = object@pcm)
```

Arguments

<code>object</code>	Object of class <code>Wave</code> or <code>WaveMC</code> .
<code>unit</code>	Unit to rescale to. "1" (default) for rescaling to numeric values in [-1, 1], "8" (i.e. 8-bit) for rescaling to integers in [0, 254], "16" (i.e. 16-bit) for rescaling to integers in [-32767, 32767], "24" (i.e. 24-bit) for rescaling to integers in [-8388607, 8388607], "32" (i.e. 32-bit) for rescaling either to integers in [-2147483647, 2147483647] (PCM <code>Wave</code> format if <code>pcm=TRUE</code>) or to numeric values in [-1, 1] (<code>FLOAT_IEEE</code> <code>Wave</code> format if <code>pcm = FALSE</code>), "64" (i.e. 64-bit) for rescaling to real values in [-1, 1] (<code>FLOAT_IEEE</code> <code>Wave</code> format), and "0" for not rescaling (hence only centering if <code>center = TRUE</code>).
<code>center</code>	If <code>TRUE</code> (default), values are centered around 0 (or 127 if <code>unit = "8"</code>).
<code>level</code>	Maximal percentage of the amplitude used for normalizing (default is 1).
<code>rescale</code>	Logical, whether to rescale to the maximal possible dynamic range.
<code>pcm</code>	Logical. By default, the <code>pcm</code> information from the object is kept. Otherwise, if <code>TRUE</code> , the object is coerced to the PCM <code>Wave</code> format. If <code>FALSE</code> , the object is coerced to the <code>FLOAT_IEEE</code> format, i.e. numeric values in [-1, 1].

Value

An object containing the normalized data of the same class as the input object, i.e. either `Wave` or `WaveMC`.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>, Sarah Schnackenberg, based on code from Matthias Heymann's former package 'sound'.

See Also

[writeWave](#), [Wave-class](#), [Wave](#), [WaveMC-class](#), [WaveMC](#)

noSilence

Cut off silence from a Wave or WaveMC object

Description

Generic function to cut off silence or low noise at the beginning and/or at the end of an object of class `Wave` or class `WaveMC`.

Usage

```
noSilence(object, zero = 0, level = 0, where = c("both", "start", "end"))
```

Arguments

object	Object of class Wave or class WaveMC .
zero	The zero level (default: 0) at which ideal cut points are determined (see Details). A typical alternative would be 127 for 8 bit Wave or WaveMC objects. If zero = NA, the mean of the left <code>Wave</code> channel (for <code>Wave</code> , resp. the mean of the first channel for <code>WaveMC</code>) is taken as zero level.
level	Values in the interval between zero and zero - level/zero + level are considered as silence.
where	One of "both" (default), "start", or "end" indicating at where to prepare the Wave or WaveMC object for concatenation.

Details

Silence is removed at the locations given by where of the [Wave](#) or [WaveMC](#) object, where silence is defined such that (in both channels if stereo, in all channels if multichannel for `WaveMC`) all values are in the interval between zero - level and zero + level. All values before (or after, respectively) the first non-silent value are removed from the object.

Value

An object of class [Wave](#) or [WaveMC](#).

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>, Sarah Schnackenberg, based on code from Matthias Heymann's former package 'sound'.

See Also

[silence](#), [Wave-class](#), [Wave](#), [WaveMC-class](#), [WaveMC](#), [extractWave](#)

noteFromFF *Deriving notes from frequencies*

Description

Deriving notes from given (fundamental) frequencies.

Usage

```
noteFromFF(x, diapason = 440, roundshift = 0)
```

Arguments

x	Fundamental frequency.
diapason	Frequency of diapason a, default is 440 (Hertz).
roundshift	Shift that indicates from here to round to the next integer (note). The default (0) is “classical” rounding as described in round . A higher value means that roundshift is added to the calculated real note value before rounding to an integer. This is useful if it is unclear that some instruments really shift the note in the center between two theoretical frequencies. Example: if $x = 452$ and $diapason = 440$, the internally calculated real value of 0.46583 is rounded to 0, but for $roundshift = 0.1$ we get 0.56583 and it is rounded to note 1.

Details

The formula used is simply $\text{round}(12 * \log(x / \text{diapason}, 2) + \text{roundshift})$.

Value

An integer representing the (rounded) difference in halftones from diapason a, i.e. indicating the note that corresponds to fundamental frequency x given the value of diapason. For example: 0 indicates diapason a, 3: c', 12: a', ...

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

[FF](#), [periodogram](#), and [tuneR](#) for a very complete example.

notenames *Generating note names from numbers*

Description

A function that generates note names from numbers

Usage

```
notenames(notes, language = c("english", "german"))
```

Arguments

notes An interger values vector, where 0 corresponds to a', notes below and above have to be specified in the corresponding halftone distance.

language Language of the note names. Currently only english and german are supported.

Value

A character vector of note names.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

Examples

```
notenames(c(-24, -12, 0, 12)) # octaves of a
notenames(3:15)                      # chromaticism

## same in german:
notenames(3:15, language = "german")
```

panorama *Narrow the Panorama of a Stereo Sample*

Description

Generic function to narrow the panorama of a stereo Wave or WaveMC object.

Usage

```
panorama(object, pan = 1)
```

Arguments

object	Object of class Wave or class WaveMC .
pan	Value in [-1,1] to narrow the panorama, see the Details below. The default (1) does not change anything.

Details

If $\text{abs}(\text{pan}) < 1$, mixtures of the two channels of the [Wave](#) or [WaveMC](#) objects are used for the left and the right channel of the returned [Sample](#) object if the object is of class [Wave](#), resp. for the first and second channel of the returned [Sample](#) object if the object is of class [WaveMC](#), so that they appear closer to the center.

For $\text{pan} = 0$, both sounds are completely in the center (i.e. averaged).

If $\text{pan} < 0$, the left and the right channel (for [Wave](#) objects, the first and the second channel for [WaveMC](#) objects) are interchanged.

Value

An object of class [Wave](#) or class [WaveMC](#) with the transformed panorama.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>, Sarah Schnackenberg, based on code by Matthias Heymann

See Also

[Wave-class](#), [Wave](#), [WaveMC-class](#), [WaveMC](#)

periodogram-methods *Periodogram (Spectral Density) Estimation on Wave objects*

Description

This function estimates one or more periodograms (spectral densities) of the time series contained in an object of class [Wave](#) or [WaveMC](#) (or directly in a [Wave](#) file) using a window running through the time series (possibly with overlapping). It returns an object of class [Wspec](#).

Usage

```
periodogram(object, ...)
## S4 method for signature 'WaveGeneral'
periodogram(object, width = length(object), overlap = 0,
  starts = NULL, ends = NULL, taper = 0, normalize = TRUE,
  frqRange = c(-Inf, Inf), ...)
## S4 method for signature 'character'
periodogram(object, width, overlap = 0, from = 1, to = Inf,
  units = c("samples", "seconds", "minutes", "hours"),
  downsample = NA, channel = c("left", "right"), pieces = 1, ...)
```

Arguments

object	An object of class Wave , WaveMC , or a character string pointing to a Wave file.
width	A window of width ‘width’ running through the time series selects the samples from which the periodograms are to be calculated.
overlap	The window can be applied by each overlapping overlap samples.
starts	Start number (in samples) for a window. If not given, this value is derived from argument ends, or will be derived width and overlap.
ends	End number (in samples) for a window. If not given, this value is derived from argument starts, or will be derived from width and overlap.
taper	proportion of data to taper. See spec.pgram for details.
normalize	Logical; if TRUE (default), two steps will be applied: (i) the input signal will be normalized to amplitude $\max(\text{abs}(\text{amplitude})) == 1$, (ii) the resulting spec values will be normalized to sum up to one for each periodogram.
frqRange	Numeric vector of two elements indicating minimum and maximum of the frequency range that is to be stored in the resulting object. This is useful to reduce memory consumption.
from	Where to start reading in the Wave file, in units.
to	Where to stop reading in the Wave file, in units.
units	Units in which from and to is given, the default is “samples”, but can be set to time intervals such as “seconds”, see the Usage Section above.
downsample	Sampling rate the object is to be downsampled to. If NA, the default, no changes are applied. Otherwise downsample must be in [2000, 192000]; typical values are 11025, 22050, and 44100 for CD quality. See also downsample .
channel	Character, indicating whether the “left” or “right” channel should be extracted (see mono for details) - stereo processing is not yet implemented.
pieces	The Wave file will be read in in pieces steps in order to reduce the amount of required memory.
...	Further arguments to be passed to the underlying function spec.pgram .

Value

An object of class [Wspec](#) is returned containing the following slots.

freq	Vector of frequencies at which the spectral density is estimated. See spectrum for details. (1)
spec	List of vectors or matrices of the spec values returned by spec.pgram at frequencies corresponding to freq. Each element of the list corresponds to one periodogram estimated from samples of the window beginning at start of the Wave or WaveMC object.
kernel	The kernel argument, or the kernel constructed from spans returned by spec.pgram . (1)
df	The distribution of the spectral density estimate can be approximated by a chi square distribution with df degrees of freedom. (1)

taper	The value of the taper argument. (1)
width	The value of the width argument. (1)
overlap	The value of the overlap argument. (1)
normalize	The value of the normalize argument. (1)
starts	If the argument starts was given in the call, its value. If the argument ends was given in the call, 'ends - width'. If neither starts nor ends was given, the start points of all periodograms. In the latter case the start points are calculated from the arguments width and overlap.
stereo	Always FALSE (for back compatibility). (1)
samp.rate	Sampling rate of the underlying Wave or WaveMC object. (1)
variance	The variance of samples in each window, corresponding to amplitude / loudness of sound.
energy	The "energy" E , also an indicator for the amplitude / loudness of sound:

$$E(x_I) := 20 * \log_{10} \sum_{j \in I} |x_j|,$$

where I indicates the interval $I := \text{start}[i]:\text{end}[i]$ for all $i := 1, \dots, \text{length}(\text{starts})$.

Those slots marked with "(1)" contain the information once, because it is unique for all periodograms of estimated by the function call.

Note

Support for processing more than one channel of [Wave](#) or [WaveMC](#) objects has not yet been implemented.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

- for the resulting objects' class: [Wspec](#),
- for plotting: [plot-Wspec](#),
- for the underlying periodogram calculations: [spec.pgram](#),
- for the input data class: [Wave-class](#), [Wave](#), [WaveMC-class](#), [WaveMC](#).

Examples

```
# constructing a Wave object (1 sec.) containing sinus sound with 440Hz:
Wobj <- sine(440)
Wobj

# Calculate periodograms in windows of 4096 samples each - without
# any overlap - resulting in an Wspec object that is printed:
```

```

Wspecobj <- periodogram(Wobj, width = 4096)
Wspecobj

# Plot the first periodogram from Wspecobj:
plot(Wspecobj)
# Plot the third one and choose a reasonable xlim:
plot(Wspecobj, which = 3, xlim = c(0, 1000))
# Mark frequency that has been generated before:
abline(v = 440, col="red")

FF(Wspecobj)           # all ~ 440 Hertz
noteFromFF(FF(Wspecobj)) # all diapason a

```

play-methods

Playing Waves

Description

Plays wave files and objects of class Wave.

Usage

```
play(object, player, ...)
```

Arguments

object	Either a filename pointing to a Wave file, or an object of class Wave or WaveMC . If the latter, it is written to a temporary file by writeWave , played by the chosen player, and deleted afterwards.
player	(Path to) a program capable of playing a wave file by invocation from the command line. If under Windows and no player is given, “mplay32.exe” or “wm-player.exe” (if the former does not exist as under Windows 7) will be chosen as the default.
...	Further arguments passed to the Wave file player. If no player and no further arguments are given under Windows, the default is: “/play /close”.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

[Wave-class](#), [WaveMC-class](#), [Wave](#), [WaveMC](#), [writeWave](#), [setWavPlayer](#)

plot-Wave

*Plotting Wave objects***Description**

Plotting objects of class Wave.

Usage

```
## S4 method for signature 'Wave,missing'
plot(x, info = FALSE, xunit = c("time", "samples"),
     ylim = NULL, main = NULL, sub = NULL, xlab = NULL, ylab = NULL,
     simplify = TRUE, nr = 2500, axes = TRUE, yaxt = par("yaxt"), las = 1,
     center = TRUE, ...)

## S4 method for signature 'WaveMC,missing'
plot(x, info = FALSE, xunit = c("time", "samples"),
     ylim = NULL, main = NULL, sub = NULL, xlab = NULL, ylab = colnames(x),
     simplify = TRUE, nr = 2500, axes = TRUE, yaxt = par("yaxt"), las = 1,
     center = TRUE, mfrow = NULL, ...)

plot.Wave.channel(x, xunit, ylim, xlab, ylab, main, nr, simplify, axes = TRUE,
                 yaxt = par("yaxt"), las = 1, center = TRUE, ...)
```

Arguments

x	Object of class Wave or WaveMC , respectively.
info	Logical, whether to include (written) information on the Wave or WaveMC object within the plot.
xunit	Character indicating which units are used for setting up user coordinates (see par) and x-axis labeling. If <code>xunit = "time"</code> , the unit is time in seconds, otherwise the number of samples.
ylim	The y (amplitude) limits of the plot.
main, sub	A title / subtitle for the plot.
xlab	Label for x-axis.
ylab	Label for y-axis (on the right side of the plot). For WaveMC objects, this can be the default <code>colnames(x)</code> (i.e. channel names of the WaveMC object), <code>NULL</code> for “channel 1”, ..., “channel nc” where <code>nc</code> is <code>ncol(x)</code> , <code>NA</code> for no labels, or a character vector of labels (one element for each channel). For Wave objects, this can be de default “left channel” (for mono) or “left channel” and “right channel” (for stereo), <code>NA</code> for no labels, or a character vector of labels (one element for each channel).
simplify	Logical, whether the plot should be “simplified”. If <code>TRUE</code> (default), not all (thousand/millions/billions) of points (samples) of the Wave or WaveMC object are

drawn, but the `nr` (see below) ranges (in form of segments) within `nr` windows of the time series.

Plotting with `simplify = FALSE` may take several minutes (depending on the number of samples in the `Wave` or `WaveMC`) and output in any vector format may be really huge.

<code>nr</code>	Number of windows (segments) to be used <i>approximately</i> (an appropriate number close to <code>nr</code> is selected) to <code>simplify</code> (see above) the plot. Only used if <code>simplify = TRUE</code> and the number of samples of the <code>Wave</code> or <code>WaveMC</code> object <code>x</code> is larger.
<code>axes</code>	Whether to plot axes, default is <code>TRUE</code> .
<code>yaxt</code>	How to plot the y-axis (" <code>n</code> " for no y-axis).
<code>las</code>	The style of the axis labels, default is <code>las = 1</code> (always horizontal), see par for details.
<code>center</code>	Whether to plot with y-axes centered around 0 (or 127 if 8-bit), default is <code>TRUE</code> .
<code>mfrow</code>	A vector indicating the arrangement of the figures, see par for details.
<code>...</code>	Further arguments to be passed to the underlying plot functions.

Details

Function `plot.Wave.channel` is a helper function to plot a single channel (left for a `Wave` object, first channel / first column of data slot of a `WaveMC` object); in particular it is *not* intended to be called by the user directly.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>, Sarah Schnackenberg

See Also

[Wave-class](#), [Wave](#), [WaveMC-class](#), [WaveMC](#) and [tuneR](#)

plot-Wspec

Plotting Wspec objects

Description

Plotting a periodogram contained in an object of class `Wspec`.

Usage

```
## S4 method for signature 'Wspec,missing'
plot(x, which = 1, type = "h", xlab = "Frequency",
     ylab = NULL, log = "", ...)
```

Arguments

x	Object of class Wspec .
which	Integer indicating which of the periodograms contained in object x to plot. Default is to plot the first one.
type	The default is to plot horizontal lines, rather than points. See plot.default for details.
xlab, ylab	Label for x-/y-axis.
log	Character - "x" if the x-axis is to be logarithmic, "y" if the y-axis is to be logarithmic (quite typical for some visualizations of periodograms), and "xy" or "yx" if both axes are to be logarithmic.
...	Further arguments to be passed to the underlying plot functions. See plot.default for details.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

see [Wspec](#), [periodogram](#) and [tuneR](#) for the constructor function and some examples.

plot-WspecMat

Plotting WspecMat objects

Description

Plotting a spectrogram (image) of an object of class [Wspec](#) or [WspecMat](#).

Usage

```
## S4 method for signature 'WspecMat,missing'
plot(x, xlab = "time", ylab = "Frequency",
     xunit = c("samples", "time"), log = "", ...)
## S4 method for signature 'Wspec'
image(x, xlab = "time", ylab = "Frequency",
      xunit = c("samples", "time"), log = "", ...)
```

Arguments

x	Object of class WspecMat (for plot) or Wspec (for image).
xlab, ylab	Label for x-/y-axis.
xunit	Character indicating which units are used to annotate the x-axis. If <code>xunit = "time"</code> , the unit is time in seconds, otherwise the number of samples.
log	Character - "z" if the z values are to be logarithmic.
...	Further arguments to be passed to the underlying image function. See image for details.

Details

Calling `image` on a `Wspec` object converts it to class `WspecMat` and calls the corresponding plot function.

Calling `plot` on a `WspecMat` object generates an `image` with correct annotated axes.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

see `image`, `Wspec`, `WspecMat`, `periodogram` and `tuneR` for the constructor function and some examples.

postaud

Equal loudness compression

Description

Do loudness equalization and cube root compression

Usage

```
postaud(x, fmax, fbtype = c("bark", "mel", "htkmel", "fcmel"),  
        broaden = FALSE)
```

Arguments

<code>x</code>	Matrix of spectra (output of <code>audspec</code>).
<code>fmax</code>	Maximum frequency in Hertz.
<code>fbtype</code>	Auditory frequency scale.
<code>broaden</code>	Use two additional frequency bands for calculation.

Value

<code>x</code>	Matrix of the per sample/frame (columns) spectra after applying the frequency dependant loudness equalization and compression.
<code>eq1</code>	Vector of the equal loudness curve.

Author(s)

Sebastian Krey <krey@statistik.tu-dortmund.de>

References

Daniel P. W. Ellis <http://www.ee.columbia.edu/~dpwe/resources/matlab/rastamat/>, Hynek Hermansky

See Also[audspec](#), [dolpc](#)**Examples**

```
testsound <- normalize(sine(400) + sine(1000) + square(250), "16")
pspectrum <- powspec(testsound@left, testsound@samp.rate)
aspectrum <- audspec(pspectrum, testsound@samp.rate)
paspectrum <- postaud(x = aspectrum$aspectrum, fmax = 5000,
  fbtype = "mel")
```

powspec

Powerspectrum

Description

Compute the powerspectrum of the input signal. Basically output a power spectrogram using a Hamming window.

Usage

```
powspec(x, sr = 8000, wintime = 0.025, steptime = 0.01, dither = FALSE)
```

Arguments

x	Vector of samples.
sr	Sampling rate of the signal.
wintime	Window length in sec.
steptime	Step between successive windows in sec.
dither	Add offset to spectrum as if dither noise.

Value

Matrix, where each column represents a power spectrum for a given frame and each row represents a frequency.

Author(s)

Sebastian Krey <krey@statistik.tu-dortmund.de>

References

Daniel P. W. Ellis: <http://www.ee.columbia.edu/~dpwe/resources/matlab/rastamat/>

See Also[specgram](#)

Examples

```
testsound <- normalize(sine(400) + sine(1000) + square(250), "16")
pspectrum <- powspec(testsound@left, testsound@samp.rate)
```

```
prepComb
```

Preparing the combination/concatenation of Wave or WaveMC objects

Description

Preparing objects of class `Wave` or class `WaveMC` for binding/combination/concatenation by removing small amounts at the beginning/end of the `Wave` or `WaveMC` in order to make the transition smooth by avoiding clicks.

Usage

```
prepComb(object, zero = 0, where = c("both", "start", "end"))
```

Arguments

<code>object</code>	Object of class <code>Wave</code> or class <code>WaveMC</code> .
<code>zero</code>	The zero level (default: 0) at which ideal cut points are determined (see Details). A typical alternative would be 127 for 8 bit <code>Wave</code> or <code>WaveMC</code> objects. If <code>zero = NA</code> , the mean of the left <code>Wave</code> channel (for a <code>Wave</code> object) or the mean of the first channel (for a <code>WaveMC</code> object) is taken as zero level.
<code>where</code>	One of "both" (default), "start", or "end" indicating at where to prepare the <code>Wave</code> or <code>WaveMC</code> object for concatenation.

Details

This function is useful to prepare objects of class `Wave` or class `WaveMC` for binding/combination/concatenation. At the side(s) indicated by `where` small amounts of the `Wave` or `WaveMC` are removed in order to make the transition between two `Waves` or `WaveMCs` smooth (avoiding clicks).

This is done by dropping all values at the *beginning* of a `Wave` or `WaveMC` before the first positive point after the zero level is crossed from negative to positive. Analogously, at the *end* of a `Wave` or `WaveMC` all points are cut after the last negative value before the last zero level crossing from negative to positive.

Value

An object of class `Wave` or class `WaveMC`.

Note

If stereo (for `Wave`), only the left channel is analyzed while the right channel will simply be cut at the same locations. If multi channel (for `WaveMC`), only the first channel is analyzed while all other channels will simply be cut at the same locations.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>, Sarah Schnackenberg, based on code from Matthias Heymann's former package 'sound'.

See Also

[bind](#), [Wave-class](#), [Wave](#), [WaveMC-class](#), [WaveMC](#), [extractWave](#), and [noSilence](#) to cut off silence

Examples

```
Wobj1 <- sine(440, duration = 520)
Wobj2 <- extractWave(sine(330, duration = 500), from = 110, to = 500)
par(mfrow = c(2,1))
plot(bind(Wobj1, Wobj2), xunit = "samples")
abline(v = 520, col = "red") # here is a "click"!

# now remove the "click" by deleting a minimal amount of information:
Wobj1 <- prepComb(Wobj1, where = "end")
Wobj2 <- prepComb(Wobj2, where = "start")
plot(bind(Wobj1, Wobj2), xunit = "samples")
```

quantize

Functions for the quantization of notes

Description

These functions apply (static) quantization of notes in order to produce sheet music by pressing the notes into bars.

Usage

```
quantize(notes, energy, parts)
quantMerge(notes, minlength, barsize, bars)
```

Arguments

notes	Series of notes, a vector of integers such as returned by noteFromFF . At least one argument (notes and/or energy) must be specified.
energy	Series of energy values, a vector of numerics such as corresponding components of a Wspec object.
parts	Number of outgoing parts. The notes vector is divided into parts bins, the outcome is a vector of the modes of all bins.
minlength	1/(length of the shortest note). Example: if the shortest note is a quaver (1/8), set minlength = 8.
barsize	One bar contains barsize number of notes of length minlength.
bars	We expect bars number of bars.

Value

quantize returns a list with components:

notes Vector of length parts corresponding to the input data The data is binned and modes corresponding to the data in those bins are returned.

energy Same as notes, but for the energy argument.

quantMerge returns a data.frame with components:

note integer representation of a note (see Arguments).

duration 1/duration of a note (see minlength in Section Arguments), if punctuation = FALSE.

punctuation Whether the note should be punctuated. If TRUE, the real duration is 1.5 times the duration given in duration.

slur currently always FALSE, sensible processing is not yet implemented. It is supposed to indicate the beginning and ending positions of slurs.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

to get the input: [noteFromFF](#), for plotting: [quantplot](#), for further processing: [lilyinput](#), to get notenames: [notenames](#); for an example, see the help in [tuneR](#).

quantplot	<i>Plotting the quantization of a melody</i>
-----------	--

Description

Plot an observed melody and (optional) an expected melody, as well as corresponding energy values (corresponding to the loudness of the sound) within a quantization grid.

Usage

```
quantplot(observed, energy = NULL, expected = NULL, bars,
  barseg = round(length(observed) / bars),
  main = NULL, xlab = NULL, ylab = "note", xlim = NULL, ylim = NULL,
  observedcol = "red", expectedcol = "grey", gridcol = "grey",
  lwd = 2, las = 1, cex.axis = 0.9, mar = c(5, 4, 4, 4) + 0.1,
  notenames = NULL, silence = "silence", plotenergy = TRUE, ...,
  axispar = list(ax1 = list(side=1), ax2 = list(side=2), ax4 = list(side=4)),
  boxpar = list(),
  energylabel = list(text="energy", side=4, line=2.5, at=rg.s-0.25, las=3),
  energypar = list(pch=20),
  expectedpar = list(),
  gridpar = list(gridbar = list(col = 1), gridinner = list(col=gridcol)),
  observedpar = list(col=observedcol, pch=15))
```


Arguments

observed	Either a vector of observed notes resulting from some quantization, or a list with components notes (observed notes) and energy (corresponding energy values), e.g. the result from a call to quantize .
energy	A vector of energy values with same quantization as observed (overwrites any given energy values if observed is a list).
expected	Expected notes (optional; in order to compare results).
bars	Number of bars to be plotted (e.g. corresponding to quantize arguments).
barseg	Number of segments (minimal length notes) in each bar.
main	Main title of the plot.
xlab, ylab	Annotation of x-/y-axes.
xlim, ylim	Range of x-/y-axis.
observedcol	Colour for the observed notes.
expectedcol	Colour for the expected notes.
gridcol	Colour of the inner-bar grid.
lwd	Line width, see par for details.
las	Orientation of axis labels, see par for details.
cex.axis	Size of tick mark labels, see par for details.
mar	Margins of the plot, see par for details.
notenames	Optionally specify other notenames (character) for the y-axis.
silence	Character string for label of the ‘silence’ (default) axis.
plotenergy	Logical indicating whether to plot energy values in the bottom part of the plot (default is TRUE) if energy values are specified, and FALSE otherwise.
...	Additional graphical parameters to be passed to underlying plot function.
axispar	A named list of three other lists (ax1, ax2, and ax4) containing parameters passed to the corresponding axis calls for the three axis time (ax1), notes (ax2), and energy (ax4).
boxpar	A list of parameters to be passed to the box generating functions.
energylabel	A list of parameters to be passed to the energy-label generating mtext call.
energypar	A list of parameters to be passed to the points function that draws the energy values.
expectedpar	A list of parameters to be passed to the rect function that draws the rectangles for expected values.
gridpar	A named list of two other lists (gridbar and gridinner) containing parameters passed to the abline functions that draw the grid lines (for bar separators and inner bar (note) separators).
observedpar	A list of parameters to be passed to the lines function that draws the observed values.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

[noteFromFF](#), [FF](#), [melodyplot](#), [quantize](#); for an example, see the help in [tuneR](#).

readMidi

Read a MIDI file

Description

A MIDI file is read and returned in form of a structured data frame containing most event information (minus some meta events and minus all system events). For details about the represented information see the reference given below.

Usage

```
readMidi(file)
```

Arguments

`file` Filename of MIDI file.

Value

A data frame consisting of columns

<code>time</code>	Time or delta-time of the events, depending on the MIDI format.
<code>event</code>	A factor indicating the event.
<code>type</code>	An integer indicating the type of a “meta event”, otherwise NA.
<code>channel</code>	The channel number or NA if not applicable.
<code>parameter1</code>	First parameter of an event, e.g. a representation for a note in a “note event”.
<code>parameter2</code>	Second parameter of an event.
<code>parameterMetaSystem</code>	Information in a “meta event”, currently all meta events are converted to a character representation (of hex, if all fails), but future versions may have more appropriate representations.
<code>track</code>	The track number.

Please see the given reference about the MIDI file format about details.

Note

The data structure may be changed or extended in future versions.

Author(s)

Uwe Ligges and Johanna Mielke

References

A good reference about the Midi file format can be found at <http://www.music.mcgill.ca/~ich/classes/mumt306/StandardMIDIfileformat.html>.

See Also

The function `getMidiNotes` extracts a more readable representation of note events only.

You may also want to read Wave (`readWave`) or MP3 (`readMP3`).

Examples

```
content <- readMidi(system.file("example_files", "Bass_sample.mid", package="tuneR"))
str(content)
content
```

`readMP3`*Read an MPEG-2 layer 3 file into a Wave object*

Description

A bare bones MPEG-2 layer 3 (MP3) file reader that returns the results as 16bit PCM data stored in a Wave object.

Usage

```
readMP3(filename)
```

Arguments

filename Filename of MP3 file.

Value

A `Wave` object.

Note

The decoder can currently only handle files which are either mono or stereo. This is a limitation of the Wave object and the underlying MAD decoder.

Author(s)

Olaf Mersmann <olafm@statistik.tu-dortmund.de>

References

The decoder source code is taken from the MAD library, see <http://www.underbit.com/products/mad/>.

See Also

[Wave](#)

Examples

```
## Not run:
## Requires an mp3 file named sample.mp3 in the current directory.
mpt <- readMP3("sample.mp3")
summary(mpt)

## End(Not run)
```

readWave

Reading Wave files

Description

Reading Wave files.

Usage

```
readWave(filename, from = 1, to = Inf,
          units = c("samples", "seconds", "minutes", "hours"), header = FALSE, toWaveMC = NULL)
```

Arguments

filename	Filename of the file to be read.
from	Where to start reading (in order to save memory by reading wave file piecewise), in units.
to	Where to stop reading (in order to save memory by reading wave file piecewise), in units.
units	Units in which from and to is given, the default is "samples", but can be set to time intervals such as "seconds", see the Usage Section above.
header	If TRUE, just header information of the Wave file are returned, otherwise (the default) the whole Wave object.
toWaveMC	If TRUE, a WaveMC-class object is returned. If NULL (default) or FALSE and a non-extensible Wave file or an extensible Wave file with no other than the "FL" and "FR" channels is found, a Wave-class object is returned, otherwise a WaveMC-class object.

Value

An object of class `Wave` or `WaveMC` or a list containing just the header information if `header = TRUE`. If the latter, some experimental support for reading bext chunks in Broadcast Wave Format files is implemented, and the content is returned as an unprocessed string (character).

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>, Sarah Schnackenberg

See Also

[Wave-class](#), [Wave](#), [WaveMC-class](#), [WaveMC](#), [writeWave](#)

Examples

```
Wobj <- sine(440)

tdir <- tempdir()
tfile <- file.path(tdir, "myWave.wav")
writeWave(Wobj, filename = tfile)
list.files(tdir, pattern = "\\wav$")
newWobj <- readWave(tfile)
newWobj
file.remove(tfile)
```

show-WaveWspec-methods

Showing objects

Description

Showing Wave, Wspec, and WspecMat objects.

Methods

object = "Wave" The Wave object is being shown. The number of samples, duration in seconds, Samplingrate (Hertz), Stereo / Mono, PCM / IEEE, and the resolution in bits are printed. Note that it does not make sense to print the whole channels containing several thousands or millions of samples.

object = "WaveMC" The WaveMC object is being shown. The number of samples, duration in seconds, Samplingrate (Hertz), number of channels, PCM / IEEE, and the resolution in bits are printed. Note that it does not make sense to print the whole channels containing several thousands or millions of samples.

object = "Wspec" The number of periodograms, Fourier frequencies, window width (used amount of data), amount of overlap of neighboring windows, and whether the periodogram(s) has/have been normalized will be printed.

object = "WspecMat" The number of periodograms, Fourier frequencies, window width (used amount of data), amount of overlap of neighboring windows, and whether the periodogram(s) has/have been normalized will be printed.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

[Wave-class](#), [Wave](#), [WaveMC-class](#), [WaveMC](#), [Wspec](#), [WspecMat](#), [plot-methods](#), [summary-methods](#), and [periodogram](#) for the constructor function and some examples

smoother

Meta Function for Smoothers

Description

Apply a smoother to estimated notes. Currently, only a running median (using [decmedian](#) in package **pastecs**) is available.

Usage

```
smoother(notes, method = "median", order = 4, times = 2)
```

Arguments

notes	Series of notes, a vector of integers such as returned by noteFromFF .
method	Currently, only a running 'median' (using decmedian in package pastecs) is available.
order	The window used for the running median corresponds to $2 \cdot \text{order} + 1$.
times	The number of times the running median is applied (default: 2).

Value

The smoothed series of notes.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

spec2cep

Spectra to Cepstra Conversion

Description

Calculate cepstra from spectral samples (in columns of spec) through Discrete Cosine Transformation.

Usage

```
spec2cep(spec, ncep = 12, type = c("t2", "t1", "t3", "t4"))
```

Arguments

spec	Input spectra (samples/time frames in columns).
ncep	Number of cepstra to return.
type	DCT Type.

Value

cep	Matrix of resulting cepstra.
dctm	Returns the DCT matrix that spec was multiplied by to give cep.

Author(s)

Sebastian Krey <krey@statistik.tu-dortmund.de>

References

Daniel P. W. Ellis: <http://www.ee.columbia.edu/~dpwe/resources/matlab/rastamat/>

See Also

[lpc2cep](#)

Examples

```
testsound <- normalize(sine(400) + sine(1000) + square(250), "16")
pspectrum <- powspec(testsound@left, testsound@samp.rate)
aspectrum <- audspec(pspectrum, testsound@samp.rate)
cepstra <- spec2cep(aspectrum$aspectrum)
```

Description

summary is a generic function used to produce result summaries of the results of various model fitting functions. The function invokes particular methods which depend on the class of the first argument.

Methods

object = "ANY" Any object for which a summary is desired, dispatches to the S3 generic.

object = "Wave" The [Wave](#) object is being shown and an additional summary of the Wave-object's (one or two) channels is given.

object = "WaveMC" The [WaveMC](#) object is being shown and an additional summary of the WaveMC-object's channels is given.

object = "Wspec" The [Wspec](#) object is being shown and as an additional output is given: df, taper (see [spectrum](#)) and for the underlying [Wave](#) object the number of channels and its sampling rate.

object = "WspecMat" The [WspecMat](#) object is being shown and as an additional output is given: df, taper (see [spectrum](#)) and for the underlying [Wave](#) object the number of channels and its sampling rate.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

For the S3 generic: [summary.default](#), [plot-methods](#), [Wave-class](#), [Wave](#), [WaveMC-class](#), [WaveMC](#), [Wspec](#), [WspecMat](#), [show](#)

Description

tuneR, a collection of examples

Functions in tuneR

tuneR consists of several functions to work with and to analyze Wave files. In the following examples, some of the functions to generate some data (such as `sine`), to read and write Wave files (`readWave`, `writeWave`), to represent or construct (multi channel) Wave files (`Wave`, `WaveMC`), to transform Wave objects (`bind`, `channel`, `downsample`, `extractWave`, `mono`, `stereo`), and to play Wave objects are used.

Other functions and classes are available to calculate several periodograms of a signal (`periodogram`, `Wspec`), to estimate the corresponding fundamental frequencies (`FF`, `FFpure`), to derive the corresponding notes (`noteFromFF`), and to apply a `smoother`. Now, the melody and corresponding energy values can be plotted using the function `melodyplot`.

A next step is the quantization (`quantize`) and a corresponding plot (`quantplot`) showing the note values for binned data. Moreover, a function called `lilyinput` (and a data-preprocessing function `quantMerge`) can prepare a data frame to be presented as sheet music by postprocessing with the music typesetting software LilyPond.

Of course, `print` (`show`), `plot` and `summary` methods are available for most classes.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de> with contributions from Sebastian Krey, Olaf Mersmann, Sarah Schnackenberg, Andrea Preusser, Anita Thieler, and Claus Weihs, as well as code fragments and ideas from the former package `sound` by Matthias Heymann and functions from ‘rastamat’ by Daniel P. W. Ellis. The included parts of the libmad MPEG audio decoder library are authored by Underbit Technologies.

Examples

```
library("tuneR") # in a regular session, we are loading tuneR

# constructing a mono Wave object (2 sec.) containing sinus
# sound with 440Hz and folled by 220Hz:
Wobj <- bind(sine(440), sine(220))
show(Wobj)
plot(Wobj) # it does not make sense to plot the whole stuff
plot(extractWave(Wobj, from = 1, to = 500))
## Not run:
play(Wobj) # listen to the sound

## End(Not run)

tmpfile <- file.path(tempdir(), "testfile.wav")
# write the Wave object into a Wave file (can be played with any player):
writeWave(Wobj, tmpfile)
# reading it in again:
Wobj2 <- readWave(tmpfile)

Wobjm <- mono(Wobj, "left") # extract the left channel
# and downsample to 11025 samples/sec.:
Wobjm11 <- downsample(Wobjm, 11025)
# extract a part of the signal interactively (click for left/right limits):
```

```

## Not run:
Wobjm11s <- extractWave(Wobjm11)

## End(Not run)
# or extract some values reproducibly
Wobjm11s <- extractWave(Wobjm11, from=1000, to=17000)

# calculating periodograms of sections each consisting of 1024 observations,
# overlapping by 512 observations:
WspecObject <- periodogram(Wobjm11s, normalize = TRUE, width = 1024, overlap = 512)
# Let's look at the first periodogram:
plot(WspecObject, xlim = c(0, 2000), which = 1)
# or a spectrogram
image(WspecObject, ylim = c(0, 1000))
# calculate the fundamental frequency:
ff <- FF(WspecObject)
print(ff)
# derive note from FF given diapason a'=440
notes <- noteFromFF(ff, 440)
# smooth the notes:
snotes <- smoother(notes)
# outcome should be 0 for diapason "a'" and -12 (12 halftones lower) for "a"
print(snotes)
# plot melody and energy of the sound:
melodyplot(WspecObject, snotes)

# apply some quantization (into 8 parts):
qnotes <- quantize(snotes, WspecObject@energy, parts = 8)
# an plot it, 4 parts a bar (including expected values):
quantplot(qnotes, expected = rep(c(0, -12), each = 4), bars = 2)
# now prepare for LilyPond
qlily <- quantMerge(snotes, 4, 4, 2)
qlily

```

updateWave

Update old Wave objects for use with new versions of tuneR

Description

Update old Wave objects generated with **tuneR** < 1.0.0 to the new class definition for use with new versions of the package.

Usage

```
updateWave(object)
```

Arguments

object An object of [Wave-class](#).

Details

This function is only needed to convert [Wave-class](#) objects that have been saved with **tuneR** versions prior to 1.0-0 to match the new class definition.

Value

An object of [Wave-class](#) as implemented in **tuneR** versions \geq 1.0-0.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>, Sarah Schnackenberg

See Also

[Wave-class](#), [Wave](#)

Examples

```
x <- sine(440)
updateWave(x)
```

Wave

Constructors and coercion for class Wave objects

Description

Constructors and coercion for class Wave objects

Usage

```
Wave(left, ...)
## S4 method for signature 'numeric'
Wave(left, right = numeric(0), samp.rate = 44100, bit = 16, pcm = TRUE, ...)
```

Arguments

left, right, samp.rate, bit, pcm

See Section “Slots” on the help page [Wave-class](#). Except for numeric, the argument left can also be a matrix (1 or 2 columns), data.frame (1 or 2 columns), list (1 or 2 elements), or WaveMC (1 or 2 channels) object representing the channels.

... Further arguments to be passed to the numeric method.

Details

The class definition has been extended in **tuneR** version 1.0-0. Saved objects of class Wave generated with former versions can be updated with [updateWave](#) to match the new definition.

Value

An object of [Wave-class](#).

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

[Wave-class](#), [WaveMC-class](#), [writeWave](#), [readWave](#), [updateWave](#)

Examples

```
# constructing a Wave object (1 sec.) containing sinus sound with 440Hz:
x <- seq(0, 2*pi, length = 44100)
channel <- round(32000 * sin(440 * x))
Wobj <- Wave(left = channel)
Wobj

# or more easily:
Wobj <- sine(440)
```

Wave-class

Class Wave

Description

Class “Wave”.

Details

The class definition has been extended in **tuneR** version 1.0-0. Saved objects of class `Wave` generated with former versions can be updated with [updateWave](#) to match the new definition.

Objects from the Class

Objects can be created by calls of the form `new("Wave", ...)`, or more conveniently using the function [Wave](#).

Slots

left: Object of class "numeric" representing the left channel.
right: Object of class "numeric" representing the right channel, NULL if mono.
stereo: Object of class "logical" indicating whether this is a stereo (two channels) or mono representation.
samp.rate: Object of class "numeric" - the sampling rate, e.g. 44100 for CD quality.
bit: Object of class "numeric", common is 16 for CD quality, or 8 for a rather rough representation.
pcm: Object of class "logical" indicating whether this is a PCM or IEEE_FLOAT Wave format.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

[Wave](#), [updateWave](#), and for multi channel Wave files see [WaveMC-class](#)

 Waveforms

Create Wave Objects of Special Waveforms

Description

Create a [Wave](#) object of special waveform such as silcence, power law (white, red, pink, ...) noise, sawtooth, sine, square, and pulse.

Usage

```
noise(kind = c("white", "pink", "power", "red"), duration = samp.rate,
      samp.rate = 44100, bit = 1, stereo = FALSE,
      xunit = c("samples", "time"), alpha = 1, ...)
```

```
pulse(freq, duration = samp.rate, from = 0, samp.rate = 44100,
      bit = 1, stereo = FALSE, xunit = c("samples", "time"),
      width = 0.1, plateau = 0.2, interval = 0.5, ...)
```

```
sawtooth(freq, duration = samp.rate, from = 0, samp.rate = 44100,
         bit = 1, stereo = FALSE, xunit = c("samples", "time"),
         reverse = FALSE, ...)
```

```
silence(duration = samp.rate, from = 0, samp.rate = 44100,
        bit = 1, stereo = FALSE, xunit = c("samples", "time"), ...)
```

```
sine(freq, duration = samp.rate, from = 0, samp.rate = 44100,
     bit = 1, stereo = FALSE, xunit = c("samples", "time"), ...)
```

```
square(freq, duration = samp.rate, from = 0, samp.rate = 44100,
       bit = 1, stereo = FALSE, xunit = c("samples", "time"),
       up = 0.5, ...)
```

Arguments

kind	The kind of noise, “white”, “pink”, “power”, or “red” (these are not dB adjusted (!) but all except for “white” are linear decreasing on a log-log scale). Algorithm for generating power law noise is taken from Timmer and König (1995).
freq	The frequency (in Hertz) to be generated.
duration	Duration of the Wave in xunit.

from	Starting value of the Wave in xunit.
samp.rate	Sampling rate of the Wave.
bit	Resolution of the Wave and rescaling unit. This may be 1 (default) for rescaling to numeric values in [-1,1], 8 (i.e. 8-bit) for rescaling to integers in [0, 254], 16 (i.e. 16-bit) for rescaling to integers in [-32767, 32767], 24 (i.e. 24-bit) for rescaling to integers in [-8388607, 8388607], 32 (i.e. 32-bit) for rescaling either to integers in [-2147483647, 2147483647] (PCM Wave format if pcm = TRUE) or to numeric values in [-1, 1] (FLOAT_IEEE Wave format if pcm = FALSE), 64 (i.e. 64-bit) for rescaling to numeric values in [-1, 1] (FLOAT_IEEE Wave format), and 0 for not rescaling at all. These numbers are internally passed to normalize . The Wave slot bit will be set to 32 if bit = 0, bit = 1 or bit = 32.
stereo	Logical, if TRUE, a stereo sample will be generated. The right channel is identical to the left one for sawtooth, silence, sine, and square. For noise, both channel are independent.
xunit	Character indicating which units are used (both in arguments duration and from). If xunit = "time", the unit is time in seconds, otherwise the number of samples.
alpha	The power for the power law noise (defaults are 1 for pink and 1.5 for red noise) $1/f^\alpha$.
reverse	Logical, if TRUE, the waveform will be mirrored vertically.
up	A number between 0 and 1 giving the percentage of the waveform at max value (= 1 - percentage of min value).
width	Relative pulses width: the proportion of time the amplitude is non-zero.
plateau	Relative plateau width: the proportion of the pulse width where amplitude is ± 1 .
interval	Relative interval between the up-going and down-going pulses with respect to the center of the wave period (0: immediatly after up-going, 1: center of the wave period).
...	Further arguments to be passed to Wave through the internal function <code>postWaveform</code> .

Value

A [Wave](#) object.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>, partly based on code from Matthias Heymann's former package 'sound', Anita Thielier, Guillaume Guénard

References

J. Timmer and M. König (1995): On generating power law noise. *Astron. Astrophys.* 300, 707-710.

See Also

[Wave-class](#), [Wave](#), [normalize](#), [noSilence](#)

Examples

```
Wobj <- sine(440, duration = 1000)
Wobj2 <- noise(duration = 1000)
Wobj3 <- pulse(220, duration = 1000)
plot(Wobj)
plot(Wobj2)
plot(Wobj3)
```

WaveMC

Constructors and coercion for class WaveMC objects

Description

Constructors and coercion for class WaveMC objects

Usage

```
WaveMC(data, ...)
## S4 method for signature 'matrix'
WaveMC(data = matrix(numeric(0), 0, 0), samp.rate = 44100, bit = 16, pcm = TRUE, ...)
```

Arguments

data	Except for a numeric matrix, the argument data can also be a numeric vector (for one channel), data.frame (columns representing channels), list (elements containing numeric vectors that represent the channels), or Wave object.
samp.rate, bit, pcm	See Section “Slots” on the help page WaveMC-class .
...	Further arguments to be passed to the matrix method.

Value

An object of [WaveMC-class](#).

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>, Sarah Schnackenberg

See Also

[WaveMC-class](#), [Wave-class](#), [writeWave](#), [readWave](#)

Examples

```
# constructing a WaveMC object (1 sec.) containing sinus sound with 440Hz:
x <- seq(0, 2*pi, length = 44100)
channel <- round(32000 * sin(440 * x))
WMCobj <- WaveMC(data = channel)
WMCobj
```

WaveMC-class

Class WaveMC

Description

Class “WaveMC”.

Details

This class has been added in **tuneR** version 1.0-0 for representation and construction of multi channel Wave files. Objects of class Wave can be transformed to the new class definition by calls of the form `as(..., "WaveMC")`. Coercion from the WaveMC class to the [Wave-class](#) works via `as(..., "Wave")` if there are no more than 2 channels. Coercing back to the [Wave-class](#) can be useful since some (very few) functions cannot yet deal with multi channel Wave objects.

Note that also the [Wave-class](#) definition has been extended in **tuneR** version 1.0-0. For more details see [Wave-class](#).

Objects from the Class

Objects can be created by calls of the form `new("WaveMC", ...)`, or more conveniently using the function [WaveMC](#).

Slots

.Data: Object of class "matrix" containing numeric data, where each column is representing one channel. Column names are the appropriate way to name different channels. The data object [MCnames](#) contains a data frame of standard names for channels in multi channel Wave files.

samp.rate: Object of class "numeric" - the sampling rate, e.g. 44100 for CD quality.

bit: Object of class "numeric", common is 16 for CD quality, or 8 for a rather rough representation.

pcm: Object of class "logical" indicating whether this is a PCM or IEEE_FLOAT Wave format.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>, Sarah Schnackenberg

See Also

[WaveMC](#), [Wave-class](#), [MCnames](#)

WavPlayer

Getting and setting the default player for Wave files

Description

Getting and setting the default player for Wave files

Usage

```
setWavPlayer(player)
getWavPlayer()
```

Arguments

player	Set the character string to call a Wave file player (including optional arguments) using options .
--------	--

Value

getWavPlayer returns the character string that has been set by setWavPlayer.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

[Wave-class](#), [Wave](#), [play](#)

writeWave

Writing Wave files

Description

Writing Wave files.

Usage

```
writeWave(object, filename, extensible = TRUE)
```

Arguments

object	Object of class Wave or WaveMC to be written to a Wave file.
filename	Filename of the file to be written.
extensible	If TRUE (default), an extensible Wave format file is written. If FALSE, a non-extensible Wave file is written.

Details

It is only possible to write a non-extensible Wave format file for objects of class [Wave](#) or for objects of class [WaveMC](#) with one or two channels (mono or stereo).

If the argument object is a [Wave-class](#) object, the channels are automatically chosen to be “FL” (for mono) or “FL” and “FR” (for stereo).

The channel mask used to arrange the channel ordering in multi channel Wave files is written according to Microsoft standards as given in the data frame [MCnames](#) containing the first 18 standard channels. In the case of writing a multi channel Wave file, the column names of the object object (`colnames(object)`) must be specified and must uniquely identify the channel ordering for [WaveMC](#) objects. The column names of the object of class [WaveMC](#) have to be a subset of the 18 standard channels and have to match the corresponding abbreviated names. (See [MCnames](#) for possible channels and the abbreviated names: “FL”, “FR”, “FC”, “LF”, “BL”, “BR”, “FLC”, “FRC”, “BC”, “SL”, “SR”, “TC”, “TFL”, “TFC”, “TFR”, “TBL”, “TBC” and “TBR”).

The function [normalize](#) can be used to transform and rescale data to an appropriate amplitude range for various Wave file formats (either pcm with 8-, 16-, 24- or 32-bit or IEEE_FLOAT with 32- or 64-bit).

Value

`writeWave` creates a Wave file, but returns nothing.

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>, Sarah Schnackenberg

See Also

[Wave-class](#), [Wave](#), [WaveMC-class](#), [WaveMC](#), [normalize](#), [MCnames](#), [readWave](#)

Examples

```
Wobj <- sine(440)

tdir <- tempdir()
tfile <- file.path(tdir, "myWave.wav")
writeWave(Wobj, filename = tfile)
list.files(tdir, pattern = "\\wav$")
newWobj <- readWave(tfile)
newWobj
file.remove(tfile)
```

Wspec-class

Class Wspec

Description

Class “Wspec” (*Wave spectrums*). Objects of this class represent a bunch of periodograms (see [periodogram](#), each generated by [spectrum](#)) corresponding to one or several windows of one [Wave](#) or [WaveMC](#) object. Redundancy (e.g. same frequencies in each of the periodograms) will be omitted, hence reducing memory consumption.

Details

The subset function “[” extracts the selected elements of slots `spec`, `starts`, `variance` and `energy` and returns the other slots unchanged.

Objects from the Class

Objects can be created by calls of the form `new("Wspec", ...)`, but regularly they will be created by calls to the function [periodogram](#).

Slots

The following slots are defined. For details see the constructor function [periodogram](#).

`freq`: Object of class "numeric".
`spec`: Object of class "list".
`kernel`: Object of class "ANY".
`df`: Object of class "numeric".
`taper`: Object of class "numeric".
`width`: Object of class "numeric".
`overlap`: Object of class "numeric".
`normalize`: Object of class "logical".
`starts`: Object of class "numeric".
`stereo`: Object of class "logical".
`samp.rate`: Object of class "numeric".
`variance`: Object of class "numeric".
`energy`: Object of class "numeric".

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

- the show, plot and summary methods,
- for the constructor function and some examples: [periodogram](#) (and hence also [spec.pgram](#), [Wave-class](#), [Wave](#), [WaveMC-class](#), and [WaveMC](#))
- [WspecMat](#) for a similar class that represents the spectrum in form of a matrix.

WspecMat-class

Class *WspecMat*

Description

Class “WspecMat” (*Wave spectrums as Matrix*). Objects of this class represent a bunch of periodograms (see [periodogram](#), each generated by [spectrum](#)) corresponding to one or several windows of one [Wave](#) or [WaveMC](#) object. Redundancy (e.g. same frequencies in each of the periodograms) will be omitted, hence reducing memory consumption.

Details

The subset function “[” extracts the selected elements of slots `spec`, `starts`, `variance` and `energy` and returns the other slots unchanged.

Objects from the Class

Objects can be created by calls of the form `new("WspecMat", ...)`, but regularly they will be created from a [Wspec](#) object by calls such as `as(Wspec_Object, "WspecMat")`.

Slots

The following slots are defined. For details see the constructor function [periodogram](#).

`freq`: Object of class "numeric".
`spec`: Object of class "matrix".
`kernel`: Object of class "ANY".
`df`: Object of class "numeric".
`taper`: Object of class "numeric".
`width`: Object of class "numeric".
`overlap`: Object of class "numeric".
`normalize`: Object of class "logical".
`starts`: Object of class "numeric".
`stereo`: Object of class "logical".
`samp.rate`: Object of class "numeric".
`variance`: Object of class "numeric".
`energy`: Object of class "numeric".

Author(s)

Uwe Ligges <ligges@statistik.tu-dortmund.de>

See Also

the show, plot and summary methods

[-methods

Extract or Replace Parts of an Object

Description

Operators act on objects to extract or replace subsets.

See Also

[Extract](#) for the S3 generic.

Index

- *Topic **IO**
 - play-methods, 32
 - readMidi, 42
 - readMP3, 43
 - readWave, 44
 - writeWave, 57
- *Topic **aplot**
 - plot-Wave, 33
- *Topic **arith**
 - Arith-methods, 3
- *Topic **classes**
 - Wave-class, 52
 - WaveMC-class, 56
 - Wspec-class, 59
 - WspecMat-class, 60
- *Topic **datagen**
 - Waveforms, 53
- *Topic **datasets**
 - MCnames, 18
- *Topic **documentation**
 - tuneR, 48
- *Topic **error**
 - equalWave, 9
- *Topic **file**
 - lilyinput, 16
 - readMidi, 42
 - readMP3, 43
 - readWave, 44
 - writeWave, 57
- *Topic **hplot**
 - melodyplot, 21
 - plot-Wave, 33
 - plot-Wspec, 34
 - plot-WspecMat, 35
 - quantplot, 40
- *Topic **interface**
 - lilyinput, 16
 - play-methods, 32
- *Topic **iplot**
 - extractWave, 9
- *Topic **manip**
 - bind, 5
 - channel, 5
 - downsample, 8
 - extractWave, 9
 - Mono-Stereo, 23
 - normalize-methods, 25
 - noSilence, 26
 - panorama, 28
 - prepComb, 38
- *Topic **methods**
 - [-methods, 61
 - Arith-methods, 3
 - length, 14
 - play-methods, 32
 - plot-Wave, 33
 - plot-Wspec, 34
 - plot-WspecMat, 35
 - show-WaveWspec-methods, 45
 - summary-methods, 48
 - Wave, 51
 - WaveMC, 55
- *Topic **misc**
 - smoother, 46
- *Topic **print**
 - show-WaveWspec-methods, 45
 - summary-methods, 48
- *Topic **ts**
 - FF, 11
 - melfcc, 19
 - periodogram-methods, 29
 - smoother, 46
- *Topic **utilities**
 - bind, 5
 - channel, 5
 - downsample, 8
 - equalWave, 9
 - extractWave, 9

- Mono-Stereo, [23](#)
- noSilence, [26](#)
- noteFromFF, [27](#)
- notenames, [28](#)
- play-methods, [32](#)
- prepComb, [38](#)
- quantize, [39](#)
- WavPlayer, [57](#)
- [, ANY-method ([-methods]), [61](#)
- [, Wave-method (Wave), [51](#)
- [, WaveMC-method (WaveMC), [55](#)
- [, Wspec-method (Wspec-class), [59](#)
- [, WspecMat-method (WspecMat-class), [60](#)
- [-methods, [61](#)

- abline, [22, 41](#)
- Arith, numeric, Wave-method (Arith-methods), [3](#)
- Arith, numeric, WaveMC-method (Arith-methods), [3](#)
- Arith, Wave, missing-method (Arith-methods), [3](#)
- Arith, Wave, numeric-method (Arith-methods), [3](#)
- Arith, Wave, Wave-method (Arith-methods), [3](#)
- Arith, WaveMC, numeric-method (Arith-methods), [3](#)
- Arith, WaveMC, WaveMC-method (Arith-methods), [3](#)
- Arith-methods, [3](#)
- audspec, [3, 36, 37](#)
- axis, [22, 41](#)

- bark2hz (freqconv), [12](#)
- bind, [5, 10, 39, 49](#)
- bind, Wave-method (bind), [5](#)
- bind, WaveMC-method (bind), [5](#)

- channel, [5, 10, 49](#)
- coerce, data.frame, Wave-method (Wave), [51](#)
- coerce, data.frame, WaveMC-method (WaveMC), [55](#)
- coerce, list, Wave-method (Wave), [51](#)
- coerce, list, WaveMC-method (WaveMC), [55](#)
- coerce, matrix, Wave-method (Wave), [51](#)
- coerce, matrix, WaveMC-method (WaveMC), [55](#)
- coerce, numeric, Wave-method (Wave), [51](#)
- coerce, numeric, WaveMC-method (WaveMC), [55](#)
- coerce, Wave, data.frame-method (Wave), [51](#)
- coerce, Wave, matrix-method (Wave), [51](#)
- coerce, Wave, WaveMC-method (Wave), [51](#)
- coerce, WaveGeneral, list-method (Wave), [51](#)
- coerce, WaveMC, data.frame-method (WaveMC), [55](#)
- coerce, WaveMC, matrix-method (WaveMC), [55](#)
- coerce, WaveMC, Wave-method (WaveMC), [55](#)
- coerce, Wspec, WspecMat-method (WspecMat-class), [60](#)

- decmedian, [46](#)
- deltas, [6](#)
- dolpc, [7, 37](#)
- downsample, [8, 30, 49](#)

- equalWave, [5, 9](#)
- Extract, [61](#)
- extractWave, [5, 6, 9, 26, 39, 49](#)

- FF, [11, 22, 27, 42, 49](#)
- FFpure, [49](#)
- FFpure (FF), [11](#)
- fft2barkmx, [4](#)
- fft2melmx, [4](#)
- freqconv, [12](#)

- getMidiNotes, [13, 43](#)
- getWavPlayer (WavPlayer), [57](#)
- groupGeneric, [3](#)

- hz2bark (freqconv), [12](#)
- hz2mel (freqconv), [12](#)

- image, [35, 36](#)
- image, ANY-method (plot-WspecMat), [35](#)
- image, Wspec-method (plot-WspecMat), [35](#)
- image-Wspec (plot-WspecMat), [35](#)
- interactive, [10](#)

- length, [14, 14](#)
- length, ANY-method (length), [14](#)
- length, Wave-method (length), [14](#)
- length, WaveMC-method (length), [14](#)
- levinson, [7](#)
- lifter, [15](#)
- lilyinput, [16, 40, 49](#)

- lines, [22](#), [41](#)
- lpc2cep, [17](#), [47](#)
- MCnames, [18](#), [56](#), [58](#)
- mel2hz (freqconv), [12](#)
- melfcc, [19](#), [23](#)
- melodyplot, [21](#), [42](#), [49](#)
- MFCC, [23](#)
- mono, [6](#), [10](#), [30](#), [49](#)
- mono (Mono-Stereo), [23](#)
- Mono-Stereo, [23](#)
- mtext, [22](#), [41](#)
- nchannel, [24](#)
- nchannel, Wave-method (nchannel), [24](#)
- nchannel, WaveMC-method (nchannel), [24](#)
- noise (Waveforms), [53](#)
- normalize, [54](#), [55](#), [58](#)
- normalize (normalize-methods), [25](#)
- normalize, Wave-method (normalize-methods), [25](#)
- normalize, WaveMC-method (normalize-methods), [25](#)
- normalize-methods, [25](#)
- noSilence, [26](#), [39](#), [55](#)
- noSilence, Wave-method (noSilence), [26](#)
- noSilence, WaveMC-method (noSilence), [26](#)
- noteFromFF, [12](#), [21](#), [22](#), [27](#), [39](#), [40](#), [42](#), [46](#), [49](#)
- notenames, [13](#), [28](#), [40](#)
- options, [57](#)
- panorama, [28](#)
- panorama, Wave-method (panorama), [28](#)
- panorama, WaveMC-method (panorama), [28](#)
- par, [22](#), [33](#), [34](#), [41](#)
- periodogram, [12](#), [27](#), [35](#), [36](#), [46](#), [49](#), [59](#), [60](#)
- periodogram (periodogram-methods), [29](#)
- periodogram, character-method (periodogram-methods), [29](#)
- periodogram, WaveGeneral-method (periodogram-methods), [29](#)
- periodogram-methods, [29](#)
- play, [49](#), [57](#)
- play (play-methods), [32](#)
- play, character-method (play-methods), [32](#)
- play, WaveGeneral-method (play-methods), [32](#)
- play-methods, [32](#)
- plot, Wave, missing-method (plot-Wave), [33](#)
- plot, WaveMC, missing-method (plot-Wave), [33](#)
- plot, Wspec, missing-method (plot-Wspec), [34](#)
- plot, WspecMat, missing-method (plot-WspecMat), [35](#)
- plot-Wave, [33](#)
- plot-Wspec, [34](#)
- plot-WspecMat, [35](#)
- plot.default, [35](#)
- plot.Wave.channel (plot-Wave), [33](#)
- points, [41](#)
- postaud, [36](#)
- powspec, [4](#), [37](#)
- prepComb, [5](#), [38](#)
- pulse (Waveforms), [53](#)
- quantize, [17](#), [39](#), [41](#), [42](#), [49](#)
- quantMerge, [17](#), [49](#)
- quantMerge (quantize), [39](#)
- quantplot, [17](#), [22](#), [40](#), [40](#), [49](#)
- readMidi, [13](#), [14](#), [42](#)
- readMP3, [43](#), [43](#)
- readWave, [43](#), [44](#), [49](#), [52](#), [55](#), [58](#)
- rect, [22](#), [41](#)
- round, [27](#)
- sawtooth (Waveforms), [53](#)
- setWavPlayer, [32](#)
- setWavPlayer (WavPlayer), [57](#)
- show, [48](#)
- show, Wave-method (show-WaveWspec-methods), [45](#)
- show, WaveMC-method (show-WaveWspec-methods), [45](#)
- show, Wspec-method (show-WaveWspec-methods), [45](#)
- show, WspecMat-method (show-WaveWspec-methods), [45](#)
- show-WaveWspec-methods, [45](#)
- silence, [26](#)
- silence (Waveforms), [53](#)
- sine, [49](#)
- sine (Waveforms), [53](#)
- smoother, [46](#), [49](#)
- spec.pgram, [30](#), [31](#), [60](#)
- spec2cep, [18](#), [47](#)

- specgram, [37](#)
- spectrum, [30](#), [48](#), [59](#), [60](#)
- square (Waveforms), [53](#)
- stereo, [5](#), [49](#)
- stereo (Mono-Stereo), [23](#)
- stop, [9](#)
- summary, ANY-method (summary-methods), [48](#)
- summary, Wave-method (summary-methods), [48](#)
- summary, WaveMC-method (summary-methods), [48](#)
- summary, Wspec-method (summary-methods), [48](#)
- summary, WspecMat-method (summary-methods), [48](#)
- summary-methods, [48](#)
- summary.default, [48](#)

- tuneR, [12](#), [17](#), [22](#), [27](#), [34–36](#), [40](#), [42](#), [48](#)
- tuneR-defunct (MFCC), [23](#)
- tuneR-package (tuneR), [48](#)

- updateWave, [50](#), [51–53](#)

- Wave, [3](#), [5](#), [6](#), [8–10](#), [14](#), [23–26](#), [29–34](#), [38](#), [39](#), [43–46](#), [48](#), [49](#), [51](#), [51](#), [52–55](#), [57–60](#)
- Wave, ANY-method (Wave), [51](#)
- Wave, data.frame-method (Wave), [51](#)
- Wave, list-method (Wave), [51](#)
- Wave, matrix-method (Wave), [51](#)
- Wave, numeric-method (Wave), [51](#)
- Wave, WaveMC-method (Wave), [51](#)
- Wave-class, [3](#), [5](#), [6](#), [8–10](#), [19](#), [24](#), [26](#), [29](#), [31](#), [32](#), [34](#), [39](#), [44–46](#), [48](#), [50–52](#), [52](#), [55–58](#), [60](#)
- Waveforms, [53](#)
- WaveMC, [3](#), [5](#), [8–10](#), [14](#), [24–26](#), [29–34](#), [38](#), [39](#), [45](#), [46](#), [48](#), [49](#), [55](#), [56–60](#)
- WaveMC, ANY-method (WaveMC), [55](#)
- WaveMC, data.frame-method (WaveMC), [55](#)
- WaveMC, list-method (WaveMC), [55](#)
- WaveMC, matrix-method (WaveMC), [55](#)
- WaveMC, numeric-method (WaveMC), [55](#)
- WaveMC, Wave-method (WaveMC), [55](#)
- WaveMC-class, [3](#), [5](#), [6](#), [8–10](#), [19](#), [23](#), [24](#), [26](#), [29](#), [31](#), [32](#), [34](#), [39](#), [44–46](#), [48](#), [52](#), [53](#), [55](#), [56](#), [58](#), [60](#)
- WavPlayer, [57](#)
- writeWave, [26](#), [32](#), [45](#), [49](#), [52](#), [55](#), [57](#)
- Wspec, [11](#), [12](#), [21](#), [30](#), [31](#), [35](#), [36](#), [39](#), [46](#), [48](#), [49](#), [60](#)
- Wspec (Wspec-class), [59](#)
- Wspec-class, [59](#)
- WspecMat, [35](#), [36](#), [46](#), [48](#), [60](#)
- WspecMat (WspecMat-class), [60](#)
- WspecMat-class, [60](#)