Sound analysis and synthesis with the package seewave

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Sound packages

	Maintainer	First version
tuneR	Uwe Ligges	September 2004
sound	Matthias Heymann	April 2005
seewave	Jérôme Sueur	March 2006
audio	Simon Urbanek	September 2008

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Sound classes

	Input	Output	Object
tuneR	readWave	writeWave	`Wave`
sound	loadSample	saveSample	`Sample`
audio	load.wave, record	save.wave	`audioSample`
seewave	–	export, savewav	`vector`, `matrix`, `ts`, `mts`, `Wave`, `Sample`, `audioSample`

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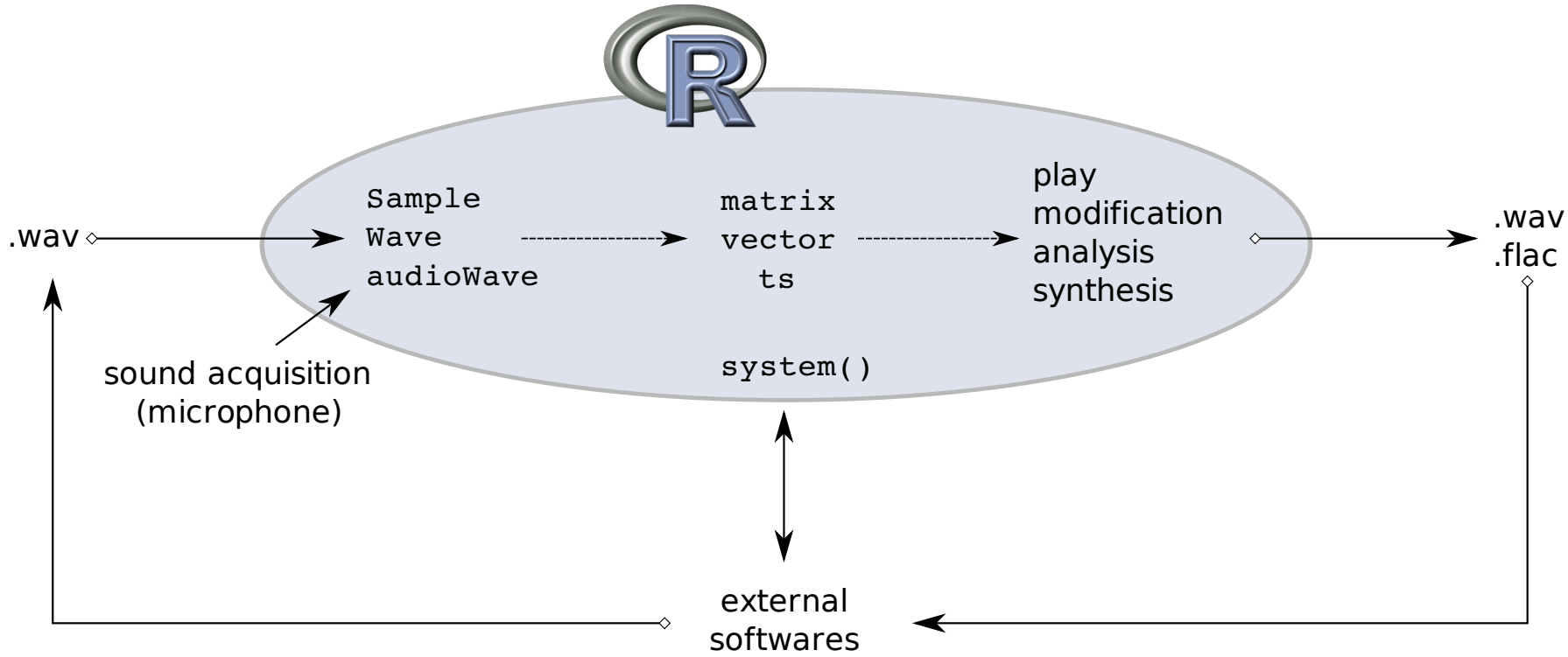
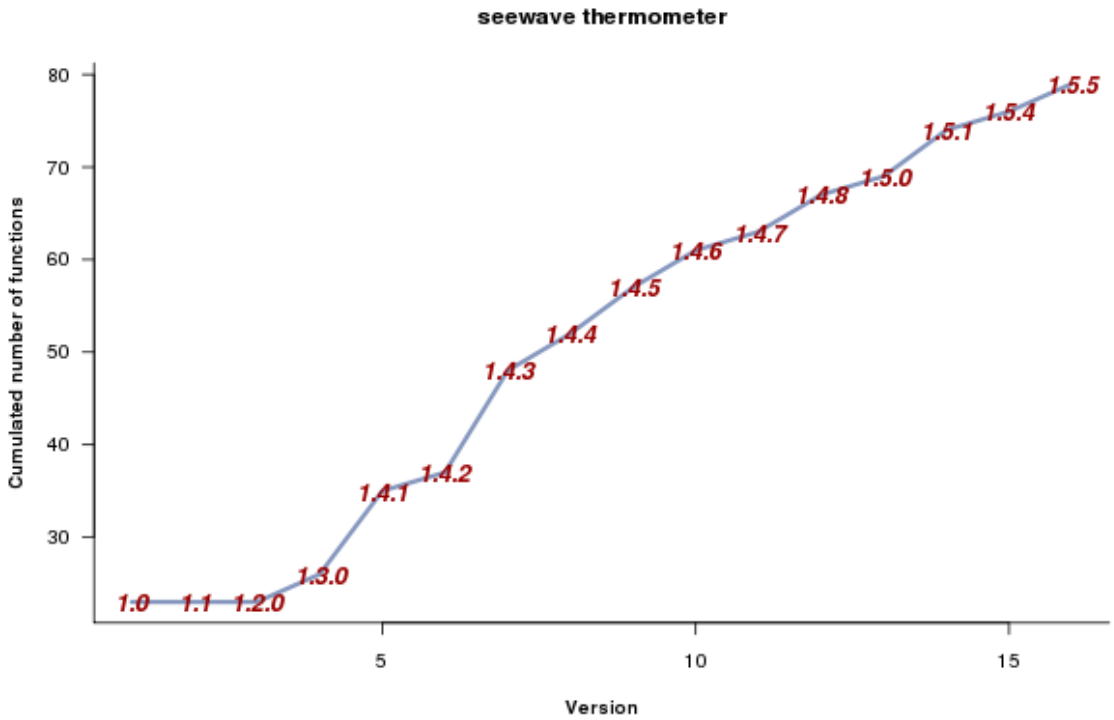
Principle


.wav
Sample
Wave
audioWave
matrix
vector
ts
play
modification
analysis
synthesis
.wav
.flac
sound acquisition
(microphone)
system()
external
softwares

What is seewave ?

- signal analysis ⇒ **bioacoustics**, neurobiology, human voice, telemetry, solid vibrations, radio signals, . . .
- ≃ 70 user-end functions



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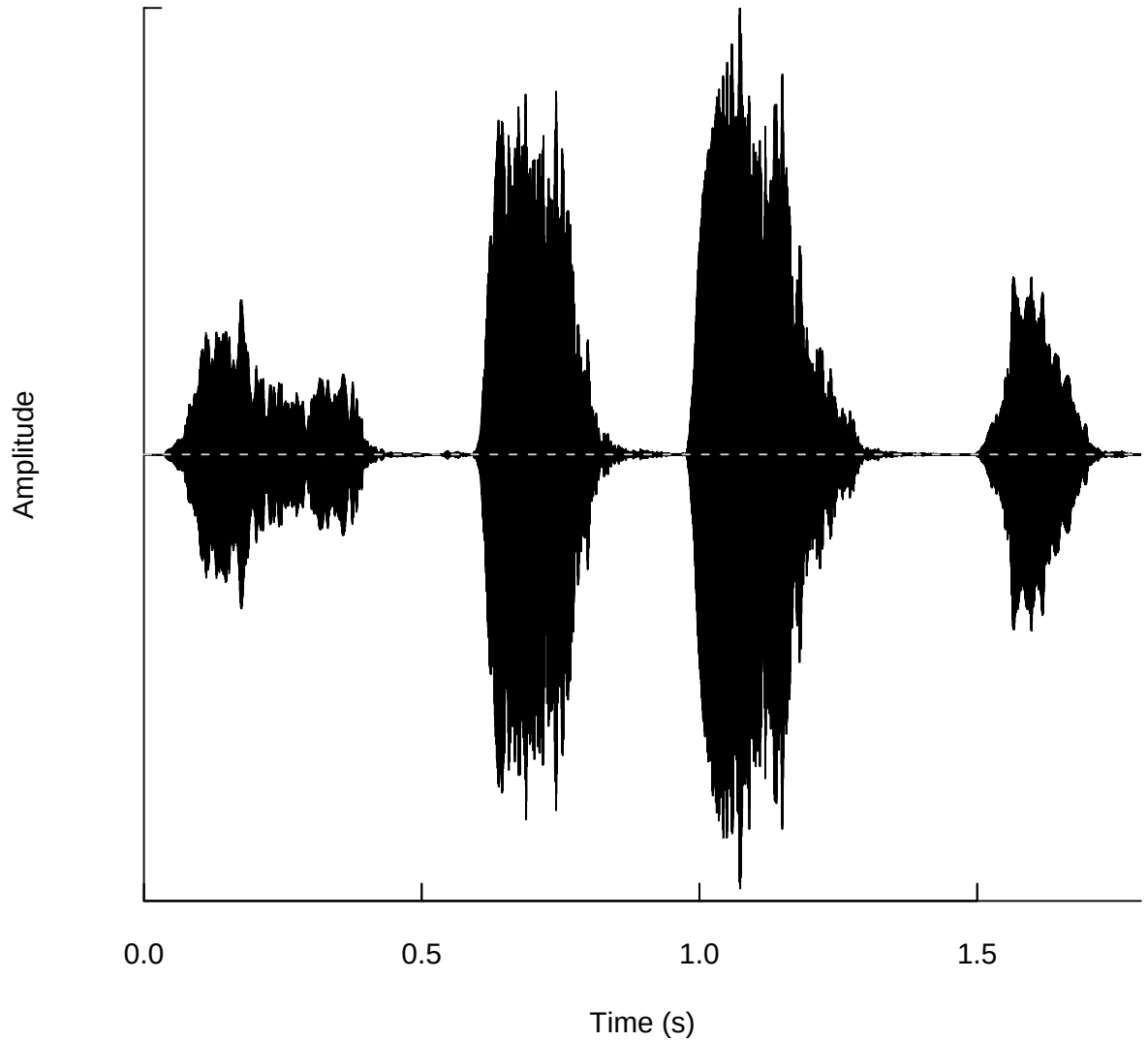
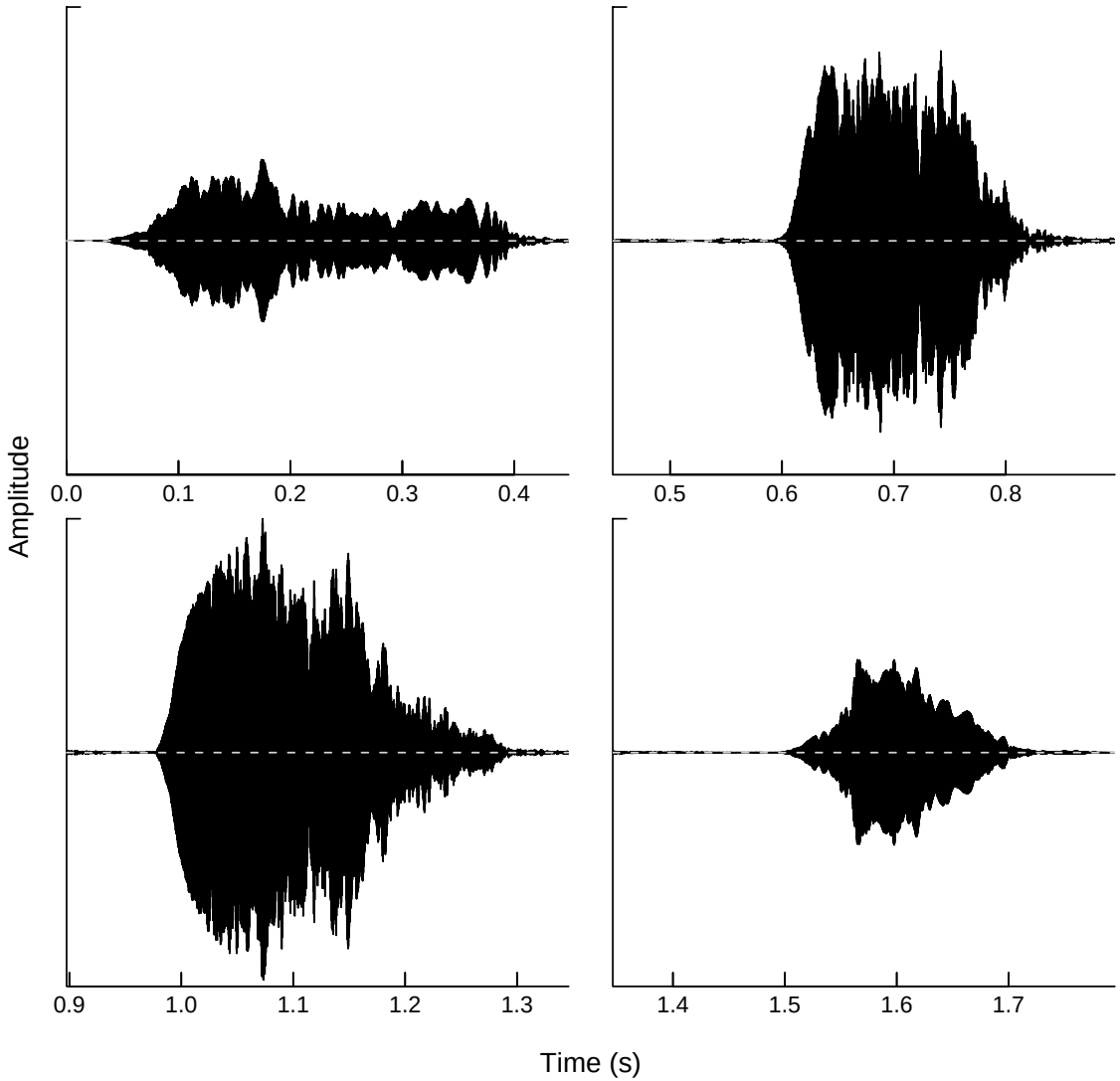
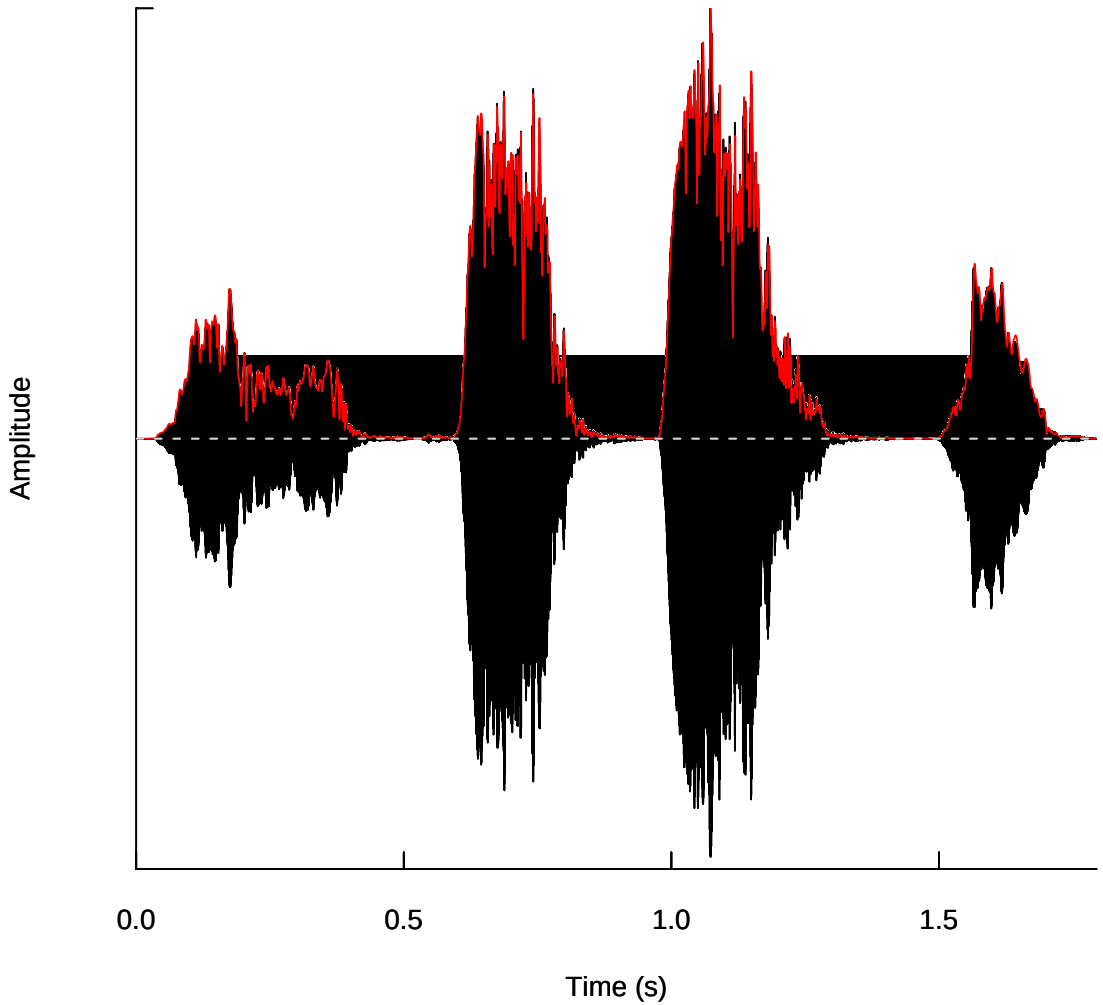
Oscillogramm (single window)



Oscillogramm (multiple window)



Envelope (absolute or Hilbert transform)



Codes

Simple oscillogram

```
oscillo(tico,f=22050)
```

Multi-frame oscillogram

```
oscillo(tico,f=22050,k=2,j=2)
```

Oscillogram and enveloppe

```
oscillo(tico,f=22050)
par(new=TRUE)
env(tico,f=22050,msmooth=c(20,0),colwave=2)
```

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Copy, cut, . . .

- copy
- cut
- paste
- delete (trim)
- repeat
- everse
- add
- mute
- remove silence

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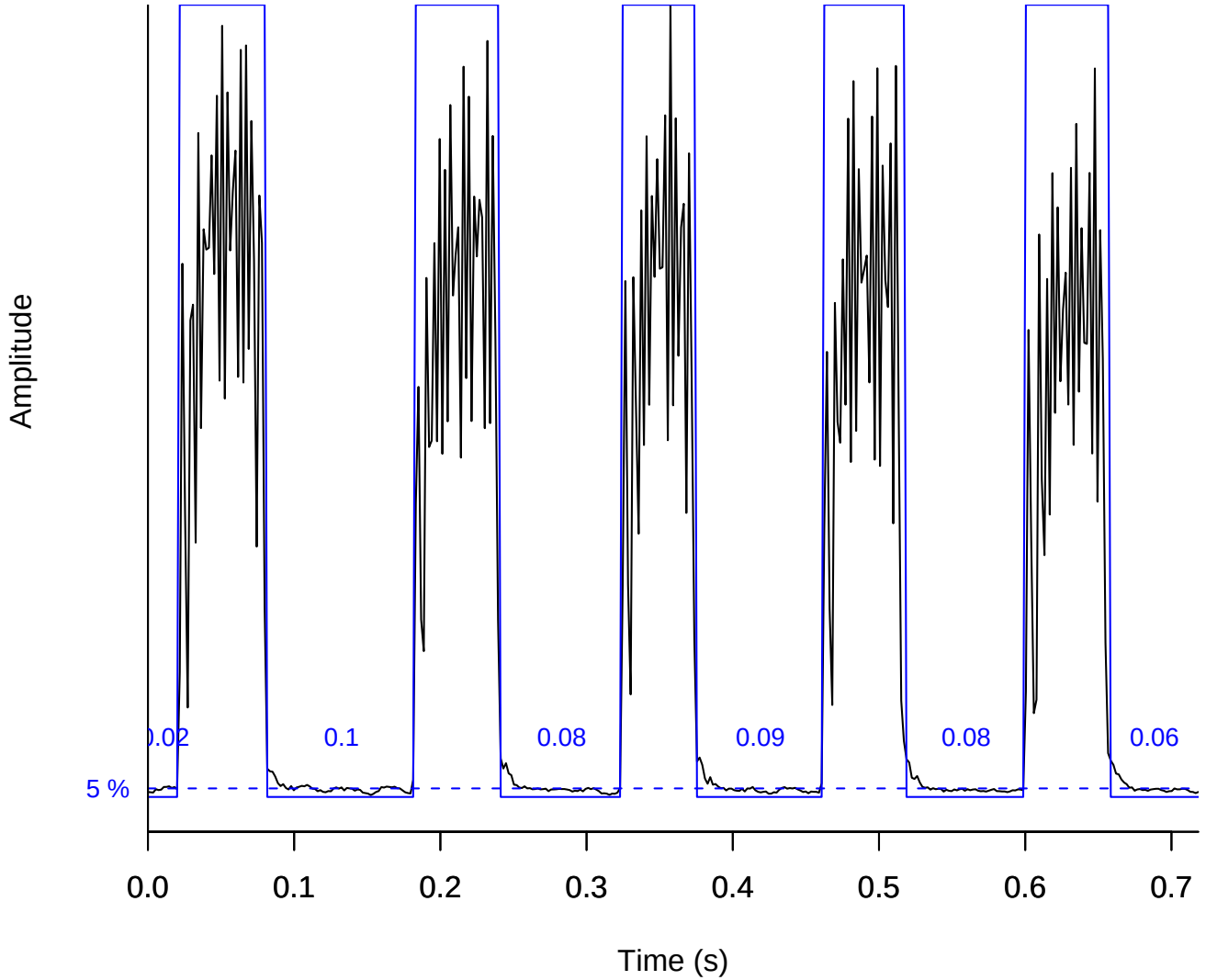
Time measurements

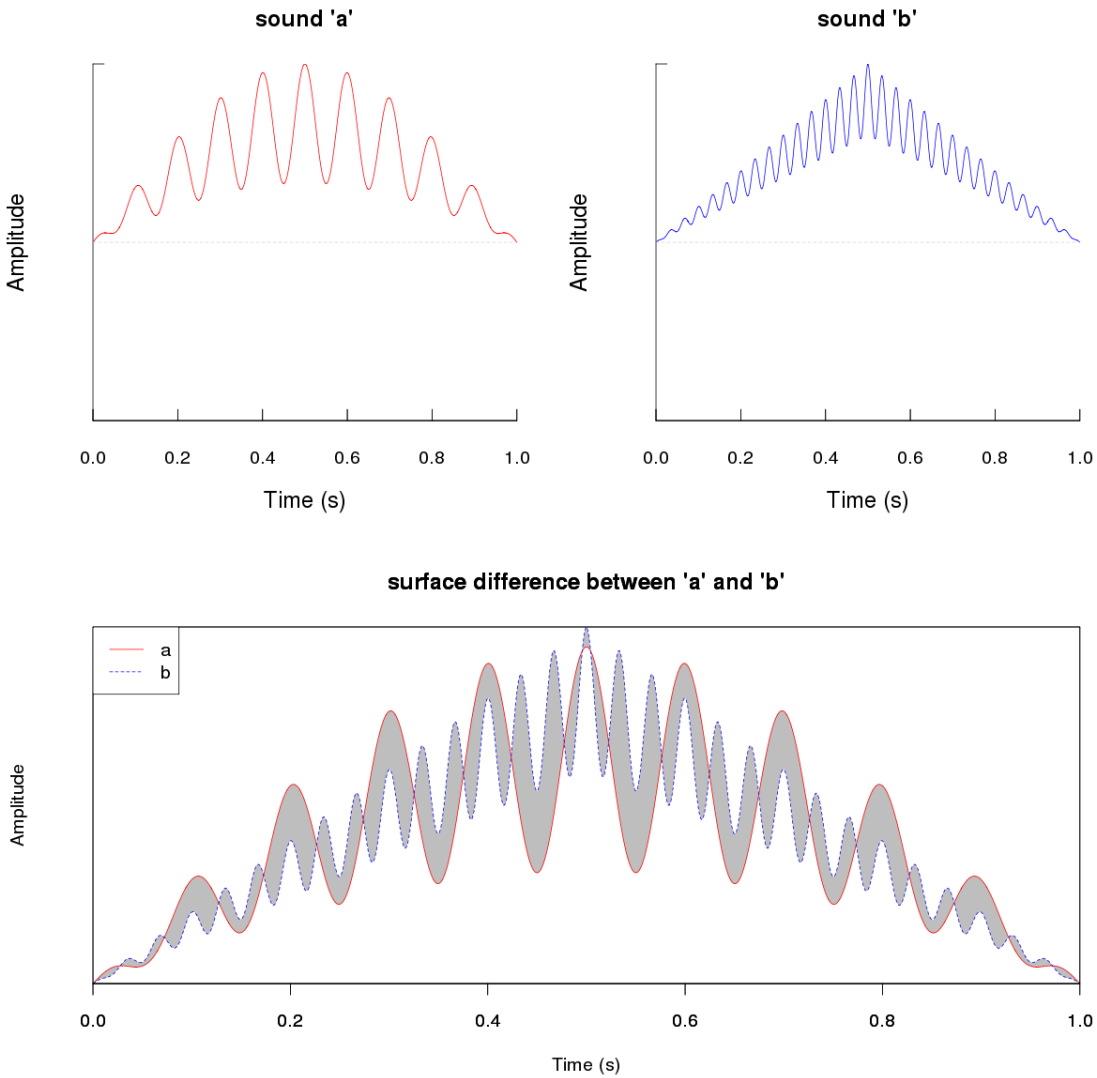
```
timer(orni,
f=22050,
threshold=5,
smooth=40,
bty="l",
xaxs="i",
colval="blue"
)
```



Comparaison

- cross-correlation
- surface difference

Comparaison : surface difference (graph)



Comparaison : surface difference (code)

```
f<-16000
a<-synth(d=1,f=f,cf=2000,am=c(50,10),shape="sine")
b<-synth(d=1,f=f,cf=2000,am=c(25,30),shape="tria")
layout(matrix(c(1,2,3,3),byrow=TRUE,nc=2))
env(a,f=f,colwave="red",title="sound 'a'")
env(b,f=f,colwave="blue",title="sound 'b'")
diffenv(a,b,f=f,plot=TRUE,
main="surface difference between 'a' and 'b'")
```

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Spectrogram (2D & 3D)

- Short-term Fourier Transform (STFT)
- several analysis windows (Hamming, Hanning, ...)
- parameters : window length, window overlap, zero-padding, amplitude clipping level
- with/without oscillogram
- full color modifications

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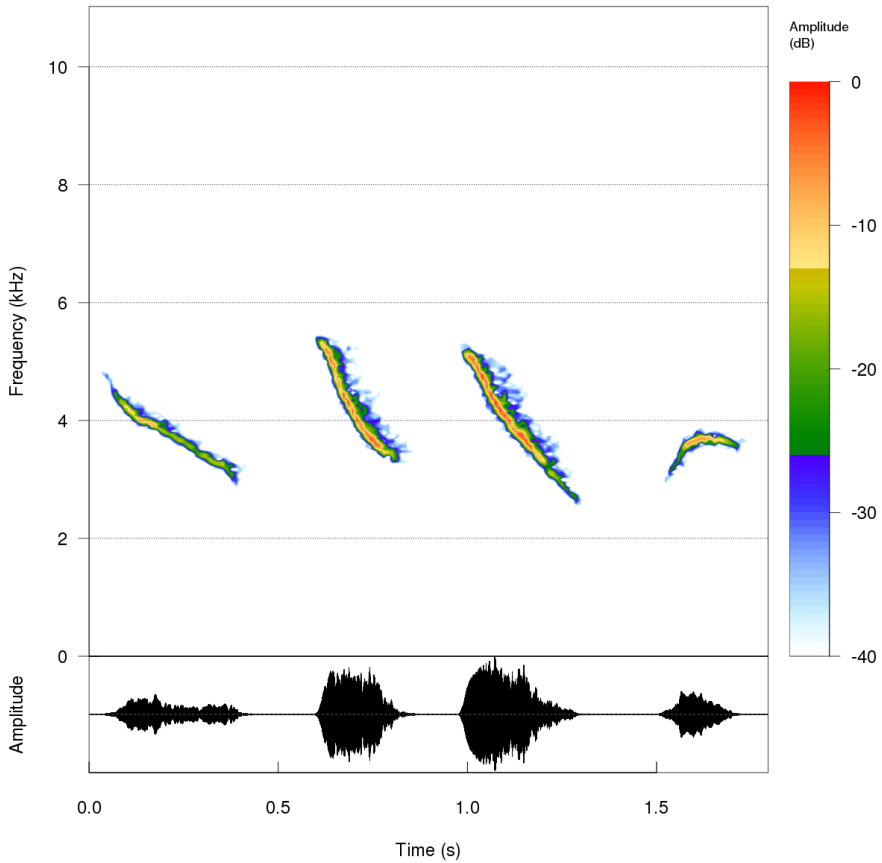
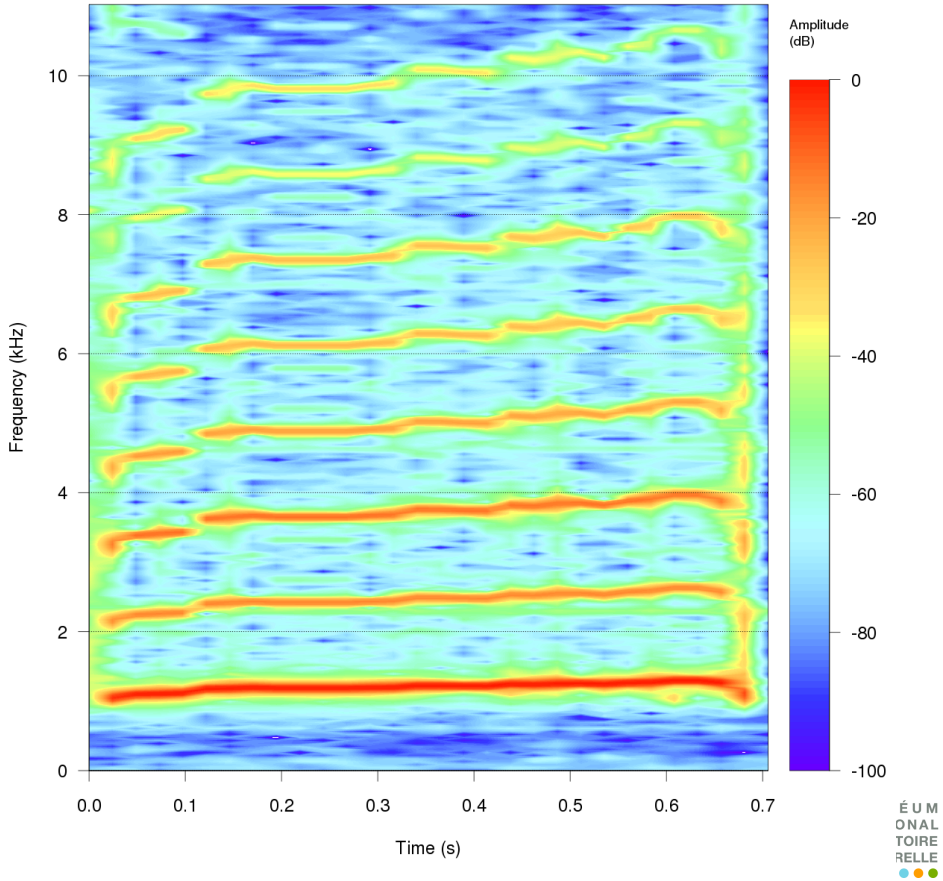
2D spectrogram (graph)

with oscillogram plot



colour modifications



2D spectrogram (code)

with oscillogram plot

```
data(tico)
spectro(tico,f=22050,
ovlp=50,zp=16,
collevels=seq(-40,0,0.5),
osc=TRUE)
```

colour modifications

```
data(peewit)
spectro(peewit,f=22050,
palette=temp.colors,
collevels=seq(-100,0,1))
```

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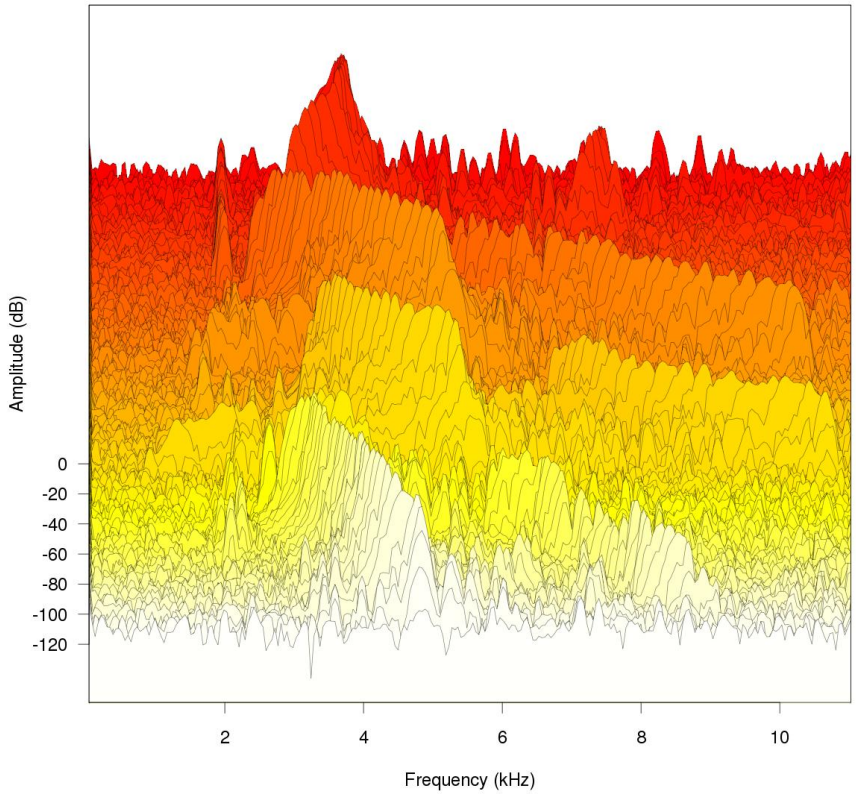
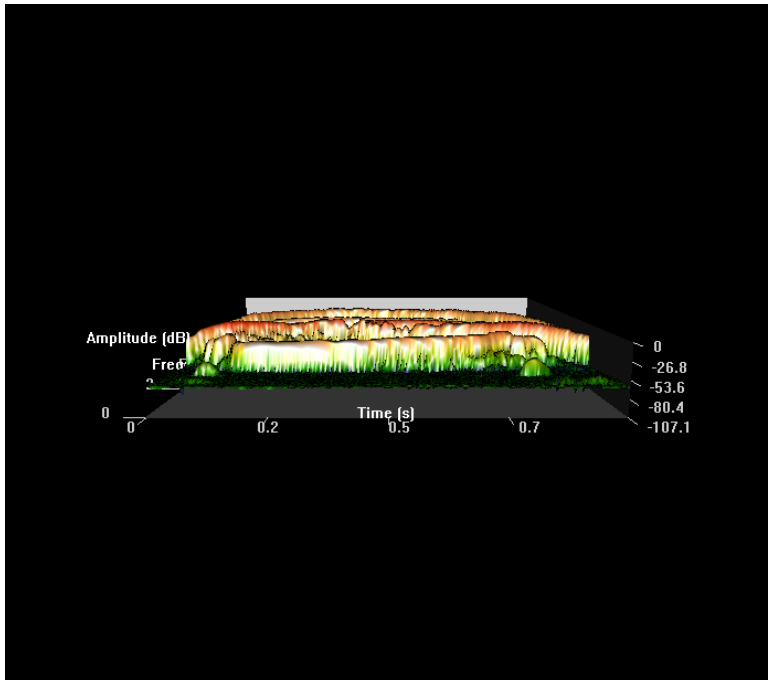
3D spectrogram (graph)

false 3D (waterfall)



true 3D using `rgl`



3D spectrogram (code)

false 3D (waterfall)

```
data(tico)
wf(tico,f=22050,
ovlp=50,hoff=0,voff=2,
border="#00000075")
```

true 3D using rgl

```
download.file(
"http://sueur.jerome.perso.neuf.fr/
WebPage_Sounds/E_chopardi_whistle.wav",
destfile="cock.wav")
cock<-loadSample("cock.wav")

spectro3D(cock,
f=22050,wl=490,
ovlp=85,zp=6,maga=4,
palette=spectro.colors)
```

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Spectrum

- static or dynamic using `rpanel`
- discrete or mean with a sliding window
- linear or dB
- automatic or manual peak identification
- symbolic analysis
- 15 spectral properties (dominant peak, quantiles, flatness, skewness, entropy, ...)

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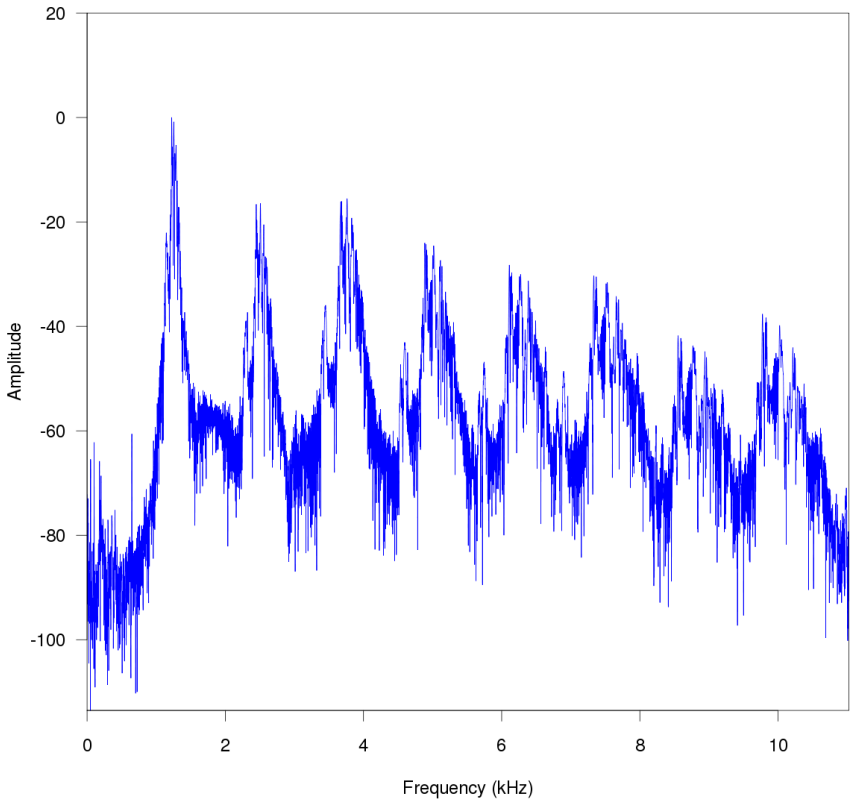
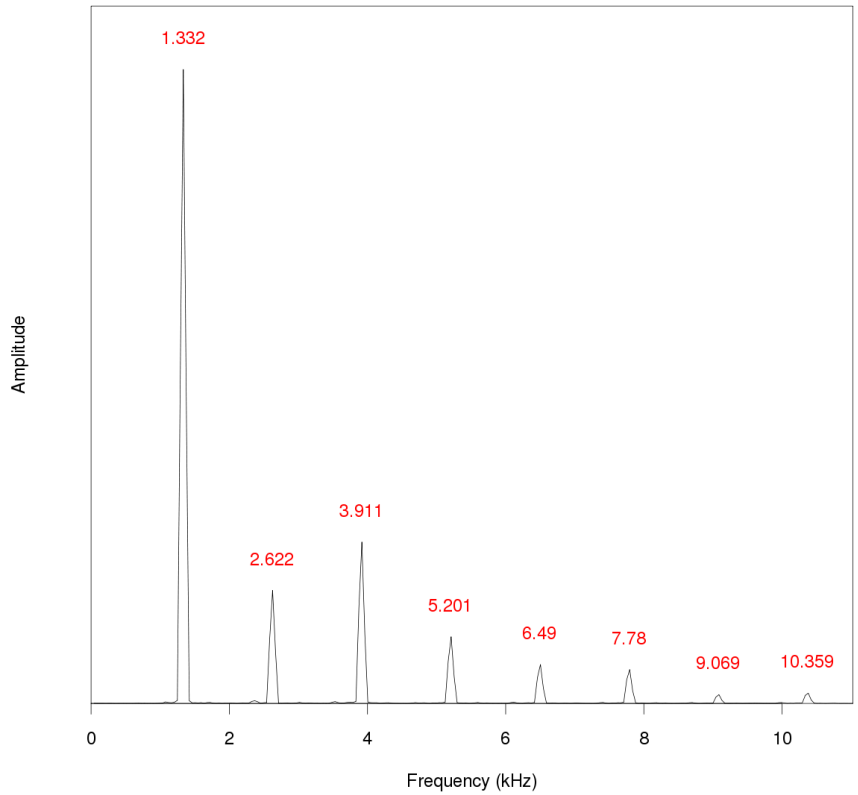
Spectrum (graph)

discrete and dB



automatic peak detection



Spectrum (code)

discrete and (weighted) dB

```
data(peewit)
spec(peewit,f=22050,
dB=TRUE,col="blue")
```

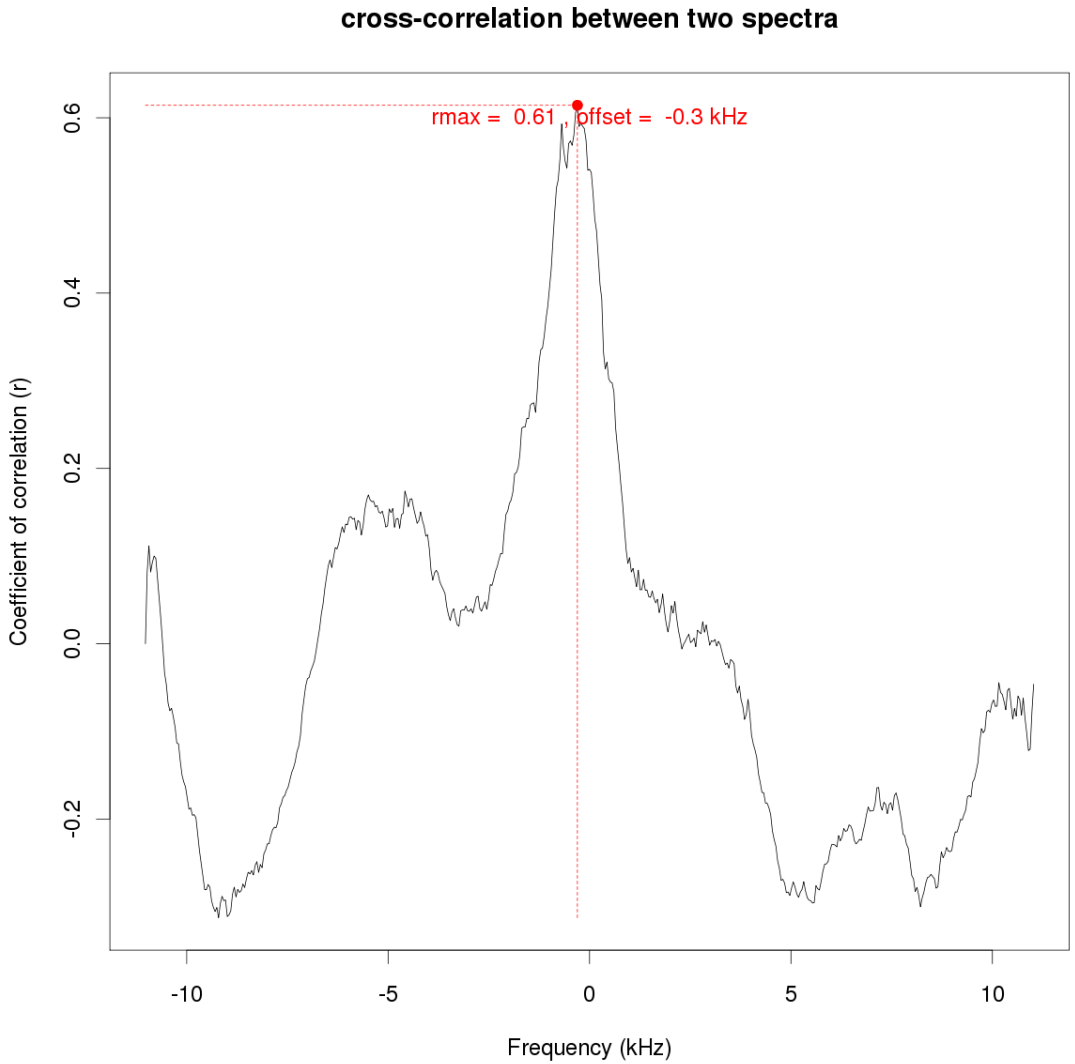
automatic peak detection

```
data(peewit)
spec(peewit,f=22050,at=0.5,peak=21)
```

Comparaison

- crosss-correlation
- surface difference
- coherence

Comparaison : cross-correlation (graph)



Comparaison : cross-correlation (code)

```
data(tico)
spec1<-spec(tico, f=22050, at=0.2, plot=FALSE)
spec2<-spec(tico, f=22050, at=1.1, plot=FALSE)
corspec(spec1,spec2,main="cross-correlation between two spectra")
```

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Frequency track

Value to track	Principle	Function
Dominant Frequency	STFT	`dfreq()`
Fundamental frequency	Cepstrum	`fund()`
	Autocorrelation	`autoc()`
Instantaneous frequency	Zero-crossing	`zc()`
	Hilbert transform	`ifreq()`

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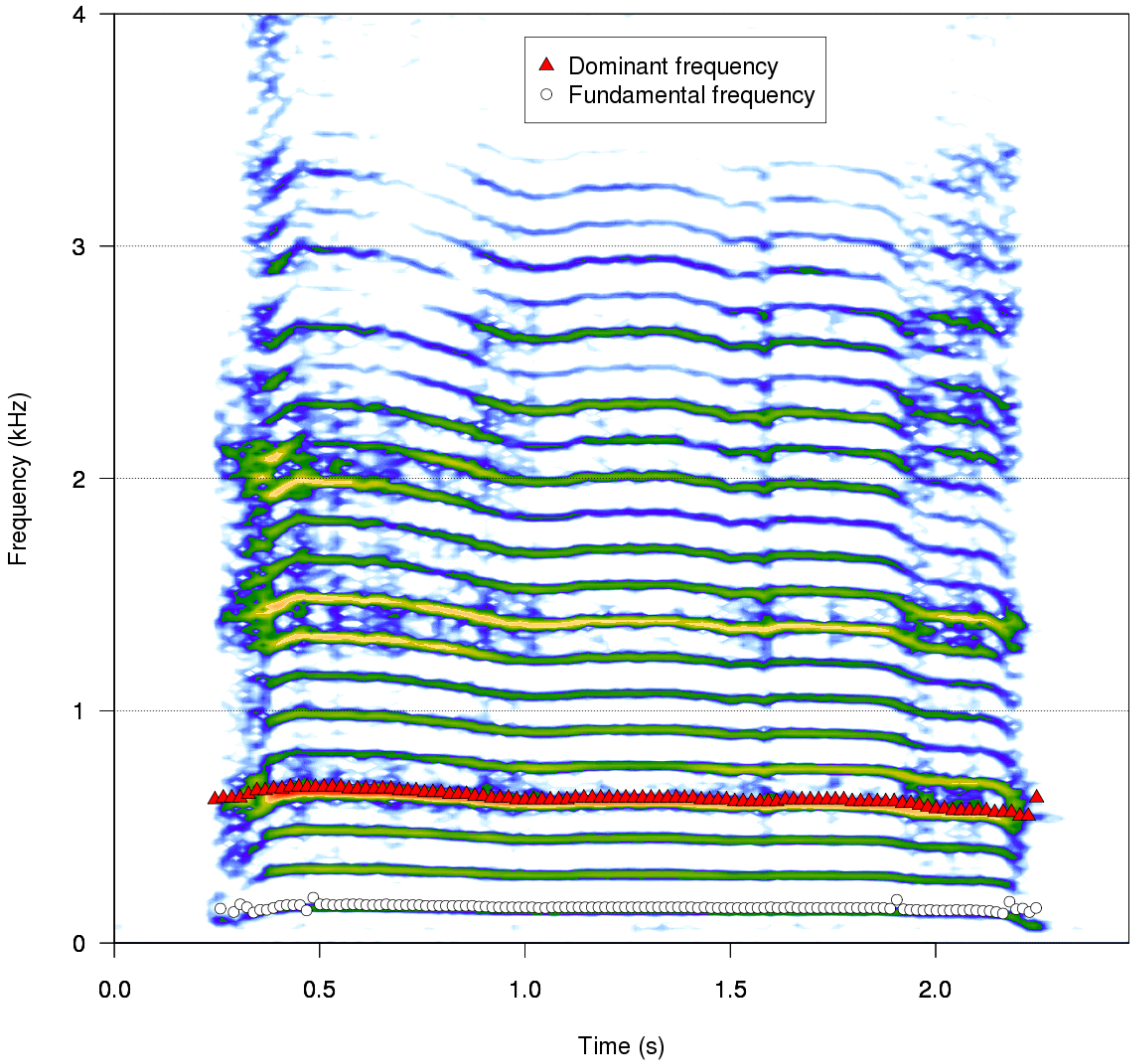
Frequency track : example (graph)



Frequency track : example (code)

```
data(sheep)
spectro(sheep, f=8000, ovlp=75, zp=16, scale=FALSE, collevels=seq(-45,0,1))
par(new=TRUE)
dfreq(sheep, f=8000, wl=1024, ovlp=85, type="p", pch=24, bg="red", ann=FALSE)
par(new=TRUE)
fund(sheep, f=8000, wl=128, fmax=200, threshold=2, type="p",
pch=21, bg="white", ann=FALSE)
legend(1,3.9, c("Dominant frequency","Fundamental frequency"),
pch=c(24,21), pt.bg=c("red","white"),bty=0)
```

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- frequency filters
- positive and negative frequency shift
- amplitude filters
- amplitude fade in and fade out
- remove amplitude (Hilbert transform)
- echo generation
- mix $(+, -, *, /)$

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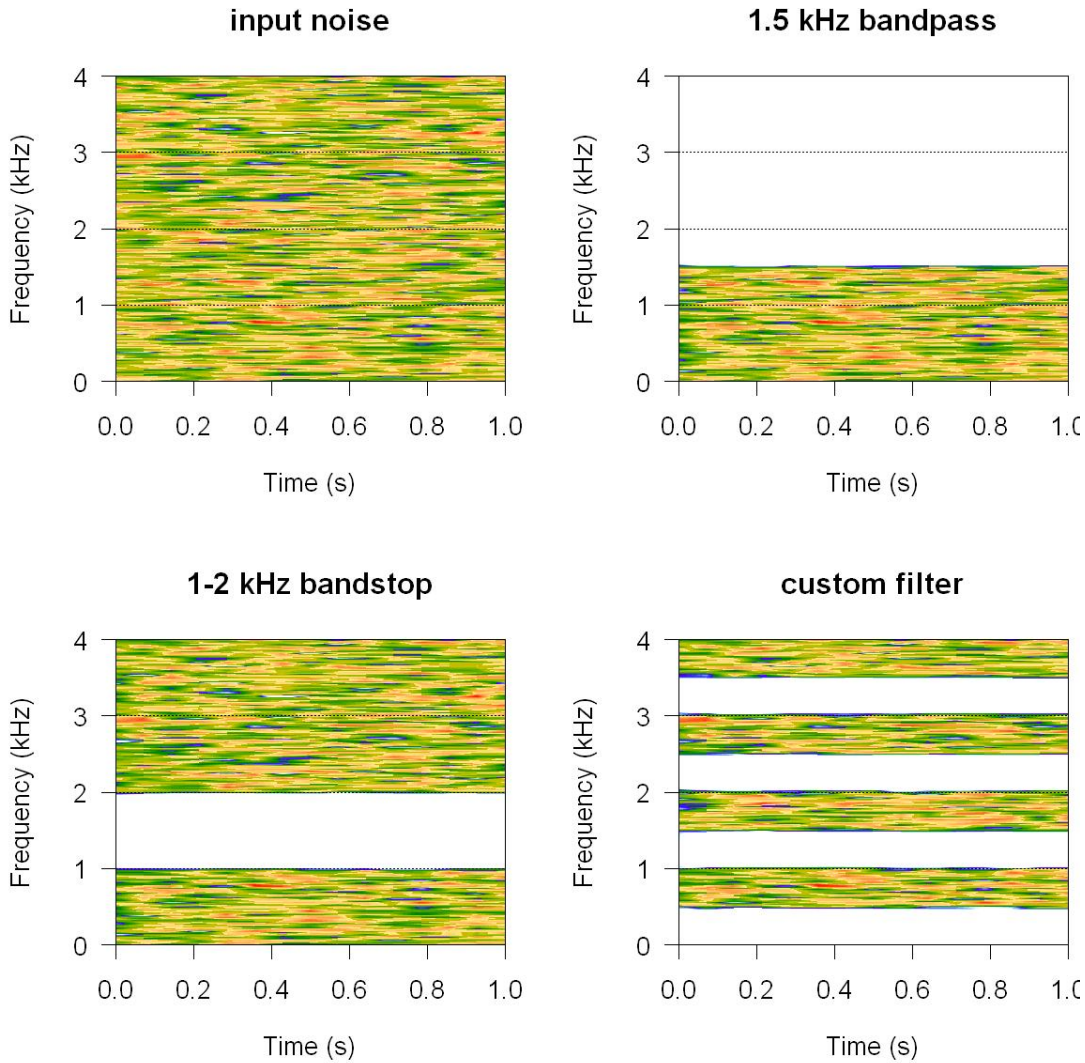
Frequency filter : example (graph)



Frequency filter : example (code)

```
par(mfrow=c(2,2))
f<-8000
a<-noise(f=f,d=1) ; spectro(a,f=f,scale=FALSE)
title(main="input noise")

b<-fir(a,f,to=1500) ; spectro(b,f=f,scale=FALSE)
title(main="1.5 kHz bandpass")

c<-fir(a,f=8000,from=1000,to=2000,bandpass=FALSE) ; spectro(c,f=f,scale=FALSE)
title(main="1-2 kHz bandstop")

myfilter1<-rep(c(rep(0,32),rep(1,32)),4)
d<-fir(a,f=f,custom=myfilter1) ; spectro(d,f=f,scale=FALSE)
title(main="custom filter")
```

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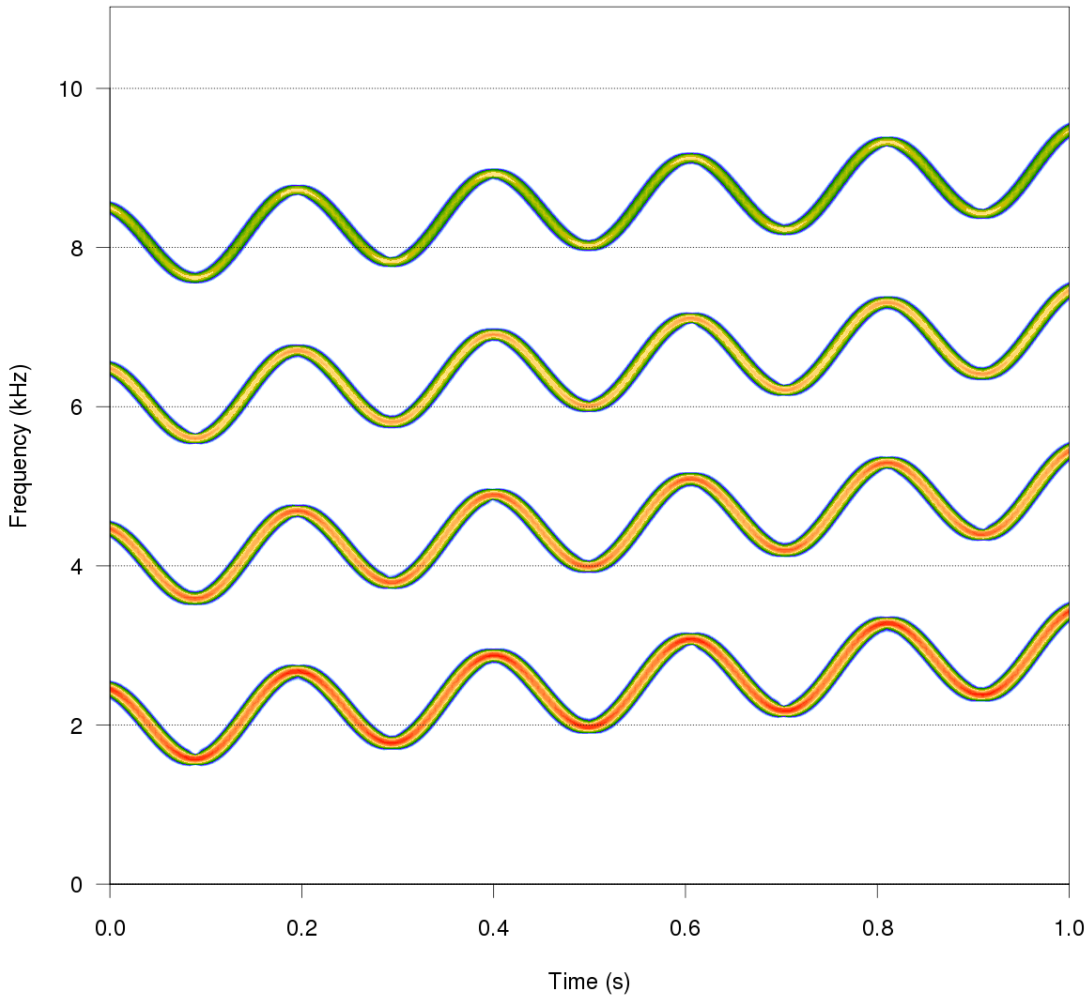
Crazy sound (graph)



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Crazy sound (code)

```
F1<-synth(f=22050,cf=2000,d=1,fm=c(500,5,1000))
F2<-synth(f=22050,a=0.8,cf=4000,d=1,fm=c(500,5,1000))
F3<-synth(f=22050,a=0.6,cf=6000,d=1,fm=c(500,5,1000))
F4<-synth(f=22050,a=0.4,cf=8000,d=1,fm=c(500,5,1000))
final<-F1+F2+F3+F4
spectro(final,f=22050,wl=512,ovlp=75,scale=FALSE)
```

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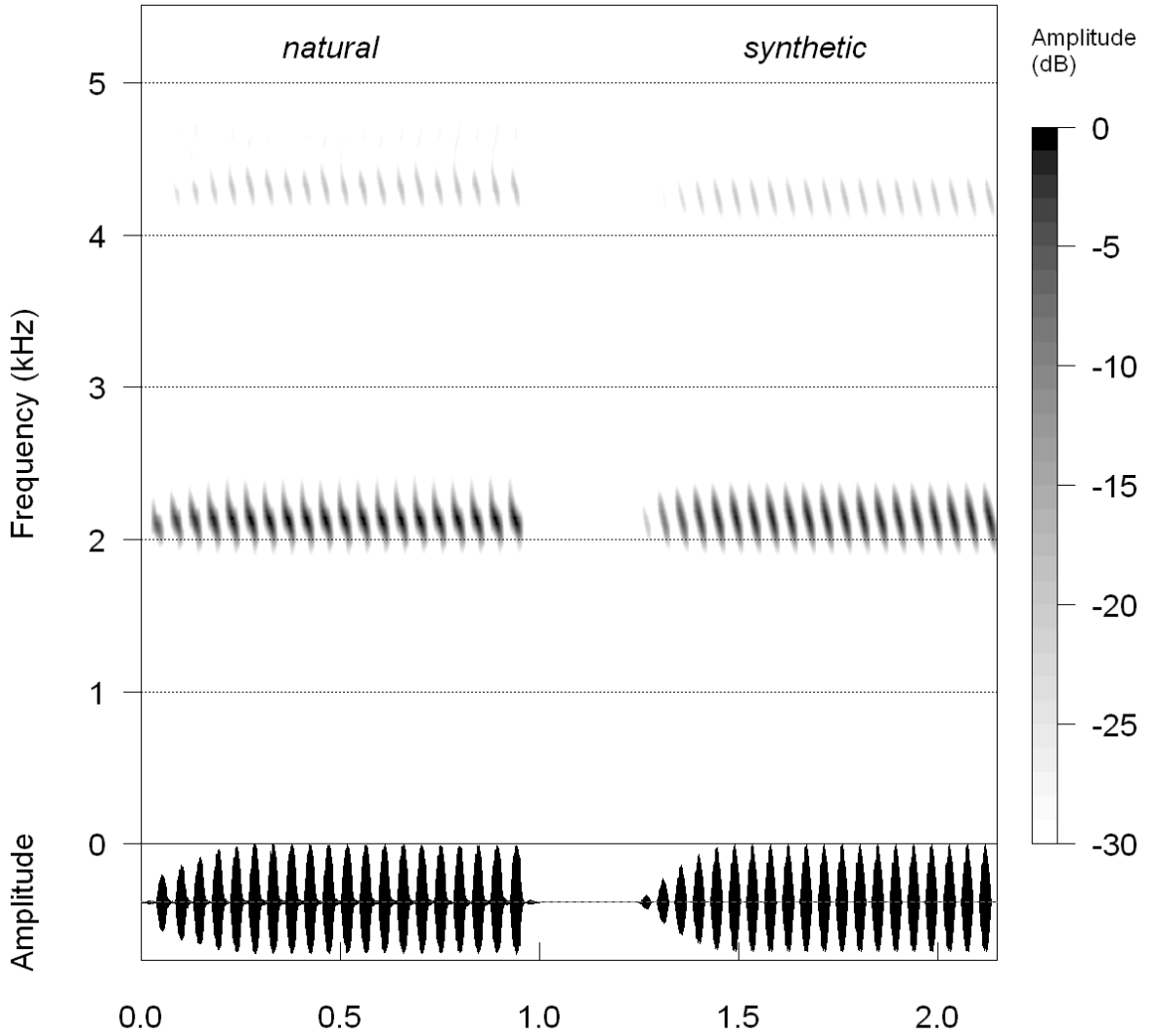
Imitation (graph)



Imitation (code)

```
data(pellucens)
f<-11025
natural<-cutw(pellucens,f=f,from=2.15, to=3.15)
s1<-synth(d=0.03,f=f,cf=2300,fm=c(0,0,-315), shape="sine")
s2<-synth(d=0.03,f=f,cf=2300*1.9,fm=c(0,0,-315), shape="sine")
s3<-s1+(0.12*s2)
s4<-s3/max(s3)
s5<-addsilw(s4,f=f,d=0.015
s6<-repw(s5,f=f,times=20)
s7<-fadew(s6,f=f,din=0.25,shape="cos")
result1<-pastew(s7,pellu,f=f)
result2<-addsilw(result1,f=f,at=1,d=0.25)
spectro(result2, f=f, wl=256, ovlp=95, osc=TRUE, palette=rev.gray.colors.1)
mtext(c("natural","synthetic"), side=3, at=c(0.2,0.7), line=1.5, font=3)
```

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HELP !

- Wigner-Ville distribution (WVD) for fast FM analysis
- Gabor transform for time/frequency analysis
- Maximum Entropy Spectral Analysis (MESA) for pulse frequency analysis
- Linear Predictive Coding (LPC) for speech analysis
- Instantaneous frequency modification for signal synthesis and modification
- ...

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- *R Core Team* : **Kurt Hornik**, **Uwe Ligges**

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