Package 'lomb'

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Type Package

Title Lomb-Scargle Periodogram

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Author Thomas Ruf, partially based on C original by Press et al. (Numerical Recipes)

Maintainer Thomas Ruf <Thomas.Ruf@vetmeduni.ac.at>

Description Computes the Lomb-Scargle Periodogram for unevenly sampled time series. Includes a randomization procedure to obtain reliable p-values.

License GPL (>= 2)

NeedsCompilation no

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`lomb-package` *Lomb-Scargle Periodogram*

Description

The Lomb-Scargle periodogram is the most wideley used method to detect even weak periodoc components in unequally sampled time series. It can also be used for equally sampled time series.

Details

Package:	lomb
Type:	Package
Version:	1.2
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License:	GPL-2

Function `lsp` computes the Lomb-Scargle periodogram for unevenly sampled times series (e.g., series with missing data). P-values for the highest peak in the periodogram are computed from the exponential distribution. Alternatively, function `randlsp` computes a p-value for the largest peak in the periodogram by repeatedly randomising the time-series sequence. Both functions allow setting the range of frequencies to be inspected, as well as the stepsize (oversampling factor) used for frequency scanning.

Author(s)

Thomas Ruf
Department of Integrative Biology and Evolution,
University of Veterinary Medicine, Vienna, Austria
Maintainer: Thomas Ruf <thomas.ruf@vetmeduni.ac.at>

References

Ruf, T. (1999) The Lomb-Scargle Periodogram in Biological Rhythm Research: Analysis of Incomplete and Unequally Spaced Time-Series. *Biological Rhythm Research* **30**: 178–201

Examples

```
data(lynx)
lsp(lynx)
```

ibex *Rumen Temperature In An Alpine Ibex*

Description

Telemetric measurements of rumen temperature in a free-living alpine ibex (*Capra ibex*) measured at unequal time intervals.

Usage

```
data(ibex)
```

Format

A data frame with 1201 observations on 3 variables.

date a character variable giving date and time of measurements.

hours a numerical variable giving hours elapsed since the first measurement.

temp a numerical variable giving rumen (stomach) temperature in degrees Celsius.

Source

A subset of data from Signer, C., Ruf, T., Arnold, W. (2011) *Functional Ecology* **25**: 537-547.

Examples

```
data(ibex)
datetime <- as.POSIXlt(ibex$date)
plot(datetime,ibex$temp,pch=19,cex=0.3)
```

lsp *Lomb-Scargle Periodogram*

Description

Computes the Lomb-Scargle periodogram for a time series with irregular (or regular) sampling intervals. Allows selecting a frequency range to be inspected, as well as the spacing of frequencies scanned.

Usage

```
lsp(x, times = NULL, from = NULL, to = NULL, type = c("frequency", "period"),
    ofac = 1, alpha = 0.01, plot = TRUE, ...)
```

Arguments

x	The data to be analysed. x can be either a two-column numerical dataframe or matrix, with sampling times in columnn 1 and measurements in column 2, a single numerical vector containing measurements, or a single vector ts object (which will be converted to a numerical vector).
times	If x is a single vector, times can be provided as a numerical vector of equal length containing sampling times. If x is a vector and times is NULL, the data are assumed to be equally sampled and times is set to 1:length(x).
from	The starting frequency (or period, depending on type) to begin scanning for periodic components.
to	The highest frequency (or period, depending on type) to scan.
type	Either "frequency" (the default) or "period". Determines the type of the periodogram x-axis.
ofac	The oversampling factor. Must be an integer>=1. Larger values of ofac lead to finer scanning of frequencies but may be time-consuming for large datasets and/or large frequency ranges (from...to).
alpha	The significance level. The periodogram plot shows a horizontal dashed line. Periodogram peaks exceeding this line can be considered significant at alpha. Defaults to 0.01. Only used if plot=TRUE.
plot	Logical. If plot=TRUE the periodogram is plotted.
...	Further graphical parameters affecting the periodogram plot.

Details

The p-value for the significance of the largest peak in the periodogram is computed from the exponential distribution, as outlined in Press et al. (1994), see below. For a more robust - but potentially time-consuming estimation of p-values see randlsp.

Significance levels in both lsp and randlsp increase with the number of frequencies inspected. Therefore, if the frequency-range of interest can be narrowed down *a priori*, use arguments "from" and "to" to do so.

Value

A named list with the following components:

scanned	A vector containing the frequencies/periods scanned.
power	A vector containing the normalised power corresponding to scanned frequencies/periods.
data	Names of the data vectors analysed.
n	The length of the data vector.
type	The periodogram type used, either "frequency" or "period".
ofac	The oversampling factor used.
n.out	The length of the output (powers). This can be >n if ofac >1.
alpha	The false alarm probability used.

sig.level	Powers > sig.level can be considered significant peaks at p=alpha.
peak	The maximum power in the frequency/period interval inspected.
peak.at	The frequency/period at which the maximum peak occurred.
p.value	The probability that the maximum peak occurred by chance.

Note

For a description of the properties of the Lomb-Scargle Periodogram, its computation and comparsion with other methods see Ruf, T. (1999). Function lsp uses the algorithm given by Press et al (1994). The Lomb-Scargle Periodogram was originaly proposed by Lomb N.R. (1976) and furher extended by Scargle J.D. (1982).

Author(s)

Thomas Ruf <thomas.ruf@vetmeduni.ac.at> based on code by Press et al (1994).

References

Lomb N.R. (1976) Least-squares frequency analysis of unequally spaced data. *Astrophysics and Space Science* **39**:447–462

Press W.H., Teukolsky S.A., Vetterling S.T., Flannery, B.P. (1994) *Numerical recipes in C: the art of scientific computing*.2nd edition. Cambridge University Press, Cambridge, 994pp.

Ruf, T. (1999) The Lomb-Scargle Periodogram in Biological Rhythm Research: Analysis of Incomplete and Unequally Spaced Time-Series. *Biological Rhythm Research* **30**: 178–201.

Scargle J.D. (1982) Studies in astronomical time series. II. Statistical aspects of spectral analysis of unevenly spaced data. *The Astrophysical Journal* **302**: 757–763.

See Also

randlsp summary.lsp

Examples

```
# ibex contains an unevenly sampled time series
data(ibex)
lsp(ibex[2:3],)
lsp(ibex$temp,times=ibex$hours,type='period',ofac=5)

# lynx contains evenly sampled data
lsp(lynx)
lynx.spec <- lsp(lynx,type='period',from=2,to=20,ofac=5)
summary(lynx.spec)
```

plot.lsp *Plot Lomb-Scargle Periodogram*

Description

Plots the normalised power as a function of frequency (or period, depending on type in function lsp).

Usage

```
## S3 method for class 'lsp'
plot(x, type = "l", main = "Lomb-Scargle Periodogram", xlab = NULL,
    ylab = "normalised power", level = TRUE, log = NULL, ...)
```

Arguments

x	Object of class lsp as returned from function lsp.
type	Character indicating the type of plotting. Any of the types as in plot.default.
main	Character. Main title of the periodogram plot. Defaults to "Lomb-Sargle Periodogram".
xlab	Character. X-axis label of the periodogram plot.
ylab	Character. Y-axis label of the periodogram plot.
level	Logical. If TRUE, the siginificance level is displayed as a dashed line.
log	By default, periodgrams of type="period" are shown with a log x-axis. If desired otherwise, use log=".." to define log-axis as in plot.default
...	Additional graphics parameters

Details

Usually, this function is only called by function lsp. It maybe called by the user for some control of the ouput. For better control, plot results from lsp ($scanned, $power) as desired.

Value

Invisibly returns the object of class lsp it is called with.

Author(s)

Thomas Ruf <thomas.ruf@vetmeduni.ac.at>

See Also

lsp

Examples

```
data(ibex)
ibex.spec <- lsp(ibex[,2:3],type='period',from=12,to=36,ofac=10, plot=FALSE)
op <- par(pch=16)
plot.lsp(ibex.spec, main="Periodogram of daily rhythms of Tb in Capra ibex",
    cex.lab=1.3,log="", type="b",level=FALSE,xaxt="n")
axis(side=1,at=seq(12,36,by=6))
par(op)
```

---

randlsp *Randomise Lomb-Scargle Periodogram*

Description

randlsp is used to obtain robust p-values for the significance of the largest peak in a Lomb-Scargle periodogram by randomisation. The data sequence is scrambled repeatedly and the probability of random peaks reaching or exceeding the peak in the original (unscrambled) periodogram is computed.

Usage

```
randlsp(repeats=1000, x, times = NULL, from = NULL, to = NULL,
    type = c("frequency", "period"), ofac = 1, alpha = 0.01,
    plot = TRUE, trace = TRUE, ...)
```

Arguments

repeats	An integer determining the number of repeated randomisations. Large numbers (>=1000) are better but can make the procedure time-consuming.
x	The data to be analysed. x can be either a two-column numerical dataframe or matrix, with sampling times in columnn 1 and measurements in column 2, a single numerical vector containing measurements, or a single vector ts object (which will be converted to a numerical vector).
times	If x is a single vector, times can be provided as a numerical vector of equal length containing sampling times. If x is a vector and times is NULL, the data are assumed to be equally sampled and times is set to 1:length(x).
from	The starting frequency (or period, depending on type) to begin scanning for periodic components.
to	The highest frequency (or period, depending on type) to scan.
type	Either "frequency" (the default) or "period". Determines the type of the periodogram x-axis.
ofac	The oversampling factor. Must be an integer >=1. Larger values of ofac lead to finer scanning of frequencies but may be time-consuming for large datasets and/or large frequency ranges (from...to).

alpha	The significance level. The periodogram plot shows a horizontal dashed line. Periodogram peaks exceeding this line can be considered significant at alpha. Defaults to 0.01. Only used if plot=TRUE.
plot	Logical. If TRUE, two plots are displayed (i) The periodogram of the original (unscrambled) data (ii) A histogram of peaks occuring by chance during sequence randomisation. A vertical line is drawn at the height of the peak in a periodogram of the original data.
trace	Logical. If TRUE, information about the progress of the randomisation procedure is printed during the running of randlsp.
...	Additional graphical parameters affecting the histogram plot.

Details

Function randlsp preserves the actual measurement intervals, which may affect the periodogram (see Nemec & Nemec 1985, below). Hence, this is a conservative randomisation procedure.

P-values from both randlsp and `lsp` increase with the number of frequencies inspected. Therefore, if the frequency-range of interest can be narrowed down *a priori*, use arguments "from" and "to" to do so.

Value

A named list with the following items:

scanned	A vector containing the frequencies/periods scanned.
power	A vector containing the normalised power corresponding to scanned frequencies/periods.
data	Names of the data vectors analysed.
n	The length of the data vector.
type	The periodogram type used, either "frequency" or "period".
ofac	The oversampling factor used.
n.out	The length of the output (powers). This can be >n if ofac >1.
peak	The maximum power in the frequency/period interval inspected.
peak.at	The frequency/period at which the maximum peak occurred.
random.peaks	A vector of peaks (with length=repeats) of maximum power values computed from randomised data.
repeats	The number of randomisations.
p.value	The probability that the peak in the original data occurred by chance, computed from randomising the data sequence.

Author(s)

Thomas Ruf <thomas.ruf@vetmeduni.ac.at>

References

Nemec A.F.L, Nemec J.M. (1985) A test of significance for periods derived using phase-dispersion-miminimization techniques. *The Astronomical Journal* **90**:2317–2320

See Also

lsp

Examples

```
data(lynx)
set.seed(444)
rand.times <- sample(1:length(lynx),30) # select a random vector of sampling times
randlsp(1000,lynx[rand.times],times=rand.times)
```

---

summary.lsp *Summarise Lomb-Scargle Periodogram Results*

Description

Summary method for class lsp.

Usage

```
## S3 method for class 'lsp'
summary(object,...)
```

Arguments

object	an object of class lsp.
...	currently, no other arguments are required.

Value

summary.lsp returns a one column data.frame with results from function lsp. Row names and contents are as follows:

Time	Name of the sampling time variable.
Data	Name of the measured variable.
Type	either "frequency" or "period".
Oversampling factor	The degee of oversampling (>=1).
From	The lowest frequency (or period, depending on type) inspected.
To	The highest frequency (or period, depending on type) inspected.
# frequencies	The number of frequencies (or periods, depending on type) inspected.
PNmax	The peak normalised power in the periodogram.

`At frequency`	The frequency at which PNmax occurred.
`At period`	The period at which PNmax occurred.
`P-value (PNmax)`	The probability that PNmax occured by chance, computed from the exponential distribution.

Author(s)

Thomas Ruf <thomas.ruf@vetmeduni.ac.at>

See Also

lsp

Examples

```
data(lynx)
summary(lsp(lynx))
```

`summary.randlsp` *Summarise Randomised Lomb-Scargle Periodogram Results*

Description

Summary method for class randlsp.

Usage

```
## S3 method for class 'randlsp'
summary(object,...)
```

Arguments

`object`	an object of class randlsp.
`...`	currently, no other arguments are required.

Value

summary.randlsp returns a one column data.frame with results from function randlsp. Row names and contents are as follows:

`Time`	Name of the sampling time variable.
`Data`	Name of the measured variable.
`Type`	either “frequency” or “period”.
`Oversampling`	The degee of oversampling (>=1).
`From`	The lowest frequency (or period, depending on type) inspected.

`To`	The highest frequency (or period, depending on type) inspected.
`# frequencies`	The number of frequencies (or periods, depending on type) inspected.
`PNmax`	The peak normalised power in the periodogram.
`At frequency`	The frequency at which PNmax occurred.
`At period`	The period at which PNmax occurred.
`Repeats`	The number of randomisations.
`P-value (PNmax)`	The probability that PNmax occurred by chance, computed from randomising the data sequence.

Author(s)

Thomas Ruf <thomas.ruf@vetmeduni.ac.at>

See Also

randlsp

Examples

```
data(lynx)
summary(randlsp(500,lynx))
```

Index