Package ‘lomb’

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Type Package
Title Lomb-Scargle Periodogram
Version 2.0
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Author Thomas Ruf, partially based on C original by Press et al. (Numerical Recipes) and the Python module Astropy.
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 exact p-values.
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Description

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

Details

| Package: | lomb |
| Type:    | Package |
| Version: | 2.0 |
| Date:    | 2021-02-01 |
| License: | GPL-3 |

Function `lsp` computes the Lomb-Scargle periodogram for unevenly sampled times series (e.g., series with missing data). P-values for the false-alarm probability of the highest peak in the periodogram are computed. Alternatively, function `randlsp` computes a bootstrap P-value for the largest peak in the periodogram by repeatedly randomizing 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)

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References


Examples

data(lynx)
lsp(lynx)
ggamma

Utility function called by pvaluev()

Description
Largely from astropy.timeseries

Usage
ggamma(N)

Arguments
N A positive number

Value
sqrt(2 / N) * exp(lgamma(N / 2) - lgamma((N - 1) / 2))

Author(s)
Thomas Ruf <thomas.ruf@vetmeduni.ac.at>.

References

See Also
pvaluev

Examples
ggamma(3)
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


Examples

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

Internal function to find significance level

Description

Called by optim to find significance value (0-1) corresponding to p-value (x).

Usage

levopt(x, alpha, fmax, tm)

Arguments

x Initial value of parameter to be optimized.
alpha Desired significance level, defaults to 0.01.
fmax Maximum frequency inspected.
tm Vector of times inspected.
**lsp**

**Value**
Scalar. The value at which the periodogram reaches significance.

**Author(s)**
Thomas Ruf <thomas.ruf@vetmeduni.ac.at>.

**References**

**See Also**
pbalance

**Examples**

```r
##---- Do not call directly, internal function
```

---

**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**

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

**Arguments**
- **x**: The data to be analyzed. x can be either a two-column numerical dataframe or matrix, with sampling times in column 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 $\geq 1$. 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.

normalize

The type of normalization used, either “standard” or “press”. If normalization is standard (the default) the periodogram is confined to the interval 0-1, and the statistical significance of the largest peak in the periodogram is computed according to Baluev (2008).if normalization is set to “press” the periodogram will be normalized using the factor $1/(2 \times \text{var}(y))$ and 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

plot

Logical. If plot=TRUE the periodogram is plotted.

... Further parameters.

Details

For a more robust - but potentially time-consuming estimation of p-values (when n is large) 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:

normalize The type of normalization used.
scanned A vector containing the frequencies/periods scanned.
power A vector containing the normalized power corresponding to scanned frequencies/periods.
data Names of the data vectors analyzed.
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 $\geq n$ if ofac $>1$.
alpha The false alarm probability used.
sig.level Powers $> \text{sig.level}$ 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


Author(s)

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

References


See Also

randlsp summary.lsp

Examples

# ibex contains an unevenly sampled time series
data(ibex)
lsp(ibex[,2:3],ofac=5)
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)

# generate unevenly sampled data
```r
time = runif(200, 1, 1000)
y = 2*cos(time/6) + rnorm(200, 0, 4)
lsp(y, times = time, ofac = 10, to = 0.3)
```

# to obtain periodogram as in Press et al (for backwards compatibility):
result = lsp(y, times = time, to = 0.3, normalize = "press")
print(result)

### pbaluev

<table>
<thead>
<tr>
<th>pbaluev</th>
<th>False alarm probability</th>
</tr>
</thead>
</table>

**Description**

Computes the statistical significance of peaks (range 0-1) in the standardized periodogram. Typically not called by the user.

**Usage**

pbaluev(Z, fmax, tm)

**Arguments**

- **Z**: the height of a periodogram peak
- **fmax**: the highest frequency inspected
- **tm**: a vector with measurement timepoints

**Details**

Based on results in extreme value theory, improved analytic estimations of false alarm probabilities are given.

**Value**

Returns the significance of the largest peak in the periodogram.

**Note**

Code based on astropy.timeseries

**Author(s)**

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

**References**

plot.lsp

See Also
summary.lsp

Examples
paluev(0.19, 2.0, 1:100)

plot.lsp

Plot Lomb-Scargle Periodogram

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

Usage
## S3 method for class 'lsp'
plot(x, main = "Lomb-Scargle Periodogram", xlabel = NULL,
ylabel = "normalized power", level = TRUE, plot=TRUE,...)

Arguments
x Object of class lsp as returned from function lsp.
main Character. Main title of the periodogram plot. Defaults to “Lomb-Scargle Periodogram”.
xlabel Character. X-axis label of the periodogram plot.
ylabel Character. Y-axis label of the periodogram plot.
level Logical. If TRUE, the significance level is displayed as a dashed line.
plot If TRUE, the periodogram is plotted.
... Further parameters.

Details
Usually, this function is only called by function lsp. It maybe called by the user for some control of the output. 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)

plot.lsp(ibex.spec, main = "Daily rhythms in Tb", xlabel = "Period (h)", ylabel = "Power", level = FALSE)

---

### randlsp

**Randomize 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 randomization. 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**

```r
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 randomizations. Large numbers (>=1000) are better but can make the procedure time-consuming.
- **x**: The data to be analyzed. x can be either a two-column numerical dataframe or matrix, with sampling times in column 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).
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.

Logical. If TRUE, two plots are displayed (i) The periodogram of the original (unscrambled) data (ii) A histogram of peaks occurring by chance during sequence randomization. A vertical line is drawn at the height of the peak in a periodogram of the original data.

Logical. If TRUE, information about the progress of the randomization procedure is printed during the running of randlsp.

Further parameters.

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

A named list with the following items:

A vector containing the frequencies/periods scanned.

A vector containing the normalized power corresponding to scanned frequencies/periods.

Names of the data vectors analyzed.

The length of the data vector.

The periodogram type used, either “frequency” or “period”.

The oversampling factor used.

The length of the output (powers). This can be >n if ofac >1.

The maximum power in the frequency/period interval inspected.

The frequency/period at which the maximum peak occurred.

A vector of peaks (with length=repeats) of maximum power values computed from randomized data.

The number of randomizations.

The probability that the peak in the original data occurred by chance, computed from randomizing the data sequence.

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


See Also

lsp

Examples

time=(runif(100,1,1000))
signal=2*cos(time/6)+rnorm(100,0,4)
randlsp(200,x=signal,times=time, to=0.2,trace=FALSE) #use more reps to get better results

summary.lsp

Summarize 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 degree 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 normalized 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 occurred by chance. May slightly vary with the normalization.

Author(s)
Thomas Ruf <thomas.ruf@vetmeduni.ac.at>

See Also
lsp

Examples
data(lynx)
summary(lsp(lynx))

summary.randlsp
Summarize 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 degree of oversampling (>=1).
From The lowest frequency (or period, depending on type) inspected.
To
# frequencies
PNmax
At frequency
At period
Repeats
P-value (PNmax)

The highest frequency (or period, depending on type) inspected.
The number of frequencies (or periods, depending on type) inspected.
The peak normalized power in the periodogram.
The frequency at which PNmax occurred.
The period at which PNmax occurred.
The number of randomizations.
The probability that PNmax occurred by chance, computed from randomizing the data sequence.

Author(s)
Thomas Ruf <thomas.ruf@vetmeduni.ac.at>

See Also
randlsp

Examples

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

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| theme_lsp | ggplot2 theme for periodogram |

Description

A theme derived from theme_bw.

Usage

```r
theme_lsp()
```
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