# Package 'quantspec'

October 20, 2015

**Version** 1.2-0

**Encoding** UTF-8

**Date** 2015-10-19

**Title** Quantile-Based Spectral Analysis of Time Series

**Depends** R (>= 3.0.0), stats4

**Suggests** testthat

**Imports** methods, graphics, quantreg, abind, zoo, snowfall, Rcpp (>= 0.11.0)

**Description** Methods to determine, smooth and plot quantile periodograms for univariate and multivariate time series.

**License** GPL (>= 2)

**URL** http://github.com/tobiaskley/quantspec

**BugReports** http://github.com/tobiaskley/quantspec/issues

**LazyData** TRUE

**LinkingTo** Rcpp

**Collate** 'Class-BootPos.R' 'generics.R' 'Class-LagOperator.R' 'Class-ClippedCov.R' 'aux-functions.R' 'Class-QSpecQuantity.R' 'Class-FreqRep.R' 'Class-ClippedFT.R' 'Class-QuantileSD.R' 'Class-IntegrQuantileSD.R' 'Class-Weight.R' 'Class-KernelWeight.R' 'Class-LagEstimator.R' 'kernels.R' 'Class-LagKernelWeight.R' 'Class-MovingBlocks.R' 'Class-QRegEstimator.R' 'Class-QuantilePG.R' 'Class-SmoothedPG.R' 'Class-SpecDistrWeight.R' 'RcppExports.R' 'data.R' 'deprecated.R' 'models.R' 'quantspec-package.R'

**NeedsCompilation** yes

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**Repository** CRAN

**Date/Publication** 2015-10-20 10:57:57

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---

`quantspec-package` *Quantile-Based Spectral Analysis of Time Series*

---

## Description

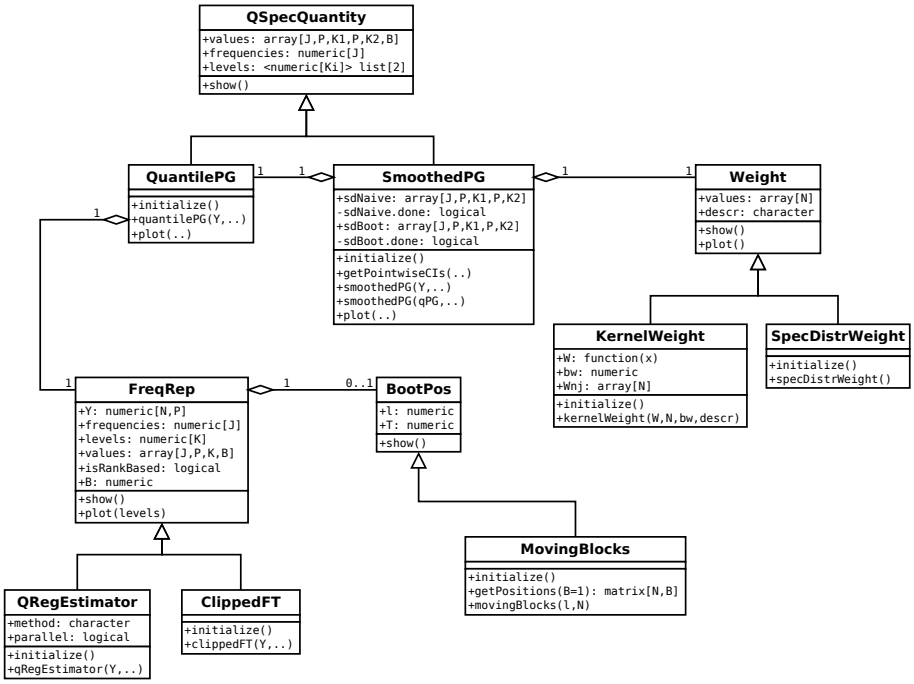
Methods to determine, smooth and plot quantile periodograms for univariate and (since v1.2-0) multivariate time series.

## Details

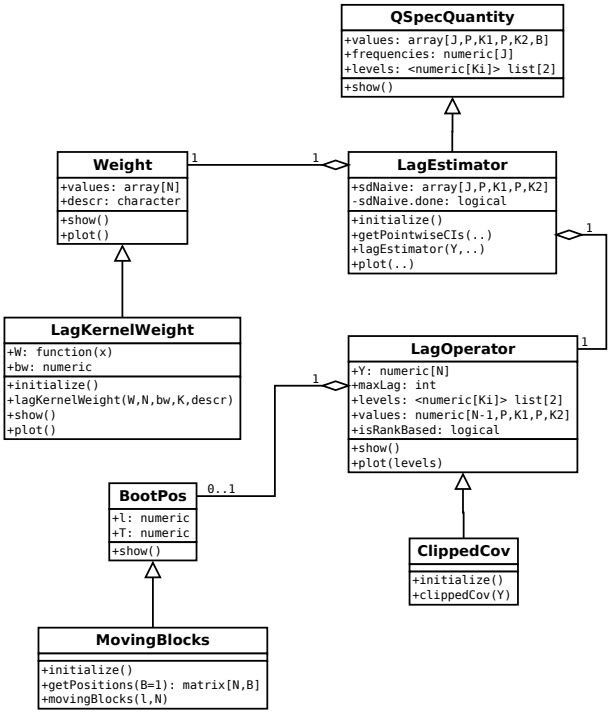
| | |
|---|---|
| Package: | quantspec |
| Type: | Package |
| Version: | 1.2-0 |
| Date: | 2015-10-19 |
| License: | GPL (>= 2) |

## Contents

The **quantspec** package contains a hierachy of S4 classes with corresponding methods and functions serving as constructors. The following class diagrams provide an overview on the structure of the package. In the first and second class diagram the classes implementing the estimators are shown. In the first diagram the classes related to periodogram-based estimation are displayed:

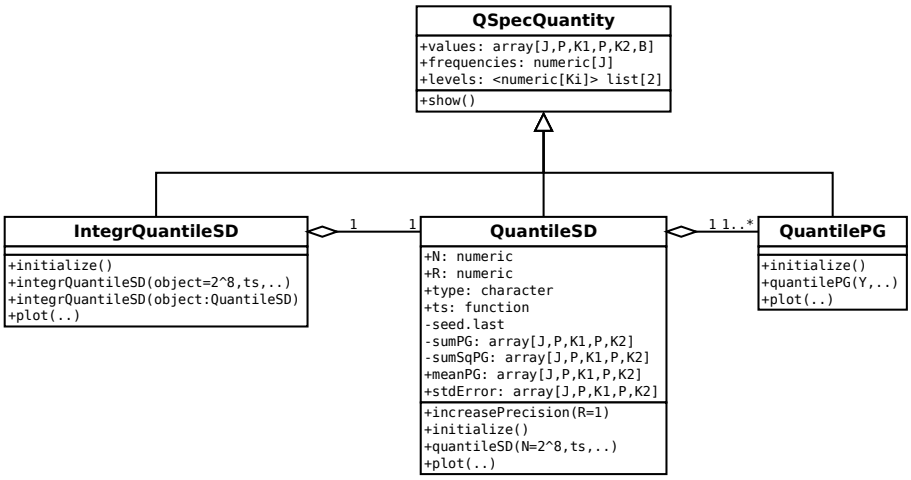



In the second diagram the classes related to lag window-based estimation are displayed:




In the third class diagram the classes implementing model quantities are displayed. A relation to the "empirical classes" is given via the fact that the quantile spectral densities are computed by simulation of quantile periodograms and a common abstract superclass `QSpecQuantity` which is

used to provide a common interface to quantile spectral quantities.




Besides the object-oriented design a few auxiliary functions exists. They serve as parameters or are mostly for internal use. A more detailed description of the framework can be found in the paper on the package (Kley, 2015).

### Organization of the source code / files in the `/R` folder

All of the source code related to the specification of a certain class is contained in a file named `Class-[Name_of_the_class].R`. This includes, in the following order,

1. all roxygen `@include` to insure the correctly generated collate for the DESCRIPTION file.
2. `\setClass` preceded by a meaningful roxygen documentation.
3. specification of an `initialize` method, where appropriate.
4. all accessor and mutator method (i. e., getter and setter); first the ones returning attributes of the object, then the ones returning associated objects.
5. constructors; use generics if there is more than one of them.
6. `show` and `plot` methods.

### Coding Conventions

To improve readability of the software and documentation this package was written in the spirit of the "Coding conventions of the Java Programming Language" (Oracle, 2015). In particular, the naming conventions for classes and methods have been adopted, where "Class names should be nouns, in mixed case with the first letter of each internal word capitalized." and "Methods should be verbs, in mixed case with the first letter lowercase, with the first letter of each internal word capitalized."

### Naming Conventions for the Documentation

To reflect the structure of the contents of the package in the documentation file, the following system for naming of the sections is adopted:

- Documentation of an S4 class is named as the name of the class followed by "-class". [cf. QuantilePG-class]
- Documentation of a constructor for an S4-class is named as the name of the class followed by "-constructor". [cf. QuantilePG-constructor]
- Documentation of a method dispaching to an object of a certain S4 class is named by the name of the method, followed by "-", followed by the name of the Class. [cf. getValues-QuantilePG]

## Author(s)

Tobias Kley

## References

Kley, T. (2014a). Quantile-Based Spectral Analysis: Asymptotic Theory and Computation. Ph.D. Dissertation, Ruhr University Bochum. http://www-brs.ub.ruhr-uni-bochum.de/netahtml/HSS/Diss/KleyTobias/.

Kley, T. (2015). An Object-Oriented Framework for Quantile-Based Spectral Analysis and a Reference Implementation in R: The quantspec Package. Vignette to this R package.

Dette, H., Hallin, M., Kley, T. & Volgushev, S. (2015). Of Copulas, Quantiles, Ranks and Spectra: an $L_1$-approach to spectral analysis. *Bernoulli*, **21**(2), 781–831. [cf. http://arxiv.org/abs/1111.7205]

Kley, T., Volgushev, S., Dette, H. & Hallin, M. (2015+). Quantile Spectral Processes: Asymptotic Analysis and Inference. *Bernoulli*, **forthcoming**. [cf. http://arxiv.org/abs/1401.8104]

Barunik, J. & Kley, T. (2015). Quantile Cross-Spectral Measures of Dependence between Economic Variables. [preprint available from the authors]

Oracle (2015). Coding conventions of the Java Programming Language. http://www.oracle.com/technetwork/java/codeconvtoc-136057.html. Accessed 2015-03-25.

---

# BootPos-class *Class for Generation of Bootstrapped Replications of a Time Series.*

---

## Description

BootPos is an S4 class that provides a common interface to different algorithms that can be used for implementation of a block bootstrap procedure in the time domain.

## Details

After initialization the bootstrapping can be performed by applying getPositions to the object.

Different block bootstraps are implemented by creating a subclass together with a getPositions method that contains the implementation of the block resampling procedure.

Currently the following implementations are available:

- MovingBlocks and getPositions-MovingBlocks.

## Slots

`l` the (expected) block length for the block bootstrap methods

`N` number of available observations to bootstrap from

## References

Lahiri, S. N. (1999). Theoretical Comparisons of Block Bootstrap Methods. *The Annals of Statistics*, **27**(1), 386–404.

---

`ClippedCov-class` *Class to calculate copula covariances from a time series with given levels.*

---

## Description

Calculates for each combination of levels $(\tau_1, \tau_2)$ and for all $k <$ `maxLag` the copula covariances $Cov(1_{X_0<\tau_1}, 1_{X_k<\tau_2})$ and writes it to `values[k]` from its superclass `LagOperator`.

## Details

For each lag `k = 0, ..., maxLag` and combination of levels $(\tau_1, \tau_2)$ from `levels.1 x levels.2` the statistic

$$\frac{1}{n}\sum_{t=1}^{n-k}(I\{\hat{F}_n(Y_t) \leq \tau_1\} - \tau_1)(I\{\hat{F}_n(Y_{t+k}) \leq \tau_2\} - \tau_2)$$

is determined and stored to the array `values`.

Currently, the implementation of this class allows only for the analysis of univariate time series.

---

`ClippedCov-constructor`

*Create an instance of the `ClippedCov` class.*

---

## Description

Create an instance of the `ClippedCov` class.

## Usage

```
clippedCov(Y, maxLag = length(Y) - 1, levels.1 = c(0.5),
  levels.2 = levels.1, isRankBased = TRUE, B = 0, l = 0,
  type.boot = c("none", "mbb"))
```

### Arguments

| | |
|---|---|
| Y | Time series to calculate the copula covariance from |
| maxLag | maximum lag between observations that should be used |
| levels.1 | a vector of numerics that determines the level of clipping |
| levels.2 | a vector of numerics that determines the level of clipping |
| isRankBased | If true the time series is first transformed to pseudo data; currently only rank-based estimation is possible. |
| B | number of bootstrap replications |
| l | (expected) length of blocks |
| type.boot | A flag to choose a method for the block bootstrap; currently two options are implemented: "none" and "mbb" which means to do a moving blocks bootstrap with B and l as specified. |

### Value

Returns an instance of ClippedCov.

### See Also

LagOperator

### Examples

```
ccf <- clippedCov(rnorm(200), maxLag = 25, levels.1 = c(0.1,0.5,0.9))
dim(getValues(ccf))
#print values for levels (.5,.5)
plot(ccf, maxLag = 20)
```

---

## ClippedFT-class *Class for Fourier transform of the clipped time series.*

---

### Description

ClippedFT is an S4 class that implements the necessary calculations to determine the Fourier transform of the clipped time series. As a subclass to FreqRep it inherits slots and methods defined there; it servers as a frequency representation of a time series as described in Kley et. al (2015+) for univariate time series and in Barunik & Kley (2015) for multivariate time series.

### Details

For each frequency $\omega$ from frequencies and level q from levels the statistic

$$\sum_{t=0}^{n-1} I\{Y_{t,i} \leq q\} \mathrm{e}^{-\mathrm{i}\omega t}$$

is determined and stored to the array values. Internally the methods mvfft and fft are used to achieve good performance.

Note that, all remarks made in the documentation of the super-class FreqRep apply.

## References

Kley, T., Volgushev, S., Dette, H. & Hallin, M. (2015+). Quantile Spectral Processes: Asymptotic Analysis and Inference. *Bernoulli*, **forthcoming**. [cf. http://arxiv.org/abs/1401.8104]

Barunik, J. & Kley, T. (2015). Quantile Cross-Spectral Measures of Dependence between Economic Variables. [preprint available from the authors]

## See Also

For an example see FreqRep.

---

`ClippedFT-constructor` *Create an instance of the* `ClippedFT` *class.*

---

## Description

The parameter `type.boot` can be set to choose a block bootstrapping procedure. If `"none"` is chosen, a moving blocks bootstrap with `l=lenTS(Y)` and `N=lenTS(Y)` would be done. Note that in that case one would also chose `B=0` which means that `getPositions` would never be called. If `B>0` then each bootstrap replication would be the undisturbed time series.

## Usage

```
clippedFT(Y, frequencies = 2 * pi/lenTS(Y) * 0:(lenTS(Y) - 1), levels = 0.5,
  isRankBased = TRUE, B = 0, l = 0, type.boot = c("none", "mbb"))
```

## Arguments

| | |
|---|---|
| `Y` | A `matrix` of real numbers containing the time series from which to determine the quantile periodogram as columns, or a `ts` object or a `zoo` object. |
| `frequencies` | A vector containing frequencies at which to determine the quantile periodogram. |
| `levels` | A vector of length `K` containing the levels at which the `ClippedFT` frequency representation is to be determined. |
| `isRankBased` | If true the time series is first transformed to pseudo data [cf. `FreqRep`]. |
| `B` | number of bootstrap replications |
| `l` | (expected) length of blocks |
| `type.boot` | A flag to choose a method for the block bootstrap; currently two options are implemented: `"none"` and `"mbb"` which means to do a moving blocks bootstrap with `B` and `l` as specified. |

## Value

Returns an instance of `ClippedFT`.

## See Also

For an example see FreqRep.

## closest.pos — *Positions of elements which are closest to some reference elements.*

### Description

For two vectors `X` and `Y` a vector of indices `I` is returned, such that `length(Y)` and `length(I)` coincide and `X[I[j]]` is an element of `X` which has minimal distance to `Y[j]`, for all `j=1,...,length(Y)`. In case that there are multiple elements with minimal distance, the smallest index (the index of the first element with minimal distance) is returned.

### Usage

```
closest.pos(X, Y)
```

### Arguments

| | |
|---|---|
| `X` | Vector of elements among which to find the closest one for each element in `Y`. |
| `Y` | Vector of elements for which to find the clostest element in `X`. |

### Value

Returns a vector of same length as `X`, with indices indicating which element in `Y` is closest.

### Examples

```
X1 <- c(1,2,3)
closest.pos(X1, 1.7)
closest.pos(X1, c(1.3,2.2))

X2 <- c(2,1,3)
closest.pos(X2, 1.5)
```

## data-sp500 — *S&P 500: Standard and Poor's 500 stock index, 2007–2010*

### Description

Contains the returns of the S&P 500 stock index for the years 2007–2010. The returns were computed as `(Adjusted.Close-Open)/Open`.

### Format

A univariate time series with 1008 observations; a `zoo` object

### Details

The data was downloaded from the Yahoo! Finance Website.

## References

Yahoo! Finance Website http://finance.yahoo.com/q/hp?s=^GSPC+Historical+Prices

## Examples

```
plot(sp500)
```

---

`data-wheatprices` *Beveridge's Wheat Price Index (detrended and demeaned), 1500–1869*

---

## Description

Contains a detrended and demeaned version of the well-known Beveridge Wheat Price Index which gives annual price data from 1500 to 1869, averaged over many locations in western and central Europe [cf. Beveridge (1921)]. The index series $x_t$ was detrended as proposed by Granger (1964), p. 21, by letting

$$y_t := \frac{x_t}{\sum_{j=-15}^{15} x_{t+j}},$$

where $x_t := x_1, t < 1$ and $x_t := x_n, t > n$. The time series in the data set is also demeaned by letting

$$z_t := y_t - n^{-1} \sum_{t=1}^{n} y_t.$$

## Format

A univariate time series $(z_t)$ with 370 observations; a `ts` object.

## Details

The index data cited in Beveridge's paper was taken from `bev` in the `tseries` package.

## References

Beveridge, W. H. (1921). Weather and Harvest Cycles. *The Economic Journal*, 31(124):429–452.

Granger, C. W. J. (1964). *Spectral Analysis of Economic Time Series*. Princeton University Press, Princeton, NJ.

## Examples

```
plot(wheatprices)
```

FreqRep-class *Class for Frequency Representation.*

## Description

FreqRep is an S4 class that encapsulates, for a multivariate time series $(Y_{t,i})_{t=0,\dots,n-1}$, $i = 1, \dots, d$ the data structures for the storage of a frequency representation. Examples of such frequency representations include

- the Fourier transformation of the clipped time series $(\{I\{Y_{t,i} \leq q\}\})$, or
- the weighted $L_1$-projection of $(Y_{t,i})$ onto an harmonic basis.

Examples are realized by implementing a sub-class to FreqRep. Currently, implementations for the two examples mentioned above are available: ClippedFT and QRegEstimator.

## Details

It is always an option to base the calculations on the pseudo data $R_{t,n,i}/n$ where $R_{t,n,i}$ denotes the rank of $Y_{t,i}$ among $(Y_{t,i})_{t=0,\dots,n-1}$.

To allow for a block bootstrapping procedure a number of B estimates determined from bootstrap replications of the time series which are yield by use of a BootPos-object can be stored on initialization.

The data in the frequency domain is stored in the array values, which has dimensions (J,P,K,B+1), where J is the number of frequencies, P is the dimension of the time series, K is the number of levels and B is the number of bootstrap replications requested on intialization. In particular, values[j,i,k,1] corresponds to the time series' frequency representation with frequencies[j], dimension i and levels[k], while values[j,i,k,b+1] is the for the same, but determined from the bth block bootstrapped replicate of the time series.

## Slots

Y The time series of which the frequency representation is to be determined.

frequencies The frequencies for which the frequency representation will be determined. On initalization frequenciesValidator is called, so that it will always be a vector of reals from $[0, \pi]$. Also, only Fourier frequencies of the form $2\pi j/n$ with integers $j$ and $n$ the length(Y) are allowed.

levels The levels for which the frequency representation will be determined. If the flag isRankBased is set to FALSE, then it can be any vector of reals. If isRankBased is set to TRUE, then it has to be from $[0, 1]$.

values The array holding the determined frequency representation. Use a getValues method of the relevant subclass to access it.

isRankBased A flag that is FALSE if the determined values are based on the original time series and TRUE if it is based on the pseudo data as described in the Details section of this topic.

positions.boot An object of type BootPos, that is used to determine the block bootstrapped replicates of the time series.

B Number of bootstrap replications to perform.

## Examples

```
Y       <- rnorm(32)
freq    <- 2*pi*c(0:31)/32
levels  <- c(0.25,0.5,0.75)
cFT     <- clippedFT(Y, freq, levels)

plot(cFT)

# Get values for all Fourier frequencies and all levels available.
V.all    <- getValues(cFT)

# Get values for every second frequency available
V.coarse <- getValues(cFT, frequencies = 2*pi*c(0:15)/16, levels = levels)

# Trying to get values on a finer grid of frequencies than available will
# yield a warning and then all values with frequencies closest to that finer
# grid.
V.fine   <- getValues(cFT, frequencies = 2*pi*c(0:63)/64, levels = levels)

# Finally, get values for the available Fourier frequencies from [0,pi] and
# only for tau=0.25
V.part   <- getValues(cFT, frequencies = 2*pi*c(0:16)/32, levels = c(0.25))

# Alternatively this can be phrased like this:
V.part.alt <- getValues(cFT, frequencies = freq[freq <= pi], levels = c(0.25))
```

---

`frequenciesValidator` *Validates if frequencies are Fourier frequencies from* $[0, \pi]$.

---

## Description

Validation of the parameter `freq` is perfomed in six steps:

1. Throw an error if parameter is not a vector or not numeric.
2. Transform each element $\omega$ of the vector to $[0, 2\pi)$, by replacing it with $\omega \bmod 2\pi$.
3. Check whether all elements $\omega$ of the vector are Fourier frequency $2\pi j/T$, $j \in Z$. If this is not the case issue a warning and round each frequency to the next Fourier frequency of the mentioned type; the smaller one, if there are two.
4. Transform each element $\omega$ with $\pi < \omega < 2\pi$ of the vector to $[0, \pi]$, by replacing it with $2\pi - \omega$.
5. Check for doubles and remove all but the first appearance.
6. Sort in ascending order.

Any subset of the six steps can be chosen, but 1 should almost always be among the steps to be performed.

### Usage

```
frequenciesValidator(freq, N, steps = 1:6)
```

### Arguments

| | |
|---|---|
| freq | the vector of frequencies to be validated. |
| N | the base of the Fourier frequencies against which the values in freq will be compared. |
| steps | a vector containing a subset of 1,2,3,4,5,6, indicating which of the steps are to be performed. |

### Value

Returns a vector of Fourier frequencies that is yield by the transformations described above.

### Examples

```
freq <- 2*pi*c(3,2,5,8,9)/10

res <- frequenciesValidator(freq, N=10, steps=1:3)
res * 10 / (2*pi) # Returns: [1] 3 2 5 8 9

res <- frequenciesValidator(freq, N=10, steps=1:4)
res * 10 / (2*pi) # Returns: [1] 3 2 5 2 1

res <- frequenciesValidator(freq, N=10, steps=1:5)
res * 10 / (2*pi) # Returns: [1] 3 2 5 1

res <- frequenciesValidator(freq, N=10, steps=1:6)
res * 10 / (2*pi) # Returns: [1] 1 2 3 5
```

---

## generics-accessors *Generic functions for accessing attributes of objects*

---

### Description

These generic functions are needed to access the objects' attributes. Note that the naming convention getAttribute was applied, where attribute is the name of the attribute/slot of the class of the object.

### Usage

```
getY(object, ...)

getValues(object, ...)

getCoherency(object, ...)
```

```
getIsRankBased(object, ...)

getB(object, ...)

getLagOperator(object, ...)

getMaxLag(object, ...)

getParallel(object, ...)

getFrequencies(object, ...)

getLevels(object, ...)

getMeanPG(object, ...)

getStdError(object, ...)

getN(object, ...)

getR(object, ...)

getType(object, ...)

getTs(object, ...)

getCoherencySdNaive(object, ...)

getSdNaive(object, ...)

getSdBoot(object, ...)

getPointwiseCIs(object, ...)

getDescr(object, ...)

getW(object, ...)

getBw(object, ...)

getWnj(object, ...)
```

## Arguments

| | |
|---|---|
| object | object from which to get the value |
| ... | optional parameters; for documentation see the documentation of the methods to each of the generic. |

## See Also

For an overview on the classes of the framework, and all of their attributes, see the class diagrams in the package description [cf. quantspec-package].

---

`generics-associations` *Generic functions for accessing associations of objects*

---

## Description

These generic functions are needed to access the objects' associated objects. Note that the naming convention `getAssociatedObject` was applied, where `AssociatedObject` is the name of the class of the associated object.

## Usage

```
getQuantilePG(object, ...)

getBootPos(object, ...)

getFreqRep(object, ...)

getQuantileSD(object, ...)

getWeight(object, ...)
```

## Arguments

| | |
|---|---|
| `object` | object from which to get the associated object |
| `...` | optional parameters; for documentation see the documentation of the methods to each of the generic. |

## See Also

For an overview on the classes of the framework, and all associations, see the class diagrams in the package description [cf. quantspec-package].

## generics-functions *Generic functions for implementation of methods of a class*

### Description

These generic functions need to be defined to allow for the automatic dispaching mechanism.

### Usage

```
increasePrecision(object, ...)

getPositions(object, ...)
```

### Arguments

| | |
|---|---|
| object | specifies the object from which the method is to be applied. |
| ... | optional parameters; for documentation see the documentation of the methods to the generic. |

### See Also

For an overview on the classes of the framework, and all of their methods, see the class diagrams in the package description [cf. quantspec-package].

## getB-FreqRep *Get* B *from a* FreqRep *object.*

### Description

Get B from a FreqRep object.

### Usage

```
## S4 method for signature 'FreqRep'
getB(object)
```

### Arguments

| | |
|---|---|
| object | FreqRep of which to get the B |

### Value

Returns the attribute B that's a slot of object.

## getB-LagOperator *Get* B *from a* LagOperator *object.*

### Description

Get B from a LagOperator object.

### Usage

```
## S4 method for signature 'LagOperator'
getB(object)
```

### Arguments

| | |
|---|---|
| object | LagOperator of which to get the B |

### Value

Returns the attribute B that's a slot of object.

## getBootPos-FreqRep *Get associated* BootPos *from a* FreqRep.

### Description

Get associated BootPos from a FreqRep.

### Usage

```
## S4 method for signature 'FreqRep'
getBootPos(object)
```

### Arguments

| | |
|---|---|
| object | FreqRep from which to get the BootPos. |

### Value

Returns the BootPos object associated.

---

`getBootPos-LagOperator` *Get associated* `BootPos` *from a* `LagOperator`.

---

## Description

Get associated `BootPos` from a `LagOperator`.

## Usage

```
## S4 method for signature 'LagOperator'
getBootPos(object)
```

## Arguments

| | |
|---|---|
| `object` | `LagOperator` from which to get the `BootPos`. |

## Value

Returns the `BootPos` object associated.

---

`getBw-KernelWeight` *Get attribute* `bw` *(bandwidth / scaling parameter used for smoothing) from a* `KernelWeight`.

---

## Description

Get attribute `bw` (bandwidth / scaling parameter used for smoothing) from a `KernelWeight`.

## Usage

```
## S4 method for signature 'KernelWeight'
getBw(object)
```

## Arguments

| | |
|---|---|
| `object` | `KernelWeight` from which to get the bandwidth `bw`. |

## Value

Returns the `bw` attribute.

## getBw-LagKernelWeight *Get attribute* bw *(bandwidth / scaling parameter used for smoothing) from a* LagKernelWeight.

### Description

Get attribute bw (bandwidth / scaling parameter used for smoothing) from a LagKernelWeight.

### Usage

```
## S4 method for signature 'LagKernelWeight'
getBw(object)
```

### Arguments

| | |
|---|---|
| object | LagKernelWeight from which to get the bandwidth bw. |

### Value

Returns the bw attribute.

## getCoherency-QuantileSD *Compute quantile coherency from a quantile spectral density kernel*

### Description

Returns quantile coherency defined as

$$\frac{f^{j_1,j_2}(\omega;\tau_1,\tau_2)}{(f^{j_1,j_1}(\omega;\tau_1,\tau_1)f^{j_2,j_2}(\omega;\tau_2,\tau_2))^{1/2}}$$

where $f^{j_1,j_2}(\omega;\tau_1,\tau_2)$ is the quantile spectral density.

### Usage

```
## S4 method for signature 'QuantileSD'
getCoherency(object, frequencies = 2 * pi *
  (0:(object@N - 1))/object@N, levels.1 = getLevels(object, 1),
  levels.2 = getLevels(object, 2), d1 = 1:(dim(object@values)[2]),
  d2 = 1:(dim(object@values)[4]))
```

### Arguments

| | |
|---|---|
| object | QuantileSD of which to get the values |
| frequencies | a vector of frequencies for which to get the values |
| levels.1 | the first vector of levels for which to get the values |
| levels.2 | the second vector of levels for which to get the values |
| d1 | optional parameter that determine for which j1 to return the data; may be a vector of elements 1, ..., D |
| d2 | same as d1, but for j2 |

### Details

For the mechanism of selecting frequencies, dimensions and/or levels see, for example, getValues-QuantileSD.

### Value

Returns data from the coherency as defined in the details.

### See Also

For examples on how to use this function go to QuantileSD.

---

## getCoherency-SmoothedPG

*Compute quantile coherency from a smoothed quantile periodogram.*

---

### Description

Returns quantile coherency defined as

$$\frac{G^{j_1,j_2}(\omega;\tau_1,\tau_2)}{(G^{j_1,j_1}(\omega;\tau_1,\tau_1)G^{j_2,j_2}(\omega;\tau_2,\tau_2))^{1/2}}$$

where $G^{j_1,j_2}(\omega;\tau_1,\tau_2)$ is the smoothed quantile periodogram.

### Usage

```
## S4 method for signature 'SmoothedPG'
getCoherency(object, frequencies = 2 * pi *
  (0:(lenTS(object@qPG@freqRep@Y) - 1))/lenTS(object@qPG@freqRep@Y),
  levels.1 = getLevels(object, 1), levels.2 = getLevels(object, 2),
  d1 = 1:(dim(object@values)[2]), d2 = 1:(dim(object@values)[4]))
```

### Arguments

| | |
|---|---|
| object | SmoothedPG of which to get the values |
| frequencies | a vector of frequencies for which to get the values |
| levels.1 | the first vector of levels for which to get the values |
| levels.2 | the second vector of levels for which to get the values |
| d1 | optional parameter that determine for which j1 to return the data; may be a vector of elements 1, ..., D |
| d2 | same as d1, but for j2 |

### Details

For the mechanism of selecting frequencies, dimensions and/or levels see, for example, getValues-SmoothedPG.

### Value

Returns data from the array values that's a slot of object.

### See Also

An example on how to use this function is analogously to the example given in getValues-QuantilePG.

---

## getCoherencySdNaive-SmoothedPG

*Get estimates for the standard deviation of the coherency computed from smoothed quantile periodogram.*

---

### Description

Determines and returns an array of dimension [J,K1,K2], where J=length(frequencies), K1=length(levels.1), and K2=length(levels.2)). Whether available or not, boostrap repetitions are ignored by this procedure. At position (j,k1,k2) the returned value is the standard deviation estimated corresponding to frequencies[j], levels.1[k1] and levels.2[k2] that are closest to the frequencies, levels.1 and levels.2 available in object; closest.pos is used to determine what closest to means.

### Usage

```
## S4 method for signature 'SmoothedPG'
getCoherencySdNaive(object, frequencies = 2 * pi *
  (0:(lenTS(object@qPG@freqRep@Y) - 1))/lenTS(object@qPG@freqRep@Y),
  levels.1 = getLevels(object, 1), levels.2 = getLevels(object, 2),
  d1 = 1:(dim(object@values)[2]), d2 = 1:(dim(object@values)[4]),
  type = c("1", "2"), impl = c("R", "C"))
```

## Arguments

| | |
|---|---|
| object | SmoothedPG of which to get the estimates for the standard deviation. |
| frequencies | a vector of frequencies for which to get the result |
| levels.1 | the first vector of levels for which to get the result |
| levels.2 | the second vector of levels for which to get the result |
| d1 | optional parameter that determine for which j1 to return the data; may be a vector of elements 1, ..., D |
| d2 | same as d1, but for j2 |
| type | can be "1", where cov(Z, Conj(Z)) is subtracted, or "2", where it's not |
| impl | choose "R" or "C" for one of the two implementations available |

## Details

If not only one, but multiple time series are under study, the dimension of the returned vector is of dimension `[J,P,K1,P,K2]`, where `P` denotes the dimension of the time series.

Requires that the SmoothedPG is available at all Fourier frequencies from $(0, \pi]$. If this is not the case the missing values are imputed by taking one that is available and has a frequency that is closest to the missing Fourier frequency; `closest.pos` is used to determine which one this is.

A precise definition on how the standard deviations of the smoothed quantile periodogram are estimated is given in Barunik and Kley (2015). The estimate returned is denoted by $\sigma(\tau_1, \tau_2; \omega)$ on p. 26 of the arXiv preprint.

Note the "standard deviation" estimated here is not the square root of the complex-valued variance. It's real part is the square root of the variance of the real part of the estimator and the imaginary part is the square root of the imaginary part of the variance of the estimator.

## Value

Returns the estimate described above.

## References

Kley, T., Volgushev, S., Dette, H. & Hallin, M. (2014). Quantile Spectral Processes: Asymptotic Analysis and Inference. http://arxiv.org/abs/1401.8104.

Barunik, J. & Kley, T. (2015). Quantile Cross-Spectral Measures of Dependence between Economic Variables. [preprint available from the authors]

## getDescr-Weight *Get attribute* descr *from a* Weight.

### Description

Get attribute descr from a Weight.

### Usage

```
## S4 method for signature 'Weight'
getDescr(object)
```

### Arguments

| | |
|---|---|
| object | Weight from which to get the descr. |

### Value

Returns the descr attribute.

## getFreqRep-QuantilePG *Get associated* FreqRep *from a* QuantilePG.

### Description

Get associated FreqRep from a QuantilePG.

### Usage

```
## S4 method for signature 'QuantilePG'
getFreqRep(object)
```

### Arguments

| | |
|---|---|
| object | QuantilePG from which to get the FreqRep. |

### Value

Returns the FreqRep object associated.

---

getFrequencies-FreqRep

*Get attribute* frequencies *from a* FreqRep.

---

## Description

Get attribute frequencies from a FreqRep.

## Usage

```
## S4 method for signature 'FreqRep'
getFrequencies(object)
```

## Arguments

| | |
|---|---|
| object | FreqRep from which to get the frequencies. |

## Value

Returns the frequencies attribute, as a vector of real numbers.

---

getFrequencies-QSpecQuantity

*Get attribute* frequencies *from a* QSpecQuantity.

---

## Description

Get attribute frequencies from a QSpecQuantity.

## Usage

```
## S4 method for signature 'QSpecQuantity'
getFrequencies(object)
```

## Arguments

| | |
|---|---|
| object | QSpecQuantity from which to get the frequencies. |

## Value

Returns the frequencies attribute, as a vector of real numbers.

## Examples

```
qPG  <- quantilePG(rnorm(10), levels.1=c(0.25,0.5))
freq <- getFrequencies(qPG)
```

---

getIsRankBased-FreqRep

*Get* isRankBased *from a* FreqRep *object*

---

## Description

Get isRankBased from a FreqRep object

## Usage

```
## S4 method for signature 'FreqRep'
getIsRankBased(object)
```

## Arguments

| | |
|---|---|
| object | FreqRep of which to get the isRankBased |

## Value

Returns the attribute isRankBased that's a slot of object.

---

getIsRankBased-LagOperator

*Get* isRankBased *from a* LagOperator *object*

---

## Description

Get isRankBased from a LagOperator object

## Usage

```
## S4 method for signature 'LagOperator'
getIsRankBased(object)
```

## Arguments

| | |
|---|---|
| object | LagOperator of which to get the isRankBased |

## Value

Returns the attribute isRankBased that's a slot of object.

---

`getLagOperator-LagEstimator` *Get associated* `LagOperator` *from a* `LagEstimator`.

---

## Description

Get associated `LagOperator` from a `LagEstimator`.

## Usage

```
## S4 method for signature 'LagEstimator'
getLagOperator(object)
```

## Arguments

| | |
|---|---|
| `object` | `LagEstimator` from which to get the `LagOperator`. |

## Value

Returns the `LagOperator` object associated.

---

`getLevels-FreqRep` *Get attribute* `levels` *from a* `FreqRep`.

---

## Description

Get attribute `levels` from a `FreqRep`.

## Usage

```
## S4 method for signature 'FreqRep'
getLevels(object)
```

## Arguments

| | |
|---|---|
| `object` | `FreqRep` from which to get the `levels`. |

## Value

Returns the `levels` attribute, as a vector of real numbers.

---

`getLevels-LagOperator` *Get attribute* `levels` *from a* `LagOperator`.

---

## Description

If the optional parameter `j` is supplied, then the `j`th vector of levels will be returned, a list with all vectors otherwise.

## Usage

```
## S4 method for signature 'LagOperator'
getLevels(object, j)
```

## Arguments

| | |
|---|---|
| `object` | `LagOperator` from which to get the `levels`. |
| `j` | Index pointing to a set of levels in the list; optional. |

## Value

Returns levels attribute, as a vector of real numbers.

---

`getLevels-QSpecQuantity`
*Get attribute* `levels` *from a* `QSpecQuantity`.

---

## Description

If the optional parameter `j` is supplied, then the `j`th vector of levels will be returned, a list with all vectors otherwise.

## Usage

```
## S4 method for signature 'QSpecQuantity'
getLevels(object, j)
```

## Arguments

| | |
|---|---|
| `object` | `QSpecQuantity` from which to get the `levels`. |
| `j` | Index pointing to a set of levels in the list; optional. |

## Value

Returns levels attribute, as a vector of real numbers.

## Examples

```
qPG         <- quantilePG(rnorm(10), levels.1=c(0.25,0.5))
levels.list <- getLevels(qPG)
levels.1    <- getLevels(qPG,1)
```

---

getMaxLag-LagOperator *Get* maxLag *from a* LagOperator *object.*

---

## Description

Get maxLag from a LagOperator object.

## Usage

```
## S4 method for signature 'LagOperator'
getMaxLag(object)
```

## Arguments

| | |
|---|---|
| object | LagOperator of which to get the maxLag |

## Value

Returns the attribute maxLag that's a slot of object.

---

getMeanPG-QuantileSD *Get* meanPG *from a quantile spectral density kernel*

---

## Description

The selection mechanism for frequencies and levels operates in the same way as described in getValues-QuantileSD. The format of the output is also described there.

## Usage

```
## S4 method for signature 'QuantileSD'
getMeanPG(object, frequencies = 2 * pi *
  (0:(getN(object) - 1))/getN(object), levels.1 = getLevels(object, 1),
  levels.2 = getLevels(object, 2), d1 = 1:(dim(object@values)[2]),
  d2 = 1:(dim(object@values)[4]))
```

### Arguments

| | |
|---|---|
| object | QuantileSD of which to get the meanPG |
| frequencies | a vector of frequencies for which to get the meanPG |
| levels.1 | the first vector of levels for which to get the meanPG |
| levels.2 | the second vector of levels for which to get the meanPG |
| d1 | optional parameter that determine for which j1 to return the meanPG; may be a vector of elements 1, ..., D |
| d2 | same as d1, but for j2 |

### Value

Returns the array meanPG that's a slot of object.

---

## getN-QuantileSD *Get* N *from a quantile spectral density kernel*

---

### Description

Get N from a quantile spectral density kernel

### Usage

```
## S4 method for signature 'QuantileSD'
getN(object)
```

### Arguments

| | |
|---|---|
| object | QuantileSD of which to get the N |

### Value

Returns the attribute N that's a slot of object.

---

getParallel-QRegEstimator

*Get* getParallel *from a* QRegEstimator *object*

---

## Description

Get getParallel from a QRegEstimator object

## Usage

```
## S4 method for signature 'QRegEstimator'
getParallel(object)
```

## Arguments

| | |
|---|---|
| object | QRegEstimator of which to get the parallel |

## Value

Returns the attribute parallel that's a slot of object.

---

getPointwiseCIs-LagEstimator

*Get pointwise confidence intervals for the quantile spectral density kernel*

---

## Description

Returns a list of two arrays lowerCIs and upperCIs that contain the upper and lower limits for a level 1-alpha confidence interval of the copula spectral density kernel. Each array is of dimension [J,K1,K2], where J=length(frequencies), K1=length(levels.1), and K2=length(levels.2)). At position (j,k1,k2) the real (imaginary) part of the returned values are the bounds of the confidence interval for the the real (imaginary) part of the quantile spectrum, which corresponds to frequencies[j], levels.1[k1] and levels.2[k2] closest to the Fourier frequencies, levels.1 and levels.2 available in object; closest.pos is used to determine what closest to means.

## Usage

```
## S4 method for signature 'LagEstimator'
getPointwiseCIs(object, frequencies = 2 * pi *
  (0:(length(object@Y) - 1))/length(object@Y), levels.1 = getLevels(object,
  1), levels.2 = getLevels(object, 2), alpha = 0.1, type = c("naive.sd",
  "boot.sd", "boot.full"))
```

### Arguments

| | |
|---|---|
| `object` | `LagEstimator` of which to get the confidence intervals |
| `frequencies` | a vector of frequencies for which to get the result |
| `levels.1` | the first vector of levels for which to get the result |
| `levels.2` | the second vector of levels for which to get the result |
| `alpha` | the level of the confidence interval; must be from $(0, 1)$ |
| `type` | a flag indicating which type of confidence interval should be returned; can only take one values at the moment. |

### Details

Currently, only one `type` of confidence interval is available:

- `"naive.sd"`: confidence intervals based on the asymptotic normality of the lag-window estimator; standard deviations are estimated using `getSdNaive`.

### Value

Returns a named list of two arrays `lowerCIS` and `upperCIs` containing the lower and upper bounds for the confidence intervals.

### Examples

```
lagEst <- lagEstimator(rnorm(2^10), levels.1=0.5)
CI.upper <- Re(getPointwiseCIs(lagEst)$upperCIs[,1,1])
CI.lower <- Re(getPointwiseCIs(lagEst)$lowerCIs[,1,1])
freq = 2*pi*(0:1023)/1024
plot(x = freq, y = rep(0.25/(2*pi),1024),
   ylim=c(min(CI.lower), max(CI.upper)),
   type="l", col="red") # true spectrum
lines(x = freq, y = CI.upper)
lines(x = freq, y = CI.lower)
```

---

## `getPointwiseCIs-SmoothedPG` *Get pointwise confidence intervals for the quantile spectral density kernel, quantile coherency or quantile coherence.*

---

### Description

Returns a list of two arrays `lowerCIs` and `upperCIs` that contain the upper and lower limits for a level `1-alpha` confidence interval of the quantity of interest. Each array is of dimension `[J,K1,K2]` if a univariate time series is being analysed or of dimension `[J,D1,K1,D2,K2]`, where `J=length(frequencies)`, `D1=length(d1)`, `D2=length(d2)`, `K1=length(levels.1)`, and `K2=length(levels.2))`. At position `(j,k1,k2)` or `(j,i1,k1,i2,k2)` the real (imaginary) part of the returned values are the bounds of the confidence interval for the the real (imaginary) part of the quantity under anlysis, which corresponds to `frequencies[j]`, `d1[i1]`, `d2[i2]`, `levels.1[k1]` and `levels.2[k2]` closest to the Fourier frequencies, `levels.1` and `levels.2` available in `object`; `closest.pos` is used to determine what closest to means.

## Usage

```
## S4 method for signature 'SmoothedPG'
getPointwiseCIs(object,
  quantity = c("spectral density", "coherency", "coherence"),
  frequencies = 2 * pi * (0:(lenTS(object@qPG@freqRep@Y) -
  1))/lenTS(object@qPG@freqRep@Y), levels.1 = getLevels(object, 1),
  levels.2 = getLevels(object, 2), d1 = 1:(dim(object@values)[2]),
  d2 = 1:(dim(object@values)[4]), alpha = 0.1, type = c("naive.sd",
  "boot.sd", "boot.full"))
```

## Arguments

| | |
|---|---|
| object | SmoothedPG of which to get the confidence intervals |
| quantity | a flag indicating for which the pointwise confidence bands will be determined. Can take one of the possible values discussed above. |
| frequencies | a vector of frequencies for which to get the result |
| levels.1 | the first vector of levels for which to get the result |
| levels.2 | the second vector of levels for which to get the result |
| d1 | optional parameter that determine for which j1 to return the data; may be a vector of elements 1, ..., D |
| d2 | same as d1, but for j2 |
| alpha | the level of the confidence interval; must be from $(0, 1)$ |
| type | a flag indicating which type of confidence interval should be returned; can take one of the three values discussed above. |

## Details

Currently, pointwise confidence bands for two different quantity are implemented:

- "spectral density": confidence intervals for the quantile spectral density as described in Kley et. al (2015+) for the univariate case and in Barunik and Kley (2015) for the multivariate case.
- "coherency": confidence intervals for the quantile coherency as described in Barunik and Kley (2015).

Currently, three different types of confidence intervals are available:

- "naive.sd": confidence intervals based on the asymptotic normality of the smoothed quantile periodogram; standard deviations are estimated using getSdNaive.
- "boot.sd": confidence intervals based on the asymptotic normality of the smoothed quantile periodogram; standard deviations are estimated using getSdBoot.
- "boot.full": confidence intervals determined by estimating the quantiles of he distribution of the smoothed quantile periodogram, by the empirical quantiles of the sample of bootstrapped replications.

## Value

Returns a named list of two arrays `lowerCIS` and `upperCIs` containing the lower and upper bounds for the confidence intervals.

## Examples

```
sPG <- smoothedPG(rnorm(2^10), levels.1=0.5)
CI.upper <- Re(getPointwiseCIs(sPG)$upperCIs[,1,1])
CI.lower <- Re(getPointwiseCIs(sPG)$lowerCIs[,1,1])
freq = 2*pi*(0:1023)/1024
plot(x = freq, y = rep(0.25/(2*pi),1024),
   ylim=c(min(CI.lower), max(CI.upper)),
   type="l", col="red") # true spectrum
lines(x = freq, y = CI.upper)
lines(x = freq, y = CI.lower)
```

---

`getPositions-MovingBlocks`

*Get Positions for the Moving Blocks Bootstrap.*

---

## Description

Get Positions for the Moving Blocks Bootstrap.

## Usage

```
## S4 method for signature 'MovingBlocks'
getPositions(object, B = 1)
```

## Arguments

| | |
|---|---|
| `object` | a `MovingBlocks` object; used to specify the parameters `N`, `l` and the type of the bootstrap. |
| `B` | Number of independent repetitions to bootstrap. |

## Value

a matrix of dimension `[N,B]` where each column gives the positions in which to reorder the observations to yield one bootstrap replication.

---

`getQuantilePG-QuantileSD`

*Get associated* `QuantilePG` *from a* `QuantileSD`.

---

## Description

Get associated `QuantilePG` from a `QuantileSD`.

## Usage

```
## S4 method for signature 'QuantileSD'
getQuantilePG(object)
```

## Arguments

| | |
|---|---|
| `object` | `QuantileSD` from which to get the `QuantilePG`. |

## Value

Returns the `QuantilePG` object associated.

---

`getQuantilePG-SmoothedPG`

*Get associated* `QuantilePG` *from a* `SmoothedPG`.

---

## Description

Get associated `QuantilePG` from a `SmoothedPG`.

## Usage

```
## S4 method for signature 'SmoothedPG'
getQuantilePG(object)
```

## Arguments

| | |
|---|---|
| `object` | `SmoothedPG` from which to get the `QuantilePG`. |

## Value

Returns the `QuantilePG` object associated.

## getQuantileSD-IntegrQuantileSD *Get associated* getQuantileSD *from an* IntegrQuantileSD.

### Description

Get associated getQuantileSD from an IntegrQuantileSD.

### Usage

```
## S4 method for signature 'IntegrQuantileSD'
getQuantileSD(object)
```

### Arguments

| | |
|---|---|
| object | IntegrQuantileSD from which to get the getQuantileSD. |

### Value

Returns the getQuantileSD object associated.

## getR-QuantileSD *Get* R *from a quantile spectral density kernel*

### Description

Get R from a quantile spectral density kernel

### Usage

```
## S4 method for signature 'QuantileSD'
getR(object)
```

### Arguments

| | |
|---|---|
| object | QuantileSD of which to get the R |

### Value

Returns the attribute R that's a slot of object.

getSdBoot-LagEstimator

*Get bootstrap estimates for the standard deviation of the lag-window type estimator.*

## Description

Determines and returns an array of dimension `[J,K1,K2]`, where `J=length(frequencies)`, `K1=length(levels.1)`, and `K2=length(levels.2))`. At position `(j,k1,k2)` the real part of the returned value is the standard deviation estimated from the real parts of the bootstrap replications and the imaginary part of the returned value is the standard deviation estimated from the imaginary part of the bootstrap replications. The estimate is determined from those bootstrap replicates of the estimator that have `frequencies[j]`, `levels.1[k1]` and `levels.2[k2]` closest to the `frequencies`, `levels.1` and `levels.2` available in `object`; `closest.pos` is used to determine what closest to means.

## Usage

```
## S4 method for signature 'LagEstimator'
getSdBoot(object, frequencies = 2 * pi *
  (0:(length(object@lagOp@Y) - 1))/length(object@lagOp@Y),
  levels.1 = getLevels(object, 1), levels.2 = getLevels(object, 2))
```

## Arguments

| | |
|---|---|
| `object` | `LagEstimator` of which to get the bootstrap estimates for the standard deviation. |
| `frequencies` | a vector of frequencies for which to get the result |
| `levels.1` | the first vector of levels for which to get the result |
| `levels.2` | the second vector of levels for which to get the result |

## Details

Requires that the `LagEstimator` is available at all Fourier frequencies from $(0, \pi]$. If this is not the case the missing values are imputed by taking one that is available and has a frequency that is closest to the missing Fourier frequency; `closest.pos` is used to determine which one this is.

If there are no bootstrap replicates available (i. e., `B == 0`) an error is returned.

Note the "standard deviation" estimated here is not the square root of the complex-valued variance. It's real part is the square root of the variance of the real part of the estimator and the imaginary part is the square root of the imaginary part of the variance of the estimator.

## Value

Returns the estimate described above.

getSdBoot-SmoothedPG *Get bootstrap estimates for the standard deviation of the smoothed quantile periodogram.*

## Description

Determines and returns an array of dimension `[J,K1,K2]`, where `J=length(frequencies)`, `K1=length(levels.1)`, and `K2=length(levels.2))`. At position `(j,k1,k2)` the real part of the returned value is the standard deviation estimated from the real parts of the bootstrap replications and the imaginary part of the returned value is the standard deviation estimated from the imaginary part of the bootstrap replications. The estimate is determined from those bootstrap replicates of the estimator that have `frequencies[j]`, `levels.1[k1]` and `levels.2[k2]` closest to the `frequencies`, `levels.1` and `levels.2` available in `object`; `closest.pos` is used to determine what closest to means.

## Usage

```
## S4 method for signature 'SmoothedPG'
getSdBoot(object, frequencies = 2 * pi *
  (0:(lenTS(object@qPG@freqRep@Y) - 1))/lenTS(object@qPG@freqRep@Y),
  levels.1 = getLevels(object, 1), levels.2 = getLevels(object, 2))
```

## Arguments

| | |
|---|---|
| `object` | `SmoothedPG` of which to get the bootstrap estimates for the standard deviation. |
| `frequencies` | a vector of frequencies for which to get the result |
| `levels.1` | the first vector of levels for which to get the result |
| `levels.2` | the second vector of levels for which to get the result |

## Details

Requires that the `SmoothedPG` is available at all Fourier frequencies from $(0, \pi]$. If this is not the case the missing values are imputed by taking one that is available and has a frequency that is closest to the missing Fourier frequency; `closest.pos` is used to determine which one this is.

If there are no bootstrap replicates available (i. e., `B == 0`) an error is returned.

Note the "standard deviation" estimated here is not the square root of the complex-valued variance. It's real part is the square root of the variance of the real part of the estimator and the imaginary part is the square root of the imaginary part of the variance of the estimator.

## Value

Returns the estimate described above.

`getSdNaive-LagEstimator`

*Get estimates for the standard deviation of the lagEstimator derived from the asymptotics (see Birr et al (2015))*

## Description

Determines and returns an array of dimension `[J,K1,K2]`, where `J=length(frequencies)`, `K1=length(levels.1)`, and `K2=length(levels.2))`. At position `(j,k1,k2)` the returned value is the standard deviation estimated corresponding to `frequencies[j]`, `levels.1[k1]` and `levels.2[k2]` that are closest to the `frequencies`, `levels.1` and `levels.2` available in `object`; `closest.pos` is used to determine what closest to means.

## Usage

```
## S4 method for signature 'LagEstimator'
getSdNaive(object, frequencies = 2 * pi *
  (0:(length(object@Y) - 1))/length(object@Y), levels.1 = getLevels(object,
  1), levels.2 = getLevels(object, 2))
```

## Arguments

| | |
|---|---|
| `object` | `LagEstimator` of which to get the estimates for the standard deviation. |
| `frequencies` | a vector of frequencies for which to get the result |
| `levels.1` | the first vector of levels for which to get the result |
| `levels.2` | the second vector of levels for which to get the result |

## Details

Requires that the `LagEstimator` is available at all Fourier frequencies from $(0, \pi]$. If this is not the case the missing values are imputed by taking one that is available and has a frequency that is closest to the missing Fourier frequency; `closest.pos` is used to determine which one this is.

Note the "standard deviation" estimated here is not the square root of the complex-valued variance. It's real part is the square root of the variance of the real part of the estimator and the imaginary part is the square root of the imaginary part of the variance of the estimator.

## Value

Returns the estimate described above.

getSdNaive-SmoothedPG *Get estimates for the standard deviation of the smoothed quantile periodogram.*

## Description

Determines and returns an array of dimension `[J,K1,K2]`, where `J=length(frequencies)`, `K1=length(levels.1)`, and `K2=length(levels.2))`. Whether available or not, boostrap repetitions are ignored by this procedure. At position `(j,k1,k2)` the returned value is the standard deviation estimated corresponding to `frequencies[j]`, `levels.1[k1]` and `levels.2[k2]` that are closest to the `frequencies`, `levels.1` and `levels.2` available in `object`; `closest.pos` is used to determine what closest to means.

## Usage

```
## S4 method for signature 'SmoothedPG'
getSdNaive(object, frequencies = 2 * pi *
  (0:(lenTS(object@qPG@freqRep@Y) - 1))/lenTS(object@qPG@freqRep@Y),
  levels.1 = getLevels(object, 1), levels.2 = getLevels(object, 2),
  d1 = 1:(dim(object@values)[2]), d2 = 1:(dim(object@values)[4]),
  impl = c("R", "C"))
```

## Arguments

| | |
|---|---|
| `object` | `SmoothedPG` of which to get the estimates for the standard deviation. |
| `frequencies` | a vector of frequencies for which to get the result |
| `levels.1` | the first vector of levels for which to get the result |
| `levels.2` | the second vector of levels for which to get the result |
| `d1` | optional parameter that determine for which j1 to return the data; may be a vector of elements 1, ..., D |
| `d2` | same as d1, but for j2 |
| `impl` | choose "R" or "C" for one of the two implementations available |

## Details

If not only one, but multiple time series are under study, the dimension of the returned vector is of dimension `[J,P,K1,P,K2,B+1]`, where `P` denotes the dimension of the time series.

Requires that the `SmoothedPG` is available at all Fourier frequencies from $(0, \pi]$. If this is not the case the missing values are imputed by taking one that is available and has a frequency that is closest to the missing Fourier frequency; `closest.pos` is used to determine which one this is.

A precise definition on how the standard deviations of the smoothed quantile periodogram are estimated is given in Barunik&Kley (2015).

Note the "standard deviation" estimated here is not the square root of the complex-valued variance. It's real part is the square root of the variance of the real part of the estimator and the imaginary part is the square root of the imaginary part of the variance of the estimator.

## Value

Returns the estimate described above.

## References

Dette, H., Hallin, M., Kley, T. & Volgushev, S. (2015). Of Copulas, Quantiles, Ranks and Spectra: an $L_1$-approach to spectral analysis. *Bernoulli*, **21**(2), 781–831. [cf. http://arxiv.org/abs/1111.7205]

---

`getStdError-QuantileSD`

*Get* `stdError` *from a quantile spectral density kernel*

---

## Description

The selection mechanism for frequencies and levels operates in the same way as described in `getValues-QuantileSD`. The format of the output is also described there.

## Usage

```
## S4 method for signature 'QuantileSD'
getStdError(object, frequencies = 2 * pi * (0:(object@N
  - 1))/object@N, levels.1 = getLevels(object, 1),
  levels.2 = getLevels(object, 2), d1 = 1:(dim(object@values)[2]),
  d2 = 1:(dim(object@values)[4]))
```

## Arguments

| | |
|---|---|
| `object` | `QuantileSD` of which to get the `stdError` |
| `frequencies` | a vector of frequencies for which to get the `stdError` |
| `levels.1` | the first vector of levels for which to get the `stdError` |
| `levels.2` | the second vector of levels for which to get the `stdError` |
| `d1` | optional parameter that determine for which j1 to return the `stdError`; may be a vector of elements 1, ..., D |
| `d2` | same as d1, but for j2 |

## Value

Returns the array `stdError` that's a slot of `object`.

## getTs-QuantileSD *Get* ts *from a quantile spectral density kernel*

### Description

Get ts from a quantile spectral density kernel

### Usage

```
## S4 method for signature 'QuantileSD'
getTs(object)
```

### Arguments

| | |
|---|---|
| object | QuantileSD of which to get the ts |

### Value

Returns the attribute ts that's a slot of object.

## getType-QuantileSD *Get* type *from a quantile spectral density kernel*

### Description

Get type from a quantile spectral density kernel

### Usage

```
## S4 method for signature 'QuantileSD'
getType(object)
```

### Arguments

| | |
|---|---|
| object | QuantileSD of which to get the type |

### Value

Returns the attribute type that's a slot of object.

getValues-FreqRep *Get values from a frequency representation.*

## Description

For two vectors `frequencies` and `levels` the values from an `object` of type `FreqRep` are returned.

## Usage

```
## S4 method for signature 'FreqRep'
getValues(object, frequencies = 2 * pi *
  (0:(lenTS(object@Y) - 1))/lenTS(object@Y), levels = object@levels,
  d = 1:(dim(object@values)[2]))
```

## Arguments

| | |
|---|---|
| `object` | `FreqRep` of which to get the values |
| `frequencies` | a vector of frequencies for which to get the values |
| `levels` | a vector of levels for which to get the values |
| `d` | optional parameter that determine of which component to return the data; may be a vector of elements 1, ..., D |

## Details

The two parameters `frequencies` and `levels` are expected to be vectors of reals; an error is thrown otherwise. If any of the `frequencies` or `levels` requested is not available from `object` a warning is issued, and the values with frequencies and levels closest to the ones requested are returned. Note that the frequencies are transformed to $[0, \pi]$ using `frequenciesValidator` when checking if they are available in `object`.

The returned array of `values` is of dimension `[J,K,B+1]`, where `J=length(frequencies)`, `K=length(levels)`, and `B` denotes the value stored in slot `B` of `object`. At position `(j,k,b)` the returned value is the one corresponding to `frequencies[j]` and `levels[k]` that are closest to the `frequencies` and `levels` available in `object`; `closest.pos` is used to determine what closest to means.

## Value

Returns data from the array `values` that's a slot of `object`.

## Examples

```
Y        <- rnorm(32)
freq     <- 2*pi*c(0:31)/32
levels   <- c(0.25,0.5,0.75)
cFT      <- clippedFT(Y, freq, levels)
V.all    <- getValues(cFT)
V.coarse <- getValues(cFT, frequencies = 2*pi*c(0:15)/16, levels = levels)
V.fine   <- getValues(cFT, frequencies = 2*pi*c(0:63)/64, levels = levels)
V.part   <- getValues(cFT, frequencies = 2*pi*c(0:16)/32, levels = c(0.25))
```

## getValues-IntegrQuantileSD

*Get values from a simulated integrated quantile spectral density kernel*

### Description

If none of the optional parameters is specified then the values are returned for all Fourier frequencies in $[0, 2\pi)$ (base given by slot N) and all levels available. The frequencies and levels can be freely specified. The returned array then has, at position (j,k1,k2,b), the value corresponding to the frequencies[j], levels.1[k1] and levels.2[k2] that are closest to the frequencies, levels.1 and levels.2 available in object; closest.pos is used to determine what closest to means.

### Usage

```
## S4 method for signature 'IntegrQuantileSD'
getValues(object, frequencies = 2 * pi *
  (0:(getN(object@qsd) - 1))/getN(object@qsd), levels.1 = getLevels(object,
  1), levels.2 = getLevels(object, 2))
```

### Arguments

| | |
|---|---|
| object | IntegrQuantileSD of which to get the values |
| frequencies | a vector of frequencies for which to get the values |
| levels.1 | the first vector of levels for which to get the values |
| levels.2 | the second vector of levels for which to get the values |

### Value

Returns data from the array values that's a slot of object.

### See Also

For examples on how to use this function go to IntegrQuantileSD.

## getValues-KernelWeight

*Get values from a weight object determined by a kernel function* W *and a bandwidth* b.

### Description

For an object of type KernelWeight and an optional integer N the weights $W_n$ are returned as a vector that has $W_n(2\pi(k-1)/n)$ at position k.

### Usage

```
## S4 method for signature 'KernelWeight'
getValues(object, N = length(object@env$values))
```

### Arguments

| | |
|---|---|
| object | KernelWeight of which to get the values |
| N | a numeric specifying the number of equaly spaced Fourier frequencies from $[0, 2\pi)$ for which the weight will be computed; by default the number N specified on construction. |

### Value

Returns a vector of size N as described in the Details section.

---

## getValues-LagEstimator

*Get values from a lag-window type estimator.*

---

### Description

The returned array of values is of dimension [J,K1,K2], where J=length(frequencies), K1=length(levels.1) and K2=length(levels.2)). At position (j,k1,k2) the returned value is the one corresponding to frequencies[j], levels.1[k1] and levels.2[k2] that are closest to the frequencies, levels.1 and levels.2 available in object; closest.pos is used to determine what closest to means.

### Usage

```
## S4 method for signature 'LagEstimator'
getValues(object, frequencies = 2 * pi *
  (0:(length(object@Y) - 1))/length(object@Y), levels.1 = getLevels(object,
  1), levels.2 = getLevels(object, 2))
```

### Arguments

| | |
|---|---|
| object | LagEstimator of which to get the values |
| frequencies | a vector of frequencies for which to get the values |
| levels.1 | the first vector of levels for which to get the values |
| levels.2 | the second vector of levels for which to get the values |

### Value

Returns data from the array values that's a slot of object.

### See Also

An example on how to use this function is analogously to the example given in getValues-QuantilePG.

## getValues-LagKernelWeight

*Get values from a weight object determined by a kernel function* W *and a bandwidth* bw.

### Description

For an object of type LagKernelWeight and an optional integer K the weights $W_k$ are returned as a vector that has $W_k((k-1)/bw)$ at position k.

### Usage

```
## S4 method for signature 'LagKernelWeight'
getValues(object, K = length(object@env$values))
```

### Arguments

| | |
|---|---|
| object | LagKernelWeight of which to get the values |
| K | a numeric that determines the largest lag. The weight will be computed for the $K$ integers $0:(K-1)$; by default the number K specified on construction. |

### Value

Returns a vector of size K as described in the Details section.

## getValues-LagOperator *Get attribute* values *from a* LagOperator.

### Description

Get attribute values from a LagOperator.

### Usage

```
## S4 method for signature 'LagOperator'
getValues(object, levels.1, levels.2)
```

### Arguments

| | |
|---|---|
| object | LagOperator from which to get the values. |
| levels.1 | the first vector of levels for which to get the values |
| levels.2 | the second vector of levels for which to get the values |

### Value

Returns the values attribute.

getValues-QuantilePG *Get values from a quantile periodogram.*

## Description

For vectors `frequencies`, `levels.1` and `levels.2` the values from an `object` of type `QuantilePG` are returned.

## Usage

```
## S4 method for signature 'QuantilePG'
getValues(object, frequencies = 2 * pi *
  (0:(lenTS(object@freqRep@Y) - 1))/lenTS(object@freqRep@Y),
  levels.1 = getLevels(object, 1), levels.2 = getLevels(object, 2),
  d1 = 1:(dim(object@freqRep@Y)[2]), d2 = 1:(dim(object@freqRep@Y)[2]))
```

## Arguments

| | |
|---|---|
| `object` | `QuantilePG` of which to get the values |
| `frequencies` | a vector of frequencies for which to get the values |
| `levels.1` | the first vector of levels for which to get the values |
| `levels.2` | the second vector of levels for which to get the values |
| `d1` | optional parameter that determine for which j1 to return the data; may be a vector of elements 1, ..., D |
| `d2` | same as d1, but for j2 |

## Details

Fetching of the periodogram values basically happens by passing `frequencies` and the union of `levels.1` and `levels.2` to `getValues`. Therefore, the parameters `frequencies`, `levels.1` and `levels.1` are expected to be vectors of reals; an error is thrown otherwise. If any of the `frequencies`, `levels.1` and `levels.2` requested is not available from `object` a warning is issued. Note that the frequencies are transformed to $[0, \pi]$ using `frequenciesValidator` when checking if they are available in `object`.

The returned array of `values` is of dimension `[J,K1,K2,B+1]`, where `J=length(frequencies)`, `K1=length(levels.1)`, `K2=length(levels.2))`, and `B` denotes the value stored in slot `B` of `freqRep` that's a slot of `object`. At position `(j,k1,k2,b)` the returned value is the one corresponding to `frequencies[j]`, `levels.1[k1]` and `levels.2[k2]` that are closest to the `frequencies`, `levels.1` and `levels.2` available in `object`; `closest.pos` is used to determine what closest to means.

## Value

Returns data from the array `values` that's a slot of `object`.

## Examples

```
Y        <- rnorm(32)
freq     <- 2*pi*c(0:31)/32
levels   <- c(0.25,0.5,0.75)
qPG      <- quantilePG(Y, levels.1=levels)
V.all    <- getValues(qPG)
V.coarse <- getValues(qPG, frequencies = 2*pi*c(0:15)/16)
V.fine   <- getValues(qPG, frequencies = 2*pi*c(0:63)/64)
V.part   <- getValues(qPG, frequencies = 2*pi*c(0:16)/32,
                           levels.1 = c(0.25), levels.2 = c(0.5,0.75))
```

---

# getValues-QuantileSD *Get values from a quantile spectral density kernel*

---

## Description

If none of the optional parameters is specified then the values are returned for all Fourier frequencies in $[0, 2\pi)$ (base given by slot `N`) and all levels available. The frequencies and levels can be freely specified. The returned array then has, at position `(j,k1,k2,b)`, the value corresponding to the `frequencies[j]`, `levels.1[k1]` and `levels.2[k2]` that are closest to the `frequencies`, `levels.1` and `levels.2` available in `object`; `closest.pos` is used to determine what closest to means.

## Usage

```
## S4 method for signature 'QuantileSD'
getValues(object, frequencies = 2 * pi * (0:(object@N -
  1))/object@N, levels.1 = getLevels(object, 1),
  levels.2 = getLevels(object, 2), d1 = 1:(dim(object@values)[2]),
  d2 = 1:(dim(object@values)[4]))
```

## Arguments

| | |
|---|---|
| `object` | `QuantileSD` of which to get the values |
| `frequencies` | a vector of frequencies for which to get the values |
| `levels.1` | the first vector of levels for which to get the values |
| `levels.2` | the second vector of levels for which to get the values |
| `d1` | optional parameter that determine for which j1 to return the data; may be a vector of elements 1, ..., D |
| `d2` | same as d1, but for j2 |

## Value

Returns data from the array `values` that's a slot of `object`.

## See Also

For examples on how to use this function go to `QuantileSD`.

getValues-SmoothedPG *Get values from a smoothed quantile periodogram.*

## Description

The returned array of values is of dimension [J,K1,K2,B+1], where J=length(frequencies), K1=length(levels.1), K2=length(levels.2)), and B denotes the value stored in slot B of freqRep [that is the number of boostrap repetitions performed on initialization]. At position (j,k1,k2,b) the returned value is the one corresponding to frequencies[j], levels.1[k1] and levels.2[k2] that are closest to the frequencies, levels.1 and levels.2 available in object; closest.pos is used to determine what closest to means. b==1 corresponds to the estimate without bootstrapping; b>1 corresponds to the b-1st bootstrap estimate.

## Usage

```
## S4 method for signature 'SmoothedPG'
getValues(object, frequencies = 2 * pi *
  (0:(lenTS(object@qPG@freqRep@Y) - 1))/lenTS(object@qPG@freqRep@Y),
  levels.1 = getLevels(object, 1), levels.2 = getLevels(object, 2),
  d1 = 1:(dim(object@values)[2]), d2 = 1:(dim(object@values)[4]))
```

## Arguments

| | |
|---|---|
| object | SmoothedPG of which to get the values |
| frequencies | a vector of frequencies for which to get the values |
| levels.1 | the first vector of levels for which to get the values |
| levels.2 | the second vector of levels for which to get the values |
| d1 | optional parameter that determine for which j1 to return the data; may be a vector of elements 1, ..., D |
| d2 | same as d1, but for j2 |

## Details

If not only one, but multiple time series are under study, the dimension of the returned vector is of dimension [J,P,K1,P,K2,B+1], where P denotes the dimension of the time series.

## Value

Returns data from the array values that's a slot of object.

## See Also

An example on how to use this function is analogously to the example given in getValues-QuantilePG.

## getValues-SpecDistrWeight

*Get values from a weight object of type* SpecDistrWeight

### Description

For an object of type SpecDistrWeight and an optional integer N the weights $W_n$ are returned as a vector that has $W_n(2\pi(k-1)/n)$ at position k.

### Usage

```
## S4 method for signature 'SpecDistrWeight'
getValues(object, N = length(object@env$values))
```

### Arguments

| | |
|---|---|
| object | SpecDistrWeight of which to get the values |
| N | a numeric specifying the number of equaly spaced Fourier frequencies from $[0, 2\pi)$ for which the weight will be computed; by default the number N specified on construction. |

### Value

Returns a vector of size N as described in the Description section.

## getW-KernelWeight

*Get attribute* W *(kernel used for smoothing) from a* KernelWeight.

### Description

Get attribute W (kernel used for smoothing) from a KernelWeight.

### Usage

```
## S4 method for signature 'KernelWeight'
getW(object)
```

### Arguments

| | |
|---|---|
| object | KernelWeight from which to get the kernel W. |

### Value

Returns the W attribute.

---

`getW-LagKernelWeight` *Get attribute* `W` *(kernel used for smoothing) from a* `LagKernelWeight`.

---

## Description

Get attribute `W` (kernel used for smoothing) from a `LagKernelWeight`.

## Usage

```
## S4 method for signature 'LagKernelWeight'
getW(object)
```

## Arguments

| | |
|---|---|
| `object` | `LagKernelWeight` from which to get the kernel `W`. |

## Value

Returns the `W` attribute.

---

`getWeight-LagEstimator`
*Get associated* `Weight` *from a* `LagEstimator`.

---

## Description

Get associated `Weight` from a `LagEstimator`.

## Usage

```
## S4 method for signature 'LagEstimator'
getWeight(object)
```

## Arguments

| | |
|---|---|
| `object` | `LagEstimator` from which to get the `Weight`. |

## Value

Returns the `Weight` object associated.

## getWeight-SmoothedPG *Get associated* Weight *from a* SmoothedPG.

### Description

Get associated Weight from a SmoothedPG.

### Usage

```
## S4 method for signature 'SmoothedPG'
getWeight(object)
```

### Arguments

| | |
|---|---|
| object | SmoothedPG from which to get the Weight. |

### Value

Returns the Weight object associated.

## getWnj-KernelWeight *Get attribute* Wnj *from a* QSpecQuantity.

### Description

If the optional parameter j is supplied, then only the jth element(s) of the vector will be returned, the entire vector otherwise.

### Usage

```
## S4 method for signature 'KernelWeight'
getWnj(object, j)
```

### Arguments

| | |
|---|---|
| object | KernelWeight from which to get the Wnj. |
| j | an integer or vector of indices specifying which Wnj[j] to return. |

### Value

Returns levels attribute, as a vector of real numbers.

### Examples

```
wgt <- kernelWeight(W=W1, N=2^3, bw=0.7)
getWnj(wgt)
getWnj(wgt, 2)
getWnj(wgt, c(2,7))
```

---

getY-FreqRep *Get* Y *from a* FreqRep *object.*

---

## Description

Get Y from a FreqRep object.

## Usage

```
## S4 method for signature 'FreqRep'
getY(object, d = 1)
```

## Arguments

| | |
|---|---|
| object | FreqRep of which to get the Y |
| d | optional parameter that determine which time series to return; may be a vector of elements 1, ..., D |

## Value

Returns the attribute Y that's a slot of object.

---

increasePrecision-QuantileSD
*Increase the precision of a* QuantileSD

---

## Description

The precision is increased by generating an additional R QuantilePG objects (independent of the previous ones) and then including them in the average.

## Usage

```
## S4 method for signature 'QuantileSD'
increasePrecision(object, R = 1, quiet = FALSE)
```

## Arguments

| | |
|---|---|
| object | The QuantileSD of which to increase the precision. |
| R | value of which to enlarge R |
| quiet | Don't report progress to console when computing the R independent quantile periodograms. |

## Value

Returns an QuantileSD object determined from oldR + R independent repetitions.

## Examples

```
# First simulate a copula spectral density from R=20 independent runs.
csd <- quantileSD(N=2^9, ts=ts1, levels.1=c(0.25,0.5), type="copula", R=20)

# Check out the result:
getR(csd)
plot(csd)

# Now increase the number of independent simulation runs to 50.
csd <- increasePrecision(csd, R=30)

# Check out the (more precise) result:
getR(csd)
plot(csd)
```

---

IntegrQuantileSD-class *Class for a simulated integrated quantile (i. e., Laplace or copula) density kernel.*

---

## Description

IntegrQuantileSD is an S4 class that implements the necessary calculations to determine an integrated version of the quantile spectral density kernel (computed via QuantileSD). In particular it can be determined for any model from which a time series of length N can be sampled via a function call ts(N).

## Details

In the simulation the quantile spectral density is first determined via QuantileSD, it's values are recovered using getValues-QuantileSD and then cumulated using cumsum.

Note that, all remarks made in the documentation of the super-class QSpecQuantity apply.

## Slots

qsd a QuantileSD from which to begin the computations.

## Examples

```
##############################################################################
## This script illustrates how to estimate integrated quantile spectral densities

## Simulate a time series Y1,...,Y128 from the QAR(1) process discussed in
## Dette et. al (2015).
```

```
set.seed(2581)
Y <- ts1(128)

## For a defined set of quantile levels ...
levels <- c(0.25,0.5,0.75)

## ... and a weight (of Type A), defined using the Epanechnikov kernel ...
wgt <- specDistrWeight()

## ... compute a smoothed quantile periodogram (based on the clipped time series).
## Repeat the estimation 100 times, using the moving blocks bootstrap with
## block length l=32.
sPG.cl <- smoothedPG(Y, levels.1 = levels, type="clipped", weight = wgt,
    type.boot = "mbb", B=100, l=32)

## Create a (model) spectral density kernel for he QAR(1) model for display
## in the next plot.
csd <- quantileSD(N=2^8, seed.init = 2581, type = "copula",
    ts = ts1, levels.1=levels, R = 100)
icsd <- integrQuantileSD(csd)

plot(sPG.cl, ptw.CIs = 0.1, qsd = icsd, type.CIs = "boot.full")
```

---

`IntegrQuantileSD-constructor` *Create an instance of the* `IntegrQuantileSD` *class.*

---

## Description

Create an instance of the `IntegrQuantileSD` class.

## Usage

```
integrQuantileSD(object = 2^8, type = c("copula", "Laplace"), ts = rnorm,
  seed.init = 2581, levels.1 = 0.5, levels.2 = levels.1, R = 1,
  quiet = FALSE)
```

## Arguments

| | |
|---|---|
| `object` | the number `N` of Fourier frequencies to be used; alternatively a `QuantileSD` object can be supplied (then all the other parameters will be ignored) |
| `type` | can be either `"Laplace"` or `"copula"`; indicates whether the marginals are to be assumed uniform $[0, 1]$ distributed. |
| `ts` | a function that has one argument `n` and, each time it is invoked, returns a new time series from the model for which the integrated quantile spectral density kernel is to be simulated. |
| `seed.init` | an integer serving as an initial seed for the simulations. |

| | |
|---|---|
| levels.1 | A vector of length K1 containing the levels x1 at which the QuantileSD is to be determined. |
| levels.2 | A vector of length K2 containing the levels x2 at which the QuantileSD is to be determined. |
| R | an integer that determines the number of independent simulations; the larger this number the more precise is the result. |
| quiet | Don't report progress to console when computing the R independent quantile periodograms. |

## Value

Returns an instance of IntegrQuantileSD.

## See Also

For an example see IntegrQuantileSD.

---

# is.wholenumber *Checks whether* x *contains integer numbers.*

---

## Description

Borrowed from the example in integer.

## Usage

```
is.wholenumber(x, tol = .Machine$double.eps^0.5)
```

## Arguments

| | |
|---|---|
| x | a vector to be checked for integers |
| tol | an optional parameter specifying to which precision the check is to be performed. |

## Value

Returns a vector of logicals with the same length as x; each element i is TRUE iff x[i] is an integer.

## Examples

```
## Not run:
is.wholenumber(1) # is TRUE
(x <- seq(1, 5, by = 0.5) )
is.wholenumber( x ) #-->  TRUE FALSE TRUE ...

## End(Not run)
```

`kernels` *Kernel function.*

## Description

Implementations of kernel functions

## Usage

```
W0(x)

W1(x)

W2(x)

W3(x)

WDaniell(x, a = (pi/2))

WParzen(u)
```

## Arguments

| | |
|---|---|
| `x` | real-valued argument to the function; can be a vector |
| `a` | real number between 0 and $\pi$ |
| `u` | real number |

## Details

Daniell kernel function `W0`:

$$\frac{1}{2\pi} I\{|x| \leq \pi\}.$$

Epanechnikov kernel `W1` (i. e., variance minimizing kernel function of order 2):

$$\frac{3}{4\pi}(1 - \frac{x}{\pi})^2 I\{|x| \leq \pi\}.$$

Variance minimizing kernel function `W2` of order 4:

$$\frac{15}{32\pi}(7(x/\pi)^4 - 10(x/\pi)^2 + 3) I\{|x| \leq \pi\}.$$

Variance minimizing kernel function `W3` of order 6:

$$\frac{35}{256\pi}(-99(x/\pi)^6 + 189(x/\pi)^4 - 105(x/\pi)^2 + 15) I\{|x| \leq \pi\}.$$

Kernel yield by convolution of two Daniell kernels:

$$\frac{1}{\pi + a}\Big(1 - \frac{|x| - a}{\pi - a} I\{a \leq |x| \leq \pi\}\Big).$$

Parzen Window for lagEstimators

## Examples

```
plot(x=seq(-8,8,0.05), y=W0(seq(-8,8,0.05)), type="l")
plot(x=seq(-8,8,0.05), y=W1(seq(-8,8,0.05)), type="l")
plot(x=seq(-8,8,0.05), y=W2(seq(-8,8,0.05)), type="l")
plot(x=seq(-8,8,0.05), y=W3(seq(-8,8,0.05)), type="l")
plot(x=seq(-pi,pi,0.05), y=WDaniell(seq(-pi,pi,0.05),a=(pi/2)), type="l")
plot(x=seq(-2,2,0.05),y=WParzen(seq(-2,2,0.05)),type = "l")
```

---

# KernelWeight-class *Class for Brillinger-type Kernel weights.*

---

## Description

KernelWeight is an S4 class that implements a weighting function by specification of a kernel function W and a scale parameter bw.

## Details

It extends the class Weight and writes

$$W_N(2\pi(k-1)/N) := \sum_{j\in Z} bw^{-1} W(2\pi bw^{-1}[(k-1)/N + j])$$

to values[k] [nested inside env] for k=1,...,N. The number length(values) of Fourier frequencies for which $W_N$ will be evaluated may be set on construction or updated when evoking the method getValues. To standardize the weights used in the convolution to unity

$$W_N^j := \sum_{j\neq s=0}^{N-1} W_n(2\pi s/N)$$

is stored to Wnj[s] for s=1,...,N, for later usage.

## Slots

W a kernel function

bw bandwidth

env An environment to allow for slots which need to be accessable in a call-by-reference manner:

values A vector storing the weights; see the Details section.

Wnj A vector storing the terms used for normalization; see the Details section.

## References

Brillinger, D. R. (1975). *Time Series: Data Analysis and Theory*. Holt, Rinehart and Winston, Inc., New York. [cf. p. 146 f.]

## See Also

Examples for implementations of kernels W can be found at: kernels.

KernelWeight-constructor

*Create an instance of the* KernelWeight *class.*

## Description

Create an instance of the KernelWeight class.

## Usage

```
kernelWeight(W = W0, N = 1, bw = 0.1 * N^(-1/5), descr = paste("bw=",
  round(bw, 3), ", N=", N, sep = ""))
```

## Arguments

| | |
|---|---|
| W | A kernel function |
| N | Fourier basis; number of grid points in $[0, 2\pi)$ for which the weights will be computed. |
| bw | bandwidth; if a vector, then a list of weights is returned |
| descr | a description to be used in some plots |

## Value

Returns an instance of KernelWeight.

## See Also

kernels

## Examples

```
wgt1 <- kernelWeight(W=W0, N=16, bw=c(0.1,0.3,0.7))
print(wgt1)
wgt2 <- kernelWeight(W=W1, N=2^8, bw=0.1)
plot(wgt2, main="Weights determined from Epanechnikov kernel")
```

## LagEstimator-class *Class for a lag-window type estimator.*

### Description

For a given time series Y a lag-window estimator of the Form

$$\hat{f}(\omega) = \sum_{|k|<n-1} K_n(k)\Gamma(Y_0, Y_k)\exp(-i\omega k)$$

will be calculated on initalization. The `LagKernelWeight` K_n is determined by the slot `weight` and the `LagOperator` $\Gamma(Y_0, Y_k)$ is defined by the slot lagOp.

### Details

Currently, the implementation of this class allows only for the analysis of univariate time series.

### Slots

`Y` the time series where the lag estimator was applied one

`weight` a `Weight` object to be used as lag window

`lagOp` a `LagOperator` object that determines which kind of bivariate structure should be calculated.

`env` An environment to allow for slots which need to be accessable in a call-by-reference manner:

`sdNaive` An array used for storage of the naively estimated standard deviations of the smoothed periodogram.

`sdNaive.done` a flag indicating whether `sdNaive` has been set yet.

## LagEstimator-constructor *Create an instance of the* `LagEstimator` *class.*

### Description

A `LagEstimator` object can be created from `numeric`, a `ts`, or a `zoo` object. Also a `LagOperator` and a `Weight` object can be used to create different types of estimators.

### Usage

```
lagEstimator(Y, frequencies = 2 * pi/length(Y) * 0:(length(Y) - 1),
  levels.1 = 0.5, levels.2 = levels.1, weight = lagKernelWeight(K =
  length(Y), bw = 100), type = c("clippedCov"))
```

### Arguments

| | |
|---|---|
| Y | a time series (numeric, ts, or zoo object) or a LagOperator from which to determine the LagEstimator |
| frequencies | A vector containing (Fourier-)frequencies at which to determine the smoothed periodogram. |
| levels.1 | the first vector of levels for which to compute the LagEstimator |
| levels.2 | the second vector of levels for which to compute the LagEstimator |
| weight | Object of type Weight to be used for smoothing. |
| type | if Y is a time series, this indicates which LagOperator will be used |

### Value

Returns an instance of LagEstimator.

### Examples

```
Y <- rnorm(100)
levels.1 <- c(0.1,0.5,0.9)
weight <- lagKernelWeight(W = WParzen,  bw = 10, K = length(Y))
lagOp <- clippedCov(Y,levels.1 = levels.1)
lagEst <- lagEstimator(lagOp, weight = weight)
```

---

## LagKernelWeight-class *Class for lag window generators*

---

### Description

LagKernelWeight is an S4 class that implements a weighting function by specification of a kernel function W and a scale parameter bw.

### Details

It extends the class Weight and writes

$$W_N(x[k]) := W(x[k]/bw)$$

to values[k] [nested inside env] for k=1,...,length(x). The points x where $W$ is evaluated may be set on construction or updated when evoking the method getValues.

### Slots

W a kernel function

bw bandwidth

env An environment to allow for slots which need to be accessable in a call-by-reference manner:

values A vector storing the weights; see the Details section.

## See Also

Examples for implementations of kernels W can be found at: kernels.

---

LagKernelWeight-constructor

*Create an instance of the* LagKernelWeight *class.*

---

## Description

Create an instance of the LagKernelWeight class.

## Usage

```
lagKernelWeight(W = WParzen, bw = K/2, K = 10, descr = paste("bw=", bw,
  ", K=", K, sep = ""))
```

## Arguments

| | |
|---|---|
| W | A kernel function |
| bw | bandwidth |
| K | a numeric that determines the largest lag. The weight will be computed for the $K$ integers $0 : (K - 1)$; by default the number K specified on construction. |
| descr | a description to be used in some plots |

## Value

Returns an instance of LagKernelWeight.

## See Also

kernels

## Examples

```
wgt1 <- lagKernelWeight(W=WParzen, K=20, bw=10)
print(wgt1)
```

## LagOperator-class *Interface Class to access different types of operators on time series.*

### Description

LagOperator is an S4 class that provides a common interface to implementations of an operator $\Gamma(Y)$ which is calculated on all pairs of observations $(Y_0, Y_k)$ with lag smaller than maxLag

### Details

Currently one implementation is available: (1) ClippedCov.

Currently, the implementation of this class allows only for the analysis of univariate time series.

### Slots

values an array of dimension c(maxLag,length(levels.1),length(levels.2)) containing the values of the operator.

Y is the time series the operator shall be applied to

maxLag maximum lag between two observations

levels a vector of numerics that determines the levels of the operator

isRankBased A flag that is FALSE if the determined values are based on the original time series and TRUE if it is based on the ranks.

positions.boot An object of type BootPos, that is used to determine the block bootstrapped replicates of the time series.

B Number of bootstrap replications to perform.

## lenTS *Validates if Y is of an appropriate type for a time series and returns the length of the time series.*

### Description

Runs timeSeriesValidator and returns the number of rows of the returned matrix.

### Usage

```
lenTS(Y)
```

### Arguments

| | |
|---|---|
| Y | the time series to be validated and of which the length is to be returned. |

### Value

Returns the length of the time series after validating it's valid.

### Examples

```
Y <- lenTS(sp500)
Y <- lenTS(wheatprices)
Y <- lenTS(rnorm(10))
## Not run: Y <- lenTS("Not a valid input")
```

---

## MovingBlocks-class *Class for Moving Blocks Bootstrap implementation.*

---

### Description

`MovingBlocks` is an S4 class that implements the moving blocks bootstrap described in K\"unsch (1989).

### Details

`MovingBlocks` extends the S4 class `BootPos` and the remarks made in its documentation apply here as well.

The Moving Blocks Bootstrap method of K\"unsch (1989) resamples blocks randomly, with replacement from the collection of overlapping blocks of length `l` that start with observation 1, 2, ..., `N-l+1`. A more precise description of the procedure can also be found in Lahiri (1999), p. 389.

### References

K\"unsch, H. R. (1989). The jackknife and the bootstrap for general stationary observations. *The Annals of Statistics*, **17**, 1217–1261.

### See Also

`getPositions-MovingBlocks`

---

## MovingBlocks-constructor *Create an instance of the `MovingBlocks` class.*

---

### Description

Create an instance of the `MovingBlocks` class.

### Usage

```
movingBlocks(l, N)
```

### Arguments

| | |
|---|---|
| l | the block length for the block bootstrap methods |
| N | number of available observations to bootstrap from |

### Value

Returns an instance of MovingBlocks.

---

## plot-FreqRep *Plot the values of the* FreqRep.

---

### Description

Creates a K x 2 plot depicting a FreqRep object. Each of the K "lines" of subplots shows the frequency representation for one value of $\tau$. The real and imaginary part are shown on the left and the right, respectively.

### Usage

```
## S4 method for signature 'FreqRep,ANY'
plot(x, ratio = 2, frequencies = 2 * pi *
  (1:(floor(lenTS(x@Y)/2)))/lenTS(x@Y), levels = x@levels,
  d = 1:(dim(x@Y)[2]))
```

### Arguments

| | |
|---|---|
| x | The FreqRep to plot. |
| ratio | quotient of width over height of the subplots; use this parameter to produce landscape or portrait shaped plots. |
| frequencies | a set of frequencies for which the values are to be plotted. |
| levels | a set of levels for which the values are to be plotted. |
| d | vector indicating which components of a multivariate time series should be in the plot. |

### Value

Plots the FreqRep for all frequencies and levels specified.

plot-IntegrQuantileSD *Plot the values of the* IntegrQuantileSD.

## Description

Creates a K x K plot depicting an integrated quantile spectral density. In each of the subplots either the real part (on and below the diagonal; i. e., $\tau_1 \leq \tau_2$) or the imaginary part (above the diagonal; i. e., $\tau_1 > \tau_2$) of

- the integrated quantile spectral density (black line),

for the combination of levels $\tau_1$ and $\tau_2$ denoted on the left and bottom margin of the plot are displayed.

## Usage

```
## S4 method for signature 'IntegrQuantileSD,ANY'
plot(x, ratio = 3/2, widthlab = lcm(1),
  xlab = expression(omega/2 * pi), ylab = NULL, frequencies = 2 * pi *
  (1:(floor(getN(getQuantileSD(x))/2)))/getN(getQuantileSD(x)),
  levels = getLevels(x, 1))
```

## Arguments

| | |
|---|---|
| x | The IntegrQuantileSD to plot |
| ratio | quotient of width over height of the subplots; use this parameter to produce landscape or portrait shaped plots. |
| widthlab | width for the labels (left and bottom); default is lcm(1), cf. layout. |
| xlab | label that will be shown on the bottom of the plots; can be an expression (for formulas), characters or NULL to force omission (to save space). |
| ylab | label that will be shown on the left side of the plots; can be an expression (for formulas), characters or NULL to force omission (to save space). |
| frequencies | a set of frequencies for which the values are to be plotted. |
| levels | a set of levels for which the values are to be plotted. |

## Value

Plots the simulated integrated quantile spectral density for all frequencies and levels specified.

plot-KernelWeight *Plot the values of the* KernelWeight.

## Description

Creates a plot visualizing the weights $W_n(\omega)$ [cf. KernelWeight-class] that are used to estimate the quantile spectral density.

## Usage

```
## S4 method for signature 'KernelWeight,missing'
plot(x, y, ylab = expression(W[n](omega)),
  xlab = expression(omega), main = x@descr, ...)
```

## Arguments

| | |
|---|---|
| x | The KernelWeight to plot. |
| y | missing arg from the generic; will be ignored. |
| ylab | label for the y-axis; optional |
| xlab | label for the x-axis; optional |
| main | titel (on top) of the plot; optional |
| ... | optional parameters used for plotting |

## Details

In the plot the values at the frequencies $2\pi j/N$, $j = L + 1 - N, \ldots, L$, $L := \lfloor N/2 \rfloor$ are shown, where $N$ is the parameter specified on construction of the object or $N := 3$, if that parameter was smaller than three. A warning is given in the later case.

## Value

Plots the KernelWeight.

## Examples

```
plot(kernelWeight(W1, bw=0.3),
       ylab=expression(W[n](x)),
       xlab=expression(x),
       main="Weights to an Epanechnikov kernel", sub="bw=0.3")
```

plot-LagEstimator *Plot the values of a* LagEstimator.

## Description

Creates a K x K plot displaying all levels combinations from the argument levels. In each of the subplots either the real part (on and below the diagonal; i. e., $\tau_1 \leq \tau_2$) or the imaginary parts (above the diagonal; i. e., $\tau_1 > \tau_2$) of the lag-window estimator, for the combination of levels $\tau_1$ and $\tau_2$ denoted on the left and bottom margin of the plot are displayed.

## Usage

```
## S4 method for signature 'LagEstimator,ANY'
plot(x, ptw.CIs = 0.1, ratio = 3/2,
  widthlab = lcm(1), xlab = expression(omega/2 * pi), ylab = NULL,
  type.scaling = c("individual", "real-imaginary", "all"),
  frequencies = x@frequencies, type.CIs = c("naive.sd"),
  levels = intersect(x@levels[[1]], x@levels[[2]]))
```

## Arguments

| | |
|---|---|
| x | The LagEstimator object to plot |
| ptw.CIs | the confidence level for the confidence intervals to be displayed; must be a number from [0,1]; if null, then no confidence intervals will be plotted. |
| ratio | quotient of width over height of the subplots; use this parameter to produce landscape or portrait shaped plots. |
| widthlab | width for the labels (left and bottom); default is lcm(1), cf. layout. |
| xlab | label that will be shown on the bottom of the plots; can be an expression (for formulas), characters or NULL to force omission (to save space). |
| ylab | label that will be shown on the left side of the plots; can be an expression (for formulas), characters or NULL to force omission (to save space). |
| type.scaling | a method for scaling of the subplots; currently there are three options: "individual" will scale each of the K^2 subplots to minimum and maximum of the values in that plot, "real-imaginary" will scale each of the subplots displaying real parts and each of the subplots displaying imaginary parts to the minimum and maximum of the values display in these subportion of plots. The option "all" will scale the subplots to the minimum and maximum in all of the subplots. |
| frequencies | a set of frequencies for which the values are to be plotted. |
| type.CIs | indicates the method to be used for determining the confidence intervals; the methods available are those provided by getPointwiseCIs-LagEstimator. |
| levels | a set of levels for which the values are to be plotted. |

## Value

Returns the plot described in the Description section.

See Birr et al. (2015)

## References

Birr, S., Volgushev, S., Kley, T., Dette, H. & Hallin, M. (2015). Quantile Spectral Analysis for Locally Stationary Time Series. http://arxiv.org/abs/1404.4605.

---

`plot-LagKernelWeight` *Plot the values of the* `LagKernelWeight`.

---

## Description

Creates a plot visualizing the weights $W_n(k$ [cf. `LagKernelWeight-class`] that are used to estimate the quantile spectral density.

## Usage

```
## S4 method for signature 'LagKernelWeight,missing'
plot(x, y, ylab = expression(W[n](k)),
  xlab = expression(k), main = x@descr, ...)
```

## Arguments

| | |
|---|---|
| `x` | The `LagKernelWeight` to plot. |
| `y` | missing arg from the generic; will be ignored. |
| `ylab` | label for the y-axis; optional |
| `xlab` | label for the x-axis; optional |
| `main` | titel (on top) of the plot; optional |
| `...` | optional parameters used for plotting |

## Details

In the plot the values at the points $k/bw$ with $k \in \{-K, \ldots, K\}$ are shown.

## Value

Plots the `LagKernelWeight`.

## Examples

```
plot(lagKernelWeight(WParzen, bw=10, K = 20),
       ylab=expression(W[n](x)),
       xlab=expression(x),
       main="Weights to the Parzen Window")
```

## plot-LagOperator *Plot the values of the* LagOperator.

### Description

Creates a K x K plot (where K is the length of the levels parameter) showing the values of the LagOperator. The plots below the diagonal show the positive Lags and the plots above display the negative ones.

### Usage

```
## S4 method for signature 'LagOperator,ANY'
plot(x, levels = intersect(x@levels.1,
  x@levels.2), maxLag = maxLag, widthlab = lcm(1), ratio = 3/2,
  xlab = expression(omega/2 * pi), ylab = NULL)
```

### Arguments

| | |
|---|---|
| x | The LagOperator to plot. |
| levels | a set of levels for which the values are to be plotted. |
| maxLag | maximum Lag that should be displayed. It defaults to the maximum number of Lags available but usually a smaller number yields a more informative result. |
| widthlab | width for the labels (left and bottom); default is lcm(1), cf. layout. |
| ratio | quotient of width over height of the subplots; use this parameter to produce landscape or portrait shaped plots. |
| xlab | label that will be shown on the bottom of the plots; can be an expression (for formulas), characters or NULL to force omission (to save space). |
| ylab | label that will be shown on the left side of the plots; can be an expression (for formulas), characters or NULL to force omission (to save space). |

## plot-QuantilePG *Plot the values of the* QuantilePG.

### Description

Creates a K x K plot depicting a quantile periodogram. Optionally, a simulated copula spectral density can be displayed. In each of the subplots either the real part (on and below the diagonal; i. e., $\tau_1 \leq \tau_2$) or the imaginary parts (above the diagonal; i. e., $\tau_1 > \tau_2$) of

- the quantile periodogram (black line),
- a simulated quantile spectral density (red line),

for the combination of levels $\tau_1$ and $\tau_2$ denoted on the left and bottom margin of the plot are displayed.

## Usage

```
## S4 method for signature 'QuantilePG,ANY'
plot(x, qsd, ratio = 3/2, widthlab = lcm(1),
  xlab = expression(omega/2 * pi), ylab = NULL,
  type.scaling = c("individual", "real-imaginary", "all"),
  frequencies = x@frequencies[-which(x@frequencies == 0)],
  levels = intersect(x@levels[[1]], x@levels[[2]]))
```

## Arguments

| | |
|---|---|
| x | The QuantilePG object to plot |
| qsd | a QuantileSD object; will be plotted if not missing. |
| ratio | quotient of width over height of the subplots; use this parameter to produce landscape or portrait shaped plots. |
| widthlab | width for the labels (left and bottom); default is lcm(1), cf. layout. |
| xlab | label that will be shown on the bottom of the plots; can be an expression (for formulas), characters or NULL to force omission (to save space). |
| ylab | label that will be shown on the left side of the plots; can be an expression (for formulas), characters or NULL to force omission (to save space). |
| type.scaling | a method for scaling of the subplots; currently there are three options: "individual" will scale each of the K^2 subplots to minimum and maximum of the values in that plot, "real-imaginary" will scale each of the subplots displaying real parts and each of the subplots displaying imaginary parts to the minimum and maximum of the values display in these subportion of plots. The option "all" will scale the subplots to the minimum and maximum in all of the subplots. |
| frequencies | a set of frequencies for which the values are to be plotted; default is all available frequencies but 0; if 0 is the only available frequency, then only 0 will be used. |
| levels | a set of levels for which the values are to be plotted. |

## Details

Currently, only the plot for the first component is shown.

## Value

Returns the plot described in the Description section.

---

plot-QuantileSD *Plot the values of the* QuantileSD.

---

## Description

Creates a K x K plot depicting a quantile spectral density. In each of the subplots either the real part (on and below the diagonal; i. e., $\tau_1 \leq \tau_2$) or the imaginary parts (above the diagonal; i. e., $\tau_1 > \tau_2$) of

- the quantile spectral density (red line),
- the means of the quantile periodograms used in the simulation (black line),

for the combination of levels $\tau_1$ and $\tau_2$ denoted on the left and bottom margin of the plot are displayed.

## Usage

```
## S4 method for signature 'QuantileSD,ANY'
plot(x, ratio = 3/2, widthlab = lcm(1),
  xlab = expression(omega/2 * pi), ylab = NULL, frequencies = 2 * pi *
  (1:(floor(x@N/2)))/x@N, levels = getLevels(x, 1))
```

## Arguments

| | |
|---|---|
| x | The QuantileSD to plot |
| ratio | quotient of width over height of the subplots; use this parameter to produce landscape or portrait shaped plots. |
| widthlab | width for the labels (left and bottom); default is lcm(1), cf. layout. |
| xlab | label that will be shown on the bottom of the plots; can be an expression (for formulas), characters or NULL to force omission (to save space). |
| ylab | label that will be shown on the left side of the plots; can be an expression (for formulas), characters or NULL to force omission (to save space). |
| frequencies | a set of frequencies for which the values are to be plotted. |
| levels | a set of levels for which the values are to be plotted. |

## Details

Currently, only the plot for the first component is shown.

## Value

Plots the simulated quantile spectral density for all frequencies and levels specified.

plot-SmoothedPG *Plot the values of a* SmoothedPG.

## Description

Creates a K x K plot depicting a smoothed quantile periodogram. Optionally, the quantile periodogram on which the smoothing was performed, a simulated quantile spectral density, and pointwise confidence intervals can be displayed. In each of the subplots either the real part (on and below the diagonal; i. e., $\tau_1 \leq \tau_2$) or the imaginary parts (above the diagonal; i. e., $\tau_1 > \tau_2$) of

- the smoothed quantile periodogram (blue line),
- the quanitle peridogram that was used for smoothing (gray line),
- a simulated quantile spectral density (red line),
- pointwise (asymptotic) confidence intervals (light gray area),

for the combination of levels $\tau_1$ and $\tau_2$ denoted on the left and bottom margin of the plot are displayed.

## Usage

```
## S4 method for signature 'SmoothedPG,ANY'
plot(x, plotPG = FALSE, qsd, ptw.CIs = 0.1,
  type.CIs = c("naive.sd", "boot.sd", "boot.full"), ratio = 3/2,
  widthlab = lcm(1), xlab = expression(omega/2 * pi), ylab = NULL,
  type.scaling = c("individual", "real-imaginary", "all"),
  frequencies = x@frequencies, levels = intersect(x@levels[[1]],
  x@levels[[2]]))
```

## Arguments

| | |
|---|---|
| x | The SmoothedPG object to plot |
| plotPG | a flag indicating weater the QuantilePG object associated with the SmoothedPG x is also to be plotted. |
| qsd | a QuantileSD object; will be plotted if not missing. |
| ptw.CIs | the confidence level for the confidence intervals to be displayed; must be a number from [0,1]; if null, then no confidence intervals will be plotted. |
| type.CIs | indicates the method to be used for determining the confidence intervals; the methods available are those provided by getPointwiseCIs-SmoothedPG. |
| ratio | quotient of width over height of the subplots; use this parameter to produce landscape or portrait shaped plots. |
| widthlab | width for the labels (left and bottom); default is lcm(1), cf. layout. |
| xlab | label that will be shown on the bottom of the plots; can be an expression (for formulas), characters or NULL to force omission (to save space). |
| ylab | label that will be shown on the left side of the plots; can be an expression (for formulas), characters or NULL to force omission (to save space). |

| | |
|---|---|
| type.scaling | a method for scaling of the subplots; currently there are three options: "individual" will scale each of the K^2 subplots to minimum and maximum of the values in that plot, "real-imaginary" will scale each of the subplots displaying real parts and each of the subplots displaying imaginary parts to the minimum and maximum of the values display in these subportion of plots. The option "all" will scale the subplots to the minimum and maximum in all of the subplots. |
| frequencies | a set of frequencies for which the values are to be plotted. |
| levels | a set of levels for which the values are to be plotted. |

## Details

Currently, only the plot for the first component is shown.

## Value

Returns the plot described in the Description section.

---

# plot-SpecDistrWeight *Plot the values of the* SpecDistrWeight.

---

## Description

Creates a plot visualizing the weights $W_n(\omega)$ [cf. SpecDistrWeight-class] that are used to estimate the integrated quantile spectral density.

## Usage

```
## S4 method for signature 'SpecDistrWeight,missing'
plot(x, y, ylab = expression(W[n](omega)),
  xlab = expression(omega), main = x@descr, ...)
```

## Arguments

| | |
|---|---|
| x | The SpecDistrWeight to plot. |
| y | missing arg from the generic; will be ignored. |
| ylab | label for the y-axis; optional |
| xlab | label for the x-axis; optional |
| main | titel (on top) of the plot; optional |
| ... | optional parameters used for plotting |

## Details

In the plot the values at the frequencies $2\pi j/128$, $j = -63, \ldots, 64$ are shown.

## Value

Plots the SpecDistrWeight.

## Examples

```
plot(specDistrWeight(),
       ylab=expression(W[n](x)),
       xlab=expression(x))
```

---

QRegEstimator-class *Class for quantile regression-based estimates in the harmonic linear model.*

---

## Description

QRegEstimator is an S4 class that implements the necessary calculations to determine the frequency representation based on the weigthed $L_1$-projection of a time series as described in Dette et. al (2015). As a subclass to FreqRep it inherits slots and methods defined there.

## Details

For each frequency $\omega$ from frequencies and level $\tau$ from levels the statistic

$$\hat{b}_n^\tau(\omega) := \arg \max_{a \in R, b \in C} \sum_{t=0}^{n-1} \rho_\tau(Y_t - a - Re(b)\cos(\omega t) - Im(b)\sin(\omega t)),$$

is determined and stored to the array values.

The solution to the minimization problem is determined using the function rq from the **quantreg** package.

All remarks made in the documentation of the super-class FreqRep apply.

## Slots

method method used for computing the quantile regression estimates. The choice is passed to qr; see the documentation of quantreg for details.

parallel a flag that signalizes that parallelization mechanisms from the package **snowfall** may be used.

## References

Dette, H., Hallin, M., Kley, T. & Volgushev, S. (2015). Of Copulas, Quantiles, Ranks and Spectra: an $L_1$-approach to spectral analysis. *Bernoulli*, **21**(2), 781–831. [cf. http://arxiv.org/abs/1111.7205]

QRegEstimator-constructor

*Create an instance of the* QRegEstimator *class.*

## Description

The parameter type.boot can be set to choose a block bootstrapping procedure. If "none" is chosen, a moving blocks bootstrap with l=length(Y) and N=length(Y) would be done. Note that in that case one would also chose B=0 which means that getPositions would never be called. If B>0 then each bootstrap replication would be the undisturbed time series.

## Usage

```
qRegEstimator(Y, frequencies = 2 * pi/lenTS(Y) * 0:(lenTS(Y) - 1),
  levels = 0.5, isRankBased = TRUE, B = 0, l = 0,
  type.boot = c("none", "mbb"), method = c("br", "fn", "pfn", "fnc",
  "lasso", "scad"), parallel = FALSE)
```

## Arguments

| | |
|---|---|
| Y | A vector of real numbers containing the time series from which to determine the quantile periodogram or a ts object or a zoo object. |
| frequencies | A vector containing frequencies at which to determine the QRegEstimator. |
| levels | A vector of length K containing the levels x at which the QRegEstimator is to be determined. |
| isRankBased | If true the time series is first transformed to pseudo data [cf. FreqRep]. |
| B | number of bootstrap replications |
| l | (expected) length of blocks |
| type.boot | A flag to choose a method for the block bootstrap; currently two options are implemented: "none" and "mbb" which means to do a moving blocks bootstrap with B and l as specified. |
| method | method used for computing the quantile regression estimates. The choice is passed to qr; see the documentation of quantreg for details. |
| parallel | a flag to allow performing parallel computations. |

## Value

Returns an instance of QRegEstimator.

## Examples

```
library(snowfall)

Y <- rnorm(100) # Try 2000 and parallel computation will in fact be faster.
```

```
# Compute without using snowfall capabilities
system.time(
  qRegEst1 <- qRegEstimator(Y, levels=seq(0.25,0.75,0.25), method="fn", parallel=FALSE)
)

# Set up snowfall
sfInit(parallel=TRUE, cpus=2, type="SOCK")
sfLibrary(quantreg)
sfExportAll()

# Compare how much faster the computation is when done in parallel
system.time(
  qRegEst2 <- qRegEstimator(Y, levels=seq(0.25,0.75,0.25), method="fn", parallel=TRUE)
)

sfStop()

# Compare results
V1 <- getValues(qRegEst1)
V2 <- getValues(qRegEst2)
sum(abs(V1-V2)) # Returns: [1] 0
```

---

`QSpecQuantity-class` *Class for a Quantile Spectral Estimator.*

---

## Description

`QSpecQuantity` is an S4 class that provides a common interface to objects that are of the functional form $f^{j_1,j_2}(\omega; x_1, x_2)$, where $j_1, j_2$ are indices denoting components of a time series or process, $\omega$ is a frequency parameter and $x_1, x_2$ are level parameters. For each combination of parameters a complex number can be stored. Examples for objects of this kind currently include the quantile (i. e., Laplace or copula) spectral density kernel [cf. `QuantileSD` for an implementation], an integrated version of the quantile spectral density kernels [cf. `IntegrQuantileSD` for an implementation], and estimators of it [cf. `QuantilePG` and `SmoothedPG` for implementations].

## Slots

`values` The array holding the values $f^{j_1,j_2}(\omega; x_1, x_2)$.

`frequencies` The frequencies $\omega$ for which the values are available.

`levels` A list of vectors containing the levels $x_i$ serving as argument for the estimator.

QuantilePG-class *Class for a quantile (i. e., Laplace or copula) periodogram.*

## Description

QuantilePG is an S4 class that implements the necessary calculations to determine one of the periodogram-like statistics defined in Dette et. al (2015) and Kley et. al (2015+).

## Details

Performs all the calculations to determine a quantile periodogram from a FreqRep object upon initialization (and on request stores the values for faster access). The two methods available for the estimation are the ones implemented as subclasses of FreqRep:

- the Fourier transformation of the clipped time series $(\{I\{Y_t \leq q\})$ [cf. ClippedFT], or
- the weighted $L_1$-projection of $(Y_t)$ onto an harmonic basis [cf. QRegEstimator].

All remarks made in the documentation of the super-class QSpecQuantity apply.

## Slots

freqRep a FreqRep object where the quantile periodogram will be based on.

## References

Dette, H., Hallin, M., Kley, T. & Volgushev, S. (2015). Of Copulas, Quantiles, Ranks and Spectra: an $L_1$-approach to spectral analysis. *Bernoulli*, **21**(2), 781–831. [cf. http://arxiv.org/abs/1111.7205]

Kley, T., Volgushev, S., Dette, H. & Hallin, M. (2015+). Quantile Spectral Processes: Asymptotic Analysis and Inference. *Bernoulli*, **forthcoming**. [cf. http://arxiv.org/abs/1401.8104]

## Examples

```
################################################################################
## This script illustrates how to work with QuantilePG objects

## Simulate a time series Y1,...,Y128 from the QAR(1) process discussed in
## Dette et. al (2015).
Y <- ts1(64)

## For a defined set of quantile levels
levels <- c(0.25,0.5,0.75)

## the various quantile periodograms can be calculated calling quantilePG:

## For a copula periodogram as in Dette et. al (2015) the option 'type="qr"'
## has to be used:
system.time(
    qPG.qr <- quantilePG(Y, levels.1 = levels, type="qr"))
```

```
## For the CR-periodogram as in Kley et. al (2014) the option 'type="clipped"'
## has to be used. If bootstrap estimates are to be used the parameters
## type.boot, B and l need to be specified.
system.time(
    qPG.cl <- quantilePG(Y, levels.1 = levels, type="clipped",
        type.boot="mbb", B=250, l=2^5))

## The two previous calls also illustrate that computation of the CR-periodogram
## is much more efficient than the quantile-regression based copula periodogram.

## Either periodogram can be plotted using the plot command
plot(qPG.cl)
plot(qPG.qr)

## Because the indicators are not centered it is often desired to exclude the
## frequency 0; further more the frequencies (pi,2pi) are not wanted to be
## included in the plot, because f(w) = Conj(f(2 pi - w)).
## Using the plot command it is possible to select frequencies and levels for
## the diagram:
plot(qPG.cl, frequencies=2*pi*(1:32)/64, levels=c(0.25))

## We can also plot the same plot together with a (simulated) quantile spectral
## density kernel
csd <- quantileSD(N=2^8, seed.init = 2581, type = "copula",
    ts = ts1, levels.1=c(0.25), R = 100)
plot(qPG.cl, qsd = csd, frequencies=2*pi*(1:32)/64, levels=c(0.25))

## Calling the getValues method allows for comparing the two quantile
## periodograms; here in a diagram:
freq <- 2*pi*(1:31)/32
V.cl <- getValues(qPG.cl, frequencies = freq, levels.1=c(0.25))
V.qr <- getValues(qPG.qr, frequencies = freq, levels.1=c(0.25))
plot(x = freq/(2*pi), Re(V.cl[,1,1,1]), type="l",
        ylab="real part -- quantile PGs", xlab=expression(omega/2*pi))
lines(x = freq/(2*pi), Re(V.qr[,1,1,1]), col="red")

## Now plot the imaginary parts of the quantile spectra for tau1 = 0.25
## and tau2 = 0.5
freq <- 2*pi*(1:31)/32
V.cl <- getValues(qPG.cl, frequencies = freq, levels.1=c(0.25, 0.5))
V.qr <- getValues(qPG.qr, frequencies = freq, levels.1=c(0.25, 0.5))
plot(x = freq/(2*pi), Im(V.cl[,1,2,1]), type="l",
    ylab="imaginary part -- quantile PGs", xlab=expression(omega/2*pi))
lines(x = freq/(2*pi), Im(V.qr[,1,2,1]), col="red")
```

---

## QuantilePG-constructor

*Create an instance of the* QuantilePG *class.*

---

## Description

The parameter type.boot can be set to choose a block bootstrapping procedure. If "none" is chosen, a moving blocks bootstrap with l=length(Y) and N=length(Y) would be done. Note that in that case one would also chose B=0 which means that getPositions would never be called. If B>0 then each bootstrap replication would be the undisturbed time series.

## Usage

```
quantilePG(Y, frequencies = 2 * pi/lenTS(Y) * 0:(lenTS(Y) - 1),
  levels.1 = 0.5, levels.2 = levels.1, isRankBased = TRUE,
  type = c("clipped", "qr"), type.boot = c("none", "mbb"), B = 0, l = 0,
  method = c("br", "fn", "pfn", "fnc", "lasso", "scad"), parallel = FALSE)
```

## Arguments

| | |
|---|---|
| Y | A vector of real numbers containing the time series from which to determine the quantile periodogram or a ts object or a zoo object. |
| frequencies | A vector containing frequencies at which to determine the quantile periodogram. |
| levels.1 | A vector of length K1 containing the levels x1 at which the QuantilePG is to be determined. |
| levels.2 | A vector of length K2 containing the levels x2. |
| isRankBased | If true the time series is first transformed to pseudo data [cf. FreqRep]. |
| type | A flag to choose the type of the estimator. Can be either "clipped" or "qr". In the first case ClippedFT is used as a frequency representation, in the second case QRegEstimator is used. |
| type.boot | A flag to choose a method for the block bootstrap; currently two options are implemented: "none" and "mbb" which means to do a moving blocks bootstrap with B and l as specified. |
| B | number of bootstrap replications |
| l | (expected) length of blocks |
| method | method used for computing the quantile regression estimates. The choice is passed to qr; see the documentation of quantreg for details. |
| parallel | a flag to allow performing parallel computations, where possible. |

## Value

Returns an instance of QuantilePG.

QuantileSD-class *Class for a simulated quantile (i. e., Laplace or copula) density kernel.*

## Description

QuantileSD is an S4 class that implements the necessary calculations to determine a numeric approximation to the quantile spectral density kernel of a model from which a time series of length N can be sampled via a function call ts(N).

## Details

In the simulation a number of R independent quantile periodograms based on the clipped time series are simulated. If type=="copula", then the rank-based version is used. The sum and the sum of the squared absolute value is stored to the slots sumPG and sumSqPG. After the simulation is completed the mean and it's standard error (of the simulated quantile periodograms) are determined and stored to meanPG and stdError. Finally, the (copula) spectral density kernel is determined by smoothing real and imaginary part of meanPG seperately for each combination of levels using smooth.spline.

Note that, all remarks made in the documentation of the super-class QSpecQuantity apply.

## Slots

N a numeric specifying the number of equaly spaced Fourier frequencies from $[0, 2\pi)$ for which the (copula) spectral density will be simulated; note that due to the simulation mechanism a larger number will also yield a better approximation.

R the number of independent repetitions performed; note that due to the simulation mechanism a larger number will also yield a better approximation; can be enlarged using increasePrecision-QuantileSD.

type can be either Laplace or copula; indicates whether the marginals are to be assumed uniform $[0, 1]$ distributed.

ts a function that allows to draw independent samples $Y_0, \ldots, Y_{n-1}$ from the process for which the (copula) spectral density kernel is to be simulated

seed.last used internally to store the state of the pseudo random number generator, so the precision can be increased by generating more pseudo random numbers that are independent from the ones previously used.

sumPG an array used to store the sum of the simulated quantile periodograms

sumSqPG an array used to store the sum of the squared absolute values of the simulated quantile periodograms

meanPG an array used to store the mean of the simulated quantile periodograms

stdError an array used to store the estimated standard error of the mean of the simulated quantile periodograms

## References

Dette, H., Hallin, M., Kley, T. & Volgushev, S. (2015). Of Copulas, Quantiles, Ranks and Spectra: an $L_1$-approach to spectral analysis. *Bernoulli*, **21**(2), 781–831. [cf. http://arxiv.org/abs/1111.7205]

Kley, T., Volgushev, S., Dette, H. & Hallin, M. (2015+). Quantile Spectral Processes: Asymptotic Analysis and Inference. *Bernoulli*, **forthcoming**. [cf. http://arxiv.org/abs/1401.8104]

Barunik, J. & Kley, T. (2015). Quantile Cross-Spectral Measures of Dependence between Economic Variables. [preprint available from the authors]

## See Also

Examples for implementations of functions `ts` can be found at: ts-models.

## Examples

```
## This script can be used to create and store a QuantileSD object

## Parameters for the simulation:
R <- 50                      # number of independent repetitions;
                             # R should be much larger than this in practice!
N <- 2^8                     # number of Fourier frequencies in [0,2pi)
ts <- ts1                    # time series model
levels <- seq(0.1,0.9,0.1)   # quantile levels
type <- "copula"             # copula, not Laplace, spectral density kernel
seed.init <- 2581            # seed for the pseudo random numbers

## Simulation takes place once the constructor is invoked
qsd <- quantileSD(N=N, seed.init = 2581, type = type,
    ts = ts, levels.1=levels, R = R)

## The simulated copula spectral density kernel can be called via
V1 <- getValues(qsd)

## It is also possible to fetch the result for only a few levels
levels.few <- c(0.2,0.5,0.7)
V2 <- getValues(qsd, levels.1=levels.few, levels.2=levels.few)

## If desired additional repetitions can be performed to yield a more precise
## simulation result by calling; here the number of independent runs is doubled.
qsd <- increasePrecision(qsd,R)

## Often the result will be stored for later usage.
save(qsd, file="QAR1.rdata")

## Take a brief look at the result of the simulation
plot(qsd, levels=levels.few)

## When plotting more than only few levels it may be a good idea to plot to
## another device; e. g., a pdf-file
K <- length(levels)
pdf("QAR1.pdf", width=2*K, height=2*K)
```

```
  plot(qsd)
dev.off()

## Now we analyse the multivariate process (eps_t, eps_{t-1}) from the
## introduction of Barunik&Kley (2015). It can be defined as
ts_mult <- function(n) {
  eps <- rnorm(n+1)
  return(matrix(c(eps[2:(n+1)], eps[1:n]), ncol=2))
}

## now we determine the quantile cross-spectral densities
qsd <- quantileSD(N=N, seed.init = 2581, type = type,
    ts = ts_mult, levels.1=levels, R = R)

## from which we can for example extract the quantile coherency
Coh <- getCoherency(qsd, freq = 2*pi*(0:64)/128)

## We now plot the real part of the quantile coherency for j1 = 1, j2 = 2,
## tau1 = 0.3 and tau2 = 0.6
plot(x = 2*pi*(0:64)/128, Re(Coh[,1,3,2,6]), type="l")
```

---

`QuantileSD-constructor`

*Create an instance of the* `QuantileSD` *class.*

---

## Description

Create an instance of the `QuantileSD` class.

## Usage

```
quantileSD(N = 2^8, type = c("copula", "Laplace"), ts = rnorm,
  seed.init = runif(1), levels.1, levels.2 = levels.1, R = 1,
  quiet = FALSE)
```

## Arguments

| | |
|---|---|
| `N` | the number of Fourier frequencies to be used. |
| `type` | can be either `Laplace` or `copula`; indicates whether the marginals are to be assumed uniform $[0, 1]$ distributed. |
| `ts` | a function that has one argument `n` and, each time it is invoked, returns a new time series from the model for which the copula spectral density kernel is to be simulated. |
| `seed.init` | an integer serving as an initial seed for the simulations. |
| `levels.1` | A vector of length `K1` containing the levels `x1` at which the `QuantileSD` is to be determined. |
| `levels.2` | A vector of length `K2` containing the levels `x2` at which the `QuantileSD` is to be determined. |

| | |
|---|---|
| R | an integer that determines the number of independent simulations; the larger this number the more precise is the result. |
| quiet | Dont't report progress to console when computing the R independent quantile periodograms. |

## Value

Returns an instance of QuantileSD.

## See Also

For examples see QuantileSD.

---

quantspec-defunct *Defunct functions in package quantspec*

---

## Description

These functions have been declared defunct since Version 1.0-1.

## Usage

```
ct(i1, i2, n)

LaplacePeriodogram(X, taus, omegas = 1:(ceiling(length(X)/2) - 1),
  fromRanks = TRUE, showProgressBar = FALSE)

plotLaplacePeriodogram(LPG, taus, F = 1:length(LPG[, 1]),
  CL = 1:length(taus), hRange = FALSE, hOffset = FALSE,
  ylabel = expression({     {         hat(f)     }[n]^{         list(tau[1],
  tau[2])     } }(omega)), oma = c(2.5, 2.5, 2.5, 2.5), mar = c(4.5, 4.5, 1,
  0) + 0.1, cex.lab = 1.5)

smoothedLaplacePeriodogram(LPG, taus, W)
```

## Arguments

| | |
|---|---|
| i1 | Parameter of DEFUNCT function. |
| i2 | Parameter of DEFUNCT function. |
| n | Parameter of DEFUNCT function. |
| X | Parameter of DEFUNCT function. |
| taus | Parameter of DEFUNCT function. |
| omegas | Parameter of DEFUNCT function. |
| fromRanks | Parameter of DEFUNCT function. |
| showProgressBar | Parameter of DEFUNCT function. |

| | |
|---|---|
| LPG | Parameter of DEFUNCT function. |
| F | Parameter of DEFUNCT function. |
| CL | Parameter of DEFUNCT function. |
| hRange | Parameter of DEFUNCT function. |
| hOffset | Parameter of DEFUNCT function. |
| ylabel | Parameter of DEFUNCT function. |
| oma | Parameter of DEFUNCT function. |
| mar | Parameter of DEFUNCT function. |
| cex.lab | Parameter of DEFUNCT function. |
| W | Parameter of DEFUNCT function. |

---

SmoothedPG-class *Class for a smoothed quantile periodogram.*

---

## Description

SmoothedPG is an S4 class that implements the necessary calculations to determine a smoothed version of one of the quantile periodograms defined in Dette et. al (2015), Kley et. al (2015+) and Barunik&Kley (2015).

## Details

For a QuantilePG $Q_n^{j_1,j_2}(\omega, x_1, x_2)$ and a Weight $W_n(\cdot)$ the smoothed version

$$\frac{2\pi}{n}\sum_{s=1}^{n-1} W_n(\omega - 2\pi s/n) Q_n^{j_1,j_2}(2\pi s/n, x_1, x_2)$$

is determined.

The convolution required to determine the smoothed periodogram is implemented using convolve.

## Slots

env An environment to allow for slots which need to be accessable in a call-by-reference manner:

- sdNaive An array used for storage of the naively estimated standard deviations of the smoothed periodogram.
- sdNaive.freq a vector indicating for which frequencies sdNaive has been computed so far.
- sdNaive.done a flag indicating whether sdNaive has been set yet.
- sdBoot An array used for storage of the standard deviations of the smoothed periodogram, estimated via bootstrap.
- sdBoot.done a flag indicating whether sdBoot.naive has been set yet.

qPG the QuantilePG to be smoothed

weight the Weight to be used for smoothing

SmoothedPG-constructor

*Create an instance of the* SmoothedPG *class.*

## Description

A SmoothedPG object can be created from either

- a numeric, a ts, or a zoo object
- a QuantilePG object.

If a QuantilePG object is used for smoothing, only the weight, frequencies and levels.1 and levels.2 parameters are used; all others are ignored. In this case the default values for the levels are the levels of the QuantilePG used for smoothing. Any subset of the levels available there can be chosen.

## Usage

```
smoothedPG(object, frequencies = 2 * pi/lenTS(object) * 0:(lenTS(object) - 1),
  levels.1 = 0.5, levels.2 = levels.1, isRankBased = TRUE,
  type = c("clipped", "qr"), type.boot = c("none", "mbb"),
  method = c("br", "fn", "pfn", "fnc", "lasso", "scad"), parallel = FALSE,
  B = 0, l = 1, weight = kernelWeight())
```

## Arguments

| | |
|---|---|
| object | a time series (numeric, ts, or zoo object) from which to determine the smoothed periodogram; alternatively a QuantilePG object can be supplied. |
| frequencies | A vector containing frequencies at which to determine the smoothed periodogram. |
| levels.1 | A vector of length K1 containing the levels x1 at which the SmoothedPG is to be determined. |
| levels.2 | A vector of length K2 containing the levels x2. |
| isRankBased | If true the time series is first transformed to pseudo data [cf. FreqRep]. |
| type | A flag to choose the type of the estimator. Can be either "clipped" or "qr". In the first case ClippedFT is used as a frequency representation, in the second case QRegEstimator is used. |
| type.boot | A flag to choose a method for the block bootstrap; currently two options are implemented: "none" and "mbb" which means to do a moving blocks bootstrap with B and l as specified. |
| method | method used for computing the quantile regression estimates. The choice is passed to qr; see the documentation of quantreg for details. |
| parallel | a flag to allow performing parallel computations, where possible. |
| B | number of bootstrap replications |
| l | (expected) length of blocks |
| weight | Object of type Weight to be used for smoothing. |

## Details

The parameter `type.boot` can be set to choose a block bootstrapping procedure. If `"none"` is chosen, a moving blocks bootstrap with `l=length(Y)` and `N=length(Y)` would be done. Note that in that case one would also chose `B=0` which means that `getPositions` would never be called. If `B>0` then each bootstrap replication would be the undisturbed time series.

## Value

Returns an instance of `SmoothedPG`.

## Examples

```
Y <- rnorm(64)
levels.1 <- c(0.25,0.5,0.75)
weight <- kernelWeight(W=W0)

# Version 1a of the constructor -- for numerics:
sPG.ft <- smoothedPG(Y, levels.1 = levels.1, weight = weight, type="clipped")
sPG.qr <- smoothedPG(Y, levels.1 = levels.1, weight = weight, type="qr")

# Version 1b of the constructor -- for ts objects:
sPG.ft <- smoothedPG(wheatprices, levels.1 = c(0.05,0.5,0.95), weight = weight)

# Version 1c of the constructor -- for zoo objects:
sPG.ft <- smoothedPG(sp500, levels.1 = c(0.05,0.5,0.95), weight = weight)

# Version 2 of the constructor:
qPG.ft <- quantilePG(Y, levels.1 = levels.1, type="clipped")
sPG.ft <- smoothedPG(qPG.ft, weight = weight)
qPG.qr <- quantilePG(Y, levels.1 = levels.1, type="qr")
sPG.qr <- smoothedPG(qPG.qr, weight = weight)
```

---

# SpecDistrWeight-class *Class for weights to estimate integrated spectral density kernels.*

---

## Description

`SpecDistrWeight` is an S4 class that implements a weighting function given by

$$W_n(\alpha) := I\{\alpha \leq 0\}$$

.

## Details

At position `k` the value $W_n(2\pi(k-1)/n$ is stored [in a vector `values` nested inside `env`] for `k=1,...,T`. The number `length(values)` of Fourier frequencies for which $W_n$ will be evaluated may be set on construction or updated when evoking the method `getValues`.

## SpecDistrWeight-constructor

*Create an instance of the* SpecDistrWeight *class.*

### Description

Create an instance of the SpecDistrWeight class.

### Usage

```
specDistrWeight(descr = "Spectral Distribution Weights")
```

### Arguments

| | |
|---|---|
| descr | a description for the weight object |

### Value

an instance of SpecDistrWeight.

### Examples

```
wgt <- specDistrWeight()
```

## timeSeriesValidator

*Validates if* Y *is of an appropriate type and converts to a numeric.*

### Description

Checks whether Y is either

- numeric,
- a ts object, or
- a zoo object.

If not, an error is returned. If it is one of the three the data is returned as a numeric.

### Usage

```
timeSeriesValidator(Y)
```

### Arguments

| | |
|---|---|
| Y | the time series to be validated. |

### Value

Returns the time series as a matrix.

### Examples

```
Y <- timeSeriesValidator(sp500)
Y <- timeSeriesValidator(wheatprices)
Y <- timeSeriesValidator(rnorm(10))
## Not run: Y <- timeSeriesValidator("Not a valid input")
```

---

## ts-models *Functions to simulate from the time series models in Kley et. al (2014).*

---

### Description

Functions to simulate from the time series models in Kley et. al (2014).

### Usage

```
ts1(n)

ts2(n)

ts3(n)
```

### Arguments

| | |
|---|---|
| n | length of the time series to be returned |

### Details

ts1 QAR(1) model from Dette et. al (2015).

ts2 AR(2) model from Li (2012):

ts3 ARCH(1) model from Lee and Subba Rao (2012):

### References

Dette, H., Hallin, M., Kley, T. & Volgushev, S. (2015). Of Copulas, Quantiles, Ranks and Spectra: an $L_1$-approach to spectral analysis. *Bernoulli*, **21**(2), 781–831. [cf. http://arxiv.org/abs/1111.7205]

Li, T.-H. (2012). Quantile Periodograms. *Journal of the American Statistical Association*, **107**, 765–776.

Lee, J., & Subba Rao, S. (2012). The Quantile Spectral Density and Comparison based Tests for Nonlinear Time Series. http://arxiv.org/abs/1112.2759.

### Examples

```
# Plot sample paths:
plot(ts1(100), type="l")
plot(ts2(100), type="l")
plot(ts3(100), type="l")
```

---

`ts-models-AR1` *Simulation of an AR(1) time series.*

---

### Description

Returns a simulated time series $(Y_t)$ that fulfills the following equation:

$$Y_t = aY_{t-1} + \epsilon_t,$$

where $a$ is a parameter and $\epsilon_t$ is independent white noise with marginal distribution specified by the parameter `innov`.

### Usage

```
AR1(n, a, overhead = 500, innov = rnorm)
```

### Arguments

| | |
|---|---|
| `n` | length of the time series to be returned |
| `a` | parameter of the model |
| `overhead` | an integer specifying the "warmup" period to reach an approximate stationary start for the times series |
| `innov` | a function that generates a random number each time `innov(1)` is called; used to specify the distribution of the innovations; `rnorm` by default |

### Value

Returns an AR(1) time series with specified parameters.

### Examples

```
plot(AR1(100, a=-0.7), type="l")
```

## ts-models-AR2 *Simulation of an AR(2) time series.*

### Description

Returns a simulated time series $(Y_t)$ that fulfills the following equation:

$$Y_t = a_1 Y_{t-1} + a_2 Y_{t-2} + \epsilon_t,$$

where $a_1$ and $a_2$ are parameters and $\epsilon_t$ is independent white noise with marginal distribution specified by the parameter `innov`.

### Usage

```
AR2(n, a1, a2, overhead = 500, innov = rnorm)
```

### Arguments

| | |
|---|---|
| `n` | length of the time series to be returned |
| `a1` | parameter |
| `a2` | parameter |
| `overhead` | an integer specifying the "warmup" period to reach an approximate stationary start for the times series |
| `innov` | a function with one parameter `n` that yields `n` independent pseudo random numbers each time it is called. |

### Value

Return an AR(2) time series with specified parameters.

### Examples

```
plot(AR2(100, a1=0, a2=0.5), type="l")
```

## ts-models-ARCH1 *Simulation of an ARCH(1) time series.*

### Description

Returns a simulated time series $(Y_t)$ that fulfills the following equation:

$$Y_t = Z_t \sigma_t, \quad \sigma_t^2 = a_0 + a_1 Y_{t-1}^2 + \epsilon_t$$

where $a_0$ and $a_1$ are parameters and $\epsilon_t$ is independent white noise with marginal distribution specified by the parameter `innov`.

### Usage

```
ARCH1(n, a0, a1, overhead = 500, innov = rnorm)
```

### Arguments

| | |
|---|---|
| n | length of the time series to be returned |
| a0 | parameter |
| a1 | parameter |
| overhead | an integer specifying the "warmup" period to reach an approximate stationary start for the times series |
| innov | a function with one parameter n that yields n independent pseudo random numbers each time it is called. |

### Value

Return an ARCH(1) time series with specified parameters.

### Examples

```
plot(ARCH1(100, a0=1/1.9, a1=0.9), type="l")
```

---

## ts-models-QAR1 *Simulation of an QAR(1) time series.*

---

### Description

Returns a simulated time series $(Y_t)$ that fulfills the following equation:

$$Y_t = \theta_1(U_t)Y_{t-1} + \theta_0(U_t),$$

where $\theta_1$ and $\theta_0$ are parameters and $U_t$ is independent white noise with uniform $[0, 1]$ marginal distributions.

### Usage

```
QAR1(n, th1 = function(u) {     1.9 * ((u - 0.5)) }, overhead = 1000,
  th0 = qnorm)
```

### Arguments

| | |
|---|---|
| n | length of the time series to be returned |
| th1 | parameter function with one argument u defined on $[0, 1]$ |
| overhead | an integer specifying the "warmup" period to reach an approximate stationary start for the times series |
| th0 | parameter function with one argument u defined on $[0, 1]$ |

## Value

Returns an QAR(1) time series with specified parameters.

## Examples

```
plot(QAR1(100), type="l")
```

---

`Weight-class` *Interface Class to access different types of weighting functions.*

---

## Description

`Weights` is an S4 class that provides a common interface to implementations of a weighting function $W_n(\omega)$.

## Details

Currently three implementations are available: (1) `KernelWeight`, (2) `LagKernelWeight` and (3) `SpecDistrWeight`.

## Slots

`values` an array containing the weights.

`descr` a description to be used in some plots.

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