Package ‘simts’

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Type Package

Title Time Series Analysis Tools

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Description A system contains easy-to-use tools as a support for time series analysis courses. In particular, it incorporates a technique called Generalized Method of Wavelet Moments (GMWM) as well as its robust implementation for fast and robust parameter estimation of time series models which is described, for example, in Guerrier et al. (2013) <doi: 10.1080/01621459.2013.799920>. More details can also be found in the paper linked to via the URL below.

Depends R (>= 3.4.0)

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Imports Rcpp, stats, utils, scales, grDevices, graphics, broom, dplyr, magrittr, methods, purrr, tidyr, robcor

LinkingTo Rcpp, RcppArmadillo

RoxygenNote 6.1.1

Encoding UTF-8

Suggests knitr, rmarkdown

VignetteBuilder knitr

URL https://github.com/SMAC-Group/simts, https://arxiv.org/pdf/1607.04543.pdf

BugReports https://github.com/SMAC-Group/simts/issues

NeedsCompilation yes

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R topics documented:

`AIC.fitsimts` *Akaike's Information Criterion*

Description

This function calculates AIC, BIC or HQ for a fitsimts object. This function currently only supports models estimated by the MLE.

Usage

```
## S3 method for class 'fitsimts'
AIC(object, k = 2, ...)
```

Arguments

`object`	A fitsimts object.
`k`	The penalty per parameter to be used; the default k = 2 is the classical AIC.
`...`	Optionally more fitted model objects.

Value

AIC, BIC or HQ

Author(s)

Stéphane Guerrier

Examples

```
set.seed(1)
n = 300
Xt = gen_gts(n, AR(phi = c(0, 0, 0.8), sigma2 = 1))
mod = estimate(AR(3), Xt)

# AIC
AIC(mod)

# BIC
AIC(mod, k = log(n))

# HQ
AIC(mod, k = 2*log(log(n)))
```

AR *Create an Autoregressive P [AR(P)] Process*

Description

Sets up the necessary backend for the AR(P) process.

Usage

```
AR(phi = NULL, sigma2 = 1)
```

Arguments

`phi`	A `vector` with double values for the ϕ of an AR(P) process (see Note for details).
`sigma2`	A `double` value for the variance, σ^2, of an AR(P) process. (see Note for details).

Value

An S3 object with called ts.model with the following structure:

process.desc Used in summary: "AR-1","AR-2", ..., "AR-P", "SIGMA2"
theta ϕ_1, ϕ_2, ..., ϕ_p, σ^2
plength Number of Parameters
desc "AR"
print String containing simplified model
obj.desc Depth of Parameters e.g. list(p,1)
starting Guess starting values? TRUE or FALSE (e.g. specified value)

Note

We consider the following model:

$$X_t = \sum_{j=1}^{p} \phi_j X_{t-1} + \varepsilon_t$$

, where ε_t is iid from a zero mean normal distribution with variance σ^2.

Author(s)

James Balamuta

Examples

```
AR(1) # Slower version of AR1()
AR(phi=.32, sigma=1.3) # Slower version of AR1()
AR(2) # Equivalent to ARMA(2,0).
```

AR1 *Definition of an Autoregressive Process of Order 1*

Description

Definition of an Autoregressive Process of Order 1

Usage

```
AR1(phi = NULL, sigma2 = 1)
```

Arguments

phi	A `double` value for the parameter ϕ (see Note for details).
sigma2	A `double` value for the variance parameter σ^2 (see Note for details).

Value

An S3 object containing the specified ts.model with the following structure:

process.desc Used in summary: "AR1","SIGMA2"

theta Parameter vector including ϕ, σ^2

plength Number of parameters

print String containing simplified model

desc "AR1"

obj.desc Depth of Parameters e.g. list(1,1)

starting Find starting values? TRUE or FALSE (e.g. specified value)

Note

We consider the following AR(1) model:

$$X_t = \phi X_{t-1} + \varepsilon_t$$

, where ε_t is iid from a zero mean normal distribution with variance σ^2.

Author(s)

James Balamuta

Examples

```
AR1()
AR1(phi=.32, sigma2 = 1.3)
```

`ar1_to_wv` *AR(1) process to WV*

Description

This function computes the Haar WV of an AR(1) process

Usage

```
ar1_to_wv(phi, sigma2, tau)
```

Arguments

`phi`	A `double` that is the phi term of the AR(1) process
`sigma2`	A `double` corresponding to variance of AR(1) process
`tau`	A `vec` containing the scales e.g. 2^{τ}

Details

This function is significantly faster than its generalized counter part `arma_to_wv`.

Value

A `vec` containing the wavelet variance of the AR(1) process.

Process Haar Wavelet Variance Formula

The Autoregressive Order 1 (AR(1)) process has a Haar Wavelet Variance given by:

$$\frac{2\sigma^2\left(4\phi^{\frac{\tau_j}{2}+1}-\phi^{\tau_j+1}-\frac{1}{2}\phi^2\tau_j+\frac{\tau_j}{2}-3\phi\right)}{\left(1-\phi\right)^2\left(1-\phi^2\right)\tau_j^2}$$

`ARIMA` *Create an Autoregressive Integrated Moving Average (ARIMA) Process*

Description

Sets up the necessary backend for the ARIMA process.

Usage

```
ARIMA(ar = 1, i = 0, ma = 1, sigma2 = 1)
```

Arguments

ar	A vector or integer containing either the coefficients for ϕ's or the process number p for the Autoregressive (AR) term.
i	An integer containing the number of differences to be done.
ma	A vector or integer containing either the coefficients for θ's or the process number q for the Moving Average (MA) term.
sigma2	A double value for the standard deviation, σ, of the ARIMA process.

Details

A variance is required since the model generation statements utilize randomization functions expecting a variance instead of a standard deviation like R.

Value

An S3 object with called ts.model with the following structure:

process.desc $AR*p$, $MA*q$

theta σ

plength Number of parameters

print String containing simplified model

obj.desc y desc replicated x times

obj Depth of parameters e.g. list(c(length(ar),length(ma),1))

starting Guess starting values? TRUE or FALSE (e.g. specified value)

Note

We consider the following model:

$$\Delta^i X_t = \sum_{j=1}^{p} \phi_j \Delta^i X_{t-j} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t$$

, where ε_t is iid from a zero mean normal distribution with variance σ^2.

Author(s)

James Balamuta

Examples

```
# Create an ARMA(1,2) process
ARIMA(ar=1,2)
# Creates an ARMA(3,2) process with predefined coefficients.
ARIMA(ar=c(0.23,.43, .59), ma=c(0.4,.3))

# Creates an ARMA(3,2) process with predefined coefficients and standard deviation
ARIMA(ar=c(0.23,.43, .59), ma=c(0.4,.3), sigma2 = 1.5)
```

ARMA *Create an Autoregressive Moving Average (ARMA) Process*

Description

Sets up the necessary backend for the ARMA process.

Usage

```
ARMA(ar = 1, ma = 1, sigma2 = 1)
```

Arguments

`ar`	A `vector` or `integer` containing either the coefficients for ϕ's or the process number p for the Autoregressive (AR) term.
`ma`	A `vector` or `integer` containing either the coefficients for θ's or the process number q for the Moving Average (MA) term.
`sigma2`	A `double` value for the standard deviation, σ, of the ARMA process.

Details

A variance is required since the model generation statements utilize randomization functions expecting a variance instead of a standard deviation like R.

Value

An S3 object with called ts.model with the following structure:

process.desc $AR*p$, $MA*q$

theta σ

plength Number of Parameters

print String containing simplified model

obj.desc y desc replicated x times

obj Depth of Parameters e.g. list(c(length(ar),length(ma),1))

starting Guess Starting values? TRUE or FALSE (e.g. specified value)

Note

We consider the following model:

$$X_t = \sum_{j=1}^{p} \phi_j X_{t-j} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t$$

, where ε_t is iid from a zero mean normal distribution with variance σ^2.

Author(s)

James Balamuta

Examples

```
# Create an ARMA(1,2) process
ARMA(ar=1,2)
# Creates an ARMA(3,2) process with predefined coefficients.
ARMA(ar=c(0.23,.43, .59), ma=c(0.4,.3))

# Creates an ARMA(3,2) process with predefined coefficients and standard deviation
ARMA(ar=c(0.23,.43, .59), ma=c(0.4,.3), sigma2 = 1.5)
```

ARMA11 *Definition of an ARMA(1,1)*

Description

Definition of an ARMA(1,1)

Usage

```
ARMA11(phi = NULL, theta = NULL, sigma2 = 1)
```

Arguments

`phi`	A `double` containing the parameter ϕ_1 (see Note for details).
`theta`	A `double` containing the parameter θ_1 (see Note for details).
`sigma2`	A `double` value for the parameter σ^2 (see Note for details).

Details

A variance is required since the model generation statements utilize randomization functions expecting a variance instead of a standard deviation like R.

Value

An S3 object with called ts.model with the following structure:

process.desc $AR1$, $MA1$, $SIGMA2$

theta ϕ, θ, σ^2

plength Number of Parameters: 3

print String containing simplified model

obj.desc Depth of Parameters e.g. list(c(1,1,1))

starting Guess Starting values? `TRUE` or `FALSE` (e.g. specified value)

Note

We consider the following model:

$$X_t = \phi X_{t-1} + \theta_1 \varepsilon_{t-1} + \varepsilon_t,$$

where ε_t is iid from a zero mean normal distribution with variance σ^2.

Author(s)

James Balamuta

Examples

```
# Creates an ARMA(1,1) process with predefined coefficients.
ARMA11(phi = .23, theta = .1, sigma2 = 1)

# Creates an ARMA(1,1) process with values to be guessed on callibration.
ARMA11()
```

---

arma11_to_wv — *ARMA(1,1) to WV*

Description

This function computes the WV (haar) of an Autoregressive Order 1 - Moving Average Order 1 (ARMA(1,1)) process.

Usage

```
arma11_to_wv(phi, theta, sigma2, tau)
```

Arguments

`phi`	A `double` corresponding to the autoregressive term.
`theta`	A `double` corresponding to the moving average term.
`sigma2`	A `double` the variance of the process.
`tau`	A `vec` containing the scales e.g. 2^τ

Details

This function is significantly faster than its generalized counter part `arma_to_wv`

Value

A `vec` containing the wavelet variance of the ARMA(1,1) process.

Process Haar Wavelet Variance Formula

The Autoregressive Order 1 and Moving Average Order 1 (ARMA(1,1)) process has a Haar Wavelet Variance given by:

$$\nu_j^2\left(\phi,\theta,\sigma^2\right) = -\frac{2\sigma^2\left(-\frac{1}{2}(\theta+1)^2\left(\phi^2-1\right)\tau_j-(\theta+\phi)(\theta\phi+1)\left(\phi^{\tau_j}-4\phi^{\frac{\tau_j}{2}}+3\right)\right)}{(\phi-1)^3(\phi+1)\tau_j^2}$$

---

arma_to_wv *ARMA process to WV*

Description

This function computes the Haar Wavelet Variance of an ARMA process

Usage

```
arma_to_wv(ar, ma, sigma2, tau)
```

Arguments

`ar`	A `vec` containing the coefficients of the AR process
`ma`	A `vec` containing the coefficients of the MA process
`sigma2`	A `double` containing the residual variance
`tau`	A `vec` containing the scales e.g. 2^τ

Details

The function is a generic implementation that requires a stationary theoretical autocorrelation function (ACF) and the ability to transform an ARMA(p,q) process into an MA(∞) (e.g. infinite MA process).

Value

A `vec` containing the wavelet variance of the ARMA process.

Process Haar Wavelet Variance Formula

The Autoregressive Order p and Moving Average Order q (ARMA(p,q)) process has a Haar Wavelet Variance given by:

$$\frac{\tau_j\left[1-\rho\left(\frac{\tau_j}{2}\right)\right]+2\sum_{i=1}^{\frac{\tau_j}{2}-1} i\left[2\rho\left(\frac{\tau_j}{2}-i\right)-\rho\left(i\right)-\rho\left(\tau_j-i\right)\right]}{\tau_j^2}\sigma_X^2$$

where σ_X^2 is given by the variance of the ARMA process. Furthermore, this assumes that stationarity has been achieved as it directly

australia — *Quarterly Increase in Stocks Non-Farm Total, Australia*

Description

A dataset containing the quarterly increase in stocks non-farm total in Australia, with frequency 4 starting from September 1959 to March 1991 with a total of 127 observations.

Usage

```
australia
```

Format

A data frame with 127 rows and 2 variables:

Quarter year and quarter

Increase quarterly increase in stocks non-farm total

Source

Time Series Data Library (citing: Australian Bureau of Statistics) `https://datamarket.com/data/set/22t0/quarterly-increase-in-stocks-non-farm-total-australia-sep-1959-m` `!ds=22t0&display=line`

auto_corr — *Empirical ACF and PACF*

Description

This function can estimate either the autocovariance / autocorrelation for univariate time series, or the partial autocovariance / autocorrelation for univariate time series.

Usage

```
auto_corr(x, lag.max = NULL, pacf = FALSE, type = "correlation",
  demean = TRUE, robust = FALSE)
```

Arguments

- `x` — A `vector` or `ts` object (of length $N > 1$).
- `lag.max` — An `integer` indicating the maximum lag up to which to compute the empirical ACF / PACF.
- `pacf` — A `boolean` indicating whether to output the PACF. If it's `TRUE`, then the function will only estimate the empirical PACF. If it's `FALSE` (the default), then the function will only estimate the empirical ACF.
- `type` — A `character` string giving the type of acf to be computed. Allowed values are "correlation" (the default) and "covariance".
- `demean` — A `boolean` indicating whether the data should be detrended (`TRUE`) or not (`FALSE`). Defaults to `TRUE`.
- `robust` — A `boolean` indicating whether a robust estimator should be used (`TRUE`) or not (`FALSE`). Defaults to `FALSE`. This only works when the function is estimating ACF.

Details

`lagmax` default is $10 * log10(N/m)$ where N is the number of observations and m is the number of time series being compared. If `lagmax` supplied is greater than the number of observations N, then one less than the total will be taken (i.e. N - 1).

Value

An `array` of dimensions $N \times 1 \times 1$.

Author(s)

Yuming Zhang

Examples

```
m = auto_corr(datasets::AirPassengers)
m = auto_corr(datasets::AirPassengers, pacf = TRUE)
```

---

best_model — *Select the Best Model*

Description

This function retrieves the best model from a selection procedure.

Usage

```
best_model(x, ic = "aic")
```

Arguments

- `x` — An object of class `select_arma`, `select_ar` or `select_ma`.
- `ic` — A `string` indicating the type of criterion to use in selecting the best model. Supported criteria include "aic" (AIC), "bic" (BIC) and "hq" (HQ).

Examples

```
set.seed(18)
xt = gen_arima(N=100, ar=0.3, d=1, ma=0.3)
x = select_arima(xt, d=1L)
best_model(x, ic = "aic")

set.seed(19)
xt = gen_ma1(100, 0.3, 1)
x = select_ma(xt, q.min=2L, q.max=5L)
best_model(x, ic = "bic")

set.seed(20)
xt = gen_arma(100, c(.3,.5), c(.1), 1, 0)
x = select_arma(xt, p.min = 1L, p.max = 4L,
                q.min = 1L, q.max = 3L)
best_model(x, ic = "hq")
```

---

check — *Diagnostics on Fitted Time Series Model*

Description

This function can perform (simple) diagnostics on the fitted time series model. It can output 6 diagnostic plots to assess the model, including (1) residuals plot, (2) histogram of distribution of standardized residuals, (3) Normal Q-Q plot of residuals, (4) ACF plot, (5) PACF plot, (6) Box test results.

Usage

```
check(model = NULL, resids = NULL, simple = FALSE)
```

Arguments

- `model` — A `fitsimts`, `lm` or `gam` object.
- `resids` — A `vector` of residuals for diagnostics.
- `simple` — A `boolean` indicating whether to return simple diagnostic plots or not.

Author(s)

Stéphane Guerrier and Yuming Zhang

Examples

```
Xt = gen_gts(300, AR(phi = c(0, 0, 0.8), sigma2 = 1))
model = estimate(AR(3), Xt)
check(model)

check(resids = rnorm(100))

Xt = gen_gts(1000, SARIMA(ar = c(0.5, -0.25), i = 0, ma = 0.5, sar = -0.8,
si = 1, sma = 0.25, s = 24, sigma2 = 1))
model = estimate(SARIMA(ar = 2, i = 0, ma = 1, sar = 1, si = 1, sma = 1, s = 24),
Xt, method = "rgmwm")
check(model)
check(model, simple=TRUE)
```

`compare_acf` *Comparison of Classical and Robust Correlation Analysis Functions*

Description

Compare classical and robust ACF of univariate time series.

Usage

```
compare_acf(x, lag.max = NULL, demean = TRUE, show.ci = TRUE,
  alpha = 0.05, plot = TRUE, ...)
```

Arguments

`x`	A `vector` or `"ts"` object (of length $N > 1$).
`lag.max`	A `integer` indicating the maximum lag up to which to compute the ACF and PACF functions.
`demean`	A `bool` indicating whether the data should be detrended (`TRUE`) or not (`FALSE`). Defaults to `TRUE`.
`show.ci`	A `bool` indicating whether to compute and show the confidence region. Defaults to `TRUE`.
`alpha`	A `double` indicating the level of significance for the confidence interval. By default `alpha` = `0.05` which gives a 1 - `alpha` = 0.95 confidence interval.
`plot`	A `bool` indicating whether a plot of the computed quantities should be produced. Defaults to `TRUE`.
`...`	Additional parameters.

Author(s)

Yunxiang Zhang

Examples

```
# Estimate both the ACF and PACF functions
compare_acf(datasets::AirPassengers)
```

`corr_analysis` *Correlation Analysis Functions*

Description

Correlation Analysis function computes and plots both empirical ACF and PACF of univariate time series.

Usage

```
corr_analysis(x, lag.max = NULL, type = "correlation", demean = TRUE,
  show.ci = TRUE, alpha = 0.05, plot = TRUE, ...)
```

Arguments

`x`	A `vector` or `"ts"` object (of length $N > 1$).
`lag.max`	A `integer` indicating the maximum lag up to which to compute the ACF and PACF functions.
`type`	A `character` string giving the type of acf to be computed. Allowed values are "correlation" (the default) and "covariance".
`demean`	A `bool` indicating whether the data should be detrended (`TRUE`) or not (`FALSE`). Defaults to `TRUE`.
`show.ci`	A `bool` indicating whether to compute and show the confidence region. Defaults to `TRUE`.
`alpha`	A `double` indicating the level of significance for the confidence interval. By default `alpha` = `0.05` which gives a 1 - `alpha` = 0.95 confidence interval.
`plot`	A `bool` indicating whether a plot of the computed quantities should be produced. Defaults to `TRUE`.
`...`	Additional parameters.

Value

Two `array` objects (ACF and PACF) of dimension $N \times S \times S$.

Author(s)

Yunxiang Zhang

Examples

```
# Estimate both the ACF and PACF functions
corr_analysis(datasets::AirPassengers)
```

derivative_first_matrix *Analytic D matrix of Processes*

Description

This function computes each process to WV (haar) in a given model.

Usage

```
derivative_first_matrix(theta, desc, objdesc, tau)
```

Arguments

theta	A vec containing the list of estimated parameters.
desc	A vector<string> containing a list of descriptors.
objdesc	A field<vec> containing a list of object descriptors.
tau	A vec containing the scales e.g. 2^τ

Details

Function returns the matrix effectively known as "D"

Value

A matrix with the process derivatives going down the column

Author(s)

James Joseph Balamuta (JJB)

deriv_2nd_ar1 *Analytic second derivative matrix for AR(1) process*

Description

Calculates the second derivative for the AR(1) process and places it into a matrix form. The matrix form in this case is for convenience of the calculation.

Usage

```
deriv_2nd_ar1(phi, sigma2, tau)
```

Arguments

`phi`	A `double` corresponding to the phi coefficient of an AR(1) process.
`sigma2`	A `double` corresponding to the error term of an AR(1) process.
`tau`	A `vec` containing the scales e.g. 2^{τ}

Value

A `matrix` with the first column containing the second partial derivative with respect to ϕ and the second column contains the second partial derivative with respect to σ^2

Process Haar WV Second Derivative

Taking the second derivative with respect to ϕ yields:

$$\frac{\partial^2}{\partial \phi^2} \nu_j^2\left(\phi, \sigma^2\right) = \frac{2\sigma^2\left(\left(\phi^2-1\right)\tau_j\left(2(\phi(7\phi+4)+1)\phi^{\frac{\tau_j}{2}-1} - (\phi(7\phi+4)+1)\phi^{\tau_j-1} + 3(\phi+1)^2\right) + \left(\phi^2-1\right)^2\tau_j^2\left(\phi^{\tau} \cdots\right.\right.}{(\phi-1)^5(\phi+1)^3\tau_j^2}$$

Taking the second derivative with respect to σ^2 yields:

$$\frac{\partial^2}{\partial \sigma^4} \nu_j^2\left(\sigma^2\right) = 0$$

Taking the derivative with respect to ϕ and σ^2 yields:

$$\frac{\partial^2}{\partial \phi \partial \sigma^2} \nu_j^2\left(\phi, \sigma^2\right) = \frac{2\left(\left(\phi^2-1\right)\tau_j\left(\phi^{\tau_j} - 2\phi^{\frac{\tau_j}{2}} - \phi - 1\right) - (\phi(3\phi+2)+1)\left(\phi^{\tau_j} - 4\phi^{\frac{\tau_j}{2}} + 3\right)\right)}{(\phi-1)^4(\phi+1)^2\tau_j^2}$$

Author(s)

James Joseph Balamuta (JJB)

`deriv_2nd_arma11` *Analytic D matrix for ARMA(1,1) process*

Description

Obtain the second derivative of the ARMA(1,1) process.

Usage

```
deriv_2nd_arma11(phi, theta, sigma2, tau)
```

Arguments

`phi`	A `double` corresponding to the phi coefficient of an ARMA(1,1) process.
`theta`	A `double` corresponding to the theta coefficient of an ARMA(1,1) process.
`sigma2`	A `double` corresponding to the error term of an ARMA(1,1) process.
`tau`	A `vec` containing the scales e.g. 2^{τ}

Value

A `matrix` with:

- The **first** column containing the second partial derivative with respect to ϕ;
- The **second** column containing the second partial derivative with respect to θ;
- The **third** column contains the second partial derivative with respect to σ^2.
- The **fourth** column contains the partial derivative with respect to ϕ and θ.
- The **fiveth** column contains the partial derivative with respect to σ^2 and ϕ.
- The **sixth** column contains the partial derivative with respect to σ^2 and θ.

Process Haar WV Second Derivative

Taking the second derivative with respect to ϕ yields:

$$\frac{\partial^2}{\partial\phi^2}\nu_j^2\left(\phi,\theta,\sigma^2\right) = \frac{2\sigma^2}{(\phi-1)^5(\phi+1)^3\tau_j^2}\left(\begin{array}{r} (\phi-1)^2\left((\phi+1)^2\left(\theta^2\phi+\theta\phi^2+\theta+\phi\right)\tau_j^2\left(\phi^{\frac{\tau_j}{2}}\right.\right. \\ -12(\phi \\ +6(\phi+1)(\phi-1)\left(\frac{1}{2}(\theta+1)^2\left(\phi^2-1\right)\tau_j+(\theta+\phi)(\theta\phi+1)\left(\phi^{\tau_j}-4\phi^{\frac{\tau_j}{2}}\right.\right. \end{array}\right.$$

Taking the second derivative with respect to θ yields:

$$\frac{\partial^2}{\partial\theta^2}\nu_j^2\left(\phi,\theta,\sigma^2\right) = \frac{2\sigma^2\left(\left(\phi^2-1\right)\tau_j+2\phi\left(\phi^{\tau_j}-4\phi^{\frac{\tau_j}{2}}+3\right)\right)}{(\phi-1)^3(\phi+1)\tau_j^2}$$

Taking the second derivative with respect to σ^2 yields:

$$\frac{\partial^2}{\partial\sigma^4}\nu_j^2\left(\phi,\theta,\sigma^2\right) = 0$$

Taking the derivative with respect to σ^2 and θ yields:

$$\frac{\partial}{\partial\theta}\frac{\partial}{\partial\sigma^2}\nu_j^2\left(\phi,\theta,\sigma^2\right) = \frac{2}{(\phi-1)^3(\phi+1)\tau_j^2}\left((\theta+1)\left(\phi^2-1\right)\tau_j+\left(2\theta\phi+\phi^2+1\right)\left(\phi^{\tau_j}-4\phi^{\frac{\tau_j}{2}}+3\right)\right)$$

Taking the derivative with respect to σ^2 and ϕ yields:

$$\frac{\partial}{\partial\phi}\frac{\partial}{\partial\sigma^2}\nu_j^2\left(\phi,\theta,\sigma^2\right) = \frac{2}{(\phi-1)^4(\phi+1)^2\tau_j^2}\left(\begin{array}{l} -(\phi-1)(\phi+1)\left(\begin{array}{l} -(\theta+\phi)(\theta\phi+1)\tau_j\left(\phi^{\frac{\tau_j}{2}}-2\right)\phi^{\frac{\tau_j}{2}-1} \\ -\theta(\theta+\phi)\left(\phi^{\tau_j}-4\phi^{\frac{\tau_j}{2}}+3\right) \\ -(\theta\phi+1)\left(\phi^{\tau_j}-4\phi^{\frac{\tau_j}{2}}+3\right) \\ -(\theta+1)^2\phi\tau_j \end{array}\right) \\ +(\phi-1)\left(-\frac{1}{2}(\theta+1)^2\left(\phi^2-1\right)\tau_j-(\theta+\phi)(\theta\phi+1)\left(\phi^{\tau_j}-4\phi^{\frac{\tau_j}{2}}+\right.\right. \\ +3(\phi+1)\left(-\frac{1}{2}(\theta+1)^2\left(\phi^2-1\right)\tau_j-(\theta+\phi)(\theta\phi+1)\left(\phi^{\tau_j}-4\phi^{\frac{\tau_j}{2}}+\right.\right. \end{array}\right.$$

Taking the derivative with respect to ϕ and θ yields:

$$\frac{\partial}{\partial\theta}\frac{\partial}{\partial\phi}\nu_j^2\left(\phi,\theta,\sigma^2\right) = -\frac{2\sigma^2}{(\phi-1)^4(\phi+1)^2\tau_j^2}\left(\begin{array}{c}\tau_j\left(\begin{array}{c}2(\theta+1)(\phi-1)(\phi+1)^2\\ +2\left(\phi^2-1\right)\left(2\theta\phi+\phi^2+1\right)\phi^{\frac{\tau_j}{2}-1}\\ -\left(\phi^2-1\right)\left(2\theta\phi+\phi^2+1\right)\phi^{\tau_j-1}\end{array}\right)\\ +2\left(\theta(\phi(3\phi+2)+1)+\phi\left(\phi^2+\phi+3\right)+1\right)\left(\phi^{\tau_j}-4\phi^{\frac{\tau_j}{2}}+3\right)\end{array}\right)$$

Author(s)

James Joseph Balamuta (JJB)

`deriv_2nd_dr` *Analytic second derivative matrix for drift process*

Description

To ease a later calculation, we place the result into a matrix structure.

Usage

```
deriv_2nd_dr(tau)
```

Arguments

`tau`	A `vec` containing the scales e.g. 2^τ

Value

A `matrix` with the first column containing the second partial derivative with respect to ω.

Author(s)

James Joseph Balamuta (JJB)

`deriv_2nd_ma1` *Analytic second derivative for MA(1) process*

Description

To ease a later calculation, we place the result into a matrix structure.

Usage

```
deriv_2nd_ma1(theta, sigma2, tau)
```

Arguments

`theta`	A `double` corresponding to the theta coefficient of an MA(1) process.
`sigma2`	A `double` corresponding to the error term of an MA(1) process.
`tau`	A `vec` containing the scales e.g. 2^τ

Value

A `matrix` with the first column containing the second partial derivative with respect to θ, the second column contains the partial derivative with respect to θ and σ^2, and lastly we have the second partial derivative with respect to σ^2.

Process Haar WV Second Derivative

Taking the second derivative with respect to θ yields:

$$\frac{\partial^2}{\partial\theta^2}\nu_j^2\left(\theta,\sigma^2\right) = \frac{2\sigma^2}{\tau_j}$$

Taking the second derivative with respect to σ^2 yields:

$$\frac{\partial^2}{\partial\sigma^4}\nu_j^2\left(\theta,\sigma^2\right) = 0$$

Taking the first derivative with respect to θ and σ^2 yields:

$$\frac{\partial}{\partial\theta}\frac{\partial}{\partial\sigma^2}\nu_j^2\left(\theta,\sigma^2\right) = \frac{2(\theta+1)\tau_j - 6}{\tau_j^2}$$

Author(s)

James Joseph Balamuta (JJB)

`deriv_ar1` *Analytic D matrix for AR(1) process*

Description

Obtain the first derivative of the AR(1) process.

Usage

```
deriv_ar1(phi, sigma2, tau)
```

Arguments

`phi`	A `double` corresponding to the phi coefficient of an AR(1) process.
`sigma2`	A `double` corresponding to the error term of an AR(1) process.
`tau`	A `vec` containing the scales e.g. 2^τ

Value

A `matrix` with the first column containing the partial derivative with respect to ϕ and the second column contains the partial derivative with respect to σ^2

Process Haar WV First Derivative

Taking the derivative with respect to ϕ yields:

$$\frac{\partial}{\partial\phi}\nu_j^2\left(\phi,\sigma^2\right) = \frac{2\sigma^2\left(\left(\phi^2-1\right)\tau_j\left(-2\phi^{\frac{\tau_j}{2}}+\phi^{\tau_j}-\phi-1\right)-\left(\phi\left(3\phi+2\right)+1\right)\left(-4\phi^{\frac{\tau_j}{2}}+\phi^{\tau_j}+3\right)\right)}{\left(\phi-1\right)^4\left(\phi+1\right)^2\tau_j^2}$$

Taking the derivative with respect to σ^2 yields:

$$\frac{\partial}{\partial\sigma^2}\nu_j^2\left(\phi,\sigma^2\right) = \frac{\left(\phi^2-1\right)\tau_j+2\phi\left(-4\phi^{\frac{\tau_j}{2}}+\phi^{\tau_j}+3\right)}{\left(\phi-1\right)^3\left(\phi+1\right)\tau_j^2}$$

Author(s)

James Joseph Balamuta (JJB)

`deriv_arma11` *Analytic D matrix for ARMA(1,1) process*

Description

Obtain the first derivative of the ARMA(1,1) process.

Usage

```
deriv_arma11(phi, theta, sigma2, tau)
```

Arguments

`phi`	A `double` corresponding to the phi coefficient of an ARMA(1,1) process.
`theta`	A `double` corresponding to the theta coefficient of an ARMA(1,1) process.
`sigma2`	A `double` corresponding to the error term of an ARMA(1,1) process.
`tau`	A `vec` containing the scales e.g. 2^τ

Value

A `matrix` with:

- The **first** column containing the partial derivative with respect to ϕ;
- The **second** column containing the partial derivative with respect to θ;
- The **third** column contains the partial derivative with respect to σ^2.

Process Haar WV First Derivative

Taking the derivative with respect to ϕ yields:

$$\frac{\partial}{\partial\phi}\nu_j^2\left(\phi,\theta,\sigma^2\right) = \frac{2\sigma^2}{(\phi-1)^4(\phi+1)^2\tau_j^2}\left(\begin{array}{c} \tau_j\left(-(\theta+1)^2(\phi-1)(\phi+1)^2 - 2\left(\phi^2-1\right)(\theta+\phi)(\theta\phi+1)\phi^{\frac{\tau_j}{2}-1} + \left(\phi^2 - \right.\right. \\ -\left(\theta^2((3\phi+2)\phi+1) + 2\theta\left(\left(\phi^2+\phi+3\right)\phi+1\right) + (3\phi+2)\phi+1 \right. \end{array}\right.$$

Taking the derivative with respect to θ yields:

$$\frac{\partial}{\partial\theta}\nu_j^2\left(\phi,\theta,\sigma^2\right) = \frac{2\sigma^2\left((\theta+1)\left(\phi^2-1\right)\tau_j + \left(2\theta\phi+\phi^2+1\right)\left(\phi^{\tau_j} - 4\phi^{\frac{\tau_j}{2}} + 3\right)\right)}{(\phi-1)^3(\phi+1)\tau_j^2}$$

Taking the derivative with respect to σ^2 yields:

$$\frac{\partial}{\partial\sigma^2}\nu_j^2\left(\phi,\theta,\sigma^2\right) = \frac{2\sigma^2\left(\left(\phi^2-1\right)\tau_j + 2\phi\left(\phi^{\tau_j} - 4\phi^{\frac{\tau_j}{2}} + 3\right)\right)}{(\phi-1)^3(\phi+1)\tau_j^2}$$

Author(s)

James Joseph Balamuta (JJB)

`deriv_dr` *Analytic D matrix for Drift (DR) Process*

Description

Obtain the first derivative of the Drift (DR) process.

Usage

```
deriv_dr(omega, tau)
```

Arguments

omega	A `double` that is the slope of the drift.
tau	A `vec` containing the scales e.g. 2^τ

Value

A `matrix` with the first column containing the partial derivative with respect to ω.

Process Haar WV First Derivative

Taking the derivative with respect to ω yields:

$$\frac{\partial}{\partial \omega}\nu_j^2\left(\omega\right) = \frac{\tau_j^2 \omega}{8}$$

Note: We are taking the derivative with respect to ω and not ω^2 as the ω relates to the slope of the process and not the processes variance like RW and WN. As a result, a second derivative exists and is not zero.

Author(s)

James Joseph Balamuta (JJB)

`deriv_ma1` *Analytic D matrix for MA(1) process*

Description

Obtain the first derivative of the MA(1) process.

Usage

```
deriv_ma1(theta, sigma2, tau)
```

Arguments

`theta`	A `double` corresponding to the theta coefficient of an MA(1) process.
`sigma2`	A `double` corresponding to the error term of an MA(1) process.
`tau`	A `vec` containing the scales e.g. 2^τ

Value

A `matrix` with the first column containing the partial derivative with respect to θ and the second column contains the partial derivative with respect to σ^2

Process Haar WV First Derivative

Taking the derivative with respect to θ yields:

$$\frac{\partial}{\partial \theta}\nu_j^2\left(\theta, \sigma^2\right) = \frac{\sigma^2\left(2\left(\theta+1\right)\tau_j - 6\right)}{\tau_j^2}$$

Taking the derivative with respect to σ^2 yields:

$$\frac{\partial}{\partial \sigma^2}\nu_j^2\left(\theta, \sigma^2\right) = \frac{\left(\theta+1\right)^2\tau_j - 6\theta}{\tau_j^2}$$

Author(s)

James Joseph Balamuta (JJB)

deriv_qn — *Analytic D matrix for Quantization Noise (QN) Process*

Description

Obtain the first derivative of the Quantization Noise (QN) process.

Usage

```
deriv_qn(tau)
```

Arguments

`tau`	A `vec` containing the scales e.g. 2^τ

Value

A `matrix` with the first column containing the partial derivative with respect to Q^2.

Process Haar WV First Derivative

Taking the derivative with respect to Q^2 yields:

$$\frac{\partial}{\partial Q^2}\nu_j^2\left(Q^2\right) = \frac{6}{\tau_j^2}$$

Author(s)

James Joseph Balamuta (JJB)

deriv_rw — *Analytic D matrix Random Walk (RW) Process*

Description

Obtain the first derivative of the Random Walk (RW) process.

Usage

```
deriv_rw(tau)
```

Arguments

`tau`	A `vec` containing the scales e.g. 2^τ

Value

A `matrix` with the first column containing the partial derivative with respect to γ^2.

Process Haar WV First Derivative

Taking the derivative with respect to γ^2 yields:

$$\frac{\partial}{\partial \gamma^2} \nu_j^2 \left(\gamma^2\right) = \frac{\tau_j^2 + 2}{12 \tau_j}$$

Author(s)

James Joseph Balamuta (JJB)

`deriv_wn` *Analytic D Matrix for a Gaussian White Noise (WN) Process*

Description

Obtain the first derivative of the Gaussian White Noise (WN) process.

Usage

```
deriv_wn(tau)
```

Arguments

`tau`	A `vec` containing the scales e.g. 2^τ

Value

A `matrix` with the first column containing the partial derivative with respect to σ^2.

Process Haar WV First Derivative

Taking the derivative with respect to σ^2 yields:

$$\frac{\partial}{\partial \sigma^2} \nu_j^2 \left(\sigma^2\right) = \frac{1}{\tau_j}$$

Author(s)

James Joseph Balamuta (JJB)

diag_boxpierce *Box-Pierce*

Description

Performs the Box-Pierce test to assess the Null Hypothesis of Independence in a Time Series

Usage

```
diag_boxpierce(x, order = NULL, stop_lag = 20, stdres = FALSE,
  plot = TRUE)
```

Arguments

`x`	An `arima` or data set.
`order`	An `integer` indicating the degrees of freedom. If ‘x‘ is not a series of residuals, then set equal to 0.
`stop_lag`	An `integer` indicating the length of lags that should be calculated.
`stdres`	A `boolean` indicating whether to standardize the residualizes (e.g. $res/sd(res)$) or not.
`plot`	A logical. If `TRUE` (the default) a plot should be produced.

Author(s)

James Balamuta, Stéphane Guerrier, Yuming Zhang

diag_ljungbox *Ljung-Box*

Description

Performs the Ljung-Box test to assess the Null Hypothesis of Independence in a Time Series

Usage

```
diag_ljungbox(x, order = NULL, stop_lag = 20, stdres = FALSE,
  plot = TRUE)
```

Arguments

`x`	An `arima` or data set.
`order`	An `integer` indicating the degrees of freedom. If ‘x‘ is not a series of residuals, then set equal to 0.
`stop_lag`	An `integer` indicating the length of lags that should be calculated.
`stdres`	A `boolean` indicating whether to standardize the residualizes (e.g. $res/sd(res)$) or not.
`plot`	A logical. If `TRUE` (the default) a plot should be produced.

Author(s)

James Balamuta, Stéphane Guerrier, Yuming Zhang

---

diag_plot *Diagnostic Plot of Residuals*

Description

This function will plot 8 diagnostic plots to assess the model used to fit the data. These include: (1) residuals plot, (2) residuals vs fitted values, (3) histogram of distribution of standardized residuals, (4) Normal Q-Q plot of residuals, (5) ACF plot, (6) PACF plot, (7) Haar Wavelet Variance Representation, (8) Box test results.

Usage

```
diag_plot(Xt = NULL, model = NULL, resids = NULL, std = FALSE)
```

Arguments

`Xt`	The data used to construct said model.
`model`	A `fitsimts`, `lm` or `gam` object.
`resids`	A `vector` of residuals for diagnostics.
`std`	A `boolean` indicating whether we use standardized residuals for (1) residuals plot and (8) Box test results.

Author(s)

Yuming Zhang

---

diag_portmanteau_ *Portmanteau Tests*

Description

Performs the Portmanteau test to assess the Null Hypothesis of Independence in a Time Series

Usage

```
diag_portmanteau_(x, order = NULL, stop_lag = 20, stdres = FALSE,
  test = "Ljung-Box", plot = TRUE)
```

Arguments

x	An `arima` or data set.
order	An `integer` indicating the degrees of freedom. If ‘x‘ is not a series of residuals, then set equal to 0.
stop_lag	An `integer` indicating the length of lags that should be calculated.
stdres	A `boolean` indicating whether to standardize the residualizes (e.g. $res/sd(res)$) or not.
test	A `string` indicating whether to perform Ljung-Box test or Box-Pierce test.
plot	A logical. If `TRUE` (the default) a plot should be produced.

Author(s)

James Balamuta, Stéphane Guerrier, Yuming Zhang

DR — *Create an Drift (DR) Process*

Description

Sets up the necessary backend for the DR process.

Usage

```
DR(omega = NULL)
```

Arguments

omega	A `double` value for the slope of a DR process (see Note for details).

Value

An S3 object with called ts.model with the following structure:

process.desc Used in summary: "DR"

theta slope

print String containing simplified model

plength Number of parameters

obj.desc y desc replicated x times

obj Depth of parameters e.g. list(1)

starting Guess starting values? TRUE or FALSE (e.g. specified value)

Note

We consider the following model:

$$Y_t = \omega t$$

Author(s)

James Balamuta

Examples

```
DR()
DR(omega=3.4)
```

---

dr_to_wv *Drift to WV*

Description

This function compute the WV (haar) of a Drift process

Usage

```
dr_to_wv(omega, tau)
```

Arguments

omega	A double corresponding to the slope of the drift
tau	A vec containing the scales e.g. 2^τ

Value

A vec containing the wavelet variance of the drift.

Process Haar Wavelet Variance Formula

The Drift (DR) process has a Haar Wavelet Variance given by:

$$\nu_j^2\left(\omega\right) = \frac{\tau_j^2 \omega^2}{16}$$

estimate — *Fit a Time Series Model to Data*

Description

This function can fit a time series model to data using different methods.

Usage

```
estimate(model, Xt, method = "mle", demean = TRUE)
```

Arguments

`model`	A time series model.
`Xt`	A `vector` of time series data.
`method`	A `string` indicating the method used for model fitting. Supported methods include `mle`, `yule-walker`, `gmwm` and `rgmwm`.
`demean`	A `boolean` indicating whether the model includes a mean / intercept term or not.

Author(s)

Stéphane Guerrier and Yuming Zhang

Examples

```
Xt = gen_gts(300, AR(phi = c(0, 0, 0.8), sigma2 = 1))
plot(Xt)
estimate(AR(3), Xt)

Xt = gen_gts(300, MA(theta = 0.5, sigma2 = 1))
plot(Xt)
estimate(MA(1), Xt, method = "gmwm")

Xt = gen_gts(300, ARMA(ar = c(0.8, -0.5), ma = 0.5, sigma2 = 1))
plot(Xt)
estimate(ARMA(2,1), Xt, method = "rgmwm")

Xt = gen_gts(300, ARIMA(ar = c(0.8, -0.5), i = 1, ma = 0.5, sigma2 = 1))
plot(Xt)
estimate(ARIMA(2,1,1), Xt, method = "mle")

Xt = gen_gts(1000, SARIMA(ar = c(0.5, -0.25), i = 0, ma = 0.5, sar = -0.8,
si = 1, sma = 0.25, s = 24, sigma2 = 1))
plot(Xt)
estimate(SARIMA(ar = 2, i = 0, ma = 1, sar = 1, si = 1, sma = 1, s = 24), Xt,
method = "rgmwm")
```

evaluate *Evalute a time series or a list of time series models*

Description

This function calculates AIC, BIC and HQ or the MAPE for a list of time series models. This function currently only supports models estimated by the MLE.

Usage

```
evaluate(models, Xt, criterion = "IC", start = 0.8, demean = TRUE,
  print = TRUE)
```

Arguments

`models`	A time series model or a list of time series models.
`Xt`	A time series (i.e gts object).
`criterion`	Either "IC" for AIC, BIC and HQ or "MAPE" for MAPE.
`start`	A `numeric` indicating the starting proportion of the data that is used for prediction (assuming criterion = "MAPE").
`demean`	A `boolean` indicating whether the model includes a mean / intercept term or not.
`print`	logical. If `TRUE` (the default) results are printed.

Value

AIC, BIC and HQ or MAPE

Author(s)

Stéphane Guerrier

Examples

```
set.seed(18)
n = 300
Xt = gen_gts(n, AR(phi = c(0, 0, 0.8), sigma2 = 1))
evaluate(AR(1), Xt)
evaluate(list(AR(1), AR(3), MA(3), ARMA(1,2),
SARIMA(ar = 1, i = 0, ma = 1, sar = 1, si = 1, sma = 1, s = 12)), Xt)
evaluate(list(AR(1), AR(3)), Xt, criterion = "MAPE")
```

gen_ar1blocks *Generate AR(1) Block Process*

Description

This function allows us to generate a non-stationary AR(1) block process.

Usage

```
gen_ar1blocks(phi, sigma2, n_total, n_block, scale = 10,
title = NULL, seed = 135, ...)
```

Arguments

phi	A double value for the autocorrection parameter ϕ.
sigma2	A double value for the variance parameter σ^2.
n_total	An integer indicating the length of the simulated AR(1) block process.
n_block	An integer indicating the length of each block of the AR(1) block process.
scale	An integer indicating the number of levels of decomposition. The default value is 10.
title	A string indicating the name of the time series data.
seed	An integer defined for simulation replication purposes.
...	Additional parameters.

Value

A vector containing the AR(1) block process.

Note

This function generates a non-stationary AR(1) block process whose theoretical maximum overlapping allan variance (MOAV) is different from the theoretical MOAV of a stationary AR(1) process. This difference in the value of the allan variance between stationary and non-stationary processes has been shown through the calculation of the theoretical allan variance given in "A Study of the Allan Variance for Constant-Mean Non-Stationary Processes" by Xu et al. (IEEE Signal Processing Letters, 2017), preprint available: https://arxiv.org/abs/1702.07795.

Author(s)

Yuming Zhang and Haotian Xu

Examples

```
Xt = gen_ar1blocks(phi = 0.9, sigma2 = 1,
n_total = 1000, n_block = 10, scale = 100)
plot(Xt)

Yt = gen_ar1blocks(phi = 0.5, sigma2 = 5, n_total = 800,
n_block = 20, scale = 50)
plot(Yt)
```

---

gen_bi *Generate Bias-Instability Process*

Description

This function allows to generate a non-stationary bias-instability process.

Usage

```
gen_bi(sigma2, n_total, n_block, title = NULL, seed = 135, ...)
```

Arguments

sigma2	A double value for the variance parameter σ^2.
n_total	An integer indicating the length of the simulated bias-instability process.
n_block	An integer indicating the length of each block of the bias-instability process.
title	A string defining the name of the time series data.
seed	An integer defined for simulation replication purposes.
...	Additional parameters.

Value

A vector containing the bias-instability process.

Note

This function generates a non-stationary bias-instability process whose theoretical maximum overlapping allan variance (MOAV) is close to the theoretical MOAV of the best approximation of this process through a stationary AR(1) process over some scales. However, this approximation is not good enough when considering the logarithmic representation of the allan variance. Therefore, the exact form of the allan variance of this non-stationary process allows us to better interpret the signals characterized by bias-instability, as shown in "A Study of the Allan Variance for Constant-Mean Non-Stationary Processes" by Xu et al. (IEEE Signal Processing Letters, 2017), preprint available: https://arxiv.org/abs/1702.07795.

Author(s)

Yuming Zhang

Examples

```
Xt = gen_bi(sigma2 = 1, n_total = 1000, n_block = 10)
plot(Xt)

Yt = gen_bi(sigma2 = 0.8, n_total = 800, n_block = 20,
title = "non-stationary bias-instability process")
plot(Yt)
```

---

gen_gts *Simulate a simts TS object using a theoretical model*

Description

Create a `gts` object based on a time series model.

Usage

```
gen_gts(n, model, start = 0, end = NULL, freq = 1, unit_ts = NULL,
  unit_time = NULL, name_ts = NULL, name_time = NULL)
```

Arguments

n	An `integer` containing the length of the time series.
model	A `ts.model` or `simts` object containing the available models in the simts package.
start	A `numeric` that provides the time of the first observation.
end	A `numeric` that provides the time of the last observation.
freq	A `numeric` that provides the rate of samples. Default value is 1.
unit_ts	A `string` that contains the unit expression of the time series. Default value is `NULL`.
unit_time	A `string` that contains the unit expression of the time. Default value is `NULL`.
name_ts	A `string` that provides an identifier for the time series data. Default value is `NULL`.
name_time	A `string` that provides an identifier for the time. Default value is `NULL`.

Details

This function accepts either a `ts.model` object (e.g. AR1(phi = .3, sigma2 =1) + WN(sigma2 = 1)) or a `simts` object.

Value

A `gts` object

Author(s)

James Balamuta and Wenchao Yang

Examples

```
# Set seed for reproducibility
set.seed(1336)
n = 1000

# AR1 + WN
model = AR1(phi = .5, sigma2 = .1) + WN(sigma2=1)
x = gen_gts(n, model)
plot(x)

# Reset seed
set.seed(1336)

# GM + WN
# Convert from AR1 to GM values
m = ar1_to_gm(c(.5,.1),10)

# Beta = 6.9314718, Sigma2_gm = 0.1333333
model = GM(beta = m[1], sigma2_gm = m[2]) + WN(sigma2=1)
x2 = gen_gts(n, model, freq = 10, unit_time = 'sec')
plot(x2)

# Same time series
all.equal(x, x2, check.attributes = FALSE)
```

---

gen_lts — *Generate a Latent Time Series Object Based on a Model*

Description

Simulate a `lts` object based on a supplied time series model.

Usage

```
gen_lts(n, model, start = 0, end = NULL, freq = 1, unit_ts = NULL,
  unit_time = NULL, name_ts = NULL, name_time = NULL,
  process = NULL)
```

Arguments

n	An `interger` indicating the amount of observations generated in this function.
model	A `ts.model` or `simts` object containing one of the allowed models.
start	A `numeric` that provides the time of the first observation.
end	A `numeric` that provides the time of the last observation.

freq	A numeric that provides the rate/frequency at which the time series is sampled. The default value is 1.
unit_ts	A string that contains the unit of measure of the time series. The default value is NULL.
unit_time	A string that contains the unit of measure of the time. The default value is NULL.
name_ts	A string that provides an identifier for the time series data. Default value is NULL.
name_time	A string that provides an identifier for the time. Default value is NULL.
process	A vector that contains model names of each column in the data object where the last name is the sum of the previous names.

Details

This function accepts either a ts.model object (e.g. AR1(phi = .3, sigma2 =1) + WN(sigma2 = 1)) or a simts object.

Value

A lts object with the following attributes:

start The time of the first observation.

end The time of the last observation.

freq Numeric representation of the sampling frequency/rate.

unit A string reporting the unit of measurement.

name Name of the generated dataset.

process A vector that contains model names of decomposed and combined processes

Author(s)

James Balamuta, Wenchao Yang, and Justin Lee

Examples

```
# AR
set.seed(1336)
model = AR1(phi = .99, sigma2 = 1) + WN(sigma2 = 1)
test = gen_lts(1000, model)
plot(test)
```

gen_nswn *Generate Non-Stationary White Noise Process*

Description

This function allows to generate a non-stationary white noise process.

Usage

```
gen_nswn(n_total, title = NULL, seed = 135, ...)
```

Arguments

`n_total`	An `integer` indicating the length of the simulated non-stationary white noise process.
`title`	A `string` defining the name of the time series data.
`seed`	An `integer` defined for simulation replication purposes.
`...`	Additional parameters.

Value

A `vector` containing the non-stationary white noise process.

Note

This function generates a non-stationary white noise process whose theoretical maximum overlapping allan variance (MOAV) corresponds to the theoretical MOAV of the stationary white noise process. This example confirms that the allan variance is unable to distinguish between a stationary white noise process and a white noise process whose second-order behavior is non-stationary, as pointed out in the paper "A Study of the Allan Variance for Constant-Mean Non-Stationary Processes" by Xu et al. (IEEE Signal Processing Letters, 2017), preprint available: `https://arxiv.org/abs/1702.07795`.

Author(s)

Yuming Zhang

Examples

```
Xt = gen_nswn(n_total = 1000)
plot(Xt)

Yt = gen_nswn(n_total = 2000, title = "non-stationary
white noise process", seed = 1960)
plot(Yt)
```

GM *Create a Gauss-Markov (GM) Process*

Description

Sets up the necessary backend for the GM process.

Usage

```
GM(beta = NULL, sigma2_gm = 1)
```

Arguments

`beta`	A `double` value for the β of an GM process (see Note for details).
`sigma2_gm`	A `double` value for the variance, σ^2_{gm}, of a GM process (see Note for details).

Details

When supplying values for β and σ^2_{gm}, these parameters should be of a GM process and NOT of an AR1. That is, do not supply AR1 parameters such as ϕ, σ^2.

Internally, GM parameters are converted to AR1 using the ‘freq‘ supplied when creating data objects (gts) or specifying a ‘freq‘ parameter in simts or simts.imu.

The ‘freq‘ of a data object takes precedence over the ‘freq‘ set when modeling.

Value

An S3 object with called ts.model with the following structure:

process.desc Used in summary: "BETA","SIGMA2"

theta β, σ^2_{gm}

plength Number of parameters

print String containing simplified model

desc "GM"

obj.desc Depth of parameters e.g. list(1,1)

starting Guess starting values? TRUE or FALSE (e.g. specified value)

Note

We consider the following model:

$$X_t = e^{(-\beta)} X_{t-1} + \varepsilon_t$$

, where ε_t is iid from a zero mean normal distribution with variance $\sigma^2(1 - e^{2\beta})$.

Author(s)

James Balamuta

Examples

```
GM()
GM(beta=.32, sigma2_gm=1.3)
```

---

gmwm — *Generalized Method of Wavelet Moments (GMWM) for IMUs, ARMA, SSM, and Robust*

Description

Performs estimation of time series models by using the GMWM estimator.

Usage

```
gmwm(model, data, model.type = "ssm", compute.v = "auto",
  robust = FALSE, eff = 0.6, alpha = 0.05, seed = 1337, G = NULL,
  K = 1, H = 100, freq = 1)
```

Arguments

model	A `ts.model` object containing one of the allowed models.
data	A `matrix` or `data.frame` object with only column (e.g. $N \times 1$), a `lts` object, or a `gts` object.
model.type	A `string` containing the type of GMWM needed: `"imu"` or `"ssm"`.
compute.v	A `string` indicating the type of covariance matrix solver. Valid values are: `"fast"`, `"bootstrap"`, `"diag"` (asymptotic diag), `"full"` (asymptotic full). By default, the program will fit a "fast" model.
robust	A `boolean` indicating whether to use the robust computation (`TRUE`) or not (`FALSE`).
eff	A `double` between 0 and 1 that indicates the efficiency.
alpha	A `double` between 0 and 1 that correspondings to the $\frac{\alpha}{2}$ value for the wavelet confidence intervals.
seed	An `integer` that controls the reproducibility of the auto model selection phase.
G	An `integer` to sample the space for IMU and SSM models to ensure optimal identitability.
K	An `integer` that controls how many times the bootstrapping procedure will be initiated.
H	An `integer` that indicates how many different samples the bootstrap will be collect.
freq	A `double` that indicates the sampling frequency. By default, this is set to 1 and only is important if `GM()` is in the model

Details

This function is under work. Some of the features are active. Others... Not so much.

The V matrix is calculated by: $diag\left[(Hi - Lo)^2\right]$.

The function is implemented in the following manner: 1. Calculate MODWT of data with levels = floor(log2(data)) 2. Apply the brick.wall of the MODWT (e.g. remove boundary values) 3. Compute the empirical wavelet variance (WV Empirical). 4. Obtain the V matrix by squaring the difference of the WV Empirical's Chi-squared confidence interval (hi - lo)^2 5. Optimize the values to obtain $\hat{\theta}$ 6. If FAST = TRUE, return these results. Else, continue.

Loop k = 1 to K Loop h = 1 to H 7. Simulate xt under $F_{\hat{\theta}}$ 8. Compute WV Empirical END 9. Calculate the covariance matrix 10. Optimize the values to obtain $\hat{\theta}$ END 11. Return optimized values.

The function estimates a variety of time series models. If type = "imu" or "ssm", then parameter vector should indicate the characters of the models that compose the latent or state-space model. The model options are:

"AR1" a first order autoregressive process with parameters (ϕ, σ^2)

"GM" a guass-markov process (β, σ_{gm}^2)

"ARMA" an autoregressive moving average process with parameters $(\phi_p, \theta_q, \sigma^2)$

"DR" a drift with parameter ω

"QN" a quantization noise process with parameter Q

"RW" a random walk process with parameter σ^2

"WN" a white noise process with parameter σ^2

If only an ARMA() term is supplied, then the function takes conditional least squares as starting values If robust = TRUE the function takes the robust estimate of the wavelet variance to be used in the GMWM estimation procedure.

Value

A `gmwm` object with the structure:

estimate Estimated Parameters Values from the GMWM Procedure

init.guess Initial Starting Values given to the Optimization Algorithm

wv.empir The data's empirical wavelet variance

ci.low Lower Confidence Interval

ci.high Upper Confidence Interval

orgV Original V matrix

V Updated V matrix (if bootstrapped)

omega The V matrix inversed

obj.fun Value of the objective function at Estimated Parameter Values

theo Summed Theoretical Wavelet Variance

decomp.theo Decomposed Theoretical Wavelet Variance by Process

scales Scales of the GMWM Object

robust Indicates if parameter estimation was done under robust or classical

eff Level of efficiency of robust estimation

model.type Models being guessed

compute.v Type of V matrix computation

augmented Indicates moments have been augmented

alpha Alpha level used to generate confidence intervals

expect.diff Mean of the First Difference of the Signal

N Length of the Signal

G Number of Guesses Performed

H Number of Bootstrap replications

K Number of V matrix bootstraps

model `ts.model` supplied to gmwm

model.hat A new value of `ts.model` object supplied to gmwm

starting Indicates whether the procedure used the initial guessing approach

seed Randomization seed used to generate the guessing values

freq Frequency of data

`gmwm_imu` *GMWM for (Robust) Inertial Measurement Units (IMUs)*

Description

Performs the GMWM estimation procedure using a parameter transform and sampling scheme specific to IMUs.

Usage

```
gmwm_imu(model, data, compute.v = "fast", robust = F, eff = 0.6, ...)
```

Arguments

`model`	A `ts.model` object containing one of the allowed models.
`data`	A `matrix` or `data.frame` object with only column (e.g. $N \times 1$), or a `lts` object, or a `gts` object.
`compute.v`	A `string` indicating the type of covariance matrix solver. "fast", "bootstrap", "asymp.diag", "asymp.comp", "fft"
`robust`	A `boolean` indicating whether to use the robust computation (TRUE) or not (FALSE).
`eff`	A `double` between 0 and 1 that indicates the efficiency.
`...`	Other arguments passed to the main gmwm function

Details

This version of the gmwm function has customized settings ideal for modeling with an IMU object. If you seek to model with an Gauss Markov, `GM`, object. Please note results depend on the `freq` specified in the data construction step within the `imu`. If you wish for results to be stable but lose the ability to interpret with respect to `freq`, then use `AR1` terms.

Value

A `gmwm` object with the structure:

estimate Estimated Parameters Values from the GMWM Procedure

init.guess Initial Starting Values given to the Optimization Algorithm

wv.empir The data's empirical wavelet variance

ci.low Lower Confidence Interval

ci.high Upper Confidence Interval

orgV Original V matrix

V Updated V matrix (if bootstrapped)

omega The V matrix inversed

obj.fun Value of the objective function at Estimated Parameter Values

theo Summed Theoretical Wavelet Variance

decomp.theo Decomposed Theoretical Wavelet Variance by Process

scales Scales of the GMWM Object

robust Indicates if parameter estimation was done under robust or classical

eff Level of efficiency of robust estimation

model.type Models being guessed

compute.v Type of V matrix computation

augmented Indicates moments have been augmented

alpha Alpha level used to generate confidence intervals

expect.diff Mean of the First Difference of the Signal

N Length of the Signal

G Number of Guesses Performed

H Number of Bootstrap replications

K Number of V matrix bootstraps

model `ts.model` supplied to gmwm

model.hat A new value of `ts.model` object supplied to gmwm

starting Indicates whether the procedure used the initial guessing approach

seed Randomization seed used to generate the guessing values

freq Frequency of data

gts *Create a simts TS object using time series data*

Description

Takes a time series and turns it into a time series oriented object that can be used for summary and graphing functions in the simts package.

Usage

```
gts(data, start = 0, end = NULL, freq = 1, unit_ts = NULL,
  unit_time = NULL, name_ts = NULL, name_time = NULL,
  data_name = NULL, Time = NULL, time_format = NULL)
```

Arguments

data	A one-column matrix, data.frame, or a numeric vector.
start	A numeric that provides the time of the first observation.
end	A numeric that provides the time of the last observation.
freq	A numeric that provides the rate/frequency at which the time series is sampled. The default value is 1.
unit_ts	A string that contains the unit of measure of the time series. The default value is NULL.
unit_time	A string that contains the unit of measure of the time. The default value is NULL.
name_ts	A string that provides an identifier for the time series data. Default value is NULL.
name_time	A string that provides an identifier for the time. Default value is NULL.
data_name	A string that contains the name of the time series data.
Time	A numeric or character vector containing the times of observations. Default value is NULL. See x object in as.Date function.
time_format	A string specifiying the format of 'Time'. If not provided, 'Time' is assumed to be all integers. Default value is NULL. See format argument in as.Date function.

Value

A gts object

Author(s)

James Balamuta and Wenchao Yang

Examples

```
m = data.frame(rnorm(50))
x = gts(m, unit_time = 'sec', name_ts = 'example')
plot(x)

x = gen_gts(50, WN(sigma2 = 1))
x = gts(x, freq = 100, unit_time = 'sec')
plot(x)
```

---

hydro *Mean Monthly Precipitation, from 1907 to 1972*

Description

Hydrology data that indicates a robust approach may be preferred to a classical approach when estimating time series.

Usage

```
hydro
```

Format

A time series object with frequency 12 starting at 1907 and going to 1972 for a total of 781 observations.

Source

https://datamarket.com/data/set/22w1/mean-monthly-precipitation-1907-1972

---

imu_time *Pulls the IMU time from the IMU object*

Description

Helper function for the IMU object to access `rownames()` with a numeric conversion.

Usage

```
imu_time(x)
```

Arguments

x	A `imu` object

Value

A `vector` with numeric information.

is.gts — *Is simts Object*

Description

Is the object a `gts`, `imu`, or `lts` object?

Usage

```
is.gts(x)

is.imu(x)

is.lts(x)

is.ts.model(x)
```

Arguments

`x`	A `gts`, `imu`, `lts` object.

Details

Uses `inherits` over `is` for speed.

Value

A `logical` value that indicates whether the object is of that class (TRUE) or not (FALSE).

Author(s)

James Balamuta

lts — *Generate a Latent Time Series Object from Data*

Description

Create a `lts` object based on a supplied matrix or data frame. The latent time series is obtained by the sum of underlying time series.

Usage

```
lts(data, start = 0, end = NULL, freq = 1, unit_ts = NULL,
  unit_time = NULL, name_ts = NULL, name_time = NULL,
  process = NULL)
```

Arguments

`data`	A multiple-column `matrix` or `data.frame`. It must contain at least 3 columns of which the last represents the latent time series obtained through the sum of the previous columns.
`start`	A `numeric` that provides the time of the first observation.
`end`	A `numeric` that provides the time of the last observation.
`freq`	A `numeric` that provides the rate/frequency at which the time series is sampled. The default value is 1.
`unit_ts`	A `string` that contains the unit of measure of the time series. The default value is `NULL`.
`unit_time`	A `string` that contains the unit of measure of the time. The default value is `NULL`.
`name_ts`	A `string` that provides an identifier for the time series data. Default value is `NULL`.
`name_time`	A `string` that provides an identifier for the time. Default value is `NULL`.
`process`	A `vector` that contains model names of each column in the `data` object where the last name is the sum of the previous names.

Value

A `lts` object

Author(s)

Wenchao Yang and Justin Lee

Examples

```
model1 = AR1(phi = .99, sigma2 = 1)
model2 = WN(sigma2 = 1)
col1 = gen_gts(1000, model1)
col2 = gen_gts(1000, model2)
testMat = cbind(col1, col2, col1+col2)
testLts = lts(testMat, unit_time = 'sec', process = c('AR1', 'WN', 'AR1+WN'))
plot(testLts)
```

MA *Create an Moving Average Q [MA(Q)] Process*

Description

Sets up the necessary backend for the MA(Q) process.

Usage

```
MA(theta = NULL, sigma2 = 1)
```

Arguments

`theta`	A `double` value for the parameter θ (see Note for details).
`sigma2`	A `double` value for the variance parameter σ^2 (see Note for details).

Value

An S3 object with called ts.model with the following structure:

process.desc Used in summary: "MA-1","MA-2", ..., "MA-Q", "SIGMA2"

theta θ_1, θ_2, ..., θ_q, σ^2

plength Number of parameters

desc "MA"

print String containing simplified model

obj.desc Depth of parameters e.g. list(q,1)

starting Guess starting values? TRUE or FALSE (e.g. specified value)

Note

We consider the following model:

$$X_t = \sum_{j=1}^{q} \theta_j \varepsilon_{t-1} + \varepsilon_t$$

, where ε_t is iid from a zero mean normal distribution with variance σ^2.

Author(s)

James Balamuta

Examples

```
MA(1) # One theta
MA(2) # Two thetas!

MA(theta=.32, sigma=1.3) # 1 theta with a specific value.
MA(theta=c(.3,.5), sigma=.3) # 2 thetas with specific values.
```

MA1 *Definition of an Moving Average Process of Order 1*

Description

Definition of an Moving Average Process of Order 1

Usage

```
MA1(theta = NULL, sigma2 = 1)
```

Arguments

`theta`	A `double` value for the parameter θ (see Note for details).
`sigma2`	A `double` value for the variance parameter σ^2 (see Note for details).

Value

An S3 object with called ts.model with the following structure:

process.desc Used in summary: "MA1","SIGMA2"

theta θ, σ^2

plength Number of parameters

print String containing simplified model

desc "MA1"

obj.desc Depth of parameters e.g. list(1,1)

starting Guess starting values? TRUE or FALSE (e.g. specified value)

Note

We consider the following model:

$$X_t = \theta \varepsilon_{t-1} + \varepsilon_t$$

, where ε_t is iid from a zero mean normal distribution with variance σ^2.

Author(s)

James Balamuta

Examples

```
MA1()
MA1(theta = .32, sigma2 = 1.3)
```

ma1_to_wv — *Moving Average Order 1 (MA(1)) to WV*

Description

This function computes the WV (haar) of a Moving Average order 1 (MA1) process.

Usage

```
ma1_to_wv(theta, sigma2, tau)
```

Arguments

`theta`	A `double` corresponding to the moving average term.
`sigma2`	A `double` the variance of the process.
`tau`	A `vec` containing the scales e.g. 2^τ

Details

This function is significantly faster than its generalized counter part `arma_to_wv`.

Value

A `vec` containing the wavelet variance of the MA(1) process.

Process Haar Wavelet Variance Formula

The Moving Average Order 1 (MA(1)) process has a Haar Wavelet Variance given by:

$$\nu_j^2\left(\theta, \sigma^2\right) = \frac{\left((\theta+1)^2\tau_j - 6\theta\right)\sigma^2}{\tau_j^2}$$

make_frame — *Default utility function for various plots titles*

Description

Adds title, grid, and required x- and y-axes.

Usage

```
make_frame(x_range, y_range, xlab, ylab, main = "", mar = c(5.1, 5.1,
  1, 2.1), add_axis_x = TRUE, add_axis_y = TRUE, col_box = "black",
  col_grid = "grey95", col_band = "grey95", col_title = "black",
  add_band = TRUE, title_band_width = 0.09, grid_lty = 1)
```

Arguments

- `x_range` A `numeric` providing the range of values for the x-axis.
- `y_range` A `numeric` providing the range of values for the y-axis.
- `xlab` A `string` that gives a title for the x-axis.
- `ylab` A `string` that gives a title for the y-axis.
- `main` A `string` that gives an overall title for the plot. Default is an empty string.
- `mar` A `vector` indicating overall margin values for the plot.
- `add_axis_x` A `boolean` indicating whether a x-axis should be added.
- `add_axis_y` A `boolean` indicating whether a y-axis should be added.
- `col_box` A `string` indicating the color for the title box.
- `col_grid` A `string` indicating the color of the grid for the plot.
- `col_band` A `string` indicating the color of the band.
- `col_title` A `string` indicating the color of the plot title.
- `add_band` A `boolean` indicating whether there should be a band.
- `title_band_width` A `double` providing the value of the band width. Default is 0.09.
- `grid_lty` A `integer` indicating the line type of the grid lines.

Value

Added title, grid, and axes.

Author(s)

Stephane Guerrier and Justin Lee

Examples

```
make_frame(x_range = c(0, 1), y_range = c(0, 1), xlab = "my xlab",
           ylab = "my ylab", main = "my title")

make_frame(x_range = c(0, 1), y_range = c(0, 1), xlab = "my xlab",
           ylab = "my ylab", add_band = FALSE)

make_frame(x_range = c(0, 1), y_range = c(0, 1), xlab = "my xlab",
           ylab = "my ylab", main = "my title", col_band = "blue3",
           col_title = "white", col_grid = "lightblue", grid_lty = 3)

make_frame(x_range = c(0, 1), y_range = c(0, 1), xlab = "my xlab",
           ylab = "my ylab", main = "my title", col_band = "blue3",
           col_title = "white", col_grid = "lightblue", grid_lty = 3,
           title_band_width = 0.18)
```

`MAPE` *Median Absolute Prediction Error*

Description

This function calculates Median Absolute Prediction Error (MAPE), which assesses the prediction performance with respect to point forecasts of a given model. It is calculated based on one-step ahead prediction and reforecasting.

Usage

```
MAPE(model, Xt, start = 0.8, plot = TRUE)
```

Arguments

`model`	A time series model.
`Xt`	A `vector` of time series data.
`start`	A `numeric` indicating the starting proportion of the data that is used for prediction.
`plot`	A `boolean` indicating whether a model accuracy plot based on MAPE is returned or not.

Value

The MAPE calculated based on one-step ahead prediction and reforecasting is returned along with its standard deviation.

Author(s)

Stéphane Guerrier and Yuming Zhang

`np_boot_sd_med` *Bootstrap standard error for the median*

Description

Non-parametric bootstrap to obtain the standard of the median of iid data.

Usage

```
np_boot_sd_med(x, B = 5000)
```

Arguments

`x`	A `vector` of data.
`B`	A `numeric` indicating the number of simulations.

Value

Bootstrap standard error for the median

---

plot.PACF *Plot Partial Auto-Covariance and Correlation Functions*

Description

The function plots the output of the `theo_pacf` and `auto_corr` functions (partial autocovariance or autocorrelation functions).

Usage

```
## S3 method for class 'PACF'
plot(x, xlab = NULL, ylab = NULL, show.ci = TRUE,
  alpha = NULL, col_ci = NULL, transparency = NULL, main = NULL,
  parValue = NULL, ...)
```

Arguments

`x`	A `"PACF"` object output from `theo_pacf` or `auto_corr`.
`xlab`	A `string` indicating the label of the x axis: the default name is 'Lags'.
`ylab`	A `string` indicating the label of the y axis: the default name is 'PACF'.
`show.ci`	A `bool` indicating whether to show the confidence region. Defaults to `TRUE`.
`alpha`	A `double` indicating the level of significance for the confidence interval. By default `alpha` = `0.05` which gives a 1 - `alpha` = 0.95 confidence interval.
`col_ci`	A `string` that specifies the color of the region covered by the confidence intervals (confidence region).
`transparency`	A `double` between 0 and 1 indicating the transparency level of the color defined in `col_ci`. Defaults to 0.25.
`main`	A `string` indicating the title of the plot. Default name is "Variable name PACF plot'.
`parValue`	A `vector` defining the margins for the plot.
`...`	Additional parameters

Author(s)

Yunxiang Zhang and Yuming Zhang

Examples

```
# Plot the Partial Autocorrelation
m = auto_corr(datasets::AirPassengers, pacf = TRUE)
plot(m)

# More customized CI
plot(m, xlab = "my xlab", ylab = "my ylab", show.ci = TRUE,
alpha = NULL, col_ci = "grey", transparency = 0.5, main = "my main")
```

`plot.simtsACF` *Plot Auto-Covariance and Correlation Functions*

Description

The function plots the output of the `theo_acf` and `auto_corr` functions (autocovariance or autocorrelation functions).

Usage

```
## S3 method for class 'simtsACF'
plot(x, xlab = NULL, ylab = NULL, show.ci = TRUE,
  alpha = NULL, col_ci = NULL, transparency = NULL, main = NULL,
  parValue = NULL, ...)
```

Arguments

`x`	An `"ACF"` object output from `theo_acf` and `auto_corr`.
`xlab`	A `string` indicating the label of the x axis: the default name is 'Lags'.
`ylab`	A `string` indicating the label of the y axis: the default name is 'ACF'.
`show.ci`	A `bool` indicating whether to show the confidence region. Defaults to `TRUE`.
`alpha`	A `double` indicating the level of significance for the confidence interval. By default `alpha` = `0.05` which gives a 1 - `alpha` = 0.95 confidence interval.
`col_ci`	A `string` that specifies the color of the region covered by the confidence intervals (confidence region).
`transparency`	A `double` between 0 and 1 indicating the transparency level of the color defined in `col_ci`. Defaults to 0.25.
`main`	A `string` indicating the title of the plot. Default name is "Variable name ACF plot'.
`parValue`	A `vector` defining the margins for the plot.
`...`	Additional parameters

Author(s)

Yunxiang Zhang, Stéphane Guerrier and Yuming Zhang

Examples

```
# Calculate the Autocorrelation
m = auto_corr(datasets::AirPassengers)

# Plot with 95% CI
plot(m)

# Plot with 90% CI
plot(m, alpha = 0.1)

# Plot without 95% CI
plot(m, show.ci = FALSE)

# More customized CI
plot(m, xlab = "my xlab", ylab = "my ylab", show.ci = TRUE,
alpha = NULL, col_ci = "grey", transparency = 0.5, main = "my main")
```

`plot_pred` *Plot Time Series Forecast Function*

Description

This function plots the time series output from a forecast method with approximate 68

Usage

```
plot_pred(x, model, n.ahead, level = NULL, xlab = NULL, ylab = NULL,
  main = NULL, ...)
```

Arguments

`x`	A `gts` object
`model`	A `ts` model
`n.ahead`	An `integer` indicating number of units of time ahead for which to make forecasts
`level`	A `double` or `vector` indicating confidence level of prediction interval. By default, it uses the levels of 0.50 and 0.95.
`xlab`	A `string` for the title of x axis
`ylab`	A `string` for the title of y axis
`main`	A `string` for the over all title of the plot
`...`	Additional parameters

Author(s)

Yuming Zhang

predict.fitsimts — *Time Series Prediction*

Description

This function plots the time series forecast.

Usage

```
## S3 method for class 'fitsimts'
predict(object, n.ahead = 10, show_last = 100,
  level = NULL, xlab = NULL, ylab = NULL, main = NULL,
  plot = TRUE, ...)
```

Arguments

`object`	A `fitsimts` object obtained from `estimate` function.
`n.ahead`	An `integer` indicating number of units of time ahead for which to make forecasts.
`show_last`	A `integer` indicating the number of last observations to show in the forecast plot.
`level`	A `double` or `vector` indicating confidence level of prediction interval. By default, it uses the levels of 0.50 and 0.95.
`xlab`	A `string` for the title of x axis.
`ylab`	A `string` for the title of y axis.
`main`	A `string` for the over all title of the plot.
`plot`	A `logical` value. logical. If `TRUE`(the default) the predictions are plotted.
`...`	Additional arguments.

Author(s)

Stéphane Guerrier and Yuming Zhang

Examples

```
Xt = gen_gts(300, AR(phi = c(0, 0, 0.8), sigma2 = 1))
model = estimate(AR(3), Xt)
predict(model)
predict(model, level = 0.95)

x = gts(as.vector(lynx), start = 1821, end = 1934, freq = 1,
unit_ts = bquote(paste(10^8," ",m^3)), name_ts = "Numbers",
unit_time = "year", data_name = "Annual Numbers of Lynx Trappings")
model = estimate(AR(1), x)
predict(model, n.ahead = 20)
predict(model, n.ahead = 20, level = 0.95)
```

```
predict(model, n.ahead = 20, level = c(0.50, 0.80, 0.95))
```

---

predict.gmwm *Predict future points in the time series using the solution of the Generalized Method of Wavelet Moments*

Description

Creates a prediction using the estimated values of GMWM through the ARIMA function within R.

Usage

```
## S3 method for class 'gmwm'
predict(object, data.in.gmwm, n.ahead = 1, ...)
```

Arguments

`object`	A `gmwm` object
`data.in.gmwm`	The data SAME EXACT DATA used in the GMWM estimation
`n.ahead`	Number of observations to forecast
`...`	Additional parameters passed to ARIMA Predict

Value

A `predict.gmwm` object with:

pred Predictions

se Standard Errors

resid Residuals from ARIMA ML Fit

QN *Create an Quantisation Noise (QN) Process*

Description

Sets up the necessary backend for the QN process.

Usage

```
QN(q2 = NULL)
```

Arguments

`q2`	A `double` value for the Q^2 of a QN process.

Value

An S3 object with called ts.model with the following structure:

process.desc Used in summary: "QN"

theta Q^2

plength Number of parameters

print String containing simplified model

desc y desc replicated x times

obj.desc Depth of parameters e.g. list(1)

starting Guess starting values? TRUE or FALSE (e.g. specified value)

Author(s)

James Balamuta

Examples

```
QN()
QN(q2=3.4)
```

`qn_to_wv` *Quantisation Noise (QN) to WV*

Description

This function compute the Haar WV of a Quantisation Noise (QN) process

Usage

```
qn_to_wv(q2, tau)
```

Arguments

`q2`	A `double` corresponding to variance of drift
`tau`	A `vec` containing the scales e.g. 2^τ

Value

A `vec` containing the wavelet variance of the QN.

Process Haar Wavelet Variance Formula

The Quantization Noise (QN) process has a Haar Wavelet Variance given by:

$$\nu_j^2\left(Q^2\right) = \frac{6Q^2}{\tau_j^2}$$

`resid_plot` *Plot the Distribution of (Standardized) Residuals*

Description

This function plots a histogram (with kernel density function and normal distribution) of the standardized residuals or a basic plot the (standardized) residuals, or both.

Usage

```
resid_plot(res, std = FALSE, type = "hist", ...)
```

Arguments

`res`	A `vector` of residuals.
`std`	A `boolean` indicating whether the residuals plot is for standardized residuals or original residuals.
`type`	A `string` indicating either: `"hist"` (standardized residual histogram with superimposed kernel density estimator and normal distribution), `"resid"` (standard residual plot), or `"both"`
`...`	Additional parameters

Author(s)

Yuming Zhang

`rgmwm` *GMWM for Robust/Classical Comparison*

Description

Creates a `rgmwm` object to compare the results generated by robust/classical method.

Usage

```
rgmwm(model, data, eff = c(0.9, 0.8, 0.6), ...)
```

Arguments

`model`	A `ts.model` object containing one of the allowed models.
`data`	A `matrix` or `data.frame` object with only one column (e.g. $N \times 1$), or a `lts` object, or a `gts` object.
`eff`	A `double vector` between 0 and 1 that indicates the efficiency.
`...`	Other arguments passed to the main `gmwm` function.

Details

By default, the `rgmwm` function will fit a classical `gmwm` object. From there, the user has the ability to specify any `eff` that is less than or equal to 0.99.

Value

A `rgmwm` object

`rtruncated_normal` *Truncated Normal Distribution Sampling Algorithm*

Description

Enables sampling from a truncated normal

Usage

```
rtruncated_normal(n, mu, sigma, a, b)
```

Arguments

`n`	An `unsigned int` indicating the number of observations to generate.
`mu`	A `double` indicating the mean of the normal.
`sigma`	A `double` indicating the standard deviation of the normal.
`a`	A `double` that is the lower bound of the truncated normal.
`b`	A `double` that is the upper bound of the truncated normal.

`RW` *Create an Random Walk (RW) Process*

Description

Sets up the necessary backend for the RW process.

Usage

```
RW(gamma2 = NULL)
```

Arguments

`gamma2`	A `double` value for the variance γ^2

Value

An S3 object with called ts.model with the following structure:

process.desc Used in summary: "RW"

theta σ

plength Number of parameters

print String containing simplified model

desc y desc replicated x times

obj.desc Depth of parameters e.g. list(1)

starting Guess starting values? TRUE or FALSE (e.g. specified value)

Note

We consider the following model:

$$Y_t = \sum_{t=0}^{T} \gamma_0 * Z_t$$

where Z_t is iid and follows a standard normal distribution.

Author(s)

James Balamuta

Examples

```
RW()
RW(gamma2=3.4)
```

`RW2dimension` *Function to Compute Direction Random Walk Moves*

Description

The RW2dimension function computes direction random walk moves.

Usage

```
RW2dimension(steps = 100, probs = c(0.25, 0.5, 0.75))
```

Arguments

`steps`	An `integer` that counts the number of steps of the random walk.
`probs`	A `vector` of `double` that specifies the probabilities to choose each direction.

Author(s)

Stéphane Guerrier

Examples

```
RW2dimension(steps = 50, probs = c(0.2, 0.5, 0.6))
```

---

rw_to_wv — *Random Walk to WV*

Description

This function compute the WV (haar) of a Random Walk process

Usage

```
rw_to_wv(gamma2, tau)
```

Arguments

gamma2	A `double` corresponding to variance of RW
tau	A `vec` containing the scales e.g. 2^{τ}

Value

A `vec` containing the wavelet variance of the random walk.

Process Haar Wavelet Variance Formula

The Random Walk (RW) process has a Haar Wavelet Variance given by:

$$\nu_j^2\left(\gamma^2\right) = \frac{\left(\tau_j^2 + 2\right)\gamma^2}{12\tau_j}$$

---

sales — *Sales Dataset*

Description

This dataset contains the US monthly clothing retail sales in millions of dollars taken from 1992 to 2016 for a total of 302 observations.

Usage

```
sales
```

Format

A dataframe with 302 rows and 1 variable:

Source

http://r-exercises.com/wp-content/uploads/2017/04/sales.csv

SARIMA — *Create a Seasonal Autoregressive Integrated Moving Average (SARIMA) Process*

Description

Sets up the necessary backend for the SARIMA process.

Usage

```
SARIMA(ar = 1, i = 0, ma = 1, sar = 1, si = 0, sma = 1,
  s = 12, sigma2 = 1)
```

Arguments

`ar`	A `vector` or `integer` containing either the coefficients for ϕ's or the process number p for the Autoregressive (AR) term.
`i`	An `integer` containing the number of differences to be done.
`ma`	A `vector` or `integer` containing either the coefficients for θ's or the process number q for the Moving Average (MA) term.
`sar`	A `vector` or `integer` containing either the coefficients for Φ's or the process number P for the Seasonal Autoregressive (SAR) term.
`si`	An `integer` containing the number of seasonal differences to be done.
`sma`	A `vector` or `integer` containing either the coefficients for Θ's or the process number Q for the Seasonal Moving Average (SMA) term.
`s`	An `integer` containing the seasonality.
`sigma2`	A `double` value for the standard deviation, σ, of the SARMA process.

Details

A variance is required since the model generation statements utilize randomization functions expecting a variance instead of a standard deviation unlike R.

Value

An S3 object with called ts.model with the following structure:

process.desc $AR*p$, $MA*q$, $SAR*P$, $SMA*Q$

theta σ

plength Number of parameters

desc Type of model

desc.simple Type of model (after simplification)

print String containing simplified model

obj.desc y desc replicated x times

obj Depth of Parameters e.g. list(c(length(ar), length(ma), length(sar), length(sma), 1, i, si))

starting Guess Starting values? TRUE or FALSE (e.g. specified value)

Author(s)

James Balamuta

Examples

```
# Create an SARIMA(1,1,2)x(1,0,1) process
SARIMA(ar = 1, i = 1, ma = 2, sar = 1, si = 0, sma =1)

# Creates an SARMA(1,0,1)x(1,1,1) process with predefined coefficients.
SARIMA(ar=0.23, i = 0, ma=0.4, sar = .3,  sma = .3)
```

SARMA *Create a Seasonal Autoregressive Moving Average (SARMA) Process*

Description

Sets up the necessary backend for the SARMA process.

Usage

```
SARMA(ar = 1, ma = 1, sar = 1, sma = 1, s = 12, sigma2 = 1)
```

Arguments

`ar`	A `vector` or `integer` containing either the coefficients for ϕ's or the process number p for the Autoregressive (AR) term.
`ma`	A `vector` or `integer` containing either the coefficients for θ's or the process number q for the Moving Average (MA) term.
`sar`	A `vector` or `integer` containing either the coefficients for Φ's or the process number P for the Seasonal Autoregressive (SAR) term.
`sma`	A `vector` or `integer` containing either the coefficients for Θ's or the process number Q for the Seasonal Moving Average (SMA) term.
`s`	A `integer` indicating the seasonal value of the data.
`sigma2`	A `double` value for the standard deviation, σ, of the SARMA process.

Details

A variance is required since the model generation statements utilize randomization functions expecting a variance instead of a standard deviation unlike R.

Value

An S3 object with called ts.model with the following structure:

process.desc $AR * p$, $MA * q$, $SAR * P$, $SMA * Q$

theta σ

plength Number of Parameters

print String containing simplified model

obj.desc y desc replicated x times

obj Depth of Parameters e.g. list(c(length(ar), length(ma), length(sar), length(sma), 1))

starting Guess Starting values? TRUE or FALSE (e.g. specified value)

Author(s)

James Balamuta

Examples

```
# Create an SARMA(1,2)x(1,1) process
SARMA(ar = 1, ma = 2,sar = 1, sma =1)

# Creates an SARMA(1,1)x(1,1) process with predefined coefficients.
SARMA(ar=0.23, ma=0.4, sar = .3, sma = .3)
```

---

savingrt *Personal Saving Rate*

Description

Personal saving as a percentage of disposable personal income (DPI), frequently referred to as "the personal saving rate," is calculated as the ratio of personal saving to DPI.

Usage

```
savingrt
```

Format

A gts time series object with frequency 12 starting at 1959 and going to 2016 for a total of 691 observations.

Source

https://fred.stlouisfed.org/series/PSAVERT `select` *Time Series Model Selection*

Description

This function performs model fitting and calculates the model selection criteria to be plotted.

Usage

```
select(model, Xt, include.mean = TRUE, criterion = "aic",
  plot = TRUE)
```

Arguments

`model`	A time series model (only ARIMA are currently supported).
`Xt`	A `vector` of time series data.
`include.mean`	A `boolean` indicating whether to fit ARIMA with the mean or not.
`criterion`	A `string` indicating which model selection criterion should be used (possible values: `"aic"` (default), `"bic"`, `"hq"`).
`plot`	A `boolean` indicating whether a model selection plot is returned or not.

Author(s)

Stéphane Guerrier and Yuming Zhang

Examples

```
set.seed(763)
Xt = gen_gts(100, AR(phi = c(0.2, -0.5, 0.4), sigma2 = 1))
select(AR(5), Xt, include.mean = FALSE)

Xt = gen_gts(100, MA(theta = c(0.2, -0.5, 0.4), sigma2 = 1))
select(MA(5), Xt, include.mean = FALSE)

Xt = gen_gts(500, ARMA(ar = 0.5, ma = c(0.5, -0.5, 0.4), sigma2 = 1))
select(ARMA(5,3), Xt, criterion = "hq", include.mean = FALSE)
```

select_arima *Run Model Selection Criteria on ARIMA Models*

Description

This function performs model fitting and calculates the model selection criteria to be plotted or used in `best_model` function.

Usage

```
select_arima(xt, p.min = 0L, p.max = 3L, d = 0L, q.min = 0L,
  q.max = 3L, include.mean = TRUE, plot = TRUE)

select_arma(xt, p.min = 0L, p.max = 3L, q.min = 0L, q.max = 3L,
  include.mean = TRUE, plot = TRUE)

select_ar(xt, p.min = 0L, p.max = 3L, include.mean = TRUE,
  plot = TRUE)

select_ma(xt, q.min = 0L, q.max = 3L, include.mean = TRUE,
  plot = TRUE)
```

Arguments

`xt`	A `vector` of univariate time series.
`p.min`	An `integer` indicating the lowest order of AR(p) process to search.
`p.max`	An `integer` indicating the highest order of AR(p) process to search.
`d`	An `integer` indicating the differencing order for the data.
`q.min`	An `integer` indicating the lowest order of MA(q) process to search.
`q.max`	An `integer` indicating the highest order of MA(q) process to search.
`include.mean`	A `bool` indicating whether to fit ARIMA with the mean or not.
`plot`	A `logical`. If `TRUE` (the default) a plot should be produced.

Examples

```
xt = gen_arima(N=100, ar=0.3, d=1, ma=0.3)
x = select_arima(xt, d=1L)

xt = gen_ma1(100, 0.3, 1)
x = select_ma(xt, q.min=2L, q.max=5L)
best_model(x)

xt = gen_arma(10, c(.4,.5), c(.1), 1, 0)
x = select_arma(xt, p.min = 1L, p.max = 4L,
                q.min = 1L, q.max = 3L)
```

simple_diag_plot *Basic Diagnostic Plot of Residuals*

Description

This function will plot four diagnostic plots to assess how well the model fits the data. These plots are: (1) residuals plot, (2) histogram of (standardized) residuals, (3) normal Q-Q plot of residuals and (4) residuals vs fitted values plot.

Usage

```
simple_diag_plot(Xt, model, std = FALSE)
```

Arguments

`Xt`	The original time series data.
`model`	The `arima` model fit to the data.
`std`	A `boolean` indicating whether we use standardized residuals for the (1) residuals plot and the (2) histogram of (standardized) residuals.

Author(s)

Yuming Zhang

simplified_print_SARIMA *Simplify and print SARIMA model*

Description

Simplify and print SARIMA model

Usage

```
simplified_print_SARIMA(p, i, q, P, si, Q, s)
```

Arguments

`p`	An `integer` denoting the length of `ar`.
`i`	An `integer` containing the number of differences to be done.
`q`	An `integer` denoting the length of `ma`.
`P`	An `integer` denoting the length of `sma`.
`si`	An `integer` containing the number of seasonal differences to be done.
`Q`	An `integer` denoting the length of `sar`.
`s`	An `integer` indicating the seasonal value of the data.

Value

An S3 object with the following structure:

print String containing simplified model

simplified Type of model (after simplification)

Author(s)

Stephane Guerrier

`summary.fitsimts` *Summary of fitsimts object*

Description

Displays summary information about fitsimts object

Usage

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

Arguments

`object`	A `fitsimts` object
`...`	Other arguments passed to specific methods

Value

Estimated parameters values with confidence intervals and standard errors.

Author(s)

Stéphane Guerrier

summary.gmwm *Summary of GMWM object*

Description

Displays summary information about GMWM object

Usage

```
## S3 method for class 'gmwm'
summary(object, inference = NULL, bs.gof = NULL,
  bs.gof.p.ci = NULL, bs.theta.est = NULL, bs.ci = NULL, B = 100,
  ...)
```

Arguments

`object`	A `GMWM` object
`inference`	A value containing either: NULL (auto), TRUE, or FALSE
`bs.gof`	A value containing either: NULL (auto), TRUE, FALSE
`bs.gof.p.ci`	A value containing either: NULL (auto), TRUE, FALSE
`bs.theta.est`	A value containing either: NULL (auto), TRUE, FALSE
`bs.ci`	A value containing either: NULL (auto), TRUE, FALSE
`B`	An `int` that indicates how many bootstraps should be performed.
`...`	Other arguments passed to specific methods

Value

A `summary.gmwm` object with:

estimate Estimated Theta Values

testinfo Goodness of Fit Information

inference Inference performed? T/F

bs.gof Bootstrap GOF? T/F

bs.gof.p.ci Bootstrap GOF P-Value CI? T/F

bs.theta.est Bootstrap Theta Estimates? T/F

bs.ci Bootstrap CI? T/F

starting Indicates if program supplied initial starting values

seed Seed used during guessing / bootstrapping

obj.fun Value of obj.fun at minimized theta

N Length of Time Series

Author(s)

JJB

theo_acf *Theoretical Autocorrelation (ACF) of an ARMA process*

Description

This function computes the theoretical Autocorrelation (ACF) of an ARMA process.

Usage

```
theo_acf(ar, ma = NULL, lagmax = 20)
```

Arguments

ar	A `vector` containing the AR coefficients.
ma	A `vector` containing the MA coefficients.
lagmax	An `integer` indicating the maximum lag up to which to compute the theoretical ACF.

Author(s)

Yuming Zhang

Examples

```
# Compute the theoretical ACF for an ARMA(1,0) (i.e. a first-order autoregressive model: AR(
theo_acf(ar = -0.25, ma = NULL)
# Computes the theoretical ACF for an ARMA(2, 1)
theo_acf(ar = c(.50, -0.25), ma = 0.20, lagmax = 10)
```

theo_pacf *Theoretical Partial Autocorrelation (PACF) of an ARMA process*

Description

This function computes the theoretical Partial Autocorrelation (PACF) of an ARMA process.

Usage

```
theo_pacf(ar, ma = NULL, lagmax = 20)
```

Arguments

ar	A `vector` containing the AR coefficients.
ma	A `vector` containing the MA coefficients.
lagmax	An `integer` indicating the maximum lag up to which to compute the theoretical PACF.

Author(s)

Yuming Zhang

Examples

```
# Computes the theoretical ACF for an ARMA(1,0) (i.e. a first-order autoregressive model: AR
theo_pacf(ar = -0.25, ma = NULL, lagmax = 7)
# Computes the theoretical ACF for an ARMA(2, 1)
theo_pacf(ar = c(.50, -0.25), ma = .20, lagmax = 10)
```

---

update.gmwm — *Update (Robust) GMWM object for IMU or SSM*

Description

Provides a way to estimate different models over the previously estimated wavelet variance values and covariance matrix.

Usage

```
## S3 method for class 'gmwm'
update(object, model, ...)
```

Arguments

object	A gmwm object.
model	A ts.model object containing one of the allowed models
...	Additional parameters (not used)

Value

A gmwm object with the structure:

estimate Estimated Parameters Values from the GMWM Procedure

init.guess Initial Starting Values given to the Optimization Algorithm

wv.empir The data's empirical wavelet variance

ci.low Lower Confidence Interval

ci.high Upper Confidence Interval

orgV Original V matrix

V Updated V matrix (if bootstrapped)

omega The V matrix inversed

obj.fun Value of the objective function at Estimated Parameter Values

theo Summed Theoretical Wavelet Variance

decomp.theo Decomposed Theoretical Wavelet Variance by Process

scales Scales of the GMWM Object

robust Indicates if parameter estimation was done under robust or classical

eff Level of efficiency of robust estimation

model.type Models being guessed

compute.v Type of V matrix computation

augmented Indicates moments have been augmented

alpha Alpha level used to generate confidence intervals

expect.diff Mean of the First Difference of the Signal

N Length of the Signal

G Number of Guesses Performed

H Number of Bootstrap replications

K Number of V matrix bootstraps

model `ts.model` supplied to gmwm

model.hat A new value of `ts.model` object supplied to gmwm

starting Indicates whether the procedure used the initial guessing approach

seed Randomization seed used to generate the guessing values

freq Frequency of data

`update.lts` *Update Object Attribute*

Description

Update the attributes of `lts`, `gts` and `imu` object

Usage

```
## S3 method for class 'lts'
update(object, type, new, keep.start = T, ...)

## S3 method for class 'gts'
update(object, type, new, keep.start = T, ...)

## S3 method for class 'imu'
update(object, type, new, ...)
```

Arguments

`object`	A `lts`, `gts` or `imu` object
`type`	A `string` that contains the attribute to be updated
`new`	The updated value for the attribute
`keep.start`	A `boolean` value that indicates whether 'start' or 'end' should remain the same when 'freq' is updated
`...`	Further arguments passed to or from other methods.

Details

This function is able to update some attributes for `gts`, `lts` and `imu` objects. For `lts` object, the attributes that can be updated are 'start', 'end', 'freq', 'unit_time', 'name_ts' and 'process'. For `gts` object, the attributes that can be updated are 'start', 'end', 'freq', 'unit_time' and 'name_ts'. For `imu` object, the attributes that can be updated are 'axis', 'freq', 'unit_time' and 'name_ts'.

If one between 'start' and 'end' is updated, the other one will also be updated, since `end-start == (N-1)/freq` must be TRUE, where `N` is the number of observations in the object.

If 'freq' is updated, by default 'start' will remain the same, and 'end' will be updated at the same time, unless you set 'keep.start = F'.

If 'unit_time' is updated, the old unit_time will be replaced by the new one, and other attributes will remain the same. It is different from the unit_time conversion feature.

Value

An object with the updated attribute.

Examples

```
gts1 = gts(rnorm(50), freq = 1, unit_time = 'sec', name_ts = 'test1')
gts2 = update(gts1, 'unit_time', 'min')
attr(gts2, 'unit_time')

gts3 = update(gts1, 'name_ts', 'test2')
attr(gts3, 'name_ts')
```

`value` *Obtain the value of an object's properties*

Description

Used to access different properties of the `gts`, `imu`, or `lts` object.

Usage

```
value(x, type)

## S3 method for class 'imu'
value(x, type)
```

Arguments

`x`	A `gts`, `imu`, or `lts` object.
`type`	A `string` indicating the field to be retrieved.

Details

To access information about `imu` properties use:

`"accel"` Returns the number of accelerometers

`"gyro"` Returns the number of gyroscopes

`"sensors"` Returns total number of sensors

Value

The method will return a single numeric or string result depending on the slot being accessed.

Methods (by class)

- `imu`: Access `imu` object properties

Author(s)

James Balamuta

`WN` *Create an White Noise (WN) Process*

Description

Sets up the necessary backend for the WN process.

Usage

```
WN(sigma2 = NULL)
```

Arguments

`sigma2`	A `double` value for the variance, σ^2, of a WN process.

Value

An S3 object with called ts.model with the following structure:

process.desc Used in summary: "WN"

theta σ

plength Number of Parameters

print String containing simplified model

desc y desc replicated x times

obj.desc Depth of Parameters e.g. list(1)

starting Guess Starting values? TRUE or FALSE (e.g. specified value)

Note

In this process, Y_t is iid from a zero mean normal distribution with variance σ^2

Author(s)

James Balamuta

Examples

```
WN()
WN(sigma2=3.4)
```

`wn_to_wv` *Gaussian White Noise to WV*

Description

This function compute the Haar WV of a Gaussian White Noise process

Usage

```
wn_to_wv(sigma2, tau)
```

Arguments

`sigma2`	A `double` corresponding to variance of WN
`tau`	A `vec` containing the scales e.g. 2^τ

Value

A `vec` containing the wavelet variance of the white noise.

Process Haar Wavelet Variance Formula

The Gaussian White Noise (WN) process has a Haar Wavelet Variance given by:

$$\nu_j^2\left(\sigma^2\right) = \frac{\sigma^2}{\tau_j^2}$$