Package ‘TSSS’

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Title Time Series Analysis with State Space Model

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Depends R (>= 3.6), datasets, stats

Suggests utils

Imports graphics

Description Functions for statistical analysis, modeling and simulation of time series with state space model, based on the methodology in Kitagawa (2020, ISBN: 978-0-367-18733-0).

License GPL (>= 2)

Contact Bug report mailing list <ismrp@grp.ism.ac.jp>

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Contents

TSSS-package — *Time Series Analysis with State Space Model*

Description

R functions for statistical analysis, modeling and simulation of time series with state space model.

Details

This package provides functions for statistical analysis, modeling and simulation of time series. These functions are developed based on source code of "FORTRAN 77 Programming for Time Series Analysis".

After that, the revised edition "Introduction to Time Series Analysis (in Japanese)" and the translation version "Introduction to Time Series Modeling" are published.

Currently the revised edition "Introduction to Time Series Modeling with Applications in R" is published, in which calculations of most of the modeling or methods are explained using this package.

References

Kitagawa, G. and Gersch, W. (1996) *Smoothness Priors Analysis of Time Series*. Lecture Notes in Statistics, No.116, Springer-Verlag.

Kitagawa, G. (2010) *Introduction to Time Series Modeling*. Chapman & Hall/CRC.

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Kitagawa, G. (1993) *FORTRAN 77 Programming for Time Series Analysis*. The Iwanami Computer Science Series, Iwanami Publishing Company (in Japanese).

Kitagawa, G. (2005) *Introduction to Time Series Analysis*. Iwanami Publishing Company (in Japanese).

Kitagawa, G. (2020) *Introduction to Time Series Modeling with R*. Iwanami Publishing Company (in Japanese).

arfit — *Univariate AR Model Fitting*

Description

Fit a univariate AR model by the Yule-Walker method, the least squares (Householder) method or the PARCOR method.

Usage

```
arfit(y, lag = NULL, method = 1, plot = TRUE, ...)
```

Arguments

`y`	a univariate time series.
`lag`	highest order of AR model. Default is $2\sqrt{n}$, where n is the length of the time series `y`.
`method`	estimation procedure. 1 : Yule-Walker method 2 : Least squares (Householder) method 3 : PARCOR method (Partial autoregression) 4 : PARCOR method (PARCOR) 5 : PARCOR method (Burg's algorithm)
`plot`	logical. If `TRUE` (default), PARCOR, AIC and power spectrum are plotted.
`...`	graphical arguments passed to the `plot` method.

Value

An object of class `"arfit"` which has a `plot` method. This is a list with the following components:

`sigma2`	innovation variance.
`maice.order`	order of minimum AIC.
`aic`	AICs of the estimated AR models.
`arcoef`	AR coefficients of the estimated AR models.
`parcor`	PARCOR.
`spec`	power spectrum (in log scale) of the AIC best AR model.
`tsname`	the name of the univariate time series `y`.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# Sunspot number data
data(Sunspot)
arfit(log10(Sunspot), lag = 20, method = 1)

# BLSALLFOOD data
data(BLSALLFOOD)
arfit(BLSALLFOOD)
```

`armachar` *Calculate Characteristics of Scalar ARMA Model*

Description

Calculate impulse response function, autocovariance function, autocorrelation function and characteristic roots of given scalar ARMA model.

Usage

```
armachar(arcoef = NULL, macoef = NULL, v, lag = 50, nf = 200, plot = TRUE, ...)
```

Arguments

`arcoef`	AR coefficients.
`macoef`	MA coefficients.
`v`	innovation variance.
`lag`	maximum lag of autocovariance function.
`nf`	number of frequencies in evaluating spectrum.
`plot`	logical. If `TRUE` (default), impulse response function, autocovariance, power spectrum, PARCOR and characteristic roots are plotted.
`...`	graphical arguments passed to the `plot` method.

Details

The ARMA model is given by

$$y_t - a_1 y_{t-1} - \cdots - a_p y_{t-p} = u_t - b_1 u_{t-1} - \cdots - b_q u_{t-q},$$

where p is AR order, q is MA order and u_t is a zero mean white noise.

Characteristic roots of AR / MA operator is a list with the following components:

- re: real part R
- im: imaginary part I
- amp: $\sqrt{R^2 + I^2}$
- atan: $\arctan(I/R)$
- degree

Value

An object of class "arma" which has a plot method. This is a list with components:

impuls	impulse response function.
acov	autocovariance function.
parcor	PARCOR.
spec	power spectrum.
croot.ar	characteristic roots of AR operator. See Details.
croot.ma	characteristic roots of MA operator. See Details.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# AR model : y(n) = a(1)*y(n-1) + a(2)*y(n-2) + v(n)
a <- c(0.9 * sqrt(3), -0.81)
armachar(arcoef = a, v = 1.0, lag = 20)

# MA model : y(n) = v(n) - b(1)*v(n-1) - b(2)*v(n-2)
b <- c(0.9 * sqrt(2), -0.81)
armachar(macoef = b, v = 1.0, lag = 20)

# ARMA model :  y(n) = a(1)*y(n-1) + a(2)*y(n-2)
#                      + v(n) - b(1)*v(n-1) - b(2)*v(n-2)
armachar(arcoef = a, macoef = b, v = 1.0, lag = 20)
```

---

armafit — *Scalar ARMA Model Fitting*

Description

Fit a scalar ARMA model by maximum likelihood method.

Usage

```
armafit(y, ar.order, ar = NULL, ma.order, ma = NULL)
```

Arguments

y	a univariate time series.
ar.order	AR order.
ar	initial AR coefficients. If NULL (default), use default initial values.
ma.order	MA order.
ma	initial MA coefficients. If NULL (default), use default initial values.

Value

`sigma2`	innovation variance.
`llkhood`	log-likelihood of the model.
`aic`	AIC of the model.
`arcoef`	AR coefficients.
`macoef`	MA coefficients.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# Sunspot number data
data(Sunspot)
y <- log10(Sunspot)
z <- armafit(y, ar.order = 3, ma.order = 3)
z

armachar(arcoef = z$arcoef, macoef = z$macoef, v = z$sigma2, lag = 20)
```

`armafit2` *Scalar ARMA Model Fitting*

Description

Estimate all ARMA models within the user-specified maximum order by maximum likelihood method.

Usage

```
armafit2(y, ar.order, ma.order)
```

Arguments

`y`	a univariate time series.
`ar.order`	maximum AR order.
`ma.order`	maximum MA order.

Value

`aicmin`	minimum AIC.
`maice.order`	AR and MA orders of minimum AIC model.
`sigma2`	innovation variance of all models.
`llkhood`	log-likelihood of all models.
`aic`	AIC of all models.
`coef`	AR and MA coefficients of all models.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# Sunspot number data
data(Sunspot)
y <- log10(Sunspot)
armafit2(y, ar.order = 5, ma.order = 5)
```

BLSALLFOOD   *BLSALLFOOD Data*

Description

The monthly time series of the number of workers engaged in food industries in the United States (January 1967 - December 1979).

Usage

```
data(BLSALLFOOD)
```

Format

A time series of 156 observations.

Source

The data were obtained from the United States Bureau of Labor Statistics (BLS).

---

boxcox   *Box-Cox Transformation*

Description

Compute Box-Cox transformation and find an optimal lambda with minimum AIC.

Usage

```
boxcox(y, plot = TRUE, ...)
```

Arguments

`y`	a univariate time series.
`plot`	logical. If `TRUE` (default), original data and transformed data with minimum AIC are plotted.
`...`	graphical arguments passed to `plot.boxcox`.

Value

An object of class `"boxcox"`, which is a list with the following components:

`mean`	mean of original data.
`var`	variance of original data.
`aic`	AIC of the model with respect to the original data.
`llkhood`	log-likelihood of the model with respect to the original data.
`z`	transformed data with the AIC best lambda.
`aic.z`	AIC of the model with respect to the transformed data.
`llkhood.z`	log-likelihood of the model with respect to the transformed data.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# Sunspot number data
data(Sunspot)
boxcox(Sunspot)

# Wholesale hardware data
data(WHARD)
boxcox(WHARD)
```

---

crscor *Cross-Covariance and Cross-Correlation*

Description

Compute cross-covariance and cross-correlation functions of the multivariate time series.

Usage

```
crscor(y, lag = NULL, outmin = NULL, outmax = NULL, plot = TRUE, ...)
```

Arguments

y	a multivariate time series.
lag	maximum lag. Default is $2\sqrt{n}$, where n is the length of the time series y.
outmin	bound for outliers in low side. A default value is -1.0e+30 for each dimension.
outmax	bound for outliers in high side. A default value is 1.0e+30 for each dimension.
plot	logical. If TRUE (default), cross-correlations are plotted.
...	graphical arguments passed to the plot method.

Value

An object of class "crscor" which has a plot method. This is a list with the following components:

cov	cross-covariances.
cor	cross-correlations.
mean	mean vector.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# Yaw rate, rolling, pitching and rudder angle of a ship
data(HAKUSAN)
y <- as.matrix(HAKUSAN[, 2:4])   # Rolling, Pitching, Rudder
crscor(y, lag = 50)

# The groundwater level and the atmospheric pressure
data(Haibara)
crscor(Haibara, lag = 50)
```

---

fftper *Compute a Periodogram via FFT*

Description

Compute a periodogram of the univariate time series via FFT.

Usage

```
fftper(y, window = 1, plot = TRUE, ...)
```

Arguments

y	a univariate time series.
window	smoothing window type. (0: box-car, 1: Hanning, 2: Hamming)
plot	logical. If TRUE (default), smoothed (log-)periodogram is plotted.
...	graphical arguments passed to plot.spg.

Details

$$\begin{array}{rll} \text{Hanning Window :} & W_0 = 0.5 & W_1 = 0.25 \\ \text{Hamming Window :} & W_0 = 0.54 & W_1 = 0.23 \end{array}$$

Value

An object of class "spg", which is a list with the following components:

period	periodogram.
smoothed.period	smoothed periodogram. If there is not a negative number, logarithm of smoothed periodogram.
log.scale	logical. If TRUE smoothed.period is logarithm of smoothed periodogram.
tsname	the name of the univariate time series y.

Note

We assume that the length N of the input time series y is a power of 2. If N is not a power of 2, calculate using the FFT by appending 0's behind the data y.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# Yaw rate, rolling, pitching and rudder angle of a ship
data(HAKUSAN)
YawRate <- HAKUSAN[, 1]
fftper(YawRate, window = 0)
```

`Haibara` *Haibara Data*

Description

A bivariate time series of the groundwater level and the atmospheric pressure that were observed at 10-minuite intervals at the Haibara observatory of the Tokai region, Japan.

Usage

```
data(Haibara)
```

Format

A data frame with 400 observations on the following 2 variables.

[, 1]	Groundwater level
[, 2]	Atmospheric pressure

Source

The data were offered by Dr. M. Takahashi and Dr. N. Matsumoto of National Institute of Advanced Industrial Science and Technology.

Examples

```
data(Haibara)

## put histograms on the diagonal
panel.hist <- function(x, ...)
{
    usr <- par("usr")
    par(usr = c(usr[1:2], 0, 1.3))
    nB <- 15; nB1 <- nB + 1
    xmin <- min(x, na.rm = TRUE)
    xmax <- max(x, na.rm = TRUE)
    w <- (xmax - xmin) / nB
    breaks <- xmin
    b <- xmin
    for (i in 1:nB) {
      b <- b + w
      breaks <- c(breaks, b)
    }
    h <- hist(x, breaks = breaks, plot = FALSE)
    y <- h$counts
    y <- y / max(y)
    rect(breaks[1:nB], 0, breaks[2:nB1], y, ...)
}
```

```
par(xaxs = "i", yaxs = "i", xaxt = "n", yaxt = "n")
pairs(Haibara, diag.panel = panel.hist, pch = 20, cex.labels = 1.5,
      label.pos = 0.9, lower.panel = NULL)
```

HAKUSAN *Ship's Navigation Data*

Description

A multivariate time series of a ship's yaw rate, rolling, pitching and rudder angles which were recorded every second while navigating across the Pacific Ocean.

Usage

```
data(HAKUSAN)
```

Format

A data frame with 1000 observations on the following 4 variables.

[, 1]	YawRate	yaw rate
[, 2]	Rolling	rolling
[, 3]	Pitching	pitching
[, 4]	Rudder	rudder angle

Source

The data were offered by Prof. K. Ohtsu of Tokyo University of Marine Science and Technology.

Examples

```
data(HAKUSAN)
HAKUSAN234 <- HAKUSAN[, c(2,3,4)]

## put histograms on the diagonal
panel.hist <- function(x, ...)
{
    usr <- par("usr")
    par(usr = c(usr[1:2], 0, 1.3))
    nB <- 20; nB1 <- nB + 1
    xmin <- min(x)
    xmax <- max(x)
    w <- (xmax - xmin) / nB
    breaks <- xmin
    b <- xmin
    for (i in 1:nB) {
      b <- b + w
      breaks <- c(breaks, b)
    }
```

```
    h <- hist(x, breaks = breaks, plot = FALSE)
    y <- h$counts; y <- y / max(y)
    rect(breaks[1:nB], 0, breaks[2:nB1], y, ...)

}

par(xaxs = "i", yaxs = "i", xaxt = "n", yaxt = "n")
pairs(HAKUSAN234, diag.panel = panel.hist, pch = 20, cex.labels = 1.5,
      label.pos = 0.9, lower.panel = NULL)
```

---

klinfo *Kullback-Leibler Information*

Description

Compute Kullback-Leibler information.

Usage

```
klinfo(distg = 1, paramg = c(0, 1), distf = 1, paramf, xmax = 10)
```

Arguments

`distg` function for the true density (1 or 2).

1 : Gaussian (normal) distribution
paramg(1): mean
paramg(2): variance
2 : Cauchy distribution
paramg(1): μ (location parameter)
paramg(2): τ^2 (dispersion parameter)

`paramg` parameter vector of true density.

`distf` function for the model density (1 or 2).

1 : Gaussian (normal) distribution
paramf(1): mean
paramf(2): variance
2 : Cauchy distribution
paramf(1): μ (location parameter)
paramf(2): τ^2 (dispersion parameter)

`paramf` parameter vector of the model density.

`xmax` upper limit of integration. lower limit xmin = `-xmax`.

Value

`nint`	number of function evaluation.
`dx`	delta.
`KLI`	Kullback-Leibler information, $I(g; f)$.
`gint`	integration of $g(y)$ over [-`xmax`, `xmax`].

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# g:Gauss, f:Gauss
klinfo(distg = 1, paramg = c(0, 1), distf = 1, paramf = c(0.1, 1.5), xmax = 8)

# g:Gauss, f:Cauchy
klinfo(distg = 1, paramg = c(0, 1), distf = 2, paramf = c(0, 1), xmax = 8)
```

`lsar` *Decomposition of Time Interval to Stationary Subintervals*

Description

Decompose time series to stationary subintervals and estimate local spectrum.

Usage

```
lsar(y, max.arorder = 20, ns0, plot = TRUE, ...)
```

Arguments

`y`	a univariate time series.
`max.arorder`	highest order of AR model.
`ns0`	length of basic local span.
`plot`	logical. If `TRUE` (default), local spectra are plotted.
`...`	graphical arguments passed to the `plot` method.

Value

An object of class `"lsar"` which has a `plot` method. This is a list with the following components:

`model`	1: pooled model is accepted. 2: switched model is accepted.
`ns`	number of observations of local span.

span	start points and end points of local spans.
nf	number of frequencies in computing local power spectrum.
ms	order of switched model.
sds	innovation variance of switched model.
aics	AIC of switched model.
mp	order of pooled model.
sdp	innovation variance of pooled model.
aics	AIC of pooled model.
spec	local spectrum.
tsname	the name of the univariate time series y.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# seismic data
data(MYE1F)
lsar(MYE1F, max.arorder = 10, ns0 = 100)
```

---

lsar.chgpt *Estimation of the Change Point*

Description

Precisely estimate a change point of subinterval for locally stationary AR model.

Usage

```
lsar.chgpt(y, max.arorder = 20, subinterval, candidate, plot = TRUE, ...)
```

Arguments

y	a univariate time series.
max.arorder	highest order of AR model.
subinterval	a vector of the form c(n0, ne) which gives a start and end point of time interval used for model fitting.
candidate	a vector of the form c(n1, n2) which gives minimum and maximum of the candidate for change point. n0+2k < n1 < n2+k < ne, (k is max.arorder)
plot	logical. If TRUE (default), y[n0:ne] and aic are plotted.
...	graphical arguments passed to the plot method.

Value

An object of class "chgpt" which has a plot method. This is a list with the following components:

aic	AICs of the AR models fitted on [n1, n2].
aicmin	minimum AIC.
change.point	estimated change point.
subint	information about the original sub-interval.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# seismic data
data(MYE1F)
lsar.chgpt(MYE1F, max.arorder = 10, subinterval = c(200, 1000),
           candidate = c(400, 800))

lsar.chgpt(MYE1F, max.arorder = 10, subinterval = c(600, 1400),
           candidate = c(800, 1200))
```

---

lsqr — *The Least Squares Method via Householder Transformation*

Description

Compute regression coefficients of the model with minimum AIC by the least squares method via Householder transformation.

Usage

```
lsqr(y, lag = NULL, period = 365, plot = TRUE, ...)
```

Arguments

y	a univariate time series.
lag	number of sine and cosine components. Default is $\sqrt{n}$, where n is the length of the time series y.
period	period of one cycle.
plot	logical. If TRUE (default), original data and fitted trigonometric polynomial are plotted.
...	graphical arguments passed to plot.lsqr.

Value

An object of class "lsqr", which is a list with the following components:

aic	AIC's of the model with order $0, \ldots, k (= 2\texttt{lag}+1)$.
sigma2	residual variance of the model with order $0, \ldots, k$.
maice.order	order of minimum AIC.
regress	regression coefficients of the model.
tripoly	trigonometric polynomial.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# The daily maximum temperatures in Tokyo
data(Temperature)
lsqr(Temperature, lag = 10)
```

---

marfit *Yule-Walker Method of Fitting Multivariate AR Model*

Description

Fit a multivariate AR model by the Yule-Walker method.

Usage

```
marfit(y, lag = NULL)
```

Arguments

y	a multivariate time series.
lag	highest order of fitted AR models. Default is $2\sqrt{n}$, where n is the length of the time series y.

Value

An object of class "maryule", which is a list with the following components:

maice.order	order of minimum AIC.
aic	AIC's of the AR models with order $0, \ldots,$lag.
v	innovation covariance matrix of the AIC best model.
arcoef	AR coefficients of the AIC best model.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# Yaw rate, rolling, pitching and rudder angle of a ship
data(HAKUSAN)
yy <- as.matrix(HAKUSAN[, c(1,2,4)])   # Yaw rate, Pitching, Rudder angle
nc <- dim(yy)[1]
n <- seq(1, nc, by = 2)
y <- yy[n, ]
marfit(y, 20)
```

---

marlsq — *Least Squares Method for Multivariate AR Model*

Description

Fit a multivariate AR model by least squares method.

Usage

```
marlsq(y, lag = NULL)
```

Arguments

`y`	a multivariate time series.
`lag`	highest AR order. Default is $2\sqrt{n}$, where n is the length of the time series `y`.

Value

An object of class `"marlsq"`, which is a list with the following components:

`maice.order`	order of the MAICE model.
`aic`	AIC of the MAR model with minimum AIC orders.
`v`	innovation covariance matrix.
`arcoef`	AR coefficient matrices.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# Yaw rate, rolling, pitching and rudder angle of a ship
data(HAKUSAN)
y <- as.matrix(HAKUSAN[, c(1,2,4)])   # Yaw rate, Rolling, Rudder angle
z <- marlsq(y)
z

marspc(z$arcoef, v = z$v)
```

---

marspc *Cross Spectra and Power Contribution*

Description

Compute cross spectra, coherency and power contribution.

Usage

```
marspc(arcoef, v, plot = TRUE, ...)
```

Arguments

arcoef	AR coefficient matrices.
v	innovation variance matrix.
plot	logical. If TRUE (default), cross spectra, coherency and power contribution are plotted.
...	graphical arguments passed to the plot method.

Value

An object of class "marspc" which has a plot method. This is a list with the following components:

spec	cross spectra.
amp	amplitude spectra.
phase	phase spectra.
coh	simple coherency.
power	decomposition of power spectra.
rpower	relative power contribution.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# Yaw rate, rolling, pitching and rudder angle of a ship
data(HAKUSAN)
yy <- as.matrix(HAKUSAN[, c(1,2,4)])
nc <- dim(yy)[1]
n <- seq(1, nc, by = 2)
y <- yy[n, ]
z <- marfit(y, lag = 20)

marspc(z$arcoef, v = z$v)
```

MYE1F *Seismic Data*

Description

The time series of East-West components of seismic waves, recorded every 0.02 seconds.

Usage

```
data(MYE1F)
```

Format

A time series of 2600 observations.

Source

Takanami, T. (1991), "ISM data 43-3-01: Seismograms of foreshocks of 1982 Urakawa-Oki earthquake", Ann. Inst. Statist. Math., 43, 605.

---

ngsim *Simulation by Non-Gaussian State Space Model*

Description

Simulation by non-Gaussian state space model.

Usage

```
ngsim(n = 200, trend = NULL, seasonal.order = 0, seasonal = NULL, arcoef = NULL,
      ar = NULL, noisew = 1, wminmax = NULL, paramw = NULL, noisev = 1,
      vminmax = NULL, paramv = NULL, seed = NULL, plot = TRUE, ...)
```

Arguments

`n`	number of data generated by simulation.
`trend`	initial values of trend component of length $m1$, where $m1$ is trend order (1, 2). If `NULL` (default), trend order is 0.
`seasonal.order`	order of seasonal component model (0, 1, 2).
`seasonal`	if `seasonal.order` > 0, initial values of seasonal component of length $p - 1$, where p is period of one season.
`arcoef`	AR coefficients.
`ar`	initial values of AR component.
`noisew`	type of the observational noise.

-1 :	Cauchy random number
-2 :	exponential distribution
-3 :	double exponential distribution
0 :	double exponential distribution (+ Euler's constant)
1 :	normal distribution (generated by inverse function)
2 :	Pearson distribution (generated by inverse function)
3 :	double exponential distribution (generated by inverse function)

`wminmax`	lower and upper bound of observational noise.
`paramw`	parameter of the observational noise density.

noisew = 1 :	variance
noisew = 2 :	dispersion parameter (tau square) and shape parameter

`noisev`	type of the system noise.

-1 :	Cauchy random number
-2 :	exponential distribution
-3 :	double exponential distribution
0 :	double exponential distribution (+ Euler's constant)
1 :	normal distribution (generated by inverse function)
2 :	Pearson distribution (generated by inverse function)
3 :	double exponential distribution (generated by inverse function)

`vminmax`	lower and upper bound of system noise.
`paramv`	parameter of the system noise density.

noisev = 1 :	variance
noisev = 2 :	dispersion parameter (tau square) and shape parameter

`seed`	arbitrary positive integer to generate a sequence of uniform random numbers. The default seed is based on the current time.
`plot`	logical. If `TRUE` (default), simulated data are plotted.
`...`	graphical arguments passed to `plot.simulate`.

Value

An object of class "simulate", giving simulated data of non-Gaussian state space model.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
ar1 <- ngsim(n = 400, arcoef = 0.95, noisew = 1, paramw = 1, noisev = 1,
             paramv = 1, seed = 555)
plot(ar1, use = c(201, 400))

ar2 <- ngsim(n = 400, arcoef = c(1.3, -0.8), noisew = 1, paramw = 1, noisev = 1,
             paramv = 1, seed = 555)
plot(ar2, use = c(201, 400))
```

---

ngsmth *Non-Gaussian Smoothing*

Description

Trend estimation by non-Gaussian smoothing.

Usage

```
ngsmth(y, noisev = 2, tau2, bv = 1.0, noisew = 1, sigma2, bw = 1.0,
       initd = 1, k = 200, plot = TRUE, ...)
```

Arguments

y	a univariate time series.
noisev	type of system noise density. 1 : Gaussian (normal) 2 : Pearson family 3 : two-sided exponential
tau2	variance or dispersion of system noise.
bv	shape parameter of system noise (for noisev = 2).

`noisew`	type of observation noise density 1 : Gaussian (normal) 2 : Pearson family 3 : two-sided exponential 4 : double exponential
`sigma2`	variance or dispersion of observation noise.
`bw`	shape parameter of observation noise (for `noisew` = 2).
`initd`	type of density function. 1 : Gaussian (normal) 2 : uniform 3 : two-sided exponential
`k`	number of intervals in numerical integration.
`plot`	logical. If `TRUE` (default), trend is plotted.
`...`	graphical arguments passed to `plot.ngsmth`.

Details

Consider a one-dimensional state space model

$$x_n = x_{n-1} + v_n,$$

$$y_n = x_n + w_n,$$

where the observation noise w_n is assumed to be Gaussian distributed and the system noise v_n is assumed to be distributed as the Pearson system

$$q(v_n) = c/(\tau^2 + v_n^2)^b$$

with $\frac{1}{2} < b < \infty$ and $c = \tau^{2b-1}\Gamma(b) \;/\; \Gamma(\frac{1}{2})\Gamma(b - \frac{1}{2})$.

This broad family of distributions includes the Cauchy distribution ($b = 1$) and t-distribution ($b = (k + 1)/2$).

Value

An object of class `"ngsmth"`, which is a list with the following components:

`llkhood`	log-likelihood.
`trend`	trend.
`smt`	smoothed density.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Kitagawa, G. and Gersch, W. (1996) *Smoothness Priors Analysis of Time Series*. Lecture Notes in Statistics, No.116, Springer-Verlag.

Examples

```
## test data
data(PfilterSample)
par(mar = c(3, 3, 1, 1) + 0.1)

# system noise density : Gaussian (normal)
s1 <- ngsmth(PfilterSample, noisev = 1, tau2 = 1.4e-02, noisew = 1, sigma2 = 1.048)
s1
plot(s1, "smt", theta = 25, phi = 30, expand = 0.25, col = "white")

# system noise density : Pearson family
s2 <- ngsmth(PfilterSample, noisev = 2, tau2 = 2.11e-10, bv = 0.6, noisew = 1,
             sigma2 = 1.042)
s2
plot(s2, "smt", theta = 25, phi = 30, expand = 0.25, col = "white")

## seismic data
data(MYE1F)
n <- length(MYE1F)
yy <- rep(0, n)
for (i in 2:n) yy[i] <- MYE1F[i] - 0.5 * MYE1F[i-1]
m <- seq(1, n, by = 2)
y <- yy[m]
z <- tvvar(y, trend.order = 2, tau2.ini = 4.909e-02, delta = 1.0e-06)

# system noise density : Gaussian (normal)
s3 <- ngsmth(z$sm, noisev = 1, tau2 = z$tau2, noisew = 2, sigma2 = pi*pi/6,
             k = 190)
s3
plot(s3, "smt", phi = 50, expand = 0.5, col = 8)
```

`Nikkei225` *Nikkei225*

Description

A daily closing values of the Japanese stock price index, Nikkei225, quoted from January 4, 1988, to December 30, 1993.

Usage

```
data(Nikkei225)
```

Format

A time series of 1480 observations.

Source

https://indexes.nikkei.co.jp/nkave/archives/data

NLmodel *The Nonlinear State-Space Model Data*

Description

The series generated by the nonlinear state-space model.

Usage

```
data(NLmodel)
```

Format

A matrix with 100 rows and 2 columns.

[, 1]	x_n
[, 2]	y_n

Details

The system model x_n and the observation model y_n are generated by following state-space model:

$$x_n = \frac{1}{2}x_{n-1} + \frac{25x_{n-1}}{x_{n-1}^2 + 1} + 8cos(1.2n) + v_n$$

$$y_n = \frac{x_n^2}{10} + w_n,$$

where $v_n \sim N(0,1)$, $w_n \sim N(0,10)$, $v_0 \sim N(0,5)$.

pdfunc *Probability Density Function*

Description

Evaluate probability density function for normal distribution, Cauchy distribution, Pearson distribution, exponential distribution, Chi-square distributions, double exponential distribution and uniform distribution.

Usage

```
pdfunc(model = "norm", mean = 0, sigma2 = 1, mu = 0, tau2 = 1, shape,
       lambda = 1, side = 1, df, xmin = 0, xmax = 1, plot = TRUE, ...)
```

Arguments

model	a character string indicating the model type of probability density function: either "norm", "Cauchy", "Pearson", "exp", "Chi2", "dexp" or "unif".
mean	mean. (valid for "norm")
sigma2	variance. (valid for "norm")
mu	location parameter μ. (valid for "Cauchy" and "Pearson")
tau2	dispersion parameter τ^2. (valid for "Cauchy" and "Pearson")
shape	shape parameter (> 0.5). (valid for "Pearson")
lambda	lambda λ. (valid for "exp")
side	1: exponential, 2: two-sided exponential. (valid for "exp")
df	degree of freedoms k. (valid for "Chi2")
xmin	lower bound of the interval.
xmax	upper bound of the interval.
plot	logical. If TRUE (default), probability density function is plotted.
...	graphical arguments passed to the plot method.

Value

An object of class "pdfunc" which has a plot method. This is a list with the following components:

density	values of density function.
interval	lower and upper bound of interval.
param	parameters of model.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# normal distribution
pdfunc(model = "norm", xmin = -4, xmax = 4)

# Cauchy distribution
pdfunc(model = "Cauchy", xmin = -4, xmax = 4)

# Pearson distribution
pdfunc(model = "Pearson", shape = 2, xmin = -4, xmax = 4)

# exponential distribution
pdfunc(model = "exp", xmin = 0, xmax = 8)

pdfunc(model = "exp", xmin = -4, xmax = 4)

# Chi-square distribution
```

```
pdfunc(model = "Chi2", df = 3, xmin = 0, xmax = 8)

# double exponential distribution
pdfunc(model = "dexp", xmin = -4, xmax = 2)

# uniform distribution
pdfunc(model = "unif", xmin = 0, xmax = 1)
```

---

period *Compute a Periodogram*

Description

Compute a periodogram of the univariate time series.

Usage

```
period(y, window = 1, lag = NULL, minmax = c(-1.0e+30, 1.0e+30),
       plot = TRUE, ...)
```

Arguments

y	a univariate time series.
window	smoothing window type. (0: box-car, 1: Hanning, 2: Hamming)
lag	maximum lag of autocovariance. If NULL (default), window = 0 : lag = n - 1, window > 0 : lag = 2 $\sqrt{n}$, where n is the length of data.
minmax	bound for outliers in low side and high side.
plot	logical. If TRUE (default), smoothed periodogram is plotted.
...	graphical arguments passed to plot.spg.

Details

$$\begin{array}{rll} \text{Hanning Window :} & W_0 = 0.5 & W_1 = 0.25 \\ \text{Hamming Window :} & W_0 = 0.54 & W_1 = 0.23 \end{array}$$

Value

An object of class "spg", which is a list with the following components:

period	periodogram(or raw spectrum).
smoothed.period	smoothed log-periodogram. Smoothed periodogram is given if there is a negative value in the smoothed periodogram.
log.scale	if TRUE "smooth the periodogram on log scale.
tsname	the name of the univariate time series y.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
## BLSALLFOOD data
data(BLSALLFOOD)
period(BLSALLFOOD)

## seismic Data
data(MYE1F)

# smoothed periodogram
period(MYE1F)

# periodogram
period(MYE1F, window = 0)

# raw spectrum
period(MYE1F, window = 0, lag = 200)

# Hamming window
period(MYE1F, window = 2)
```

---

pfilter *Particle Filtering and Smoothing*

Description

Trend estimation by particle filter and smoother.

Usage

```
pfilter(y, m = 10000, model = 0, lag = 20, initd = 0, sigma2, tau2,
        alpha = 0.99, bigtau2 = NULL, init.sigma2 = 1, xrange = NULL,
        seed = NULL, plot = TRUE, ...)
```

Arguments

y	univariate time series.
m	number of particles.
model	model for the system noise. 0: normal distribution 1: Cauchy distribution 2: Gaussian mixture distribution

$\alpha\ N(0, \tau^2)$ + (1 - α) $N(0, T^2)$,
where N is the normal density.

`lag`	lag length for fixed-lag smoothing.
`initd`	type of initial state distribution. 0: normal distribution 1: uniform distribution 2: Cauchy distribution 3: fixed point (default value = 0)
`sigma2`	observation noise variance σ^2.
`tau2`	system noise variance τ^2 for `model` = 0 or dispersion parameter for `model` = 1.
`alpha`	mixture weight α. (valid for `model` = 2)
`bigtau2`	variance of the second component T^2. (valid for `model` = 2)
`init.sigma2`	variance for `initd` = 0 or dispersion parameter of initial state distribution for `initd` = 2.
`xrange`	specify the lower and upper bounds of the distribution's range.
`seed`	arbitrary positive integer to generate a sequence of uniform random numbers. The default seed is based on the current time.
`plot`	logical. If `TRUE` (default), marginal smoothed distribution is plotted.
`...`	graphical arguments passed to the `plot` method.

Details

This function performs particle filtering and smoothing for the first order trend model;

$$x_n = x_{n-1} + v_n, \quad \text{(system model)}$$
$$y_n = x_n + w_n, \quad \text{(observation model)}$$

where y_n is a time series, x_n is the state vector. The system noise v_n and the observation noise w_n are assumed to be white noises which follow a Gaussian distribution or a Cauchy distribution, and non-Gaussian distribution, respectively.

The algorithm of the particle filter and smoother are presented in Kitagawa (2020). For more details, please refer to Kitagawa (1996) and Doucet et al. (2001).

Value

An object of class `"pfilter"` which has a `plot` method. This is a list with the following components:

`llkhood`	log-likelihood.

`smooth.dist` marginal smoothed distribution of the trend $T(i,j)$ $(i = 1, ..., n, j = 1, ..., 7)$, where n is the length of y.

j = 4:	50% point
j = 3, 5:	1-sigma points (15.87% and 84.14% points)
j = 2, 6:	2-sigma points (2.27% and 97.73% points)
j = 1, 7:	3-sigma points (0.13% and 99.87% points)

References

Kitagawa, G. (1996) *Monte Carlo filter and smoother for non-Gaussian nonlinear state space models*, J. of Comp. and Graph. Statist., 5, 1-25.

Doucet, A., de Freitas, N. and Gordon, N. (2001) *Sequential Monte Carlo Methods in Practice*, Springer, New York.

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

See Also

`pfilterNL` performs particle filtering and smoothing for nonlinear non-Gaussian state-space model.

Examples

```
data(PfilterSample)
y <- PfilterSample

## Not run:
pfilter(y, m = 100000, model = 0, lag = 20, initd = 0, sigma2 = 1.048,
        tau2 = 1.4e-2, xrange = c(-4, 4), seed = 2019071117)

pfilter(y, m = 100000, model = 1, lag = 20 , initd = 0, sigma2 = 1.045,
        tau2 = 3.53e-5, xrange = c(-4, 4), seed = 2019071117)

pfilter(y, m = 100000, model = 2, lag = 20 , initd = 0, sigma2 = 1.03,
        tau2 = 0.00013, alpha = 0.991, xrange = c(-4, 4), seed = 2019071117)

## End(Not run)
```

`pfilterNL` *Particle Filtering and Smoothing for Nonlinear State-Space Model*

Description

Trend estimation by particle filter and smoother via nonlinear state-space model.

Usage

```
pfilterNL(y, m = 10000, lag = 20, sigma2, tau2, xrange = NULL, seed = NULL,
          plot = TRUE, ...)
```

Arguments

`y`	univariate time series.
`m`	number of particles.
`lag`	lag length for fixed-lag smoothing.
`sigma2`	observation noise variance.
`tau2`	system noise variance.
`xrange`	specify the lower and upper bounds of the distribution's range.
`seed`	arbitrary positive integer to generate a sequence of uniform random numbers. The default seed is based on the current time.
`plot`	logical. If `TRUE` (default), marginal smoothed distribution is plotted.
`...`	graphical arguments passed to the `plot` method.

Details

This function performs particle filtering and smoothing for the following nonlinear state-space model;

$$x_n = \frac{1}{2}x_{n-1} + \frac{25x_{n-1}}{x_{n-1}^2+1} + 8cos(1.2n) + v_n, \quad \text{(system model)}$$
$$y_n = \frac{x_n^2}{10} + w_n, \quad \text{(observation model)}$$

where y_n is a time series, x_n is the state vector. The system noise v_n and the observation noise w_n are assumed to be white noises which follow a Gaussian distribution and v_0 ~ $N(0, 5)$.

The algorithm of the particle filtering and smoothing are presented in Kitagawa (2020). For more details, please refer to Kitagawa (1996) and Doucet et al. (2001).

Value

An object of class `"pfilter"` which has a `plot` method. This is a list with the following components:

`llkhood`	log-likelihood.
`smooth.dist`	marginal smoothed distribution of the trend $T(i, j)$ $(i = 1, ..., n, j = 1, ..., 7)$, where n is the length of `y`.

j = 4:	50% point
j = 3, 5:	1-sigma points (15.87% and 84.14% points)
j = 2, 6:	2-sigma points (2.27% and 97.73% points)
j = 1, 7:	3-sigma points (0.13% and 99.87% points)

References

Kitagawa, G. (1996) *Monte Carlo filter and smoother for non-Gaussian nonlinear state space models*, J. of Comp. and Graph. Statist., 5, 1-25.

Doucet, A., de Freitas, N. and Gordon, N. (2001) *Sequential Monte Carlo Methods in Practice*, Springer, New York.

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

See Also

pfilter performs particle filtering and smoothing for linear non-Gaussian state-space model.

Examples

```
data(NLmodel)
x <- NLmodel[, 2]
pfilterNL(x, m = 100000, lag = 20 , sigma2 = 10.0, tau2 = 1.0,
          xrange = c(-20, 20), seed = 2019071117)
```

PfilterSample *Sample Data for Particle Filter and Smoother*

Description

An artificially generated sample data with shifting mean value.

Usage

```
data(PfilterSample)
```

Format

A time series of 400 observations.

Details

This data generated by the following models;

$$y_n \sim N(\mu_n, 1), \quad \mu_n \begin{aligned} &= 0, & 1 <= n <= 100 \\ &= 1, & 101 <= n <= 200 \\ &= -1, & 201 <= n <= 300 \\ &= 0, & 301 <= n <= 400 \end{aligned}$$

---

plot.boxcox *Plot Box-Cox Transformed Data*

Description

Plot original data and transformed data with minimum AIC.

Usage

```
## S3 method for class 'boxcox'
plot(x, rdata = NULL, ...)
```

Arguments

x	an object of class "boxcox".
rdata	original data, if necessary.
...	further graphical parameters may also be supplied as arguments.

---

plot.lsqr — *Plot Fitted Trigonometric Polynomial*

Description

Plot original data and fitted trigonometric polynomial returned by lsqr.

Usage

```
## S3 method for class 'lsqr'
plot(x, rdata = NULL, ...)
```

Arguments

x	an object of class "lsqr".
rdata	original data, if necessary.
...	further graphical parameters may also be supplied as arguments.

---

plot.ngsmth — *Plot Smoothed Density Function*

Description

Plot the smoothed density function returned by ngsmth.

Usage

```
## S3 method for class 'ngsmth'
plot(x, type = c("trend", "smt"), theta = 0, phi = 15,
          expand = 1, col = "lightblue", ticktype= "detail", ...)
```

Arguments

x	an object of class "ngsmth".
type	plotted values, either or both of "trend" and "smt".
theta, phi, expand, col, ticktype	graphical parameters in perspective plot persp.
...	further graphical parameters may also be supplied as arguments.

`plot.polreg` *Plot Fitted Polynomial Trend*

Description

Plot trend component of fitted polynomial returned by `polreg`.

Usage

```
## S3 method for class 'polreg'
plot(x, rdata = NULL, ...)
```

Arguments

`x`	an object of class `"polreg"`.
`rdata`	original data, if necessary.
`...`	further graphical parameters may also be supplied as arguments.

`plot.season` *Plot Trend, Seasonal and AR Components*

Description

Plot trend component, seasonal component, AR component and noise returned by `season`.

Usage

```
## S3 method for class 'season'
plot(x, rdata = NULL, ...)
```

Arguments

`x`	an object of class `"season"`.
`rdata`	original data, if necessary.
`...`	further graphical parameters may also be supplied as arguments.

plot.simulate *Plot Simulated Data Generated by State Space Model*

Description

Plot simulated data of Gaussian / non-Gaussian generated by state space model.

Usage

```
## S3 method for class 'simulate'
plot(x, use = NULL, ...)
```

Arguments

x	an object of class "simulate" as returned by simssm and ngsim.
use	start and end time c(x1, x2) to be plotted actually.
...	further graphical parameters may also be supplied as arguments.

plot.smooth *Plot Posterior Distribution of Smoother*

Description

Plot posterior distribution (mean and standard deviations) of the smoother returned by tsmooth.

Usage

```
## S3 method for class 'smooth'
plot(x, rdata = NULL, ...)
```

Arguments

x	an object of class "smooth".
rdata	original data, if necessary.
...	further graphical parameters may also be supplied as arguments.

plot.spg *Plot Smoothed Periodogram*

Description

Plot smoothed periodogram or logarithm of smoothed periodogram.

Usage

```
## S3 method for class 'spg'
plot(x, type = "vl", ...)
```

Arguments

x	an object of class "spg" as returned by period and fftper.
type	type of plot. ("l": lines, "vl" : vertical lines)
...	further graphical parameters may also be supplied as arguments.

plot.trend *Plot Trend and Residuals*

Description

Plot trend component and residuals returned by trend.

Usage

```
## S3 method for class 'trend'
plot(x, rdata = NULL, ...)
```

Arguments

x	an object of class "trend".
rdata	original data, if necessary.
...	further graphical parameters may also be supplied as arguments.

plot.tvspc — *Plot Evolutionary Power Spectra Obtained by Time Varying AR Model*

Description

Plot evolutionary power spectra obtained by time varying AR model returned by `tvspc`.

Usage

```
## S3 method for class 'tvspc'
plot(x, tvv = NULL, dx = 2, dy = 0.25, ...)
```

Arguments

`x`	an object of class `"tvspc"`.
`tvv`	time varying variance as returned by `tvvar`.
`dx`	step width for the X axis.
`dy`	step width for the Y axis.
`...`	further graphical parameters may also be supplied as arguments.

Examples

```
# seismic data
data(MYE1F)
v <- tvvar(MYE1F, trend.order = 2, tau2.ini = 6.6e-06, delta = 1.0e-06,
           plot = FALSE )

z <- tvar(v$nordata, trend.order = 2, ar.order = 8, span = 20,
          outlier = c(630, 1026), tau2.ini = 6.6e-06, delta = 1.0e-06,
          plot = FALSE)

spec <- tvspc(z$arcoef, z$sigma2, span = 20, nf = 400)
plot(spec, tvv = v$tvv, dx = 2, dy = 0.10)
```

polreg — *Polynomial Regression Model*

Description

Estimate the trend using the AIC best polynomial regression model.

Usage

```
polreg(y, order, plot = TRUE, ...)
```

Arguments

`y`	a univariate time series.
`order`	maximum order of polynomial regression.
`plot`	logical. If `TRUE` (default), original data and trend component are plotted.
`...`	graphical arguments passed to `plot.polreg`.

Value

An object of class `"polreg"`, which is a list with the following components:

`order.maice`	MAICE (minimum AIC estimate) order.
`sigma2`	residual variance of the model with order M. ($0 \leq M \leq$ `order`)
`aic`	AIC of the model with order M. ($0 \leq M \leq$ `order`)
`daic`	AIC - minimum AIC.
`coef`	regression coefficients $A(I, M)$ with order M. ($1 \leq M \leq$ `order`, $1 \leq I \leq M$)
`trend`	trend component.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# The daily maximum temperatures for Tokyo
data(Temperature)
polreg(Temperature, order = 7)

# Wholesale hardware data
data(WHARD)
y <- log10(WHARD)
polreg(y, order = 15)
```

`Rainfall` *Rainfall Data*

Description

Number of rainy days in two years (1975-1976) at Tokyo, Japan.

Usage

```
data(Rainfall)
```

Format

Integer-valued time series of 366 observations.

Source

The data were obtained from Tokyo District Meteorological Observatory. https://www.data.jma.go.jp/obd/stats/etrn/

---

season *Seasonal Adjustment*

Description

Seasonal adjustment by state space modeling.

Usage

```
season(y, trend.order = 1, seasonal.order = 1, ar.order = 0, trade = FALSE,
       period = NULL, tau2.ini = NULL, filter = c(1, length(y)),
       predict = length(y), arcoef.ini = NULL, log = FALSE, log.base = "e",
       minmax = c(-1.0e+30, 1.0e+30), plot = TRUE, ...)
```

Arguments

`y`	a univariate time series with or without the tsp attribute.
`trend.order`	trend order (0, 1, 2 or 3).
`seasonal.order`	seasonal order (0, 1 or 2).
`ar.order`	AR order (0, 1, 2, 3, 4 or 5).
`trade`	logical; if `TRUE`, the model including trading day effect component is considered.
`period`	If the tsp attribute of `y` is `NULL`, valid number of seasons in one period in the case that `seasonal.order` > 0 and/or `trade` = `TRUE`. 4 : quarterly data 12 : monthly data 5 : daily data (5 days a week) 7 : daily data (7 days a week) 24 : hourly data
`tau2.ini`	initial estimate of variance of the system noise τ^2 less than 1.
`filter`	a numerical vector of the form `c(x1,x2)` which gives start and end position of filtering.
`predict`	the end position of prediction ($\geq$ `x2`).
`arcoef.ini`	initial estimate of AR coefficients (for `ar.order` > 0).
`log`	logical. If `TRUE`, the data `y` is log-transformed.

`log.base`	the letter "e" (default) or "10" specifying the base of logarithmic transformation. Valid only if log = TRUE.
`minmax`	lower and upper limits of observations.
`plot`	logical. If `TRUE` (default), trend, seasonal, AR and noise components are plotted.
`...`	graphical arguments passed to `plot.season`.

Value

An object of class `"season"`, which is a list with the following components:

`tau2`	variance of the system noise.
`sigma2`	variance of the observational noise.
`llkhood`	log-likelihood of the model.
`aic`	AIC of the model.
`trend`	trend component (for `trend.order` > 0).
`seasonal`	seasonal component (for `seasonal.order` > 0).
`arcoef`	AR coefficients (for `ar.order` > 0).
`ar`	AR component (for `ar.order` > 0).
`day.effect`	trading day effect (for `trade` = `TRUE`).
`noise`	noise component.
`cov`	covariance matrix of smoother.

Note

For time series with the tsp attribute, set `frequency` to `period`.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# BLSALLFOOD data
data(BLSALLFOOD)
season(BLSALLFOOD, trend.order = 2, seasonal.order = 1, ar.order = 2)

season(BLSALLFOOD, trend.order = 2, seasonal.order = 1, ar.order = 2,
       filter = c(1, 132))

# Wholesale hardware data
data(WHARD)
season(WHARD, trend.order = 2, seasonal.order = 1, ar.order = 0, trade = TRUE,
       log = TRUE)

season(WHARD, trend.order = 2, seasonal.order = 1, ar.order = 0, trade = TRUE,
       filter = c(1, 132), log = TRUE)
```

simssm *Simulation by Gaussian State Space Model*

Description

Simulate time series by Gaussian State Space Model.

Usage

```
simssm(n = 200, trend = NULL, seasonal.order = 0, seasonal = NULL,
       arcoef = NULL,  ar = NULL, tau1 = NULL, tau2 = NULL, tau3 = NULL,
       sigma2 = 1.0, seed = NULL, plot = TRUE, ...)
```

Arguments

`n`	the number of data generated by simulation.
`trend`	initial values of trend component of length $m1$, where $m1$ is trend order (1, 2). If `NULL` (default), trend order is 0.
`seasonal.order`	order of seasonal component model (0, 1, 2).
`seasonal`	if `seasonal.order` > 0, initial values of seasonal component of length $p-1$, where p is period of one season.
`arcoef`	AR coefficients.
`ar`	initial values of AR component.
`tau1`	variance of trend component model.
`tau2`	variance of AR component model.
`tau3`	variance of seasonal component model.
`sigma2`	variance of the observation noise.
`seed`	arbitrary positive integer to generate a sequence of uniform random numbers. The default seed is based on the current time.
`plot`	logical. If `TRUE` (default), simulated data are plotted.
`...`	graphical arguments passed to `plot.simulate`.

Value

An object of class `"simulate"`, giving simulated data of Gaussian state space model.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# BLSALLFOOD data
data(BLSALLFOOD)
m1 <- 2; m2 <- 1; m3 <- 2
z <- season(BLSALLFOOD, trend.order = m1, seasonal.order = m2, ar.order = m3)

nl <- length(BLSALLFOOD)
trend <- z$trend[m1:1]
arcoef <- z$arcoef
period <- 12
seasonal <- z$seasonal[(period-1):1]
ar <- z$ar[m3:1]
tau1 <- z$tau2[1]
tau2 <- z$tau2[2]
tau3 <- z$tau2[3]
simssm(n = nl, trend, seasonal.order = m2, seasonal, arcoef, ar, tau1, tau2, tau3,
        sigma2 = z$sigma2, seed = 333)
```

Sunspot *Sunspot Number Data*

Description

Yearly numbers of sunspots from to 1749 to 1979.

Usage

```
data(Sunspot)
```

Format

A time series of 231 observations; yearly from 1749 to 1979.

Details

Sunspot is a part of the dataset `sunspot.year` from 1700 to 1988. Value "0" is converted into "0.1" for log transformation.

`Temperature` *Temperatures Data*

Description

The daily maximum temperatures in Tokyo (from 1979-01-01 to 1980-04-30).

Usage

```
data(Temperature)
```

Format

A time series of 486 observations.

Source

The data were obtained from Tokyo District Meteorological Observatory. https://www.data.jma.go.jp/obd/stats/etrn/

`trend` *Trend Estimation*

Description

Estimate the trend by state space model.

Usage

```
trend(y, trend.order = 1, tau2.ini = NULL, delta, plot = TRUE, ...)
```

Arguments

`y`	a univariate time series.
`trend.order`	trend order.
`tau2.ini`	initial estimate of variance of the system noise τ^2. If `tau2.ini` = `NULL`, the most suitable value is chosen in $\tau^2 = 2^{-k}$.
`delta`	search width (for `tau2.ini` is specified (not `NULL`)) .
`plot`	logical. If `TRUE` (default), trend component and residuals are plotted.
`...`	graphical arguments passed to `plot.trend`.

Details

The trend model can be represented by a state space model

$$x_n = F x_{n-1} + G v_n,$$
$$y_n = H x_n + w_n,$$

where F, G and H are matrices with appropriate dimensions. We assume that v_n and w_n are white noises that have the normal distributions $N(0, \tau^2)$ and $N(0, \sigma^2)$, respectively.

Value

An object of class `"trend"`, which is a list with the following components:

`trend`	trend component.
`residual`	residuals.
`tau2`	variance of the system noise τ^2.
`sigma2`	variance of the observational noise σ^2.
`llkhood`	log-likelihood of the model.
`aic`	AIC.
`cov`	covariance matrix of smoother.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# The daily maximum temperatures for Tokyo
data(Temperature)
trend(Temperature, trend.order = 1, tau2.ini = 0.223, delta = 0.001)

trend(Temperature, trend.order = 2)
```

`tsmooth` *Prediction and Interpolation of Time Series*

Description

Predict and interpolate time series based on state space model by Kalman filter.

Usage

```
tsmooth(y, f, g, h, q, r, x0 = NULL, v0 = NULL, filter.end = NULL,
        predict.end = NULL, minmax = c(-1.0e+30, 1.0e+30), missed = NULL,
        np = NULL, plot = TRUE, ...)
```

Arguments

`y`	a univariate time series y_n.
`f`	state transition matrix F_n.
`g`	matrix G_n.
`h`	matrix H_n.
`q`	system noise variance Q_n.
`r`	observational noise variance R.
`x0`	initial state vector $X(0 \mid 0)$.
`v0`	initial state covariance matrix $V(0 \mid 0)$.
`filter.end`	end point of filtering.
`predict.end`	end point of prediction.
`minmax`	lower and upper limits of observations.
`missed`	start position of missed intervals.
`np`	number of missed observations.
`plot`	logical. If `TRUE` (default), mean vectors of the smoother and estimation error are plotted.
`...`	graphical arguments passed to `plot.smooth`.

Details

The linear Gaussian state space model is

$$x_n = F_n x_{n-1} + G_n v_n,$$

$$y_n = H_n x_n + w_n,$$

where y_n is a univariate time series, x_n is an m-dimensional state vector.

F_n, G_n and H_n are $m \times m$, $m \times k$ matrices and a vector of length m , respectively. Q_n is $k \times k$ matrix and R_n is a scalar. v_n is system noise and w_n is observation noise, where we assume that $E(v_n, w_n) = 0$, $v_n \sim N(0, Q_n)$ and $w_n \sim N(0, R_n)$. User should give all the matrices of a state space model and its parameters. In current version, F_n, G_n, H_n, Q_n, R_n should be time invariant.

Value

An object of class `"smooth"`, which is a list with the following components:

`mean.smooth`	mean vectors of the smoother.
`cov.smooth`	variance of the smoother.
`esterr`	estimation error.
`llkhood`	log-likelihood.
`aic`	AIC.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Kitagawa, G. and Gersch, W. (1996) *Smoothness Priors Analysis of Time Series*. Lecture Notes in Statistics, No.116, Springer-Verlag.

Examples

```
## Example of prediction (AR model)
data(BLSALLFOOD)
BLS120 <- BLSALLFOOD[1:120]
z1 <- arfit(BLS120, plot = FALSE)
tau2 <- z1$sigma2

# m = maice.order, k=1
m1 <- z1$maice.order
arcoef <- z1$arcoef[[m1]]
f <- matrix(0.0e0, m1, m1)
f[1, ] <- arcoef
if (m1 != 1)
  for (i in 2:m1) f[i, i-1] <- 1
g <- c(1, rep(0.0e0, m1-1))
h <- c(1, rep(0.0e0, m1-1))
q <- tau2[m1+1]
r <- 0.0e0
x0 <- rep(0.0e0, m1)
v0 <- NULL

s1 <- tsmooth(BLS120, f, g, h, q, r, x0, v0, filter.end = 120, predict.end = 156)
s1

plot(s1, BLSALLFOOD)

## Example of interpolation of missing values (AR model)
z2 <- arfit(BLSALLFOOD, plot = FALSE)
tau2 <- z2$sigma2

# m = maice.order, k=1
m2 <- z2$maice.order
arcoef <- z2$arcoef[[m2]]
f <- matrix(0.0e0, m2, m2)
f[1, ] <- arcoef
if (m2 != 1)
  for (i in 2:m2) f[i, i-1] <- 1
g <- c(1, rep(0.0e0, m2-1))
h <- c(1, rep(0.0e0, m2-1))
q <- tau2[m2+1]
r <- 0.0e0
x0 <- rep(0.0e0, m2)
v0 <- NULL
```

```
tsmooth(BLSALLFOOD, f, g, h, q, r, x0, v0, missed = c(41, 101), np = c(30, 20))
```

---

tvar *Time Varying Coefficients AR Model*

Description

Estimate time varying coefficients AR model.

Usage

```
tvar(y, trend.order = 2, ar.order = 2, span, outlier = NULL, tau2.ini = NULL,
     delta, plot = TRUE)
```

Arguments

`y`	a univariate time series.
`trend.order`	trend order (1 or 2).
`ar.order`	AR order.
`span`	local stationary span.
`outlier`	positions of outliers.
`tau2.ini`	initial estimate of variance of the system noise τ^2. If `tau2.ini` = `NULL`, the most suitable value is chosen in $\tau^2 = 2^{-k}$.
`delta`	search width.
`plot`	logical. If `TRUE` (default), PARCOR is plotted.

Details

The time-varying coefficients AR model is given by

$$y_t = a_{1,t} y_{t-1} + \ldots + a_{p,t} y_{t-p} + u_t$$

where $a_{i,t}$ is i-lag AR coefficient at time t and u_t is a zero mean white noise.

The time-varying spectrum can be plotted using AR coefficient `arcoef` and variance of the observational noise `sigma2` by `tvspc`.

Value

`arcoef`	time varying AR coefficients.
`sigma2`	variance of the observational noise σ^2.
`tau2`	variance of the system noise τ^2.
`llkhood`	log-likelihood of the model.
`aic`	AIC.
`parcor`	PARCOR.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Kitagawa, G. and Gersch, W. (1996) *Smoothness Priors Analysis of Time Series*. Lecture Notes in Statistics, No.116, Springer-Verlag.

Kitagawa, G. and Gersch, W. (1985) *A smoothness priors time varying AR coefficient modeling of nonstationary time series*. IEEE trans. on Automatic Control, AC-30, 48-56.

See Also

`tvspc`, `plot.tvspc`

Examples

```
# seismic data
data(MYE1F)
z <- tvar(MYE1F, trend.order = 2, ar.order = 8, span = 20,
          outlier = c(630, 1026), tau2.ini = 6.6e-06, delta = 1.0e-06)
z

spec <- tvspc(z$arcoef, z$sigma2)
plot(spec)
```

`tvspc` *Evolutionary Power Spectra by Time Varying AR Model*

Description

Estimate evolutionary power spectra by time varying AR model.

Usage

```
tvspc(arcoef, sigma2, var = NULL, span = 20, nf = 200)
```

Arguments

`arcoef`	time varying AR coefficients.
`sigma2`	variance of the observational noise.
`var`	time varying variance.
`span`	local stationary span.
`nf`	number of frequencies in evaluating power spectrum.

Value

return an object of class `"tvspc"` giving power spectra, which has a `plot` method (`plot.tvspc`).

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Kitagawa, G. and Gersch, W. (1996) *Smoothness Priors Analysis of Time Series*. Lecture Notes in Statistics, No.116, Springer-Verlag.

Kitagawa, G. and Gersch, W. (1985) *A smoothness priors time varying AR coefficient modeling of nonstationary time series*. IEEE trans. on Automatic Control, AC-30, 48-56.

Examples

```
# seismic data
data(MYE1F)
z <- tvar(MYE1F, trend.order = 2, ar.order = 8, span = 20,
          outlier = c(630, 1026), tau2.ini = 6.6e-06, delta = 1.0e-06)
spec <- tvspc(z$arcoef, z$sigma2)
plot(spec)
```

`tvvar` *Time Varying Variance*

Description

Estimate time-varying variance.

Usage

```
tvvar(y, trend.order, tau2.ini = NULL, delta, plot = TRUE, ...)
```

Arguments

`y`	a univariate time series.
`trend.order`	trend order.
`tau2.ini`	initial estimate of variance of the system noise τ^2. If `tau2.ini` = `NULL`, the most suitable value is chosen in $\tau^2 = 2^{-k}$.
`delta`	search width.
`plot`	logical. If `TRUE` (default), transformed data, trend and residuals are plotted.
`...`	graphical arguments passed to the `plot` method.

Details

Assuming that $\sigma^2_{2m-1} = \sigma^2_{2m}$, we define a transformed time series $s_1, \dots, s_{N/2}$ by

$$s_m = y^2_{2m-1} + y^2_{2m},$$

where y_n is a Gaussian white noise with mean 0 and variance σ^2_n. s_m is distributed as a χ^2 distribution with 2 degrees of freedom, so the probability density function of s_m is given by

$$f(s) = \frac{1}{2\sigma^2} e^{-s/2\sigma^2}.$$

By further transformation

$$z_m = \log \left(\frac{s_m}{2} \right),$$

the probability density function of z_m is given by

$$g(z) = \frac{1}{\sigma^2} \exp \left\{ z - \frac{e^z}{\sigma^2} \right\} = \exp \left\{ (z - \log \sigma^2) - e^{(z - \log \sigma^2)} \right\}.$$

Therefore, the transformed time series is given by

$$z_m = \log \sigma^2 + w_m,$$

where w_m is a double exponential distribution with probability density function

$$h(w) = \exp \{ w - e^w \}.$$

In the space state model

$$z_m = t_m + w_m$$

by identifying trend components of z_m, the log variance of original time series y_n is obtained.

Value

An object of class "tvvar" which has a plot method. This is a list with the following components:

tvv	time varying variance.
nordata	normalized data.
sm	transformed data.
trend	trend.
noise	residuals.
tau2	variance of the system noise.
sigma2	variance of the observational noise.
llkhood	log-likelihood of the model.
aic	AIC.
tsname	the name of the univariate time series y.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Kitagawa, G. and Gersch, W. (1996) *Smoothness Priors Analysis of Time Series*. Lecture Notes in Statistics, No.116, Springer-Verlag.

Kitagawa, G. and Gersch, W. (1985) *A smoothness priors time varying AR coefficient modeling of nonstationary time series*. IEEE trans. on Automatic Control, AC-30, 48-56.

Examples

```
# seismic data
data(MYE1F)
tvvar(MYE1F, trend.order = 2, tau2.ini = 6.6e-06, delta = 1.0e-06)
```

---

unicor *Autocovariance and Autocorrelation*

Description

Compute autocovariance and autocorrelation function of the univariate time series.

Usage

```
unicor(y, lag = NULL, minmax = c(-1.0e+30, 1.0e+30), plot = TRUE, ...)
```

Arguments

`y`	a univariate time series.
`lag`	maximum lag. Default is $2\sqrt{n}$, where n is the length of the time series `y`.
`minmax`	thresholds for outliers in low side and high side.
`plot`	logical. If `TRUE` (default), autocorrelations are plotted.
`...`	graphical arguments passed to the `plot` method.

Value

An object of class `"unicor"` which has a `plot` method. This is a list with the following components:

`acov`	autocovariances.
`acor`	autocorrelations.
`acov.err`	error bound for autocovariances.
`acor.err`	error bound for autocorrelations.
`mean`	mean of `y`.
`tsname`	the name of the univariate time series `y`.

References

Kitagawa, G. (2020) *Introduction to Time Series Modeling with Applications in R*. Chapman & Hall/CRC.

Examples

```
# Yaw rate, rolling, pitching and rudder angle of a ship
data(HAKUSAN)
Yawrate <- HAKUSAN[, 1]
unicor(Yawrate, lag = 50)

# seismic data
data(MYE1F)
unicor(MYE1F, lag = 50)
```

`WHARD` *Wholesale Hardware Data*

Description

The monthly record of wholesale hardware data. (January 1967 - November 1979)

Usage

```
data(WHARD)
```

Format

A time series of 155 observations.

Source

The data were obtained from the United States Bureau of Labor Statistics (BLS).

Index