

Package ‘nlts’

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Title Nonlinear Time Series Analysis

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Description R functions for (non)linear time series analysis with an emphasis on nonparametric autoregression and order estimation, and tests for linearity / additivity.

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add.test	<i>Lagrange multiplier test for additivity in a timeseries</i>
----------	--

Description

add.test is a function to test the permissibility of the additive autoregressive model:

Usage

```
add.test(x, order, n.cond = FALSE)
```

Arguments

x	A time series (vector without missing values).
order	a scalar representing the order to be considered.
n.cond	The number of observation to condition on. The default is order (must be >= order)

Details

$$N(t) = f_1(N(t-1)) + f_2(N(t-2)) + \dots + f_d(N(t-d)) + e(t)$$

against the alternative:

$$N(t) = F(N(t-1), N(t-2), \dots, N(t-d)) + e(t)$$

This is the Lagrange multiplier test for additivity developed by Chen et al. (1995: test II).

Value

a vector is returned consisting of the asymptotic chi-square value, the associated d.f. and asymptotic p.val for the test of additivity.

References

Chen, R., Liu, J.S. & Tsay, R.S. (1995) Additivity tests for nonlinear autoregression. *Biometrika*, 82, 369-383. <https://doi.org/10.1093/biomet/82.2.369>

Bjornstad, O.N., Begon, M., Stenseth, N.C., Falck, W., Sait, S.M., & Thompson, D.J. (1998) Population dynamics of the Indian meal moth: demographic stochasticity and delayed regulatory mechanisms. *Journal of Animal Ecology*, 67, 110-126. <https://doi.org/10.1046/j.1365-2656.1998.00168.x>

Examples

```
data(plodia)
add.test(sqrt(plodia), order = 3)
```

```
contingency.periodogram
```

The contingency periodogram for periodicity in categorical time series

Description

A function to estimate the contingency periodogram to test for periodicity in categorical time series.

Usage

```
contingency.periodogram(x, maxper = 6, exact = FALSE)
```

Arguments

x	A vector representing the categorical time series.
maxper	the maximum lag (period) considered.
exact	If TRUE the FISHER exact test is calculated

Details

This is the contingency periodogram of Pierre Legedre and Pierre Dutielle to test for periodicity in categorical time series. I have coded the function so as to provide both the Fisher exact test and the asymptotic chi-square test.

Value

An object of class "contingency.periodogram" is returned consisting of a matrix with a row for each period considered. The columns are:

exact.p	the Fisher exact test at each lag (if exact=TRUE).
chi2	the asymptotic chi-square value.
df	the chi-square degrees-of-freedom.
asympt.p	the chi-squared asymptotic p-value.

References

Legendre et al. (1981) The contingency periodogram: A method for identifying rhythms in series of nonmetric ecological data. *Journal of Ecology*, 69, 965-979. <https://doi.org/10.2307/2259648>

Examples

```
data(plodia)
data<-as.factor((scale(plodia) > 0))
fit <- contingency.periodogram(data, maxper = 9)
## Not run: plot(fit)
```

lin.order.cls	<i>The order of a time series using cross-validation of the linear autoregressive model (conditional least-squares).</i>
---------------	--

Description

A function to estimate the order of a time series using cross-validation of the linear autoregressive model. Coefficients are estimated using conditional least-squares. I coded this functions to estimate the order of ecological time series. Bjornstad et al. (1998, 2001)

Usage

```
lin.order.cls(x, order = 1:5, n.cond = 5, echo = TRUE)
```

Arguments

x	A time series without missing values
order	The candidate orders. The default is 1:5
n.cond	The number of observation to condition on. The default is 5 (must be \geq max(order))
echo	if TRUE a counter for the data points and the orders is produced to monitor progress.

Details

The time series is normalized prior to cross-validation.

Note that if the dynamics is highly nonlinear, the nonparametric order-estimators ([ll.order](#)) may be more appropriate. (I coded this function to use for comparison with the nonparametric methods, because these also uses (nonlinear) conditional least-squares.)

Value

An object of class "lin.order" is returned consisting of the following components:

order	the grid of orders considered.
CVd	the cross-validation errors across the grid of orders.

References

Bjornstad, O.N., Begon, M., Stenseth, N. C., Falck, W., Sait, S. M. and Thompson, D. J. 1998. Population dynamics of the Indian meal moth: demographic stochasticity and delayed regulatory mechanisms. *Journal of Animal Ecology* 67:110-126. <https://doi.org/10.1046/j.1365-2656.1998.00168.x>
 Bjornstad, O.N., Sait, S.M., Stenseth, N.C., Thompson, D.J. & Begon, M. 2001. Coupling and the impact of specialised enemies on the dimensionality of prey dynamics. *Nature* 401: 1001-1006. <https://doi.org/10.1038/35059003>

See Also

[ll.order](#)

Examples

```
data(plodia)
fit <- lin.order.cls(sqrt(plodia), order=1:5)
## Not run: plot(fit)
summary(fit)
```

lin.test

A Tukey one-degree-of-freedom test for linearity in time series.

Description

a function to test the permissibility of the linear autoregressive model:

Usage

```
lin.test(x, order)
```

Arguments

x A time series (vector without missing values).
order a scalar representing the order to be considered.

Details

$$N(t) = a_0 + a_1N(t-1) + a_2N(t-2) + \dots + a_dN(t-d) + e(t)$$

against the alternative:

$$N_t = F(N(t-1), N(t-2), \dots, N(t-d)) + e(t)$$

This is the Tukey one-degree-of-freedom test of linearity developed by Tsay (1986). Orders up to 5 is permissible. [although the code is easily extended].

Value

A vector is returned consisting of the asymptotic F-value, the associated numerator and denominator d.f.'s and asymptotic p.val for the test of linearity

References

Tsay, R.S. (1986) Nonlinearity tests for time series. *Biometrika*, 73, 461-466. <https://doi.org/10.1093/biomet/73.2.461>

Examples

```
data(plodia)
lin.test(sqrt(plodia), order = 3)
```

ll.edm

Nonlinear forecasting of local polynomial 'empirical dynamic model'.

Description

A function to forecast a local polynomial 'empirical dynamic model'.

Usage

```
ll.edm(x, order, bandwidth, len = NA, deg = 2)
```

Arguments

x	A time series without missing values.
order	The order for the nonparametric (local polynomial) autoregression.
bandwidth	The bandwidth for the nonparametric (local polynomial) autoregression.
len	The length of the predicted time-series. If NA the length of the training time series will be used.
deg	The degree of the local polynomial.

Details

The function produces a nonlinear (nonparametric) forecast using the conditional mean method of Fan et al (1996). A Gaussian kernel is used for the local polynomial autoregression.

The bandwidth and order is best estimated with the [ll.order](#)-function.

Missing values are NOT permitted.

If deg is set to 0, the forecast uses the Nadaraya-Watson (locally constant) estimator of the conditional expectation against lagged-abundances.

Value

A time series with the nonlinear (nonparametric) forecast is returned

References

- Fan, J., Yao, Q., & Tong, H. (1996) Estimation of conditional densities and sensitivity measures in nonlinear dynamical systems. *Biometrika*, 83, 189-206. <https://doi.org/10.1093/biomet/83.1.189>
- Loader, C. (1999) *Local Regression and Likelihood*. Springer, New York. <https://doi.org/10.2307/1270956>

See Also

[ll.order](#)

Examples

```
data(plodia)

sim1 <- ll.edm(sqrt(plodia), order=2, bandwidth = 1.5)
```

ll.order	<i>Consistent nonlinear estimate of the order using local polynomial regression.</i>
----------	--

Description

A function to estimate the order of a time series using the nonparametric order selection method of Cheng and Tong (1992, 1994) as modified by Yao & Tong (1994; see also Fan, Yao & Tong 1996). The method uses leave-one-out cross-validation of the locally linear regression against lagged-abundances.

Usage

```
ll.order(x, order = 1:5, step = 1, deg = 2, bandwidth = c(seq(0.3, 1.5,
  by = 0.1), 2:10), cv = TRUE, echo = TRUE)
```

Arguments

x	A time series without missing values.
order	The candidate orders. The default is 1:5.
step	The time step for prediction.
deg	The degree of the local polynomial.
bandwidth	The candidate bandwidths to be considered.
cv	if TRUE leave-one-out cross-validation will be performed.
echo	if TRUE a counter shows the progress

Details

The time series is normalized prior to cross-validation.

A Gaussian kernel is used for the locally linear regression.

The bandwidth is optimized using cross-validation. If a single bandwidth is provided, no cross validation of bandwidth will be carried out. Highly nonlinear data will require more narrow bandwidths. If NA is returned it may be because the min bandwidth considered is too small relative to the density of data.

Missing values are NOT permitted.

If deg is set to 0, the order is estimated on the basis of the Nadaraya-Watson (locally constant) estimator of the conditional expectation against lagged-abundances (Cheng and Tong 1992, 1994).

Value

An object of class "ll.order" is returned consisting of the following components:

grid	the grid of orders, bandwidths, and CV's.
grid\$order	the orders.
grid\$CV	the cross-validation score across the grid of orders and bandwidths. (If cv = TRUE).
grid\$GCV	the generalized cross-validation score.
grid\$bandwidth	the bandwidths.
grid\$df	the degrees of freedom of the fitted model.
order	the vector of orders considered.
deg	The degree of the local polynomial.

References

- Cheng, B. & Tong, H. (1992) On consistent nonparametric order determination and chaos. *Journal of Royal Statistical Society B*, 54, 427-449.
- Cheng, B. & Tong, H. (1994) Orthogonal projection, embedding dimension and sample size in chaotic time series from a statistical perspective. *Philosophical Transactions of the Royal Society London, A*, 348, 325-341. <https://doi.org/10.1098/rsta.1994.0094>
- Fan, J., Yao, Q., & Tong, H. (1996) Estimation of conditional densities and sensitivity measures in nonlinear dynamical systems. *Biometrika*, 83, 189-206. <https://doi.org/10.1093/biomet/83.1.189>
- Yao, Q. & Tong, H. (1994) Quantifying the influence of initial values on non-linear prediction. *Journal of Royal Statistical Society B*, 56, 701-725.
- Bjornstad, O.N., Sait, S.M., Stenseth, N.C., Thompson, D.J., & Begon, M. (2001) Coupling and the impact of specialised enemies on the dimensionality of prey dynamics. *Nature*, 409, 1001-1006. <https://doi.org/10.1038/35059003>
- Loader, C. (1999) *Local Regression and Likelihood*. Springer, New York. <https://doi.org/10.1007/b98858>

Examples

```
data(plodia)

fit <- ll.order(sqrt(plodia), order=1:3, bandwidth
               = seq(0.5, 1.5, by = 0.5))

## Not run: plot(fit)

summary(fit)
```

lpx

Utility function

Description

hack to make ll.order work with locfit >1.5. not to be called by the user.

Usage

```
lpx(x, nn = 0, h = 0, adpen = 0, deg = 2, acri = "none",
    scale = FALSE, style = "none")
```

Arguments

x	...
nn	...
h	...
adpen	...
deg	...
acri	...
scale	...
style	...

Details

not to be called by the user.

Author(s)

Catherine Loader

mkx *Utility function*

Description

A function to create matrix of lagged time series. Called by various functions.

Usage

mkx(x, lags)

Arguments

x A univariate time series.
lags The vector of time lags.

Details

If lags is c(1,4), say, then the function returns a matrix that consist of columns x(t-1), x(t-4), x(t).

Value

A matrix of lagged abundances. The last column is the current

Author(s)

Upmanu Lall

References

Lall, U. & Sharma, A. (1996) A nearest neighbor bootstrap for time series resampling. *Water Resources Research*, 32, 679-693. <https://doi.org/10.1029/95wr02966>

plodia *Time series of Meal Moth abundance*

Description

This is replicate 3 in Bjornstad et al. (1998).

Usage

plodia

Format

A vector containing 55 values

References

Bjornstad, O. N., M. Begon, N. C. Stenseth, W. Falck, S. M. Sait, and D. J. Thompson. 1998. Population dynamics of the Indian meal moth: demographic stochasticity and delayed regulatory mechanisms. *Journal of Animal Ecology* 67:110-126. <https://doi.org/10.1046/j.1365-2656.1998.00168.x>

plot.contingency.periodogram
Plot contingency periodograms

Description

'plot' method for "contingency.periodogram" class object.

Usage

```
## S3 method for class 'contingency.periodogram'
plot(x, ...)
```

Arguments

x an object of class "contingency.periodogram", usually, as a result of a call to contingency.periodogram.
... generic plot arguments.

Value

A contingency periodogram is plotted. The line represents the critical value based on the chi-squared test (95%).

See Also

[contingency.periodogram](#)

plot.lin.order *Plot linear cross-validation for time-series order*

Description

'plot' method for class "lin.order".

Usage

```
## S3 method for class 'lin.order'
plot(x, ...)
```

Arguments

x an object of class "lin.order", usually, as a result of a call to `lin.order.cls` or `lin.order.mle`.
... generic plot arguments.

Value

A xy-plot of order against cross-validation error is produced.

See Also

[lin.order.cls](#)

plot.ll.order

Plot nonparametric cross-validation for time-series order

Description

'plot' method for class "ll.order".

Usage

```
## S3 method for class 'll.order'  
plot(x, ...)
```

Arguments

x an object of class "ll.order", usually, as a result of a call to `ll.order`.
... generic plot arguments.

Details

See [ll.order](#) for details.

Value

A xy-plot of minimum cross-validation error against order is produced.

See Also

[ll.order](#)

plot.lomb	<i>Plot Lomb periodograms</i>
-----------	-------------------------------

Description

'plot' method for objects of class "lomb".

Usage

```
## S3 method for class 'lomb'  
plot(x, ...)
```

Arguments

x	an object of class "lomb", usually, as a result of a call to spec.lomb.
...	generic plot arguments.

Value

A Lomb periodogram is composed of a xy-plot of amplitude against frequency.

See Also

[spec.lomb](#)

plot.ppl1	<i>Plot function for prediction profile objects</i>
-----------	---

Description

'plot' method for class "ppl1".

Usage

```
## S3 method for class 'ppl1'  
plot(x, ...)
```

Arguments

x	an object of class "ppl1", usually, as a result of a call to prediction.profile.l1.
...	generic plot arguments.

Details

See [prediction.profile.l1](#) for details.

Value

A xy-plot of one minus the cross-validation error (i.e. the prediction accuracy against prediction time step).

See Also

[prediction.profile.ll](#)

plot.specar.ci	<i>Plot ar-spectra with CI's</i>
----------------	----------------------------------

Description

'plot' method for class "specar.ci".

Usage

```
## S3 method for class 'specar.ci'  
plot(x, period = TRUE, ...)
```

Arguments

x	an object of class "specar.ci", usually, as a result of a call to specar.ci .
period	if TRUE x-axis is period, if FALSE frequency.
...	generic plot arguments.

Value

A xy-plot of amplitude against period (or frequency).

See Also

[specar.ci](#)

portman.Q	<i>Ljung-Box test for whiteness in a time series.</i>
-----------	---

Description

portman.Q uses the cumulative ACF to test for whiteness of a time series.

Usage

```
portman.Q(x, K)
```

Arguments

x	A time series (vector without missing values).
K	the maximum lag of the ACF to be used in the test.

Details

This is the Ljung-Box version of the the Portemanteau test for whiteness (Tong 1990). It may in particular be usefull to test for whiteness in the residuals from time series models.

Value

A vector is returned consisting of the asymptotic chi-square value, the associated d.f. and asymptotic p.val for the test of whiteness.

References

Tong, H. (1990) Non-linear time series : a dynamical system approach. Clarendon Press, Oxford.

Examples

```
data(plodia)

portman.Q(sqrt(plodia), K = 10)

fit <- ar(sqrt(plodia))
portman.Q(na.omit(fit$resid), K = 10)
```

predict.ll.order *Predict values from ll.order object.*

Description

Calculates the leave-one-out predicted values for the optimal ll.order object

Usage

```
## S3 method for class 'll.order'  
predict(object, ...)
```

Arguments

object an object of class "ll.order", usually, as a result of a call to ll.order.
... no other arguments currently allowed

Details

See [ll.order](#) for details.

Value

A data frame with observed and predicted values for the optimal ll-model is returned.

See Also

[ll.order](#)

prediction.profile.ll *Nonlinear forecasting at varying lags using local polynomial regression.*

Description

A wrapper function around ll.order to calculate prediction profiles (a la Sugihara and May 1990 and Yao and Tong 1994). The method uses leave-one-out cross-validation of the local regression (with CV optimized bandwidth) against lagged-abundances at various lags.

Usage

```
prediction.profile.ll(x, step = 1:10, order = 1:5, deg = 2,  
  bandwidth = c(seq(0.3, 1.5, by = 0.1), 2:10))
```


Arguments

x	A time series without missing values.
step	The vector of time steps for forward prediction.
order	The candidate orders. The default is 1:5.
deg	The degree of the local polynomial.
bandwidth	The candidate bandwidths to be considered.

Details

see [ll.order](#) for details.

Value

An object of class "ppll" consisting of a list with the following components:

step	the prediction steps considered.
CV	the cross-validation error.
order	the optimal order for each step.
bandwidth	the optimal bandwidth for each step.
df	the degrees of freedom for each step.

References

Sugihara, G., and May, R.M. (1990) Nonlinear forecasting as a way of distinguishing chaos from measurement error in time series. *Nature* 344, 734-741. <https://doi.org/10.1038/344734a0>

Yao, Q. and Tong, H. (1994) Quantifying the influence of initial values on non-linear prediction. *Journal of Royal Statistical Society B*, 56, 701-725.

Fan, J., Yao, Q., and Tong, H. (1996) Estimation of conditional densities and sensitivity measures in nonlinear dynamical systems. *Biometrika*, 83, 189-206. <https://doi.org/10.1093/biomet/83.1.189>

See Also

[ll.order](#)

Examples

```
data(plodia)

fit <- prediction.profile.ll(sqrt(plodia), step=1:3, order=1:3,
  bandwidth = seq(0.5, 1.5, by = 0.5))

## Not run: plot(fit)
```

print.ll.order	<i>Print nonparametric cross-validation for time-series order</i>
----------------	---

Description

'print' method for class "ll.order".

Usage

```
## S3 method for class 'll.order'
print(x, verbose = FALSE, ...)
```

Arguments

x	an object of class "ll.order", usually, as a result of a call to ll.order.
verbose	if TRUE provides a raw-printing of the object.
...	no other arguments currently allowed

Details

See [ll.order](#) for details.

Value

A matrix summarizing the minimum cross-validation error (cv.min) and the associated Gaussian-kernel bandwidth (bandwidth.opt) and model degrees-of-freedom for each order considered.

See Also

[ll.order](#)

spec.lomb	<i>The Lomb periodogram for unevenly sampled data</i>
-----------	---

Description

The function to estimate the Lomb periodogram for a spectral analysis of unevenly sampled data.

Usage

```
spec.lomb(y = stop("no data arg"), x = stop("no time arg"), freq = NULL)
```

Arguments

y	vector of length n representing the unevenly sampled time series.
x	the a vector (of length n) representing the times of observation.
freq	the frequencies at which the periodogram is to be calculated. If NULL the canonical frequencies (the Fourier frequencies) are used.

Details

This is the Lomb periodogram to test for periodicity in time series of unevenly sampled data.

Missing values should be deleted in both x and y before execution.

Value

An object of class "lomb" is returned consisting of the following components:

freq	the frequencies as supplied.
spec	the estimated amplitudes at the different frequencies.
f.max	the frequency of maximum amplitude.
per.max	the corresponding period of maximum amplitude.
p	the level of significance associated with the max period.

References

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

Examples

```
data(plodia)

y <- sqrt(plodia)
x <- 1:length(y)

#make some missing values
y[10:19] <- NA; x[10:19] <- NA
#omit NAs
y <- na.omit(y); x <- na.omit(x)

#the lomb p'gram
fit <- spec.lomb(y, x)
summary(fit)
## Not run: plot(fit)
```

specar.ci *Confidence interval for the ar-spectrum and the dominant period.*

Description

A function to estimate a "confidence interval" for the power spectrum and in particular a confidence interval for the dominant period. The function uses resampling of the autoregressive parameters to attain the estimate.

Usage

```
specar.ci(x, order, resamp = 500, nfreq = 100, echo = TRUE)
```

Arguments

x	A time series without missing values.
order	a scalar representing the order to be considered. If "aic" the order is selected automatically using the AIC criterion.
resamp	the number of resamples of the ar-coefficients from the covariance matrix.
nfreq	the number of points at which to save the value for the power spectrum (and confidence envelope).
echo	If TRUE, a counter for each run shows the progress.

Details

A "confidence interval" for the periodogram is obtained by resampling the ar-coefficients using the variance-covariance matrix from the ar.mle object.

If a zero'th order process is chosen by using the AIC criterion, a first order process will be used.

If the dynamics is highly nonlinear, the parametric estimate of the power spectrum may be inappropriate.

Value

An object of class "specar.ci" is returned consisting of the following components:

order	the ar-order.
spectrum\$freq	the spectral frequencies.
spectrum\$spec	the estimated power-spectrum of the data.
resamp\$spectrum	gives the quantile summary for the resampling distribution of the spectral powers.
resamp\$maxfreq	the full vector of output for the resampled max.frequencies.

See Also

[plot.specar.ci](#) [summary.specar.ci](#)

Examples

```
data(plodia)

fit <- specar.ci(sqrt(plodia), order=3, resamp=10)

## Not run: plot(fit, period=FALSE)

summary(fit)
```

summary.lin.order *Summarize linear cross-validation for time-series order*

Description

‘summary’ method for class "lin.order".

Usage

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

Arguments

object	an object of class "lin.order", usually, as a result of a call to <code>lin.order.cls</code> or <code>lin.order.mle</code> .
...	no other arguments currently allowed

Value

A slightly prettyfied version of the object is printed.

See Also

[lin.order.cls](#)

summary.l1.order	<i>Summarize nonparametric cross-validation for time-series order</i>
------------------	---

Description

'summary' method for class "l1.order".

Usage

```
## S3 method for class 'l1.order'
summary(object, GCV = FALSE, ...)
```

Arguments

object	an object of class "l1.order", usually, as a result of a call to l1.order.
GCV	if TRUE (or if cross-validation was not done), uses GCV values.
...	no other arguments currently allowed

Details

See [l1.order](#) for details.

Value

A matrix summarizing the minimum cross-validation error (cv.min) and the associated Gaussian-kernel bandwidth (bandwidth.opt) and model degrees-of-freedom for each order considered.

See Also

[l1.order](#)

summary.lomb	<i>Summarizes Lomb periodograms</i>
--------------	-------------------------------------

Description

'summary' method for objects of class "lomb".

Usage

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

Arguments

object an object of class "lomb", usually, as a result of a call to spec.lomb.
 ... generic plot arguments.

Value

A list summarizing the analysis is printed:

period the dominant period.
 p.val the p.value.

See Also

[spec.lomb](#)

summary.specar.ci *Summarize ar-spectra with CI's*

Description

'summary' method for objects of class "specar.ci".

Usage

```
## S3 method for class 'specar.ci'
summary(object, period = TRUE, ...)
```

Arguments

object an object of class "specar.ci", usually, as a result of a call to specar.ci.
 period If TRUE the summary is given in terms of the period, if false it is in terms of the
 frequency
 ... generic plot arguments.

Value

A list summarizing the analysis is printed:

period the dominant period.
 p.val the p.value.

See Also

[specar.ci](#)

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