Package ‘tseriesEntropy’

August 9, 2023

**Title**  Entropy Based Analysis and Tests for Time Series

**Version**  0.7-2

**Depends**  R (>= 2.14.0)

**Imports**  cubature, methods, parallel, stats, graphics, ks

**Suggests**  knitr, rmarkdown

**LazyLoad**  yes

**Encoding**  UTF-8

**Description**  Implements an Entropy measure of dependence based on the Bhattacharya-Hellinger-Matusita distance. Can be used as a (nonlinear) autocorrelation/crosscorrelation function for continuous and categorical time series. The package includes tests for serial and cross dependence and nonlinearity based on it. Some routines have a parallel version that can be used in a multicore/cluster environment. The package makes use of S4 classes.

**Maintainer**  Simone Giannerini <simone.giannerini@unibo.it>

**License**  GPL (>= 2)

**RoxygenNote**  7.2.3

**NeedsCompilation**  yes

**Author**  Simone Giannerini [aut, cre] (<https://orcid.org/0000-0002-0710-668X>)

**Repository**  CRAN

**Date/Publication**  2023-08-09 20:40:08 UTC

**R topics documented:**

  Srho .................................................. 2
  Srho-class .......................................... 4
  Srho.test ............................................ 5
  Srho.test-class ...................................... 7
  Srho.test.AR.p ..................................... 8
  Srho.test.ts.p ...................................... 10
  Srho.ts ............................................. 13
  Srho.ts-class ....................................... 15
  surrogate.AR ...................................... 16
Description

Entropy based measure of serial and cross dependence for integer or categorical data. Implements a normalized version of the Hellinger/Matusita distance. As shown in the references the metric measure is a proper distance.

Usage

\[
\text{Srho}(x, y, \text{lag.max}, \text{stationary} = \text{TRUE}, \text{plot} = \text{TRUE}, \text{version} = \text{c("FORTRAN","R")}, \text{nor} = \text{FALSE})
\]

Arguments

- **x, y**: integer or factor time series objects or vectors. (y is missing in the univariate case).
- **lag.max**: maximum lag at which to calculate Srho; default is round(N/4) where N is the number of observations.
- **stationary**: logical. If TRUE assumes stationarity and computes marginal probabilities by using N observations. If FALSE uses N-k observations where k is the lag.
- **plot**: logical. If TRUE (the default) Srho is plotted.
- **version**: either "FORTRAN" or "R". FORTRAN version is the default and is preferred over the pure R version which is considerably slower but is included in case of portability issues.
- **nor**: logical. If TRUE normalizes Srho with respect to its attainable maximum. Defaults to FALSE.

Details

**Univariate version: serial entropy** Srho(x, lag.max, stationary = TRUE, plot = TRUE, version = c("FORTRAN","R"), nor = FALSE)

**Bivariate version: cross entropy** Srho(x, y, lag.max, stationary = TRUE, plot = TRUE, version = c("FORTRAN","R"), nor = FALSE)

This implementation of the measure is normalized to take values in [0, 1]. Normalization is performed with respect to the maximum attainable value computed analytically. This makes the results of Srho comparable among different series.
Value

An object of S4 class "Srho", which is a list with the following elements:

- **.Data**: vector of lag.max elements containing Srho computed at each lag.
- **lags**: integer vector that contains the lags at which Srho is computed.
- **stationary**: Object of class "logical": TRUE if the stationary version is computed.
- **data.type**: Object of class "character": contains the data type.
- **notes**: Object of class "character": additional notes.

Warning

Unlike ccf the lag k value returned by Srho(x,y) estimates Srho between x[t] and y[t+k]. The result is returned invisibly if plot is TRUE.

Author(s)

Simone Giannerini<simone.giannerini@unibo.it>

References


See Also

See Also *Srho.test*. The function *Srho.ts* implements the same measure for numeric data.

Examples

```r
## UNIVARIATE VERSION
x <- as.integer(rbinom(n=20,size=4,prob=0.5))
Srho(x,lag.max=4)

## BIVARIATE VERSION
y <- as.integer(rbinom(n=20,size=4,prob=0.5))
Srho(x,y,lag.max=4)

## EXAMPLE 1: the effect of normalization
## computes the maximum attainable value by correlating x with itself
set.seed(12)
K <- 5       # number of categories
smax <- 1-1/sqrt(K) # theoretical maximum under the uniform distribution
x <- as.integer(sample(1:K,size=1e3,replace=TRUE)) # generates the sequence
```
Srho-class

Class "Srho"

Description
A class for Srho and its extensions

Objects from the Class
Objects can be created by calls of the form new("Srho", ...).

Slots
.Data: Object of class "numeric": contains Srho computed on the data set.
lags: Object of class "integer": contains the lags at which Srho is computed.
stationary: Object of class "logical": TRUE if the stationary version is computed.
data.type: Object of class "character": contains the data type.
notes: Object of class "character": additional notes.

Methods
plot signature(x = "Srho", y = "missing"): ...
show signature(object = "Srho"): ...

Author(s)
Simone Giannerini <simone.giannerini@unibo.it>

See Also
See Also Srho.test

Examples
showClass("Srho")
**Srho.test**

*Entropy Test For Serial And Cross Dependence For Categorical Sequences*

**Description**

Bootstrap/permutation tests of serial and cross dependence for integer or categorical sequences.

**Usage**

```r
Srho.test(x, y, lag.max=10, B = 1000, stationary = TRUE, plot = TRUE, quant = c(0.95, 0.99), nor = FALSE)
```

**Arguments**

- `x, y`: integer or factor time series objects or vectors. (`y` is missing in the univariate case).
- `lag.max`: maximum lag at which to calculate Srho; the default is 10.
- `B`: number of bootstrap/permutation replications.
- `stationary`: logical. If TRUE assumes stationarity and computes marginal probabilities by using all the N observations. If FALSE uses N-k observations where k is the lag.
- `plot`: logical. If TRUE (the default) produces a plot of Srho together with permutation confidence bands under the null hypothesis of independence.
- `quant`: quantiles to be specified for the computation of the significant lags and the plot of confidence bands. Up to 2 quantiles can be specified. Defaults are 95% and 99%.
- `nor`: logical. If TRUE normalizes Srho with respect to its attainable maximum. Defaults to FALSE.

**Details**

- **Univariate version: test for serial dependence**
  ```r
  Srho.test(x, lag.max, B = 1000, stationary = TRUE, plot = TRUE, quant = c(0.95, 0.99), nor = FALSE)
  ```

- **Bivariate version: test for cross dependence**
  ```r
  Srho.test(x, y, lag.max, B = 1000, stationary = TRUE, plot = TRUE, quant = c(0.95, 0.99), nor = FALSE)
  ```

**Value**

An object of class "Srho.test", which is a list with the following elements:

- `.Data`: vector of `lag.max` elements containing Srho computed at each lag.
- `quantiles`: Object of class "matrix": contains the quantiles of the bootstrap/permutation distribution under the null hypothesis.
- `test.type`: Object of class "character": contains a description of the type of test performed.
significant.lags
Object of class "list": contains the lags at which Srho exceeds the confidence bands at quant% under the null hypothesis.

p.value
Object of class "numeric": contains the bootstrap p-value for each lag.

lags
integer vector that contains the lags at which Srho is computed.

stationary
Object of class "logical": TRUE if the stationary version is computed.

data.type
Object of class "character": contains the data type.

notes
Object of class "character": additional notes.

Warning
Unlike ccf the lag k value returned by Srho.test(x,y) estimates Srho between x[t] and y[t+k]. The result is returned invisibly if plot is TRUE.

Author(s)
Simone Giannerini<simone.giannerini@unibo.it>

References


See Also
See also Srho, Srho.ts. The function Srho.test.ts implements the same test for numeric data.

Examples
set.seed(12)
x <- as.integer(rbinom(n=30,size=4,prob=0.5))
y <- as.integer(rbinom(n=30,size=4,prob=0.5))
z <- as.integer(c(4,abs(x[-30]*2-2))-rbinom(n=30,size=1,prob=1/2))

# no dependence
Srho.test(x,lag.max=4)  # univariate
Srho.test(x,y,lag.max=4)  # bivariate

# lag 1 dependence
Srho.test(x,z,lag.max=4)  # bivariate
Description

A class of tests for serial dependence and nonlinearity based upon Srho.

Objects from the Class

Objects can be created by calls of the form new("Srho.test", ...).

Slots

.Data: Object of class "numeric": contains Srho computed on the data set.
call: Object of class "call": contains the call to the routine.
call.h: Object of class "call": contains the call to the routine used for obtaining the surrogates or the bootstrap replicates under the null hypothesis.
quantiles: Object of class "matrix": contains the quantiles of the bootstrap/permutation distribution under the null hypothesis.
test.type: Object of class "character": contains a description of the type of test performed.
significant.lags: Object of class "list": contains the lags at which Srho exceeds the confidence bands at quant under the null hypothesis.
p.value: Object of class "numeric": contains the bootstrap p-value for each lag.
lags: Object of class "integer": contains the lags at which Srho is computed.
stationary: TRUE if the stationary version is computed.
data.type: Object of class "character": contains the data type.
notes: Object of class "character": additional notes.

Extends

Class "Srho", directly.

Methods

plot signature(x = "Srho.test", y = "missing"): ...
show signature(object = "Srho.test"): ...

Author(s)

Simone Giannerini <simone.giannerini@unibo.it>

See Also

See Also Srho
Examples

```r
showClass("Srho.test")
```

---

**Srho.test.AR.p**

**Entropy Tests For Nonlinearity In Time Series - Parallel Version**

**Description**

Entropy test of nonlinearity for time series based on `Srho.ts` and surrogate data obtained through the sieve bootstrap. The parallel version requires parallel.

**Usage**

```r
Srho.test.AR(x, y, lag.max = 10, B = 100, plot = TRUE, quant = c(0.95, 0.99),
            bw = c("reference", "mlcv", "lscv", "scv", "pi"), bdiag=TRUE,
            method = c("integral", "summation"), tol = 0.001, order.max = NULL,
            fit.method=c("yule-walker", "burg", "ols", "mle", "yw"), smoothed = TRUE ,...)
```

```r
## Parallel version
Srho.test.AR.p(x, y, lag.max = 10, B = 100, plot = TRUE, quant = c(0.95, 0.99),
              bw = c("reference", "mlcv", "lscv", "scv", "pi"), bdiag=TRUE,
              method = c("integral", "summation"), tol = 0.001, order.max = NULL,
              fit.method=c("yule-walker", "burg", "ols", "mle", "yw"), smoothed = TRUE,
              nwork=detectCores(),...)
```

**Arguments**

- **x, y** univariate numeric time series object or numeric vectors (`y` is missing in the univariate case).
- **lag.max** maximum lag at which to calculate Srho; the default is 10.
- **B** number of surrogate time series.
- **plot** logical. If `TRUE` (the default) produces a plot of Srho together with confidence bands under the null hypothesis of linearity at 95% and 99%.
- **quant** quantiles to be specified for the computation of the significant lags and the plot of confidence bands. Up to 2 quantiles can be specified. Defaults are 95% and 99%.
- **bw** see `Srho.ts`.
- **bdiag** see `Srho.ts`.
- **method** see `Srho.ts`.
- **tol** see `Srho.ts`.
- **order.max** see `surrogate.ARs`.
- **fit.method** see `surrogate.ARs`. 
smoothed logical. If TRUE (the default) uses the smoothed sieve bootstrap in surrogate.ARs to generate surrogates. Otherwise uses the classic sieve by calling surrogate.AR.

nwork number of workers/processes to be used in parallel environments.

... further arguments, typically passed to hcubature.

Details

For each lag from 1 to lag.max Srho.test.AR computes a test for nonlinearity for time series based on Srho.ts. The distribution under the null hypothesis of linearity is obtained through the sieve bootstrap. The routine requires the package parallel to spawn multiple workers.

Value

An object of class "Srho.test", which is a list with the following elements:

.data vector of lag.max elements containing Srho computed at each lag.
call: Object of class "call": contains the call to the routine.
call.h: Object of class "call": contains the call to the routine used for obtaining the surrogates or the bootstrap replicates under the null hypothesis
quantiles Object of class "matrix": contains the quantiles of the surrogate distribution under the null hypothesis.
test.type Object of class "character": contains a description of the type of test performed.
significant.lags Object of class "list": contains the lags at which Srho exceeds the confidence bands at quant% under the null hypothesis.
p.value Object of class "numeric": contains the bootstrap p-value for each lag.
lags integer vector that contains the lags at which Srho is computed.
estationary Object of class "logical": TRUE if the stationary version is computed. Set to FALSE by default as only the non-stationary version is implemented.
data.type Object of class "character": contains the data type.
notes Object of class "character": additional notes.

Author(s)

Simone Giannerini<simone.giannerini@unibo.it>

References


See Also

See Also Srho.ts, surrogate.AR, surrogate.ARs, Srho.test.AR.
Examples

```r
## Not run:
## ************************************************************
## WARNING: computationally intensive, increase B with caution
## ************************************************************

# modify nwork to match the number of available cores
set.seed(13)
x <- arima.sim(n=120, model = list(ar=0.8));
result <- Srho.test.AR.p(x, lag.max = 5, B = 100, bw='reference', method='integral', nwork=2)

## ** Compare timings **
system.time(Srho.test.AR.p(x, lag.max = 5, B = 100, bw='reference', method='integral', nwork=4))
system.time(Srho.test.AR(x, lag.max = 5, B = 100, bw='reference', method='integral'))

## End(Not run)
```

---

Srho.test.ts.p

### Description

Entropy test of serial and cross dependence for numeric time series (continuous state space) based on Srho.ts. The distribution under the null hypothesis of independence is obtained by means of bootstrap/permutations methods (see ci.type). The parallel version requires parallel.

### Usage

```r
Srho.test.ts(x, y, lag.max = 10, B = 100, plot = TRUE, quant = c(0.95, 0.99),
bw = c("reference", "mlcv", "lscv", "scv", "pi"), bdiag=TRUE,
method =c("integral","summation"), tol=1e-03, ci.type = c("mbb","perm"),...)
```

```r
## Parallel version
Srho.test.ts.p(x, y, lag.max = 10, B = 100, plot = TRUE, quant = c(0.95, 0.99),
bw = c("reference", "mlcv", "lscv", "scv", "pi"), bdiag=TRUE,
method =c("integral","summation"), tol=1e-03, ci.type = c("mbb","perm"),
nwork=detectCores(),...)
```

### Arguments

- `x, y` univariate numeric time series object or numeric vectors (`y` is missing in the univariate case).
- `lag.max` maximum lag at which to calculate Srho; the default is 10.
- `B` number of bootstrap/permutation replications.
- `plot` logical. If `TRUE` (the default) produces a plot of Srho together with confidence bands under the null hypothesis at levels set by `quant`.  

---

Srho.test.ts.p

### Entropy Tests Of Serial And Cross Dependence For Time Series
quantiles to be specified for the computation of the significant lags and the plot of confidence bands. Up to 2 quantiles can be specified. Defaults are 95% and 99%.

bw
see \texttt{Srho.ts}.

bdiag
see \texttt{Srho.ts}.

method
see \texttt{Srho.ts}.

tol
see \texttt{Srho.ts}.

ci.type
confidence interval type. determines how the distribution under the null hypothesis is obtained. \texttt{mbb} uses a moving block bootstrap with block length equal to \texttt{blag}, which is equal to \texttt{lag.max} by default. The option \texttt{perm} uses permutation methods (each resampled series is a random permutation of the original series). The option \texttt{mbb} makes sense only in the bivariate case for which is the default.

nwork
number of workers/processes to be used in parallel environments.

... further arguments, typically, the MBB block length \texttt{blag} or the arguments passed to \texttt{hcubature}.

**Details**

**Univariate version: test for serial dependence**  \texttt{Srho.test.ts.p(x, lag.max = 10, B = 100, plot = TRUE, quant = c(0.95, 0.99), bdiag=TRUE, bw = c("reference", "mlcv", "lscv", "scv", "pi"), method=c("integral","summation"), tol=1e-03, ci.type = c("perm"), nwork=detectCores())}

**Bivariate version: test for cross dependence**  \texttt{Srho.test.ts.p(x, y, lag.max = 10, B = 100, plot = TRUE, quant = c(0.95, 0.99), bdiag=TRUE, bw = c("reference", "mlcv", "lscv", "scv", "pi"), method=c("integral","summation"), tol=1e-03, ci.type = c("mbb","perm"), nwork=detectCores())}

For each lag from 1 to \texttt{lag.max} (serial dependence) or from \(-\texttt{lag.max}\) to \texttt{lag.max} (cross dependence) \texttt{Srho.test.ts} computes a test for serial/cross dependence for time series based on \texttt{Srho.ts}. The distribution under the null hypothesis of independence is obtained through either permutation or bootstrap methods. If the option \texttt{mbb} is chosen (bivariate case only) the resampled series use a moving block bootstrap to account for the serial dependence of the original series so that the test will have better size than the permutation version.

**Value**

An object of class "Srho.test", which is a list with the following elements:

- **.Data**: vector containing Srho computed at each lag.
- **call**: Object of class "call": contains the call to the routine.
- **call.h**: Object of class "call": contains the call to the routine used for obtaining the surrogates or the bootstrap replicates under the null hypothesis.
- **quantiles**: Object of class "matrix": contains the quantiles of the distribution under the null hypothesis.
- **test.type**: Object of class "character": contains a description of the type of test performed.
significant.lags
Object of class "list": contains the lags at which Srho exceeds the confidence bands at quant% under the null hypothesis.

p.value
Object of class "numeric": contains the bootstrap p-value for each lag.

lags
integer vector that contains the lags at which Srho is computed.

stationary
Object of class "logical": TRUE if the stationary version is computed. Set to FALSE by default as only the non-stationary version is implemented.

data.type
Object of class "character": contains the data type.

notes
Object of class "character": additional notes.

Author(s)
Simone Giannerini<simone.giannerini@unibo.it>

References

See Also
See Also Srho.test.ts and Srho.ts. The function Srho.test implements the same test for integer/categorical data. For a test for nonlinear serial dependence see Srho.test.AR, Trho.test.AR, Trho.test.SA, together with their parallel versions: Srho.test.AR.p, Trho.test.AR, Trho.test.SA.

Examples
```r
## Not run:
## ************************************************************
## WARNING: computationally intensive, increase B with caution
## ************************************************************
set.seed(13)
n <- 120
w <- rnorm(n)
x <- arima.sim(n, model = list(ar=0.8));
y <- arima.sim(n, model = list(ar=0.8));
z <- lag(x,-1) + rnorm(n,sd=2) # dependence at lag 1

# UNIVARIATE VERSION
res1 <- Srho.test.ts.p(w, lag.max = 5, B = 40, ci.type="perm") # independence
res2 <- Srho.test.ts.p(x, lag.max = 5, B = 40, ci.type="perm") # dependence

# BIVARIATE VERSION
res3 <- Srho.test.ts.p(x, y, lag.max = 5, B = 40, ci.type="mbb") # independence
res4 <- Srho.test.ts.p(x, z, lag.max = 5, B = 40, ci.type="mbb") # dependence

## End(Not run)
```
**Srhol.ts**

### Entropy Measure Of Serial And Cross Dependence

**Description**

Entropy based measure of serial and cross dependence for continuous data. For integer/categorical data see `Srhol`. Implements a normalized version of the Hellinger/Matusita distance. As shown in the references the metric measure is a proper distance.

**Usage**

```r
Srhol.ts(x, y, lag.max = 10, bw = c("reference", "mlcv", "lscv", "scv", "pi"), bdiag=TRUE, method = c("integral", "summation"), plot = TRUE, tol = 0.001, ...)
```

**Arguments**

- `x`, `y`: univariate numeric time series object or numeric vectors (`y` is missing in the univariate case).
- `lag.max`: maximum lag at which to calculate `Srhol`; default is 10
- `bw`: Object of class "character": bandwidth selection method, can be "reference", "mlcv", "lscv", "scv", "pi".
- `bdiag`: Object of class "logical": if `TRUE` uses the diagonal version of the bandwidth selectors `lscv`, `scv`, `pi`.
- `method`: Object of class "character": computation method, can be "integral" or "summation".
- `plot`: logical. If `TRUE` (the default) `Srhol` is plotted.
- `tol`: max. tolerance, passed to `hcubature`.
- `...`: further arguments, typically passed to `hcubature`.

**Details**

**Univariate version: serial entropy**

```r
Srhol.ts(x, lag.max = 10,
    bw = c("reference", "mlcv", "lscv", "scv", "pi"),
    bdiag=TRUE,
    method = c("integral", "summation"),
    plot = TRUE, tol = 0.001)
```

**Bivariate version: cross entropy**

```r
Srhol.ts(x, y, lag.max = 10,
    bw = c("reference", "mlcv", "lscv", "scv", "pi"),
    bdiag=TRUE,
    method = c("integral", "summation"),
    plot = TRUE, tol = 0.001)
```

The bandwidth selection methods are the following:

- `mlcv`: maximum likelihood cross-validation.
- `lscv`: least-squares cross-validation, see `Hlscv`.
- `scv`: smoothed cross-validation, see `Hscv`.
- `pi`: plugin, see `Hpi`.

If `bdiag = TRUE` (the default), the diagonal bandwidth selectors `Hlscv.diag`, `Hscv.diag`, `Hpi.diag` are used.
Value

An object of class "Srho.ts", with the following slots:

- **.Data**: Object of class "numeric": contains $\text{Srho}$ computed on the data set.
- **method**: Object of class "character": computation method.
- **bandwidth**: Object of class "character": bandwidth selection method.
- **lags**: Object of class "integer": contains the lags at which $\text{Srho}$ is computed.
- **stationary**: Object of class "logical": TRUE if the stationary version is computed.
- **data.type**: Object of class "character": contains the data type.
- **notes**: Object of class "character": additional notes.

Author(s)

Simone Giannerini<simone.giannerini@unibo.it>

References


See Also

*Srho.test.ts, hcubature, ks*. The function *Srho* implements the same measure for integer/categorical data.

Examples

```r
set.seed(11)
x <- arima.sim(list(order = c(1,0,0), ar = 0.8), n = 50)
S <- Srho.ts(x, lag.max=5, method="integral", bw="mlcv")

# creates a nonlinear dependence at lag 1
y <- c(runif(1), x[-50]*2*0.8-0.3)
S <- Srho.ts(x, y, lag.max=3, method="integral", bw="mlcv")
```
Description

A class for Srho for continuous data/time series.

Objects from the Class

Objects can be created by calls of the form new("Srho.ts", ...).

Slots

- `.Data`: Object of class "numeric": contains Srho computed on the data set.
- `method`: Object of class "character": computation method, can be "integral" or "summation".
- `bandwidth`: Object of class "character": bandwidth selection method.
- `lags`: Object of class "integer": contains the lags at which Srho is computed.
- `stationary`: Object of class "logical": TRUE if the stationary version is computed.
- `data.type`: Object of class "character": contains the data type.
- `notes`: Object of class "character": additional notes.

Extends

Class "Srho", directly.

Methods

- `show` signature(object = "Srho.ts"): ...

Author(s)

Simone Giannerini<simone.giannerini@unibo.it>

See Also

See Also Srho.test, Srho

Examples

`showClass("Srho.ts")`
surrogate.AR

**Surrogate Time Series Through AR Modeling (Sieve Bootstrap)**

**Description**

Starting from a time series \( x \) given as input, the function generates surrogate series by means of the sieve bootstrap. The surrogates can be used for testing for non linearity in time series.

**Usage**

```
surrogate.AR(x, order.max = NULL, fit.method = c("yule-walker", "burg", "ols", "mle", "yw"), nsurr)
```

**Arguments**

- **x** a univariate numeric time series object or a numeric vector.
- **order.max** maximum order of the AR model to fit. Passed to `ar`.
- **fit.method** character string giving the method used to fit the AR model. It is passed to `ar` and has to be one of the strings in the default argument (partial matching works). Defaults to "yule-walker".
- **nsurr** number of surrogates.

**Details**

Let \( N \) be the length of the series \( x \). The best AR model is chosen by means of the AIC criterion. The residuals of the model are resampled with replacement. Surrogate series are obtained by driving the fitted model with the resampled residuals.

**Value**

A list with the following elements:

- **surr** a matrix with \( N \) rows and \( nsurr \) columns, in each column is stored a surrogate.
- **call** contains the call to the routine.

**Author(s)**

Simone Giannerini<simone.giannerini@unibo.it>

**References**


surrogate.ARs

See Also

See also surrogate.AR, Trho.test.AR, surrogate.SA, Trho.test.SA.

Examples

set.seed(1345)
# Generates a AR(1) series
x <- arima.sim(n=120, model = list(ar=0.8));
x.surr <- surrogate.AR(x, nsurr=3);
plot.ts(x.surr$surr,col=4);

## Check that the surrogates have the same ACF of x
corig <- acf(x,10,plot=FALSE)$acf[,1];
csurr <- acf(x.surr$surr[,1],10,plot=FALSE)$acf[,1];
round(cbind(corig,csurr,"abs(difference"=abs(corig-csurr)),3)

---

**surrogate.ARs**

*Surrogate Time Series Through A Modeling (Smoothed Sieve Bootstrap)*

**Description**

Starting from a time series $x$ given as input, the function generates surrogate series by means of the smoothed sieve bootstrap. The surrogates can be used for testing for non linearity in time series.

**Usage**

```
surrogate.ARs(x, order.max = NULL, 
fit.method = c("yule-walker","burg", "ols", "mle", "yw"), nsurr)
```

**Arguments**

- `x` : a univariate numeric time series object or a numeric vector.
- `order.max` : maximum order of the AR model to fit. Passed to `ar`.
- `fit.method` : character string giving the method used to fit the AR model. It is passed to `ar` and has to be one of the strings in the default argument (partial matching works). Defaults to "yule-walker".
- `nsurr` : number of surrogates.

**Details**

Let $N$ be the length of the series $x$. The best AR model is chosen by means of the AIC criterion. Surrogate series are obtained by driving the fitted model with the smoothed resampled residuals. Smoothing is performed through Kernel density estimation with a Gaussian Kernel by using the defaults of `density`. 
surrogate.SA

**Value**

A list with the following elements:

- `surr`: a matrix with \( N \) rows and \( nsurr \) columns, in each column is stored a surrogate.
- `call`: contains the call to the routine.

**Author(s)**

Simone Giannerini<simone.giannerini@unibo.it>

**References**


**See Also**

See also `surrogate.AR`, `Trho.test.AR`, `surrogate.SA`, `Trho.test.SA`.

**Examples**

```r
set.seed(1345)
# Generates a AR(1) series
x <- arima.sim(n=120, model = list(ar=0.8));
x.surr <- surrogate.ARs(x, order.max=NULL, nsurr=3);
plot.ts(x.surr$surr,col=4);

## Check that the surrogates have the same ACF of x
corig <- acf(x,10,plot=FALSE)$acf[,,1];
csurr <- acf(x.surr$surr[,1],10,plot=FALSE)$acf[,,1];
round(cbind(corig,csurr,"abs(difference")=abs(corig-csurr)),3)
```

---

**surrogate.SA**

**Surrogate Time Series Through Simulated Annealing**

**Description**

Starting from a time series \( x \) given as input, the function generates surrogate series through Simulated Annealing. Each surrogate series is a constrained random permutation having the same autocorrelation function (up to \( n\text{lag} \) lags) of the original series \( x \). The surrogates can be used for testing for non linearity in time series.

**Usage**

```r
surrogate.SA(x, nlag, nsurr, Te = 0.0015, RT = 0.9, eps.SA = 0.05, nsuccmax = 30, nmax = 300, che = 1e+05)
```
surrogate.SA

Arguments

- **x**: a univariate numeric time series object or a numeric vector.
- **nlag**: minimization is performed w.r.t. to the first nlag lags.
- **nsurr**: number of surrogates.
- **Te**: starting value for the temperature.
- **RT**: reduction factor for the temperature Te.
- **eps.SA**: target tolerance.
- **nsuccmax**: Te is decreased after nsuccmax*N successes.
- **nmax**: Te is decreased after nmax*N successes.
- **che**: after che*2N global iterations the algorithm starts again.

Details

Let N be the length of the series x. Sensible (N-dependent) defaults are derived for the parameters of the algorithm, there should not be the need to change them. In case, the user could try increasing eps.SA.

Value

A list with the following elements:

- **surr**: a matrix with N rows and nsurr columns, in each column is stored a surrogate.
- **call**: contains the call to the routine.

Author(s)

Simone Giannerini<simone.giannerini@unibo.it>

References


See Also

See Also **Trho.test.SA**, **surrogate.AR**, **Trho.test.AR**.

Examples

```r
set.seed(1345)
# Generates a AR(1) series
x <- arima.sim(n=120, model = list(ar=0.8));
x.surr <- surrogate.SA(x, nlag=10, nsurr=3);
plot.ts(x.surr$surr,col=4);
```
## Check that the surrogates have the same ACF of x

corig <- acf(x,10,plot=FALSE)$acf[,1];

csurr <- acf(x.surr$surr[,1],10,plot=FALSE)$acf[,1];

round(cbind(corig,csurr,"abs(difference")=abs(corig-csurr)),3)

---

### Description

Entropy test of nonlinearity for time series based on \texttt{Srho.ts} and surrogate data obtained through the sieve bootstrap (AR modeling). The parallel version requires \texttt{parallel}.

### Usage

\texttt{Trho.test.AR(x, y, lag.max = 10, B = 100, plot = TRUE, quant = c(0.95, 0.99), bw = c("reference", "mlcv", "lscv", "scv", "pi"), bdiag=TRUE, method = c("integral", "summation"), tol = 0.001, order.max = NULL, fit.method=c("yule-walker", "burg", "ols", "mle", "yw"), smoothed = TRUE,...)}

\texttt{## Parallel version}

\texttt{Trho.test.AR.p(x, y, lag.max = 10, B = 100, plot = TRUE, quant = c(0.95, 0.99), bw = c("reference", "mlcv", "lscv", "scv", "pi"), bdiag=TRUE, method = c("integral", "summation"), tol = 0.001, order.max = NULL, fit.method=c("yule-walker", "burg", "ols", "mle", "yw"), smoothed = TRUE, nwork=detectCores(),...)}

### Arguments

- **x, y** : univariate numeric time series object or numeric vectors (\(y\) is missing in the univariate case).
- **lag.max** : maximum lag at which to calculate Trho; the default is 10.
- **B** : number of surrogate time series.
- **plot** : logical. If TRUE (the default) produces a plot of Trho together with confidence bands under the null hypothesis of linearity at 95\% and 99\%.
- **quant** : quantiles to be specified for the computation of the significant lags and the plot of confidence bands. Up to 2 quantiles can be specified. Defaults are 95\% and 99\%.
- **bw** : see \texttt{Srho.ts}.
- **bdiag** : see \texttt{Srho.ts}.
- **method** : see \texttt{Srho.ts}.
- **tol** : see \texttt{Srho.ts}.
- **order.max** : see \texttt{surrogate.ARs}.
fit.method    see surrogate.ARs.
smoothed     logical. If TRUE (the default) uses the smoothed sieve bootstrap in surrogate.ARs to generate surrogates. Otherwise uses the classic sieve by calling surrogate.AR.
nwork        number of workers/processes to be used in parallel environments.

Details
For each lag from 1 to lag.max Trho.test.AR computes a test for nonlinearity for time series based on Srho.ts. The distribution under the null hypothesis of a linear Gaussian process is obtained through the sieve bootstrap. The routine requires the package parallel to spawn multiple workers.

Value
An object of class "Srho.test", which is a list with the following elements:

.Data         vector of lag.max elements containing Trho computed at each lag.
call:         Object of class "call": contains the call to the routine.
call.h:       Object of class "call": contains the call to the routine used for obtaining the surrogates or the bootstrap replicates under the null hypothesis
test.type     Object of class "character": contains a description of the type of test performed.
significant.lags
              Object of class "list": contains the lags at which Trho exceeds the confidence bands at quant% under the null hypothesis.
p.value       Object of class "numeric": contains the bootstrap p-value for each lag.
lags          integer vector that contains the lags at which Trho is computed.
stationary    Object of class "logical": TRUE if the stationary version is computed. Set to FALSE by default as only the non-stationary version is implemented.
data.type      Object of class "character": contains the data type.
notes          Object of class "character": additional notes.

Author(s)
Simone Giannerini<simone.giannerini@unibo.it>

References

See Also
See Also Srho.ts, surrogate.AR, surrogate.ARs, Trho.test.AR.
Examples

```r
## Not run:
# modify nwork to match the number of available cores
set.seed(13)
b <- 100
x <- arima.sim(n=120, model = list(ar=0.8));
result <- Trho.test.AR.p(x, lag.max = 5, B=b, nwork=2)

## ** Compare timings **
system.time(Trho.test.AR.p(x,lag.max = 5,B=b, nwork=4))
system.time(Trho.test.AR(x, lag.max = 5,B=b))

## End(Not run)
```

Description

Entropy test of nonlinearity for time series based on `Srho.ts` and surrogate data obtained through Simulated Annealing. The parallel version requires parallel.

Usage

```r
Trho.test.SA(x, y, lag.max = 10, B = 100, plot = TRUE, quant = c(0.95, 0.99),
          bw = c("reference", "mlcv", "lscv", "scv", "pi"), bdiag=TRUE,
          method =c("integral","summation"), tol=1e-03, nlag=trunc(length(x)/4),
          Te=0.0015, RT=0.9, eps.SA=0.05, nsuccmax=30, nmax=300, che=100000,...)
```

```r
Trho.test.SA.p(x, y, lag.max = 10, B = 100, plot = TRUE, quant = c(0.95, 0.99),
          bw = c("reference", "mlcv", "lscv", "scv", "pi"), bdiag=TRUE,
          method =c("integral","summation"), tol=1e-03, nlag=trunc(length(x)/4), Te=0.0015,
          RT=0.9, eps.SA=0.05, nsuccmax=30, nmax=300, che=100000, nwork=detectCores(),...)
```

Arguments

- **x, y**
  - univariate numeric time series object or numeric vectors (`y` is missing in the univariate case).
- **lag.max**
  - maximum lag at which to calculate Trho; the default is 10.
- **B**
  - number of surrogate time series.
- **plot**
  - logical. If `TRUE`(the default) produces a plot of Trho together with confidence bands under the null hypothesis of linearity at 95% and 99%.
- **quant**
  - quantiles to be specified for the computation of the significant lags and the plot of confidence bands. Up to 2 quantiles can be specified. Defaults are 95% and 99%.
For each lag from 1 to \(\text{lag.max}\) \text{Trho.test.SA} computes a test for nonlinearity for time series based on \text{Srho.ts}. The distribution under the null hypothesis of a linear Gaussian process is obtained through a generalization of surrogate data methods. Surrogate time series are obtained through Simulated Annealing (SA). Sensible (N-dependent) defaults are derived for the parameters of the SA algorithm, there should not be the need to change them. The routine requires the package parallel to spawn multiple workers.

\section*{Value}

An object of class "Srho.test", which is a list with the following elements:

- \text{.Data} vector of \(\text{lag.max}\) elements containing \(\text{Trho}\) computed at each lag.
- \text{call:} Object of class "call": contains the call to the routine.
- \text{call.h:} Object of class "call": contains the call to the routine used for obtaining the surrogates or the bootstrap replicates under the null hypothesis.
- \text{quantiles} Object of class "matrix": contains the quantiles of the surrogate distribution under the null hypothesis.
- \text{test.type} Object of class "character": contains a description of the type of test performed.
- \text{significant.lags} Object of class "list": contains the lags at which \(\text{Trho}\) exceeds the confidence bands at quant\% under the null hypothesis.
- \text{p.value} Object of class "numeric": contains the bootstrap p-value for each lag.
- \text{lags} integer vector that contains the lags at which \(\text{Trho}\) is computed.
- \text{stationary} Object of class "logical": TRUE if the stationary version is computed. Set to FALSE by default as only the non-stationary version is implemented.
- \text{data.type} Object of class "character": contains the data type.
- \text{notes} Object of class "character": additional notes.
Author(s)
Simone Giannerini<simone.giannerini@unibo.it>

References

See Also
See Also *Srho.ts, surrogate.SA, Trho.test.SA*.

Examples
```r
## Not run:
# modify nwork to match the number of available cores
set.seed(13)
x <- arima.sim(n=120, model = list(ar=0.8));
result <- Trho.test.SA.p(x, lag.max = 5, B = 100, bw='reference', nwork=2)

## ** Compare timings **
system.time(Trho.test.SA.p(x, lag.max = 5, B = 100, bw='reference', nwork=4))
system.time(Trho.test.SA(x, lag.max = 5, B = 100, bw='reference'))

## End(Not run)
```
# Index

**classes**
- Srho-class, 4
- Srho.test-class, 7
- Srho.ts-class, 15

**ts**
- Srho, 2
- Srho.test, 5
- Srho.test.AR.p, 8
- Srho.test.ts.p, 10
- Srho.ts, 13
- surrogate.AR, 16
- surrogate.ARs, 17
- surrogate.SA, 18
- Trho.test.AR.p, 20
- Trho.test.SA.p, 22

ar, 16, 17
density, 17

hcube, 9, 11, 13, 14, 21, 23
Hlscl, 13
Hpi, 13
Hscv, 13

ks, 14

plot, Srho, missing-method (Srho-class), 4
plot, Srho.test, missing-method
  (Srho.test-class), 7
show, Srho, method (Srho-class), 4
show, Srho.test-method
  (Srho.test-class), 7
show, Srho.ts-method (Srho.ts-class), 15
Srho, 2, 6, 7, 13–15
Srho-class, 4
Srho.test, 3, 4, 5, 12, 15
Srho.test-class, 7
Srho.test.AR, 9, 12
Srho.test.AR (Srho.test.AR.p), 8
Srho.test.ts, 6, 12, 14
Srho.test.ts (Srho.test.ts.p), 10
Srho.test.ts.p, 10
Srho.ts, 3, 6, 8–12, 13, 20–24
Srho.ts-class, 15
surrogate.AR, 9, 16, 17–19, 21
surrogate.ARs, 8, 9, 17, 20, 21
surrogate.SA, 17, 18, 18, 23, 24
Trho.test.AR, 12, 17–19, 21
Trho.test.AR (Trho.test.AR.p), 20
Trho.test.AR.p, 20
Trho.test.SA, 12, 17–19, 24
Trho.test.SA (Trho.test.SA.p), 22
Trho.test.SA.p, 22