Package ‘trend’

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Title Non-Parametric Trend Tests and Change-Point Detection

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Depends R (>= 2.12.0)

Description The analysis of environmental data often requires
the detection of trends and change-points.
This package provides the Mann-Kendall Trend Test,
seasonal Mann-Kendall Test,
correlated seasonal Mann-Kendall Test,
partial Mann-Kendall Trend test,
(Seasonal) Sen's slope, partial correlation trend test and
change-point test after Pettitt.

ZipData yes

NeedsCompilation yes

Suggests Kendall, zyp

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R topics documented:

`trend-package` *Non-Parametric Trend Tests and Change-Point Detection*

Description

The analysis of environmental data often requires the detection of trends and change-points. This package provides the Mann-Kendall Trend Test, seasonal Mann-Kendall Test, correlated seasonal Mann-Kendall Test, partial Mann-Kendall Trend test, (Seasonal) Sen's slope, partial correlation trend test and change-point test after Pettitt.

Details

Package:	trend
Type:	Package
Version:	0.2.0
Date:	2016-05-14
License:	GPL-3
LazyLoad:	yes

csmk.test	Correlated Seasonal Mann-Kendall Test
cs.test	Cox and Stuart trend test
maxau	Suspended sediment concentration (s) and discharge (Q) for the River Rhine at Maxau, annual averages
mk.test	Mann-Kendall Trend Test
PagesData	Simulated data of Page
partial.cor.trend.test	Partial correlation trend test
partial.mk.test	Partial Mann-Kendall Test
pettitt.test	Pettitt's test for change-point-detection
sea.sens.slope	Seasonal Sen's slope and intercept
sens.slope	Sen's slope and intercept
smk.test	Seasonal Mann-Kendall Test
summary.trend.test	Summary Method for Class 'trend'
wm.test	Wallis and Moore phase-frequency test
ww.test	Wald-Wolfowitz test for independence and stationarity

Author(s)

Thorsten Pohlert

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References

Bahrenberg, G., Giese, E. and Nipper, J., (1992): Statistische Methoden in der Geographie, Band 2 Multivariate Statistik, Teubner, Stuttgart.

CHR (ed., 2010): Das Abflussregime des Rheins und seiner Nebenfluesse im 20. Jahrhundert, Report no I-22 of the CHR, p. 172.

D. R. Cox and A. Stuart (1955), Quick sign tests for trend in location and dispersion. Biometrika 42, 80-95.

Hipel, K.W. and McLeod, A.I., (2005). Time Series Modelling of Water Resources and Environmental Systems. http://www.stats.uwo.ca/faculty/aim/1994Book/.

Hirsch, R., J. Slack and R. Smith, (1982): Techniques of Trend Analysis for Monthly Water Quality Data. Water Resour. Res., 18, 107-121.

Libiseller, C. and Grimvall, A., (2002). Performance of partial Mann-Kendall tests for trend detection in the presence of covariates. Environmetrics 13, 71-84, http://dx.doi.org/10.1002/env.507.

Pettitt, A. N., (1979). A non-parametric approach to the change point problem. Journal of the Royal Statistical Society Series C, Applied Statistics 28, 126-135.

Richard O. Gilbert. (1987). Statistical methods for environmental pollution monitoring. John Wiley & Sons. pp 230

R. K. Rai, A. Upadhyay, C. S. P. Ojha and L. M. Lye (2013), Statistical analysis of hydro-climatic variables. In: R. Y. Surampalli, T. C. Zhang, C. S. P. Ojha, B. R. Gurjar, R. D. Tyagi and C. M. Kao (ed. 2013), *Climate change modelling, mitigation, and adaptation*. Reston, VA: ASCE. doi = 10.1061/9780784412718.

L. Sachs (1997), *Angewandte Statistik*. Berlin: Springer.

Sen, P.K., (1968): Estimates of the regression coefficient based on Kendall's tau, Journal of the American Statistical Association, 63, 1379–1389.

C.-D. Schoenwiese (1992), *Praktische Statistik*. Berlin: Gebr. Borntraeger.

W. A. Wallis and G. H. Moore (1941): A significance test for time series and other ordered observations. Tech. Rep. 1. National Bureau of Economic Research. New York.

A. Wald and J. Wolfowitz (1943), An exact test for randomness in the non-parametric case based on serial correlation. *Annual Mathematical Statistics* 14, 378–388.

WMO (2009), *Guide to Hydrological Practices*. Volume II, Management of Water Resources and Application of Hydrological Practices, WMO-No. 168.

See Also

`cor`, `cor.test`, `csmk.test`, `mk.test`, `PagesData`, `partial.mk.test`, `partial.cor.trend.test`, `pettitt.test`, `print.trend.test`, `sea.sens.slope`, `sens.slope` `smk.test`, `summary.trend.test`, `wm.test`, `ww.test`, `cs.test`

`cs.test` *Cox and Stuart trend test*

Description

Performes the non-parametric Cox and Stuart trend test (two-sided test).

Usage

```
cs.test(x)
```

Arguments

`x`	a vector or a time series object of class "ts"

Details

First, the series is devided by three. It is compared, whether the data of the first third of the series are larger or smaller than the data of the last third of the series. The test statistic of the Cox-Stuart trend test for $n > 30$ is calculated as:

$$z = \frac{\| S - \frac{n}{6} \|}{\sqrt{\frac{n}{12}}}$$

where S denotes the maximum of the number of signs, i.e. $+$ or $-$, respectively. The z-statistic is normally distributed. For $n \leq 30$ a continuity correction of -0.5 is included in the denominator.

Value

An object of class "htest"

`method`	a character string indicating the chosen test
`data.name`	a character string giving the name(s) of the data
`statistic`	the Cox-Stuart z-value
`alternative`	a character string describing the alternative hypothesis
`p.value`	the p-value for the test

Note

NA values are omitted. Many ties in the series will lead to reject H0 in the present test.

Author(s)

T. Pohlert

References

L. Sachs (1997), *Angewandte Statistik*. Berlin: Springer.

C.-D. Schoenwiese (1992), *Praktische Statistik*. Berlin: Gebr. Borntraeger.

D. R. Cox and A. Stuart (1955), Quick sign tests for trend in location and dispersion. *Biometrika* 42, 80-95.

See Also

mk.test

Examples

```
## Example from Schoenwiese (1992, p. 114)
## Number of frost days in April at Munich from 1957 to 1968
## z = -0.5, Accept H0
frost <- ts(data=c(9,12,4,3,0,4,2,1,4,2,9,7), start=1957)
cs.test(frost)

## Example from Sachs (1997, p. 486-487)
## z ~ 2.1, Reject H0 on a level of p = 0.0357
x <- c(5,6,2,3,5,6,4,3,7,8,9,7,5,3,4,7,3,5,6,7,8,9)
cs.test(x)

data(Nile)
cs.test(Nile)
```

`csmk.test` *Correlated Seasonal Mann-Kendall Test*

Description

Performs a Seasonal Mann-Kendall test under the presence of correlated seasons.

Usage

```
csmk.test(x)
```

Arguments

x	A time series object that comprises >= 2 seasons

Details

The Mann-Kendall statistics are first computed for each season seperately. The variance - covariance matrix is computed according to Libiseller and Grimvall (2002) and ties are taken into account. Finally the corrected Z-statistics for the entire series is calculated as follows:

$$Z = \mathbf{1}^T \mathbf{S} / \mathbf{1}^T \mathbf{X}\tilde{}\mathbf{1}$$

Z denotes the quantile of the normal distribution, 1 indicates a vector with all elements equal to one, S is the vector of Mann-Kendall scores for each season and X denotes the variance - covariance matrix.

Value

`method`	The chosen method (i.e. CSMK)
`Sg`	Vector of Mann-Kendall scores for each season
`varSg`	Vector of the variance of Mann-Kendall scores for each season
`Zg`	Vector of Z-values for each season
`pvalg`	Vector of p-values for each season
`Covar`	Variance - Covariance matrix for the seasonal Mann-Kendall statistics
`Correl`	Correlation matrix for the seasonal Mann-Kendall statistics
`Stot`	Mann-Kendall score for the entire series
`Z`	Z-value for the entire series
`Varianz`	variance for the entire series
`pvalue`	p-value for the entire series

Generic function summary.trend.test is provided.

Warning

Current Version is for complete observations only.

Author(s)

T. Pohlert

References

Hipel, K.W. and McLeod, A.I., (2005). Time Series Modelling of Water Resources and Environmental Systems. Electronic reprint of our book orginally published in 1994. `http://www.stats.uwo.ca/faculty/aim/1994Book/`.

Libiseller, C. and Grimvall, A., (2002). Performance of partial Mann-Kendall tests for trend detection in the presence of covariates. Environmetrics 13, 71-84, `http://dx.doi.org/10.1002/env.507`.

See Also

`cor`, `cor.test`, `mk.test`, `smk.test`, `SeasonalMannKendall`, `summary.trend.test`

Examples

```
data(co2)
plot(co2)
res <- csmk.test(co2)
summary.trend.test(res)

data(nottem)
plot(nottem)
res <- csmk.test(nottem)
summary.trend.test(res)
```

---

maxau — *Annual suspended sediment concentration and flow data, River Rhine*

Description

Annual time series of average suspended sediment concentration (s) in mg/l and average discharge (Q) in m^3 / s at the River Rhine, 1965.1-2009.1

Usage

```
data(maxau)
```

Format

The format is: mts [1:45, 1:2] 37.4 31.3 26.4 28.8 32.9 ... - attr(*, "dimnames")=List of 2 ..$: NULL ..$: chr [1:2] "s" "Q" - attr(*, "tsp")= num [1:3] 1965 2009 1 - attr(*, "class")= chr [1:2] "mts" "ts"

Source

BfG, Germany

Examples

```
data(maxau)
plot(maxau)
```

`mk.test` *Mann-Kendall Test*

Description

Performs a univariate Mann-Kendall test

Usage

```
mk.test(x)
```

Arguments

`x`	A time series object

Details

The Mann-Kendall statistics is computed taking ties into account.

Value

`method`	The chosen method (i.e. MK)
`Sg, Stot`	Mann-Kendall score
`varSg, Varianz`	variance of Mann-Kendall score
`Zg, Z`	Z-value (quantile of the normal distribution)
`pvalg, pvalue`	p-value
`Covar`	Variance - Covariance matrix
`Correl`	Correlation matrix

Generic function summary.trend.test is provided.

Warning

Current Version is for complete observations only.

Author(s)

T. Pohlert

References

Hipel, K.W. and McLeod, A.I., (2005). Time Series Modelling of Water Resources and Environmental Systems. Electronic reprint of our book orginally published in 1994. `http://www.stats.uwo.ca/faculty/aim/1994Book/`.

Libiseller, C. and Grimvall, A., (2002). Performance of partial Mann-Kendall tests for trend detection in the presence of covariates. Environmetrics 13, 71-84, `http://dx.doi.org/10.1002/env.507`.

See Also

cor.test, MannKendall, partial.mk.test, sens.slope summary.trend.test

Examples

```
data(Nile)
plot(Nile)
res <- mk.test(Nile)
summary.trend.test(res)

## Compare with cor()
n <- length(Nile)
cor.test(x=(1:n),y=Nile, meth="kendall")

data(maxau)
Q <- maxau[,"Q"]
plot(Q)
res <- mk.test(Q)
summary.trend.test(res)
```

PagesData — *Simulated data of Page (1955) as test-example for change-point detection*

Description

Simulated data of Page (1955) as test-example for change-point detection taken from Table 1 of Pettitt (1979)

Usage

```
data(maxau)
```

Format

a vector that contains 40 elements

Details

According to the publication of Pettitt (1979), the series comprise a significant $p = 0.014$ change-point at $i = 17$. The function pettitt.test computes the same U statistics as given by Pettitt (1979) in Table1, row 4.

Source

Page, E. S., (1954). A test for a change in a parameter occuring at an unknown point. Biometrika 41, 100-114.

Pettitt, A. N., (1979). A non-parametric approach to the change point problem. Journal of the Royal Statistical Society Series C, Applied Statistics 28, 126-135.

See Also

pettitt.test

Examples

```
data(PagesData)
pettitt.test(PagesData)
```

`partial.cor.trend.test` *Partial correlation trend test*

Description

Performs a partial correlation trend test with either the Pearson's or the Spearman's correlation coefficients ($r(tx.z)$).

Usage

```
partial.cor.trend.test(x, z, method = c("pearson", "spearman"))
```

Arguments

`x`	a "vector" or "ts" object that contains the variable, which is tested for trend (i.e. correlated with time)
`z`	a "vector" or "ts" object that contains the variable, which effect on "x" is partialled out
`method`	a character string indicating which correlation coefficient is to be computed. One of "pearson" (default) or "spearman", can be abbreviated.

Details

This function conducts a partial correlation trend test using either the "pearson" correlation coefficient, or the "spearman" rank correlation coefficient (Hipel and McLoed (2005), p. 882). The partial correlation coefficient for the response variable "x" with time "t", when the effect of the explanatory variable "z" is partialled out, is defined as:

$$r_{tx.z} = \frac{r_{tx} - r_{tz}\tilde{\ } r_{xz}}{\sqrt{1 - r_{tz}^2}\tilde{\ }\sqrt{1 - r_{xz}^2}}$$

The H0: $r_{tx.z} = 0$ (i.e. no trend for "x", when effect of "z" is partialled out) is tested against the alternate Hypothesis, that there is a trend for "x", when the effect of "z" is partialled out.

The partial correlation coefficient is tested for significance with the student t distribution on $df = n - 2$ degree of freedom.

Value

An object of class "htest"

method	a character string indicating the chosen test
data.name	a character string giving the name(s) of the data
cor	the correlation-matrix with t, x and z
statistic	the value of the test statistic
estimate	the partial correlation coefficient $r(tx.z)$
parameter	the degrees of freedom of the test statistic in the case that it follows a t distribution
alternative	a character string describing the alternative hypothesis
p.value	the p-value of the test

Warning

Current Version is for complete observations only.

Author(s)

T. Pohlert

References

Hipel, K.W. and McLeod, A.I., (2005). Time Series Modelling of Water Resources and Environmental Systems. http://www.stats.uwo.ca/faculty/aim/1994Book/.

Bahrenberg, G., Giese, E. and Nipper, J., (1992): Statistische Methoden in der Geographie, Band 2 Multivariate Statistik, Teubner, Stuttgart.

See Also

cor, cor.test, partial.r, partial.mk.test,

Examples

```
data(maxau)
a <- tsp(maxau) ; tt <- a[1]:a[2]
s <- maxau[,"s"] ; Q <- maxau[,"Q"]
maxau.df <- data.frame(Year = tt, s =s, Q = Q)
plot(maxau.df)

partial.cor.trend.test(s,Q, method="pearson")
partial.cor.trend.test(s,Q, method="spearman")
```

`partial.mk.test` *Partial Mann-Kendall Test*

Description

Performs a partial Mann-Kendall test

Usage

```
partial.mk.test(x, z)
```

Arguments

`x`	a "vector" or "ts" object that contains the variable, which is tested for trend (i.e. correlated with time)
`z`	a "vector" or "ts" object that contains the variable, which effect on "x" is partialled out

Details

According to Libiseller and Grimvall (2002), the expected value for the Mann-Kendall Score of variable "a" that is correlated with the covariate "b" is: $E = S_b * \sigma_{ab}/\sigma_{bb}$

Furthermore, the expected variance of "a" is: $Var = \sigma_{aa} - \sigma_{ab}/\sigma_{bb} * \sigma_{ba}$

Finally, the Z-Quantile is defined as: $Z = (S_a - E)/\sqrt(Var)$

Value

An object of class "htest"

`method`	a character string indicating the chosen test
`data.name`	a character string giving the name(s) of the data
`statistic`	the value of the test statistic
`estimate`	the Mann-Kendall score S and the variance varS
`alternative`	a character string describing the alternative hypothesis
`p.value`	the p-value of the test

Warning

Current Version is for complete observations only. The "method=='Partial'" is in testing mode.

Author(s)

T. Pohlert

References

Libiseller, C. and Grimvall, A., (2002). Performance of partial Mann-Kendall tests for trend detection in the presence of covariates. Environmetrics 13, 71-84, http://dx.doi.org/10.1002/env.507.

See Also

partial.cor.trend.test, summary.trend.test

Examples

```
data(maxau)
s <- maxau[,"s"]; Q <- maxau[,"Q"]
partial.mk.test(s,Q)
```

---

pettitt.test — *Pettitt's test for change-point-detection*

Description

Performes a nonparametric U-test after Pettitt in order to test for a shift in the central tendcency of a time series. The H0-hypothesis is: no change is tested against the HA-Hypothesis: change.

Usage

```
pettitt.test(x)
```

Arguments

x	a vector or a time series object of class "ts"

Details

The test is conducted in accordance to Pettitt's proposed method. First a vector that comprises the U-Statistics is calculated:

$$U_i = \sum_{k=1}^{i} \tilde{} \sum_{j=i+1}^{n} \mathrm{sgn}(x_k - x_j)$$

for $(1 \leq i \leq n)$. For a two-sided test, the maximum of the absolute obtained U-statistics is taken as the test statistic K:

$$K = \max |U_i|$$

Finally, the approximate probability for a two-sided test is calculated according to

$$2 \exp^{-6K^2/(T^3+T^2)}$$

Value

An object of class "htest"

`method`	a character string indicating the chosen test
`data.name`	a character string giving the name(s) of the data
`statistic`	the maximum K of the absolute values of the U-statistics
`estimate`	probable change point at time step tau
`nobs`	number of total observations
`alternative`	a character string describing the alternative hypothesis
`p.value`	the p-value for the test

Warning

The current function is for complete observations only. The approximate probability is good for $p \leq 0.5$.

Author(s)

T. Pohlert

References

CHR (ed., 2010): Das Abflussregime des Rheins und seiner Nebenfluesse im 20. Jahrhundert, Report no I-22 of the CHR, p. 172.

Pettitt, A. N., (1979). A non-parametric approach to the change point problem. Journal of the Royal Statistical Society Series C, Applied Statistics 28, 126-135.

See Also

`efp` `sctest.efp`

Examples

```
data(maxau) ; plot(maxau[,"s"])
s.res <- pettitt.test(maxau[,"s"])
n <- s.res$nobs
i <- s.res$estimate
s.1 <- mean(maxau[1:i,"s"])
s.2 <- mean(maxau[(i+1):n,"s"])
s <- ts(c(rep(s.1,i), rep(s.2,(n-i))))
tsp(s) <- tsp(maxau[,"s"])
lines(s, lty=2)
print(s.res)


data(PagesData) ; pettitt.test(PagesData)
```

`print.trend.test` *Print Method for Class 'trend.test'*

Description

Print Method for Class 'trend.test'

Usage

```
## S3 method for class 'trend.test'
print(x, ...)
```

Arguments

`x`	An object of class "trend.test"
`...`	Further arguments. (Currently not in use!).

Warning

Current Version is for complete observations only.

Author(s)

T. Pohlert

References

Hipel, K.W. and McLeod, A.I., (2005). Time Series Modelling of Water Resources and Environmental Systems. http://www.stats.uwo.ca/faculty/aim/1994Book/.

Libiseller, C. and Grimvall, A., (2002). Performance of partial Mann-Kendall tests for trend detection in the presence of covariates. Environmetrics 13, 71-84.

See Also

`csmk.test`, `mk.test`, `partial.mk.test`, `smk.test`, `summary`

Examples

```
### ** Examples
data(Nile)
plot(Nile)
res <- mk.test(Nile)
print.trend.test(res)

data(maxau)
Q <- maxau[,"Q"]
plot(Q)
```

```
res <- mk.test(Q)
print.trend.test(res)
```

`sea.sens.slope` *Seasonal Sen's slope and intercept*

Description

Computes seasonal Sen's slope for linear rate of change and the corresponding intercept

Usage

```
sea.sens.slope(x)
```

Arguments

x	an time series object of class "ts"

Value

A list of class "trend.test".

b.sen	The value of Sen's slope
intercept	The intercept
nobs	Number of records

Warning

Current Version is for complete observations only.

Author(s)

T. Pohlert

References

Hipel, K.W. and McLeod, A.I., (2005). Time Series Modelling of Water Resources and Environmental Systems. http://www.stats.uwo.ca/faculty/aim/1994Book/.

Sen, P.K., (1968): Estimates of the regression coefficient based on Kendall's tau, Journal of the American Statistical Association, 63, 1379–1389.

See Also

mk.test, zyp.sen, lm

Examples

```
sea.sens.slope(nottem)
```

`sens.slope` *Sen's slope and intercept*

Description

Computes Sen's slope for linear rate of change and the corresponding intercept

Usage

```
sens.slope(x, level = 0.95)
```

Arguments

`x`	an time series object of class "ts"
`level`	the level of significance

Details

This test computes both the slope (i.e. linear rate of change) and intercept according to Sen's method. First, a set of linear slopes is calculated as follows:

$$d_k = \frac{x_j - x_i}{j - i}$$

for $(1 \leq i < j \leq n)$, where d is the slope, x denotes the variable, n is the number of data, and i, j are indices.

Sen's slope is then calculated as the median from all slopes: $b_{Sen} = \mathrm{median}(d_k)$. The intercepts are computed for each timestep i as given by

$$a_i = x_i - b_{Sen} \times i$$

and the corresponding intercept is as well the median of all intercepts.

This function also computes the upper and lower confidence limits for sens slope.

Value

A list of class "trend.test".

`b.sen`	The value of Sen's slope
`b.sen.up, b.sen.lo`	The corresponding value of Sen's slope for the upper (lower) confidence limit
`intercept`	The intercept
`nobs`	Number of records
`D`	A vector of individual slopes
`varS`	The variance of the Mann-Kendall score
`conf.int`	The confidence intervall for the upper and lower bounds

Warning

Current Version is for complete observations only.

Author(s)

T. Pohlert

References

Hipel, K.W. and McLeod, A.I., (2005). Time Series Modelling of Water Resources and Environmental Systems. http://www.stats.uwo.ca/faculty/aim/1994Book/.

Sen, P.K., (1968): Estimates of the regression coefficient based on Kendall's tau, Journal of the American Statistical Association, 63, 1379–1389.

See Also

mk.test, zyp.sen, lm

Examples

```
data(maxau) ; plot(maxau[,"s"])
sen.res <- sens.slope(maxau[,"s"])
t <- (1:(length(maxau[,"s"])))
s.pred <- sen.res$intercept + sen.res$b.sen * t
s.pred.ts <- ts(s.pred)
tsp(s.pred.ts) <- tsp(maxau[,"s"])
lines(s.pred.ts, lty=2)
```

---

smk.test *Seasonal Mann-Kendall Test*

Description

Performs a Seasonal Mann-Kendall test

Usage

```
smk.test(x)
```

Arguments

x	A time series object comprising >= 2 seasons

Details

The Mann-Kendall statistics are first computed for each season seperately. The variance - covariance matrix is computed according to Libiseller and Grimvall (2002) and ties are taken into account. However, in the case of "method==smk" the covariance between the seasons is set to zero. Finally the Z-statistics for the entire series is calculated as follows:

$$Z = \mathbf{1}^T\mathbf{S}/\mathbf{1}^T\mathbf{X}\tilde{}\mathbf{1}$$

Z denotes the quantile of the normal distribution, 1 indicates a vector with all elements equal to one, S is the vector of Mann-Kendall scores for each season and X denotes the variance - covariance matrix (which is zero between the seasons).

Value

`method`	The chosen method (i.e. SMK)
`Sg`	Vector of Mann-Kendall scores for each season
`varSg`	Vector of the variance of Mann-Kendall scores for each season
`Zg`	Vector of Z-values for each season
`pvalg`	Vector of p-values for each season
`Covar`	Variance - Covariance matrix for the seasonal Mann-Kendall statistics
`Correl`	Correlation matrix for the seasonal Mann-Kendall statistics
`Stot`	Mann-Kendall score for the entire series
`Z`	Z-value for the entire series
`Varianz`	variance for the entire series
`pvalue`	p-value for the entire series

Generic function summary.trend.test is provided.

Warning

Current Version is for complete observations only.

Author(s)

T. Pohlert

References

Hipel, K.W. and McLeod, A.I., (2005). Time Series Modelling of Water Resources and Environmental Systems. http://www.stats.uwo.ca/faculty/aim/1994Book/.

Hirsch, R., J. Slack and R. Smith, (1982): Techniques of Trend Analysis for Monthly Water Quality Data. Water Resour. Res., 18, 107-121.

Libiseller, C. and Grimvall, A., (2002). Performance of partial Mann-Kendall tests for trend detection in the presence of covariates. Environmetrics 13, 71-84, http://dx.doi.org/10.1002/env.507.

See Also

csmk.test, mk.test, SeasonalMannKendall, summary.trend.test

Examples

```
data(co2)
plot(co2)
res <- smk.test(co2)
summary.trend.test(res)

data(nottem)
plot(nottem)
res <- smk.test(nottem)
summary.trend.test(res)
```

---

summary.trend.test *Summary Method for Class 'trend.test'*

Description

Summary Method for Class 'trend.test'

Usage

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

Arguments

object	An object of class "trend"
...	Further arguments. (Currently not in use!).

Warning

Current Version is for complete observations only.

Author(s)

T. Pohlert

References

Hipel, K.W. and McLeod, A.I., (2005). Time Series Modelling of Water Resources and Environmental Systems. http://www.stats.uwo.ca/faculty/aim/1994Book/.

Libiseller, C. and Grimvall, A., (2002). Performance of partial Mann-Kendall tests for trend detection in the presence of covariates. Environmetrics 13, 71-84, http://dx.doi.org/10.1002/env.507.

See Also

csmk.test, mk.test, partial.mk.test, smk.test, summary

Examples

```
### ** Examples
data(Nile)
plot(Nile)
res <- mk.test(Nile)
summary.trend.test(res)

data(maxau)
Q <- maxau[,"Q"]
plot(Q)
res <- mk.test(Q)
summary.trend.test(res)
```

---

wm.test *Wallis and Moore phase-frequency test*

Description

Performes the non-parametric Wallis and Moore phase-frequency test for testing the H0-hypothesis, whether the series comprises random data, against the HA-Hypothesis, that the series is significantly different from randomness (two-sided test).

Usage

```
wm.test(x)
```

Arguments

x	a vector or a time series object of class "ts"

Details

The test statistic of the phase-frequency test for $n > 30$ is calculated as:

$$z = \frac{\|h - \frac{2n-7}{3}\|}{\sqrt{\frac{16n-29}{90}}}$$

where h denotes the number of phases, whereas the first and the last phase is not accounted. The z-statistic is normally distributed. For $n \leq 30$ a continuity correction of -0.5 is included in the denominator.

Value

An object of class "htest"

`method`	a character string indicating the chosen test
`data.name`	a character string giving the name(s) of the data
`statistic`	the Wallis and Moore z-value
`alternative`	a character string describing the alternative hypothesis
`p.value`	the p-value for the test

Note

NA values are omitted. Many ties in the series will lead to reject H0 in the present test.

Author(s)

T. Pohlert

References

L. Sachs (1997), *Angewandte Statistik*. Berlin: Springer.

C.-D. Schoenwiese (1992), *Praktische Statistik*. Berlin: Gebr. Borntraeger.

W. A. Wallis and G. H. Moore (1941): A significance test for time series and other ordered observations. Tech. Rep. 1. National Bureau of Economic Research. New York.

See Also

`mk.test`

Examples

```
## Example from Schoenwiese (1992, p. 113)
## Number of frost days in April at Munich from 1957 to 1968
## z = -0.124, Accept H0
frost <- ts(data=c(9,12,4,3,0,4,2,1,4,2,9,7), start=1957)
wm.test(frost)

## Example from Sachs (1997, p. 486)
## z = 2.56, Reject H0 on a level of p < 0.05
x <- c(5,6,2,3,5,6,4,3,7,8,9,7,5,3,4,7,3,5,6,7,8,9)
wm.test(x)

data(nottem)
wm.test(nottem)

data(maxau)
wm.test(maxau[, "s"])
```

`ww.test` *Wald-Wolfowitz test for independence and stationarity*

Description

Performes the non-parametric Wald-Wolfowitz test for independence and stationarity (two-sided test).

Usage

```
ww.test(x)
```

Arguments

`x`	a vector or a time series object of class "ts"

Details

Let $x_1, x_2, ..., x_n$ denote the sampled data, then the test statistic of the Wald-Wolfowitz test is calculated as:

$$R = \sum_{i=1}^{n-1} x_i x_{i+1} + x_1 x_n$$

The expected value of R is:

$$E(R) = \frac{s_1^2 - s_2}{n-1}$$

The expected variance is:

$$V(R) = \frac{s_2^2 - s_4}{n-1} - E(R)^2 + \frac{s_1^4 - 4 s_1^2 s_2 + 4 s_1 s_3 + s_2^2 - 2 s_4}{(n-1)(n-2)}$$

with:

$$s_t = \sum_{i=1}^{n} x_i^t, ~~t = 1, 2, 3, 4$$

For $n > 10$ the test statistic is normally distributed, with:

$$z = \frac{R - E(R)}{\sqrt{V(R)}}$$

ww.test calculates p-values from the standard normal distribution for the two-sided case.

Value

An object of class "htest"

`method`	a character string indicating the chosen test
`data.name`	a character string giving the name(s) of the data
`statistic`	the Wald-Wolfowitz z-value
`alternative`	a character string describing the alternative hypothesis
`p.value`	the p-value for the test

Note

NA values are omitted.

Author(s)

T. Pohlert

References

R. K. Rai, A. Upadhyay, C. S. P. Ojha and L. M. Lye (2013), Statistical analysis of hydro-climatic variables. In: R. Y. Surampalli, T. C. Zhang, C. S. P. Ojha, B. R. Gurjar, R. D. Tyagi and C. M. Kao (ed. 2013), *Climate change modelling, mitigation, and adaptation*. Reston, VA: ASCE. doi = 10.1061/9780784412718.

A. Wald and J. Wolfowitz (1943), An exact test for randomness in the non-parametric case based on serial correlation. *Annual Mathematical Statistics* 14, 378–388.

WMO (2009), *Guide to Hydrological Practices*. Volume II, Management of Water Resources and Application of Hydrological Practices, WMO-No. 168.

Examples

```
data(nottem)
ww.test(nottem)

data(Nile)
ww.test(Nile)

set.seed(200)
x <- rnorm(100)
ww.test(x)
```

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