Package 'LPTime'

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Type Package

Title LP Nonparametric Approach to Non-Gaussian Non-Linear Time Series Modelling

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Depends orthopolynom

Suggests lattice

Description Specially designed rank transform based Legendre Polynomial-like (LP) orthonormal transformations are implemented for non-linear signal processing.

License GPL (>= 2)

NeedsCompilation no

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LPTime-package *Algorithm to analyze nonlinear time series data*

Description

This package provides general tools for analyzing non-Gaussian nonlinear multivariate time series models. The algorithm is described in the paper *Nonlinear Time Series Modeling by LPTime, Nonparametric Empirical Learning., by Mukhopadhyay and Parzen (2013).* The central idea behind LPTime time series modelling algorithm is to convert the original univariate time series $X(t)$ into

$$\text{Vec}(X)(t) = [\text{T}_1[X](t), \ldots, \text{T}_k[X](t)]^T$$

via tailor-made orthonormal (mid-rank based) nonlinear transformation that automatically tackles heavy-tailed process (such as daily S&P 500 return data) by injecting robustness in the time series analysis, applicable for discrete and continuous time series data modelling.

The main functions are as follows: (1) `LPTime`; (2) `LPiTrack`

Details

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Author(s)

Subhadeep Mukhopadhyay, Shinjini Nandi

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References

Mukhopadhyay, S. and Nandi, S. (2015). *LPiTrack: Eye Movement Pattern Recognition Algorithm and Application to Biometric Identification.*

Mukhopadhyay, S. and Parzen, E. (2014). *LP approach to statistical modeling. arXiv:1405.2601.*

Mukhopadhyay S. and Parzen E. (2013). *Nonlinear Time Series Modeling by LPTime, Nonparametric Empirical Learning. arXiv:1308.0642.*

Parzen E. and Mukhopadhyay S. (2013a). *LP Mixed Data Science: Outline of Theory. arXiv:1311.0562.*

Parzen, E. and Mukhopadhyay, S. (2012). *Modeling, Dependence, Classification, United Statistical Science, Many Cultures. arXiv:1204.4699.*

See Also

LPTime, LP.moment, LP.comoment, LPiTrack

Examples

```
library(LPTime)
data(EyeTrack.sample)
head(LPiTrack(EyeTrack.sample), m = c(3, 5, 15), p = 3)
```

EyeTrack.sample   *EyeTrack.sample: Coordinates of eye-trajectory*

Description

A matrix with first column as x coordinates and second column as y coordinates of the random eye-movements of a person to study an object.

Usage

```
data("EyeTrack.sample")
```

Format

The format is: chr "EyeTrack.sample"

Details

A matrix of dimension 8743×2

Examples

```
library(lattice)
data(EyeTrack.sample)

greentranslucent <- rgb(0,100,0,50,maxColorValue=255)
xyplot(y~x,data = data.frame(EyeTrack.sample),col=greentranslucent, pch=16,
     main = "Eye-trajectory",xlab = "X", ylab = "Y",
     sub = "Spatial fixation regions highlighted")
```

`LP.moment` *Finds LP moments of a random variable or comoments of two random variables*

Description

Evaluates m LP moments of a random variable.
Estimates LP-comoment matrix of order $m \times m$ between X and Y , i.e., covariance between the LP transformations of X and Y; where the random variables could be discrete or continuous.

Usage

```
LP.moment(x, m)
LP.comoment(x, y,zero.order = TRUE, m)
```

Arguments

`x`	The observations on the variable X.
`y`	The observations on the variable Y.
`zero.order`	Logical argument set to TRUE if zero-order LP comoments are required.
`m`	The number of LP moments to be found using `LP.moment`; or The order of LP - comoment matrix.

Details

LP moments of a general random variable (discrete or continuous) is defined as

$$\text{LP}[j;\ X] = \text{LP}[j, 0; X, X] = \text{E}[X\ T_j(X; X)].$$

LP comoments are the cross-covariance between higher-order orthonormal LP score functions $T_j(X; X)$ and $T_k(Y; Y)$

$$\text{LP}[j, k; X, Y] = \text{E}[T_j(X; X)\, T_k(Y; Y)].$$

Zero-order LP-comoments are defined as

$$\text{LP}[j, 0; X, Y] = \text{E}[T_j(X; X)\, Y],$$

and

$$\text{LP}[0, k; X, Y] = \text{E}[X\, T_k(Y; Y)].$$

Value

A vector of LP moments.
A matrix of LP co-moments between X and Y.

Author(s)

Subhadeep Mukhopadhyay

References

Mukhopadhyay S. and Parzen E. (2014). *LP approach to statistical modeling.arXiv:1405.2601.*

Parzen E. and Mukhopadhyay S. (2013a). *LP Mixed Data Science:Outline of Theory. arXiv:1311.0562.*

See Also

LPTrans

Examples

```
xdata <- rnorm(100)
head(LP.moment(xdata, m =4))

require(stats)
data(faithful)
head(LP.comoment(faithful$eruptions,faithful$waiting,m=4))
```

LPiTrack *Algorithm for eye-movement signal processing*

Description

Implements a generic nonparametric statistical algorithm to analyze eye-movement trajectory data.

Usage

```
LPiTrack(xy_mat, m = c(3, 5, 15), p = 10)
```

Arguments

xy_mat	A matrix with first column as x-coordinates and second column as y-coordinates of trajectory data.
m	A vector of three items. m[1]: The number of orthonormal LP-transformations to implement LPTime function. m[2]: The order of LP comoment matrix, excluding zero-order co-moments. m[3]: Number of LP moments.
p	The lag-order for vector autoregressive model to be fitted to the data to extract temporal features in the data.

Details

This function simultaneously extracts all Temporal-Spatial-Static features from the trajectory data integrating `LPTime`, `LP.comoment` and `LP.moment` functions. `LPTime` fits VAR model on the LP transformed series to capture the joint (horizontal and vertical) dynamics of the eye-movement pattern. `LP.moment` is applied on the series $r(t)$ (where we define $r^2(t) = X^2(t) + Y^2(t)$), $X(t), Y(t)$, and their first and second order differences to capture the static pattern. `LP.comoment` is applied on the following three series: $(r(t), \Delta r(t))$, $(X(t), Y(t))$ and $(\Delta X(t), \Delta Y(t))$ to extract nonparametric copula-based spatial fixation patterns.

Value

A vector representation of LP features for the trajectory data, which can be used as covariates (signatures) for subsequent prediction modelling.

Author(s)

Shinjini Nandi

References

Mukhopadhyay, S. and Nandi, S. (2015). *LPiTrack: Eye Movement Pattern Recognition Algorithm and Application to Biometric Identification.*

See Also

`LPTime`, `LP.moment`, `LP.comoment`

Examples

```
library(LPTime)
data(EyeTrack.sample)
head(LPiTrack(as.matrix(EyeTrack.sample), m = c(4,5, 15), p=3))
```

`LPTime` *Fits Vector Autoregressive model on LP transformed time series data*

Description

Accepts possibly non-Gaussian non-linear univariate (stationary) time series data; converts it to multivariate LP-transformed series and fits a vector autoregressive (VAR) model.

Usage

```
LPTime(z, exo = NULL, m = 3, p = 10)
```

Arguments

`z`	Endogenous time series to be included in the VAR model.
`exo`	Exogenous time series to be included in the VAR model.
`m`	The number of required LP-transformations.
`p`	Lag-order of autoregression.

Details

LPTime algorithm models univariate stationary nonlinear process $X(t)$ via linear modelling of the multivariate time series:

$$\mathrm{Vec}(X)(t) = [\mathrm{T}_1[X](t), \ldots, \mathrm{T}_m[X](t)]^T,$$

where each of the time series components $\mathrm{T}_j[X](t)$ are polynomials of rank transformed $X(t)$.

It fits vector autoregressive model of the form

$$\mathrm{Vec}(\mathrm{T}[X])(t) = \sum_{k=1}^{p} A(k;p)\,\mathrm{Vec}(\mathrm{T}[X])(t-k) \;+\; \epsilon(t).$$

where $\epsilon(t)$ is multivariate mean zero Gaussian white noise with covariance Σ_p.

Value

A matrix of the estimated autoregressive coefficients obtained from LP-VAR model.

Author(s)

Shinjini Nandi

References

Mukhopadhyay, S. and Parzen, E. (2013). *Nonlinear time series modeling by LPTime, nonparametric empirical learning. arXiv:1308.0642.*

See Also

LPTrans, VAR

Examples

```
library(LPTime)
data(EyeTrack.sample)
head( LPTime(EyeTrack.sample, m = 2, p = 2))
```

`LPTrans` *This function computes m specially-designed LP orthonormal basis functions of a random variable*

Description

Computes LP Score functions for a given random variable X.

Usage

```
LPTrans(x, m)
```

Arguments

`x`	Observation from random variable X.
`m`	The number of LP transformations to be computed.

Details

For random variable X(either discrete or continuous) construct the LP transformed series by Gram Schmidt orthonormalization of the powers of

$$\mathrm{T}_1[X] = \frac{F^{\mathrm{mid}}(X) - 0.5}{\sigma[F^{\mathrm{mid}}(X)]}$$

where $F^{\mathrm{mid}}(x;\, X) = F(x; X) - 0.5p(x;\, X),\ p(x;\, X) = \mathrm{Pr}[X = x],\ F(x;\, X) = \mathrm{Pr}[X \le x]$, and $\sigma(X)$ denotes the standard deviation of the random variable X.
For X continuous, $\mathrm{T}_j[X] = \mathrm{Leg}_j[F(X)]$, where Leg_j denotes jth shifted orthonormal Legendre Polynomial $\mathrm{Leg}_j(u),\ 0 < u < 1$. Now define the UNIT LP basis function as follows:

$$\mathrm{S}_j(u;\, X) = \mathrm{T}_j[Q(u;\, X)],\ 0 < u < 1.$$

Our score functions are custom constructed (non-parametrically designed data-adaptive score functions) for each random variable X which can be discrete or continuous.

Value

A matrix of order $n \times m$ where n is the number of observations on X. Each column of the matrix is an orthonormal LP score function.

Author(s)

Subhadeep Mukhopadhyay

References

Mukhopadhyay, S. and Parzen, E. (2014). *LP approach to statistical modeling.arXiv:1405.2601.*

Mukhopadhyay, S. and Parzen, E. (2013). *Nonlinear time series modeling by LPTime,nonparametric empirical learning. arXiv:1308.0642.*

Parzen, E. and Mukhopadhyay, S. (2013b). *United Statistical Algorithms, LP comoment,Copula Density, Nonparametric Modeling. 59th ISI World Statistics Congress (WSC), Hong Kong.*

Examples

```
library(lattice)
#Example from Eye Trajectory data
data(EyeTrack.sample)
x.coords <- EyeTrack.sample[,1]

x.diff <- diff(x.coords) #Differenced x-coordinate series
trans.x.diff <- LPTrans(x.diff, m = 4)
head(trans.x.diff)

x.diff.std <- (x.diff - mean(x.diff))/sd(x.diff)

x.series <- cbind(x.diff.std, ts(LPTrans(x.diff, m = 4)))
colnames(x.series) <- c("Difference of X",paste("LPTrans(diff(X)) [,",1:4,"]", sep = ""))
xyplot(x.series,outer = TRUE,
       main = "Plot of differenced x-coordinates
and its LP-transformations over time"
       )
```

VAR *Estimates a Vector Autoregressive model of order p.*

Description

Estimation of a Vector Autoregressive model (VAR) by computing OLS per equation.

Usage

```
VAR(y, p = 1, exogen = NULL)
```

Arguments

y	Endogenous variable for the VAR model.
p	lag-order for the autoregressive model.
exogen	Exogenous variable for the VAR model.

Details

Estimates a VAR by OLS per equation. The model is of the following form

$$\boldsymbol{y}_t = A_1 \boldsymbol{y}_{t-1} + \ldots + A_p \boldsymbol{y}_{t-p} + C D_t + \boldsymbol{u}_t$$

where $\boldsymbol{y}_t$ is a $K \times 1$ vector of endogenous variables and u_t assigns a spherical disturbance term of the same dimension. The coefficient matrices $A_1, \ldots, A_p$ are of dimension $K \times K$. No seasonality or trend term can be included in the model.

Value

A matrix of coefficients from fitting the VAR model.

Author(s)

Shinjini Nandi

References

Wei, William W.S. (2006). *Time Series Analysis - Univariate and Multivariate Methods*

Brockwell, P.J. and Davis, R.A. (1996). *Introduction to Time Series and Forecasting , Second Edition, Springer, New York*

See Also

LPTime

Examples

```
library(LPTime)
data(EyeTrack.sample)
head( VAR(y = EyeTrack.sample, p = 2))
```

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