Package 'fpcb'

October 13, 2022

Version 0.1.0

Type Package

Title Predictive Confidence Bands for Functional Time Series Forecasting

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Description Functions to represent functional objects under a Reproducing Kernel Hilbert Space (RKHS) framework as described in Muñoz & González (2010). Autoregressive Hilbertian Model for functional time series using RKHS and predictive confidence bands construction as proposed in Hernández et al (2021).

Encoding UTF-8

License GPL (>= 3)

Imports FNN

Repository CRAN

NeedsCompilation yes

RoxygenNote 7.1.1

BugReports https://github.com/nicolashernandezb/fpcb/issues

Date/Publication 2021-06-07 06:50:13 UTC

R topics documented:

fpcb-package *Predictive confindence bands for functional time series forecasting*

Description

Functions to represent functional objects under a Reproducing Kernel Hilbert Space (RKHS) framework as described in Muñoz & González (2010). <doi:10.1016/j.patrec.2009.07.014>. Autoregressive Hilbertian Model for functional time series using RKHS and predictive confidence bands construction as proposed in Hernández et al (2021) <arXiv:2105.13627>.

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References

- A. Muñoz, J. González, Representing functional data using support vector machines, Pattern Recognition Letters 31 (2010) 511–516. <doi:10.1016/j.patrec.2009.07.014>.
- Martos, G. et al (2018): Entropy Measures for Stochastic Processes with Applications in Functional Anomaly Detection. Entropy 20(1): 33 (2018). <doi:10.3390/e20010033>.
- D. Wang, Z. Zhao, R. Willett, C. Y. Yau, Functional autoregressive processes in reproducing kernel hilbert spaces, arXiv preprint arXiv:2011.13993 (2020).
- N. Hernández, J. Cugliari, J. Jacques. Simultaneous Predictive Bands for Functional Time Series using Minimum Entropy Sets. arXiv:2105.13627 (2021).

arh_rkhs *Autoregressive Hilbertian Model using RKHS*

Description

Estimates an autoregresive Hilbertian model of order 1 for functional time series. The temporal dependence is estimated in the Hilbert projection space which has a reproducing kernel as proposed in Hernández et al (2021) <arXiv:2105.13627> and Wang et al (2020) <arXiv:2011.13993>.

Usage

```
arh_rkhs(fdata)
```

Arguments

fdata	an fdata object containing the functional objects and the lambda coefficients of the d dimensional RKHS representation.

Value

fdata	smoothed curves.
lambda_cent	centered coefficients of the d dimensional RKHS representation.
lambda_ce	average coefficients of the d dimensional RKHS representation.
rho	autocorrelation operator computed as: $Gamma_0 Psi$ = $Gamma_1$. $Gamma_0$ correspond to the Covariance and $Gamma_0$ correspond to the Cross-Covariance (of lag 1) operators, both estimated using the coefficients $lambda$.

Author(s)

N. Hernández and J. Cugliari

References

N. Hernández, J. Cugliari, J. Jacques. Simultaneous Predictive Bands for Functional Time Series using Minimum Entropy Sets. arXiv:2105.13627 (2021). D. Wang, Z. Zhao, R. Willett, C. Y. Yau, Functional autoregressive processes in reproducing kernel hilbert spaces, arXiv preprint arXiv:2011.13993 (2020).

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fdata_rkhs *functional data in rkhs*

Description

Representing functinal data using Reproducing Kernel Hilbert Spaces. Approximate each curve with a smooth function using a kernel function.

Usage

```
fdata_rkhs(curves, rk, gamma = 1e-05)
```

Arguments

curves	a data matrix with observations (curves) in rows and the discretizations points in columns.
rk	kernek function rk object.
gamma	regularization parameter. Defaoult value = 1e-5.

Details

With this function each function can be represented with a vector in R^d.

Value

data	input curves.
fdata	smoothed curves.
lambda	coefficients of the (stable) and d dimensional RKHS representation.
alpha	coefficients of the RKHS expansion.
gamma	regularization parameter.

Author(s)

N. Hernández and J. Cugliari

References

A. Muñoz, J. González, Representing functional data using support vector machines, Pattern Recognition Letters 31 (2010) 511–516. <doi:10.1016/j.patrec.2009.07.014>.

Examples

```
t = 1:50
curves = matrix(sin(t)+rnorm(length(t)),nrow=1)
f.data <- fdata_rkhs(curves, rk = rk(t,sigma = 0.01))
plot(t,curves, xlab='time', ylab='PM10 dataset', col='gray', lty=1, type='b')
lines(t,f.data$fdata, col='blue', lty=1)
```

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predict_rkhs *Predict functional time series using ARH RKHS.*

Description

using an ARH of order 1 obtain 1 step ahead forecast and 1-$alpha$ predictive confidence bands for the forecasted function.

Usage

```
predict_rkhs(
  model,
  newdata,
  bands = FALSE,
  B = 100,
  level = 0.95,
  kvec = round(sqrt(2 * B))
)
```

Arguments

model	a arh_rkhs object containing the functional objects and the lambda coefficients of the d dimensional RKHS representation and the autocorrelation operator.
newdata	an optional data frame in which to look for variables with which to predict. If missing, the fitted values are used.
bands	logical variable indicating if the predictive confidence band is computed. Default = FALSE.
B	number of bootstrap replicates for the band construction. Needed if bands = TRUE. Default = 100.
level	confidence level for the band construction. Needed if bands = TRUE. Default = 0.95.
kvec	number of neighbour points to consider in the computation of the minimum entropy set.

Value

forecast	1 step ahead forecast.
fitted	fitted values.
UB	upper bound of the 1-$alpha$ predictive confidence band.
LB	lower bound of the 1-$alpha$ predictive confidence band.
bootsrap.pred	bootstrap pseudo replicates.
bootsrap.pred.inband	bootstrap pseudo replicates included in the 1-$alpha$ predictive confidence band.
res	estimation residuals.

Author(s)

N. Hernández and J. Cugliari

References

N. Hernández, J. Cugliari, J. Jacques. Simultaneous Predictive Bands for Functional Time Series using Minimum Entropy Sets. arXiv:2105.13627 (2021).

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rk *kernel function*

Description

Computes the Gram matrix of the gaussian kernel over a grid of values and computes its singular value decomposition.

Usage

```
rk(grid, sigma = 1, r, tol = 1e-08)
```

Arguments

grid	grid of points where the kernel function is evaluated.
sigma	is the temperature of the kernel (standard deviation)
r	the dimension of the basis system of the Gran matrix (K). If missing then r is the rank of K.
tol	A tolerance to keep the first d eigenvalues of A. Default = 1e-08.

Value

grid	grid of points where the kernel function is evaluated.
K	Kernel Gram matrix
U	first r eigenvectors of K using svd.
D	first r eigenvectors of K using svd.

Author(s)

J. Cugliari and N. Hernández

Examples

```
grid = seq(0,1,,100)
rk(grid, sigma = 1)
```

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