Package 'geofd'

January 29, 2020

Version 2.0

Author Ramon Giraldo <rgiraldoh@unal.edu.co>, Pedro Delicado <pedro.delicado@upc.edu>, Jorge Mateu <mateu@mat.uji.es>

Maintainer Pedro Delicado <pedro.delicado@upc.edu>

Title Spatial Prediction for Function Value Data

Description Kriging based methods are used for predicting functional data (curves) with spatial dependence.

License GPL-2

Depends fda

Repository CRAN

Date 2020-01-29

NeedsCompilation no

Date/Publication 2020-01-29 15:00:02 UTC

R topics documented:

geofd-package *Spatial Prediction for Function Value Data*

Description

Kriging based methods are used for predicting functional data (curves) with spatial dependence. Initially the curves are pre-processed by fitting a Fourier or B-splines basis functions. Then the spatial dependence among curves is estimated by means of the trace-variogram function. Finally the parameters for performing prediction by Ordinary Kriging at unsampled locations are estimated by solving a linear system based on the estimated trace-variogram.

Details

Index:

```
geofd-package           Spatial prediction for function value data
```

Author(s)

Ramon Giraldo <rgiraldoh@unal.edu.co>, Pedro Delicado <pedro.delicado@upc.edu>, Jorge Mateu <mateu@mat.uji.es>

Maintainer: Pedro Delicado <pedro.delicado@upc.edu>

fit.tracevariog *Variogram Estimation*

Description

Fits a parametric model to a empirical variogram and estimates covariance parameters. Aditionally all fitted variogram models are plotted for verification purpose.

Usage

```
fit.tracevariog(emp.trace.vari, models, sigma2.0, phi.0,
                fix.nugget=FALSE, nugget=0,
                fix.kappa=TRUE, kappa=0.5,
                max.dist.variogram=NULL)
```

Arguments

`emp.trace.vari`	empirical trace-variogram. An object returned from the `trace.variog` function.
`models`	a character vector of correlation function names used in geoR against which empirical trace variogram will be fitted.
`sigma2.0`	initial value for the covariance parameter σ^2 (partial sill).

`phi.0` initial value for the covariance parameter ϕ (range).

`fix.nugget` logical, indicating whether the `nugget` parameter should be estimated or not.

`nugget` value for the nugget parameter.

`fix.kappa` logical, indicating whether the `kappa` parameter should be estimated or not.

`kappa` value of the smoothness parameter.

`max.dist.variogram` a numerical value defining the maximum distance considered when fitting the variogram.

Details

Variogram models and parameters

When the `cov.model` parameter is `NULL` a function determines the optimal model between spherical, exponential gaussian and matern using the received parameters. The arguments `sigma2.0` and `phi.0` are used as initial values for fitting each variogram model.

The parameters `fix.nugget`, `nugget`, `fix.kappa`, `kappa` and `max.dist.variogram` are the same for each variogram model specified in `models`.

Value

A list with the following components:

`trace.vari` choosed theoretical variogram model

`trace.vari.array` vector of all fitted theoretical variogram models

Author(s)

Ramon Giraldo <rgiraldoh@unal.edu.co>,
Pedro Delicado <pedro.delicado@upc.edu>,
Jorge Mateu <mateu@mat.uji.es>.

References

Giraldo, R. (2009) *Geostatistical Analysis of Functional Data.* Ph.D. thesis. Universitat Politecnica de Catalunya.

Giraldo, R., Delicado, P. and Mateu, J. (2012) **geofd***: An R package for function-valued geostatistical prediction*. Revista Colombiana de Estadistica. 35, 385-407.

`l2.norm` *Calculates L2 norm among functions*

Description

Calculates the integral of the squared differences between functions

Usage

```
l2.norm(s, datafd, M)
```

Arguments

`s`	number of sites where the original dataset was measured
`datafd`	a functional data object representing a smoothed dataset. See DETAILS below.
`M`	symmetric matrix defining the roughness penalty for functions expressed in terms of a B-spline or Fourier basis. See DETAILS below.

Details

Roughness penalty matrix

This matrix is the output of one of the following functions: `fourierpen` y `bsplinepen`. The used function depends upon the smoothing type which is going to be applied.

When the roughness penalty matrix is being calculated, the following considerations are taked in count:

- The differential operator passed as parameter for both `fourierpen` and `bsplinepen` is always zero.
- When the selected smooth method is bsplines, the basis object passed to `bsplinepen` is the output of the function `create.bspline.basis` using `argvals` as the `rangeval` parameter, `nbasis` as the number of basis functions parameter and the default order of b-splines, which is four, a cubic spline, as the `norder` parameter.
- When the selected smooth method is fourier, the basis object is the output of the function `fourierpen`. The parameters `rangeval` and `nbasis` are the same as for `create.bspline.basis`, and the `period` parameter as the number of observations on each curve.

Value

The calculated matrix of squared differences between each observation for each measured site. This matrix has two properties:

- Is symmetric.
- It's diagonal is filled with zeros.

See Also

okfd for doing Ordinary Kriging for function-value data, trace.variog for functional empirical trace variogram calculation, fit.tracevariog for fitting a variogram model in the functional scenario.

---

maritimes.avg *Moncton averages*

Description

Moncton averages

Usage

```
data(maritimes.avg)
```

Format

A matrix with 365 averages.

---

maritimes.coords *Coordinates of the sites referred by maritimes.data*

Description

The geographical coordinates in decimal degrees of 35 weather stations.

Usage

```
data(maritimes.coords)
```

Format

A matrix with the coordinates of 35 weather stations.

Source

The coordinates were obtained from the database of geographic coordinate information http://www.tageo.com

maritimes.data *Maritime provinces temperatures*

Description

Temperature measurements recorded at 35 weather stations located in the Maritime Provinces over a region of Canada consisting of three provinces: Nova Scotia (NS), New Brunswick (NB), and Prince Edward Island (PEI).

Usage

```
data(maritimes.data)
```

Format

A matrix with 365 observations on 35 sites.

Details

This data set contains information of daily temperatures averaged over the years 1960 to 1994 (February 29th combined with February 28th)

Source

The data for each station were obtained from the Meteorological Service of Canada http://climate.weather.gc.ca

okfd *Function for doing Ordinary Kriging for function-value Data*

Description

This function allows to carry out prediction by Ordinary Kriging for function-value data by considering a Fourier or B-splines basis for smoothing the observed data set

Usage

```
okfd(new.coords, coords, data, smooth.type=NULL, nbasis=max(50,dim(data)[1]),
    argvals=seq(0, 1, len = dim(data)[1]), lambda=0, cov.model=NULL,
    fix.nugget=FALSE, nugget=0, fix.kappa=TRUE,
    kappa=0.5, max.dist.variogram=NULL)
```

Arguments

new.coords	an n x 2 matrix containing the coordinates of the new n sites where functional Kriging has to be done
coords	an s x 2 matrix containing the coordinates of the n sites where functional data are observed
data	an m x s matrix with values for the observed functions
smooth.type	a string with the name of smoothing method to be applied to data. Available choices are: "bsplines" and "fourier".
nbasis	a numeric value defining the number of basis functions used to smooth the discrete data set recorded at each site
argvals	a vector of argument values corresponding to the observations in matrix data
lambda	optional. Penalization parameter for smoothing the observed functions.
cov.model	a string with the name of the correlation function. Default is NULL, see DETAILS below.
fix.nugget	logical, indicating whether the nugget parameter should be estimated or not.
nugget	value for the nugget parameter.
fix.kappa	logical, indicating whether the kappa parameter should be estimated or not.
kappa	value of the smoothness parameter.
max.dist.variogram	a numerical value defining the maximum distance considered when fitting the variogram.

Details

This function is a common sequence of the proposed process for doing Ordinary Kriging in the functional scenario, covers from the preparation of the original data and variogram estimation, unto data prediction.

Functional data object

This is an object of the class fd it can be created using some functions like Data2fd or smooth.basis, take in count if a penalization parameter is going to be used.

Penalization parameter

The penalization parameter lambda is used in both smoothing methods. When the selected smooth method is:

1. bsplines, the function which uses it is fdPar
2. fourier, the function which uses it is Data2fd

Functional data object

The function which creates the functional data object is determined based on the selected smooth method:

- When it is bsplines, the functional data object must be created using two different functions, fdPar and smooth.basis in order to include the penalization parameter lambda.
- When it is fourier, the functional data object is directly returned by Data2fd because it includes the penalization parameter, the basis object, the argument values and the data, all at the same time.

Value

A list with the following components:

coords	a matrix containing the coordinates of the sites where functional data are observed.
data	a matrix with values for the observed functions.
argvals	a vector of argument values corresponding to the observations in matrix data
nbasis	a numeric value defining the number of basis functions used to smooth the discrete data set recorded at each site.
lambda	penalization parameter for smoothing the observed functions.
new.coords	matrix containing the coordinates of the new sites where functional Kriging has to be done.
emp.trace.vari	empirical trace-variogram.
trace.vari	choosed theoretical variogram model
new.Eu.d	distance matrix among sampling and new sites.
functional.Kriging.weights	functional Kriging weights.
krig.new.data	predicted values for the new sites.
pred.var	prediction variance.
trace.vari.array	vector of all fitted variogram models.
datafd	a functional data object containing a smooth of the data.

Author(s)

Ramon Giraldo <rgiraldoh@unal.edu.co>,
Pedro Delicado <pedro.delicado@upc.edu>,
Jorge Mateu <mateu@mat.uji.es>.

References

Giraldo, R. (2009) *Geostatistical Analysis of Functional Data.* Ph.D. thesis. Universitat Politecnica de Catalunya.

Giraldo, R., Delicado, P. and Mateu, J. (2012) **geofd***: An R package for function-valued geostatistical prediction*. Revista Colombiana de Estadistica. 35, 385-407.

See Also

l2.norm for calculating L2 norm among functions, trace.variog for functional empirical trace variogram calculation, fit.tracevariog for fitting a variogram model in the funcional scenario.

Examples

```
# First example: one site prediction using B-splines for smoothing

data(maritimes.avg)
data(maritimes.coords)
data(maritimes.data)

coord.cero <- matrix(c(-64.06, 45.79),nrow=1,ncol=2)

n<-dim(maritimes.data)[1]

argvals<-seq(1,n, by=1)

# Prediction by okfd

okfd.res<-okfd(new.coords=coord.cero, coords=maritimes.coords,
              data=maritimes.data, nbasis=65, argvals=argvals,
              fix.nugget=TRUE, kappa=0.7)

# Smoothed and predicted curves, and predicted site average values are plotted

plot(okfd.res$datafd, lty=1, col=8,
    main="Smoothed", xlab="Day", ylab="Temperature (Degrees C)")

lines(okfd.res$argvals, okfd.res$krig.new.data,
      col=1, lwd=2, type="l", lty=1,
      main="Predictions", xlab="Day", ylab="Temperature (Degrees C)")

lines(maritimes.avg,  type="p", pch=20,cex=0.5, col=2, lwd=1)

# Second example: multiple sites prediction using Fourier basis functions for smoothing

data(maritimes)

n<-dim(maritimes.data)[1]

argvals<-seq(1,n, by=1)

col1<-sample( (min(maritimes.coords[,1])*100):(max(maritimes.coords[,1])*100),
              10, replace=TRUE)/100

col2<-sample( (min(maritimes.coords[,2])*100):(max(maritimes.coords[,2])*100),
              10, replace=TRUE)/100

new.coords <- cbind(col1,col2)

# Prediction by okfd

okfd.res<-okfd(new.coords=new.coords, coords=maritimes.coords,
              data=maritimes.data, smooth.type="fourier",
              nbasis=65, argvals=argvals)
```

```
# The smoothed and predicted curves are plotted

par(mfrow=c(1,2))

plot(okfd.res$datafd, lty=1, col=8,
    main="Smoothed", xlab="Day", ylab="Temperature (Degrees C)")

matplot(okfd.res$argvals, okfd.res$krig.new.data, col=1, lwd=1, type="l", lty=1,
        main="Predictions", xlab="Day", ylab="Temperature (Degrees C)")
```

`okfd.cv` *Function for doing Cross-Validation analysis for Ordinary Kriging for function-value data*

Description

Unreviewed

Usage

```
okfd.cv(coords, data, argnames=c("argument", "sites", "values"),
        one.model=TRUE, smooth.type=NULL,
        array.nbasis=max(50,dim(data)[1]),
        argvals=seq(0,1,len=dim(data)[1]), array.lambda=0, cov.model=NULL,
        fix.nugget=FALSE, nugget=0, fix.kappa=TRUE, kappa=0.5,
        max.dist.variogram=NULL)
```

Arguments

`coords`	coordinates of the sites where functional data are observed (dim: s by 2)
`data`	matrix with values for the observed functions (dim: m by s)
`argnames`	a character vector of length three containing: the name of the argument (argvals), a description of the sites (coord), the name of the observed function values.
`one.model`	logical, indicates whether the cross validation is going to be done just one model or one model for each site. Deafult is TRUE. See details below.
`smooth.type`	a string with the name of smoothing method to be applied to `data`. Available choices are: "bsplines" and "fourier".
`array.nbasis`	array with values for the number of elements in the cubic B-spline basis.
`argvals`	a set of argument values. (length: m)
`array.lambda`	array of penalization parameters for smoothing the observed functions.
`cov.model`	a string with the name of the correlation function. Default is NULL, see `DETAILS` below.
`fix.nugget`	logical, indicating whether the `nugget` parameter should be estimated or not.

nugget	value for the nugget parameter.
fix.kappa	logical, indicating whether the kappa parameter should be estimated or not.
kappa	value of the smoothness parameter.
max.dist.variogram	a numerical value defining the maximum distance considered when fitting the variogram.

Details

Validation models

The parameter one.model is used to define the models used in the cross validation:

- If it is TRUE, a model and smoothed data are created before the beginning and used inside the cross validation process.
- If it is FALSE, then for each site a model and smoothed data are created and used on each iteration.

Value

A list with the following components:

k.opt	unreviewed
l.opt	unreviewed
krig.cv	unreviewed
mse.cv	unreviewed
mse.cv.opt	unreviewed
fd.models	unreviewed

Author(s)

Ramon Giraldo <rgiraldoh@unal.edu.co>,
Pedro Delicado <pedro.delicado@upc.edu>,
Jorge Mateu <mateu@mat.uji.es>.

References

Giraldo, R. (2009) *Geostatistical Analysis of Functional Data.* Ph.D. thesis. Universitat Politecnica de Catalunya.

Giraldo, R., Delicado, P. and Mateu, J. (2012) **geofd***: An R package for function-valued geostatistical prediction*. Revista Colombiana de Estadistica. 35, 385-407.

plot.geofd *Plot Trace Variogram and adjusted models*

Description

This funcion produces a plot of an object of class geofd which contains...

Usage

```
## S3 method for class 'geofd'
plot(x, emp.trace.vari=x$emp.trace.vari,
                    trace.vari.array=x$trace.vari.array,
                    colors=rainbow(length(trace.vari.array)), ...)
```

Arguments

x	a list containing elements emp.trace.vari and trace.vari.array described below. Typically an object of the class "geofd". If not provided the arguments emp.trace.vari and trace.vari.array must be provided instead.
emp.trace.vari	empirical trace-variogram.
trace.vari.array	vector of variogram models.
colors	a character vector of color names used to plot each variogram model. Dimensions must be the same of trace.vari.array.
...	graphical arguments to be passed to plot.

trace.variog *Empirical Variograms for function-value data*

Description

Computes empirical trace-variograms using the L2 norm matrix for the semivariance values. Output a variogram cloud.

Usage

```
trace.variog(coords, L2norm, bin=FALSE, max.dist, uvec="default",
             breaks="default", nugget.tolerance)
```

Arguments

coords	an s x 2 matrix containing the coordinates of the n sites where functional data are observed.
L2norm	L2 norm among functions.
bin	logical, indicating whether the output is the binned variogram.
max.dist	a numerical value defining the maximum distance for the variogram.
uvec	a vector with values defining the centers of the bins or the number of bins. Only used when 'bin = TRUE'.
breaks	a vector with values defining the variogram binning. Only used when 'bin = TRUE'.
nugget.tolerance	a numeric value defining the shortest lag distance. Only used when 'bin = TRUE'.

Details

Binned variogram This is just a visual feature adapted from the cloud variogram and it doesn't have any relation against the fitting of the variogram model or the calculation of the predictions.

Value

An object of the class variogram which is a list with the following components:

u	a vector with distances.
v	a vector with estimated variogram values at distances given in u.
max.dist	maximum distance of the variogram.
output.type	variogram type.
Eu.d	euclidian distance array among sites.
L2norm	echoes the 'L2norm' argument.
bins.lim	limits defining the interval spanned by each bin. Only returned when 'bin = TRUE'.
nugget.tolerance	echoes the 'nugget.tolerance' argument.

Author(s)

Ramon Giraldo <rgiraldoh@unal.edu.co>,
Pedro Delicado <pedro.delicado@upc.edu>,
Jorge Mateu <mateu@mat.uji.es>.

References

Giraldo, R. (2009) *Geostatistical Analysis of Functional Data.* Ph.D. thesis. Universitat Politecnica de Catalunya.

Giraldo, R., Delicado, P. and Mateu, J. (2012) **geofd***: An R package for function-valued geostatistical prediction*. Revista Colombiana de Estadistica. 35, 385-407.

Examples

```
# First example: creating a binned variogram
# okfd first example

data(maritimes.avg)
data(maritimes.coords)
data(maritimes.data)
coord.cero <- matrix(c(-64.06, 45.79),nrow=1,ncol=2)
n<-dim(maritimes.data)[1]
argvals<-seq(1,n, by=1)
okfd.res<-okfd(new.coords=coord.cero, coords=maritimes.coords,
              data=maritimes.data, nbasis=65, argvals=argvals, fix.nugget=TRUE,
              kappa=0.7)

# Calculating the empiricial trace bin variogram
new.emp.trace.vari <- trace.variog(coords=okfd.res$coords,
                      L2norm=okfd.res$emp.trace.vari$L2norm, bin=TRUE)

# The empirical trace cloud variogram is replaced with the trace bin variogram
okfd.res$emp.trace.vari <- new.emp.trace.vari

# The modified okfd result is plotted
plot(okfd.res)
```

Index