

Package ‘geofd’

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

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R topics documented:

geofd-package	2
fit.tracevariog	2
l2.norm	4
maritimes.avg	5
maritimes.coords	5
maritimes.data	6
okfd	6
okfd.cv	10
plot.geofd	12
trace.variog	12

Index	15
--------------	-----------

 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

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 fit.tracevariog

Variogram Estimation

Description

Fits a parametric model to a empirical variogram and estimates covariance parameters. Additionally 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 `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). For further details see documentation for the parameter `ini.cov.pars` from the `variofit` function.

phi.0	initial value for the covariance parameter ϕ (range). For further details see documentation for the parameter ini.cov.pars from the variofit function.
fix.nugget	logical, indicating whether the nugget parameter should be estimated or not. For further details see documentation for the parameter nugget from the variofit function.
nugget	value for the nugget parameter. For further details see documentation for the parameter nugget from the variofit function.
fix.kappa	logical, indicating whether the kappa parameter should be estimated or not. For further details see documentation for the parameter fix.kappa from the variofit function.
kappa	value of the smoothness parameter. For further details see documentation for the parameter kappa from the variofit function.
max.dist.variogram	a numerical value defining the maximum distance considered when fitting the variogram. For further details see documentation for the parameter max.dist from the variofit function.

Details

This function makes use of the [variofit](#) function.

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

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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 Estadística. 35, 385-407.

l2.norm	<i>Calculates L2 norm among functions</i>
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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 taken 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	<i>Moncton averages</i>
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Description

Moncton averages

Usage

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

Format

A matrix with 365 averages.

maritimes.coords	<i>Coordinates of the sites referred by maritimes.data</i>
------------------	------------------------------------------------------------

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

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

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:

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

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References

- Giraldo, R. (2009) *Geostatistical Analysis of Functional Data*. Ph.D. thesis. Universitat Politècnica de Catalunya.
- Giraldo, R., Delicado, P. and Mateu, J. (2012) **geofd**: *An R package for function-valued geostatistical prediction*. *Revista Colombiana de Estadística*. 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 functional 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$dataafd, 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	<i>Function for doing Cross-Validation analysis for Ordinary Kriging for function-value data</i>
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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)

<code>array.lambda</code>	array of penalization parameters for smoothing the observed functions.
<code>cov.model</code>	a string with the name of the correlation function. Default is NULL, see DETAILS below. For further details see documentation for the parameter <code>cov.model</code> from the <code>variofit</code> function.
<code>fix.nugget</code>	logical, indicating whether the nugget parameter should be estimated or not. For further details see documentation for the parameter <code>nugget</code> from the <code>variofit</code> function.
<code>nugget</code>	value for the nugget parameter. For further details see documentation for the parameter <code>nugget</code> from the <code>variofit</code> function.
<code>fix.kappa</code>	logical, indicating whether the kappa parameter should be estimated or not. For further details see documentation for the parameter <code>fix.kappa</code> from the <code>variofit</code> function.
<code>kappa</code>	value of the smoothness parameter. For further details see documentation for the parameter <code>kappa</code> from the <code>variofit</code> function.
<code>max.dist.variogram</code>	a numerical value defining the maximum distance considered when fitting the variogram. For further details see documentation for the parameter <code>max.dist</code> from the <code>variofit</code> function.

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:

<code>k.opt</code>	unreviewed
<code>l.opt</code>	unreviewed
<code>krig.cv</code>	unreviewed
<code>mse.cv</code>	unreviewed
<code>mse.cv.opt</code>	unreviewed
<code>fd.models</code>	unreviewed

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References

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

plot.geofd	<i>Plot Trace Variogram and adjusted models</i>
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Description

This function 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

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

trace.variog	<i>Empirical Variograms for function-value data</i>
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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 $s \times 2$ 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 as in variog . Only used when 'bin = TRUE'.
breaks	a vector with values defining the variogram binning as in variog . 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.

The binning is made in the same manner as in [variog](#) because it uses the `.define.bins` function.

Value

An object of the class `variogram` as the [variog](#) function 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 as in variog . Only returned when 'bin = TRUE'.
nugget.tolerance	echoes the 'nugget.tolerance' argument.

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

- *Topic **datagen**
 - okfd, 6
 - okfd.cv, 10
- *Topic **datasets**
 - maritimes.avg, 5
 - maritimes.coords, 5
 - maritimes.data, 6
- *Topic **dplot**
 - plot.geofd, 12
- *Topic **math**
 - l2.norm, 4
- *Topic **smooth**
 - okfd, 6
 - okfd.cv, 10
- *Topic **spatial,datagen**
 - geofd-package, 2
- *Topic **spatial**
 - fit.tracevariog, 2
 - okfd, 6
 - okfd.cv, 10
 - plot.geofd, 12
 - trace.variog, 12

- bsplinepen, 4

- create.bspline.basis, 4

- Data2fd, 7, 8

- fd, 7
- fdPar, 7, 8
- fit.tracevariog, 2, 5, 9
- fourierpen, 4

- geofd (geofd-package), 2
- geofd-package, 2
- geofd.fit.tracevariog
 - (fit.tracevariog), 2
- geofd.l2.norm (l2.norm), 4
- geofd.maritimes.avg (maritimes.avg), 5

- geofd.maritimes.coords
 - (maritimes.coords), 5
- geofd.maritimes.data (maritimes.data), 6
- geofd.okfd (okfd), 6
- geofd.okfd.cv (okfd.cv), 10
- geofd.trace.variog (trace.variog), 12

- l2.norm, 4, 9

- maritimes.avg, 5
- maritimes.coords, 5
- maritimes.data, 6

- okfd, 5, 6
- okfd.cv, 10

- plot, 12
- plot.geofd, 12

- smooth.basis, 7, 8

- trace.variog, 5, 9, 12

- variofit, 2, 3, 7, 11
- variog, 2, 13