

Package ‘rtop’

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Type Package

Title Interpolation of Data with Variable Spatial Support

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sp

Suggests parallel, intamap, spacetime, data.table, reshape2

Description Data with irregular spatial support, such as runoff related data or data from administrative units, can with 'rtop' be interpolated to locations without observations with the top-kriging method. A description of the package is given by Skøien et al (2014) <[doi:10.1016/j.cageo.2014.02.009](https://doi.org/10.1016/j.cageo.2014.02.009)>.

License GPL (>= 2)

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and modified to R in this package.)

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| | |
|--------------|---|
| rtop-package | <i>A package providing methods for analysis and spatial interpolation of data with an irregular support</i> |
|--------------|---|

Description

This package provides geostatistical methods for analysis and interpolation of data that has an irregular support, such as runoff characteristics or population health data. The methods in this package are based on the top-kriging approach suggested in Skoien et al (2006), with some extensions from Gottschalk (1993). This package can be used as an add-on package for the automatic interpolation package developed within the intamap project (www.intamap.org).

Workflow

The work flow within the package suggests that the user is interested in a prediction of a process at a series of locations where observations have not been made. The example below shows a regionalization of mean annual runoff in Austria.

Although it is possible to perform each step with all necessary arguments, the easiest interface to the method is to store all variables (such as observations, prediction locations and parameters) in an rtop-object, which is created by a call to `createRtopObject`. The element `params` below consists of changes to the default parameters. A further description can be found in `getRtopParams`. The changes below means that the functions will use geostatistical distance instead of full regularization, and that the variogram model will be fitted to the variogram cloud. Most other functions in the rtop-package can take this object as an argument, and will add the results as one or more new element(s) to this object.

The data in the example below are stored as shape-files in the `extdata`-directory of the rtop-package, use the directory of your own data instead. The observations consist of mean summer runoff from 138 catchments in Upper Austria. The predictionLocations are 863 catchments in the same region. observations and predictionLocations can either be stored as `SpatialPolygonsDataFrame`-objects, or as `sf`-polygons.

```
rpath = system.file("extdata",package="rtop")
library(sf)
observations = st_read(rpath, "observations")
predictionLocations = st_read(rpath,"predictionLocations")
```

```
# Create a column with the specific runoff:
observations$obs = observations$QSUMMER_OB/observations$AREASQKM
params = list(gDist = TRUE, cloud = TRUE)
rtopObj = createRtopObject(observations, predictionLocations,
                          params = params)
```

There are help-methods available in cases when data are not available as shape-files, or when the observations are not part of the shape-files. See [readAreaInfo](#) and [readAreas](#).

A call to [rtopVariogram](#) adds the sample variogram to the object, whereas [rtopFitVariogram](#) fits a variogram model. The last function will call [rtopVariogram](#) if `rtopObj` does not contain a sample variogram.

```
rtopObj = rtopVariogram(rtopObj)
rtopObj = rtopFitVariogram(rtopObj, maxn = 2000)
```

The function [checkVario](#) is useful to produce some diagnostic plots for the sample variogram and the fitted variogram model.

```
checkVario(rtopObj)
```

The interpolation function ([rtopKrige](#)) solves the kriging system based on the computed regularized semivariances. The covariance matrices are created in a separate regularization function ([varMat](#)), and are stored in the `rtop`-object for easier access if it is necessary to redo parts of the analysis, as this is the computationally expensive part of the interpolation. Cross-validation can be called with the argument `cv=TRUE`, either in `params` or in the call to [rtopKrige](#).

```
rtopObj = rtopKrige(rtopObj)
if (is(rtopObj$predictions, "Spatial")) {
  spplot(rtopObj$predictions, col.regions = bpy.colors(), c("var1.pred"))
} else {
# the plotting order to get small polygons on top is not automatic with sf,
# but here is a method that works without modifying the predictions
library(dplyr)
# Arrange according to areas attribute in descending order
rtopObj$predictions |> arrange(desc(AREASQKM)) |>
# Make ggplot and set fill color to var1.pred
ggplot(aes(fill = var1.pred)) + geom_sf()
}
rtopObj = rtopKrige(rtopObj, cv = TRUE)

if (is(rtopObj$predictions, "Spatial")) {
  spplot(rtopObj$predictions, col.regions = bpy.colors(), c("var1.pred", "var1.var"))
} else {
# Here is an alternative method for plotting small polygons on top of the larger ones,
# modifying the predictions
rtopObj$predictions = rtopObj$predictions[order(rtopObj$predictions$AREASQ, decreasing = TRUE), ]
```

```
# It is also possible to change the order of the polygons
  ggplot(rtopObj$predictions) + aes(fill = var1.pred) + geom_sf() + scale_fill_distiller(palette = "YlOrBr")
}
```

References

L. Gottschalk. Interpolation of runoff applying objective methods. *Stochastic Hydrology and Hydraulics*, 7:269-281, 1993.

Skoien J. O., R. Merz, and G. Bloschl. Top-kriging - geostatistics on stream networks. *Hydrology and Earth System Sciences*, 10:277-287, 2006.

Skoien, J. O., Bloschl, G., Laaha, G., Pebesma, E., Parajka, J., Viglione, A., 2014. Rtop: An R package for interpolation of data with a variable spatial support, with an example from river networks. *Computers & Geosciences*, 67.

checkVario

Plot variogram fitted to data with support

Description

The function will create diagnostic plots for analysis of the variograms fitted to sample variograms of data with support

Usage

```
## S3 method for class 'rtop'
checkVario(object, acor = 1, log = "xy", cloud = FALSE,
           gDist = TRUE, acomp = NULL, curveSmooth = FALSE, params = list(), ...)
```

```
## S3 method for class 'rtopVariogramModel'
checkVario(object,
           sampleVariogram = NULL, observations = NULL,
           areas = NULL, dists = NULL, acomp = NULL,
           params = list(), compVars = list(), acor = 1,
           log = "xy", legx = NULL, legy = NULL,
           plotNugg = TRUE, curveSmooth = FALSE, ...)
```

Arguments

| | |
|--------|---|
| object | either: object of class <code>rtop</code> (see rtop-package), or an object of type <code>rtopVariogram</code> |
| acor | unit correction factor in the key, e.g. to see numbers more easily interpretable for large areas. As an example, <code>ucor = 0.000001</code> when area is given in square meters and should rather be shown as square kilometers. Note that this parameter also changes the value of the nugget to the new unit. |
| log | text variable for log-plots, default to log-log "xy", can otherwise be set to "x", "y" or "" |

| | |
|-----------------|---|
| cloud | logical; whether to look at the cloud variogram instead of the binned variogram |
| gDist | logical; whether to use ghosh-distance for semivariogram regularization instead of full integration of the semivariogram |
| sampleVariogram | a sample variogram of the data |
| observations | a set of observations |
| areas | either an array of areas that should be used as examples, or the number of areas per order of magnitude (similar to the parameter <code>amul</code> ; see getRtopParams . <code>amul</code> from <code>rtopObj</code> or from the default parameter set will be used if not defined here. |
| dists | either an array of distances that should be used as examples, or the number of distances per order of magnitude (similar to the parameter <code>amul</code> ; see getRtopParams . <code>amul</code> from <code>rtopObj</code> or from the default parameter set will be used if not defined here. |
| acomp | either a matrix with the area bins that should be visualized, or a number giving the number of pairs to show. If a sample variogram is given, the <code>acomp</code> pairs with highest number of pairs will be used |
| curveSmooth | logical or numerical; describing whether the curves in the last plot should be smoothed or not. If numeric, it gives the degrees of freedom (<code>df</code>) for the splines used for smoothing. See also smooth.spline |
| params | list of parameters to modify the default parameters of <code>rtopObj</code> or the default parameters found from getRtopParams |
| compVars | a list of variograms of <code>gstat</code> -type for comparison, see vgm . The names of the variograms in the list will be used in the key. |
| legx | x-coordinate of the legend for fine-tuning of position, see x-argument of legend |
| legy | y-coordinate of the legend for fine-tuning of position, see y-argument of legend |
| plotNugg | logical; whether the nugget effect should be added to the plot or not |
| ... | arguments to lower level functions |

Value

The function gives diagnostic plots for the fitted variograms, where the regularized variograms are shown together with the sample variograms and possibly also user defined variograms. In addition, if an `rtopObject` is submitted, the function will also give plots of the relationship between variance and area size and a scatter plot of the fit of the observed and regularized variogram values. The sizes of the dots are relative to the number of pairs in each group.

Author(s)

Jon Olav Skoien

References

Skoien J. O., R. Merz, and G. Bloschl. Top-kriging - geostatistics on stream networks. *Hydrology and Earth System Sciences*, 10:277-287, 2006.

Skoien, J. O., Bloschl, G., Laaha, G., Pebesma, E., Parajka, J., Viglione, A., 2014. Rtop: An R package for interpolation of data with a variable spatial support, with an example from river networks. *Computers & Geosciences*, 67.

Examples

```
library(gstat)
rpath = system.file("extdata",package="rtop")
library(sf)
observations = st_read(rpath, "observations")
predictionLocations = st_read(rpath,"predictionLocations")

# Create a column with the specific runoff:
observations$obs = observations$QSUMMER_OB/observations$AREASQKM
params = list(cloud = TRUE, gDist = TRUE)
rtopObj = createRtopObject(observations, predictionLocations,
                          params = params)

# Fit a variogram (function also creates it)
rtopObj = rtopFitVariogram(rtopObj, maxn = 2000)
checkVario(rtopObj,
           compVars = list(first = vgm(5e-6, "Sph", 30000,5e-8),
                          second = vgm(2e-6, "Sph", 30000,5e-8)))

rtopObj = checkVario(rtopObj, acor = 0.000001,
                    acomp = data.frame(ac11 = c(2,2,2,2,3,3,3,4,4),
                                       ac12 = c(2,3,4,5,3,4,5,4,5)))
rtopObj = checkVario(rtopObj, cloud = TRUE, identify = TRUE,
                    acor = 0.000001)
```

createRtopObject

Create an object for interpolation within the rtop package

Description

This is a help function for creating an object (see [rtop-package](#) to be used for interpolation within the rtop package

Usage

```
createRtopObject(observations, predictionLocations,
                formulaString, params=list(), overlapObs,
                overlapPredObs, ...)
```

Arguments

| | |
|---------------------|---|
| observations | SpatialPolygonsDataFrame or <i>sf</i> -polygons with observations |
| predictionLocations | a SpatialPolygons , SpatialPolygonsDataFrame -object or <i>sf</i> -polygons with prediction locations |
| formulaString | formula that defines the dependent variable as a linear model of independent variables; suppose the dependent variable has name <i>z</i> , for ordinary and simple kriging use the formula $z \sim 1$; for universal kriging, suppose <i>z</i> is linearly dependent on <i>x</i> and <i>y</i> , use the formula $z \sim x + y$. The formulaString defaults to "value~1" if value is a part of the data set. If not, the first column of the data set is used. Universal kriging is not yet properly implemented in the <i>rtop</i> -package, this element is mainly used for defining the dependent variable. |
| params | parameters to modify the default parameters of the <i>rtop</i> -package, set internally in this function by a call to getRtopParams |
| overlapObs | matrix with observations that overlap each other |
| overlapPredObs | matrix with observations and predictionLocations that overlap each other |
| ... | Extra parameters to getRtopParams and possibility to pass deprecated arguments |

Value

An object of class *rtop* with observations, prediction locations, parameters and possible other elements useful for interpolation in the *rtop*-package. Most other externally visible functions in the package will be able to work with this object, and add the results as a new element.

Author(s)

Jon Olav Skoien

References

Skoien J. O., R. Merz, and G. Bloschl. Top-kriging - geostatistics on stream networks. *Hydrology and Earth System Sciences*, 10:277-287, 2006.

Skoien, J. O., Bloschl, G., Laaha, G., Pebesma, E., Parajka, J., Viglione, A., 2014. Rtop: An R package for interpolation of data with a variable spatial support, with an example from river networks. *Computers & Geosciences*, 67.

See Also

[getRtopParams](#)

Examples

```
rpath = system.file("extdata",package="rtop")
library(sf)
observations = st_read(rpath, "observations")
predictionLocations = st_read(rpath, "predictionLocations")
```

```
# Create a column with the specific runoff:
observations$obs = observations$QSUMMER_OB/observations$AREASQKM

# Setting some parameters
params = list(gDist = TRUE, cloud = FALSE)
# Create a column with the specific runoff:
observations$obs = observations$QSUMMER_OB/observations$AREASQKM
# Build an object
rtopObj = createRtopObject(observations, predictionLocations,
                           params = params)
```

downloadRtopExampleData

Download additional example data

Description

Download additional example data from Vienna University of Technology

Usage

```
downloadRtopExampleData(folder = system.file("extdata",
                                             package="rtop"))
```

Arguments

folder the folder to which the downloaded data set will be copied

Value

The function will have as a side effect that additional example data is downloaded from Vienna University of Technology. This will for the default case replace the existing example data-set in the rtop package. Alternatively the user can specify a separate directory for the data set.

Author(s)

Jon Olav Skoien

References

Skoien J. O., R. Merz, and G. Bloschl. Top-kriging - geostatistics on stream networks. *Hydrology and Earth System Sciences*, 10:277-287, 2006.

Skoien, J. O., Bloschl, G., Laaha, G., Pebesma, E., Parajka, J., Viglione, A., 2014. Rtop: An R package for interpolation of data with a variable spatial support, with an example from river networks. *Computers & Geosciences*, 67.

Examples

```
## Not run:
downloadRtopExampleData()
rpath = system.file("extdata",package="rtop")
library(sf)
observations = st_read(rpath,"observations")

## End(Not run)
```

| | |
|--------------------|---|
| <code>gDist</code> | <i>calculate geostatistical distances between areas</i> |
|--------------------|---|

Description

Calculate geostatistical distances (Ghosh-distances) between areas

Usage

```
## S3 method for class 'rtop'
gDist(object, params = list(), ...)
## S3 method for class 'SpatialPolygonsDataFrame'
gDist(object, object2 = NULL, ...)
## S3 method for class 'SpatialPolygons'
gDist(object, object2 = NULL, ...)
## S3 method for class 'list'
gDist(object, object2 = NULL, diag = FALSE, debug.level = 0, ...)
```

Arguments

| | |
|--------------------------|--|
| <code>object</code> | object of class SpatialPolygons or SpatialPolygonsDataFrame with boundaries of areas; or list of discretized areas, typically from a call to rtopDisc ; or object of class <code>rtop</code> with such boundaries and/or discretized elements (the individual areas) |
| <code>params</code> | a set of parameters, used to modify the default parameters for the <code>rtop</code> package, set in getRtopParams . The argument <code>params</code> can also be used for the other methods, through the <code>...</code> -argument. |
| <code>object2</code> | an object of same type as <code>object</code> , except for <code>rtop</code> ; for calculation of geostatistical distances also between the elements in the two different objects |
| <code>diag</code> | logical; if <code>TRUE</code> only calculate the geostatistical distances between each element and itself, only when the objects are lists of discretized areas and <code>object2 = object</code> or <code>object2 = NULL</code> |
| <code>debug.level</code> | <code>debug.level = 0</code> will suppress output from the call to <code>varMat</code> , done for calculation of the geostatistical distances |
| <code>...</code> | other parameters, for <code>gDist.list</code> when calling one of the other methods, or for varMat , in which the calculations take place |

Value

If called with one list of discretized elements, a matrix with the geostatistical distances between the elements within the list. If called with two lists of discretized elements, a matrix with the geostatistical distances between the elements in the two lists. If called with `diag = TRUE`, the function returns an array of the geostatistical distance within each of the elements in the list.

If called with one `SpatialPolygons` or `SpatialPolygonsDataFrame` or the function returns a list with one matrix with geostatistical distances between the elements of the object. If called with two objects, the list will also contain a matrix of the geostatistical distances between the elements of the two objects, and an array of the geostatistical distances within the elements of the second object.

If called with an `rtop`-object, the function will return the object, amended with the list above.

Note

The geostatistical distance can be seen as the average distance between points in two elements, or the average distance within points in a single element. The distance measure is also sometimes referred to as Ghosh-distance, from Ghosh (1951) who found analytical expressions for these distances between blocks with regular geometry.

The use of geostatistical distances within `rtop` is based on an idea from Gottschalk (1993), who suggested to replace the traditional regularization of variograms within block-kriging (as done in the original top-kriging application of Skoien et al (2006)) with covariances of the geostatistical distance. The covariance between two areas can then be found as $C(a1, a2) = cov(gd)$ where gd is the geostatistical distance between the two areas $a1$ and $a2$, instead of an integration of the covariance function between the two areas.

`rtop` is based on semivariograms instead of covariances, and the semivariogram value between the two areas can be found as $gamma(a1, a2) = g(gd) - 0.5 (g(gd1) + g(gd2))$ where g is a semivariogram valid for point support, $gd1$ and $gd2$ are the geostatistical distances within each of the two areas.

Author(s)

Jon Olav Skoien

References

- Ghosh, B. 1951. Random distances within a rectangle and between two rectangles. *Bull. Calcutta Math. Soc.*, 43, 17-24.
- Gottschalk, L. 1993. Correlation and covariance of runoff. *Stochastic Hydrology and Hydraulics*, 7, 85-101.
- Skoien, J. O., R. Merz, and G. Bloschl. 2006. Top-kriging - geostatistics on stream networks. *Hydrology and Earth System Sciences*, 10, 277-287.
- Skoien, J. O., Bloschl, G., Laaha, G., Pebesma, E., Parajka, J., Viglione, A., 2014. `Rtop`: An R package for interpolation of data with a variable spatial support, with an example from river networks. *Computers & Geosciences*, 67.

Examples

```
rpath = system.file("extdata",package="rtop")
library(sf)
observations = st_read(rpath, "observations")
gDist = gDist(observations)
```

| | |
|---------------|---|
| getRtopParams | <i>Setting parameters for the intamap package</i> |
|---------------|---|

Description

This function sets a range of the parameters for the intamap package, to be included in the object described in [rtop-package](#)

Usage

```
getRtopParams(params,newPar, observations, formulaString, ...)
```

Arguments

| | |
|---------------|---|
| params | An existing set of parameters for the interpolation process, of class <code>intamapParams</code> or a list of parameters for modification of the default parameters |
| newPar | A list of parameters for updating <code>params</code> or for modification of the default parameters. Possible parameters with their defaults are given below |
| observations | SpatialPolygonsDataFrame with observations, used for setting some of the default parameters |
| formulaString | formula that defines the dependent variable as a linear model of independent variables, see e.g. createRtopObject for more details. |
| ... | Individual parameters for updating <code>params</code> or for modification of the default parameters. Possible parameters with their defaults are given below |

model = "Ex1" - variogram model type. Currently the following models are implemented:

Exp - Exponential model

Ex1 - Multiplication of a modified exponential and fractal model, the same model as used in Skoien et al(2006).

Gau - Gaussian model

Ga1 - Multiplication of gaussian and fractal model

Sph - Spherical model

Sp1 - Multiplication of spherical and fractal model

Fra - Fractal model

parInit - the initial parameters and the limits of the variogram model to be fitted, given as a matrix with three columns, where the first column is the lower limit, the second column is the upper limit and the third column are starting values.

nugget = FALSE - logical; if TRUE, nugget effect should be estimated

unc = TRUE - logical; if TRUE the variance of observations are in column `unc`

rresol = 100 - minimum number of discretization points in each area

hresol = 5 - number of discretization points in one direction for elements in binned variograms

cloud = FALSE - logical; if TRUE use the cloud variogram for variogram fitting

amul = 1 - defines the number of areal bins within one order of magnitude. Numbers between 1 and 3 are possible, as this parameter refers to the `axp` parameter of `axTicks`.

dmul = 3 - defines the number of distance bins within one order of magnitude. Numbers between 1 and 3 are possible, as this parameter refers to the `axp` parameter of `axTicks`.

fit.method = 9 - defines the type of Least Square method for fitting of variogram. The methods 1-7 correspond to the similar methods in `fit.variogram`.

1 - weighted least squares with number of pairs per bin:
 $err = n * (yobs - ymod)^2$

2 - weighted least squares difference according to Cressie (1985):
 $err2 = abs(yobs/ymod - 1)$

6 - ordinary least squares difference: $err = (yobs - ymod)^2$

7 - similar to default of `gstat`, where higher weights are given to shorter distances $err = n/h^2 * (yobs - ymod)^2$

8 - Opposite of weighted least squares difference according to Cressie (1985):
 $err3 = abs(ymod/yobs - 1)$

9 - neutral WLS-method - $err = min(err2, err3)$

gDistEst = FALSE - use geostatistical distance when fitting variograms

gDistPred = FALSE - use geostatistical distance for semivariogram matrices

gDist - parameter to set jointly `gDistEst = gDistPred = gDist`

nmax = 10 for local kriging: the number of nearest observations that should be used for a kriging prediction or simulation, where nearest is defined in terms of the space of the spatial locations. By default, 10 observations are used.

maxdist = Inf - for local kriging: only observations within a distance of `maxdist` from the prediction location are used for prediction or simulation; if combined with `nmax`, both criteria apply

hstype = "regular" - sampling type for binned variograms

rstype = "rtop" - sampling type for the elements, see also `rtopDisc`

nclus = 1 - number of CPUs to use if parallel processing is wanted; `nclus = 1` means no parallelization

cnAreas = 100 - limit whether parallel processing should be applied; the minimum number of areas in `varMat`, and also controlling when to use parallel

processing in `rtopDisc`, when
 $nAreas * params\$rresol / 100 > cnAreas$

clusType = NULL - the cluster type to be started for parallel processing; uses the default type of the system when `clusType = NULL`

outfile = NULL file where output can be printed during parallel execution

varClean = FALSE logical; if TRUE it will remove highly correlated areas from the covariance matrix during simulation

wlim = 1.5 - an upper limit for the norm of the weights in kriging, see `rtopKrige`

wlimMethod = "all" which method to use for reducing the norm of the weights if necessary. Either "all", which modifies all weights equally or "neg" which reduces negative weights and large weights more than the smallest weights

singularSolve - logical; When TRUE, the kriging function will attempt to solve singular kriging matrices by removing catchments that have the same correlations. This will usually happen when two catchments are almost overlapping, and they are discretized with the same points. See also `rtopKrige`.

cv = FALSE - logical; for cross-validation of observations

debug.level = 1 - used in some functions for giving additional output. See individual functions for more information.

partialOverlap = FALSE whether to work with partially overlapping areas

olim = 1e-4 smallest overlapping area to be used for partial overlap, relative to the smallest of the areas

nclus = 1 option to use parallel processing, `nclus > 1` defines the number of workers to be started

clusType = NA which cluster type to start if `nclus > 1`; the default is used if `nclusType = NA`

cnAreas = 200 The minimum number of observations or observations plus predictions allowing parallelization in the creation of the covariance matrix

cDim = 1e6 The minimum number of discretization points for allowing parallelization in the discretization process

observations - used for initial values of parameters if supplied

formulaString - used for initial values of parameters if supplied

Value

A list of the parameters with class `rtopParams` to be included in the object described in [rtop-package](#)

Note

This function will mainly be called by `createRtopObject`, but can also be called by the user to create a parameter set or update an existing parameter set. If none of the arguments is a list of class `rtopParams`, the function will assume that the argument(s) are modifications to the default set of parameters. The function can also be called by other functions in the `rtop`-package if the users chooses not to work with an object of class `rtop`.

If the function is called with two lists of parameters (but the first one is not of class `rtopParams`) they are both seen as modifications to the default parameter set. If they share some parameters, the parameter values from the second list will be applied.

Parallel processing has been included for some of the functions. The default is no parallel processing, and the package also attempts to decide whether it is sensible to start a set of clusters and distribute jobs to them based on the size of the job. The default limit might not be the best for every system.

Author(s)

Jon Olav Skoien

References

Cressie, N. 1985. Fitting variogram models by weighted least squares. *Mathematical Geology*, 17 (5), 563-586

Skoien J. O., R. Merz, and G. Bloschl. Top-kriging - geostatistics on stream networks. *Hydrology and Earth System Sciences*, 10:277-287, 2006

Skoien, J. O., Bloschl, G., Laaha, G., Pebesma, E., Parajka, J., Viglione, A., 2014. Rtop: An R package for interpolation of data with a variable spatial support, with an example from river networks. *Computers & Geosciences*, 67.

See Also

[createRtopObject](#) and [rtop-package](#)

Examples

```
# Create a new set of intamapParameters, with default parameters:
params = getRtopParams()
# Make modifications to the default list of parameters
params = getRtopParams(newPar = list(gDist = TRUE, nugget = FALSE))
# Make modifications to an existing list of parameters
params = getRtopParams(params = params, newPar = list(gDist = TRUE,
nugget = FALSE))
```

plot.rtopVariogramCloud

Plot and Identify Data Pairs on Sample Variogram Cloud

Description

Plot a sample variogram cloud, possibly with identification of individual point pairs

Usage

```
## S3 method for class 'rtopVariogramCloud'
plot(x, ...)
```

Arguments

x object of class `variogramCloud`

... parameters that are passed through to `plot.variogramCloud` The most important are:

identify logical; if TRUE, the plot allows identification of a series of individual point pairs that correspond to individual variogram cloud points (use left mouse button to select; right mouse button ends)

digitize logical; if TRUE, select point pairs by digitizing a region with the mouse (left mouse button adds a point, right mouse button ends)

xlim limits of x-axis

ylim limits of y-axis

xlab x axis label

ylab y axis label

keep logical; if TRUE and `identify` is TRUE, the labels identified and their position are kept and glued to object `x`, which is returned. Subsequent calls to plot this object will now have the labels shown, e.g. to plot to `hardcopy`

Note

This function is mainly a wrapper around `plot.variogramCloud`, necessary because of different column names and different class names. The description of arguments and value can therefore be found in the help page of `plot.variogramCloud`.

Author(s)

Jon Olav Skoien

References

<http://www.gstat.org/>

See Also

`plot.gstatVariogram`

Examples

```
rpath = system.file("extdata",package="rtop")
library(sf)
observations = st_read(rpath, "observations")

observations$obs = observations$QSUMMER_OB/observations$AREASQKM

# Create the sample variogram
rtopVario = rtopVariogram(observations, params = list(cloud = TRUE))
plot(rtopVario)
```

| | |
|--------------|---|
| readAreaInfo | <i>create SpatialPointsDataFrame with observations of data with a spatial support</i> |
|--------------|---|

Description

readAreaInfo will read a text file with observations and descriptions of data with a spatial support.

Usage

```
readAreaInfo(fname = "ainfo.txt", id = "id",
             iobs = "iobs", obs = "obs", unc = "unc",
             filenames= "filenames", sep = "\t",
             debug.level = 1, moreCols = list(NULL))
```

Arguments

| | |
|-------------|---|
| fname | name of file with areal information |
| id | name of column with observation id |
| iobs | name of column with number of observations |
| obs | name of column with observations |
| unc | name of column with possible uncertainty of observation |
| filenames | name of column with filenames of areas if different names than id should be used. |
| sep | separator in csv-file |
| debug.level | used for giving additional output |
| moreCols | name of other column names the user wants included in ainfo |

Details

The function is of particular use when data are not available as shape-files, or when the observations are not part of the shape-files. This function is mainly for compatibility with the former FORTRAN-version. The simplest way to read the data in that case is through [st_read](#). See also [rtop-package](#).

Value

[SpatialPointDataFrame](#) with information about observations and/or predictionLocations.

Author(s)

Jon Olav Skoien

| | |
|-----------|--|
| readAreas | <i>help file for creating SpatialPolygonsDataFrame with observations and/or predictionLocations of data with a spatial support</i> |
|-----------|--|

Description

readAreas will read area-files, add observations and convert the result to [SpatialPolygonsDataFrame](#)

Usage

```
readAreas(object, adir=".", ftype = "xy", projection = NA, ...)
```

Arguments

| | |
|------------|--|
| object | either name of file with areal information or SpatialPointsDataFrame with observations |
| adir | directory where the files with areal information are to be found |
| ftype | type of file, the only type supported currently is "xy", referring to x- and y-coordinates of boundaries |
| projection | add projection to the object if input is boundary-files |
| ... | further parameters to be passed to readAreaInfo |

Details

If object is a file name, [readAreaInfo](#) will be called. If it is a [SpatialPointsDataFrame](#) with observations and/or predictionLocations, the function will read areal data from files according to the ID associated with each observation/predictionLocation.

The function is of particular use when data are not available as shape-files, or when the observations are not part of the shape-files. This function is mainly for compatibility with the former FORTRAN-version. The simplest way to read the data in that case is through [st_read](#). See also [rtop-package](#).

Value

The function creates a [SpatialPolygonsDataFrame](#) of observations and/or predictionLocations, depending on the information given in object.

Author(s)

Jon Olav Skoien

| | |
|-------------|--|
| rtopCluster | <i>start, access, stop or restart a cluster for parallel computation with rtop</i> |
|-------------|--|

Description

Convenience function for using parallel computation with rtop. The function is usually not called by the user.

Usage

```
rtopCluster(nclus, ..., action = "start", type, outfile = NULL)
```

Arguments

| | |
|---------|---|
| nclus | The number of workers in the cluster |
| ... | Arguments for clusterEvalQ ; commands to be evaluated for each worker, such as library-calls |
| action | Defines the action of the function. There are three options: "start" Starts a new cluster if necessary, reuses an existing if it has already been started "restart" Stops the cluster and starts it again. To be used in case there are difficulties with the cluster, or if the user wants to change the type of the cluster |
| type | The type of cluster; see makeCluster for more details. The default of makeCluster is used if type is missing or NA. |
| outfile | File to direct the output, makeCluster for more details. |

Details

It is usually not necessary for the user to call this function for starting or accessing a cluster. This is done automatically by the different rtop-functions when needed if the parameter nclus is larger than one (see [getRtopParams](#)). If the user actually starts the cluster by a call to this function, it will also be necessary to set the nclus parameter to a value larger than one for the cluster to be used by different functions.

Restarting the cluster might be necessary if the cluster has a problem (e.g. does not return memory) or if the user wants to change to a different cluster type.

Stopping the cluster is useful when the user does not want to continue with parallel computation and wants to close down the workers.

Value

If the function is called with action equal to "start" or "restart", the result is a cluster with nclus workers. The cluster is also added to the global options with the name rtopCluster (getOption("rtopCluster")).

If the function is called with action equal to "stop", the function stops the cluster, sets the rtopCluster of options to NULL and returns NULL to the user.

Author(s)

Jon Olav Skoien

| | |
|----------|-------------------------|
| rtopDisc | <i>Discretize areas</i> |
|----------|-------------------------|

Description

rtopDisc will discretize an area for regularization or calculation of Ghosh-distance

Usage

```
## S3 method for class 'rtop'
rtopDisc(object, params = list(),...)
## S3 method for class 'SpatialPolygonsDataFrame'
rtopDisc(object, params = list(), bb = bbox(object), ...)
## S3 method for class 'SpatialPolygons'
rtopDisc(object, params = list(), bb = bbox(object), ...)
## S3 method for class 'rtopVariogram'
rtopDisc(object, params = list(), ...)
```

Arguments

| | |
|--------|--|
| object | object of class SpatialPolygons or SpatialPolygonsDataFrame or rtopVariogram, or an object with class rtop that includes one of the above |
| bb | boundary box, usually modified to be the common boundary box for two spatial object |
| params | possibility to pass parameters to modify the default parameters for the rtop package, set in getRtopParams . Typical parameters to modify for this function are: <ul style="list-style-type: none"> • rresol = 100; minimum number of discretization points in areas • hresol = 5; number of discretization points in one direction for areas in binned variograms • hstype = "regular"; sampling type for binned variograms • rstype = "rtop"; sampling type for real areas |
| ... | Possibility to pass individual parameters |

Details

There are different options for discretizing the objects. When the areas from the bins are discretized, the options are random or regular sampling, regular sampling is the default.

For the real areas, regular sampling appears to have computational advantages compared with random sampling. In addition to the traditional regular sampling, rtop also offers a third type of sampling which assures that the same discretization points are used for overlapping areas.

Starting with a coarse grid covering the region of interest, this will for a certain support be refined till a requested minimum number of points from the grid is within the support. In this way, for areal supports, the number of points in the area with the largest number of points will be approximately four times the requested minimum number of points. This methods also assure that points used to discretize a large support will be reused when discretizing smaller supports within the large one, e.g. subcatchments within larger catchments.

Value

The function returns a list of discretized areas, or if called with an rtop-object as argument, the object with lists of discretizations of the observations and prediction locations (if part of the object). If the function is called with an rtopVariogram (usually this is an internal call), the list contains discretized pairs of hypothetical objects from each bin of the semivariogram with a centre-to-centre distance equal to the average distance between the objects in a certain bin.

Author(s)

Jon Olav Skoien

References

Skoien J. O., R. Merz, and G. Bloschl. Top-kriging - geostatistics on stream networks. *Hydrology and Earth System Sciences*, 10:277-287, 2006.

Skoien, J. O., Bloschl, G., Laaha, G., Pebesma, E., Parajka, J., Viglione, A., 2014. Rtop: An R package for interpolation of data with a variable spatial support, with an example from river networks. *Computers & Geosciences*, 67.

See Also

[rtopVariogram](#)

rtopFitVariogram

Fit variogram model to sample variogram of data with spatial support

Description

rtopFitVariogram will fit a variogram model to the estimated binned variogram or cloud variogram of data with an areal support.

Usage

```
## S3 method for class 'rtop'
rtopFitVariogram(object, params = list(), iprint = 0, ...)
## S3 method for class 'SpatialPolygonsDataFrame'
rtopFitVariogram(object, params=list(), ...)
## S3 method for class 'SpatialPointsDataFrame'
rtopFitVariogram(object, params=list(), ...)
## S3 method for class 'rtopVariogram'
rtopFitVariogram(object, observations, dists = NULL,
                  params=list(), mr = FALSE, aOver = NULL, iprint = 0, ...)
## S3 method for class 'rtopVariogramCloud'
rtopFitVariogram(object, observations, dists = NULL,
                  aOver = NULL, params=list(), mr = FALSE, iprint = 0, ...)
```

Arguments

| | |
|--------------|--|
| object | object of class <code>rtopVariogram</code> or <code>rtopVariogramCloud</code> , or an object with class <code>rtop</code> that includes the sample variograms. The object can also be of class <code>SpatialPolygonsDataFrame</code> or <code>SpatialPointsDataFrame</code> with observations. If object is a <code>SpatialPointsDataFrame</code> , it must have a column with name <code>area</code> . |
| observations | the observations, passed as a <code>Spatial*DataFrame</code> object, if object is an <code>rtopVariogram</code> or <code>rtopVariogramCloud</code> |
| params | a set of parameters, used to modify the default parameters for the <code>rtop</code> package, set in <code>getRtopParams</code> . The argument <code>params</code> can also be used for the other methods, through the <code>...</code> -argument. |
| dists | either a matrix with geostatistical distances (created by a call to the function <code>gDist</code> or a list with the areas discretized (from a call to <code>rtopDisc</code> . |
| mr | logical; defining whether the function should return a list with discretized elements and geostatistical distances, even if it was not called with an <code>rtop</code> -object as argument. |
| aOver | a matrix with the overlapping areas of the observations, used for computation of the nugget effect. It will normally be recomputed by the function if it is <code>NULL</code> and necessary |
| iprint | print flag that is passed to <code>sceua</code> |
| ... | Other parameters to functions called from <code>rtopFitVariogram</code> . For the three first methods of the function, <code>...</code> can also include parameters to the last two methods. |

Value

The function creates an object with the fitted variogram Model (`variogramModel`) and a `data.frame` (`varFit`) with the differences between the sample semivariances and the regularized semivariances. If `mr = TRUE`, the function also returns other objects (discretized elements and geostatistical distances, if created) as a part of the returned object. If the function is called with an `rtop`-object as argument, it will return an `rtop`-object with `variogramModel` and `varFit` added to the object, in addition to other objects created.

Note

There are several options for fitting of the `variogramModel`, where the parameters can be set in `params`, which is a list of parameters for modification of the default parameters of the `rtop`-package given in a call to `getRtopParams`. The first choice is between individual fitting and binned fitting. This is based on the type of variogram submitted, individual fitting is done if a cloud variogram (of class `rtopVariogramCloud`) is passed as argument, and binned fitting if the submitted variogram is of class `rtopVariogram`. If the function is called with an object of class `rtop`, having both `variogram` and `variogramCloud` among its arguments, the variogram model is fitted to the variogram which is consistent with the parameter `cloud`.

Author(s)

Jon Olav Skoien

References

Skoien J. O., R. Merz, and G. Bloschl. Top-kriging - geostatistics on stream networks. *Hydrology and Earth System Sciences*, 10:277-287, 2006.

Skoien, J. O. and G. Bloschl. Spatio-Temporal Top-Kriging of Runoff Time Series. *Water Resources Research* 43:W09419, 2007.

Skoien, J. O., Bloschl, G., Laaha, G., Pebesma, E., Parajka, J., Viglione, A., 2014. Rtop: An R package for interpolation of data with a variable spatial support, with an example from river networks. *Computers & Geosciences*, 67.

Examples

```
rpath = system.file("extdata",package="rtop")
library(sf)
observations = st_read(rpath, "observations")
predictionLocations = st_read(rpath,"predictionLocations")

# Create a column with the specific runoff:
observations$obs = observations$QSUMMER_OB/observations$AREASQKM

# Setting some parameters
params = list(gDist = TRUE, cloud = FALSE)
# Create a column with the specific runoff:
observations$obs = observations$QSUMMER_OB/observations$AREASQKM
# Build an object
rtopObj = createRtopObject(observations,predictionLocations,
                           params = params)
# Fit a variogram (function also creates it)
rtopObj = rtopFitVariogram(rtopObj)
rtopObj$variogramModel
```

 rtopKrige

Spatial interpolation of data with spatial support

Description

rtopKrige perform spatial interpolation or cross validation of data with areal support.

Usage

```
## S3 method for class 'rtop'
rtopKrige(object, varMatUpdate = FALSE, params = list(), ...)
## S3 method for class 'SpatialPolygonsDataFrame'
rtopKrige(object, predictionLocations = NULL,
           varMatObs, varMatPredObs, varMat, params = list(),
           formulaString, sel, ...)
## S3 method for class 'STSDf'
rtopKrige(object, predictionLocations = NULL,
           varMatObs, varMatPredObs, varMat, params = list(),
           formulaString, sel, olags = NULL, plags = NULL,
           lagExact = TRUE, ...)
## Default S3 method:
rtopKrige(object, predictionLocations = NULL,
           varMatObs, varMatPredObs, varMat, params = list(),
           formulaString, sel, wret = FALSE, ...)
```

Arguments

| | |
|---------------------|---|
| object | object of class rtop or SpatialPolygonsDataFrame or STSDf |
| varMatUpdate | logical; if TRUE, also existing variance matrices will be recomputed, if FALSE, only missing variance matrices will be computed, see also varMat |
| predictionLocations | SpatialPolygons or SpatialPolygonsDataFrame or STSDf with prediction locations. NULL if cross validation is to be performed. |
| varMatObs | covariance matrix of observations, where diagonal must consist of internal variance, typically generated from call to varMat |
| varMatPredObs | covariance matrix between observation locations and prediction locations, typically generated from call to varMat |
| varMat | list covariance matrices including the two above |
| params | a set of parameters, used to modify the default parameters for the rtop package, set in getRtopParams . Additionally, it is possible overrule some of the parameters in object\$params by passing them as separate arguments. |

| | |
|---------------|---|
| formulaString | formula that defines the dependent variable as a linear model of independent variables, see e.g. createRtopObject for more details. |
| sel | array of prediction location numbers, if only a limited number of locations are to be interpolated/crossvalidated |
| wret | logical; if TRUE, return a matrix of weights instead of the predictions, useful for batch processing of time series, see also details |
| olags | A vector describing the relative lag which should be applied for the observation locations. See also details |
| plags | A vector describing the relative lag which should be applied for the prediction locations. See also details |
| lagExact | logical; whether differences in lagtime should be computed exactly or approximate |
| ... | from <code>rtopKrige.rtop</code> , arguments to be passed to <code>rtopKrige.default</code> . In <code>rtopKrige.default</code> , parameters for modification of the object parameters or default parameters. Of particular interest are <code>cv</code> , a logical for doing cross-validation, <code>nmax</code> , and <code>maxdist</code> for maximum number of neighbours and maximum distance to neighbours, respectively, and <code>wlim</code> , the limit for the absolute values of the weights. It can also be useful to set <code>singularSolve</code> if some of the areas are almost similar, see also details below. |

Details

This function is the interpolation routine of the `rtop`-package. The simplest way of calling the function is with an `rtop`-object that contains the fitted variogram model and all the other necessary data (see [createRtopObject](#) or [rtop-package](#)).

The function will, if called with covariance matrices between observations and between observations and prediction locations, use these for the interpolation. If the function is called without these matrices, `varMat` will be called to create them. These matrices can therefore be reused if necessary, an advantage as it is computationally expensive to create them.

The interpolation that takes part within `rtopKrige.default` is based on the semivariance matrices between observations and between observations and prediction locations. It is therefore possible to use this function also to interpolate data where the matrices have been created in other ways, e.g. based on distances in geographical space or distances along a stream.

The function returns the weights rather than the predictions if `wret = TRUE`. This is useful for batch processing of time series, e.g. once the weights are created, they can be used to compute the interpolated values for each time step.

`rtop` is able to take some advantage of multiple CPUs, which can be invoked with the parameter `nclus`. When it gets a number larger than one, `rtopKrige` will start a cluster with `nclus` workers, if the `parallel`-package has been installed.

The parameter `singularSolve` can be used when some areas are almost completely overlapping. In this case, the discretization of them might be equal, and the covariances to other areas will also be equal. The kriging matrix will in this case be singular. When `singularSolve = TRUE`, `rtopKrige` will remove one of the neighbours, and instead work with the mean of the two observations. An overview of removed neighbours can be seen in the resulting object, under the name `removed`.

Kriging of time series is possible when observations and predictionLocations are spatiotemporal objects of type `STSDf`. The interpolation is still spatial, in the sense that the regularisation of the variograms are just done using the spatial extent of the observations, not a possible temporal extent, such as done by Skoien and Bloschl (2007). However, it is possible to make predictions based on observations from different time steps, through the use of the lag-vectors. These vectors describe a typical "delay" for each observation and prediction location. This delay could for runoff related variables be similar to travel time to each gauging location. For a certain prediction location, earlier time steps would be picked for neighbours with shorter travel time and later time steps for neighbours with slower travel times.

The `lagExact` parameter indicates whether to use a weighted average of two time steps, or just the time step which is closest to the difference in lag times.

The use of lag times should in theory increase the computation time, but might, due to different computation methods, even speed up the computation when the number of neighbours to be used (parameter `nmax`) is small compared to the number of observations. If computation is slow, it can be useful to test `olags = rep(0, dim(observations)[1])` and similar for `predictionLocations`.

Value

If called with `SpatialPolygonsDataFrame`, the function returns a `SpatialPolygonsDataFrame` with predictions, either at the locations defined in `predictionLocations`, or as leave-one-out cross-validation predictions at the same locations as in object if `cv = TRUE`

If called with an `rtop`-object, the function returns the same object with the predictions added to the object.

Author(s)

Jon Olav Skoien

References

Skoien J. O., R. Merz, and G. Bloschl. Top-kriging - geostatistics on stream networks. *Hydrology and Earth System Sciences*, 10:277-287, 2006.

Skoien, J. O. and G. Bloschl. Spatio-Temporal Top-Kriging of Runoff Time Series. *Water Resources Research* 43:W09419, 2007.

Skoien, J. O., Bloschl, G., Laaha, G., Pebesma, E., Parajka, J., Viglione, A., 2014. Rtop: An R package for interpolation of data with a variable spatial support, with an example from river networks. *Computers & Geosciences*, 67.

Examples

```
# The following command will download the complete example data set
# downloadRtopExampleData()
# observations$obs = observations$QSUMMER_OB/observations$AREASQKM

rpath = system.file("extdata", package="rtop")
library(sf)
observations = st_read(rpath, "observations")
```

```

predictionLocations = st_read(rpath,"predictionLocations")

# Setting some parameters; nclus > 1 will start a cluster with nclus
# workers for parallel processing
params = list(gDist = TRUE, cloud = FALSE, nclus = 1, rresol = 25)

# Create a column with the specific runoff:
observations$obs = observations$QSUMMER_OB/observations$AREASQKM

# Build an object
rtopObj = createRtopObject(observations, predictionLocations,
                          params = params)

# Fit a variogram (function also creates it)
rtopObj = rtopFitVariogram(rtopObj)

# Predicting at prediction locations
rtopObj = rtopKrige(rtopObj)

# Cross-validation
rtopObj = rtopKrige(rtopObj,cv=TRUE)
cor(rtopObj$predictions$observed,rtopObj$predictions$var1.pred)

```

rtopSim

Spatial simulation of data with spatial support

Description

rtopSim will conditionally or unconditionally simulate data with areal support. This function should be seen as experimental, some issues are described below.

Usage

```

## S3 method for class 'rtop'
rtopSim(object, varMatUpdate = FALSE, beta = NA,
        largeFirst = TRUE, replace = FALSE, params = list(),
        dump = NULL, debug.level, ...)
## Default S3 method:
rtopSim(object = NULL, predictionLocations,
        varMatObs, varMatPredObs, varMatPred, variogramModel, ...)

```

Arguments

| | |
|--------------|--|
| object | object of class rtop or SpatialPolygonsDataFrame or sf (st_sf) or NULL |
| varMatUpdate | logical; if TRUE, also existing variance matrices will be recomputed, if FALSE, only missing variance matrices will be computed, see also varMat |

| | |
|---------------------|--|
| beta | The expected mean of the data, for unconditional simulations |
| largeFirst | Although the simulation method follows a random path around the prediction-Locations, simulating the largest area first will assure that the true mean of the simulated values will be closer to beta |
| replace | logical; if observation locations are also present as predictions, should they be replaced? This is particularly when doing conditional simulations for a set of observations with uncertainty. |
| params | a set of parameters, used to modify the standard parameters for the rtop package, set in getRtopParams . The argument params can also be used for the other methods, through the ...-argument. |
| dump | file name for saving the updated object, after adding variance matrices. Useful if there are problems with the simulation, particularly if it for some reason crashes. |
| debug.level | logical that controls some output, will override the object parameters |
| predictionLocations | SpatialPolygons or SpatialPolygonsDataFrame or sf-object with locations for simulations. |
| varMatObs | covariance matrix of possible observations, where diagonal must consist of internal variance, typically generated from call to varMat |
| varMatPredObs | covariance matrix between possible observation locations and simulation locations, typically generated from call to varMat |
| varMatPred | covariance matrix between simulation locations, typically generated from a call to varMat |
| variogramModel | a variogram model of type rtopVariogramModel |
| ... | possible modification of the object parameters or default parameters. |

Details

This function can do constrained or unconstrained simulation for areas. The simplest way of calling the function is with an rtop-object that contains the fitted variogram model and all the other necessary data (see [createRtopObject](#) or [rtop-package](#)). `rtopSim` is the only function in `rtop` which does not need observations. However, a variogram model is still necessary to perform simulations.

The arguments `beta` and `largeFirst` are only used for unconditional simulations.

The function is still in an experimental stage, and might change in the future. There are some issues with the current implementation:

- Numerical issues can in some cases give negative estimation variances, which will result in an invalid distribution for the simulation. This will result in simulated NA values for these locations.
- The variability of simulated values for small areas (such as small headwater catchments) will be relatively high based on the statistical uncertainty. This could be overestimated compared to the uncertainty which is possible based on rainfall.

Value

If called with `SpatialPolygons` or `sf` as `predictionLocations` and either `SpatialPolygonsDataFrame`, `sf` or `NULL` for `observations`, the function returns a `SpatialPolygonsDataFrame` or `sf` with simulations at the locations defined in `predictionLocations`

If called with an `rtop`-object, the function returns the same object with the simulations added to the object.

Author(s)

Jon Olav Skoien

References

Skoien J. O., R. Merz, and G. Bloschl. Top-kriging - geostatistics on stream networks. *Hydrology and Earth System Sciences*, 10:277-287, 2006.

Skoien, J. O., Bloschl, G., Laaha, G., Pebesma, E., Parajka, J., Viglione, A., 2014. Rtop: An R package for interpolation of data with a variable spatial support, with an example from river networks. *Computers & Geosciences*, 67.

Examples

```
# The following command will download the complete example data set
# downloadRtopExampleData()

rpath = system.file("extdata",package="rtop")
library(sf)
observations = st_read(rpath, "observations")
predictionLocations = st_read(rpath,"predictionLocations")

# Setting some parameters; nclus > 1 will start a cluster with nclus
# workers for parallel processing
params = list(gDist = TRUE, cloud = FALSE, nclus = 1, rresol = 25)

# Create a column with the specific runoff:
observations$obs = observations$QSUMMER_OB/observations$AREASQKM

# Build an object
rtopObj = createRtopObject(observations, predictionLocations,
                          params = params, formulaString = "obs~1")

# Fit a variogram (function also creates it)
rtopObj = rtopFitVariogram(rtopObj)

# Conditional simulations for two new locations
rtopObj10 = rtopSim(rtopObj, nsim = 5)
rtopObj11 = rtopObj

# Unconditional simulation at the observation locations
# (These are moved to the predictionLocations)
```

```

rtopObj11$predictionLocations = rtopObj11$observations
rtopObj11$observations = NULL
# Setting varMatUpdate to TRUE, to make sure that covariance
# matrices are recomputed
rtopObj12 = rtopSim(rtopObj11, nsim = 10, beta = 0.01,
                   varMatUpdate = TRUE)

summary(data.frame(rtopObj11$simulations))
summary(data.frame(rtopObj12$simulations))

```

| | |
|---------------|---|
| rtopVariogram | <i>create variogram for data with spatial support</i> |
|---------------|---|

Description

rtopVariogram will create binned variogram or cloud variogram of data with an areal support.

Usage

```

## S3 method for class 'rtop'
rtopVariogram(object, params = list(), ...)
## S3 method for class 'SpatialPolygonsDataFrame'
rtopVariogram(object, ...)
## S3 method for class 'SpatialPointsDataFrame'
rtopVariogram(object, formulaString, params=list(), cloud,
              abins, dbins, ...)
## S3 method for class 'STSDf'
rtopVariogram(object, formulaString, params=list(), cloud,
              abins, dbins, data.table = FALSE, ...)

```

Arguments

| | |
|---------------|---|
| object | object of class rtop (see rtop-package) or a SpatialPolygonsDataFrame or SpatialPointsDataFrame with information about observations. If object is a SpatialPointsDataFrame , it must have a column with name area. |
| formulaString | formula that defines the dependent variable as a linear model of independent variables; suppose the dependent variable has name z, for ordinary and simple kriging use the formula $z \sim 1$; for universal kriging, suppose z is linearly dependent on x and y, use the formula $z \sim x + y$. The formulaString defaults to "value~1" if value is a part of the data set. If not, the first column of the data set is used. |
| params | a set of parameters, used to modify the default parameters for the rtop package, set in getRtopParams . |

| | |
|------------|--|
| cloud | logical; if TRUE, calculate the semivariogram cloud, can be used to overrule the cloud parameter in params. |
| abins | possibility to set areal bins (not yet implemented) |
| dbins | possibility to set distance bins (not yet implemented) |
| data.table | an option to use data.table internally for the variogram computation for STSDF-objects |
| ... | parameters to other functions called, e.g. gstat's variogram -function and to rtopVariogram.SpatialPointsDataFrame when the method is called with an object of a different class |

Value

The function creates a variogram, either of type `rtopVariogram` or `rtopVariogramCloud`. This variogram is based on the [variogram](#) function from `gstat`, but has additional information about the spatial size or length of the observations. An `rtop`-object with the variogram added is returned if the function is called with an `rtop`-object as argument.

For spatio-temporal objects ([STSDF](#)), the variogram is the spatially variogram, averaged for all time steps. There is a possibility to use `data.table` internally in this function, which can improve computation time for some cases.

Note

The variogram cloud is similar to the variogram cloud from [gstat](#), with the area/length added to the resulting `data.frame`. The binned variogram is also based on the area or length, in addition to the distance between observations. The bins are equally distanced in the \log_{10} -space of the distances and areas (lengths). The size of the bins is decided from the parameters `amu1` and `dmu1`, defining the number of bins per order of magnitude (1:10, 10:100, and so on).

The distances between areas are in this function based on the centre of gravity.

Author(s)

Jon Olav Skoien

References

Skoien J. O., R. Merz, and G. Bloschl. Top-kriging - geostatistics on stream networks. *Hydrology and Earth System Sciences*, 10:277-287, 2006.

Skoien, J. O., Bloschl, G., Laaha, G., Pebesma, E., Parajka, J., Viglione, A., 2014. Rtop: An R package for interpolation of data with a variable spatial support, with an example from river networks. *Computers & Geosciences*, 67.

Examples

```
## Not run:
library(sf)
rpath = system.file("extdata", package="rtop")
observations = st_read(rpath, "observations")
# Create a column with the specific runoff:
```

```

observations$obs = observations$QSUMMER_OB/observations$AREASQKM

vario = rtopVariogram(observations, cloud = TRUE)

## End(Not run)

```

sceua

*Optimisation with the Shuffle Complex Evolution method***Description**

Calibration function which searches a parameter set which is minimizing the value of an objective function

Usage

```

sceua(OFUN, pars, lower, upper, maxn = 10000, kstop = 5, pcento = 0.01,
      ngs = 5, npg = 2 * length(pars) + 1, nps = length(pars) + 1,
      nspl = 2 * length(pars) + 1, mings = ngs, iniflg = 1, iprint = 0, iround = 3,
      peps = 0.0001, plog = rep(FALSE,length(pars)), implicit = NULL, timeout = NULL, ...)

```

Arguments

| | |
|--------|--|
| OFUN | A function to be minimized, with first argument the vector of parameters over which minimization is to take place. It should return a scalar result as an indicator of the error for a certain parameter set |
| pars | a vector with the initial guess the parameters |
| lower | the lower boundary for the parameters |
| upper | the upper boundary for the parameters |
| maxn | the maximum number of function evaluations |
| kstop | number of shuffling loops in which the criterion value must change by the given percentage before optimization is terminated |
| pcento | percentage by which the criterion value must change in given number (kstop) of shuffling loops to continue optimization |
| ngs | number of complexes in the initial population |
| npg | number of points in each complex |
| nps | number of points in a sub-complex |
| nspl | number of evolution steps allowed for each complex before complex shuffling |
| mings | minimum number of complexes required, if the number of complexes is allowed to reduce as the optimization proceeds |
| iniflg | flag on whether to include the initial point in population. iniflg = 0, not included. iniflg = 1, included |

| | |
|-----------------------|--|
| <code>iprint</code> | flag for controlling print-out after each shuffling loop. <code>iprint < 0</code> : no output. <code>iprint = 1</code> : print information on the best point of the population. <code>iprint > 0</code> : print information on every point of the population |
| <code>iround</code> | number of significant digits in print-out |
| <code>peps</code> | convergence level for parameter set (lower number means smaller difference between parameters of the population required for stop) |
| <code>plog</code> | whether optimization should be done in log10-domain. Either a single TRUE value for all parameters, or a vector with TRUE/FALSE for the different parameters |
| <code>implicit</code> | function for implicit boundaries for the parameters (e.g. $\text{sum}(\text{pars}[4]+\text{pars}[5]) < 1$). See below for details |
| <code>timeout</code> | if different from NULL: maximum time in seconds for execution before the optimization returns with the parameters so far. |
| <code>...</code> | arguments for the objective function, must be named |

Details

scea is an R-implementation of the Shuffle Complex Evolution - University of Arizona (Duan et al., 1992), a global optimization method which "combines the strengths of the simplex procedure of Nelder and Mead (1965) with the concepts of controlled random search (Price, 1987), competitive evolution (Holland, 1975)" with the concept of complex shuffling, developed by Duan et al. (1992).

This implementation follows the Fortran implementation relatively close, but adds the possibility of searching in log-space for one or more of the parameters, and it uses the capability of R to pass functions as arguments, making it possible to pass implicit conditions to the parameter selection.

The objective function OFUN is a function which should give an error value for each parameter set. It should never return non-numeric values such as NA, NULL, or Inf. If some parameter combinations can give such values, the return value should rather be a large number.

The function works with fixed upper and lower boundaries for the parameters. If the possible range of a parameter might span several orders of magnitude, it might be better to search in log-space for the optimal parameter, to reduce the risk of being trapped in local optima. This can be set with the argument `plog`, which is either a single value (FALSE/TRUE) or a vector for all parameters. `plog = c(TRUE, FALSE, FALSE, TRUE, TRUE)` means that the search for parameters 1,4 and 5 should be in log10-space, whereas the search for parameters 2 and 3 are in normal space.

Implicit boundaries can be evoked by passing a function `implicit` to `scea`. This function should give 0 when parameters are acceptable and 1 if not. If, for example, the condition is that the following sum of parameters four and five should be limited:

$$\text{sum}(\text{pars}[4]+\text{pars}[5]) \leq 1$$

then the function will be `implicit = function(pars) (2*pars[4] + pars[5]) > 1`

Value

The function returns a list with the following elements

par - a vector of the best parameters combination

value - the value of the objective function for this parameter set

convergence - a list of two values

funConvergence - the function convergence relative to pcento

parConvergence - the parameter convergence relative to peps

counts - the number of function evaluations

iterations - the number of shuffling loops

timeout - logical; TRUE if the optimization was aborted because the timeout time was reached, FALSE otherwise

There are also two elements returned as attributes:

parset - the entire set of parameters from the last evolution step

xf - the values of the objective function from the last evolution step

The last two can be accessed as `attr("parset")` and `attr("xf")`, if the result is stored as `sceuares`.

Author(s)

Jon Olav Skoien

References

Duan, Q., Sorooshian, S., and Gupta, V.K., 1992. Effective and efficient global optimization for conceptual rainfall-runoff models. *Water Resour. Res.* 28 (4), 1015-1031.

Holland, H.H., 1975. *Adaptation in natural and artificial systems*, University of Michigan Press, Ann Arbor.

Nelder, J.A. and Mead, R., 1965. A simplex method for function minimization, *Comput. J.*, 7(4), 308-313.

Price, W.L., 1987. Global optimization algorithms for a CAD workstation, *J. Optim. Theory Appl.*, 55(1), 133-146.

Skoien, J. O., Bloschl, G., Laaha, G., Pebesma, E., Parajka, J., Viglione, A., 2014. Rtop: An R package for interpolation of data with a variable spatial support, with an example from river networks. *Computers & Geosciences*, 67.

Examples

```
set.seed(1)
# generate example data from a function with three parameters
# with some random noise
fun = function(x, pars) pars[2]*sin(x*pars[1])+pars[3]
x = rnorm(50, sd = 3)
y = fun(x, pars = c(5, 2, 3)) + rnorm(length(x), sd = 0.3)
plot(x,y)

# Objective function, summing up squared differences
OFUN = function(pars, x, yobs) {
  yvals = fun(x, pars)
  sum((yvals-yobs)^2)
```

```
}  
  
sceuares = sceua(OFUN, pars = c(0.1,0.1,0.1), lower = c(-10,0,-10),  
                upper = c(10,10,10), x = x, yobs = y)  
sceuares  
xx = seq(min(x), max(x), 0.1)  
lines(xx, fun(xx, pars = sceuares$par))
```

useRtopWithIntamap *Integrates the rtop package with the intamap package*

Description

This function makes it possible to use `rtop`-objects in the functions of the package. It is necessary to load the `intamap`-package before calling this function.

Usage

```
useRtopWithIntamap()
```

Value

The function will have as side effect that the `intamap` package is loaded, and that `rtop`-methods are registered for the `intamap`-functions `estimateParameters`, `spatialPredict` and `methodParameters`.

Author(s)

Jon Olav Skoien

References

Pebesma, E., Cornford, D., Dubois, G., Heuvelink, G.B.M., Hristopulos, D., Pilz, J., Stohlker, U., Morin, G., Skoien, J.O. INTAMAP: The design and implementation of an interoperable automated interpolation Web Service. *Computers and Geosciences* 37 (3), 2011.

Skoien J. O., R. Merz, and G. Blöschl. Top-kriging - geostatistics on stream networks. *Hydrology and Earth System Sciences*, 10:277-287, 2006.

Skoien, J. O., Blöschl, G., Laaha, G., Pebesma, E., Parajka, J., Viglione, A., 2014. `Rtop`: An R package for interpolation of data with a variable spatial support, with an example from river networks. *Computers & Geosciences*, 67.

Examples

```
if (require(intamap)) useRtopWithIntamap()
```

| | |
|----------------|---|
| variogramModel | <i>create or update variogram model</i> |
|----------------|---|

Description

This gives an easier interface to the parameters of the variogram model

Usage

```
rtopVariogramModel(model = "Ex1", sill = NULL, range = NULL,
  exp = NULL, nugget = NULL, exp0 = NULL,
  observations = NULL, formulaString = obs~1)
## S3 method for class 'rtop'
updateRtopVariogram(object, ...)
## S3 method for class 'rtopVariogramModel'
updateRtopVariogram(object, action = "mult", ...,
  checkVario = FALSE,
  sampleVariogram = NULL, observations = NULL)
```

Arguments

| | |
|-----------------|---|
| model | variogram model, currently "Ex1" is the only implemented, see Skoien et al (2006) |
| sill | sill of variogram |
| range | range of variogram |
| exp | the exponent of the fractal part of the variogram, see Skoien et al (2006) |
| exp0 | gives the angle of the first part of the variogram in a log-log plot (weibull type), should be between 0 and 2. See Skoien et al (2006) |
| nugget | nugget of point variogram |
| formulaString | formula that defines the dependent variable as a linear model of independent variables, see e.g. createRtopObject for more details. |
| object | either: object of class rtop (see rtop-package), or an rtopVariogramModel. |
| action | character variable defining whether the new parameters should be add(-ed), mult(-iplied) or replace the former parameters. Leaving the parameters equal to NULL will cause no change. |
| checkVario | logical, will issue a call to checkVario if TRUE |
| sampleVariogram | a sample variogram of the data |
| observations | a set of observations |
| ... | parameters to lower level functions |

Value

The function helps creating and updating the parameters of the variogram, by using common names and simple update methods. This is mainly for manual fitting of the variogram. The automatic call to `checkVario` makes it easier to visualize the effect of the changes to the variogram

Author(s)

Jon Olav Skoien

See Also

[rtop-package](#)

Examples

```
## Not run:
library(sf)
rpath = system.file("extdata",package="rtop")
observations = st_read(rpath,"observations")
# Create a column with the specific runoff:
observations$obs = observations$QSUMMER_OB/observations$AREASQKM
predictionLocations = st_read(rpath,"predictionLocations")
rtopObj = createRtopObject(observations,predictionLocations)
# Fit a variogram (function also creates it)
rtopObj = rtopFitVariogram(rtopObj)
rtopObj = updateRtopVariogram(rtopObj, exp = 1.5, action = "mult",
                             checkVario = TRUE)

## End(Not run)
```

| | |
|--------|---|
| varMat | <i>create a semivariogram matrix between a set of locations, or semivariogram matrices between and within two sets of locations</i> |
|--------|---|

Description

`varMat` will create a semivariogram matrix between all the supports in a set of locations (observations or prediction locations) or semivariogram matrices between all the supports in one or two sets of locations, and also between them.

Usage

```
## S3 method for class 'rtop'
varMat(object, varMatUpdate = FALSE, fullPred = FALSE, params = list(), ...)
## S3 method for class 'SpatialPolygonsDataFrame'
varMat(object, object2 = NULL, ...)
## S3 method for class 'SpatialPolygons'
varMat(object, object2 = NULL, variogramModel,
```

```

    overlapObs, overlapPredObs, ...)
## S3 method for class 'list'
varMat(object, object2 = NULL, coor1, coor2, maxdist = Inf,
        variogramModel, diag = FALSE, sub1, sub2,
        debug.level = ifelse(interactive(), 1, 0), ...)

```

Arguments

| | |
|----------------|---|
| object | either: 1) an object of class <code>rtop</code> (see rtop-package) or 2) a SpatialPolygonsDataFrame , or SpatialPolygons , or 3) a matrix with geostatistical distances (see gDist or 4) a list with discretized supports |
| varMatUpdate | logical; if TRUE, also existing variance matrices will be recomputed, if FALSE, only missing variance matrices will be computed |
| fullPred | logical; whether to create the full covariance matrix also for the predictions, mainly used for simulations |
| params | a set of parameters, used to modify the default parameters for the <code>rtop</code> package, set in getRtopParams . |
| object2 | if object is not an object of class <code>rtop</code> ; an object of the same class as object with a possible second set of locations with support |
| variogramModel | variogramModel to be used in calculation of the semivariogram matrix (matrices) |
| ... | typical parameters to modify from the default parameters of the <code>rtop</code> -package (or modifications of the previously set parameters for the <code>rtop</code> -object), see also getRtopParams . These can also be passed in a list named <code>params</code> , as for the <code>rtop</code> -method. Typical parameters to modify for this function: rresol = 100 minimum number of discretization points, in call to rtopDisc if necessary rstype = "rtop" sampling type from areas, in call to rtopDisc if necessary gDistPred = FALSE use geostatistical distance for semivariogram matrices gDist parameter to set jointly <code>gDistEst = gDistPred = gDist</code> |
| overlapObs | matrix with observations that overlap each other |
| overlapPredObs | matrix with observations and predictionLocations that overlap each other |
| coor1 | coordinates of centroids of object |
| coor2 | coordinates of centre-of-gravity of object2 |
| maxdist | maximum distance between areas for inclusion in semivariogram matrix |
| diag | logical; if TRUE only the semivariogram values along the diagonal will be calculated, typical for semivariogram matrix of prediction locations |
| sub1 | semivariogram array for subtraction of inner variances of areas |
| sub2 | semivariogram array for subtraction of inner variances of areas |
| debug.level | <code>debug.level >= 1</code> will give output for every element |

Value

The lower level versions of the function calculates a semivariogram matrix between locations in `object` or between the locations in `object` and the locations in `object2`. The method for `object` of type `rtop` calculates semivariogram matrices between observation locations, between prediction locations, and between observation locations and prediction locations, and adds these to `object`.

Note

The argument `varMatUpdate` is typically used to avoid repeated computations of the same variance matrices. Default is `FALSE`, which will avoid recomputation of the variance matrix for the observations if the procedure is cross-validation before interpolation. Should be set to `TRUE` if the variogram Model has been changed, or if observation and/or prediction locations have been changed.

If an `rtop`-object contains observations and/or predictionLocations of type `STSDf`, the covariance matrix is computed based on the spatial properties of the object.

Author(s)

Jon Olav Skoien

References

Skoien J. O., R. Merz, and G. Bloschl. Top-kriging - geostatistics on stream networks. *Hydrology and Earth System Sciences*, 10:277-287, 2006.

Skoien, J. O., Bloschl, G., Laaha, G., Pebesma, E., Parajka, J., Viglione, A., 2014. Rtop: An R package for interpolation of data with a variable spatial support, with an example from river networks. *Computers & Geosciences*, 67.

See Also

[gDist](#)

Examples

```
## Not run:
library(sf)
rpath = system.file("extdata",package="rtop")
observations = st_read(rpath,"observations")
vmod = list(model = "Ex1", params = c(0.00001,0.007,350000,0.9,1000))
vm = varMat(observations, variogramModel = vmod)

## End(Not run)
```

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