Package 'specsim'

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Type Package

Title Continuous spectral simulation of random fields

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Author Daisy Arroyo [aut, cre], Xavier Emery [aut, cre]

Maintainer Daisy Arroyo <darroyof@udec.cl>

Imports grDevices, graphics, stats

Description An implementation of a continuous spectral algorithm (specsim) for simulating stationary and intrinsic vector Gaussian random fields in Euclidian spaces. The following stationary and intrinsic covariance models can be reproduced: spherical, cubic, penta, exponential, Gaussian, Askey, Wendland, Matérn, J-Bessel, Laguerre, Hypergeometric, Power, Spline, iterated exponential, Gamma, Cauchy, stable and mixed Power. The package also provides a statistical testing to check the normality of the distribution of the simulated random field or of its generalized increments, as well as a function for mapping realizations of a simulated vector random field, a function for calculating the experimental variograms of realizations constructed on a regular grid and a function for checking sufficient validity conditions for the multivariate Matérn covariance model.

Depends R(>= 3.5.0)

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License GPL (>= 3)

Collate cova.R Hygeo1F2.R maps.R specsim.R spectraldensity.R test.R validationMatern.R variograms.R

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R topics documented:

`specsim-package` *Continuous spectral simulation of random fields*

Description

This package provides a set of functions that simulate vector Gaussian random fields in R^d. This package is not available from CRAN, but can easily be installed using the following R code: install.packages("specsim_1.0.tar.gz", repos=NULL, type = "source")

Details

Package:	specsim
Type:	Package
Version:	1.0
Date:	2020-09-01
License:	GPL-2

Overview

The package provides eight functions:

1) `cova` and `test` are used for testing the distribution of the simulated random field for particular models and over a small set of points.

2) `spectraldensity` and `Hygeo1F2` are used for calculating the spectral density for a given frequency vector u in R^d and specific covariance models.

3) `validationMatern` checks sufficient validity conditions for the multivariate Matérn covariance model.

4) `maps` creates a color scale representation of realizations of a simulated vector random field.

5) `variograms` calculates the experimental variograms of realizations constructed on a regular grid.

6) Finally, `specsim` runs for a given number of realizations and basic random fields, specific parameters and models and coordinates of the target locations in R^d.

Author(s)

Daisy Arroyo and Xavier Emery

Maintainer: Daisy Arroyo <darroyof@udec.cl>

References

Apanasovich T. V., Genton M. G., Sun Y (2012), A valid Matern class of cross-covariance functions for multivariate random fields with any number of components. *Journal of the American Statistical Association* 107 (497), 180-193.

Arroyo, D. Emery, X. (2017), Spectral simulation of vector random fields with stationary Gaussian increments in d-dimensional Euclidean spaces, *Stochastic Environmental Research and Risk Assessment* 31 (7), 1583-1592.

Arroyo, D. Emery, X. (2018), Simulation of intrinsic random fields of order k with a continuous spectral algorithm, *Stochastic Environmental Researchand Risk Assessment* 32 (11), 3245-3255.

Emery, X., Arroyo, D. Porcu, E. (2016), An improved spectral turning-bands algorithm for simulating stationary vector Gaussian random fields, *Stochastic Environmental Research and Risk Assessment* 30 (7), 1863-1873.

`cova` *Covariance values for two models: Matérn (ordinary covariance) and Power (generalized covariance)*

Description

This function allows computing covariance values for two models: Matérn and Power

Usage

```
cova(model, h, b)
```

Arguments

`model`	One of the covariance models: `"Matern"` or `"Power"`
`h`	lag separation distance
`b`	parameter of the model: for Matérn, it is the shape parameter; for power, it is the exponent

Value

The covariance value for the model type with the specified lag separation distance and the shape parameter or exponent

Author(s)

Daisy Arroyo, <darroyof@udec.cl> and Xavier Emery, <xemery@ing.uchile.cl>

Examples

```
# Compute covariance for a distance h and Matérn covariance
h <- 10
b <- 0.5
model <- "Matern"
cova(model, h, b)
```

`Hygeo1F2` *Generalized Hypergeometric function: particular cases for Askey and Wendland models*

Description

Generalized Hypergeometric function: particular cases for Askey and Wendland models.

Askey:	with $d = 2$ and $\nu = 2$
Wendland:	with $d = 2$, $\nu = 3$ and $k = 1$

Usage

```
Hygeo1F2(z, model)
```

Arguments

z	point where the hypergeometric function will be evaluated
model	covariance model

Value

A value of generalized hypergeometric function evaluated for z in R

Author(s)

Daisy Arroyo, <darroyof@udec.cl> and Xavier Emery, <xemery@ing.uchile.cl>

Examples

```
# Evaluation of Hypergeometric function at z=1, for Askey covariance
z <- 1
model <- "Askey"
Hygeo1F2(z, model)
```

---

maps *Color scale representation of a realization*

Description

This function allows displaying a color scale representation of a simulated random field. Valid for simulation over a regular grid in the Euclidean space R^d with $d = 2$ or $d = 3$

Usage

```
maps(simu, viewsimu, coord, nnodes, gridmesh, slice, mapname, width.png, height.png)
```

Arguments

simu	File with one realization of the simulated random field
viewsimu	View at the XY, XZ, or YZ plane: "XY", "XZ" or "YZ"
coord	Coordinates of the locations where the random field has been simulated
nnodes	A vector with the number of grid nodes along X and Y directions ($d = 2$), or X, Y and Z directions ($d = 3$)
gridmesh	A vector with the grid mesh along X and Y directions (if $d = 2$: c(dx,dy)), or X, Y and Z directions (if $d = 3$: c(dx,dy,dz))
slice	Index of the grid slice to display

mapname	Name of PNG output file
width.png	Display width depending on whether the grid is square or rectangular. By default, the value is for a square grid
height.png	Display height depending on whether the grid is square or rectangular. By default, the value is for a square grid

Value

A PNG file(s) with a map of one realization of the random field

Author(s)

Daisy Arroyo, <darroyof@udec.cl> and Xavier Emery, <xemery@ing.uchile.cl>

Examples

```
# A map of one realization of a simulated bivariate Matérn random field on a regular grid
# with 500x500 nodes
set.seed(9784498)
nx <- 500
ny <- 500
coord <- cbind(c(rep(1, times = ny))%x%c(1:nx), (c(1:ny)%x%c(rep(1, times = nx))))
model <- "Matern"
# Calculating the scale parameters, shape parameters and colocated correlation matrices
a <- matrix(c(20, (0.5*(20^-2+100^-2))^-0.5, (0.5*(20^-2+100^-2))^-0.5, 100), 2, 2)
nu <- matrix(c(1.5, 1, 1, 0.5), 2, 2)
C <- matrix(c(1, 0.5, 0.5, 1), 2, 2)
# dimension
d <- 2
# Checking the validity of the parameters
validationMatern(a, nu, C, d)
# Building a list of parameters of the simulation
parameters <- list("C" = C, "a" = a, "nu1" = nu, "nu2" = c())
# Generating one realization
simu <- specsim(coord, a0 = 10, nu0 = 0.5, model, parameters, N = 1, L = 1000, "Matern")
# Display of realization of simulated bivariate random field
maps(simu, viewsimu="XY", coord, c(nx,ny), c(1,1), slice=1, "Matern")
```

---

specsim *Continuous spectral simulation of random fields*

Description

This function allows simulating scalar and vector random fields defined in an Euclidian space by a continuous spectral algorithm

Usage

```
specsim(coord, a0, nu0, model, parameters, N, L, filename)
```

Arguments

coord	Coordinates of the locations targeted for simulation
a0	Scale parameter of the Matérn spectral density g used to simulate the frequency vectors
nu0	Shape parameter of the Matérn spectral density g
model	selected covariance model, chosen from "spherical", "cubic", "penta", "exponential", "Gaussian", "Askey", "Wendland", "Matern", "JBessel", "Laguerre", "Hypergeometric", "Power", "Spline", "iterated_exponential", "Gamma", "Cauchy", "stable1", "stable2", "mixed_Power".
parameters	List of parameter values
N	Number of realizations to generate
L	Number of basic random fields to use
filename	Name of output txt file

Value

An $n * (N * P)$ matrix containing the N simulated values for each coordinate (total = n) and for each random field component (P)

Author(s)

Daisy Arroyo, <darroyof@udec.cl> and Xavier Emery, <xemery@ing.uchile.cl>

Examples

```
# Simulation of a bivariate Matérn random field on a regular grid with 500x500 nodes
set.seed(9784498)
nx <- 500
ny <- 500
coord <- cbind(c(rep(1, times = ny))%x%c(1:nx), (c(1:ny)%x%c(rep(1, times = nx))))
model <- "Matern"
# calculating the scale parameters, shape parameters and colocated correlation matrices
a <- matrix(c(20, (0.5*(20^-2+100^-2))^-0.5, (0.5*(20^-2+100^-2))^-0.5, 100), 2, 2)
nu <- matrix(c(1.5, 1, 1, 0.5), 2, 2)
C <- matrix(c(1, 0.5, 0.5, 1), 2, 2)
# dimension
d <- 2
# Checking the validity of the bivariate Matérn model parameters
validationMatern(a, nu, C, d)
# Building a list of parameters for simulation
parameters <- list("C" = C, "a" = a, "nu1" = nu, "nu2" = c())
# Simulation and generation of a txt file with name "Matern"
simu <- specsim(coord, a0 = 10, nu0 = 0.5, model, parameters, N = 1, L = 1000, "Matern")
# Display of realization of simulated bivariate random field
maps(simu, viewsimu="XY", coord, c(nx,ny), c(1,1), slice=1, "Matern")
```

spectraldensity *Spectral density associated with a given covariance model*

Description

This function calculates the spectral density associated with a covariance model

Usage

```
spectraldensity(u, model, parameters)
```

Arguments

u	frequency vector
model	selected covariance model, chosen from one of "spherical", "cubic", "penta", "exponential", "Gaussian", "Askey", "Wendland", "Matern", "JBessel", "Laguerre", "Hypergeometric", "Power", "Spline", "iterated_exponential", "Gamma", "Cauchy", "stable1", "stable2", "mixed_Power"
parameters	list of parameter values for example: new.params <- list("C" = [number or matrix], "a" = [number or matrix], "nu1" = [number or matrix], "nu2" = [number or matrix])

Value

A matrix-valued spectral density value associated with a covariance model, for the chosen frequency vector u in R^d

Author(s)

Daisy Arroyo, <darroyof@udec.cl> and Xavier Emery, <xemery@ing.uchile.cl>

Examples

```
# Bivariate Matern spectral density matrix for a vector u in R^2
u <- matrix(rnorm(1), 1, 2)
model <- "Matern"
# calculate the scale parameters, shape parameters and colocated correlation matrices
a <- matrix(c(20, (0.5*(20^-2+100^-2))^-0.5, (0.5*(20^-2+100^-2))^-0.5, 100), 2, 2)
nu <- matrix(c(1.5, 1, 1, 0.5), 2, 2)
C <- matrix(c(1, 0.5, 0.5, 1), 2, 2)
parameters <- list("C" = C, "a" = a, "nu1" = nu, "nu2" = c())
spectraldensity(u, model, parameters)
```

`test` *Testing the distribution of the simulated random fields with Shapiro-Wilk normality test*

Description

This function allows testing the distribution of the generalized increments of simulated random fields with Shapiro-Wilk normality test, for selected bivariate models

Usage

```
test(simu, coord1, coord2, lambda, model, parameters, N, filename)
```

Arguments

`simu`	File with realizations
`coord1`	First set of locations
`coord2`	Second set of locations
`lambda`	Set of weights
`model`	Covariance, variogram or generalized covariance model of the target random field
`parameters`	List of parameter values
`N`	Number of realizations
`filename`	Name of PNG output file

Value

A probability-probability (P-P) plot: proportions of times when the test is accepted (value 0) and when the test is rejected (value 1) are counted and compared to the significance levels

Author(s)

Daisy Arroyo, <darroyof@udec.cl> and Xavier Emery, <xemery@ing.uchile.cl>

Examples

```
# A particular case for a simulated bivariate Matérn random field with L=100 and L=1000
L <- c(100, 1000)
N <- 10000
coord <- matrix(c(1, 1, 11, 1, 1, 11, 11, 11, 6, 1, 1, 6, 11, 6, 6, 11, 6, 6), nrow=9, ncol=2,
byrow=TRUE)
model <- "Matern"
# calculate the scale parameters, shape parameters and colocated correlation matrices
a <- matrix(c(5, (0.5*(5^-2+10^-2))^-0.5, (0.5*(5^-2+10^-2))^-0.5, 10), 2, 2)
nu <- matrix(c(1.5, 1, 1, 0.5), 2, 2)
C <- matrix(c(1, 0.5, 0.5, 1), 2, 2)
# dimension
d <- 2
# Checking the validity of the parameters of bivariate Matérn model
validationMatern(a, nu, C, d)
# Building a list of parameters to the simulation
```

```
parameters.SRF2 <- list("C" = C, "a" = a, "nu1" = nu, "nu2" = c())
# Simulation with L=100 and L=1000, respectively:
simu.SRF2.L100 <- specsim(coord, a0 = 15, nu0 = 0.5, model, parameters.SRF2, N, L[1])
simu.SRF2.L1000 <- specsim(coord, a0 = 15, nu0 = 0.5, model, parameters.SRF2, N, L[2])
# Put the two simulations together in an array
simu.SRF2 <- array(c(simu.SRF2.L100, simu.SRF2.L1000), dim = c(9, 2*N, 2))
# Preparing to the test
coord1 <- coord[c(1,2,3,4,9), ]
coord2 <- coord[5:9, ]
lambda <- c(0.25, 0.25, 0.25, 0.25, -1)
# Test and generate a png file named "test_SRF2"
test(simu.SRF2, coord1, coord2, lambda, model, parameters.SRF2, N, "test_SRF2")
```

`validationMatern` *Check the validity of a multivariate Matérn covariance model*

Description

Check the validity of a multivariate Matérn covariance model based on the sufficient conditions given by Apanasovich et al. (2012)

Usage

```
validationMatern(a, nu, C, d)
```

Arguments

`a`	Matrix of scale factors
`nu`	Matrix of shape factors
`C`	Matrix of colocated correlation
`d`	Space dimension

Value

V: 1 if sufficient conditions are fulfilled, 0 otherwise

Author(s)

Daisy Arroyo, <darroyof@udec.cl> and Xavier Emery, <xemery@ing.uchile.cl>

References

Apanasovich T. V., Genton M. G., Sun Y (2012), A valid Matérn class of cross-covariance functions for multivariate random fields with any number of components. *Journal of the American Statistical Association* 107 (497), 180-193.

Examples

```
# Checking the validity of a bivariate Matérn model with given parameter matrices
a <- matrix(c(20, (0.5*(20^-2+100^-2))^-0.5, (0.5*(20^-2+100^-2))^-0.5, 100), 2, 2)
nu <- matrix(c(1.5, 1, 1, 0.5), 2, 2)
C <- matrix(c(1, 0.5, 0.5, 1), 2, 2)
# dimension
d <- 2
# Checking the validity of parameters of bivariate Matérn model
validationMatern(a, nu, C, d)
```

`variograms` *Comparison of the experimental direct and cross-variograms of N realizations (calculated along one grid axis) with the theoretical direct and cross-variograms*

Description

This function allows plotting experimental direct and cross-variograms for N realizations (green lines), average of experimental direct and cross-variograms (red lines) and theoretical direct and cross-variograms (black lines). Valid for simulations over a regular grid in the Euclidean space R^d (with $d = 2$ or $d = 3$)

Usage

```
variograms(simu, nnodes, nvar, N, dimsimu, hmax, model, parameters, variogname)
```

Arguments

`simu`	File containing a matrix with realizations
`nnodes`	A vector with the number of grid nodes along X and Y directions (if $d = 2$), or X, Y and Z directions (if $d = 3$)
`nvar`	Number of random field components
`N`	Number of realizations
`dimsimu`	Along which axis (between 1 and d) the variograms will be calculated
`hmax`	The maximum distance (grid meshes) for the calculation of variograms in the direction of the chosen axis
`model`	Theoretical variogram model
`parameters`	List of parameter values
`variogname`	Name of PNG output file

Value

A PNG file(s) with direct and cross-variograms (experimental, average and theoretical)

Author(s)

Daisy Arroyo, <darroyof@udec.cl> and Xavier Emery, <xemery@ing.uchile.cl>

Examples

```
# Direct and cross-variograms of a bivariate Matérn random field on a regular grid
# with 500x500 nodes
# Thirty realizations (N = 30) are generated
set.seed(9784498)
nx <- 500
ny <- 500
coord <- cbind(c(rep(1, times = ny))%x%c(1:nx), (c(1:ny)%x%c(rep(1, times = nx))))
model <- "Matern"
# calculate the scale parameters, shape parameters and colocated correlation matrices
a <- matrix(c(20, (0.5*(20^-2+100^-2))^-0.5, (0.5*(20^-2+100^-2))^-0.5, 100), 2, 2)
nu <- matrix(c(1.5, 1, 1, 0.5), 2, 2)
C <- matrix(c(1, 0.5, 0.5, 1), 2, 2)
parameters <- list("C" = C, "a" = a, "nu1" = nu, "nu2" = c())
simu <- specsim(coord, a0 = 10, nu0 = 0.5, model, parameters, N = 30, L = 1000, "Matern")
# plot of direct and cross-variograms calculated along the abscissa axis for distances
# ranging from 0 to 120 units
variograms(simu, c(nx,ny), nvar=2, N=30, dimsimu=1, hmax=120, model, parameters,
"Matern")
```

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