Package 'INLAtools'

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Type Package

Title Functionalities for the 'INLA' Package

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Description Contain code to work with a C struct, in short cgeneric, to define a Gaussian Markov random (GMRF) model. The cgeneric contain code to specify GMRF elements such as the graph and the precision matrix, and also the initial and prior for its parameters, useful for model inference. It can be accessed from a C program and is the recommended way to implement new GMRF models in the 'INLA' package (<https://www.r-inla.org>). The 'INLAtools' implement functions to evaluate each one of the model specifications from R. The implemented functionalities leverage the use of 'cgeneric' models and provide a way to debug the code as well to work with the prior for the model parameters and to sample from it. The `generic0` can be used to implement intrinsic models with the scaling as proposed in Sørbye & Rue (2014) <doi:10.1016/j.spasta.2013.06.004>, and the required constraints. A very useful functionality is the Kronecker product method that creates a new model from multiple cgeneric models. It also works with the rgeneric, the R version of the cgeneric intended to easy try implementation of new GMRF models. The Kronecker between two cgeneric models where each one needs a constraint, such as spatio-temporal intrinsic interaction models, the needed constraints are automatically set.

License GPL (>= 2)

URL https://github.com/eliaskrainski/INLAtools

BugReports https://github.com/eliaskrainski/INLAtools/issues

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Imports methods, utils

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Contents

`cgeneric-class` *Organize data for the latent GMRF C interface for* `INLA`.

Description

A GMRF is defined from model parameters θ that would parametrize a (sparse) precision matrix.

The elements of a GMR are:

- `graph` to define the non-zero precision matrix pattern. only the upper triangle including the diagonal is needed.
- `Q` vector where the
  - first element (N) is the size of the matrix,
  - second element (M) is the number of non-zero elements in the upper part (including) diagonal
  - the remaining (M) elements are the actual precision (upper triangle plus diagonal) elements whose order shall follow the graph definition.
- `mu` the mean vector,
- `initial` vector with

  - first element as the number of the parameters in the model
  - remaining elements should be the initials for the model parameters.
- `log.norm.const` log of the normalizing constant.
- `log.prior` log of the prior for the model parameters.

Usage

```
cgeneric(model, ...)

## S3 method for class 'character'
cgeneric(model, ...)

## S3 method for class '`function`'
cgeneric(model, ...)

## S3 method for class 'cgeneric'
cgeneric(model, ...)

## S3 method for class 'inla.cgeneric'
cgeneric(model, ...)

cgenericBuilder(...)

mapper1(model)

cgeneric_shlib_path(package, useINLAprecomp, debug)

## S3 method for class 'cgeneric'
print(x, ...)

## S3 method for class 'cgeneric'
summary(object, ...)

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

Arguments

`model`	object class for what a `cgeneric` method exists. if it is a character, a specific function will be called, for example cgeneric("iid", ...") calls cgeneric_iid(...).
`...`	additional arguments passed on to methods It should include `n` and `debug`. For `cgenericBuild` and `model` as a character string with the name of the C function and `shlib` as the path to the shared object containing such function. If `shlib` is not provided it can be built using `cgeneric_shlib_path` for the `package` (character with the R package containing it), in which `useINLAprecomp` (logical) indicates if it is to use the one contained within `INLA` or in the package. When using the inlabru package, one can also provide a `mapper` which will be evaluated by the bru_get_mapper inlabru's function.

package	character giving the name of the package that contains the cgeneric model.
useINLAprecomp	logical, indicating if it is to use the shared object previously copied and compiled by INLA.
debug	integer, used as verbose in debug.
x	a cgeneric object
object	a cgeneric object
y	not used

Value

a method to build a cgeneric should return a named list of cgeneric class that contains a named list f that contains (at least):

- model a character always equal to cgeneric,
- n an integer greater than 0, and
- cgeneric as a named list that contains the data needed to define the model. Each element on ...$f$cgeneric is also a named list containing ints, doubles, characters, matrices and smatrices.
- (possible) extraconstr as a named list with: A as a n times k matrix and e as a length k vector.

The cgeneric_shlib_path function returns a character with the path to the shared lib.

Functions

- cgeneric(character): Call a function named as cgeneric_[model] to build a cgeneric.
- cgeneric(`function`): The cgeneric method for function.
- cgeneric(cgeneric): Check, append cgeneric class, returns model unchanged.
- cgeneric(inla.cgeneric): Check and converts a regular inla.cgeneric object to cgeneric.
- cgenericBuilder(): Build a cgeneric from a list of arguments.
- mapper1(): A default mapper for a cgeneric/rgeneric model
- cgeneric_shlib_path(): Make the lib path for the shared lib of a package.
- print(cgeneric): Print the cgeneric object
- summary(cgeneric): A summary for a cgeneric object
- plot(cgeneric): A plot for a cgeneric object

Note

The graph and Q non-zero pattern should match, its elements should be ordered by row, and only its upper part stored.

`cgeneric_generic0` *Build a* `cgeneric` *object for a* `generic0` *model.*

Description

Build data needed to implement a model whose precision has a conditional precision parameter. This uses the C interface in the 'INLA' package, that can be used as a linear predictor model component with an 'f' term.

Usage

```
cgeneric_generic0(R, param, constr = TRUE, scale = TRUE, ...)

cgeneric_iid(n, param, constr = FALSE, ...)
```

Arguments

`R`	the structure matrix for the model definition.
`param`	length two vector with the parameters `a` and `p` for the PC-prior distribution defined from $$P(\sigma > a) = p$$ where σ can be interpreted as marginal standard deviation of the process if scale = TRUE. See details.
`constr`	logical indicating if it is to add a sum-to-zero constraint. Default is TRUE.
`scale`	logical indicating if it is to scale the model. See detais.
`...`	arguments (debug,useINLAprecomp,shlib) passed on to `cgeneric`.
`n`	integer required to specify the model size

Details

The precision matrix is defined as

$$Q = \tau R$$

where the structure matrix R is supplied by the user and τ is the precision parameter. Following Sørbie and Rue (2014), if scale = TRUE the model is scaled so that

$$Q = \tau s R$$

where s is the geometric mean of the diagonal elements of the generalized inverse of R.

$$s = \exp \sum_i \log((R^-)_{ii})/n$$

If the model is scaled, the geometric mean of the marginal variances, the diagonal of Q^{-1}, is one. Therefore, when the model is scaled, τ is the marginal precision, otherwise τ is the conditional precision.

Value

a cgeneric object, see cgeneric-class().

Functions

- cgeneric_iid(): The cgeneric_iid uses the cgeneric_generic0 with the structure matrix as the identity.

References

Sigrunn Holbek Sørbye and Håvard Rue (2014). Scaling intrinsic Gaussian Markov random field priors in spatial modelling. Spatial Statistics, vol. 8, p. 39-51.

---

cgeneric_get — cgeneric_get *is an internal function used to query* graph, Q, initial, mu *or* log_prior *from a* cgeneric *model.*

Description

The generic_get retrieve a model property specified by cmd on an cgeneric object. The functions listed below are for each cmd case.

Usage

```
cgeneric_get(
  model,
  cmd = c("graph", "Q", "initial", "mu", "log_prior"),
  theta,
  optimize = TRUE
)

cgeneric_initial(model)

cgeneric_mu(model, theta)

cgeneric_graph(model, optimize)

cgeneric_Q(model, theta, optimize)

cgeneric_prior(model, theta)
```

Arguments

model	a cgeneric object.
cmd	an string to specify which model element to get
theta	numeric vector with the model parameters. If missing, the initial will be used.
optimize	logical indicating if it is to be returned only the elements and not as a sparse matrix.

Value

depends on cmd

numeric scalar (if numeric vector is provided for theta) or vector (if numeric matrix is provided for theta).

Functions

- cgeneric_initial(): Retrive the initial parameter(s) of an cgeneric model.
- cgeneric_mu(): Evaluate the mean for an cgeneric model.
- cgeneric_graph(): Retrieve the graph of an cgeneric object
- cgeneric_Q(): Retrieve the precision of an cgeneric object
- cgeneric_prior(): Evaluate the prior for an cgeneric model

See Also

check the examples in cgeneric_generic0()

Examples

```
library(INLAtools)
old.par <- par(no.readonly = TRUE)

## Setting the prior parameters
prior.par <- c(1, 0.5) # P(sigma > 1) = 0.5
cmodel <- cgeneric(
  model = "iid", n = 10,
  param = prior.par)

## prior summaries: sigma and log-precision
(lamb <- -log(prior.par[2])/prior.par[1])
(smedian <- qexp(0.5, lamb))
(smean <- 1/lamb)

## mode: at the minimum of - log-prior
(lpmode <- optimize(function(x)
  -cgeneric_prior(cmodel, theta = x),
  c(-10, 30))$minimum)
## mean: integral of x*f(x)dx
(lpmean <- integrate(function(x)
  exp(cgeneric_prior(cmodel, theta = matrix(x, 1)))*x,
  -10, 30)$value)

## prior visualization: log(precision) and sigma
par(mfrow = c(1, 2))
plot(function(x)
 exp(cgeneric_prior(cmodel, theta = matrix(x, nrow=1))),
  -3, 3, n = 601, xlab = "log-precision",
  ylab = "density")
abline(v = lpmode, lwd = 3, col = 2)
rug(-2*log(smedian), lwd = 3, col = 3)
```

```
rug(lpmean, lwd = 3, col = 4)
plot(function(x)
 exp(cgeneric_prior(cmodel,
  theta = matrix(
    -2*log(x),
    nrow = 1))+log(2)-log(x)),
  1/100, 10, n = 1000,
  xlab = expression(sigma),
  ylab = "density")
plot(function(x) dexp(x, lamb),
   1/100, 10, n = 1000,
   add = TRUE, lty = 2, col = 2)
rug(smedian, lwd = 3, col = 3)
rug(smean, lwd = 3, col = 4)

par(old.par)
```

`extraconstr` *Kronecker (product) between* `extraconstr`*, implemented for* `kronecker()` *methods.*

Description

Kronecker (product) between `extraconstr`, implemented for `kronecker()` methods.

Usage

```
kronecker_extraconstr(c1, c2, n1, n2)
```

Arguments

`c1`, `c2`	named list with two elements: `A` and `e`, where `nrow(A)` should be equal to `length(e)`. These are constraint definitions.
`n1`, `n2`	integer with each model's length.

Value

The constraint definition for the whole latent model built from the Kronecker product. A length two named list. 'A' a matrix and 'e' a vector where nrow(A)=length(e) and ncol(A)=(n1*n2).

findGetFunction *Search a function and retrieve it.*

Description

Search a function and retrieve it.

Usage

```
findGetFunction(fName, package, debug = FALSE)
```

Arguments

fName	character with the name of the function
package	character with the package name
debug	logical indicating if it is to print intermediate progress finding

Details

if 'missing(package)' it will search on the loaded packages, first in the exported functions, and then among the non-exported ones. NOTE: 'package' can include any installed package, see `installed.packages()`

Value

function. The (first) package name where it was found is returned as an attribute named "package"

inlaQ *Define the method to extract the precision from an inla output object.*

Description

Define the method to extract the precision from an inla output object.

Usage

```
inlaQ(model, ...)
```

Arguments

model	an inla output
...	used to pass the 'prior' argument, as logical (default is TRUE) to indicate if it is to retrieve the prior or the posterior precision.

Details

extract the joint prior precision for the latent field at the mode of the hyperparameters

is.zero *Define the is.zero method*

Description

Define the is.zero method

Usage

```
is.zero(x, tol)

## Default S3 method:
is.zero(x, tol)

## S3 method for class 'matrix'
is.zero(x, tol)

## S3 method for class 'Matrix'
is.zero(x, tol)
```

Arguments

x	an R object
tol	numeric to be used as (absolute) tolerance. if missing (default) it will consider x==0.

Value

logical

Methods (by class)

- is.zero(default): The is.zero.default definition
- is.zero(matrix): The is.zero.matrix definition
- is.zero(Matrix): The is.zero.Matrix definition

kronecker *Kronecker between* cgeneric|rgeneric *to implement interaction between GMRF models.*

Description

Kronecker between cgeneric|rgeneric to implement interaction between GMRF models.

Usage

```
## S4 method for signature 'cgeneric,cgeneric'
kronecker(X, Y, FUN = "*", make.dimnames = FALSE, ...)

## S4 method for signature 'cgeneric,rgeneric'
kronecker(X, Y, FUN = "*", make.dimnames = FALSE, ...)

## S4 method for signature 'rgeneric,cgeneric'
kronecker(X, Y, FUN = "*", make.dimnames = FALSE, ...)

## S4 method for signature 'rgeneric,rgeneric'
kronecker(X, Y, FUN = "*", make.dimnames = FALSE, ...)
```

Arguments

X	cgeneric or rgeneric
Y	cgeneric or rgeneric
FUN	see kronecker()
make.dimnames	see kronecker()
...	see kronecker()

Value

A cgeneric object if kronecker between two cgeneric, otherwise a rgeneric object.

Functions

- kronecker(X = cgeneric, Y = cgeneric): Build a cgeneric to implement the interaction between two GMRF models each one implemented as a cgeneric.
- kronecker(X = cgeneric, Y = rgeneric): Build a rgeneric to implement the interaction between two GMRF models, the first as a cgeneric and the second as a rgeneric.
- kronecker(X = rgeneric, Y = cgeneric): Build a rgeneric to implement the interaction between two GMRF models, the first as a rgeneric and the second as a cgeneric.
- kronecker(X = rgeneric, Y = rgeneric): Build a rgeneric to implement the interaction between two GMRF models each one implemented as a rgeneric.

---

multi_generic_model *Combine two or more* cgeneric *or* rgeneric *models*

Description

Constructs a multiple kronecker product model from a list of model objects. The resulting model contains a corresponding inlabru::bm_multi() mapper. This can be used as an alternative to a binary tree of kronecker product models.

Usage

```
multi_generic_model(models, ...)

multi_generic_model_mapper(models)
```

Arguments

models	A list of cgeneric or rgeneric models, optionally with names
...	Arguments passed on to every kronecker() call.

Details

The last model in the list has the slowest index variation, and the first model has the fastest index variation. This matches the latent variable ordering of standard INLA:f() model components with (main, group, replicate).

Value

A 'cgeneric' or 'rgeneric' model object, containing a multi-kronecker product model, with a corresponding inlabru::bm_multi() mapper.

Functions

- multi_generic_model_mapper(): Buidl the bm_multi mapper for a list of models

---

packageCheck *To check package version and load*

Description

To check package version and load

Usage

```
packageCheck(name, minimum_version, quietly = FALSE)
```

Arguments

name	character with the name of the package
minimum_version	character with the minimum required version
quietly	logical indicating if messages shall be printed

Note

Original in inlabru package function check_package_version_and_load

pc-utils *Internal functions to check PC-prior parameters.*

Description

Internal functions to check PC-prior parameters.

Usage

```
pcParamCheck(npars, reference, probability)

pclrange(lrange, lam, d = 2, log = FALSE)

pcrange(range, lam, d = 2, log = FALSE)
```

Arguments

npars	number of parameters.
reference	numeric vector to set the reference for each parameter for its PC-prior.
probability	numeric vector with to set the probability statement of the PC prior for each parameter. For sigma probability statement is P(sigma > reference) = p whereas for range it is P(range < reference). If NA, 0 or 1, the corresponding reference will be used as fixed. If missing, all the parameters considered as known (fixed) and equal the corresponding reference value.
lrange	numeric with the log of the (practical) range
lam	numeric with the prior parameter
d	integer to specify the domain dimention
log	logical indicating if the density is to be returned in the log scale
range	numeric with the of the (practical) range.

Functions

- pcParamCheck(): Check the PC-prior arguments.
- pclrange(): Penalized Complexity (PC) prior for the log of the practical range.
- pcrange(): Penalized Complexity (PC) prior for the practical range.

Examples

```
# P(range < 2.0) = 0.1
 lam <- -log(0.1) * 2.0
 plot(function(x) pcrange(x, lam), 1/100, 10, n = 100)
```

rgeneric-class *Organize data for the latent GMRF R interface for* INLA.

Description

A GMRF is defined from model parameters θ that would parametrize a (sparse) precision matrix.

The elements of a GMR are:

- graph to define the non-zero precision matrix pattern. only the upper triangle including the diagonal is needed.
- Q vector where the
  - first element (N) is the size of the matrix,
  - second element (M) is the number of non-zero elements in the upper part (including) diagonal
  - the remaining (M) elements are the actual precision (upper triangle plus diagonal) elements whose order shall follow the graph definition.
- mu the mean vector,
- initial vector with
  - first element as the number of the parameters in the model
  - remaining elements should be the initials for the model parameters.
- log.norm.const log of the normalizing constant.
- log.prior log of the prior for the model parameters.

Usage

```
rgeneric(model, n, debug = FALSE, ...)

## Default S3 method:
rgeneric(model, n, debug = FALSE, ...)

## S3 method for class 'rgeneric'
rgeneric(model, ...)

## S3 method for class 'inla.rgeneric'
rgeneric(model, ...)

## S3 method for class 'rgeneric'
print(x, ...)

## S3 method for class 'rgeneric'
summary(object, ...)

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

Arguments

model	an object used to define the model. See the 'rgeneric' vignette from the INLA package.
n	integer with the dimension of the model
debug	logical indicating debug state.
...	not used
x	a rgeneric object
object	a rgeneric object
y	not used

Value

rgeneric/ inla.rgeneric object.

Functions

- rgeneric(default): The rgeneric default method.
- rgeneric(rgeneric): Returns the model object unchanged.
- rgeneric(inla.rgeneric): Check and converts a regular inla.rgeneric object to rgeneric.
- print(rgeneric): Print the rgeneric object
- summary(rgeneric): A summary for a rgeneric object
- plot(rgeneric): A plot for a rgeneric object

Note

Recommended for prototyping, whereas cgeneric is recommended for production.

---

rgeneric_get rgeneric_get *is an internal function used to query* graph, Q, initial, mu *or* prior *from a* rgeneric.

Description

The generic_get retrieve a model property specified by cmd on an rgeneric object. The functions listed below are for each cmd case.

Usage

```
rgeneric_get(
  model,
  cmd = c("graph", "Q", "initial", "mu", "log_prior"),
  theta,
  ...
)

rgeneric_initial(model)

rgeneric_mu(model, theta)

rgeneric_graph(model, optimize)

rgeneric_Q(model, theta, optimize)

rgeneric_prior(model, theta)
```

Arguments

model	a rgeneric object.
cmd	an string to specify which model element to get
theta	numeric vector with the model parameters. If missing, the initial will be used.
...	additional arguments passed on to methods. E.g.: optimize = FALSE return the graph and precision as a sparse matrix whereas optimize = TRUE retur the graph as arow/col indexes and the precision as a numeric vector with its elements.
optimize	logical indicating if it is to be returned only the elements and not as a sparse matrix.

Value

depends on cmd

numeric scalar (if numeric vector is provided for theta) or vector (if numeric matrix is provided for theta).

Functions

- rgeneric_initial(): Retrive the initial parameter(s) of an rgeneric model.
- rgeneric_mu(): Evaluate the mean for an rgeneric model.
- rgeneric_graph(): Retrieve the graph of an rgeneric object
- rgeneric_Q(): Retrieve the precision of an rgeneric object
- rgeneric_prior(): Evaluate the prior for an rgeneric model

Examples

```
library(INLAtools)
old.par <- par(no.readonly = TRUE)

## Setting the prior parameters
prior.par <- c(1, 0.5) # P(sigma > 1) = 0.5
cmodel <- cgeneric(
  model = "iid", n = 10,
  param = prior.par)

## prior summaries: sigma and log-precision
(lamb <- -log(prior.par[2])/prior.par[1])
(smedian <- qexp(0.5, lamb))
(smean <- 1/lamb)

## mode: at the minimum of - log-prior
(lpmode <- optimize(function(x)
  -cgeneric_prior(cmodel, theta = x),
  c(-10, 30))$minimum)
## mean: integral of x*f(x)dx
(lpmean <- integrate(function(x)
  exp(cgeneric_prior(cmodel, theta = matrix(x, 1)))*x,
  -10, 30)$value)

## prior visualization: log(precision) and sigma
par(mfrow = c(1, 2))
plot(function(x)
 exp(cgeneric_prior(cmodel, theta = matrix(x, nrow=1))),
  -3, 3, n = 601, xlab = "log-precision",
  ylab = "density")
abline(v = lpmode, lwd = 3, col = 2)
rug(-2*log(smedian), lwd = 3, col = 3)
rug(lpmean, lwd = 3, col = 4)
plot(function(x)
 exp(cgeneric_prior(cmodel,
  theta = matrix(
    -2*log(x),
    nrow = 1))+log(2)-log(x)),
  1/100, 10, n = 1000,
  xlab = expression(sigma),
  ylab = "density")
plot(function(x) dexp(x, lamb),
   1/100, 10, n = 1000,
   add = TRUE, lty = 2, col = 2)
rug(smedian, lwd = 3, col = 3)
rug(smean, lwd = 3, col = 4)

par(old.par)
```

Sparse *To store in i,j,x sparse matrix format*

Description

To store in i,j,x sparse matrix format

Usage

```
Sparse(A, unique = TRUE, na.rm = FALSE, zeros.rm = FALSE)
```

Arguments

A	matrix or Matrix
unique	logical (default is TRUE) to ensure that the internal representation is unique and there are no duplicated entries. (Do not change this unless you know what you are doing.)
na.rm	logical (default is FALSE) indicating if it is to replace 'NA"s in the matrix with zeros.
zeros.rm	logical (default is FALSE) indicating if it is to remove zeros in the matrix. Applied after na.rm.

Note

This is based in INLA::inla.as.sparse(), but allow all combinations of 'na.rm' and 'zeros.rm'.

---

upperPadding *Padding (a list of) sparse matrices.*

Description

Padding (a list of) sparse matrices.

Usage

```
upperPadding(M, relative = FALSE, ...)
```

Arguments

M	'Matrix' (or a list of them).
relative	logical. If 'M" is a list, it indicates if it is to be returned a relative index and the value for each matrix. See details.
...	additional arguments passed to Sparse.

Details

This is useful to prepare a matrix, or a list of, sparse matrices for use in some 'cgeneric' code.

Define a graph of the union of the supplied matrices and return the row ordered diagonal plus upper triangle after padding with zeroes each one so that all the returned matrices have the same pattern.

If relative=FALSE, each columns of 'xx' is the elements of the corresponding matrix after being padded to fill the pattern of the union graph. If relative=TRUE, each element of 'xx' would be a list with a relative index, 'r', for each non-zero elements of each matrix is returned relative to the union graph, the non-lower elements, 'x', of the corresponding matrix, and a vector, 'o', with the number of non-zero elements for each line of each resulting matrix.

Value

If a unique matrix is given, return the upper triangle considering the 'T' representation in the `dgTMatrix`, from the `Matrix` package. If a list of matrices is given, return a list of two elements: 'graph' and 'xx'. The 'graph' is the union of the graph from each matrix. If relative=FALSE, 'xx' is a matrix with number of column equals the the number of matrices imputed. If relative=TRUE, it is a list of length equal the number of matrices imputed. See details.

Examples

```
A <- sparseMatrix(
  i = c(1, 1, 2, 3, 3, 5),
  j = c(2, 5, 3, 4, 5, 5),
  x = -c(0:3,NA,1), symmetric = TRUE)
A
upperPadding(A)
upperPadding(A, na.rm = TRUE)
upperPadding(A, zeros.rm = TRUE)
upperPadding(A, na.rm = TRUE, zeros.rm = TRUE)
B <- Diagonal(nrow(A), -colSums(A, na.rm = TRUE))
B
upperPadding(list(a = A, b = B), na.rm = TRUE, zeros.rm = TRUE)
upperPadding(list(a = A, b = B), relative = TRUE)
```

Index