Package: adlaplaceGrf (via r-universe)

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Type Package

Title FEM Matern Gaussian Random Fields for Adlaplace

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Description Tensor-product B-spline finite-element ingredients for Matern Gaussian random fields (mass, stiffness, and higher-order Grams) for use with the adlaplace Laplace approximation framework. Provides design and Gram matrix construction on regular grids, with optional terra SpatRaster / SpatVector input, and AD tape builders for random_fem_ssq_* / random_fem_det_*.

SystemRequirements OpenMP

License MPL-2.0

Depends R (>= 4.1.0), adlaplace (>= 0.5.0)

Imports methods, stats, Matrix, splines, Rcpp, RCppAD

LinkingTo Rcpp, adlaplace, RcppEigen, trustOptim, Matrix, RCppAD

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Contents

`fem_chol_pattern` *Symbolic LDL pattern for a sparse FEM precision structure*

Description

Builds the permutation and unit-lower pattern required by `adlaplace`'s `chol_update` for a precision with the same sparsity as `Q_structure` (typically the union of FEM Gram patterns).

Usage

```
fem_chol_pattern(Q_structure)
```

Arguments

`Q_structure`	Symmetric sparse matrix with the structural nonzeros of `Q(theta)` (numeric values only need to make the matrix positive definite for symbolic analysis; diagonals are inflated if needed).

Value

A list with `perm` (0-based), `L1` (`dtCMatrix` / unit lower), and `perm_inv` (0-based), suitable for the `chol` slot of a `random_fem_*` precision payload.

fem_precision *Assemble FEM Matern precision Q2 or Q3 from Grams*

Description

Assemble FEM Matern precision Q2 or Q3 from Grams

Usage

```
fem_precision(kappa, tau, C, G, G2, G3 = NULL, alpha = 2L)
```

Arguments

kappa, tau	Positive SPDE parameters.
C, G, G2, G3	Sparse Grams from grf_bspline().
alpha	2 or 3.

Value

Sparse dgCMatrix precision.

fem_precision_payload *Build* random_fem_ssq_* / random_fem_det_* *precision payload for adlaplace*

Description

Build random_fem_ssq_* / random_fem_det_* precision payload for adlaplace

Usage

```
fem_precision_payload(fem, alpha = 2L)
```

Arguments

fem	Result of grf_bspline() (or list with C, G, G2, optional G3).
alpha	2 or 3.

Value

List for ad_data@precision: Grams, chol pattern, and Q CSC coefficients aligned for on-tape assembly.

fem_Q_structure *Structural nonzero pattern for Q2 or Q3 from Grams*

Description

Structural nonzero pattern for Q2 or Q3 from Grams

Usage

```
fem_Q_structure(C, G, G2, G3 = NULL)
```

Arguments

C, G, G2, G3	Sparse Grams from grf_bspline(); G3 may be NULL for alpha = 2.

Value

Symmetric sparse matrix with the union of Gram nonzero patterns.

grf_bspline *Tensor-product B-spline FEM ingredients for a 2D Matern GRF*

Description

Builds the design matrix of tensor-product B-splines at evaluation coordinates together with sparse mass, stiffness, and higher-order Gram matrices used in the SPDE FEM precision for operator orders alpha = 2 and 3.

Usage

```
grf_bspline(coords, knots, degree = 2L, ...)

## S4 method for signature 'list'
grf_bspline(coords, knots, degree = 2L, ...)

## S4 method for signature 'data.frame'
grf_bspline(coords, knots, degree = 2L, ...)
```

Arguments

coords	Evaluation locations. For a data.frame (e.g. sites_eval from expand.grid), rows are point coordinates with columns x and y. For a plain list(x, y) of axis sequences, the full tensor grid is formed with expand.grid. With **terra**, SpatRaster / SpatVector are also accepted.

knots	Knot-line positions on each axis: `list(x = seq(...), y = seq(...))` of unique increasing breakpoints (domain endpoints included). These are expanded to open B-spline knot vectors. With terra, a `SpatRaster` whose grid defines knot lines is also accepted.
degree	B-spline degree; must be `>= 2`. Default `2` (alpha = 2). Use `degree = 3` when assembling `G3` for alpha = 3.
...	Passed to methods (unused for `list` / `data.frame`).

Details

Coefficient ordering is column-major (`vec`) over the `n_x` by `n_y` array of tensor basis indices: basis `(i, j)` maps to column `i + (j - 1) * n_x`.

Value

A list with:

A `dgCMatrix` design, `n` by `n_x * n_y`

C, G, G2 sparse Grams

G3 sparse Gram or `NULL` if `degree < 3`

degree, knots, n_basis metadata (`n_basis = c(n_x, n_y)`)

Examples

```
sites_list <- list(x = seq(0, 1, by = 0.25), y = seq(0, 1, by = 0.25))
sites_eval <- do.call(expand.grid, sites_list)
fem <- grf_bspline(sites_eval, sites_list, degree = 2L)
```

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matern-class *Matern FEM spatial random field term*

Description

Formula term for a 2D Matern GRF via tensor-product B-spline FEM, wired to adlaplaceGrf kernels `random_fem_ssq_2` / `random_fem_det_2` (shape nu = 1) or `random_fem_ssq_3` / `random_fem_det_3` (nu = 2). The quadratic form is a random shard; the log-determinant is a parameters companion via `adlaplace::extra_ad_fun()`. The first argument is a **column name** in `data` (like `adlaplace::iid()`): that column holds observation locations as a 2-column matrix, WKT text, or HEX WKB points. Knot lines are supplied at construction; the observation design matrix is built later in `adlaplace::design()` from `data`.

Usage

```
matern(
  x,
  knots,
  shape = 1L,
  init = c(1, 1),
  lower = c(1e-09, 1e-09),
  upper = c(Inf, Inf),
  parscale = c(1, 1)
)

## S4 method for signature 'matern'
extra_ad_fun(term)

## S4 method for signature 'matern'
design(term, data)

## S4 method for signature 'matern'
precision(term, data)

## S4 method for signature 'matern'
random_info(term, data)

## S4 method for signature 'matern'
theta_info(term)

## S4 method for signature 'matern'
beta_info(term, data)
```

Arguments

x	Name of the geometry / coordinate column in data.
knots	Knot lines as list(x = ..., y = ...) or a terra SpatRaster (cell-center x/y become the knot lines).
shape	Matern smoothness nu (1 or 2). Default 1L (SPDE alpha = 2, quadratic B-splines). Use 2 for nu = 2 / cubic B-splines.
init	Initial values for (range, sd) on the natural scale, where range = sqrt(8*nu)/kappa is the practical range (same units as coordinates; matches geostatsp/INLA) and sd is the marginal SD of the Matern field. Internally converted to SPDE (kappa, tau).
lower, upper	Bounds for (range, sd).
parscale	Optimization scales for (range, sd).
term	A matern term.
data	Model data frame (passed by adlaplace generics).

Details

In 2D, B-spline degree and SPDE order alpha equal shape + 1.

Value

A `matern` term object.

Functions

- `extra_ad_fun(matern)`: Companion parameters density for the FEM log-determinant shard.
- `design(matern)`: Design matrix of B-spline basis evaluations at coordinates in `data[[term@term]]`.
- `precision(matern)`: FEM precision payload for `random_fem_*`.
- `random_info(matern)`: Random-effect metadata (one row per basis weight).
- `theta_info(matern)`: Theta info for practical `range = sqrt(8*nu)/kappa` and field `sd` (log scale when `transform_theta` is TRUE).
- `beta_info(matern)`: Beta info (none).

`matern_est` *Posterior mean, SD, and simulations of a matern field on a raster*

Description

Evaluates the fitted Matern GRF on `eval_grid` under the Laplace approximation for the random effects (outer parameters fixed at the MLE). Returns a SpatRaster with layers `mean`, `sd`, and optionally `sim1` ... `simn`.

Usage

```
matern_est(fit, eval_grid, n = 0L)
```

Arguments

`fit`	An `"adlaplace_fit"` from `adlaplace::adlaplace()` that includes exactly one `matern()` term.
`eval_grid`	A terra `SpatRaster` whose cell centers are evaluation sites.
`n`	Number of posterior simulations of the field. Default `0` (mean and sd only).

Value

A `SpatRaster` with `n + 2` layers: `mean`, `sd`, and `sim1`...`simn` when `n > 0`.

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