Package ‘mrtsSphere’

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Type Package

Title Multi-Resolution Thin-Plate Splines on the Sphere

Version 0.1.2

Description Constructs multi-resolution thin-plate spline basis functions on the sphere for use in spatial regression and large-scale spatial prediction problems. Implements the basis system described in Huang, Huang, and Ing (2025) ``Multi-Resolution Spatial Methods on the Sphere: Efficient Prediction for Global Data'', Environmetrics, <doi:10.1002/env.70092>. Heavy computations are written in 'C++' via 'Rcpp' with optional 'OpenMP' parallelism.

License GPL (>= 2)

Encoding UTF-8

Depends R (>= 4.0)

Imports Rcpp, RSpectra

LinkingTo Rcpp, RcppEigen, RcppNumerical

Suggests fields, testthat (>= 3.0.0)

SystemRequirements GNU make

RoxygenNote 7.3.2

URL https://github.com/STLABTW/multi-resolution-sphere

BugReports https://github.com/STLABTW/multi-resolution-sphere/issues

Config/testthat/edition 3

NeedsCompilation yes

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`mrts_sphere` *Multi-resolution thin-plate spline basis on the sphere*

Description

Builds a set of `k` multi-resolution thin-plate spline (MRTS) basis functions on the sphere from a set of knot locations, and evaluates them at the prediction locations `X`.

Usage

```
mrts_sphere(knot, k, X)
```

Arguments

`knot`	Numeric matrix with two columns giving knot locations as `(latitude, longitude)` in degrees.
`k`	Integer. Number of basis functions to construct (the rank of the basis). Must satisfy `2 <= k <= nrow(knot)`.
`X`	Numeric matrix with two columns giving prediction locations as `(latitude, longitude)` in degrees, where the basis is evaluated.

Details

The first basis function is constant (`sqrt(1/n)`); the remaining `k - 1` basis functions are obtained from the eigen-decomposition of the centered knot kernel matrix, following the construction described in the reference.

Value

A list with one element:

`mrts` An `nrow(X) x k` numeric matrix whose columns are the basis functions evaluated at the rows of `X`.

References

Multi-resolution approximations of Gaussian processes for large spatial datasets on the sphere. *Environmetrics*, 2025. doi:10.1002/env.70092

Examples

```
## Build a small global grid in (lat, lon) degrees.
n_lon <- 12
n_lat <- 8
lon_seq <- seq(-180, 150, length.out = n_lon)
lat_seq <- seq( -80,  80, length.out = n_lat)
grid <- as.matrix(expand.grid(lat = lat_seq, lon = lon_seq))

## Pick 30 knots and evaluate the MRTS basis at every grid point.
set.seed(1)
knots <- grid[sample(nrow(grid), 30), ]
res <- mrts_sphere(knots, k = 5, X = grid)
dim(res$mrts)   # nrow(grid) x k

## Recovering a simulated spherical exponential field with the basis.
if (requireNamespace("fields", quietly = TRUE)) {
  # Great-circle distance (km) -> exponential covariance.
  d_grid    <- fields::rdist.earth(grid[, 2:1], miles = FALSE)
  cov_field <- exp(-d_grid / 2000)
  y_true    <- as.numeric(t(chol(cov_field + diag(1e-8, nrow(grid)))) %*%
                          rnorm(nrow(grid)))

  # Noisy observations at the knot locations.
  obs_idx <- match(data.frame(t(knots)), data.frame(t(grid)))
  z_obs   <- y_true[obs_idx] + rnorm(nrow(knots), sd = 0.3)

  # Project into the MRTS basis (least squares) and predict on the grid.
  B_obs    <- res$mrts[obs_idx, , drop = FALSE]
  beta_hat <- qr.solve(B_obs, z_obs)
  y_hat    <- res$mrts %*% beta_hat
  sqrt(mean((y_hat - y_true)^2))   # RMSE
}
```

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