Package ‘smnet’

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Description Fits flexible additive models to data on stream networks, taking account of flow-connectivity of the network. Models are fitted using penalised least squares.
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get_adjacency

Construct a Stream Network Adjacency Matrix

Description

Builds a sparse adjacency matrix from a user specified SSN data directory, by extracting and processing the binaryID.db table. The resulting output of this function is required input for fitting spatial additive network models to SSN objects using the main smnet function.

Usage

get_adjacency(ssn_directory, netID = 1)

Arguments

ssn_directory Required character string indicating the path to the location of the .ssn directory which contains the binaryID.db table.
netID Logical. Integer specifying the particular stream network of interest within the SSN object. Defaults to 1.

Value

List object with components

- adjacency: Sparse adjacency matrix of class spam with row and column dimension equal to the number of stream segments. If the i^th column has non-zero elements j_1 and j_2 then this indicates that j_1 and j_2 are direct upstream neighbours of i. If the i^th column has sum 1, then this indicates that i has only one upstream neighbour, and therefore no confluence lies between them; by default the spatial penalties treat these differently.
- bid: Character vector of binary identifiers for each stream segment, used only for automatic calculation of Shreve’s stream order within smnet

Author(s)

Alastair Rushworth

See Also

smnet, plot.smnet, predict.smnet
Specify Smooth Terms in Formulae

Description

Function used to set up univariate or bivariate smooth terms based on P-splines, for use within a call to smnet.

Usage

\[ m(..., k = -1, cyclic = F) \]

Arguments

- \( \ldots \) one or more variables for creating P-spline smooths.
- \( k \) integer defining the number of uniformly spaced B-spline basis functions for the smooth, default is 10. For 2d (and higher) smooths, this is the marginal basis size.
- \( cyclic \) logical vector indicating whether the smooth should be cyclic. Based on the harmonic smoother of Eiler and Marx (2004)

Value

List object with components

- \( \text{term} \): character vector of the names of the variables involved in the smooth to be set up
- \( \text{bs.dim} \): number of B-spline basis functions to be used in the smooth

Author(s)

Alastair Rushworth

References

Modified version of \( s \) originally from package mgcv, Simon Wood (2014).

See Also

smnet, plot.smnet, predict.smnet
network

Specify Network Smoother in Formulae

Description

This function specifies all of the information required to smooth parameters over the segments of a stream network using an adjacency matrix, and a vector of flow weights.

Usage

network(adjacency = NULL, weight = "autoShreve", fixed.df = NULL)

Arguments

adjacency
A sparse adjacency matrix of class `spam` that describes the flow connectedness of the stream network. adjacency is typically obtained from a call to get_adjacency

weight
A character string indicating the column name of a numeric vector of flow weights contained in the data.object that has been passed to `smnet`. Defaults to "autoShreve" which automatically constructs a weighting based on Shreve order, useful if data does not include an appropriate weight. For more information on choosing appropriate weight inputs from a given data set, see show_weights.

fixed.df
Positive scalar indicating a fixed number of degrees of freedom to allocate to the stream network component, overriding the criterion minimisation for this component. Under the default setting, NULL, the degrees of freedom are chosen automatically.

Value

A list combining the processed input components above. For internal use within smnet.

- adjacency: Sparse adjacency matrix
- weight: Numeric vector of flow weights
- netID: Integer identifying network of interest

Author(s)

Alastair Rushworth
**Description**

Plot linear, univariate and bivariate smooth effects and network smooth terms that resulting from a call to `smnet()`.

**Usage**

```r
## S3 method for class 'smnet'
plot(
  x,
  type = "covariates",
  se = FALSE,
  res = FALSE,
  weight = NULL,
  sites = FALSE,
  sites.col = NULL,
  sites.cex = 1,
  network.col = NULL,
  shadow = 0,
  key = TRUE,
  legend.text = NULL,
  legend.range = NULL,
  ...
)
```

**Arguments**

- `x`: An object of class `smnet`.
- `type`: Character string identifying the type of plot to be produced. The default, `type = 'covariates'`, produces plots of all linear and smooth components (the latter corresponding to each appearance of `m()` in the model formula). `type = 'full'` plots the stream network fitted mean using the full set of spatial points contained in the associated SSN object. `type = 'segments'` plots the stream network fitted mean using a set of connected line segments to represent the spatial network, this can be faster for large networks than `type = 'full'`.
- `se`: Logical. When `TRUE` and `type = 'covariates'`, standard errors are shown on plots of linear and smooth terms. When `type = 'segment'` or `type = 'full'` spatial standard errors are plotted.
- `res`: Logical. When `TRUE`, partial residuals are shown on plots of linear and smooth components. Ignored when `type = 'full'` or `type = 'segments'`.
- `weight`: Positive real number that scales stream segment widths (as determined using Shreve order) to indicate relative size of stream segments. Ignored when `type = 'covariate'`. Currently only `autoShreve` is supported, defaults to `NULL` in which all streams segments are plotted with lines with identical widths.
sites Logical indicating whether locations of observation sites should be added to spatial plots. Ignored when type = 'covariate' and defaults to FALSE.

sites.col Single colour to plot observation locations. If not provided, points will be coloured according to the default legend and average observation at each location.

sites.cex Expansion factor for the size of plotted observation points.

network.col Single colour to represent all stream segments. By default, network is coloured according to fitted values from model. Ignored when type = 'covariate'.

shadow Positive scalar that adds a black outline to spatial stream segment plots, useful if the colour scale has many light colours. Ignored when type = 'covariate' and defaults to 0 (no shadow is drawn).

key Logical. Plots a colour legend for network plots. Ignored when type = 'covariates'.

legend.text Character annotation to add to color scale. Ignored if key = FALSE or type = 'covariates'.

legend.range Range of values represented by the color scale. Ignored if key = FALSE or type = 'covariates'.

... Other arguments passed to plot().

Author(s)

Alastair Rushworth

predict.smnet Make Predictions Using a Fitted Stream Network Model.

Description

Get predictions and standard errors for a new set of spatial locations and associated covariate values from a model fitted by smnet().

Usage

## S3 method for class 'smnet'
predict(object, newdata = NULL, ...)

Arguments

object Object of class smnet, usually the result of a call to smnet()

newdata data.frame containing new covariate values at which to make predictions.

... other arguments passed to predict.smnet()
`show_weights`  

**Value**  

List object with components  

- `predictions`: vector of predictions corresponding to prediction points in the original `SpatialStreamNetwork` input object  
- `predictions.se`: vector of prediction standard errors  

**Author(s)**  

Alastair Rushworth  

---  

**show_weights**  

*Search for and Validate Weights Columns in an SSN Object*  

**Description**  

Explore SSN objects for valid stream weights for use in fitting stream network models.  

**Usage**  

`show_weights(SSNobject, adjacency, netID = 1)`  

**Arguments**  

- **SSNobject**  
  SpatialStreamNetwork containing data to be searched for valid network weights for the smooth, default is 10. For 2d (and higher) smooths, this is the marginal basis size.  
- **adjacency**  
  adjacency object corresponding to SSNobject, resulting from a call to `get_adjacency()`.  
- **netID**  
  Positive integer indicating the network number to investigate, if multiple networks are contained in SSNobject. Default is 1.  

**Author(s)**  

Alastair Rushworth  

**See Also**  

`smnet, plot.smnet, predict.smnet`
Additive Modelling for Stream Networks

Description

Fits (Gaussian) additive models to river network data based on the flexible modelling framework described in O’Donnell et al. (2014). Data must be in the form of a SpatialStreamNetwork object as used by the SSN package (Ver Hoef et al., 2012). Smoothness of covariate effects is represented via a penalised B-spline basis (P-splines) and parameter estimates are obtained using penalised least-squares. Optimal smoothness is achieved by optimization of AIC, GCV or AICC. The formula interpreter used for penalised additive components is modelled on the code found in the package mgcv.

Usage

smnet(formula, data.object, netID = 1, method = "AICC", control = NULL)

Arguments

- **formula**: A formula statement similar to those used by lm and mgcv:::gam. Smooth functions are represented with m(., k = 20) function, up to 2d smooth interactions are currently supported. Spatial network components are specified using network(...) function. Further details can be found in m and network and the examples below.

- **data.object**: An object of class SpatialStreamNetwork.

- **netID**: Integer indicating the particular stream network to model, generally only user-specified when multiple networks are contained within data.object, default is 1.

- **method**: Character string determining the performance criterion for choosing optimal smoothness, options are "AICC", "AIC" or "GCV".

- **control**: A list of options that control smoothness selection via optimisation. See 'Details'.

Details

control is a list whose elements control smoothness selection: maxit limits the number of iterations made by the optimiser (default = 500). approx, positive integer, if specified indicates the number of Monte-Carlo samples to collect using an approximate version of performance criterion when direct evaluation is slow - this may be much faster if the network has a large number of segments or the data is large, for example approx = 100 often works well (defaults to NULL). checks, logical, specifies whether additivity checks should be performed on the input weights default = TRUE. trace, default = 0, if set to 1, optim will print progress. tol, the relative tolerance of optim. optim.method, the optimiser - default is “Nelder-Mead” see ?optim for details.
Value

Object of class `smnet` with components

- `fitted.values`: vector of fitted values
- `residuals`: vector of residuals: response minus fitted values
- `coefficients`: vector of parameter estimates
- `R2`: $R^2$ statistic
- `R2.adj`: adjusted $R^2$ statistic
- `df.residual`: residual degrees of freedom
- `ssn.object`: unchanged SSN input data object
- `internals`: model objects for internal use by other functions

Author(s)

Alastair Rushworth

References


See Also

get_adjacency.plot.smnet

Examples

```r
# As an example, create a simulated SSN object
# Save the object to a temporary location
set.seed(12)
ssn_path <- paste(tempdir(), "example_network", sep = "")

# If example network doesn't already exist, then attempt to create it
# Otherwise, read from the temporary directory
example_network <- try(importSSN(ssn_path, predpts = 'preds', o.write = TRUE), silent = TRUE)
if('try-error' %in% class(example_network)){
  example_network <- createSSN(
    n = 50,
    obsDesign = binomialDesign(200),
    predDesign = binomialDesign(50),
    importToR = TRUE,
    path = ssn_path,
    treeFunction = iterativeTreeLayout
  )
```

# plot the simulated network structure with prediction locations
# plot(example_network, bty = "n", xlab = "x-coord", ylab = "y-coord")

## create distance matrices, including between predicted and observed
createDistMat(example_network, "preds", o.write = TRUE, amongpred = TRUE)

## extract the observed and predicted data frames
observed_data <- getSSNdata.frame(example_network, "Obs")
prediction_data <- getSSNdata.frame(example_network, "preds")

## associate continuous covariates with the observation locations
# data generated from a normal distribution
obs <- rnorm(200)
obsvdata[, "X"] <- obs
observed_data[, "X2"] <- obs^2

## associate continuous covariates with the prediction locations
# data generated from a normal distribution
pred <- rnorm(50)
prediction_data[, "X"] <- pred
prediction_data[, "X2"] <- pred^2

## simulate some Gaussian data that follows a 'tail-up' spatial process
sims <- SimulateOnSSN(
  ssn.object = example_network,
  ObsSimDF = observed_data,
  PredSimDF = prediction_data,
  PredID = "preds",
  formula = ~ 1 + X,
  coefficients = c(1, 10),
  CorModels = c("Exponential.tailup"),
  use.nugget = TRUE,
  CorParms = c(10, 5, 0.1),
  addfunccol = "addfunccol")

## extract the observed and predicted data frames, now with simulated values
sim1DFpred <- getSSNdata.frame(sims, "preds")
sim1preds <- sim1DFpred[, "Sim_Values"]
sims[, "Sim_Values"] <- NA
sim1DFpred[, "Sim_Values"] <- NA
sims <- putSSNdata.frame(sim1DFpred, sims, "preds")

# create the adjacency matrix for use with smnet
adjacency <- get_adjacency(
  ssn_path,
  net = 1
)

# not run - plot the adjacency matrix
# display(adjacency[[1]])
# sometimes it is useful to see which variables are valid network weights
# in the data contained within the SSN object
show_weights(sims, adjacency)

# fit a penalised spatial model to the stream network data
# Sim_Values are quadratic in the X covariate. To highlight
# the fitting of smooth terms, this is treated as non-linear
# and unknown using m().
mod_smn <- smnet(formula = Sim_Values ~ m(X) + m(X2) +
                 network(adjacency = adjacency, weight = "shreve"),
                 data.object = sims, netID = 1)

# not run - plot different summaries of the model
plot(mod_smn, type = "network-covariates")
plot(mod_smn, type = "network-segments", weight = 4, shadow = 2)
plot(mod_smn, type = "network-full", weight = 4, shadow = 2)

# obtain predictions at the prediction locations and plot
# against true values
preds <- predict(mod_smn, newdata = getSSNdata.frame(sims, "preds"))
plot(preds$predictions, sim1preds)

# obtain summary of the fitted model
summary(mod_smn)

# delete the simulated data
unlink(ssn_path, recursive = TRUE)

---

### Description

Generate summaries of linear and smooth components of an smnet object.

### Usage

```r
## S3 method for class 'smnet'
summary(object, verbose = TRUE, ...)
```

### Arguments

- **object**: An object of class smnet.
- **verbose**: Logical. Whether to print summaries to the console.
- **...**: other arguments passed to summary.
Value

List object with components

- **linear.terms**: the linear components of the fitted model
- **smooth.terms**: the values of the smoothing parameters on the log scale, and the partial degrees of freedom associated with each smooth component. Note: Network components always have two smoothing parameters, where the second is a (usually small) ridge parameter.

Author(s)

Alastair Rushworth

See Also

smnet, plot.smnet

Examples

```
# As an example, create a simulated SSN object
# Save the object to a temporary location
set.seed(12)
ssn_path <- paste(tempdir(), "/example_network", sep = "")

# If example network doesn't already exist, then attempt to create it
# Otherwise, read from the temporary directory
example_network <- try(importSSN(ssn_path, o.write = TRUE), silent = TRUE)
if(!"try-error" %in% class(example_network)){
  example_network <- createSSN(
    n = 50,
    obsDesign = binomialDesign(200),
    predDesign = binomialDesign(50),
    importToR = TRUE,
    path = ssn_path,
    treeFunction = iterativeTreeLayout
  )
}

## create distance matrices, including between predicted and observed
createDistMat(example_network, "preds", o.write=TRUE, amongpred = TRUE)

## extract the observed and predicted data frames
observed_data <- getSSNdata.frame(example_network, "Obs")
prediction_data <- getSSNdata.frame(example_network, "preds")

## associate continuous covariates with the observation locations
# data generated from a normal distribution
obs <- rnorm(200)
observed_data[,"X"] <- obs
observed_data[,"X2"] <- obs^2
```
## associate continuous covariates with the prediction locations

### data generated from a normal distribution

```r
pred <- rnorm(50)
prediction_data[, "X"] <- pred
prediction_data[, "X2"] <- pred^2
```

### simulate some Gaussian data that follows a 'tail-up' spatial process

```r
sims <- SimulateOnSSN(
  ssn.object = example_network,
  ObsSimDF = observed_data,
  PredSimDF = prediction_data,
  PredID = "preds",
  formula = ~ 1 + X,
  coefficients = c(1, 10),
  CorModels = c("Exponential.tailup"),
  use.nugget = TRUE,
  CorParms = c(10, 5, 0.1),
  addfunccol = "addfunccol")$ssn.object
```

### extract the observed and predicted data frames, now with simulated values

```r
sim1DFpred <- getSSNdata.frame(sims, "preds")
sim1preds <- sim1DFpred[, "Sim_Values"]
sim1DFpred[, "Sim_Values"] <- NA
sims <- putSSNdata.frame(sim1DFpred, sims, "preds")
```

# create the adjacency matrix for use with smnet

```r
adjacency <- get_adjacency(
  ssn_path, 
  net = 1
)
```

# not run - plot the adjacency matrix

```r
# display(adjacency[[1]])
```

# sometimes it is useful to see which variables are valid network weights

### in the data contained within the SSN object

```r
show_weights(sims, adjacency)
```

# fit a penalised spatial model to the stream network data

### Sim_Values are quadratic in the X covariate. To highlight

### the fitting of smooth terms, this is treated as non-linear

### and unknown using m().

```r
mod_smn <- smnet(formula = Sim_Values ~ m(X) + m(X2) + network(adjacency = adjacency, weight = "shreve"),
                  data.object = sims, netID = 1)
```

# not run - plot different summaries of the model

```r
plot(mod_smn, type = "network-covariates")
plot(mod_smn, type = "network-segments", weight = 4, shadow = 2)
plot(mod_smn, type = "network-full", weight = 4, shadow = 2)
```

# obtain predictions at the prediction locations and plot
# against true values
preds <- predict(mod_smn, newdata = getSSNdata.frame(sims, "preds"))
plot(preds$predictions, sim1preds)

# obtain summary of the fitted model
summary(mod_smn)

#' # delete the simulated data
unlink(ssn_path, recursive = TRUE)
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