Package ‘smurf’

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**Type** Package

**Title** Sparse Multi-Type Regularized Feature Modeling

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**Description** Implementation of the SMuRF algorithm of Devriendt et al. (2021) <doi:10.1016/j.insmatheco.2020.11.010> to fit generalized linear models (GLMs) with multiple types of predictors via regularized maximum likelihood.

**URL** https://gitlab.com/TReynkens/smurf

**License** GPL (>= 2)

**BugReports** https://gitlab.com/TReynkens/smurf/-/issues

**Depends** R (>= 3.4)

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**Repository** CRAN

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Description

Implementation of the SMuRF algorithm of Devriendt et al. (2021) <doi:10.1016/j.insmatheco.2020.11.010> to fit generalized linear models (GLMs) with multiple types of predictors via regularized maximum likelihood.

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See Also

Useful links:

- https://gitlab.com/TReynkens/smurf
- Report bugs at https://gitlab.com/TReynkens/smurf/-/issues
**coef.glmsmurf**  

**Coefficients of Estimated Model**

**Description**

Function to extract the coefficients of the estimated model. `coefficients` is an *alias* for it.

**Usage**

```r
## S3 method for class 'glmsmurf'
coef(object, ...)

## S3 method for class 'glmsmurf'
coefficients(object, ...)
```

**Arguments**

- `object`: An object of class `glmsmurf`, typically the result of a call to `glmsmurf` or `glmsmurf.fit`.
- `...`: Additional arguments which are currently ignored.

**Value**

A vector containing the coefficients of the estimated model in `object`.

**See Also**

`coef_reest, coef, summary.glmsmurf, glmsmurf, glmsmurf-class`

**Examples**

```r
## See example(glmsmurf) for examples
```

**coef_reest**  

**Coefficients of Re-estimated Model**

**Description**

Function to extract the coefficients of the re-estimated model. `coefficients_reest` is an *alias* for it.
Usage

coef_reest(object, ...)

## S3 method for class 'glmsmurf'
c coef_reest(object, ...)

coefficients_reest(object, ...)

## S3 method for class 'glmsmurf'
c coefficients_reest(object, ...)

Arguments

object An object for which the extraction of model coefficients is meaningful. E.g. an object of class 'glmsmurf', typically the result of a call to glmsmurf or glmsmurf.fit.

... Additional arguments which are currently ignored.

Value

A vector containing the coefficients of the re-estimated model in object, when they are available, or, otherwise, the coefficients of the estimated model in object with a warning.

See Also

c coef.glmsmurf, coef, summary.glmsmurf, glmsmurf, glmsmurf-class

Examples

## See example(glmsmurf) for examples

| deviance.glmsmurf |
| Deviance of Estimated Model |

Description

Function to extract the deviance of the estimated model.

Usage

## S3 method for class 'glmsmurf'
deviance(object, ...)

Usage

deviance.glmsmurf
deviance_reest

Arguments

object An object of class 'glmsmurf', typically the result of a call to glmsmurf or glmsmurf.fit.
...
Additional arguments which are currently ignored.

Value

The deviance of the estimated model in object.

See Also

deviance_reest, deviance, summary.glmsmurf, glmsmurf, glmsmurf-class

Examples

## See example(glmsmurf) for examples

```
deviance_reest
```

Deviance of Re-estimated Model

Description

Function to extract the deviance of the re-estimated model.

Usage

deviance_reest(object, ...)

## S3 method for class 'glmsmurf'
deviance_reest(object, ...)
Examples

## See example(glmsmurf) for examples
### fitted_reest

**Fitted Values of Re-estimated Model**

#### Description

Function to extract the fitted values of the re-estimated model.

#### Usage

```r
fitted_reest(object, ...)
```

#### Arguments

- `object`: An object for which the extraction of fitted values is meaningful. E.g. an object of class 'glmsmurf', typically the result of a call to `glmsmurf` or `glmsmurf.fit`.
- `...`: Additional arguments which are currently ignored.

#### Value

A vector containing the fitted values of the re-estimated model in `object`, when they are available or, otherwise, the fitted values of the estimated model in `object` with a warning.

#### See Also

`fitted.glmsmurf`, `fitted.glmsmurf.glmsmurf-class`

#### Examples

```r
## See example(glmsmurf) for examples
```

### glmsmurf

**Fit a Multi-Type Regularized GLM Using the SMuRF Algorithm**

#### Description

SMuRF algorithm to fit a generalized linear model (GLM) with multiple types of predictors via regularized maximum likelihood. `glmsmurf.fit` contains the fitting function for a given design matrix.
Usage

glmsmurf(
  formula,  
  family,   
  data,     
  weights,  
  start,    
  offset,   
  lambda,   
  lambda1 = 0, 
  lambda2 = 0, 
  pen.weights, 
  adj.matrix, 
  standardize = TRUE, 
  control = list(), 
  x.return = FALSE, 
  y.return = TRUE, 
  pen.weights.return = FALSE
)

glmsmurf.fit(
  X, 
  y, 
  weights, 
  start, 
  offset, 
  family, 
  pen.cov, 
  n.par.cov, 
  group.cov, 
  refcat.cov, 
  lambda, 
  lambda1 = 0, 
  lambda2 = 0, 
  pen.weights, 
  adj.matrix, 
  standardize = TRUE, 
  control = list(), 
  formula = NULL, 
  data = NULL, 
  x.return = FALSE, 
  y.return = FALSE, 
  pen.weights.return = FALSE
)
Arguments

**formula**  
A formula object describing the model to be fitted. Penalties are specified using the \( p \) function. For `glmsmurf.fit` this is an optional argument which is only used when penalty weights are computed using a generalized additive model (GAM).

**family**  
A family object specifying the error distribution and link function for the model.

**data**  
A data frame containing the model response and predictors for \( n \) observations.

**weights**  
An optional vector of prior weights to use in the likelihood. It should be a numeric vector of length \( n \) (the number of observations), or NULL. When NULL or nothing is given, equal prior weights (all ones) will be used.

**start**  
A vector containing the starting values for the coefficients. It should either be a numeric vector of length \( p+1 \) (with \( p \) the number of parameters excluding the intercept) or NULL. In the latter case, the link function applied to the weighted average of the response vector is used as starting value for the intercept and zero for the other coefficients.

**offset**  
A vector containing the offset for the model. It should be a vector of size \( n \) or NULL (no offset). Offset(s) specified using the formula object will be ignored!

**lambda**  
Either the penalty parameter, a positive number; or a string describing the method and measure used to select the penalty parameter:

- "is.aic" (in-sample; Akaike Information Criterion (AIC)),
- "is.bic" (in-sample; Bayesian Information Criterion (BIC)),
- "is.gcv" (in-sample; Generalized Cross-Validation (GCV) score),
- "oos.dev" (out-of-sample; deviance),
- "oos.mse" (out-of-sample; Mean Squared Error (MSE)),
- "oos.dss" (out-of-sample; Dawid-Sebastiani Score (DSS)),
- "cv.dev" (cross-validation (CV); deviance),
- "cv.mse" (CV; MSE),
- "cv.dss" (CV; DSS),
- "cv1se.dev" (CV with one standard error (SE) rule; deviance),
- "cv1se.mse" (CV with one SE rule; MSE),
- "cv1se.dss" (CV with one SE rule; DSS).

E.g. "is.aic" indicates in-sample selection of lambda with the AIC as measure. When `lambda` is missing or NULL, it will be selected using cross-validation with the one standard error rule and the deviance as measure ("cv1se.dev").

**lambda1**  
The penalty parameter for the \( L_1 \)-penalty in Sparse (Generalized) Fused Lasso or Sparse Graph-Guided Fused Lasso is \( \lambda \times \lambda_1 \). A positive numeric with default 0 (no extra \( L_1 \)-penalty).

**lambda2**  
The penalty parameter for the \( L_2 \)-penalty in Group (Generalized) Fused Lasso or Group Graph-Guided Fused Lasso is \( \lambda \times \lambda_2 \). A positive numeric with default 0 (no extra \( L_2 \)-penalty).

**pen.weights**  
Either a string describing the method to compute the penalty weights:

- "eq" (default; equal penalty weights),
• "stand" (standardization penalty weights),
• "glm" (adaptive GLM penalty weights),
• "glm. stand" (stand. ad. GLM penalty weights),
• "gam" (ad. GAM penalty weights),
• "gam. stand" (stand. ad. GAM penalty weights);

or a list with the penalty weight vector per predictor. This list should have length
equal to the number of predictors and predictor names as element names.

adj.matrix A named list containing the adjacency matrices (a.k.a. neighbor matrices) for
each of the predictors with a Graph-Guided Fused Lasso penalty. The list ele-
ments should have the names of the corresponding predictors. If only one pre-
dictor has a Graph-Guided Fused Lasso penalty, it is also possible to only give
the adjacency matrix itself (not in a list).

standardize Logical indicating if predictors with a Lasso or Group Lasso penalty are stan-
dardized, default is TRUE. The returned coefficients are always on the original
(i.e. non-standardized) scale.

control A list of parameters used in the fitting process. This is passed to glmsmurf.control.

x.return Logical indicating if the used model matrix should be returned in the output
object, default is FALSE.

y.return Logical indicating if the used response vector should be returned in the output
object, default is TRUE.

pen.weights.return Logical indicating if the list of the used penalty weight vector per predictor
should be returned in the output object, default is FALSE.

X Only for glmsmurf.fit: the design matrix including ones for the intercept. A
n by (p+1) matrix which can be of numeric matrix class (matrix-class) or of
class Matrix (Matrix-class) including sparse matrix class (dgCMatrix-class).

y Only for glmsmurf.fit: the response vector, a numeric vector of size n.

pen.cov Only for glmsmurf.fit: a list with the penalty type per predictor (covariate). A
named list of strings with predictor names as element names. Possible types:
"none" (no penalty, e.g. for intercept), "lasso" (Lasso), "grouplasso" (Group
Lasso), "flasso" (Fused Lasso), "gflasso" (Generalized Fused Lasso), "2dflasso"
(2D Fused Lasso) or "ggflasso" (Graph-Guided Fused Lasso).

n.par.cov Only for glmsmurf.fit: a list with the number of parameters to estimate per
predictor (covariate). A named list of strictly positive integers with predictor
names as element names.

group.cov Only for glmsmurf.fit: a list with the group of each predictor (covariate) which is only used for the Group Lasso penalty. A named list of positive in-
tegers with predictor names as element names where 0 means no group.

refcat.cov Only for glmsmurf.fit: a list with the number of the reference category in the
original order of the levels of each predictor (covariate). When the predictor is
not a factor or no reference category is present, it is equal to 0. This number
will only be taken into account for a Fused Lasso, Generalized Fused Lasso or
Graph-Guided Fused Lasso penalty when a reference category is present.
Details

See the package vignette for more details and a complete description of a use case.

As a user, it is important to take the following into account:

- The estimated coefficients are rounded to 7 digits.
- The cross-validation folds are not deterministic. The validation sample for selecting lambda out-of-sample is determined at random when no indices are provided in 'validation.index' in the control object argument. In these cases, the selected value of lambda is hence not deterministic. When selecting lambda in-sample, or out-of-sample when indices are provided in 'validation.index' in the control object argument, the selected value of lambda is deterministic.
- The glmsmurf function can handle many use cases and is preferred for general use. The glmsmurf.fit function requires a more thorough understanding of the package internals and should hence be used with care!

Value

An object of class 'glmsmurf' is returned. See glmsmurf-class for more details about this class and its generic functions.

References


See Also

  glmsmurf-class, glmsmurf.control, p, glm

Examples

```r
# Munich rent data from catdata package
data("rent", package = "catdata")

# The considered predictors are the same as in
# Response is monthly rent per square meter in Euro

# Urban district in Munich
rent$area <- as.factor(rent$area)

# Decade of construction
rent$year <- as.factor(floor(rent$year / 10) * 10)

# Number of rooms
rent$rooms <- as.factor(rent$rooms)

# Quality of the house with levels "fair", "good" and "excellent"
```
```r
rent$quality <- as.factor(rent$good + 2 * rent$best)
levels(rent$quality) <- c("fair", "good", "excellent")

# Floor space divided in categories (0, 30), [30, 40), ..., [130, 140)
sizeClasses <- c(0, seq(30, 140, 10))
rent$size <- as.factor(sizeClasses[findInterval(rent$size, sizeClasses)])

# Is warm water present?
rent$warm <- factor(rent$warm, labels = c("yes", "no"))

# Is central heating present?
rent$central <- factor(rent$central, labels = c("yes", "no"))

# Does the bathroom have tiles?
rent$tiles <- factor(rent$tiles, labels = c("yes", "no"))

# Is there special furniture in the bathroom?
rent$bathextra <- factor(rent$bathextra, labels = c("no", "yes"))

# Is the kitchen well-equipped?
rent$kitchen <- factor(rent$kitchen, labels = c("no", "yes"))

# Create formula with 'rentm' as response variable,
# 'area' with a Generalized Fused Lasso penalty,
# 'year', 'rooms', 'quality' and 'size' with Fused Lasso penalties,
# and the other predictors with Lasso penalties.
formu <- rentm ~ p(area, pen = "gflasso") +
  p(year, pen = "flasso") + p(rooms, pen = "flasso") +
  p(quality, pen = "flasso") + p(size, pen = "flasso") +
  p(warm, pen = "lasso") + p(central, pen = "lasso") +
  p(tiles, pen = "lasso") + p(bathextra, pen = "lasso") +
  p(kitchen, pen = "lasso")

# Fit a multi-type regularized GLM using the SMuRF algorithm.
# We use standardization adaptive penalty weights based on an initial GLM fit.
# The value for lambda is selected using cross-validation
# (with the deviance as loss measure and the one standard error rule), see example(plot_lambda)
munich.fit <- glmsmurf(formula = formu, family = gaussian(), data = rent,
  pen.weights = "glm.stand", lambda = 0.02)

###
# S3 methods for glmsmurf objects

# Model summary
summary(munich.fit)

# Get coefficients of estimated model
```
glmsmurf-class

The functions `glmsmurf` and `glmsmurf.fit` return objects of the S3 class `glmsmurf` which partially inherits from the `glm` and `lm` classes.

Value

An object of class `glmsmurf` is a list with at least following components:

- `coefficients` Coefficients of the estimated model.
- `residuals` Working residuals of the estimated model, see `glm`: 
  \[
  (y_1 - \mu_1)/(d\mu/d\eta(\eta_1)), \ldots, (y_n - \mu_n)/(d\mu/d\eta(\eta_n)).
  \]
<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>fitted.values</code></td>
<td>Fitted mean values of the estimated model ( (\mu_1, \ldots, \mu_n) = (g^{-1}(\eta_1), \ldots, g^{-1}(\eta_n)) ) with ( g^{-1} ) the inverse link function.</td>
</tr>
<tr>
<td><code>rank</code></td>
<td>Numeric rank of the estimated model, i.e. the number of unique non-zero coefficients.</td>
</tr>
<tr>
<td><code>family</code></td>
<td>The used <code>family</code> object.</td>
</tr>
<tr>
<td><code>linear.predictors</code></td>
<td>Linear fit of the estimated model on the link scale ( (\eta_1, \ldots, \eta_n) ).</td>
</tr>
<tr>
<td><code>deviance</code></td>
<td>Deviance of the estimated model: minus twice the log-likelihood, up to a constant.</td>
</tr>
<tr>
<td><code>aic</code></td>
<td>Akaike Information Criterion of the estimated model: (-2 \times L + 2 \times \text{rank} ) with ( L ) the log-likelihood.</td>
</tr>
<tr>
<td><code>bic</code></td>
<td>Bayesian Information Criterion of the estimated model: (-2 \times L + \ln(n^<em>) \times \text{rank} ) with ( n^</em> ) the number of observations excluding those with weight 0.</td>
</tr>
<tr>
<td><code>gcv</code></td>
<td>Generalized Cross-Validation score of the estimated model: ( \text{deviance}/(n^* \times (1 - \text{rank}/n^*)^2) ).</td>
</tr>
<tr>
<td><code>null.deviance</code></td>
<td>Deviance of the null model, i.e. the model with only an intercept and offset.</td>
</tr>
<tr>
<td><code>df.residual</code></td>
<td>Residual degrees of freedom of the estimated model, i.e. the number of observations (excluding those with weight 0) minus the rank of the estimated model.</td>
</tr>
<tr>
<td><code>df.null</code></td>
<td>Residual degrees of freedom for the null model, i.e. the number of observations (excluding those with weight 0) minus the rank of the null model.</td>
</tr>
<tr>
<td><code>obj.fun</code></td>
<td>Value of the objective function of the estimated model: minus the regularized scaled log-likelihood of the estimated model.</td>
</tr>
<tr>
<td><code>weights</code></td>
<td>The prior weights that were initially supplied. Note that they are called <code>prior.weights</code> in the output of <code>glm</code>.</td>
</tr>
<tr>
<td><code>offset</code></td>
<td>The used offset vector.</td>
</tr>
<tr>
<td><code>lambda</code></td>
<td>The used penalty vector: initially supplied by the user, or selected in-sample, out-of-sample or using cross-validation.</td>
</tr>
<tr>
<td><code>lambda1</code></td>
<td>The used penalty parameter for the ( L_1 )-penalty in Sparse (Generalized) Fused Lasso or Sparse Graph-Guided Fused Lasso is ( \lambda \times \lambda_1 ).</td>
</tr>
<tr>
<td><code>lambda2</code></td>
<td>The used penalty parameter for the ( L_2 )-penalty in Group (Generalized) Fused Lasso or Group Graph-Guided Fused Lasso is ( \lambda \times \lambda_2 ).</td>
</tr>
<tr>
<td><code>iter</code></td>
<td>The number of iterations that are performed to fit the model.</td>
</tr>
<tr>
<td><code>converged</code></td>
<td>An integer code indicating whether the algorithm converged successfully: ( \text{0: Successful convergence.} ) ( \text{1: Maximum number of iterations reached.} ) ( \text{2: Two subsequent restarts were performed.} ) ( \text{3: Low step size (i.e. below 1e-14).} )</td>
</tr>
<tr>
<td><code>final.stepsize</code></td>
<td>Final step size used in the algorithm.</td>
</tr>
<tr>
<td><code>n.par.cov</code></td>
<td>List with number of parameters to estimate per predictor (covariate).</td>
</tr>
<tr>
<td><code>pen.cov</code></td>
<td>List with penalty type per predictor (covariate).</td>
</tr>
</tbody>
</table>
group.cov: List with group of each predictor (covariate) for Group Lasso where 0 means no group.

refcat.cov: List with number of the reference category in the original order of the levels of each predictor (covariate) where 0 indicates no reference category.

control: The used control list, see `glmsmurf.control`.

Optionally, following elements are also included:

X: The model matrix, only returned when the argument `x.return` in `glmsmurf` or `glmsmurf.fit` is TRUE.

y: The response vector, only returned when the argument `y.return` in `glmsmurf` or `glmsmurf.fit` is TRUE.

pen.weights: List with the vector of penalty weights per predictor (covariate), only returned when the argument `pen.weights.return` in `glmsmurf` or `glmsmurf.fit` is TRUE.

When the model is re-estimated, i.e. `reest = TRUE` in `glmsmurf.control`, the following components are also present:

glm.reest: Output from the call to `speedglm` or `glm` to fit the re-estimated model.

coefficients.reest: Coefficients of the re-estimated model.

residuals.reest: Working residuals of the re-estimated model.

fitted.values.reest: Fitted mean values of the re-estimated model.

rank.reest: Numeric rank of the re-estimated model, i.e. the number of unique non-zero re-estimated coefficients.

linear.predictors.reest: Linear fit of the re-estimated model on the link scale.

deviance.reest: Deviance of the re-estimated model.

aic.reest: AIC of the re-estimated model.

bic.reest: BIC of the re-estimated model.

gcv.reest: GCV score of the re-estimated model.

df.residual.reest: Residual degrees of freedom of the re-estimated model.

obj.fun.reest: Value of the objective function of the re-estimated model: minus the regularized scaled log-likelihood of the re-estimated model.

X.reest: The model matrix used in the re-estimation, only returned when the argument `x.return` in `glmsmurf` or `glmsmurf.fit` is TRUE.

When lambda is not given as input but selected in-sample, out-of-sample or using cross-validation, i.e. the lambda argument in `glmsmurf` or `glmsmurf.fit` is a string describing the selection method, the following components are also present:
lambda.method Method (in-sample, out-of-sample or cross-validation (possibly with the one standard error rule)) and measure (AIC, BIC, GCV score, deviance, MSE or DSS) used to select lambda. E.g. "is.bic" indicates in-sample selection of lambda with the BIC as measure.

lambda.vector Vector of lambda values that were considered in the selection process.

lambda.measures List with for each of the relevant measures a matrix containing for each considered value of lambda (rows) the measure for the whole data (in-sample), for the validation data (out-of-sample) or per cross-validation fold (cross-validation) (columns).

lambda.coefficients Matrix containing for each considered value of lambda (rows) the estimated (when lambda.reest = FALSE in glmsmurf.control) or re-estimated (when lambda.reest = TRUE) coefficients when selecting lambda in-sample or out-of-sample (or using cross-validation with one fold); and NULL otherwise.

When the object is output from glmsmurf, following elements are also included:

call The matched call.
formula The supplied formula.
terms The terms object used.
contrasts The contrasts used (when relevant).
xlevels The levels of the factors used in fitting (when relevant).

S3 generics

Following S3 generic functions are available for an object of class "glmsmurf":

coeff Extract coefficients of the estimated model.
coeff_reest Extract coefficients of the re-estimated model, when available.
deviance Extract deviance of the estimated model.
deviance_reest Extract deviance of the re-estimated model, when available.
family Extract family object.
fitted Extract fitted values of the estimated model.
fitted_reest Extract fitted values of the re-estimated model, when available.
plot Plot coefficients of the estimated model.
plot_reest Plot coefficients of the re-estimated model, when available.
plot_lambda Plot goodness-of-fit statistics or information criteria as a function of lambda, when lambda is selected in-sample, out-of-sample or using cross-validation.
predict Obtain predictions using the estimated model.
predict_reest Obtain predictions using the re-estimated model, when available.
residuals Extract residuals of the estimated model.
residuals_reest Extract residuals of the re-estimated model, when available.
summary Print a summary of the estimated model, and of the re-estimated model (when available).
**glmsmurf.control**

**See Also**

`glmsmurf`, `glm`, `lm`

**Examples**

```r
## See example(glmsmurf) for examples
```

---

**Description**

Control function to handle parameters for fitting a multi-type regularized generalized linear model (GLM) using the SMuRF algorithm. The function sets defaults and performs input checks on the provided parameters.

**Usage**

```r
glmsmurf.control(  
  epsilon = 1e-08,  
  maxiter = 10000,  
  step = NULL,  
  tau = 0.5,  
  reest = TRUE,  
  lambda.vector = NULL,  
  lambda.min = NULL,  
  lambda.max = NULL,  
  lambda.length = 50L,  
  lambda.reest = FALSE,  
  k = 5L,  
  oos.prop = 0.2,  
  validation.index = NULL,  
  ncores = NULL,  
  po.ncores = NULL,  
  print = FALSE  
)
```

**Arguments**

- **epsilon**: Numeric tolerance value for stopping criterion. A numeric strictly larger than 0, default is `1e-8`.
- **maxiter**: Maximum number of iterations of the SMuRF algorithm. A numeric larger than or equal to 1, default is `10000`.
- **step**: Initial step size, a numeric strictly larger than 0 or `NULL`. When `NULL` (default), it is equal to 0.1 times the sample size.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>tau</td>
<td>Parameter for backtracking the step size. A numeric strictly between 0 and 1, default is 0.5.</td>
</tr>
<tr>
<td>reest</td>
<td>A logical indicating if the obtained (reduced) model is re-estimated using speedglm or glm. Default is TRUE.</td>
</tr>
<tr>
<td>lambda.vector</td>
<td>Values of lambda to consider when selecting the optimal value of lambda. A vector of strictly positive numerics (which is preferably a decreasing sequence as we make use of warm starts) or NULL (default). When NULL, it is set to an exponential decreasing sequence of length lambda.length between lambda.max and lambda.min.</td>
</tr>
<tr>
<td>lambda.min</td>
<td>Minimum value of lambda to consider when selecting the optimal value of lambda. A strictly positive numeric or NULL (default). When NULL, it is equal to 0.0001 times lambda.max. This argument is ignored when lambda.vector is not NULL.</td>
</tr>
<tr>
<td>lambda.max</td>
<td>Maximum value of lambda to consider when selecting the optimal value of lambda. A strictly positive numeric larger than lambda.min or NULL (default). In the latter case, lambda.max will be determined based on the used penalty types such that it is one of the smallest values of lambda that results in an intercept-only model. This argument is ignored when lambda.vector is not NULL.</td>
</tr>
<tr>
<td>lambda.length</td>
<td>Number of lambda values to consider when selecting the optimal value of lambda. A strictly positive integer, default is 50. This argument is ignored when lambda.vector is not NULL.</td>
</tr>
<tr>
<td>lambda.reest</td>
<td>Logical indicating if the re-estimated coefficients are used when selecting lambda, default is FALSE. This argument is only used if reest is TRUE.</td>
</tr>
<tr>
<td>k</td>
<td>Number of folds when selecting lambda using cross-validation. A strictly positive integer, default is 5 (i.e. five-fold cross-validation). This number cannot be larger than the number of observations. Note that cross-validation with one fold (k=1) is the same as in-sample selection of lambda.</td>
</tr>
<tr>
<td>oos.prop</td>
<td>Proportion of the data that is used as the validation sample when selecting lambda out-of-sample. A numeric strictly between 0 and 1, default is 0.2. This argument is ignored when validation.index is not NULL.</td>
</tr>
<tr>
<td>validation.index</td>
<td>Vector containing the row indices of the data matrix corresponding to the observations that are used as the validation sample. This argument is only used when lambda is selected out-of-sample. Default is NULL meaning that randomly 100{oos.prop}% of the data are used as validation sample.</td>
</tr>
<tr>
<td>ncores</td>
<td>Number of cores used when performing cross-validation. A strictly positive integer or NULL (default). When NULL, max(nc-1, 1) cores are used where nc is the number of cores as determined by detectCores.</td>
</tr>
<tr>
<td>po.ncores</td>
<td>Number of cores used when computing the proximal operators. A strictly positive integer or NULL (default). When NULL or ncores &gt; 1, po.ncores is set to 1.</td>
</tr>
<tr>
<td>print</td>
<td>A logical indicating if intermediate results need to be printed, default is FALSE.</td>
</tr>
</tbody>
</table>

**Details**

More details on the selection of lambda can be found in the package vignette.
Value
A list with elements named as the arguments.

See Also
Fitting procedures: `glmsmurf` and `glmsmurf.fit` (given design matrix), `glm.control`

Examples
```r
## See example(plot_lambda) for examples
```

---

**p**  
*Define Individual Subpenalties for a Multi-Type Regularized GLM*

Description
Function used to define regularization terms in a `glmsmurf` model formula.

Usage
```r
p(pred1, pred2 = NULL, pen = "lasso", refcat = NULL, group = NULL)
```

Arguments
- **pred1**: Name of the predictor used in the regularization term.
- **pred2**: Either `NULL` (default) meaning that only one predictor is used in the regularization term, or the name of the second predictor that is used in a 2D Fused Lasso regularization term.
- **pen**: Type of penalty for this predictor, one of
  - "none" (no penalty),
  - "lasso" (Lasso),
  - "grouplasso" (Group Lasso),
  - "flasso" (Fused Lasso),
  - "gflasso" (Generalized Fused Lasso),
  - "2dflasso" (2D Fused Lasso),
  - "ggflasso" (Graph-Guided Fused Lasso).
  Default is "lasso".
- **refcat**: Reference level when `pred1` is a factor and `pen` is "none", "flasso", "gflasso", or "ggflasso"; otherwise `refcat` is ignored. Default is `NULL` which means that the first level of `pred1` is used as the reference level (if `refcat` is not ignored).
- **group**: Group to which the predictor belongs, only used for a Group Lasso penalty. Default is `NULL` which means that predictor does not belong to a group.
Details

Predictors with no penalty, a Lasso penalty or a Group Lasso penalty should be numeric or a factor which can be non-numeric. Predictors with a Fused Lasso, Generalized Fused Lasso, Graph-Guided Fused Lasso or 2D Fused Lasso penalty should be given as a factor which can also be non-numeric. When a predictor is given as a factor, there cannot be any unused levels. For a predictor with a Fused Lasso penalty, the levels should be ordered from smallest to largest. The first level will be the reference level, but this can be changed using the \texttt{refcat} argument.

When \( \lambda_1 \lambda_1 > 0 \) or \( \lambda_1 \lambda_2 > 0 \) in \texttt{glmsmurf}, no reference level is used for the Fused Lasso, Generalized Fused Lasso and Graph-Guided Fused Lasso penalties, and \texttt{refcat} will hence be ignored.

If \( \text{pred2} \) is different from \texttt{NULL}, \text{pen} should be set to "2dflasso", and vice versa. Note that there cannot be any unused levels in the interaction between \text{pred1} and \text{pred2}.

When adding an interaction between \text{pred1} and \text{pred2} with a 2D Fused Lasso penalty, the 1D effects should also be present in the model and the reference categories for the 1D predictors need to be the respective first levels. The reference level for the 2D predictor will then be the 2D level where at least one of the 1D components is equal to the 1D reference levels. It is also allowed to add binned factors, of predictors that are included in the model, in the interaction. They should have the original predictor name + '.binned' as predictor names. For example: the original predictors 'age' and 'power' are included in the model and the interaction of 'age.binned' and 'power.binned' can also be present in the model formula.

An overview of the different penalty types and their usage can be found in the package vignette.

See Also

\texttt{glmsmurf}

Examples

```r
# Munich rent data from catdata package
data("rent", package = "catdata")

# The considered predictors are the same as in
# Response is monthly rent per square meter in Euro

# Urban district in Munich
rent$area <- as.factor(rent$area)

# Decade of construction
rent$year <- as.factor(floor(rent$year / 10) * 10)

# Number of rooms
rent$rooms <- as.factor(rent$rooms)

# Quality of the house with levels "fair", "good" and "excellent"
rent$quality <- as.factor(rent$good + 2 * rent$best)
levels(rent$quality) <- c("fair", "good", "excellent")
```
# Floor space divided in categories (0, 30), [30, 40), ..., [130, 140)
sizeClasses <- c(0, seq(30, 140, 10))
rent$size <- as.factor(sizeClasses[findInterval(rent$size, sizeClasses)])

# Is warm water present?
rent$warm <- factor(rent$warm, labels = c("yes", "no"))

# Is central heating present?
rent$central <- factor(rent$central, labels = c("yes", "no"))

# Does the bathroom have tiles?
rent$tiles <- factor(rent$tiles, labels = c("yes", "no"))

# Is there special furniture in the bathroom?
rent$batheextra <- factor(rent$batheextra, labels = c("no", "yes"))

# Is the kitchen well-equipped?
rent$kitchen <- factor(rent$kitchen, labels = c("no", "yes"))

# Create formula with 'rentm' as response variable,
# 'area' with a Generalized Fused Lasso penalty,
# 'year', 'rooms', 'quality' and 'size' with Fused Lasso penalties
# where the reference category for 'year' is changed to 2000,
# 'warm' and 'central' are in one group for the Group Lasso penalty,
# 'tiles' and 'batheextra' are not regularized and
# 'kitchen' has a Lasso penalty
formu <- rentm ~ p(area, pen = "gflasso") +
    p(year, pen = "flasso", refcat = 2000) + p(rooms, pen = "flasso") +
    p(quality, pen = "flasso") + p(size, pen = "flasso") +
    p(warm, pen = "grouplasso", group = 1) + p(central, pen = "grouplasso", group = 1) +
    p(tiles, pen = "none") + batheextra +
    p(kitchen, pen = "lasso")

# Fit a multi-type regularized GLM using the SMuRF algorithm.
# We use standardization adaptive penalty weights based on an initial GLM fit.
munich.fit <- glmsmurf(formula = formu, family = gaussian(), data = rent,
    pen.weights = "glm.stand", lambda = 0.1)

# Model summary
summary(munich.fit)

---

**plot.glmsmurf**  
*Plot Coefficients of Estimated Model*

**Description**

Function to plot the coefficients of the estimated model.
plot_lambda

Usage

```r
## S3 method for class 'glmsmurf'
plot(x, xlab = "Index", ylab = "Estimated coefficients", basic = FALSE, ...)
```

Arguments

- `x`: An object of class 'glmsmurf', typically the result of a call to `glmsmurf` or `glmsmurf.fit`.
- `xlab`: Label for the x-axis, default is "Index".
- `ylab`: Label for the y-axis, default is "Estimated coefficients".
- `basic`: Logical indicating if the basic lay-out is used for the plot, default is FALSE.
- `...`: Additional arguments for the `plot` function.

Details

When `basic=FALSE`, the improved lay-out for the plot is used. Per predictor, groups of equal coefficients are indicated in the same color (up to 8 colors), and zero coefficients are indicated by grey squares.

See Also

- `plot_reest`, `coef.glmsmurf`, `summary.glmsmurf`, `glmsmurf`, `glmsmurf-class`

Examples

```r
## See example(glmsmurf) for examples
```

---

### plot_lambda

**Plot Goodness-of-Fit Statistics or Information Criteria**

**Description**

Function to plot the goodness-of-fit statistics or information criteria as a function of lambda when lambda is selected in-sample, out-of-sample or using cross-validation.

**Usage**

```r
plot_lambda(x, ...)  
```

```r
## S3 method for class 'glmsmurf'
plot_lambda(
  x,
  xlab = NULL,
  ylab = NULL,
  lambda.opt = TRUE,
  cv1se = TRUE,
)  
```
plot_lambda

log.lambda = TRUE,
...
)

Arguments

x An object for which the extraction of goodness-of-fit statistics or information criteria is meaningful. E.g. an object of class `glmsmurf`, typically the result of a call to glmsmurf or glmsmurf.fit.
...

Additional arguments for the plot function.

xlab Label for the x-axis. The default value is NULL which means that substitute(log(lambda)) is used when log.lambda=TRUE and substitute(lambda) when log.lambda=FALSE.

ylab Label for the y-axis. The default value is NULL which means that the y-axis label is determined based on method that was used to select lambda.

lambda.opt Logical indicating if the optimal value of lambda should be indicated on the plot by a vertical dashed line. Default is TRUE.

cv1se Logical indicating if the standard errors should be indicated on the plot when cross-validation with the one standard error rule is performed (e.g. "cv1se.dev"). Default is TRUE.

log.lambda Logical indicating if the logarithm of lambda is plotted on the x-axis, default is TRUE.

Details

This plot can only be made when lambda is selected in-sample, out-of-sample or using cross-validation (possibly with the one standard error rule), see the lambda argument of glmsmurf.

See Also

`glmsmurf`, `glmsmurf-class`

Examples

# Munich rent data from catdata package
data("rent", package = "catdata")

# The considered predictors are the same as in
# Response is monthly rent per square meter in Euro

# Urban district in Munich
rent$area <- as.factor(rent$area)

# Decade of construction
rent$year <- as.factor(floor(rent$year / 10) * 10)

# Number of rooms
rent$rooms <- as.factor(rent$rooms)

# Quality of the house with levels "fair", "good" and "excellent"
rent$quality <- as.factor(rent$good + 2 * rent$best)
levels(rent$quality) <- c("fair", "good", "excellent")

# Floor space divided in categories (0, 30), [30, 40), ..., [130, 140)
sizeClasses <- c(0, seq(30, 140, 10))
rent$size <- as.factor(sizeClasses[findInterval(rent$size, sizeClasses)])

# Is warm water present?
rent$warm <- factor(rent$warm, labels = c("yes", "no"))

# Is central heating present?
rent$central <- factor(rent$central, labels = c("yes", "no"))

# Does the bathroom have tiles?
rent$tiles <- factor(rent$tiles, labels = c("yes", "no"))

# Is there special furniture in the bathroom?
rent$bathextra <- factor(rent$bathextra, labels = c("no", "yes"))

# Is the kitchen well-equipped?
rent$kitchen <- factor(rent$kitchen, labels = c("no", "yes"))

# Create formula with 'rentm' as response variable,
# 'area' with a Generalized Fused Lasso penalty,
# 'year', 'rooms', 'quality' and 'size' with Fused Lasso penalties,
# and the other predictors with Lasso penalties.
formu <- rentm ~ p(area, pen = "gflasso") +
  p(year, pen = "flasso") + p(rooms, pen = "flasso") +
  p(quality, pen = "flasso") + p(size, pen = "flasso") +
  p(warm, pen = "lasso") + p(central, pen = "lasso") +
  p(tiles, pen = "lasso") + p(bathextra, pen = "lasso") +
  p(kitchen, pen = "lasso")

# Fit a multi-type regularized GLM using the SMuRF algorithm and select the optimal value of lambda
# using cross-validation (with the deviance as loss measure and the one standard error rule).
# We use standardization adaptive penalty weights based on an initial GLM fit.
# The number of values of lambda to consider in cross-validation is
# set to 10 using the control argument (default is 50).
munich.fit.cv <- glmmsmurf(formula = formu, family = gaussian(), data = rent,
  pen.weights = "glm.stand", lambda = "cv1se.dev",
  control = list(lambda.length = 10L, ncores = 1L))

# Plot average deviance over cross-validation folds as a function of the logarithm of lambda
plot_lambda(munich.fit.cv)
# Zoomed plot
plot_lambda(munich.fit.cv, xlim = c(-7, -3.5), ylim = c(1575, 1750))
plot_reest

Plot Coefficients of Re-estimated Model

Description

Function to plot the coefficients of the re-estimated model.

Usage

plot_reest(x, ...)

## S3 method for class 'glmsmurf'
plot_reest(
  x,
  xlab = "Index",
  ylab = "Re-estimated coefficients",
  basic = FALSE,
  ...
)

Arguments

x  An object for which the extraction of model coefficients is meaningful. E.g. an object of class 'glmsmurf', typically the result of a call to glmsmurf or glmsmurf.fit.
...
  Additional arguments for the plot function.
xlab  Label for the x-axis, default is "Index".
ylab  Label for the y-axis, default is "Re-estimated coefficients".
basic  Logical indicating if the basic lay-out is used for the plot, default is FALSE.

Details

When the re-estimated model is not included in x, the coefficients of the estimated model in x are plotted with a warning.

See plot.glmsmurf for more details.

See Also

plot.glmsmurf, coef_reest, summary.glmsmurf, glmsmurf, glmsmurf-class

Examples

## See example(glm) for examples
**predict.glmsmurf**  
Predictions Using Estimated Model

**Description**
Function to obtain predictions using the estimated model.

**Usage**
```r
## S3 method for class 'glmsmurf'
predict(
  object,
  newdata = NULL,
  newoffset = NULL,
  type = c("link", "response", "terms"),
  ...
)
```

**Arguments**
- `object`: An object of class 'glmsmurf', typically the result of a call to glmsmurf or glmsmurf.fit.
- `newdata`: Optionally, a data frame containing the predictors used in the prediction. This can only be used when object contains a formula. When newdata is omitted, the predictions are based on the data used to fit the model in object.
- `newoffset`: Optionally, a vector containing a new offset to be used in the prediction. When newoffset is omitted, the predictions use the offset which was used to fit the model in object.
- `type`: Type of prediction. The default is on the scale of the linear predictors ("link"). Another option is on the scale of the response variable ("response"). For type "terms" a matrix containing the fitted values of each term in the model, on the linear predictor scale, is returned.
- `...`: Additional arguments which are currently ignored.

**Value**
A vector containing the predicted values using the estimated model in object.

**See Also**
- predict_reest, predict.glm, predict.glmsmurf, glmsmurf-class

**Examples**
```r
## See example(glmsmurf) for examples
```
Predictions Using Re-estimated Model

**Description**

Function to obtain predictions using the re-estimated model.

**Usage**

```r
predict_reest(object, ...)  
## S3 method for class 'glmsmurf'
predict_reest(  
  object,  
  newdata = NULL,  
  newoffset = NULL,  
  type = c("link", "response", "terms"),  
  ...  
)
```

**Arguments**

- `object` An object for which predictions are meaningful. E.g. an object of class 'glmsmurf', typically the result of a call to `glmsmurf` or `glmsmurf.fit`.
- `...` Additional arguments which are currently ignored.
- `newdata` Optionally, a data frame containing the predictors used in the prediction. This can only be used when `object` contains a formula. When `newdata` is omitted, the predictions are based on the data used to fit the model in `object`.
- `newoffset` Optionally, a vector containing a new offset to be used in the prediction. When `newoffset` is omitted, the predictions use the offset which was used to fit the model in `object`.
- `type` Type of prediction. The default is on the scale of the linear predictors ("link"). Another option is on the scale of the response variable ("response"). For type "terms" a matrix containing the fitted values of each term in the model, on the linear predictor scale, is returned.

**Value**

A vector containing the predicted values using the re-estimated model in `object`, when this is available, or, otherwise, the predicted values using the estimated model in `object` with a warning.

**See Also**

`predict.glmsmurf`, `predict.glm`, `predict.glmsmurf`, `glmsmurf-class`
residuals.glmsmurf

Examples
## See example(glmsmurf) for examples

---

residuals.glmsmurf  Residuals of Estimated Model

Description
Function to extract the residuals of the estimated model. resid is an alias for it.

Usage
## S3 method for class 'glmsmurf'
residuals(
  object,
  type = c("deviance", "pearson", "working", "response", "partial"),
  ...
)

## S3 method for class 'glmsmurf'
resid(
  object,
  type = c("deviance", "pearson", "working", "response", "partial"),
  ...
)

Arguments
  object  An object of class 'glmsmurf', typically the result of a call to glmsmurf or glmsmurf.fit.
  type    Type of residuals that should be returned. One of "deviance" (default), "pearson", "working", "response" or "partial".
  ...     Additional arguments which are currently ignored.

Details
See glm.summaries for an overview of the different types of residuals.

Value
A vector containing the residuals of the estimated model in object.

See Also
residuals_reest, residuals, glm.summaries, glmsmurf-class
residuals_reest

## See example(glmmsurf) for examples

---

### Description

Function to extract the residuals of the re-estimated model. `resid_reest` is an alias for it.

### Usage

```r
residuals_reest(object, ...)  
## S3 method for class 'glmmsurf'
residuals_reest(  
  object,  
  type = c("deviance", "pearson", "working", "response", "partial"),  
  ...  
)
```

```r
resid_reest(object, ...)  
## S3 method for class 'glmmsurf'
resid_reest(  
  object,  
  type = c("deviance", "pearson", "working", "response", "partial"),  
  ...  
)
```

### Arguments

- **object**: An object for which the extraction of model residuals is meaningful. E.g. an object of class `glmmsurf`, typically the result of a call to `glmmsurf` or `glmmsurf.fit`.
- **...**: Additional arguments which are currently ignored.
- **type**: Type of residuals that should be returned. One of "deviance" (default), "pearson", "working", "response" or "partial".

### Details

See `glm.summaries` for an overview of the different types of residuals.

### Value

A vector containing the residuals of the re-estimated model in `object` when they are available, or, otherwise, the residuals of the estimated model in `object` with a warning.
summary.glmsmurf

See Also

residuals.glmsmurf, residuals.glm, summaries.glmsmurf-class

Examples

## See example(glmsmurf) for examples

---

**summary.glmsmurf**  
*Summary of a Multi-Type Regularized GLM Fitted Using the SMuRF Algorithm*

Description

Function to print a summary of a glmsmurf-object.

Usage

```r
## S3 method for class 'glmsmurf'
summary(object, digits = 3L, ...)
```

Arguments

- `object`  
  An object of class `glmsmurf`, typically the result of a call to glmsmurf or glmsmurf.fit.

- `digits`  
  The number of significant digits used when printing, default is 3.

- `...`  
  Additional arguments which are currently ignored.

See Also

summary.glm, glmsmurf, glmsmurf-class

Examples

## See example(glmsmurf) for examples
Index

coeff, 3, 4, 16
coefficients.glmsmurf (coeff.glmsmurf), 3
coefficients_reest (coeff_reest), 3

detectCores, 18
deviance, 5, 16
deviance.glmsmurf, 4, 5
deviance_reest, 5, 5, 16

family, 9, 14, 16
fitted, 6, 7, 16
fitted.glmsmurf, 6, 7
fitted_reest, 6, 7, 16

formula, 9

glm, 11, 13–15, 17, 18
glm.control, 19
glm.summaries, 28–30
glmsmurf, 3–7, 7, 13, 15–17, 19, 20, 22, 23, 25–30
glmsmurf-class, 13
glmsmurf.control, 10, 11, 15, 16, 17
glmsmurf.fit, 3–7, 13, 15, 19, 22, 23, 25–30

lm, 17

p, 9, 11, 19
plot, 16, 22, 23, 25
plot.glmsmurf, 21, 25
plot_lambda, 16, 22
plot_reest, 16, 22, 25
predict, 16, 26, 27
predict.glm, 26, 27
predict.glmsmurf, 26, 27
predict_reest, 16, 26, 27

resid.glmsmurf (residuals.glmsmurf), 28
resid_reest (residuals_reest), 29
residuals, 16, 28, 30

smurf (smurf-package), 2
smurf-package, 2
speedglm, 15, 18
summary, 16
summary.glm, 30
summary.glmsmurf, 3–5, 22, 25, 30
terms, 16