

# Package ‘glinternet’

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**Type** Package

**Title** Learning Interactions via Hierarchical Group-Lasso  
Regularization

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**Depends**

**Suggests**

**Description** Group-Lasso INTERaction-NET. Fits linear pairwise-interaction models that satisfy strong hierarchy: if an interaction coefficient is estimated to be nonzero, then its two associated main effects also have nonzero estimated coefficients. Accommodates categorical variables (factors) with arbitrary numbers of levels, continuous variables, and combinations thereof. Implements the machinery described in the paper “Learning interactions via hierarchical group-lasso regularization” (JCGS 2015, Volume 24, Issue 3). Michael Lim & Trevor Hastie (2015) <DOI:10.1080/10618600.2014.938812>.

**License** GPL-2

**URL** [http://web.stanford.edu/~hastie/Papers/glinternet\\_jcgs.pdf](http://web.stanford.edu/~hastie/Papers/glinternet_jcgs.pdf)

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coef.glinternet      *Return main effect and interaction coefficients.*

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### Description

Returns the actual main effect and interaction coefficients that satisfy the sum constraints in a linear interaction model. See the paper below for details.

### Usage

```
## S3 method for class 'glinternet'
coef(object, lambdaIndex = NULL, ...)
```

### Arguments

object	Fitted "glinternet" model object.
lambdaIndex	Index of lambda value at which to extract coefficients. If NULL, return the coefficients for all values of lambda in the path.
...	Not used.

### Details

Returns the actual main effect and interaction coefficients. These satisfy the sum constraints in the original linear interaction model.

### Value

A list of length lambda if lambdaIndex is not provided. Otherwise, of length lambdaIndex. Each component (for each lambda) is itself a list, with components

mainEffects	A list with components cat and cont, each an index vector of the categorical and continuous (resp) main-effect variables. Just as in activeSet, the indexing is separate for each type of variable. See ?glinternet for details.
mainEffectsCoef	List of coefficients for the main effects in mainEffects, also with names cat and cont
interactions	List of interactions, with components contcont, catcont and catcat, each 2-column matrices of variable indices.
interactionsCoef	List of interaction coefficients for interactions, also with names contcont, catcont and catcat. For categorical-categorical interactions, each is provided as a L1 x L2 matrix.

### Author(s)

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**References**

"Learning interactions via hierarchical group-lasso regularization"

**See Also**

glinternet.cv, predict.glinternet, predict.glinternet.cv, plot.glinternet.cv, glinternet

**Examples**

```
Y = rnorm(100)
X = matrix(rnorm(100*10), nrow=100)
numLevels = rep(1, 10)
fit = glinternet(X, Y, numLevels)
coeffs = coef(fit)
```

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glinternet	<i>Fit a linear interaction model with group-lasso regularization that enforces strong hierarchy in the estimated coefficients</i>
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**Description**

The regularization path is computed along a grid of values for the regularization parameter lambda. Can deal with categorical variables with arbitrary numbers of levels, continuous variables, and combinations of the two. Accommodates squared error loss and logistic loss.

The multicore option requires that the package be compiled with OpenMP support. Examples of compilers that qualify include gcc ( $\geq 4.2$ ) and icc. We also recommend a higher level of optimization, such as -O3 in gcc.

**Usage**

```
glinternet(X, Y, numLevels, lambda = NULL, nLambda = 50, lambdaMinRatio = 0.01,
  interactionCandidates=NULL, interactionPairs=NULL, screenLimit = NULL, numToFind = NULL,
  family = c("gaussian", "binomial"), tol = 1e-05, maxIter=5000, verbose=FALSE,
  numCores = 1)
```

**Arguments**

X	Matrix of features or predictors with dimension nobs x nvars; each row is an observation vector. Categorical variables must be coded as 0, 1, 2, ...
Y	Target variable of length nobs. Continuous for squared error loss, 0-1 for logistic loss.
numLevels	Number of levels for each variable, of length nvars. Set to 1 for continuous variables.
lambda	A user supplied lambda sequence. Typical usage is to have the program compute its own lambda sequence based on nLambda and lambdaMinRatio. Supplying a value of lambda overrides this.

nLambda	The number of lambda values. Default is 50.
lambdaMinRatio	Smallest value for lambda, as a fraction of lambdaMax, the (data derived) entry value (i.e. the smallest value for which all coefficients are zero). The default is 0.01.
interactionCandidates	An optional vector of variable indices. This will force the algorithm to only consider interactions between interactionCandidates and all other variables.
interactionPairs	An optional nx2 matrix of variable indices. This will force the algorithm to only consider the interaction pairs defined by this matrix. For example, matrix(c(1,2,1,5), ncol=2, byrow=TRUE) restricts the model to two interaction pairs: one between variables 1 and 2, and another between 1 and 5.
screenLimit	If not null (the default), limits the size of the interaction search space to screenLimit x nvars by only considering interactions with the best screenLimit candidate main effects at each point along the regularization path. Set this accordingly for large problems or if there are memory limitations.
numToFind	Stops the program after numToFind interaction pairs are found. Default is null - fit all values of lambda.
family	A character string describing the target variable: "gaussian" for continuous (the default), "binomial" for logistic.
tol	Convergence tolerance in the adaptive FISTA algorithm.
maxIter	Maximum number of iterations in adaptive FISTA. Default 5000.
verbose	Prints progress. False by default.
numCores	Number of threads to run. For this to work, the package must be installed with OpenMP enabled. Default is 1 thread.

### Details

The sequence of models implied by lambda is fit by FISTA (fast iterative soft thresholding) with adaptive step size and adaptive momentum restart. The continuous features are standardized to have unit norm and mean zero before computing the lambda sequence and fitting. The returned coefficients are unstandardized. Categorical variables are not standardized.

### Value

An object of class `glinternet` with the components

call	The user function call.
fitted	The fitted values, with dimension nobs x nLambda. If numToFind is specified, the program is likely to stop before all nLambda models have been fit.
lambda	The actual lambda sequence used.
objValue	Objective values for each lambda.
activeSet	A list (of length nLambda) of the variables found. Internally, the categorical and continuous variables are separated into two groups, and each has their own indexing system (1-based). For example, the categorical-continuous interaction $c(i, j)$ refers to the interaction between the $i$ -th categorical variable with the $j$ -th continuous variable.

betahat	List (of length lambda) of coefficients for the variables in activeSet. The first component is the intercept. Subsequent entries correspond to the variables in activeSet. For example, if the first variable in activeSet is a 3-level categorical variable, then components 2-4 of betahat are the coefficients for this variable.
numLevels	The number of levels for each variable.
family	The target variable type.

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### References

Michael Lim and Trevor Hastie (2013) *Learning interactions via hierarchical group-lasso regularization*, <https://arxiv.org/abs/1308.2719>

### See Also

glinternet.cv, predict.glinternet, predict.glinternet.cv, plot.glinternet.cv, coef.glinternet

### Examples

```
# gaussian response, continuous features
Y = rnorm(100)
X = matrix(rnorm(100*10), nrow=100)
numLevels = rep(1, 10)
fit = glinternet(X, Y, numLevels)

#binary response, continuous features
Y = rbinom(100, 1, 0.5)
fit = glinternet(X, Y, numLevels, family="binomial")

#binary response, categorical variables
X = matrix(sample(0:2, 100*10, replace=TRUE), nrow=100)
numLevels = rep(3, 10)
fit = glinternet(X, Y, numLevels, family="binomial")
```

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glinternet.cv

*Cross-validation for glinternet*

---

### Description

Does k-fold cross validation for glinternet and returns a value of lambda.

**Usage**

```
glinternet.cv(X, Y, numLevels, nFolds = 10, lambda=NULL, nLambda=50,
lambdaMinRatio=0.01, interactionCandidates=NULL, interactionPairs=NULL,
screenLimit=NULL, family=c("gaussian", "binomial"), tol=1e-5, maxIter=5000,
verbose=FALSE, numCores=1)
```

**Arguments**

X	X matrix as in glinternet.
Y	Target Y as in glinternet.
numLevels	Number of levels numLevels as in glinternet.
nFolds	Number of folds - default is 10.
lambda	lambda as in glinternet.
nLambda	nLambda as in glinternet.
lambdaMinRatio	lambdaMinRatio as in glinternet.
interactionCandidates	interactionCandidates as in glinternet.
interactionPairs	interactionPairs as in glinternet.
screenLimit	screenLimit as in glinternet.
family	family as in glinternet.
tol	tol as in glinternet.
maxIter	maxIter as in glinternet.
verbose	verbose as in glinternet.
numCores	numCores as in glinternet.

**Details**

The lambda sequence is computed using all the data. nFolds models are fit, each time with one of the folds omitted. The error is accumulated, and the average error and standard deviation over the folds is computed. The lambda value that minimizes the average error is returned, and a model with this lambda is fit to the full data set.

**Value**

An object of class `glinternet.cv` with the components

call	The user function call.
glinternetFit	Glinternet object fitted on the full data using a lambda sequence that terminates at lambdaHat.
fitted	Vector for fitted values (same length as Y). This is from the model fitted at lambdaHat.
activeSet	activeSet is a list variables found for the model fitted with lambdaHat.
betahat	Unstandardized coefficients for the variables in activeSet.

lambda	The actual sequence of lambda values used for the cross validation.
lambdaHat	The value of lambda that minimizes the cv error curve.
lambdaHat1Std	The largest value of lambda that produces a cv error that is within 1 standard deviation of the minimum cv error. This will always be at least as large as lambdaHat.
cvErr	The vector of cross validation errors. Same length as lambda.
cvErrStd	Standard deviation for cv errors across the nFolds folds.
family	The response type.
numLevels	Input number of levels for each variable.
nFolds	The number of folds used.

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**See Also**

glinternet, predict.glinternet, predict.glinternet.cv, plot.glinternet.cv

**Examples**

```
Y = rnorm(100)
numLevels = sample(1:5, 10, replace=TRUE)
X = sapply(numLevels, function(x) if (x==1)
  rnorm(100) else sample(0:(x-1), 100, replace=TRUE))
fit = glinternet.cv(X, Y, numLevels, nFolds=3)
```

---

plot.glinternet.cv *Plot CV error from glinternetCV object.*

---

**Description**

Plots the cross validation error against the lambda index. Uses ggplot2 if found on the user's system.

**Usage**

```
## S3 method for class 'glinternet.cv'
plot(x, ...)
```

**Arguments**

x	"glinternetCV" object.
...	Not used.

**Value**

A plot of CV error.

**Author(s)**

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**See Also**

glinternet, glinternet.cv, predict.glinternet.cv, predict.glinternet

---

predict.glinternet      *Make predictions from a "glinternet" object.*

---

**Description**

Similar to other predict methods, this function returns fitted values on the response scale. Also gives the option to return the link function.

**Usage**

```
## S3 method for class 'glinternet'
predict(object, X, type = c("response", "link"), lambda=NULL, ...)
```

**Arguments**

object	Fitted "glinternet" model object.
X	Matrix of new values for which to make predictions. Must have the same number of variables as during training the model, and all the variables must have the same number of levels.
type	Return fitted Y values or the link function.
lambda	User input lambda sequence. Must be subset of the lambdas used in fitting. If NULL (the default), predict at all the lambdas used during fitting.
...	Not used. Other arguments to predict.

**Details**

If lambda is not specified, makes predictions at all the fitted lambda values. Users may provide their own lambda sequence, but this must be a subset of the values used to fit the models.

**Value**

A matrix of predicted values, with columns corresponding to each fitted model.



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**See Also**

glinternet, glinternet.cv, predict.glinternet.cv, plot.glinternet.cv

**Examples**

```
Y = rnorm(100)
numLevels = sample(1:5, 10, replace=TRUE)
X = sapply(numLevels, function(x) if (x==1)
rnorm(100) else sample(0:(x-1), 100, replace=TRUE))
fit = glinternet(X, Y, numLevels)
max(abs(fit$fitted - predict(fit, X)))
```

---

predict.glinternet.cv *Make predictions from a "glinternetCV" object.*

---

**Description**

Similar to other predict methods, this function returns fitted values on the response scale. Also gives the option to return the link function.

**Usage**

```
## S3 method for class 'glinternet.cv'
predict(object, X, type = c("response", "link"),
lambdaType=c("lambdaHat", "lambdaHat1Std"), ...)
```

**Arguments**

object	"glinternetCV" object.
X	Matrix of new values for which to make predictions. Must have the same number of variables as during training the model, and all the variables must have the same number of levels.
type	Return fitted Y values or the link function.
lambdaType	lambdaHat corresponds to the lambda value that gives the minimum CV error. lambdaHat1Std picks the largest value of lambda for which the CV error is within 1 standard error of the minimum.
...	Not used.

**Details**

Makes predictions using the model fitted at the appropriate lambda value.

**Value**

A vector of predicted values.

**Author(s)**

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**See Also**

`glinternet`, `glinternet.cv`, `predict.glinternet`

**Examples**

```
Y = rnorm(100)
numLevels = sample(1:5, 10, replace=TRUE)
X = sapply(numLevels, function(x) if (x==1)
  rnorm(100) else sample(0:(x-1), 100, replace=TRUE))
fit = glinternet.cv(X, Y, numLevels, nFolds=3)
max(abs(fit$fitted - predict(fit, X)))
```

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