Package ‘rare’

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Type Package

Title Linear Model with Tree-Based Lasso Regularization for Rare Features

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Description Implementation of an alternating direction method of multipliers algorithm for fitting a linear model with tree-based lasso regularization, which is proposed in Algorithm 1 of Yan and Bien (2018) <arXiv:1803.06675>. The package allows efficient model fitting on the entire 2-dimensional regularization path for large datasets. The complete set of functions also makes the entire process of tuning regularization parameters and visualizing results hassle-free.

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rare-package     Model path for tree-based lasso framework for selecting rare features

Description

The package fits the linear model with tree-based lasso regularization proposed in Yan and Bien (2018) using alternating direction method of multipliers (ADMM). The ADMM algorithm is proposed in Algorithm 1 of the same paper. The package also provides tools for tuning regularization parameters, making predictions from the fitted model and visualizing recovered groups of the covariates in a dendrogram.

Details

Its main functions are rarefit, rarefit.cv, rarefit.predict, group.recover and group.plot.

Author(s)

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References

**data.dtm**

**Document-term matrix for adjectives in TripAdvisor hotel reviews**

**Description**


**Usage**

data.dtm

**Format**

An object of class `dgCMatrix` with 500 rows and 200 columns.

**See Also**

data.rating, data.hc.

---

**data.hc**

**Hierarchical clustering tree for adjectives in TripAdvisor data set**

**Description**

An `hclust` tree for the 200 adjectives appearing in the TripAdvisor reviews. The tree was generated with 100-dimensional word embeddings pre-trained by GloVe (Pennington et al., 2014) on Gigaword5 and Wikipedia2014 corpora for the adjectives.

**Usage**

data.hc

**Format**

An object of class `hclust` of length 7.

**Source**

Embeddings available at [http://nlp.stanford.edu/data/glove.6B.zip](http://nlp.stanford.edu/data/glove.6B.zip)

**References**

data.rating  
*TripAdvisor hotel review ratings*

**Description**

A length-500 TripAdvisor review ratings on the scale 1 to 5.

**Usage**

data.rating

**Format**

An object of class `integer` of length 500.

**Source**

TripAdvisor Data Set used in https://www.cs.virginia.edu/~hw5x/paper/rp166f-wang.pdf

---

**find.leaves**  
*Find all descendant leaves of a node in an hclust tree*

**Description**

The function recursively finds all leaves that are descendants of a node in an `hclust` tree.

**Usage**

`find.leaves(ind, merge)`

**Arguments**

- **ind**  
  Index of the tree node. For an `hclust` tree of \( p \) leaves, \(-j\) denotes the \( j \)th leaf and \( k \) denotes the interior node formed at the \( k \)th merging in constructing the tree. The range of \( \text{ind} \) is \([-1, \ldots, -p, 1, \ldots, p-1]\) where \( p-1 \) is the number of interior nodes.

- **merge**  
  A \((p-1)\)-by-2 matrix that encodes the order of mergings in constructing the tree. `merge` uses the same notation for nodes and mergings in an `hclust` object. See `hclust` for details.

**Value**

Returns a sequence of indices for descendant leaves in the leaf set \([1, \ldots, p]\). Unlike the notation used in `ind`, we use positive integers to denote leaves here.
Examples

```r
## Not run:
hc <- hclust(dist(USArrests), "ave")
# Descendant leaves of the 10th leaf (should be itself)
find.leaves(-10, hc$merge)

# Descendant leaves of the 10th interior node
find.leaves(10, hc$merge)

# Descendant leaves of the root (should be all leaves)
ind_root <- nrow(hc$merge)
all.equal(find.leaves(ind_root, hc$merge), hc$order)

## End(Not run)
```

---

**group.plot**

*Visualize groups by coloring branches and leaves of an hclust tree*

**Description**

The function plots an hclust tree with branches and leaves colored based on group membership. The groups span the covariate indices \{1, ..., nvars\}. Covariates from the same group share equal coefficient (\(\beta\)), and sibling groups have different coefficients. The function determines groups based on the sparsity in \(\gamma\). In an hclust tree, the branch and leaf are colored in blue, red or gray according to \(\beta[i]\) being positive, negative or zero, respectively. The larger the magnitude of \(\beta[i]\) is, the darker the color will be. So branches and leaves from the same group will have the same color.

**Usage**

```r
group.plot(beta, gamma, A, hc, nbreaks = 20)
```

**Arguments**

- **beta**: Length-\(nvars\) vector of covariate coefficient.
- **gamma**: Length-\(nnodes\) vector of latent variable coefficient. Note that rarefit returns NA as gamma value when \(\alpha\) is zero, in which case our problem becomes the lasso on \(\beta\).
- **A**: \(nvars\)-by-\(nnodes\) binary matrix encoding ancestor-descendant relationships between leaves and nodes in the tree.
- **hc**: An hclust tree of \(nvars\) leaves where each leaf corresponds to a covariate.
- **nbbreaks**: Number of breaks in binning \(\beta\) elements (positive part and negative part are done separately). Each bin is associated with a color based on the magnitude and positivity/negativity of \(\beta\) elements in the bin.
Examples

```r
## Not run:
# See vignette for more details.
set.seed(100)
ts <- sample(1:length(data$rating), 400) # Train set indices
# Fit the model on train set
ourfit <- rarefit(y = data$rating[ts], X = data$dtm[ts, ], hc = data$hc, lam.min.ratio = 1e-6,
nlam = 20, nalpha = 10, rho = 0.01, eps1 = 1e-5, eps2 = 1e-5, maxite = 1e4)
# Cross validation
ourfit.cv <- rarefit.cv(ourfit, y = data$rating[ts], X = data$dtm[ts, ],
rho = 0.01, eps1 = 1e-5, eps2 = 1e-5, maxite = 1e4)
# Visualize the groups at optimal beta and gamma
ibest.lambda <- ourfit.cv$ibest[1]
ibest.alpha <- ourfit.cv$ibest[2]
beta.opt <- ourfit$beta[[ibest.alpha]][, ibest.lambda]
gamma.opt <- ourfit.gamma[[ibest.alpha]][, ibest.lambda] # works if ibest.alpha > 1
# Visualize the groups at optimal beta and gamma
group.plot(beta.opt, gamma.opt, ourfit$A, data$hc)

## End(Not run)
```

---

**group.recover**

Recover aggregated groups of leaf indices

Description

The function finds aggregated groups of leaf indices by traversing non-zero gamma elements and finding descendant leaves at each gamma element. In our problem, gamma are latent variables corresponding to tree nodes. The order of the traversal is post-order, i.e., a node is visited after its descendants.

Usage

```r
group.recover(gamma, A, postorder = seq(ncol(A)))
```

Arguments

- **gamma**: Length-`nnodes` latent variable coefficients. Note that `rarefit` returns `NA` as gamma value when alpha is zero, in which case our problem becomes the lasso on beta.
- **A**: `nvars`-by-`nnodes` binary matrix encoding ancestor-descendant relationships between leaves and nodes in the tree.
- **postorder**: Length-`nnodes` integer vector encoding post-order traversal of the tree nodes such that `seq(nnodes)[postorder]` ensures a node appear after its descendants. Default is `seq(nnodes)`, which gives post-order when `A` is generated using `tree.matrix` for an hclust tree.
Value

Returns a list of recovered groups of leaf indices.

Examples

```r
## Not run:
# See vignette for more details.
set.seed(100)
ts <- sample(1:length(data.rating), 400) # Train set indices
# Fit the model on train set
ourfit <- rarefit(y = data.rating[ts], X = data.dtm[ts, ], hc = data.hc, lam.min.ratio = 1e-6,
nlam = 20, nalpha = 10, rho = 0.01, eps1 = 1e-5, eps2 = 1e-5, maxite = 1e4)
# Cross validation
ourfit.cv <- rarefit.cv(ourfit, y = data.rating[ts], X = data.dtm[ts, ],
                        rho = 0.01, eps1 = 1e-5, eps2 = 1e-5, maxite = 1e4)
# Group recovered at optimal beta and gamma
ibest.lambda <- ourfit.cv$ibest[1]
ibest.alpha <- ourfit.cv$ibest[2]
gamma.opt <- ourfit$gamma[[ibest.alpha]][, ibest.lambda] # works if ibest.alpha > 1
groups.opt <- group.recover(gamma.opt, ourfit$A)
```

## End(Not run)

---

### rarefit

**Fit the rare feature selection model**

---

**Description**

Fit the rare feature selection model proposed in Yan and Bien (2018):

\[
\min_{\beta, \gamma} 0.5 \cdot ||y - X\beta - \beta_01_n||_2^2 + \lambda \cdot (\alpha \cdot ||\gamma - \text{root}||_1 + (1 - \alpha) \cdot ||\beta||_1)
\]

using an alternating direction method of multipliers (ADMM) algorithm described in Algorithm 1 of the same paper. The regularization path is computed over a two-dimensional grid of regularization parameters: `lambda` and `alpha`. Of the two, `lambda` controls the overall amount of regularization, and `alpha` controls the tradeoff between sparsity and fusion of $\beta$ (larger `alpha` induces more fusion in $\beta$).

**Usage**

```r
rarefit(y, X, A = NULL, Q = NULL, hc, intercept = T, lambda = NULL,
        alpha = NULL, nlam = 50, lam.min.ratio = 1e-04, nalpha = 10,
        rho = 0.01, eps1 = 1e-06, eps2 = 1e-05, maxite = 1e+06)
```
Arguments

**y**  
Length-nobs response variable.

**X**  
nobs-by-nvars input matrix: each row is an observation vector and each column stores a count covariate.

**A**  
nvars-by-nnodes binary matrix encoding ancestor-descendant relationships between leaves and tree nodes, where nnodes is the total number of tree nodes. A[i,j] is 1 if the ith leaf is a descendant of the jth node in the tree, and 0 otherwise. A should be in sparse matrix format (inherit from class `sparseMatrix` as in package `Matrix`). When A is NULL, the function will learn A from hc.

**Q**  
(nvars+nnodes)-by-nnodes matrix with columns forming an orthonormal basis for the null space of \([I_nvars : -A]\). When Q is NULL, the function will learn Q using the singular value decomposition.

**hc**  
An hclust tree of nvars leaves where each leaf corresponds to a covariate. If the tree is not an hclust object, user needs to provide the matrix A instead.

**intercept**  
Whether intercept be fitted (default = TRUE) or set to zero (FALSE).

**lambda**  
A user-supplied lambda sequence. Typical usage is to have the program compute its own lambda sequence based on nlam and lam.min.ratio.

**alpha**  
A user-supplied alpha sequence. If letting the program compute its own alpha sequence, a length-nalpha sequence of equally-spaced alpha values between 0 and 1 will be used. In practice, user may want to provide a more fine alpha sequence to tune the model to its best performance (e.g., alpha = c(1-exp(seq(0, log(1e-2), len = nalpha)).

**nlam**  
Number of lambda values (default = 50).

**lam.min.ratio**  
Smallest value for lambda, as a fraction of lambda.max (i.e., the smallest value for which all coefficients are zero). The default value is 1e-4.

**nalpha**  
Number of alpha values (default = 10).

**rho**  
Penalty parameter for the quadratic penalty in the ADMM algorithm. The default value is 1e-2.

**eps1**  
Convergence threshold in terms of the absolute tolerance level for the ADMMM algorithm. The default value is 1e-6.

**eps2**  
Convergence threshold in terms of the relative tolerance level for the ADMM algorithm. The default value is 1e-5.

**maxite**  
Maximum number of passes over the data for every pair of (lambda, alpha). The default value is 1e6.

Details

The function splits model fitting path by alpha. At each alpha value, the model is fit on the entire sequence of lambda with warm start. We recommend including an intercept (by setting intercept=T) unless the input data have been centered.

Value

Returns regression coefficients for beta and gamma and intercept beta0. We use a *matrix-nested-within-list* structure to store the coefficients: each list item corresponds to an alpha value; matrix (or vector) in that list item stores coefficients at various lambda values by columns (or entries).
beta0  
Length-nalpha list with each item storing intercept across various lambda in a vector: \( \text{beta0}[[j]][i] \) is intercept fitted at \((\text{lambda}[i], \text{alpha}[j])\). If intercept = FALSE, beta0 is NULL.

beta  
Length-nalpha list with each item storing beta coefficient at various lambda in columns of a nvars-by-nlam matrix: \( \text{beta}[[j]][, i] \) is beta coefficient fitted at \((\text{lambda}[i], \text{alpha}[j])\).

gamma  
Length-nalpha list with each item storing gamma coefficient at various lambda in columns of a nnodes-by-nlam matrix: \( \text{gamma}[[j]][, i] \) is gamma coefficient vector fitted at \((\text{lambda}[i], \text{alpha}[j])\). If \( \text{alpha}[j] = 0 \), the problem becomes the lasso on beta and is solved with \text{glmnet} on beta, in which case \( \text{gamma}[[j]] = \text{NA} \).

lambda  
Sequence of lambda values used in model fit.

alpha  
Sequence of alpha values used in model fit.

A  
Binary matrix encoding ancestor-descendant relationship between leaves and nodes in the tree.

Q  
Matrix with columns forming an orthonormal basis for the null space of \( [I_{n,\text{vars}} : -A] \).

intercept  
Whether an intercept is included in model fit.

References


See Also

\texttt{rarefit.cv, rarefit.predict}

Examples

```r
## Not run:
# See vignette for more details.
s.set.seed(100)
ts <- sample(1:length(data.rating), 400) # Train set indices
# Fit the model on train set
t.ourfit <- rarefit(y = data.rating[ts], X = data.dtm[ts, ], hc = data.hc, lam.min.ratio = 1e-6,
                   nlam = 20, nalpha = 10, rho = 0.01, eps1 = 1e-5, eps2 = 1e-5, maxite = 1e4)

## End(Not run)
```
rarefit.cv  

*Perform K-fold cross validation*

**Description**

The function does K-fold cross validation (CV) to choose an optimal pair of \((\lambda, \alpha)\) on which the model performs best according to the chosen error metric: mean squared error or mean absolute error.

**Usage**

```
rarefit.cv(fitObj, y, X, errtype = "mean-squared-error", nfolds = 5, ...)```

**Arguments**

- `fitObj` Output of `rarefit`
- `y` Response variable.
- `X` \(nobs\)-by-\(nvars\) input matrix: each row is an observation vector and each column stores a count covariate.
- `errtype` Type of error metric used in cross validation. Available choices are *mean-squared-error* (default) and *mean-absolute-error*.
- `nfolds` Number of folds (default is 5)
- `...` Other arguments that can be passed to `rarefit`

**Value**

- `folds` A length-\(nfolds\) list with the \(k\)th element being elements in the \(k\)th fold.
- `errs` A \(nlam\)-by-\(nalpha\)-by-\(nfolds\) 3-dimensional array of errors. \(errs[i,j,k]\) is error incurred in using \(\lambda[i]\) and \(\alpha[j]\) on the \(k\)th fold.
- `m` A \(nlam\)-by-\(nalpha\) matrix for storing CV error (i.e., mean error across folds). \(m[i,j]\) is CV error incurred in using \(\lambda[i]\) and \(\alpha[j]\).
- `se` A \(nlam\)-by-\(nalpha\) matrix for storing standard error across folds. \(se[i,j]\) is standard error incurred in using \(\lambda[i]\) and \(\alpha[j]\).
- `ibest` Indices of pair of \((\lambda, \alpha)\) minimizing CV error.
- `lambda.best` Value of \(\lambda\) minimizing CV error.
- `alpha.best` Value of \(\alpha\) minimizing CV error.

**See Also**

`rarefit`, `rarefit.predict`
## Examples

```r
## Not run:
# See vignette for more details.
set.seed(100)
ts <- sample(1:length(data.rating), 400) # Train set indices
# Fit the model on train set
ourfit <- rarefit(y = data.rating[ts], X = data.dtm[ts], , hc = data.hc, lam.min.ratio = 1e-6, 
nlam = 20, nalp = 10, rho = 0.01, eps1 = 1e-5, eps2 = 1e-5, maxite = 1e4)
# Cross validation
ourfit.cv <- rarefit.cv(ourfit, y = data.rating[ts], X = data.dtm[ts], , 
 rho = 0.01, eps1 = 1e-5, eps2 = 1e-5, maxite = 1e4)

## End(Not run)
```

---

### rarefit.predict

*Make predictions from a rarefit object and a rarefit.cv object*

## Description

The function makes predictions using a rarefit object at optimal (lambda, alpha) chosen by `rarefit.cv`.

## Usage

```r
rarefit.predict(fitobj, cvobj, newx)
```

## Arguments

- **fitobj**: Output of `rarefit`.
- **cvobj**: Output of `rarefit.cv`.
- **newx**: Matrix of new values for x at which predictions are made.

## Value

Returns a sequence of predictions.

## See Also

`rarefit`, `rarefit.cv`
Examples

```r
## Not run:
# See vignette for more details.
set.seed(100)
ts <- sample(1:length(data.rating), 400) # Train set indices
# Fit the model on train set
ourfit <- rarefit(y = data.rating[ts], X = data.dtm[ts], hc = data.hc, lam.min.ratio = 1e-6,
nlam = 20, nalpha = 10, rho = 0.01, eps1 = 1e-5, eps2 = 1e-5, maxite = 1e4)
# Cross validation
ourfit.cv <- rarefit.cv(ourfit, y = data.rating[ts], X = data.dtm[ts],
rho = 0.01, eps1 = 1e-5, eps2 = 1e-5, maxite = 1e4)
# Prediction on test set
pred <- rarefit.predict(ourfit, ourfit.cv, data.dtm[-ts], )
pred.error <- mean((pred - data.rating[-ts])^2)
## End(Not run)
```

---

tree.matrix  
Generate matrix A encoding ancestor-descendant relationships in an hclust tree  

Description

The function generates the binary matrix A defined in Yan and Bien (2018). The matrix encodes ancestor-descendant relationships between leaves and tree nodes in an hclust tree.

Usage

```r
tree.matrix(hc)
```

Arguments

- `hc`  
  An hclust object.

Value

Returns a nvars-by-nnodes binary matrix A where nvars is the number of leaves (we associate covariate with leaf), and nnodes is the number of tree nodes (including both leaves and interior nodes). For an hclust tree, nnodes = 2*nvars-1. A[i, j] is 1 if the i-th leaf is a descendant of the j-th node in the tree, and 0 otherwise. By default, we let the first nvars columns correspond to leaves and the remaining nvars-1 columns correspond to interior nodes. A is in sparse matrix format (inherit from class `sparseMatrix` as in package Matrix).

References

See Also

find.leaves for finding descendant leaves of a node.

Examples

```r
## Not run:
# For a perfect binary tree of depth 2 below
#
#   3
#   /\ 
#  1 2
#  /\ /\ 
# -1 -2 -3 -4
#
# A can expressed as the following:
A_true <- cbind(diag(4),
               as.matrix(c(1, 1, 0, 0)),
               as.matrix(c(0, 0, 1, 1)),
               as.matrix(c(1, 1, 1, 1)))
# Now use tree.matrix to generate A
tree0 <- list()
tree0$merge <- matrix(c(-1, -2, -3, -4, 1, 2),
                      ncol = 2, byrow = TRUE)
tree0$labels <- c("leaf1", "leaf2", "leaf3", "leaf4")
A <- tree.matrix(tree0)
all(A_true == as.matrix(A))

# Another example
hc <- hclust(dist(USArrests), "ave")
A <- tree.matrix(hc)
```

## End(Not run)
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