

# Package ‘FeaLect’

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**Type** Package

**Title** Scores Features for Feature Selection

**Version** 1.20

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**Author** Habil Zare

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**Depends** lars, rms

**Description** For each feature, a score is computed that can be useful for feature selection. Several random subsets are sampled from the input data and for each random subset, various linear models are fitted using lars method. A score is assigned to each feature based on the tendency of LASSO in including that feature in the models. Finally, the average score and the models are returned as the output. The features with relatively low scores are recommended to be ignored because they can lead to overfitting of the model to the training data. Moreover, for each random subset, the best set of features in terms of global error is returned. They are useful for applying Bolasso, the alternative feature selection method that recommends the intersection of features subsets.

**License** GPL (>= 2)

**LazyLoad** yes

**Repository** CRAN

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**NeedsCompilation** no

**RoxygenNote** 6.0.1

## Contents

FeaLect-package . . . . .	2
compute.balanced . . . . .	3

compute.logistic.score . . . . .	5
doctor.validate . . . . .	6
FeaLect . . . . .	7
ignore.redundant . . . . .	10
input.check.FeaLect . . . . .	11
mcl_sll . . . . .	12
random.subset . . . . .	13
train.doctor . . . . .	14

<b>Index</b>	<b>17</b>
--------------	-----------

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FeaLect-package	<i>Scores Features for Feature Selection</i>
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## Description

Suppose you have a feature matrix with 200 features and only 20 samples and your goal is to build a classifier. You can run the FeaLect() function to compute the scores for your features. Only the relatively high score features (say the top 20) are recommended for further analysis. In this way, one can prevent overfitting by reducing the number of features significantly.

## Details

The DESCRIPTION file:

```

Package:      FeaLect
Type:        Package
Title:       Scores Features for Feature Selection
Version:     1.20
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Depends:    lars, rms
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```

Index of help topics:

FeaLect	Computes the scores of the features.
FeaLect-package	Scores Features for Feature Selection
compute.balanced	Balances between negative and positive samples

	by oversampling.
compute.logistic.score	Fits a logistic regression model using the linear scores
doctor.validate	Validates a model using validating samples.
ignore.redundant	Refines a feature matrix
input.check.FeaLect	Checks the inputs to Fealect() function.
mcl_sll	MCL and SLL lymphoma subtypes
random.subset	Selects a random subset of the input.
train.doctor	Fits various models based on a combination on penalized linear models and logistic regression.

**Author(s)**

Habil Zare

Maintainer: Habil Zare &lt;zare@u.washington.edu&gt;

**References**

Zare, Habil, et al. "Scoring relevancy of features based on combinatorial analysis of Lasso with application to lymphoma diagnosis." *BMC genomics*. Vol. 14. No. 1. BioMed Central, 2013.

**See Also**

[FeaLect](#), [train.doctor](#), [doctor.validate](#), [random.subset](#), [compute.balanced](#), [compute.logistic.score](#), [ignore.redundant](#), [input.check.FeaLect](#), [lars](#)-package, and [SparseLearner](#)-package

**Examples**

```
library(FeaLect)
data(mcl_sll)
F <- as.matrix(mcl_sll[ , -1]) # The Feature matrix
L <- as.numeric(mcl_sll[ , 1]) # The labels
names(L) <- rownames(F)
message(dim(F)[1], " samples and ", dim(F)[2], " features.")

## For this data, total.num.of.models is suggested to be at least 100.
FeaLect.result.1 <- FeaLect(F=F, L=L, maximum.features.num=10, total.num.of.models=20, talk=TRUE)
```

---

compute.balanced

*Balances between negative and positive samples by oversampling.*


---

**Description**

If negative samples are less than positive ones, more copies of the negative cases are added and vice versa.

**Usage**

```
compute.balanced(F_, L_)
```

**Arguments**

F\_                    The feature matrix, each column is a feature.  
L\_                    The vector of labels named according to the rows of F.

**Details**

Considerably unbalanced classes may be probabilistic for fitting some models.

**Value**

Returns a list of:

F\_                    The feature matrix, each column is a feature.  
L\_                    The vector of labels named according to the rows of F.

**Author(s)**

Habil Zare

**References**

"Statistical Analysis of Overfitting Features", manuscript in preparation.

**See Also**

[FeaLect](#), [train.doctor](#), [doctor.validate](#), [random.subset](#), [compute.balanced](#), [compute.logistic.score](#), [ignore.redundant](#), [input.check.FeaLect](#)

**Examples**

```
library(FeaLect)
data(mcl_s11)
F <- as.matrix(mcl_s11[ , -1]) # The Feature matrix
L <- as.numeric(mcl_s11[ , 1]) # The labels
names(L) <- rownames(F)
message(L)

balanced <- compute.balanced(F_=F, L_=L)
message(balanced$L_)
```

---

`compute.logistic.score`*Fits a logistic regression model using the linear scores*

---

### Description

A logistic regression model is fitted to the linear scores using `lrm()` function and the logistic scores are computed using the formula:  $1/(1+\exp(-(a+bX)))$  where *a* and *b* are the logistic coefficients.

### Usage

```
compute.logistic.score(F_, L_, considered.features, training.samples, validating.samples,  
  linear.scores, report.fitting.failure = TRUE)
```

### Arguments

`F_` The feature matrix, each column is a feature.

`L_` The vector of labels named according to the rows of `F`.

`training.samples` The names of rows of `F` that should be considered as training samples.

`validating.samples` The names of rows of `F` that should be considered as validating samples.

`considered.features` The names of columns of `F` that determine the features of interest.

`linear.scores` A vector that contains for each training or validating sample, a linear score predicted by the linear method.

`report.fitting.failure` If TRUE, any failure in fitting the linear or logistic models will be printed.

### Details

The logistic regression will be fitted to all training and validating samples.

### Value

Returns a list of:

`logistic.scores`

A vector of predicted logistic values for all samples.

`logistic.cofs`

The coefficients that are computed by logistic regression.

### Note

Logistic regression is also done on top of fitting the linear models.

**Author(s)**

Habil Zare

**References**

"Statistical Analysis of Overfitting Features", manuscript in preparation.

**See Also**

[FeaLect](#), [train.doctor](#), [doctor.validate](#), [random.subset](#), [compute.balanced](#), [compute.logistic.score](#), [ignore.redundant](#), [input.check.FeaLect](#)

**Examples**

```
library(FeaLect)
data(mcl_s11)
F <- as.matrix(mcl_s11[, -1]) # The Feature matrix
L <- as.numeric(mcl_s11[, 1]) # The labels
names(L) <- rownames(F)
all.samples <- rownames(F); ts <- all.samples[5:10]; vs <- all.samples[c(1,22)]
L <- L[c(ts,vs)]
L

asymptotic.scores <- c(1,0.9,0.8,0.2,0.1,0.1,0.7,0.2)

compute.logistic.score(F_=F, L_=L, training.samples=ts, validating.samples=vs,
  considered.features=colnames(F), linear.scores= asymptotic.scores)
```

---

doctor.validate	<i>Validates a model using validating samples.</i>
-----------------	--

---

**Description**

A model fitted on the training samples, can be validated on a separate validating set. The recall, precision, and accuracy of the model are computed.

**Usage**

```
doctor.validate(true.labels, predictions)
```

**Arguments**

true.labels	A vector of 0 and 1.
predictions	A vector of 0 and 1.

**Details**

F-measure is equal to: 2 times precision times recall / (precision+recall).

**Value**

F-measure, precision, and recall are calculated. Also, the mis-labeled cases are reported.

**Author(s)**

Habil Zare

**References**

"Statistical Analysis of Overfitting Features", manuscript in preparation.

**See Also**

[FeaLect](#), [train.doctor](#), [doctor.validate](#), [random.subset](#), [compute.balanced](#), [compute.logistic.score](#), [ignore.redundant](#), [input.check.FeaLect](#)

**Examples**

```
tls <- c(1,1,1,0,0)
ps <- c(1,1,0,1,0)
names(tls) <- 1:5; names(ps) <- 1:5

doctor.validate(true.labels=tls, predictions=ps)
```

---

FeaLect

*Computes the scores of the features.*

---

**Description**

Several random subsets are sampled from the input data and for each random subset, various linear models are fitted using lars method. A score is assigned to each feature based on the tendency of LASSO in including that feature in the models. Finally, the average score and the models are returned as the output.

**Usage**

```
FeaLect(F, L, maximum.features.num = dim(F)[2], total.num.of.models, gamma = 3/4,
persistence = 1000, talk = FALSE, minimum.class.size = 2,
report.fitting.failure = FALSE, return_linear.models = TRUE, balance = TRUE,
replace = TRUE, plot.scores = TRUE)
```

**Arguments**

<code>F</code>	The feature matrix, each column is a feature.
<code>L</code>	The vector of labels named according to the rows of <code>F</code> .
<code>maximum.features.num</code>	Upto this number of features are allowed to contribute to each linear model.
<code>total.num.of.models</code>	The total number of models that are fitted.
<code>gamma</code>	A value in range 0-1 that determines the relative size of sample subsets.
<code>persistence</code>	Maximum number of tries for randomly choosing samples, If we try this many times and the obtained labels are all the same, we give up (maybe the whole labels are the same) with the error message: " Not enough variation in the labels...".
<code>talk</code>	If TRUE, some messages are printed during the computations.
<code>minimum.class.size</code>	The size of both positive and negative classes should be greater than this threshold after sampling.
<code>report.fitting.failure</code>	If TRUE, any failure in fitting the linear or logistic models will be printed.
<code>return_linear.models</code>	The models are memory intensive, so for if they more than 1000, we may decide to ignore them to prevent memory outage.
<code>balance</code>	If TRUE, the cases will be balanced for the same number of positive vs. negatives by oversampling before fitting the linear model.
<code>replace</code>	If TRUE, the subsets are sampled with replacement.
<code>plot.scores</code>	If TRUE, the scores are plotted in logarithmic scale after each iteration.

**Details**

See the reference for more details.

**Value**

Returns a list of:

<code>log.scores</code>	A vector containing the logarithm of final scores.
<code>feature.matrix</code>	The input feature matrix.
<code>labels</code>	The input labels
<code>total.num.of.models</code>	The total number of models that are fitted.
<code>maximum.features.num</code>	Upto this number of features are allowed to contribute to each linear model.
<code>feature.scores.history</code>	The matrix of history of feature scores where column <code>i</code> contains the scores after <code>i</code> runs.

`num.of.features.score`      A vector, entry *i* contains the number of times that *i* has been the best number of features.  
`best.feature.num`            The *i*'th value of this vector is the best number of features for the *i*'th model.  
`mislabeleding.record`        A vector that keeps track of the frequency of mislabelling for each cases.  
`doctors`                      List of all models which are created by `train.doctor()` function.  
`best.features.intersection`    Best features are computed for each sampling and their intersection is reported as this vector of features names  
`features.with.best.global.error`    A list containing the sets of features. The set *i* was the best for *i*'th sampling.  
`time.taken`                  Total time used for executing this function.

**Note**

Logistic regression is also done on top of fitting the linear models.

**Author(s)**

Habil Zare

**References**

"Statistical Analysis of Overfitting Features", manuscript in preparation.

**See Also**

[FeaLect](#), [train.doctor](#), [doctor.validate](#), [random.subset](#), [compute.balanced](#), [compute.logistic.score](#), [ignore.redundant](#), [input.check.FeaLect](#)

**Examples**

```

library(FeaLect)
data(mcl_s11)
F <- as.matrix(mcl_s11[ , -1]) # The Feature matrix
L <- as.numeric(mcl_s11[ , 1]) # The labels
names(L) <- rownames(F)
message(dim(F)[1], " samples and ", dim(F)[2], " features.")

## For this data, total.num.of.models is suggested to be at least 100.
FeaLect.result <- FeaLect(F=F,L=L,maximum.features.num=10,total.num.of.models=20,talk=TRUE)

```

---

ignore.redundant      *Refines a feature matrix*

---

### Description

If the value a feature is the same for all points (e.g. =0), it can be ignored.

### Usage

```
ignore.redundant(F, num.of.values = 1)
```

### Arguments

F	The feature matrix, each column is a feature.
num.of.values	A feature should have more than this threshold non-zero values not to be ignored.

### Value

The refined feature matrix.

### Author(s)

Habil Zare

### References

"Statistical Analysis of Overfitting Features", manuscript in preparation.

### See Also

[FeaLect](#), [train.doctor](#), [doctor.validate](#), [random.subset](#), [compute.balanced](#), [compute.logistic.score](#), [ignore.redundant](#), [input.check.FeaLect](#)

### Examples

```
library(FeaLect)
data(mcl_s11)
F <- as.matrix(mcl_s11[, -1]) # The Feature matrix
#F <- cbind(F, rep(1, times=dim(F)[1]))
message(dim(F)[1], " samples and ", dim(F)[2], " features.")

G <- ignore.redundant(F)
message("for ", dim(G)[1], " samples, ", dim(G)[2], " features are left.")
```

---

input.check.FeaLect     *Checks the inputs to Fealect() function.*

---

### Description

We should have: F as a matrix, L as a vector, and length of L be equal to number of rows of F. They should have names accordingly.

### Usage

```
input.check.FeaLect(F_, L_, maximum.features.num, gamma)
```

### Arguments

F\_                    The feature matrix, each column is a feature.  
L\_                    The vector of labels named according to the rows of F.  
maximum.features.num                    Upto this number of features are allowed to contribute to each linear model.  
gamma                A value in range 0-1 that determines the relative size of sample subsets.

### Details

If the input is not appropriate, error or warning message will be produced.

### Value

Returns a list of:

F\_                    The feature matrix, each column is a feature.  
L\_                    The vector of labels named according to the rows of F.  
maximum.features.num                    Upto this number of features are allowed to contribute to each linear model.

### Author(s)

Habil Zare

### References

"Statistical Analysis of Overfitting Features", manuscript in preparation.

### See Also

[FeaLect](#), [train.doctor](#), [doctor.validate](#), [random.subset](#), [compute.balanced](#), [compute.logistic.score](#), [ignore.redundant](#), [input.check.FeaLect](#)

## Examples

```
library(FeaLect)
data(mcl_sll)
F <- as.matrix(mcl_sll[, -1]) # The Feature matrix
L <- as.numeric(mcl_sll[, 1]) # The labels
names(L) <- rownames(F)

checked <- input.check.FeaLect(F_=F, L_=L, maximum.features.num=10, gamma=3/4)
```

---

mcl\_sll

*MCL and SLL lymphoma subtypes*

---

## Description

A total of 237 features are identified for 22 lymphoma patients.

## Usage

```
data(mcl_sll)
```

## Format

A matrix. Each of the 237 columns represents a features except the first column which contains the label vector. Each of the 22 rows represents a patients.

## Details

7 cases diagnosed with Mantel Cell Lymphoma (MCL) and 15 cases with Small Lymphocytic Lymphoma (SLL). The presented features are computed based on flow cytometry data. The first column contains the label vector which has value 1 for MCL cases and 0 for SLL cases.

## Source

British Columbia Cancer Agency

## References

"Statistical Analysis of Overfitting Features", manuscript in preparation.

## See Also

[FeaLect](#), [train.doctor](#), [doctor.validate](#), [random.subset](#), [compute.balanced](#), [compute.logistic.score](#), [ignore.redundant](#), [input.check.FeaLect](#)

**Examples**

```

library(FeaLect)
data(mcl_s11)
F <- as.matrix(mcl_s11[ , -1]) # The Feature matrix
L <- as.numeric(mcl_s11[ , 1]) # The labels
names(L) <- rownames(F)
message(dim(F)[1], " samples and ", dim(F)[2], " features.")
L

```

---

random.subset	<i>Selects a random subset of the input.</i>
---------------	--

---

**Description**

If a subset of samples are selected randomly, the navigate of positive classes might be too sparse or even empty. This function will repeat sampling until the classes are appropriate in this sense.

**Usage**

```
random.subset(F_, L_, gamma, persistence = 1000, minimum.class.size=2, replace)
```

**Arguments**

F_	The feature matrix, each column is a feature.
L_	The vector of labels named according to the rows of F.
gamma	A value in range 0-1 that determines the relative size of sample subsets.
persistence	Maximum number of tries for randomly choosing samples, If we try this many times and the obtained labels are all the same, we give up (maybe the whole labels are the same) with the error message: " Not enough variation in the labels...".
minimum.class.size	A lower bound on the number of samples in each class.
replace	If TRUE, sampling is done by replacement.

**Details**

The function also returns a refined feature matrix by ignoring too sparse features after sampling.

**Value**

Returns a list of:

X_	The sampled feature matrix, each column is a feature after ignoring the redundant ones.
Y_	The vector of labels named according to the rows of X_.
remainder.samples	The names of the rows of F_ which do not appear in X_, later on can be used for validation.

**Author(s)**

Habil Zare

**References**

"Statistical Analysis of Overfitting Features", manuscript in preparation.

**See Also**

[FeaLect](#), [train.doctor](#), [doctor.validate](#), [random.subset](#), [compute.balanced](#), [compute.logistic.score](#), [ignore.redundant](#), [input.check.FeaLect](#)

**Examples**

```
library(FeaLect)
data(mcl_s11)
F <- as.matrix(mcl_s11[, -1]) # The Feature matrix
L <- as.numeric(mcl_s11[, 1]) # The labels
names(L) <- rownames(F)
message(dim(F)[1], " samples and ", dim(F)[2], " features.")

XY <- random.subset(F_=F, L_=L, gamma=3/4, replace=TRUE)
XY$remainder.samples
```

---

train.doctor

*Fits various models based on a combination on penalized linear models and logistic regression.*

---

**Description**

Various linear models are fitted to the training samples using lars method. The models differ in the number of features and each is validated by validating samples. A score is also assigned to each feature based on the tendency of LASSO in including that feature in the models.

**Usage**

```
train.doctor(F_, L_, training.samples, validating.samples, considered.features,
             maximum.features.num, balance = TRUE, return_linear.models = TRUE,
             report.fitting.failure = FALSE)
```

**Arguments**

`F_`                    The feature matrix, each column is a feature.

`L_`                    The vector of labels named according to the rows of F.

`training.samples`     The names of rows of F that should be considered as training samples.

validating.samples	The names of rows of F that should be considered as validating samples.
considered.features	The names of columns of F that determine the features of interest.
maximum.features.num	Upto this number of features are allowed to contribute to each linear model.
balance	If TRUE, the cases will be balanced for the same number of positive vs. negatives by oversampling before fitting the linear model.
return_linear.models	The models are memory intensive, so for if they more than 1000, we may decide to ignore them to prevent memory outage.
report.fitting.failure	If TRUE, any failure in fitting the linear of logistic models will be printed.

### Details

See the reference for more details.

### Value

Returns a list of:

linear.models	The result of model fitting computed by lars().
best.number.of.features	According to best accuracy.
probabilities	The best computed logistic score.
accuracy	The best F-measure.
best.logistic.cof	According to best accuracy.
contribution.to.feature.scores	This vector should be added to the total feature scores.
contribution.to.feature.scores.frequency	This vector should be added to the total frequency of features.
training.samples	Input, the names of rows of F that should be considered as training samples.
validating.samples	Input, the names of rows of F that should be considered as validating samples.
precision	Ratio of number of true positives to predicted positives.
recall	Ratio of number of true positives to real positives.
selected.features.sequence	A list of sets of features which are selected in different models.
global.errors	A vector of global error of the linear fits.
features.with.best.global.error	A vector of names of good features in terms of global error of linear fits.

**Note**

Logistic regression is also done on top of fitting the linear models.

**Author(s)**

Habil Zare

**References**

"Statistical Analysis of Overfitting Features", manuscript in preparation.

**See Also**

[FeaLect](#), [train.doctor](#), [doctor.validate](#), [random.subset](#), [compute.balanced](#), [compute.logistic.score](#), [ignore.redundant](#), [input.check.FeaLect](#)

**Examples**

```
library(FeaLect)
data(mcl_s11)
F <- as.matrix(mcl_s11[ , -1]) # The Feature matrix
L <- as.numeric(mcl_s11[ , 1]) # The labels
names(L) <- rownames(F)
message(dim(F)[1], " samples and ", dim(F)[2], " features.")

all.samples <- rownames(F); ts <- all.samples[5:10]; vs <- all.samples[c(1,22)]

doctor <- train.doctor(F_=F, L_=L, training.samples=ts, validating.samples=vs,
  considered.features=colnames(F), maximum.features.num=10)
```

# Index

- \* **classif**
  - compute.balanced, 3
  - compute.logistic.score, 5
  - doctor.validate, 6
  - FeaLect, 7
  - FeaLect-package, 2
  - ignore.redundant, 10
  - input.check.FeaLect, 11
  - random.subset, 13
  - train.doctor, 14
- \* **datasets**
  - mcl\_s11, 12
- \* **debugging**
  - input.check.FeaLect, 11
- \* **error**
  - input.check.FeaLect, 11
- \* **misc**
  - input.check.FeaLect, 11
- \* **models**
  - compute.balanced, 3
  - compute.logistic.score, 5
  - doctor.validate, 6
  - FeaLect, 7
  - FeaLect-package, 2
  - ignore.redundant, 10
  - input.check.FeaLect, 11
  - random.subset, 13
  - train.doctor, 14
- \* **multivariate**
  - compute.balanced, 3
  - compute.logistic.score, 5
  - doctor.validate, 6
  - FeaLect, 7
  - FeaLect-package, 2
  - ignore.redundant, 10
  - input.check.FeaLect, 11
  - random.subset, 13
  - train.doctor, 14
- \* **package**
  - FeaLect-package, 2
- \* **regression**
  - compute.balanced, 3
  - compute.logistic.score, 5
  - doctor.validate, 6
  - FeaLect, 7
  - FeaLect-package, 2
  - ignore.redundant, 10
  - input.check.FeaLect, 11
  - random.subset, 13
  - train.doctor, 14
- compute.balanced, 3, 3, 4, 6, 7, 9–12, 14, 16
- compute.logistic.score, 3, 4, 5, 6, 7, 9–12, 14, 16
- doctor.validate, 3, 4, 6, 6, 7, 9–12, 14, 16
- FeaLect, 3, 4, 6, 7, 7, 9–12, 14, 16
- FeaLect-package, 2
- ignore.redundant, 3, 4, 6, 7, 9, 10, 10, 11, 12, 14, 16
- input.check.FeaLect, 3, 4, 6, 7, 9–11, 11, 12, 14, 16
- lars, 3
- mcl\_s11, 12
- random.subset, 3, 4, 6, 7, 9–12, 13, 14, 16
- train.doctor, 3, 4, 6, 7, 9–12, 14, 14, 16