

# Package ‘inTrees’

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**Title** Interpret Tree Ensembles

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**Imports** RRF, arules, gbm, xtable, xgboost, data.table, methods

**Description** For tree ensembles such as random forests, regularized random forests and gradient boosted trees, this package provides functions for: extracting, measuring and pruning rules; selecting a compact rule set; summarizing rules into a learner; calculating frequent variable interactions; formatting rules in latex code. Reference: Interpreting tree ensembles with inTrees (Houtao Deng, 2019, <[doi:10.1007/s41060-018-0144-8](https://doi.org/10.1007/s41060-018-0144-8)>).

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**BugReports** <https://github.com/softwaredeng/inTrees/issues>

**License** GPL (>= 3)

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applyLearner	<i>apply a simplified tree ensemble learner (STEL) to data</i>
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### Description

apply STEL to data and get predictions

### Usage

```
applyLearner(learner, X)
```

### Arguments

learner	a matrix with rules ordered by priority
X	predictor variable matrix

### Value

predictions for the data

### See Also

[buildLearner](#)

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buildLearner	<i>build a simplified tree ensemble learner (STEL)</i>
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---

### Description

Build a simplified tree ensemble learner (STEL). Currently works only for classification problems.

### Usage

```
buildLearner(ruleMetric, X, target, minFreq = 0.01)
```

### Arguments

ruleMetric	a matrix including the conditions, predictions, and and metrics
X	predictor variable matrix
target	target variable
minFreq	minimum frequency of a rule condition in order to be included in STEL.

**Value**

a matrix including the conditions, prediction, and metrics, ordered by priority.

**Author(s)**

Houtao Deng

**References**

Houtao Deng, Interpreting Tree Ensembles with inTrees, technical report, 2014

**Examples**

```
data(iris)
library(RRF)
X <- iris[,1:(ncol(iris)-1)]
target <- iris[,"Species"]
rf <- RRF(X,as.factor(target),ntree=100) # build an ordinary RF
treeList <- RF2List(rf)
ruleExec <- extractRules(treeList,X)
ruleExec <- unique(ruleExec)
ruleMetric <- getRuleMetric(ruleExec,X,target) # measure rules
ruleMetric <- pruneRule(ruleMetric,X,target) # prune each rule
#ruleMetric <- selectRuleRRF(ruleMetric,X,target) # rule selection
learner <- buildLearner(ruleMetric,X,target)
pred <- applyLearner(learner,X)
read <- presentRules(learner,colnames(X)) # more readable format

# format the rule and metrics as a table in latex code
library(xtable)
print(xtable(read), include.rownames=FALSE)
print(xtable(ruleMetric[1:2,]), include.rownames=FALSE)
```

---

dataSimulate

*Simulate data*

---

**Description**

Simulate data

**Usage**

```
dataSimulate(flag = 1, nCol = 20, nRow = 1000)
```

**Arguments**

flag	1 (default): team optimization; 2: non-linear; 3: linear.
nCol	the number of columns in the data set. must $\geq 2$ .
nRow	the number of rows in the data set.

**Value**

predictor variable matrix and target variable

**Examples**

```
res <- dataSimulate(flag=1)
X <- res$X;
target <- res$target
```

---

dicretizeVector      *discretize a variable*

---

**Description**

discretize a variable

**Usage**

```
dicretizeVector(v, K = 3)
```

**Arguments**

v                      vector  
K                      discretize into up to K levels with equal frequency

**Value**

discretized levels for v

**Examples**

```
data(iris)
dicretizeVector(iris[,1],3)
```

---

extractRules      *Extract rules from a list of trees*

---

**Description**

Extract rule conditions from a list of trees. Use functions RF2List/GBM2List to transform RF/GBM objects to list of trees.

**Usage**

```
extractRules(treeList, X, ntree = 100, maxdepth = 6, random = FALSE, digits = NULL)
```

**Arguments**

treeList	tree list
X	predictor variable matrix
ntree	conditions are extracted from the first ntree trees
maxdepth	conditions are extracted from the top maxdepth levels from each tree
random	the max depth for each tree is an integer randomly chosen between 1 and maxdepth
digits	digits for rounding

**Value**

a set of rule conditions

**Examples**

```
library(RRF)
data(iris)
X <- iris[,1:(ncol(iris)-1)]
target <- iris[,"Species"]
rf <- RRF(X,as.factor(target),ntree=100) # build an ordinary RF
treeList <- RF2List(rf)
ruleExec <- extractRules(treeList,X,digits=4) # transform to R-executable rules
ruleExec <- unique(ruleExec)
```

---

GBM2List

*Transform gbm object to a list of trees*


---

**Description**

Transform gbm object to a list of trees that can be used for rule condition extraction

**Usage**

```
GBM2List(gbm1,X)
```

**Arguments**

gbm1	gbm object
X	predictor variable matrix

**Value**

a list of trees in an inTrees-required format

**See Also**

[RF2List](#)

**Examples**

```

library(gbm)
data(iris)
X <- iris[,1:(ncol(iris)-1)]
target <- iris[,"Species"]
gbmFit <- gbm(Species~ ., data=iris, n.tree = 400,
              interaction.depth = 10,distribution="multinomial")
treeList <- GBM2List(gbmFit,X)
ruleExec = extractRules(treeList,X)
ruleExec <- unique(ruleExec)
#ruleExec <- ruleExec[1:min(2000,length(ruleExec)),,drop=FALSE]
ruleMetric <- getRuleMetric(ruleExec,X,target)
ruleMetric <- pruneRule(ruleMetric,X,target)
ruleMetric <- unique(ruleMetric)
learner <- buildLearner(ruleMetric,X,target)
pred <- applyLearner(learner,X)
readableLearner <- presentRules(learner,colnames(X)) # more readable format
err <- 1-sum(pred==target)/length(pred);

```

---

getFreqPattern

*calculate frequent variable interactions*


---

**Description**

calculate frequent variable interactions

**Usage**

```
getFreqPattern(ruleMetric, minsup = 0.01, minconf = 0.5, minlen = 1, maxlen = 4)
```

**Arguments**

ruleMetric	a matrix including conditions, predictions, and the metrics
minsup	minimum support of conditions in a tree ensemble
minconf	minimum confidence of the rules
minlen	minimum length of the conditions
maxlen	max length of the conditions

**Value**

a matrix including frequent variable interactions (in a form of conditions), predictions, length, support, and confidence.

**Examples**

```

library(RRF)
library(arules)
data(iris)
X <- iris[,1:(ncol(iris)-1)]
target <- iris[,"Species"]
rf <- RRF(X,as.factor(target),ntree=100) # build an ordinary RF
treeList <- RF2List(rf)
ruleExec <- extractRules(treeList,X) # transform to R-executable rules
ruleMetric <- getRuleMetric(ruleExec,X,target)
freqPattern <- getFreqPattern(ruleMetric)
freqPatternMetric <- getRuleMetric(freqPattern,X,target)

```

---

getRuleMetric

*Assign outcomes to a conditions, and measure the rules*


---

**Description**

Assign outcomes to a conditions, and measure the rules

**Usage**

```
getRuleMetric(ruleExec, X, target)
```

**Arguments**

ruleExec	a set of rule conditions
X	predictor variable matrix
target	target variable

**Value**

a matrix including the conditions, predictions, and metrics

**References**

Houtao Deng, Interpreting Tree Ensembles with inTrees, technical report, 2014

**Examples**

```

library(RRF)
data(iris)
X <- iris[,1:(ncol(iris)-1)]
target <- iris[,"Species"]
rf <- RRF(X,as.factor(target),ntree=100) # build an ordinary RF
treeList <- RF2List(rf)
ruleExec <- extractRules(treeList,X) # transform to R-executable rules
ruleExec <- unique(ruleExec)
ruleMetric <- getRuleMetric(ruleExec,X,target) # measure rules

```

---

presentRules                      *Present a learner using column names instead of X[i,]*

---

### Description

Present a learner using column names instead of X[i,]

### Usage

```
presentRules(rules, colN, digits)
```

### Arguments

rules	a set of rules
colN	a vector including the column names
digits	digits for rounding

### Value

a matrix including the conditions (with column names), etc.

### See Also

[buildLearner](#)

### Examples

```
# See function "buildLearner"
```

---

pruneRule                      *Prune irrelevant variable-value pair from a rule condition*

---

### Description

Prune irrelevant variable-value pair from a rule condition

### Usage

```
pruneRule(rules, X, target, maxDecay = 0.05, typeDecay = 2)
```

### Arguments

rules	A matrix including the rules and metrics
X	predictor variable matrix
target	target variable vector
maxDecay	threshold of decay
typeDecay	1: relative error; 2: error; default :2



**Value**

A matrix including the rules each being pruned, and metrics

**Author(s)**

Houtao Deng

**References**

Houtao Deng, Interpreting Tree Ensembles with inTrees, technical report, 2014

**See Also**

[buildLearner](#)

**Examples**

```
# see function "buildLearner"
```

---

RF2List

*Transform a random forest object to a list of trees*

---

**Description**

Transform a random forest object to a list of trees

**Usage**

```
RF2List(rf)
```

**Arguments**

rf                    random forest object

**Value**

a list of trees

**See Also**

[GBM2List](#)

**Examples**

```
library(RRF)
data(iris)
X <- iris[,1:(ncol(iris)-1)]
target <- iris[, "Species"]
rf <- RRF(X, as.factor(target), ntree=100) # build an ordinary RF
treeList <- RF2List(rf)
ruleExec <- extractRules(treeList, X) # transform to R-executable rules
```

---

selectRuleRRF	<i>select a set of relevant and non-redundant rules</i>
---------------	---

---

**Description**

select a set of relevant and non-redundant rules using regularized random forests

**Usage**

```
selectRuleRRF(ruleMetric, X, target)
```

**Arguments**

ruleMetric	a matrix including the rules and metrics
X	predictor variable matrix
target	response variable

**Value**

a matrix including a set of relevant and non-redundant rules, and their metrics

**Author(s)**

Houtao Deng

**See Also**

[buildLearner](#)

**Examples**

```
# See function "buildLearner:
```

---

**XGB2List***Transform an xgboost object to a list of trees*

---

**Description**

Transform an xgboost object to a list of trees

**Usage**

```
XGB2List(xgb, X)
```

**Arguments**

xgb	xgboost object
X	predictor variable matrix

**Value**

a list of trees in an inTrees-required format

**See Also**

[XGB2List](#)

**Examples**

```
library(data.table)
library(xgboost)
# test data set 1: iris
X <- within(iris,rm("Species")); Y <- iris[, "Species"]
X <- within(iris,rm("Species")); Y <- iris[, "Species"]
model_mat <- model.matrix(~. -1, data=X)
xgb <- xgboost(model_mat, label = as.numeric(Y) - 1, nrounds = 20,
  objective = "multi:softprob", num_class = 3 )
tree_list <- XGB2List(xgb,model_mat)
```

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