Package ‘rbooster’

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Title AdaBoost Framework for Any Classifier
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Description This is a simple package which provides a function that boosts pre-ready or custom-made classifiers. Package uses Discrete AdaBoost (<doi:10.1006/jcss.1997.1504>) and Real AdaBoost (<doi:10.1214/aos/1016218223>) for two class, SAMME (<doi:10.4310/SII.2009.v2.n3.a8>) and SAMME.R (<doi:10.4310/SII.2009.v2.n3.a8>) for multiclass classification.

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Author Fatih Saglam [aut, cre] (<https://orcid.org/0000-0002-2084-2008>), Hasan Bulut [ctb]
Maintainer Fatih Saglam <fatih.saglam@omu.edu.tr>
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### AdaBoost Framework for Any Classifier

**Description**

This function allows you to use any classifier to be used in Discrete or Real AdaBoost framework.

**Usage**

```r
booster(
  x_train,
  y_train,
  classifier = "rpart",
  predictor = NULL,
  method = "discrete",
  x_test = NULL,
  y_test = NULL,
  weighted_bootstrap = FALSE,
  max_iter = 50,
  lambda = 1,
  print_detail = TRUE,
  print_plot = FALSE,
  bag_frac = 0.5,
  p_weak = NULL,
  ...
)
```

```r
discrete_adaboost(
  x_train,
  y_train,
  classifier = "rpart",
  predictor = NULL,
  x_test = NULL,
  y_test = NULL,
  weighted_bootstrap = FALSE,
  max_iter = 50,
  lambda = 1,
  print_detail = TRUE,
  print_plot = FALSE,
  bag_frac = 0.5,
  p_weak = NULL,
  ...
)
```

```r
real_adaboost(
  x_train,
```
```r
y_train,
classifier = "rpart",
predictor = NULL,
x_test = NULL,
y_test = NULL,
weighted_bootstrap = FALSE,
max_iter = 50,
lambda = 1,
print_detail = TRUE,
print_plot = FALSE,
bag_frac = 0.5,
p_weak = NULL,
...
)
```

**Arguments**

- `x_train`: feature matrix.
- `y_train`: a factor class variable. Boosting algorithm allows for k >= 2. However, not all classifiers are capable of multiclass classification.
- `classifier`: pre-ready or a custom classifier function. Pre-ready classifiers are "rpart", "glm", "gnb", "dnb", "earth".
- `predictor`: prediction function for classifier. It's output must be a factor variable with the same levels of `y_train`.
- `method`: "discrete" or "real" for Discrete or Real Adaboost.
- `x_test`: optional test feature matrix. Can be used instead of predict function. `print_detail` and `print_plot` gives information about test.
- `y_test`: optional a factor test class variable with the same levels as `y_train`. Can be used instead of predict function. `print_detail` and `print_plot` gives information about test.
- `weighted_bootstrap`: If classifier does not support case weights, `weighted_bootstrap` must be TRUE used for weighting. If classifier supports weights, it must be FALSE. default is FALSE.
- `max_iter`: maximum number of iterations. Default to 30. Probably should be higher for classifiers other than decision tree.
- `lambda`: a parameter for model weights. Default to 1. Higher values leads to unstable weak classifiers, which is good sometimes. Lower values leads to slower fitting.
- `print_detail`: a logical for printing errors for each iteration. Default to TRUE
- `print_plot`: a logical for plotting errors. Default to FALSE.
- `bag_frac`: a value between 0 and 1. It represents the proportion of cases to be used in each iteration. Smaller datasets may be better to create weaker classifiers. 1 means all cases. Default to 0.5. Ignored if `weighted_bootstrap` == TRUE.
- `p_weak`: number of variables to use in weak classifiers. It is the number of columns in `x_train` by default. Lower values lead to weaker classifiers.
- `...`: additional arguments for classifier and predictor functions. weak classifiers.
Details

method can be "discrete" and "real" at the moment and indicates Discrete AdaBoost and Real AdaBoost. For multiclass classification, "discrete" means SAMME, "real" means SAMME.R algorithm.

Pre-ready classifiers are "rpart", "glm", "dnb", "gnb", "earth", which means CART, logistic regression, Gaussian naive bayes, discrete naive bayes and MARS classifier respectively.

predictor is valid only if a custom classifier function is given. A custom classifier function should be as function(x_train,y_train,weights,...) and its output is a model object which can be placed in predictor. predictor function is function(model,x_new,type ...) and its output must be a vector of class predictions. type must be "pred" or "prob", which gives a vector of classes or a matrix of probabilities, which each column represents each class. See vignette("booster",package = "booster") for examples.

lambda is a multiplier of model weights.

weighted_bootstrap is for bootstrap sampling in each step. If the classifier accepts case weights then it is better to turn it off. If classifier does not accept case weights, then weighted bootstrap will make it into weighted classifier using bootstrap. Learning may be slower this way.

bag_frac helps a classifier to be "weaker" by reducing sample size. Stronger classifiers may require lower proportions of bag_frac. p_weak does the same by reducing number of variables.

Value

a booster object with below components.

n_train Number of cases in the input dataset.
w Case weights for the final boost.
p Number of features.
weighted_bootstrap TRUE if weighted bootstrap applied. Otherwise FALSE.
max_iter Maximum number of boosting steps.
lambda The multiplier of model weights.
predictor Function for prediction
alpha Model weights.
err_train A vector of train errors in each step of boosting.
err_test A vector of test errors in each step of boosting. If there are no test data, it returns NULL
models Models obtained in each boosting step
x_classes A list of datasets, which are x_train separated for each class.
n_classes Number of cases for each class in input dataset.
k_classes Number of classes in class variable.
bag_frac Proportion of input dataset used in each boosting step.
class_names Names of classes in class variable.
Author(s)
Fatih Saglam, fatih.saglam@omu.edu.tr

References

See Also
predict.booster

Examples

```r
require(rbooster)

## n number of cases, p number of variables, k number of classes.

cv_sampler <- function(y, train_proportion) {
  unlist(lapply(unique(y), function(m) sample(which(y==m), round(sum(y==m))*train_proportion)))
}

data_simulation <- function(n, p, k, train_proportion) {
  means <- seq(0, k*2.5, length.out = k)
  x <- do.call(rbind, lapply(means, 
    function(m) matrix(data = rnorm(n = round(n/k)*p, 
      mean = m, 
      sd = 2), 
      nrow = round(n/k))))
  y <- factor(rep(letters[1:k], each = round(n/k)))
  train_i <- cv_sampler(y, train_proportion)
  data <- data.frame(x, y = y)
  data_train <- data[train_i,]
  data_test <- data[-train_i,]
  return(list(data = data, 
    data_train = data_train, 
    data_test = data_test))
}

### binary classification

dat <- data_simulation(n = 500, p = 2, k = 2, train_proportion = 0.8)

mm <- booster(x_train = dat$data_train[,1:2],
  y_train = dat$data_train[,3],
  classifier = "rpart",
  method = "discrete",
  x_test = dat$data_test[,1:2],
  y_test = dat$data_test[,3],
  weighted_bootstrap = FALSE,
  max_iter = 100,
  lambda = 1,
  max_depth = 5)```
print_detail = TRUE,
print_plot = TRUE,
bag_frac = 1,
p_weak = 2)

## test prediction
mm$test_prediction

## or
pp <- predict(object = mm, newdata = dat$data_test[,1:2], type = "pred")

## test error
tail(mm$err_test, 1)
sum(dat$data_test[,3] != pp)/nrow(dat$data_test)

### multiclass classification

### binary classification, custom classifier

## a custom regression classifier function
classifier_lm <- function(x_train, y_train, weights, ...){
y_train_code <- c(-1,1)
y_train_coded <- sapply(levels(y_train), function(m) y_train_code[(y_train == m) + 1])

# a custom regression classifier function
classifier_lm <- function(x_train, y_train, weights, ...){
y_train_code <- c(-1,1)
y_train_coded <- sapply(levels(y_train), function(m) y_train_code[(y_train == m) + 1])
y_train_coded <- y_train_coded[,1]

model <- lm.wfit(x = as.matrix(cbind(1,x_train)), y = y_train_coded, w = weights)
return(list(coefficients = model$coefficients,
            levels = levels(y_train)))

## predictor function

predictor_lm <- function(model, x_new, type = "pred", ...) {
  coef <- model$coefficients
  levels <- model$levels

  fit <- as.matrix(cbind(1, x_new))%*%coef
  probs <- 1/(1 + exp(-fit))
  probs <- data.frame(probs, 1 - probs)
  colnames(probs) <- levels

  if (type == "pred") {
    preds <- factor(levels[apply(probs, 1, which.max)], levels = levels, labels = levels)
    return(preds)
  }
  if (type == "prob") {
    return(probs)
  }
}

## real AdaBoost

mm <- booster(x_train = x_train,
              y_train = y_train,
              classifier = classifier_lm,
              predictor = predictor_lm,
              method = "real",
              x_test = x_test,
              y_test = y_test,
              weighted_bootstrap = FALSE,
              max_iter = 50,
              lambda = 1,
              print_detail = TRUE,
              print_plot = TRUE,
              bag_frac = 0.5,
              p_weak = 2)

## test prediction

mm$test_prediction

pp <- predict(object = mm, newdata = x_test, type = "pred", print_detail = TRUE)

## test error

tail(mm$err_test, 1)
sum(y_test != pp)/nrow(x_test)

## discrete AdaBoost

mm <- booster(x_train = x_train,
              y_train = y_train,
classifier = classifier_lm,
predictor = predictor_lm,
method = "discrete",
x_test = x_test,
y_test = y_test,
weighted_bootstrap = FALSE,
max_iter = 50,
lambda = 1,
print_detail = TRUE,
print_plot = TRUE,
bag_frac = 0.5,
p_weak = 2)
## test prediction
mm$test_prediction
pp <- predict(object = mm, newdata = x_test, type = "pred", print_detail = TRUE)
## test error
tail(mm$err_test, 1)
sum(y_test != pp)/nrow(x_test)
# plot function can be used to plot errors
plot(mm)
# more examples are in vignette("booster", package = "rbooster")

<table>
<thead>
<tr>
<th>discretize</th>
<th>Discretize</th>
</tr>
</thead>
</table>

**Description**
Discretizes numeric variables

**Usage**
discretize(xx, breaks = 3, boundaries = NULL, categories = NULL, w = NULL)

**Arguments**
- **xx**: matrix or data.frame whose variables needs to be discretized.
- **breaks**: number of categories for each variable. Ignored if boundaries ! = NULL.
- **boundaries**: user-defined upper and lower limit matrix of discretization for each variable. Default is NULL.
- **categories**: user-defined category names for each variable. Default is NULL.
- **w**: sample weights for quantile calculation.

**Details**
Uses quantiles for discretization. However, quantiles may be equal in some cases. Then equal interval discretization used instead.
**predict.booster**

**Value**

a list consists of:

- `x_discrete` data.frame of discretized variables. Each variable is a factor.
- `boundaries` upper and lower limit matrix of discretization for each variable.
- `categories` category names for each variable.

**Author(s)**

Fatih Saglam, fatih.saglam@omu.edu.tr

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**predict.booster** Prediction function for Adaboost framework

**Description**

Makes predictions based on booster function

**Usage**

```r
## S3 method for class 'booster'
predict(object, newdata, type = "pred", print_detail = FALSE, ...)
```

```r
## S3 method for class 'discrete_adaboost'
predict(object, newdata, type = "pred", print_detail = FALSE, ...)
```

```r
## S3 method for class 'real_adaboost'
predict(object, newdata, type = "pred", print_detail = FALSE, ...)
```

**Arguments**

- `object` booster object
- `newdata` a factor class variable. Boosting algorithm allows for
- `type` pre-ready or a custom classifier function.
- `print_detail` prints the prediction process. Default is FALSE.
- `...` additional arguments.

**Details**

Type "pred" will give class predictions. "prob" will give probabilities for each class.

**Value**

A vector of class predictions or a matrix of class probabilities depending of type

**See Also**

[predict()]
predict.w_naive_bayes  
*Predict Discrete Naive Bayes*

**Description**

Function for Naive Bayes algorithm prediction.

**Usage**

```r
## S3 method for class 'w_naive_bayes'
predict(object, newdata = NULL, type = "prob", ...)

## S3 method for class 'w_discrete_naive_bayes'
predict(object, newdata, type = "prob", ...)

## S3 method for class 'w_gaussian_naive_bayes'
predict(object, newdata = NULL, type = "prob", ...)
```

**Arguments**

- `object`  
  "w_bayes" class object.

- `newdata`  
  new observations which predictions will be made on.

- `type`  
  "pred" or "prob".

- `...`  
  additional arguments.

**Details**

Calls `predict.w_discrete_naive_bayes` or `predict.w_gaussian_naive_bayes` accordingly.

Type "pred" will give class predictions. "prob" will give probabilities for each class.

**Value**

A vector of class predictions or a matrix of class probabilities depending of `type`.

**See Also**

[predict()], [rbooster::predict.w_discrete_naive_bayes()], [rbooster::predict.w_gaussian_naive_bayes()]
**Naive Bayes algorithm with case weights**

**Description**

Function for Naive Bayes algorithm classification with case weights.

**Usage**

- `w_naive_bayes(x_train, y_train, w = NULL, discretize = TRUE, breaks = 3)`
- `w_gaussian_naive_bayes(x_train, y_train, w = NULL)`
- `w_discrete_naive_bayes(x_train, y_train, breaks = 3, w = NULL)`

**Arguments**

- `x_train` explanatory variables.
- `y_train` a factor class variable.
- `w` a vector of case weights.
- `discretize` If `TRUE` numerical variables are discretized and discrete naive bayes is applied, ignored if `discretize = TRUE`.
- `breaks` number of break points for discretization.

**Details**

`w_naive_bayes` calls `w_gaussian_naive_bayes` or `w_discrete_naive_bayes`.

- If `discrete = FALSE`, `w_gaussian_naive_bayes` is called. It uses Gaussian densities with case weights and allows multiclass classification.
- If `discrete = TRUE`, `w_discrete_naive_bayes` is called. It uses conditional probabilities for each category with laplace smoothing and allows multiclass classification.

**Value**

A `w_naive_bayes` object with below components.

- `n_train` Number of cases in the input dataset.
- `p` Number of explanatory variables.
- `x_classes` A list of datasets, which are `x_train` separated for each class.
- `n_classes` Number of cases for each class in input dataset.
- `k_classes` Number of classes in class variable.
- `priors` Prior probabilities.
- `class_names` Names of classes in class variable.
- `means` Weighted mean estimations for each variable.
stds          Weighted standard deviation estimations for each variable.
categories    Labels for discretized variables.
boundaries    Upper and lower boundaries for discretization.
ps            probabilities for each variable categories.

Examples

library(rbooster)
## short functions for cross-validation and data simulation
cv_sampler <- function(y, train_proportion) {
  unlist(lapply(unique(y), function(m) sample(which(y==m), round(sum(y==m))*train_proportion)))
}
data_simulation <- function(n, p, k, train_proportion){
  means <- seq(0, k*1.5, length.out = k)
  x <- do.call(rbind, lapply(means,
      function(m) matrix(data = rnorm(n = round(n/k)*p, mean = m, sd = 2),
      nrow = round(n/k))))
  y <- factor(rep(letters[1:k], each = round(n/k)))
  train_i <- cv_sampler(y, train_proportion)
  data <- data.frame(x, y = y)
data_train <- data[train_i,]
data_test <- data[-train_i,]
  return(list(data = data,
      data_train = data_train,
      data_test = data_test))
}

### binary classification example
n <- 500
p <- 10
k <- 2
data <- data_simulation(n = n, p = p, k = k, train_proportion = 0.8)
x <- dat$data[,1:p]
y <- dat$data[,p+1]

x_train <- dat$data_train[,1:p]
y_train <- dat$data_train[,p+1]

x_test <- dat$data_test[,1:p]
y_test <- dat$data_test[,p+1]

## discretized Naive Bayes classification
mm1 <- w_naive_bayes(x_train = x_train, y_train = y_train, discretize = TRUE, breaks = 4)
preds1 <- predict(object = mm1, newdata = x_test, type = "pred")
table(y_test, preds1)
# or
mm2 <- w_discrete_naive_bayes(x_train = x_train, y_train = y_train, breaks = 4)
preds2 <- predict(object = mm2, newdata = x_test, type = "pred")
    table(y_test, preds2)

## Gaussian Naive Bayes classification
mm3 <- w_naive_bayes(x_train = x_train, y_train = y_train, discretize = FALSE)
preds3 <- predict(object = mm3, newdata = x_test, type = "pred")
    table(y_test, preds3)

# or
mm4 <- w_gaussian_naive_bayes(x_train = x_train, y_train = y_train)
preds4 <- predict(object = mm4, newdata = x_test, type = "pred")
    table(y_test, preds4)

## multiclass example
n <- 500
p <- 10
k <- 5
dat <- data_simulation(n = n, p = p, k = k, train_proportion = 0.8)
x <- dat$data[,1:p]
y <- dat$data[,p+1]

x_train <- dat$data_train[,1:p]
y_train <- dat$data_train[,p+1]

x_test <- dat$data_test[,1:p]
y_test <- dat$data_test[,p+1]

# discretized
mm5 <- w_discrete_naive_bayes(x_train = x_train, y_train = y_train, breaks = 4)
preds5 <- predict(object = mm5, newdata = x_test, type = "pred")
    table(y_test, preds5)

# gaussian
mm6 <- w_gaussian_naive_bayes(x_train = x_train, y_train = y_train)
preds6 <- predict(object = mm6, newdata = x_test, type = "pred")
    table(y_test, preds6)

## example for case weights
n <- 500
p <- 10
k <- 5
dat <- data_simulation(n = n, p = p, k = k, train_proportion = 0.8)
x <- dat$data[,1:p]
y <- dat$data[,p+1]

x_train <- dat$data_train[,1:p]
y_train <- dat$data_train[,p+1]

# discretized
weights <- ifelse(y_train == "a" | y_train == "c", 1, 0.01)
mm7 <- w_discrete_naive_bayes(x_train = x_train, y_train = y_train, breaks = 4, w = weights)
preds7 <- predict(object = mm7, newdata = x_test, type = "pred")
table(y_test, preds7)

# gaussian
weights <- ifelse(y_train == "b" | y_train == "d", 1, 0.01)
mm8 <- w_gaussian_naive_bayes(x_train = x_train, y_train = y_train, w = weights)
preds8 <- predict(object = mm8, newdata = x_test, type = "pred")
table(y_test, preds8)
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