

# Package: SDMtune (via r-universe)

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**Type** Package

**Title** Species Distribution Model Selection

**Version** 1.3.1

**Description** User-friendly framework that enables the training and the evaluation of species distribution models (SDMs). The package implements functions for data driven variable selection and model tuning and includes numerous utilities to display the results. All the functions used to select variables or to tune model hyperparameters have an interactive real-time chart displayed in the 'RStudio' viewer pane during their execution.

**License** GPL-3

**URL** <https://consbiol-unibern.github.io/SDMtune/>

**BugReports** <https://github.com/ConsBiol-unibern/SDMtune/issues>

**SystemRequirements** Java (>= 8)

**Depends** R (>= 4.1.0)

**Imports** cli (>= 3.4.1), dismo (>= 1.3-9), gbm (>= 2.1.5), ggplot2 (>= 3.4.0), jsonlite (>= 1.6), maxnet (>= 0.1.4), methods, nnet (>= 7.3-12), randomForest (>= 4.6-14), Rcpp (>= 1.0.1), rlang (>= 0.4.5), rstudioapi (>= 0.10), stringr (>= 1.4.0), terra (>= 1.6-47), whisker (>= 0.3-2)

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**VignetteBuilder** knitr

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**Collate** 'ANN-class.R' 'BRT-class.R' 'Maxent-class.R' 'Maxnet-class.R'  
 'RF-class.R' 'RcppExports.R' 'SWD-class.R' 'SDMmodel-class.R'  
 'SDMmodel2MaxEnt.R' 'SDMmodelCV-class.R' 'SDMtune-class.R'  
 'SDMtune-package.R' 'addSamplesToBg.R' 'aicc.R' 'auc.R'  
 'chart-utils.R' 'checkMaxentInstallation.R' 'combineCV.R'  
 'confMatrix.R' 'convertFolds.R' 'corVar.R' 'doJk.R'  
 'getTunableArgs.R' 'gridSearch.R' 'maxentTh.R' 'maxentVarImp.R'  
 'mergeSWD.R' 'modelReport.R' 'optimizeModel.R' 'plotCor.R'  
 'plotJk.R' 'plotPA.R' 'plotPred.R' 'plotROC.R' 'plotResponse.R'  
 'plotVarImp.R' 'predict-ANN.R' 'predict-BRT.R'  
 'predict-Maxent.R' 'predict-Maxnet.R' 'predict-RF.R'  
 'predict-SDMmodel.R' 'predict-SDMmodelCV.R' 'prepareSWD.R'  
 'randomFolds.R' 'randomSearch.R' 'reduceVar.R' 'swd2csv.R'  
 'thinData.R' 'thresholds.R' 'train.R' 'trainANN.R' 'trainBRT.R'  
 'trainMaxent.R' 'trainMaxnet.R' 'trainRF.R' 'trainValTest.R'  
 'tss.R' 'utils.R' 'varImp.R' 'varSel.R' 'virtualSp.R' 'zzz.R'

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addSamplesToBg *Add Samples to Background*

**Description**

The function add the presence locations to the background. This is equivalent to the Maxent argument `addsamplestobackground=true`.

**Usage**

`addSamplesToBg(x, all = FALSE)`

**Arguments**

- `x` [SWD](#) object.
- `all` logical. If TRUE it adds all the presence locations even if already included in the background locations. This is equivalent to the `Maxent` argument `addallsamplestobackground=true`.

**Value**

An object of class [SWD](#).

**Author(s)**

Sergio Vignali

**Examples**

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

data

# Add presence locations with values not included in the backgrounds to the
# background locations
new_data <- addSamplesToBg(data)
new_data

# Add all the presence locations to the background locations, even if they
# have values already included in the backgrounds
new_data <- addSamplesToBg(data,
                          all = TRUE)

new_data
```

---

aicc	<i>AICc</i>
------	-------------

---

**Description**

Compute the Akaike Information Criterion corrected for small samples size (Warren and Seifert, 2011).

**Usage**

```
aicc(model, env)
```

**Arguments**

`model` [SDMmodel](#) object.  
`env` [rast](#) containing the environmental variables.

**Details**

The function is available only for **Maxent** and **Maxnet** methods.

**Value**

The computed AICc

**Author(s)**

Sergio Vignali

**References**

Warren D.L., Seifert S.N., (2011). Ecological niche modeling in Maxent: the importance of model complexity and the performance of model selection criteria. *Ecological Applications*, 21(2), 335–342.

**See Also**

[auc](#) and [tss](#).

**Examples**

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
```

```

p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                   p = p_coords,
                   a = bg_coords,
                   env = predictors,
                   categorical = "biome")

# Train a model
model <- train(method = "Maxnet",
               data = data,
               fc = "1")

# Compute the AICc
aicc(model,
      env = predictors)

```

---

ANN-class

*Artificial Neural Network*


---

## Description

This Class represents an Artificial Neural Network model object and hosts all the information related to the model.

## Usage

```
## S4 method for signature 'ANN'
show(object)
```

## Arguments

object            ANN object

## Details

See [nnet](#) for the meaning of the slots.

## Slots

size integer. Number of the units in the hidden layer.  
decay numeric. Weight decay.  
rang numeric. Initial random weights.  
maxit integer. Maximum number of iterations.  
model [nnet](#). The randomForest model object.

**Author(s)**

Sergio Vignali

---

`auc`*AUC*

---

**Description**

Compute the AUC using the Man-Whitney U Test formula.

**Usage**

```
auc(model, test = NULL)
```

**Arguments**

<code>model</code>	An <a href="#">SDMmodel</a> or <a href="#">SDMmodelCV</a> object.
<code>test</code>	<a href="#">SWD</a> object when <code>model</code> is an <a href="#">SDMmodel</a> object; logical or <a href="#">SWD</a> object when <code>model</code> is an <a href="#">SDMmodelCV</a> object. If not provided it computes the training AUC, see details.

**Details**

For [SDMmodelCV](#) objects, the function computes the mean of the training AUC values of the k-folds. If `test = TRUE` it computes the mean of the testing AUC values for the k-folds. If `test` is an [SWD](#) object, it computes the mean AUC values for the provided testing dataset.

**Value**

The value of the AUC.

**Author(s)**

Sergio Vignali

**References**

Mason, S. J. and Graham, N. E. (2002), Areas beneath the relative operating characteristics (ROC) and relative operating levels (ROL) curves: Statistical significance and interpretation. *Q.J.R. Meteorol. Soc.*, 128: 2145-2166.

**See Also**

[aicc](#) and [tss](#).

## Examples

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

# Split presence locations in training (80%) and testing (20%) datasets
datasets <- trainValTest(data,
                        test = 0.2,
                        only_presence = TRUE)

train <- datasets[[1]]
test <- datasets[[2]]

# Train a model
model <- train(method = "Maxnet",
              data = train,
              fc = "1")

# Compute the training AUC
auc(model)

# Compute the testing AUC
auc(model,
     test = test)

# Same example but using cross validation instead of training and testing
# datasets
folds <- randomFolds(data,
                    k = 4,
                    only_presence = TRUE)

model <- train(method = "Maxnet",
              data = data,
              fc = "1",
              folds = folds)

# Compute the training AUC
auc(model)
```



```
# Compute the testing AUC
auc(model,
      test = TRUE)

# Compute the AUC for the held apart testing dataset
auc(model,
      test = test)
```

---

BRT-class

*Boosted Regression Tree*

---

## Description

This Class represents a Boosted Regression Tree model objects and hosts all the information related to the model.

## Usage

```
## S4 method for signature 'BRT'
show(object)
```

## Arguments

object            BRT object

## Details

See [gbm](#) for the meaning of the slots.

## Slots

distribution character. Name of the used distribution.

n.trees integer. Maximum number of grown trees.

interaction.depth integer. Maximum depth of each tree.

shrinkage numeric. The shrinkage parameter.

bag.fraction numeric. Random fraction of data used in the tree expansion.

model [gbm](#). The Boosted Regression Tree model object.

## Author(s)

Sergio Vignali

---

`checkMaxentInstallation`*Check Maxent Installation*

---

**Description**

The function checks if Maxent is correctly installed.

**Usage**

```
checkMaxentInstallation(verbose = TRUE)
```

**Arguments**

<code>verbose</code>	logical, if TRUE the function provides useful messages to understand what is not correctly installed.
----------------------	-------------------------------------------------------------------------------------------------------

**Details**

In order to have Maxent correctly configured is necessary that:

- Java is installed;
- the package "rJava" is installed;
- the file "maxent.jar" is in the correct folder.

**Value**

TRUE if Maxent is correctly installed, FALSE otherwise.

**Author(s)**

Sergio Vignali

**Examples**

```
checkMaxentInstallation()
```

**Description**

This function combines cross-validation models by retraining a new model with all presence and absence/background locations and the same hyperparameters.

**Usage**

```
combineCV(model)
```

**Arguments**

model            [SDMmodelCV](#) object.

**Details**

This is an utility function to retrain a model with all data after, for example, the hyperparameters tuning ([gridSearch](#), [randomSearch](#) or [optimizeModel](#)) to avoid manual setting of the hyperparameters in the [train](#) function.

**Value**

An [SDMmodel](#) object.

**Author(s)**

Sergio Vignali

**Examples**

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                   pattern = "grd",
                   full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")
```

```

# Create 4 random folds splitting only the presence data
folds <- randomFolds(data,
                    k = 4,
                    only_presence = TRUE)

model <- train(method = "Maxnet",
              data = data,
              folds = folds)

# Define the hyperparameters to test
h <- list(reg = 1:2,
          fc = c("lqp", "lqph"))

# Run the function using the AUC as metric
output <- gridSearch(model,
                    hypers = h,
                    metric = "auc")

output@results
output@models

# Order results by highest test AUC
output@results[order(-output@results$test_AUC), ]

# Combine cross validation models for output with highest test AUC
idx <- which.max(output@results$test_AUC)
combined_model <- combineCV(output@models[[idx]])
combined_model

```

---

confMatrix

*Confusion Matrix*

---

## Description

Computes Confusion Matrixes for threshold values varying from 0 to 1.

## Usage

```
confMatrix(model, test = NULL, th = NULL, type = NULL)
```

## Arguments

model	<a href="#">SDMmodel</a> object.
test	<a href="#">SWD</a> testing locations, if not provided it uses the training dataset.
th	numeric vector. If provided it computes the evaluation at the given thresholds. Default is NULL and it computes the evaluation for the unique predicted values at presence and absence/background locations.
type	character. The output type used for "Maxent" and "Maxnet" methods, possible values are "cloglog" and "logistic".

## Details

- For models trained with the **Maxent** method the argument type can be: "raw", "logistic" and "cloglog".
- For models trained with the **Maxnet** method the argument type can be: "link", "exponential", "logistic" and "cloglog", see [maxnet](#) for more details.

## Value

The Confusion Matrix for all the used thresholds.

## Author(s)

Sergio Vignali

## Examples

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

# Train a model
model <- train(method = "Maxnet",
              data = data,
              fc = "1")

# Get the confusion matrix for thresholds ranging from 0 to 1
cm <- confMatrix(model,
                type = "cloglog")

head(cm)
tail(cm)

# Get the confusion matrix for a specific threshold
confMatrix(model,
          type = "logistic",
          th = 0.6)
```

---

 corVar

*Print Correlated Variables*


---

### Description

Utility that prints the name of correlated variables and the relative correlation coefficient value.

### Usage

```
corVar(
  bg,
  method = "spearman",
  cor_th = NULL,
  order = TRUE,
  remove_diagonal = TRUE
)
```

### Arguments

bg	<a href="#">SWD</a> object with the locations used to compute the correlation between environmental variables.
method	character. The method used to compute the correlation matrix.
cor_th	numeric. If provided it prints only the variables whose correlation coefficient is higher or lower than the given threshold.
order	logical. If TRUE the variable are ordered from the most to the less highly correlated.
remove_diagonal	logical. If TRUE the values in the diagonal are removed.

### Value

A data.frame with the variables and their correlation.

### Author(s)

Sergio Vignali

### Examples

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
  pattern = "grd",
  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare background locations
```

```

bg_coords <- terra::spatSample(predictors,
                               size = 10000,
                               method = "random",
                               na.rm = TRUE,
                               xy = TRUE,
                               values = FALSE)

# Create SWD object
bg <- prepareSWD(species = "Virtual species",
                 a = bg_coords,
                 env = predictors,
                 categorical = "biome")

# Get the correlation among all the environmental variables
corVar(bg,
        method = "spearman")

# Get the environmental variables that have a correlation greater or equal to
# the given threshold
corVar(bg,
        method = "pearson",
        cor_th = 0.8)

```

---

doJk

*Jackknife Test*


---

## Description

Run the Jackknife test for variable importance removing one variable at time.

## Usage

```

doJk(
  model,
  metric,
  variables = NULL,
  test = NULL,
  with_only = TRUE,
  env = NULL,
  return_models = FALSE,
  progress = TRUE
)

```

## Arguments

**model** [SDMmodel](#) or [SDMmodelCV](#) object.

**metric** character. The metric used to evaluate the models, possible values are: "auc", "tss" and "aicc".

variables	vector. Variables used for the test, if not provided it takes all the variables used to train the model.
test	<b>SWD</b> . If provided it reports the result also for the testing dataset. Not used for <b>aicc</b> and <b>SDMmodelCV</b> .
with_only	logical. If TRUE it runs the test also for each variable in isolation.
env	<b>rast</b> containing the environmental variables, used only with "aicc".
return_models	logical. If TRUE returns all the models together with the test result.
progress	logical. If TRUE shows a progress bar.

### Value

A data frame with the test results. If `return_model = TRUE` it returns a list containing the test results together with the models.

### Author(s)

Sergio Vignali

### Examples

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                   pattern = "grd",
                   full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

# Split presence locations in training (80%) and testing (20%) datasets
datasets <- trainValTest(data,
                        test = 0.2,
                        only_presence = TRUE)

train <- datasets[[1]]
test <- datasets[[2]]

# Train a model
model <- train(method = "Maxnet",
              data = train,
              fc = "lq")
```



```
# Execute the Jackknife test only for the environmental variables "bio1" and
# "bio12", using the metric AUC
doJk(model,
      metric = "auc",
      variables = c("bio1", "bio12"),
      test = test)

# The same without testing dataset
doJk(model,
      metric = "auc",
      variables = c("bio1", "bio12"))

# Execute the Jackknife test only for the environmental variables "bio1" and
# "bio12", using the metric TSS but without running the test for one single
# variable
doJk(model,
      metric = "tss",
      variables = c("bio1", "bio12"),
      test = test,
      with_only = FALSE)

# Execute the Jackknife test only for the environmental variables "bio1" and
# "bio12", using the metric AICc but without running the test for one single
# variable
doJk(model,
      metric = "aicc",
      variables = c("bio1", "bio12"),
      with_only = FALSE,
      env = predictors)

# Execute the Jackknife test for all the environmental variables using the
# metric AUC and returning all the trained models
jk <- doJk(model,
           metric = "auc",
           test = test,
           return_models = TRUE)

jk$results
jk$models_without
jk$models_withonly
```

---

getTunableArgs

*Get Tunable Arguments*

---

## Description

Returns the name of all function arguments that can be tuned for a given model.

## Usage

```
getTunableArgs(model)
```

**Arguments**

model [SDMmodel](#) or [SDMmodelCV](#) object.

**Value**

character vector.

**Author(s)**

Sergio Vignali

**Examples**

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

# Train a Maxnet model and get tunable hyperparameters
model <- train(method = "Maxnet",
              data = data,
              fc = "1")

getTunableArgs(model)
```

---

gridSearch

*Grid Search*

---

**Description**

Given a set of possible hyperparameter values, the function trains models with all the possible combinations of hyperparameters.

**Usage**

```
gridSearch(  
  model,  
  hypers,  
  metric,  
  test = NULL,  
  env = NULL,  
  save_models = TRUE,  
  interactive = TRUE,  
  progress = TRUE  
)
```

**Arguments**

model	<a href="#">SDMmodel</a> or <a href="#">SDMmodelCV</a> object.
hypers	named list containing the values of the hyperparameters that should be tuned, see details.
metric	character. The metric used to evaluate the models, possible values are: "auc", "tss" and "aicc".
test	<a href="#">SWD</a> object. Testing dataset used to evaluate the model, not used with <a href="#">aicc</a> and <a href="#">SDMmodelCV</a> objects.
env	<a href="#">rast</a> containing the environmental variables, used only with "aicc".
save_models	logical. If FALSE the models are not saved and the output contains only a data frame with the metric values for each hyperparameter combination. Set it to FALSE when there are many combinations to avoid R crashing for memory overload.
interactive	logical. If FALSE the interactive chart is not created.
progress	logical. If TRUE shows a progress bar.

**Details**

To know which hyperparameters can be tuned you can use the output of the function [getTunableArgs](#). Hyperparameters not included in the hypers argument take the value that they have in the passed model.

An interactive chart showing in real-time the steps performed by the algorithm is displayed in the Viewer pane.

**Value**

[SDMtune](#) object.

**Author(s)**

Sergio Vignali

**See Also**

[randomSearch](#) and [optimizeModel](#).

**Examples**

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

# Split presence locations in training (80%) and testing (20%) datasets
datasets <- trainValTest(data,
                        test = 0.2,
                        only_presence = TRUE)

train <- datasets[[1]]
test <- datasets[[2]]

# Train a model
model <- train(method = "Maxnet",
              data = train,
              fc = "1")

# Define the hyperparameters to test
h <- list(reg = 1:2,
         fc = c("lqp", "lqph"))

# Run the function using the AUC as metric
output <- gridSearch(model,
                    hypers = h,
                    metric = "auc",
                    test = test)

output@results
output@models

# Order results by highest test AUC
output@results[order(-output@results$test_AUC), ]

# Run the function using the AICc as metric and without saving the trained
# models, helpful when numerous hyperparameters are tested to avoid memory
```

```

# problems
output <- gridSearch(model,
                     hypers = h,
                     metric = "aicc",
                     env = predictors,
                     save_models = FALSE)

output@results

```

---

Maxent-class

*Maxent*


---

## Description

This Class represents a MaxEnt model objects and hosts all the information related to the model.

## Usage

```

## S4 method for signature 'Maxent'
show(object)

```

## Arguments

object            Maxent object

## Slots

results matrix. The result that usually MaxEnt provide as a csv file.

reg numeric. The value of the regularization multiplier used to train the model.

fc character. The feature class combination used to train the model.

iter numeric. The number of iterations used to train the model.

extra\_args character. Extra arguments used to run MaxEnt.

lambdas vector. The lambdas parameters of the model.

coeff data.frame. The lambda coefficients of the model.

formula formula. The formula used to make prediction.

lpn numeric. Linear Predictor Normalizer.

dn numeric. Density Normalizer.

entropy numeric. The entropy value.

min\_max data.frame. The minimum and maximum values of the continuous variables, used for clamping.

## Author(s)

Sergio Vignali

---

`maxentTh`*MaxEnt Thresholds*

---

**Description**

Returns the value of the thresholds generated by the MaxEnt software.

**Usage**

```
maxentTh(model)
```

**Arguments**

`model` [SDMmodel](#) object trained using the "Maxent" method.

**Value**

data.frame with the thresholds.

**Author(s)**

Sergio Vignali

**See Also**

[maxentVarImp](#).

**Examples**

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

# Train a Maxent model
model <- train(method = "Maxent",
              data = data,
```

```
fc = "1")  
maxentTh(model)
```

---

maxentVarImp	<i>Maxent Variable Importance</i>
--------------	-----------------------------------

---

### Description

Shows the percent contribution and permutation importance of the environmental variables used to train the model.

### Usage

```
maxentVarImp(model)
```

### Arguments

model [SDMmodel](#) or [SDMmodelCV](#) object trained using the "Maxent" method.

### Details

When an [SDMmodelCV](#) object is passed to the function, the output is the average of the variable importance of each model trained during the cross validation.

### Value

A data frame with the variable importance.

### Author(s)

Sergio Vignali

### See Also

[maxentTh](#).

### Examples

```
# Acquire environmental variables  
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),  
                  pattern = "grd",  
                  full.names = TRUE)  
  
predictors <- terra::rast(files)  
  
# Prepare presence and background locations  
p_coords <- virtualSp$presence  
bg_coords <- virtualSp$background
```

```
# Create SWD object
data <- prepareSWD(species = "Virtual species",
                   p = p_coords,
                   a = bg_coords,
                   env = predictors,
                   categorical = "biome")

# Train a Maxent model
# The next line checks if Maxent is correctly configured but you don't need
# to run it in your script
model <- train(method = "Maxent",
              data = data,
              fc = "1")

maxentVarImp(model)
```

---

Maxnet-class

*Maxnet*

---

## Description

This Class represents a Maxnet model objects and hosts all the information related to the model.

## Usage

```
## S4 method for signature 'Maxnet'
show(object)
```

## Arguments

object            Maxnet object

## Slots

reg numeric. The value of the regularization multiplier used to train the model.

fc character. The feature class combination used to train the model.

model maxnet. The maxnet model object.

## Author(s)

Sergio Vignali



---

`mergeSWD`*Merge SWD Objects*

---

## Description

Merge two [SWD](#) objects.

## Usage

```
mergeSWD(swd1, swd2, only_presence = FALSE)
```

## Arguments

<code>swd1</code>	<a href="#">SWD</a> object.
<code>swd2</code>	<a href="#">SWD</a> object.
<code>only_presence</code>	logical If TRUE only for the presence locations are merged and the absence/background locations are taken only from the <code>swd1</code> object.

## Details

- In case the two [SWD](#) objects have different columns, only the common columns are used in the merged object.
- The [SWD](#) object is created in a way that the presence locations are always before than the absence/background locations.

## Value

The merged [SWD](#) object.

## Author(s)

Sergio Vignali

## Examples

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
```

```

      p = p_coords,
      a = bg_coords,
      env = predictors,
      categorical = "biome")

# Split only presence locations in training (80%) and testing (20%) datasets
datasets <- trainValTest(data,
                        test = 0.2,
                        only_presence = TRUE)
train <- datasets[[1]]
test <- datasets[[2]]

# Merge the training and the testing datasets together
merged <- mergeSWD(train,
                  test,
                  only_presence = TRUE)

# Split presence and absence locations in training (80%) and testing (20%)
datasets
datasets <- trainValTest(data,
                        test = 0.2)
train <- datasets[[1]]
test <- datasets[[2]]

# Merge the training and the testing datasets together
merged <- mergeSWD(train, test)

```

---

 modelReport

*Model Report*


---

## Description

Make a report that shows the main results.

## Usage

```

modelReport(
  model,
  folder,
  test = NULL,
  type = NULL,
  response_curves = FALSE,
  only_presence = FALSE,
  jk = FALSE,
  env = NULL,
  clamp = TRUE,
  permut = 10,
  verbose = TRUE
)

```

**Arguments**

model	<a href="#">SDMmodel</a> object.
folder	character. The name of the folder in which to save the output. The folder is created in the working directory.
test	<a href="#">SWD</a> object with the test locations.
type	character. The output type used for "Maxent" and "Maxnet" methods, possible values are "cloglog" and "logistic".
response_curves	logical, if TRUE it plots the response curves in the html output.
only_presence	logical, if TRUE it uses only the range of the presence location for the marginal response.
jk	logical, if TRUE it runs the jackknife test.
env	<a href="#">rast</a> . If provided it computes and adds a prediction map to the output.
clamp	logical for clumping during prediction, used for response curves and for the prediction map.
permut	integer. Number of permutations.
verbose	logical, if TRUE prints informative messages.

**Details**

The function produces a report similar to the one created by MaxEnt software. See [terra](#) documentation to see how to pass factors.

**Author(s)**

Sergio Vignali

**Examples**

```
# If you run the following examples with the function example(),
# you may want to set the argument ask like following: example("modelReport",
# ask = FALSE)
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                    pattern = "grd",
                    full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                   p = p_coords,
                   a = bg_coords,
```

```

        env = predictors,
        categorical = "biome")

# Split presence locations in training (80%) and testing (20%) datasets
datasets <- trainValTest(data,
                        test = 0.2,
                        only_presence = TRUE)
train <- datasets[[1]]
test <- datasets[[2]]

# Train a model
model <- train(method = "Maxnet",
              data = train,
              fc = "1q")

# Create the report
## Not run:
modelReport(model,
            type = "cloglog",
            folder = "my_folder",
            test = test,
            response_curves = TRUE,
            only_presence = TRUE,
            jk = TRUE,
            env = predictors,
            permut = 2)
## End(Not run)

```

---

optimizeModel

*Optimize Model*


---

## Description

The function uses a Genetic Algorithm implementation to optimize the model hyperparameter configuration according to the chosen metric.

## Usage

```

optimizeModel(
  model,
  hypers,
  metric,
  test = NULL,
  pop = 20,
  gen = 5,
  env = NULL,
  keep_best = 0.4,
  keep_random = 0.2,
  mutation_chance = 0.4,

```

```

    interactive = TRUE,
    progress = TRUE,
    seed = NULL
  )

```

### Arguments

model	<a href="#">SDMmodel</a> or <a href="#">SDMmodelCV</a> object.
hypers	named list containing the values of the hyperparameters that should be tuned, see details.
metric	character. The metric used to evaluate the models, possible values are: "auc", "tss" and "aicc".
test	<a href="#">SWD</a> object. Testing dataset used to evaluate the model, not used with aicc and <a href="#">SDMmodelCV</a> objects.
pop	numeric. Size of the population.
gen	numeric. Number of generations.
env	<a href="#">rast</a> containing the environmental variables, used only with "aicc".
keep_best	numeric. Percentage of the best models in the population to be retained during each iteration, expressed as decimal number.
keep_random	numeric. Probability of retaining the excluded models during each iteration, expressed as decimal number.
mutation_chance	numeric. Probability of mutation of the child models, expressed as decimal number.
interactive	logical. If FALSE the interactive chart is not created.
progress	logical. If TRUE shows a progress bar.
seed	numeric. The value used to set the seed to have consistent results.

### Details

To know which hyperparameters can be tuned you can use the output of the function [getTunableArgs](#). Hyperparameters not included in the hypers argument take the value that they have in the passed model.

An interactive chart showing in real-time the steps performed by the algorithm is displayed in the Viewer pane.

Part of the code is inspired by [this post](#).

### Value

[SDMtune](#) object.

### Author(s)

Sergio Vignali

**See Also**

[gridSearch](#) and [randomSearch](#).

**Examples**

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
  pattern = "grd",
  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
  p = p_coords,
  a = bg_coords,
  env = predictors,
  categorical = "biome")

# Split presence locations in training (80%) and testing (20%) datasets
datasets <- trainValTest(data,
  val = 0.2,
  test = 0.2,
  only_presence = TRUE,
  seed = 61516)

train <- datasets[[1]]
val <- datasets[[2]]

# Train a model
model <- train("Maxnet",
  data = train)

# Define the hyperparameters to test
h <- list(reg = seq(0.2, 5, 0.2),
  fc = c("l", "lq", "lh", "lp", "lqp", "lqph"))

# Run the function using as metric the AUC
## Not run:
output <- optimizeModel(model,
  hypers = h,
  metric = "auc",
  test = val,
  pop = 15,
  gen = 2,
  seed = 798)

output@results
output@models
output@models[[1]] # Best model
```

```
## End(Not run)
```

---

plotCor *Plot Correlation*

---

### Description

Plot a correlation matrix heat map with the value of the correlation coefficients according with the given method. If `cor_th` is passed then it prints only the coefficients that are higher or lower than the given threshold.

### Usage

```
plotCor(bg, method = "spearman", cor_th = NULL, text_size = 3)
```

### Arguments

<code>bg</code>	<a href="#">SWD</a> object used to compute the correlation matrix.
<code>method</code>	character. The method used to compute the correlation matrix.
<code>cor_th</code>	numeric. If provided it prints only the coefficients that are higher or lower than the given threshold.
<code>text_size</code>	numeric, used to change the size of the text.

### Value

A [ggplot](#) object.

### Author(s)

Sergio Vignali

### Examples

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare background locations
bg_coords <- terra::spatSample(predictors,
                              size = 9000,
                              method = "random",
                              na.rm = TRUE,
                              xy = TRUE,
                              values = FALSE)
```

```
# Create SWD object
bg <- prepareSWD(species = "Virtual species",
                 a = bg_coords,
                 env = predictors,
                 categorical = "biome")

# Plot heat map
plotCor(bg,
        method = "spearman")

# Plot heat map showing only values higher than given threshold and change
# text size
plotCor(bg,
        method = "spearman",
        cor_th = 0.8,
        text_size = 4)
```

---

plotJk

*Plot Jackknife Test*

---

## Description

Plot the Jackknife Test for variable importance.

## Usage

```
plotJk(jk, type = c("train", "test"), ref = NULL)
```

## Arguments

jk	data.frame with the output of the <a href="#">doJk</a> function.
type	character, "train" or "test" to plot the result of the test on the train or testing dataset.
ref	numeric. The value of the chosen metric for the model trained using all the variables. If provided it plots a vertical line showing the reference value.

## Value

A [ggplot](#) object.

## Author(s)

Sergio Vignali



**Examples**

```

# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

# Split presence locations in training (80%) and testing (20%) datasets
datasets <- trainValTest(data,
                        test = 0.2,
                        only_presence = TRUE)

train <- datasets[[1]]
test <- datasets[[2]]

# Train a model
model <- train(method = "Maxnet",
              data = train,
              fc = "lq")

# Execute the Jackknife test for all the environmental variables using the
# metric AUC
jk <- doJk(model,
          metric = "auc",
          test = test)

# Plot Jackknife test result for training
plotJk(jk,
      type = "train",
      ref = auc(model))

#' # Plot Jackknife test result for testing
plotJk(jk,
      type = "test",
      ref = auc(model, test = test))

```

## Description

Plot a presence absence map using the given threshold.

## Usage

```
plotPA(  
  map,  
  th,  
  colors = NULL,  
  hr = FALSE,  
  filename = "",  
  overwrite = FALSE,  
  wopt = list(),  
  ...  
)
```

## Arguments

map	<a href="#">rast</a> object with the prediction.
th	numeric. The threshold used to convert the output in a presence/absence map.
colors	vector. Colors to be used, default is NULL and it uses red and blue.
hr	logical. If TRUE it produces an output with high resolution.
filename	character. If provided the raster map is saved in a file. It must include the extension.
overwrite	logical. If TRUE an existing file is overwritten.
wopt	list. Writing options passed to <a href="#">writeRaster</a> .
...	Unused arguments.

## Value

A [ggplot](#) object.

## Author(s)

Sergio Vignali

## See Also

[plotPred](#).

## Examples

```
map <- terra::rast(matrix(runif(400, 0, 1),  
                           nrow = 20,  
                           ncol = 20))  
  
plotPA(map,  
       th = 0.8)
```

```
# Custom colors
plotPA(map,
      th = 0.5,
      colors = c("#d8b365", "#018571"))

## Not run:
# Save the file. The following command will save the map in the working
# directory. Note that `filename` must include the extension.
plotPA(map,
      th = 0.7,
      filename = "my_map.tif")
## End(Not run)
```

---

plotPred

*Plot Prediction*

---

## Description

Plot Prediction output.

## Usage

```
plotPred(map, lt = "", colorramp = NULL, hr = FALSE)
```

## Arguments

map	<a href="#">rast</a> object with the prediction.
lt	character. Legend title.
colorramp	vector. A custom colour ramp given as a vector of colours (see example), default is NULL and uses a blue/red colour ramp.
hr	logical. If TRUE produces an output with high resolution.

## Value

A [ggplot](#) object.

## Author(s)

Sergio Vignali

## See Also

[plotPA](#).

**Examples**

```
map <- terra::rast(matrix(runif(400, 0, 1),
                          nrow = 20,
                          ncol = 20))

plotPred(map,
          lt = "Habitat suitability \ncloglog")

# Custom colors
plotPred(map,
          lt = "Habitat suitability",
          colramp = c("#2c7bb6", "#ffffbf", "#d7191c"))
```

---

plotResponse

*Plot Response Curve*


---

**Description**

Plot the Response Curve of the given environmental variable.

**Usage**

```
plotResponse(
  model,
  var,
  type = NULL,
  only_presence = FALSE,
  marginal = FALSE,
  fun = mean,
  rug = FALSE,
  color = "red"
)
```

**Arguments**

model	<a href="#">SDMmodel</a> or <a href="#">SDMmodelCV</a> object.
var	character. Name of the variable to be plotted.
type	character. The output type used for "Maxent" and "Maxnet" methods, possible values are "cloglog" and "logistic".
only_presence	logical. If TRUE it uses only the presence locations when applying the function for the marginal response.
marginal	logical. If TRUE it plots the marginal response curve.
fun	function used to compute the level of the other variables for marginal curves.
rug	logical. If TRUE it adds the rug plot for the presence and absence/background locations, available only for continuous variables.
color	The color of the curve, default is "red".

## Details

- Note that fun is not a character argument, you must use mean and not "mean".
- If you want to modify the plot, first you have to assign the output of the function to a variable, and then you have two options:
  - Modify the ggplot object by editing the theme or adding additional elements
  - Get the data with `ggplot2::ggplot_build()` and then build your own plot (see examples)

## Value

A `ggplot` object.

## Author(s)

Sergio Vignali

## Examples

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

# Train a model
model <- train(method = "Maxnet",
              data = data,
              fc = "1q")

# Plot cloglog response curve for a continuous environmental variable (bio1)
plotResponse(model,
            var = "bio1",
            type = "cloglog")

# Plot marginal cloglog response curve for a continuous environmental
# variable (bio1)
plotResponse(model,
            var = "bio1",
            type = "cloglog",
```

```
        marginal = TRUE)

# Plot logistic response curve for a continuous environmental variable
# (bio12) adding the rugs and giving a custom color
plotResponse(model,
             var = "bio12",
             type = "logistic",
             rug = TRUE,
             color = "blue")

# Plot response curve for a categorical environmental variable (biome) giving
# a custom color
plotResponse(model,
             var = "biome",
             type = "logistic",
             color = "green")

# Modify plot
# Change y axes limits
my_plot <- plotResponse(model,
                       var = "bio1",
                       type = "cloglog")

my_plot +
  ggplot2::scale_y_continuous(limits = c(0, 1))

# Get the data and create your own plot:
df <- ggplot2::ggplot_build(my_plot)$data[[1]]
plot(df$x, df$y,
     type = "l",
     lwd = 3,
     col = "blue",
     xlab = "bio1",
     ylab = "cloglog output")

# Train a model with cross validation
folds <- randomFolds(data,
                    k = 4,
                    only_presence = TRUE)

model <- train(method = "Maxnet",
              data = data,
              fc = "lq",
              folds = folds)

# Plot cloglog response curve for a continuous environmental variable (bio17)
plotResponse(model,
             var = "bio1",
             type = "cloglog")

# Plot logistic response curve for a categorical environmental variable
# (biome) giving a custom color
plotResponse(model,
             var = "biome",
```

```
type = "logistic",  
color = "green")
```

---

plotROC

*Plot ROC curve*

---

### Description

Plot the ROC curve of the given model and print the AUC value.

### Usage

```
plotROC(model, test = NULL)
```

### Arguments

model            [SDMmodel](#) object.  
test            [SWD](#) object. The testing dataset.

### Value

A [ggplot](#) object.

### Author(s)

Sergio Vignali

### Examples

```
# Acquire environmental variables  
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),  
                  pattern = "grd",  
                  full.names = TRUE)  
  
predictors <- terra::rast(files)  
  
# Prepare presence and background locations  
p_coords <- virtualSp$presence  
bg_coords <- virtualSp$background  
  
# Create SWD object  
data <- preparesWD(species = "Virtual species",  
                  p = p_coords,  
                  a = bg_coords,  
                  env = predictors,  
                  categorical = "biome")  
  
# Split presence locations in training (80%) and testing (20%) datasets  
datasets <- trainValTest(data,
```

```
                                test = 0.2,  
                                only_presence = TRUE)  
train <- datasets[[1]]  
test <- datasets[[2]]  
  
# Train a model  
model <- train(method = "Maxnet",  
               data = train,  
               fc = "1")  
  
# Plot the training ROC curve  
plotROC(model)  
  
# Plot the training and testing ROC curves  
plotROC(model,  
         test = test)
```

---

plotVarImp

*Plot Variable Importance*

---

## Description

Plot the variable importance as a bar plot.

## Usage

```
plotVarImp(df, color = "grey")
```

## Arguments

df	data.frame. A data.frame containing the the name of the variables as first column and the value of the variable importance as second column.
color	character. The colour of the bar plot.

## Value

A [ggplot](#) object.

## Author(s)

Sergio Vignali

## Examples

```
# Acquire environmental variables  
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),  
                   pattern = "grd",  
                   full.names = TRUE)
```



```
predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                   p = p_coords,
                   a = bg_coords,
                   env = predictors,
                   categorical = "biome")

# Train a model
model <- train(method = "Maxnet",
               data = data,
               fc = "1")

# Compute variable importance
vi <- varImp(model,
             permut = 1)

# Plot variable importance
plotVarImp(vi)

# Plot variable importance with custom color
plotVarImp(vi,
           color = "red")
```

---

predict,ANN-method      *Predict ANN*

---

## Description

Predict the output for a new dataset from a trained ANN model.

## Usage

```
## S4 method for signature 'ANN'
predict(object, data, type, clamp)
```

## Arguments

object	<a href="#">ANN</a> object.
data	data.frame with the data for the prediction.
type	Not used.
clamp	Not used.

**Details**

Used by the [predict,SDMmodel-method](#), not exported.

**Value**

A vector with the predicted values.

**Author(s)**

Sergio Vignali

---

predict,BRT-method      *Predict BRT*

---

**Description**

Predict the output for a new dataset from a trained BRT model.

**Usage**

```
## S4 method for signature 'BRT'  
predict(object, data, type, clamp)
```

**Arguments**

object	<a href="#">BRT</a> object.
data	data.frame with the data for the prediction.
type	Not used.
clamp	Not used.

**Details**

Used by the [predict,SDMmodel-method](#), not exported.

The function uses the number of tree defined to train the model and the "response" type output.

**Value**

A vector with the predicted values.

**Author(s)**

Sergio Vignali

---

predict,Maxent-method *Predict Maxent*

---

## Description

Predict the output for a new dataset from a trained Maxent model.

## Usage

```
## S4 method for signature 'Maxent'  
predict(object, data, type = c("cloglog", "logistic", "raw"), clamp = TRUE)
```

## Arguments

object	<a href="#">Maxent</a> object.
data	data.frame with the data for the prediction.
type	character. MaxEnt output type, possible values are "cloglog", "logistic" and "raw".
clamp	logical for clumping during prediction.

## Details

Used by the [predict,SDMmodel-method](#), not exported.

The function performs the prediction in **R** without calling the **MaxEnt** Java software. This results in a faster computation for large datasets and might result in a slightly different output compared to the Java software.

## Value

A vector with the prediction

## Author(s)

Sergio Vignali

## References

Wilson P.D., (2009). Guidelines for computing MaxEnt model output values from a lambdas file.

---

predict,Maxnet-method *Predict Maxnet*

---

### Description

Predict the output for a new dataset from a trained Maxnet model.

### Usage

```
## S4 method for signature 'Maxnet'  
predict(  
  object,  
  data,  
  type = c("link", "exponential", "cloglog", "logistic"),  
  clamp = TRUE  
)
```

### Arguments

object	<a href="#">Maxnet</a> object.
data	data.frame with the data for the prediction.
type	character. Maxnet output type, possible values are "link", "exponential", "cloglog" and "logistic".
clamp	logical for clumping during prediction.

### Details

Used by the [predict,SDMmodel-method](#), not exported.

### Value

A vector with the predicted values.

### Author(s)

Sergio Vignali

---

predict,RF-method      *Predict RF*

---

### Description

Predict the output for a new dataset from a trained RF model.

### Usage

```
## S4 method for signature 'RF'  
predict(object, data, type, clamp)
```

### Arguments

object	RF object.
data	data.frame with the data for the prediction.
type	Not used.
clamp	Not used.

### Details

Used by the [predict,SDMmodel-method](#), not exported.

### Value

A vector with the predicted probabilities of class 1.

### Author(s)

Sergio Vignali

---

predict,SDMmodel-method  
*Predict*

---

### Description

Predict the output for a new dataset given a trained [SDMmodel](#) model.

**Usage**

```
## S4 method for signature 'SDMmodel'
predict(
  object,
  data,
  type = NULL,
  clamp = TRUE,
  filename = "",
  overwrite = FALSE,
  wopt = list(),
  extent = NULL,
  ...
)
```

**Arguments**

object	<a href="#">SDMmodel</a> object.
data	data.frame, <a href="#">SWD</a> or <a href="#">rast</a> with the data for the prediction.
type	character. Output type, see details, used only for <b>Maxent</b> and <b>Maxnet</b> methods.
clamp	logical for clumping during prediction, used only for <b>Maxent</b> and <b>Maxnet</b> methods.
filename	character. If provided the raster map is saved in a file. It must include the extension.
overwrite	logical. If TRUE an existing file is overwritten.
wopt	list. Writing options passed to <a href="#">writeRaster</a> .
extent	<a href="#">ext</a> object, if provided it restricts the prediction to the given extent.
...	Additional arguments to pass to the <a href="#">predict</a> function.

**Details**

- filename, and extent are arguments used only when the prediction is run for a [rast](#) object.
- For models trained with the **Maxent** method the argument type can be: "raw", "logistic" and "cloglog". The function performs the prediction in **R** without calling the **MaxEnt** Java software. This results in a faster computation for large datasets and might result in a slightly different output compared to the Java software.
- For models trained with the **Maxnet** method the argument type can be: "link", "exponential", "logistic" and "cloglog", see [maxnet](#) for more details.
- For models trained with the **ANN** method the function uses the "raw" output type.
- For models trained with the **RF** method the output is the probability of class 1.
- For models trained with the **BRT** method the function uses the number of trees defined to train the model and the "response" output type.

**Value**

A vector with the prediction or a [rast](#) object if data is a raster [rast](#).

**Author(s)**

Sergio Vignali

**References**

Wilson P.D., (2009). Guidelines for computing MaxEnt model output values from a lambdas file.

**Examples**

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

# Split presence locations in training (80%) and testing (20%) datasets
datasets <- trainValTest(data,
                        test = 0.2,
                        only_presence = TRUE)

train <- datasets[[1]]
test <- datasets[[2]]

# Train a model
model <- train(method = "Maxnet",
              data = train,
              fc = "1")

# Make cloglog prediction for the test dataset
predict(model,
       data = test,
       type = "cloglog")

# Make logistic prediction for the whole study area
predict(model,
       data = predictors,
       type = "logistic")

## Not run:
# Make logistic prediction for the whole study area and save it in a file.
# Note that the filename must include the extension. The function saves the
```

```
# file in your working directory
predict(model,
        data = predictors,
        type = "logistic",
        filename = "my_map.tif")
## End(Not run)
```

---

predict,SDMmodelCV-method

*Predict for Cross Validation*

---

## Description

Predict the output for a new dataset given a trained [SDMmodelCV](#) model. The output is given as the provided function applied to the prediction of the k models.

## Usage

```
## S4 method for signature 'SDMmodelCV'
predict(
  object,
  data,
  fun = "mean",
  type = NULL,
  clamp = TRUE,
  filename = "",
  overwrite = FALSE,
  wopt = list(),
  extent = NULL,
  progress = TRUE,
  ...
)
```

## Arguments

object	<a href="#">SDMmodelCV</a> object.
data	data.frame, <a href="#">SWD</a> or raster <a href="#">rast</a> with the data for the prediction.
fun	character. Function used to combine the output of the k models. Note that fun is a character argument, you must use "mean" and not mean. You can also pass a vector of character containing multiple function names, see details.
type	character. Output type, see details, used only for <b>Maxent</b> and <b>Maxnet</b> methods.
clamp	logical for clumping during prediction, used only for <b>Maxent</b> and <b>Maxnet</b> methods.
filename	character. If provided the raster map is saved in a file. It must include the extension.
overwrite	logical. If TRUE an existing file is overwritten.



wopt	list. Writing options passed to <a href="#">writeRaster</a> .
extent	<a href="#">ext</a> object, if provided it restricts the prediction to the given extent.
progress	logical. If TRUE shows a progress bar during prediction.
...	Additional arguments to pass to the <a href="#">predict</a> function.

### Details

- filename, and extent are arguments used only when the prediction is run for a [rast](#) object.
- When a character vector is passed to the fun argument, than all the given functions are applied and a named list is returned, see examples.
- When filename is provided and the fun argument contains more than one function name, the saved files are named as filename\_fun, see example.
- For models trained with the **Maxent** method the argument type can be: "raw", "logistic" and "cloglog". The function performs the prediction in **R** without calling the **MaxEnt** Java software. This results in a faster computation for large datasets and might result in a slightly different output compared to the Java software.
- For models trained with the **Maxnet** method the argument type can be: "link", "exponential", "logistic" and "cloglog", see [maxnet](#) for more details.
- For models trained with the **ANN** method the function uses the "raw" output type.
- For models trained with the **RF** method the output is the probability of class 1.
- For models trained with the **BRT** method the function uses the number of trees defined to train the model and the "response" output type.

### Value

A vector with the prediction or a [rast](#) object if data is a [rast](#) or a list in the case of multiple functions.

### Author(s)

Sergio Vignali

### References

Wilson P.D., (2009). Guidelines for computing MaxEnt model output values from a lambdas file.

### Examples

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background
```

```
# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

# Create 4 random folds splitting only the presence data
folds <- randomFolds(data,
                    k = 4,
                    only_presence = TRUE)

model <- train(method = "Maxnet",
              data = data,
              fc = "1",
              folds = folds)

# Make cloglog prediction for the whole study area and get the result as
# average of the k models
predict(model,
       data = predictors,
       fun = "mean",
       type = "cloglog")

# Make cloglog prediction for the whole study area, get the average, standard
# deviation, and maximum values of the k models, and save the output in three
# files.
# The following commands save the output in the working directory. Note that
# the `filename` must include the extension
## Not run:
maps <- predict(model,
               data = predictors,
               fun = c("mean", "sd", "max"),
               type = "cloglog",
               filename = "prediction.tif")

# In this case three files are created: prediction_mean.tif,
# prediction_sd.tif and prediction_max.tif
plotPred(maps$mean)
plotPred(maps$sd)
plotPred(maps$max)

# Make logistic prediction for the whole study area, given as standard
# deviation of the k models, and save it in a file
predict(model,
       data = predictors,
       fun = "sd",
       type = "logistic",
       filename = "my_map.tif")
## End(Not run)
```

---

`prepareSWD`*Prepare an SWD object*

---

### Description

Given the coordinates, the species' name and the environmental variables, the function creates an [SWD](#) object (sample with data).

### Usage

```
prepareSWD(  
  species,  
  env,  
  p = NULL,  
  a = NULL,  
  categorical = NULL,  
  verbose = TRUE  
)
```

### Arguments

<code>species</code>	character. The name of the species.
<code>env</code>	<a href="#">rast</a> containing the environmental variables used to extract the values at coordinate locations.
<code>p</code>	data.frame. The coordinates of the presence locations.
<code>a</code>	data.frame. The coordinates of the absence/background locations.
<code>categorical</code>	vector indicating which of the environmental variable are categorical.
<code>verbose</code>	logical, if TRUE prints informative messages.

### Details

The [SWD](#) object is created in a way that the presence locations are always before than the absence/background locations.

### Value

An [SWD](#) object.

### Author(s)

Sergio Vignali

**Examples**

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create the SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

data
```

---

randomFolds

*Create Random Folds*


---

**Description**

Create random folds for cross validation.

**Usage**

```
randomFolds(data, k, only_presence = FALSE, seed = NULL)
```

**Arguments**

data	<b>SWD</b> object that will be used to train the model.
k	integer. Number of fold used to create the partition.
only_presence	logical, if TRUE the random folds are created only for the presence locations and all the background locations are included in each fold, used mainly for presence-only methods.
seed	integer. The value used to set the seed for the fold partition.

**Details**

When `only_presence = FALSE`, the proportion of presence and absence is preserved.

**Value**

list with two matrices, the first for the training and the second for the testing dataset. Each column of one matrix represents a fold with TRUE for the locations included in and FALSE excluded from the partition.

**Author(s)**

Sergio Vignali

**Examples**

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd", full.names = TRUE)
predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

data <- prepareSWD(species = "Virtual species", p = p_coords, a = bg_coords,
                  env = predictors, categorical = "biome")

# Create 4 random folds splitting presence and absence locations
folds <- randomFolds(data, k = 4)

# Create 4 random folds splitting only the presence locations
folds <- randomFolds(data, k = 4, only_presence = TRUE)
```

---

randomSearch

*Random Search*

---

**Description**

The function performs a random search in the hyperparameters space, creating a population of random models each one with a random combination of the provided hyperparameters values.

**Usage**

```
randomSearch(
  model,
  hypers,
  metric,
  test = NULL,
  pop = 20,
  env = NULL,
  interactive = TRUE,
  progress = TRUE,
  seed = NULL
)
```

**Arguments**

model	<a href="#">SDMmodel</a> or <a href="#">SDMmodelCV</a> object.
hypers	named list containing the values of the hyperparameters that should be tuned, see details.
metric	character. The metric used to evaluate the models, possible values are: "auc", "tss" and "aicc".
test	<a href="#">SWD</a> object. Test dataset used to evaluate the model, not used with aicc and <a href="#">SDMmodelCV</a> objects.
pop	numeric. Size of the population.
env	<a href="#">rast</a> containing the environmental variables, used only with "aicc".
interactive	logical. If FALSE the interactive chart is not created.
progress	logical. If TRUE shows a progress bar.
seed	numeric. The value used to set the seed to have consistent results.

**Details**

To know which hyperparameters can be tuned you can use the output of the function [getTunableArgs](#). Hyperparameters not included in the hypers argument take the value that they have in the passed model.

An interactive chart showing in real-time the steps performed by the algorithm is displayed in the Viewer pane.

**Value**

[SDMtune](#) object.

**Author(s)**

Sergio Vignali

**Examples**

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
```

```

        env = predictors,
        categorical = "biome")

# Split presence locations in training (80%) and testing (20%) datasets
datasets <- trainValTest(data,
                        test = 0.2,
                        only_presence = TRUE)
train <- datasets[[1]]
test <- datasets[[2]]

# Train a model
model <- train(method = "Maxnet",
              data = train,
              fc = "1")

# Define the hyperparameters to test
h <- list(reg = seq(0.2, 3, 0.2),
         fc = c("lqp", "lqph", "lh"))

# Run the function using as metric the AUC
output <- randomSearch(model,
                      hypers = h,
                      metric = "auc",
                      test = test,
                      pop = 10,
                      seed = 25)

output@results
output@models

# Order results by highest test AUC
output@results[order(-output@results$test_AUC), ]

```

---

reduceVar

*Reduce Variables*


---

### Description

Remove variables whose importance is less than the given threshold. The function removes one variable at time and after trains a new model to get the new variable contribution rank. If `use_jk` is `TRUE` the function checks if after removing the variable the model performance decreases (according to the given metric and based on the starting model). In this case the function stops removing the variable even if the contribution is lower than the given threshold.

### Usage

```

reduceVar(
  model,
  th,
  metric,
  test = NULL,

```

```

env = NULL,
use_jk = FALSE,
permut = 10,
use_pc = FALSE,
interactive = TRUE,
verbose = TRUE
)

```

### Arguments

model	<a href="#">SDMmodel</a> or <a href="#">SDMmodelCV</a> object.
th	numeric. The contribution threshold used to remove variables.
metric	character. The metric used to evaluate the models, possible values are: "auc", "tss" and "aicc", used only if use_jk is TRUE.
test	<a href="#">SWD</a> object containing the test dataset used to evaluate the model, not used with aicc, and if use_jk = FALSE.
env	<a href="#">rast</a> containing the environmental variables, used only with "aicc".
use_jk	Flag to use the Jackknife AUC test during the variable selection, if FALSE the function uses the percent variable contribution.
permut	integer. Number of permutations, used if use_pc = FALSE.
use_pc	logical. If TRUE and the model is trained using the <a href="#">Maxent</a> method, the algorithm uses the percent contribution computed by Maxent software to score the variable importance.
interactive	logical. If FALSE the interactive chart is not created.
verbose	logical. If TRUE prints informative messages.

### Details

An interactive chart showing in real-time the steps performed by the algorithm is displayed in the Viewer pane.

### Value

The model trained using the selected variables.

### Author(s)

Sergio Vignali

### Examples

```

# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

```



```
# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

# Split presence locations in training (80%) and testing (20%) datasets
datasets <- trainValTest(data,
                        test = 0.2,
                        only_presence = TRUE)

train <- datasets[[1]]
test <- datasets[[2]]

# Train a Maxnet model
model <- train(method = "Maxnet",
              data = train,
              fc = "lq")

# Remove all variables with permutation importance lower than 2%
output <- reduceVar(model,
                  th = 2,
                  metric = "auc",
                  test = test,
                  permut = 1)

# Remove variables with permutation importance lower than 3% only if testing
# TSS doesn't decrease
## Not run:
output <- reduceVar(model,
                  th = 3,
                  metric = "tss",
                  test = test,
                  permut = 1,
                  use_jk = TRUE)

# Remove variables with permutation importance lower than 2% only if AICc
# doesn't increase
output <- reduceVar(model,
                  th = 2,
                  metric = "aicc",
                  permut = 1,
                  use_jk = TRUE,
                  env = predictors)

# Train a Maxent model
model <- train(method = "Maxent",
              data = train,
```

```
fc = "lq")

# Remove all variables with percent contribution lower than 2%
output <- reduceVar(model,
                    th = 2,
                    metric = "auc",
                    test = test,
                    use_pc = TRUE)

## End(Not run)
```

---

RF-class

*Random Forest*

---

## Description

This Class represents a Random Forest model objects and hosts all the information related to the model.

## Usage

```
## S4 method for signature 'RF'
show(object)
```

## Arguments

object            RF object

## Details

See [randomForest](#) for the meaning of the slots.

## Slots

mtry integer. Number of variable randomly sampled.  
ntree integer. Number of grown trees.  
nodesize integer. Minimum size of terminal nodes.  
model [randomForest](#). The randomForest model object.

## Author(s)

Sergio Vignali

---

SDMmodel-class	<i>SDMmodel</i>
----------------	-----------------

---

**Description**

This Class represents an SDMmodel object and hosts all the information related to the model.

**Usage**

```
## S4 method for signature 'SDMmodel'
show(object)
```

**Arguments**

object                    SDMmodel object

**Slots**

data [SWD](#) object. The data used to train the model.  
 model An object of class [ANN](#), [BRT](#), [RF](#), [Maxent](#) or [Maxnet](#).

**Author(s)**

Sergio Vignali

---

SDMmodel2MaxEnt	<i>SDMmodel2MaxEnt</i>
-----------------	------------------------

---

**Description**

Converts an [SDMmodel](#) object containing a [Maxent](#) model into a dismo [MaxEnt](#) object.

**Usage**

```
SDMmodel2MaxEnt(model)
```

**Arguments**

model                    [SDMmodel](#) object to be converted.

**Value**

The converted dismo [MaxEnt](#) object.

**Author(s)**

Sergio Vignali

**Examples**

```

# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                    pattern = "grd",
                    full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                   p = p_coords,
                   a = bg_coords,
                   env = predictors,
                   categorical = "biome")

# Train a Maxent model
model <- train(method = "Maxent",
               data = data,
               fc = "1")

dismo_model <- SDMmodel2MaxEnt(model)
dismo_model

```

---

SDMmodelCV-class

*SDMmodelCV*


---

**Description**

This Class represents an SDMmodel model object with replicates and hosts all the models trained during the cross validation.

**Usage**

```

## S4 method for signature 'SDMmodelCV'
show(object)

```

**Arguments**

object                    SDMmodelCV object

**Slots**

models list. A list containing all the models trained during the cross validation.  
data [SWD](#) object. Full dataset used to make the partitions.

`fold`s list with two matrices, the first for the training and the second for the testing dataset. Each column of one matrix represents a fold with TRUE for the locations included in and FALSE excluded from the partition.

### Author(s)

Sergio Vignali

---

SDMtune-class

*SDMtune class*

---

### Description

Class used to save the results of one of the following functions: [gridSearch](#), [randomSearch](#) or [optimizeModel](#).

Plot an SDMtune object. Use the `interactive` argument to create an interactive chart.

### Usage

```
## S4 method for signature 'SDMtune'
show(object)

## S4 method for signature 'SDMtune,missing'
plot(x, title = "", interactive = FALSE)
```

### Arguments

<code>object</code>	SDMtune object
<code>x</code>	SDMtune object.
<code>title</code>	character. The title of the plot.
<code>interactive</code>	logical, if TRUE plot an interactive chart.

### Value

If `interactive = FALSE` the function returns a [ggplot](#) object otherwise it returns an `SDMtuneChart` object that contains the path of the temporary folder where the necessary files to create the chart are saved. In both cases the objects are returned as invisible.

### Slots

`results` `data.frame`. Results with the evaluation of the models.  
`models` list. List of [SDMmodel](#) or [SDMmodelCV](#) objects.

### Author(s)

Sergio Vignali

**Examples**

```

# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd", full.names = TRUE)
predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species", p = p_coords, a = bg_coords,
                  env = predictors, categorical = "biome")

# Split presence locations in training (80%) and testing (20%) datasets
datasets <- trainValTest(data, test = 0.2, only_presence = TRUE)
train <- datasets[[1]]
test <- datasets[[2]]

# Train a model
model <- train(method = "Maxnet", data = train, fc = "1")

# Define the hyperparameters to test
h <- list(reg = 1:5, fc = c("lqp", "lqph"))

# Run the gridSearch function using as metric the AUC
output <- gridSearch(model, hypers = h, metric = "auc", test = test)
output

# Plot the output
plot(output, title = "My experiment")

# Plot the interactive chart
p <- plot(output, title = "My experiment", interactive = TRUE)
# Print the temporary folder that stores the files used to create the chart
str(p)

```

---

SWD-class

*Sample With Data*


---

**Description**

Object similar to the MaxEnt SWD format that hosts the species name, the coordinates of the locations and the value of the environmental variables at the location places.

**Usage**

```

## S4 method for signature 'SWD'
show(object)

```

**Arguments**

object            SWD object

**Details**

The object can contains presence/absence, presence/background, presence only or absence/background only data. Use the [prepareSWD](#) function to create the object.

**Slots**

species character. Name of the species.

coords data.frame. Coordinates of the locations.

data data.frame. Value of the environmental variables at location sites.

pa numeric. Vector with 1 for presence and 0 for absence/background locations.

**Author(s)**

Sergio Vignali

---

swd2csv

*SWD to csv*

---

**Description**

Save an [SWD](#) object as csv file.

**Usage**

```
swd2csv(swd, file_name)
```

**Arguments**

swd                [SWD](#) object.

file\_name        character. The name of the file in which to save the object, see details.

**Details**

- The file\_name argument should include the extension (i.e. my\_file.csv).
- If file\_name is a single name the function saves the presence absence/background locations in a single file, adding the column **pa** with 1s for presence and 0s for absence/background locations. If file\_name is a vector with two names, it saves the object in two files: the first name is used for the presence locations and the second for the absence/background locations.

**Author(s)**

Sergio Vignali

## Examples

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

## Not run:
# The following commands save the output in the working directory
# Save the SWD object as a single csv file
swd2csv(data,
        file_name = "train_data.csv")

# Save the SWD object in two separate csv files
swd2csv(data,
        file_name = c("presence.csv", "absence.csv"))
## End(Not run)
```

---

thinData

*Thin Data*

---

## Description

Remove all but one location per raster cell. The function removes NAs and if more than one location falls within the same raster cell it selects randomly one.

## Usage

```
thinData(coords, env, x = "x", y = "y", verbose = TRUE, progress = TRUE)
```

## Arguments

coords	data.frame or matrix with the coordinates, see details.
env	<a href="#">rast</a> containing the environmental variables.
x	character. Name of the column containing the x coordinates.
y	character. Name of the column containing the y coordinates.
verbose	logical, if TRUE prints an informative message.
progress	logical, if TRUE shows a progress bar.



## Details

- **coords** and **env** must have the same coordinate reference system.
- The **coords** argument can contain several columns. This is useful if the user has information related to the coordinates that doesn't want to lose with the thinning procedure. The function expects to have the x coordinates in a column named "x", and the y coordinates in a column named "y". If this is not the case, the name of the columns containing the coordinates can be specified using the arguments **x** and **y**.

## Value

a matrix or a data frame with the thinned locations.

## Author(s)

Sergio Vignali

## Examples

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare background locations, by sampling also on areas with NA values
bg_coords <- terra::spatSample(predictors,
                              size = 9000,
                              method = "random",
                              xy = TRUE,
                              values = FALSE)

nrow(bg_coords)

# Thin the locations
# The function will remove the coordinates that have NA values for some
# predictors. Note that the function expects to have the coordinates in two
# columns named "x" and "y"

colnames(bg_coords)
thinned_bg <- thinData(bg_coords,
                     env = predictors)

nrow(thinned_bg)

# Here we sample only on areas without NA values and then we double the
# coordinates
bg_coords <- terra::spatSample(predictors,
                              size = 9000,
                              method = "random",
                              na.rm = TRUE,
                              xy = TRUE,
                              values = FALSE)
```

```

thinned_bg <- thinData(rbind(bg_coords, bg_coords),
                      env = predictors)

nrow(thinned_bg)

# In case of a dataframe containing more than two columns (e.g. a dataframe
# with the coordinates plus an additional column with the age of the species)
# and custom column names, use the function in this way
age <- sample(c(1, 2),
             size = nrow(bg_coords),
             replace = TRUE)

data <- cbind(age, bg_coords)
colnames(data) <- c("age", "X", "Y")

thinned_bg <- thinData(data,
                      env = predictors,
                      x = "X",
                      y = "Y")

head(data)

```

---

thresholds

*Thresholds*

---

### Description

Compute three threshold values: minimum training presence, equal training sensitivity and specificity and maximum training sensitivity plus specificity together with fractional predicted area and the omission rate. If a test dataset is provided it returns also the equal test sensitivity and specificity and maximum test sensitivity plus specificity thresholds and the p-values of the one-tailed binomial exact test.

### Usage

```
thresholds(model, type = NULL, test = NULL)
```

### Arguments

model	<a href="#">SDMmodel</a> object.
type	character. The output type used for "Maxent" and "Maxnet" methods, possible values are "cloglog" and "logistic".
test	<a href="#">SWD</a> testing locations, if not provided it returns the training and test thresholds.

### Details

The equal training sensitivity and specificity minimizes the difference between sensitivity and specificity. The one-tailed binomial test checks that test points are predicted no better than by a random prediction with the same fractional predicted area.

**Value**

data.frame with the thresholds.

**Author(s)**

Sergio Vignali

**Examples**

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

# Split presence locations in training (80%) and testing (20%) datasets
datasets <- trainValTest(data,
                        test = 0.2,
                        only_presence = TRUE)

train <- datasets[[1]]
test <- datasets[[2]]

# Train a model
model <- train(method = "Maxnet",
              data = train,
              fc = "1")

# Get the cloglog thresholds
thresholds(model,
           type = "cloglog")

# Get the logistic thresholds passing the test dataset
thresholds(model,
           type = "logistic",
           test = test)
```

train

*Train***Description**

Train a model using one of the following methods: Artificial Neural Networks, Boosted Regression Trees, Maxent, Maxnet or Random Forest.

**Usage**

```
train(method, data, folds = NULL, progress = TRUE, ...)
```

**Arguments**

method	character or character vector. Method used to train the model, possible values are "ANN", "BRT", "Maxent", "Maxnet" or "RF", see details.
data	<a href="#">SWD</a> object with presence and absence/background locations.
folds	list. Output of the function <a href="#">randomFolds</a> or folds object created with other packages, see details.
progress	logical. If TRUE shows a progress bar during cross validation.
...	Arguments passed to the relative method, see details.

**Details**

- For the ANN method possible arguments are (for more details see [nnet](#)):
  - size: integer. Number of the units in the hidden layer.
  - decay numeric. Weight decay, default is 0.
  - rang numeric. Initial random weights, default is 0.7.
  - maxit integer. Maximum number of iterations, default is 100.
- For the BRT method possible arguments are (for more details see [gbm](#)):
  - distribution: character. Name of the distribution to use, default is "bernoulli".
  - n.trees: integer. Maximum number of tree to grow, default is 100.
  - interaction.depth: integer. Maximum depth of each tree, default is 1.
  - shrinkage: numeric. The shrinkage parameter, default is 0.1.
  - bag.fraction: numeric. Random fraction of data used in the tree expansion, default is 0.5.
- For the RF method the model is trained as classification. Possible arguments are (for more details see [randomForest](#)):
  - mtry: integer. Number of variable randomly sampled at each split, default is  $\text{floor}(\sqrt{\text{number of variables}})$ .
  - ntree: integer. Number of tree to grow, default is 500.
  - nodesize: integer. Minimum size of terminal nodes, default is 1.
- Maxent models are trained using the arguments "removeduplicates=false" and "addsamplestobackground=false". Use the function [thinData](#) to remove duplicates and the function [addSamplesToBg](#) to add presence locations to background locations. For the Maxent method, possible arguments are:

- reg: numeric. The value of the regularization multiplier, default is 1.
- fc: character. The value of the feature classes, possible values are combinations of "l", "q", "p", "h" and "t", default is "lqph".
- iter: numeric. Number of iterations used by the MaxEnt algorithm, default is 500.
- Maxnet models are trained using the argument "addsamplestobackground = FALSE", use the function [addSamplesToBg](#) to add presence locations to background locations. For the Maxnet method, possible arguments are (for more details see [maxnet](#)):
  - reg: numeric. The value of the regularization intensity, default is 1.
  - fc: character. The value of the feature classes, possible values are combinations of "l", "q", "p", "h" and "t", default is "lqph".

The folds argument accepts also objects created with other packages: **ENMeval** or **blockCV**. In this case the function converts internally the folds into a format valid for **SDMtune**.

When multiple methods are given as method argument, the function returns a named list of model object, with the name corresponding to the used method, see examples.

### Value

An [SDMmodel](#) or [SDMmodelCV](#) or a list of model objects.

### Author(s)

Sergio Vignali

### References

- Venables, W. N. & Ripley, B. D. (2002) Modern Applied Statistics with S. Fourth Edition. Springer, New York. ISBN 0-387-95457-0.
- Brandon Greenwell, Bradley Boehmke, Jay Cunningham and GBM Developers (2019). gbm: Generalized Boosted Regression Models. <https://CRAN.R-project.org/package=gbm>.
- A. Liaw and M. Wiener (2002). Classification and Regression by randomForest. R News 2(3), 18–22.
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- Steven Phillips (2017). maxnet: Fitting 'Maxent' Species Distribution Models with 'glmnet'. <https://CRAN.R-project.org/package=maxnet>.
- Muscarella, R., Galante, P.J., Soley-Guardia, M., Boria, R.A., Kass, J., Uriarte, M. and R.P. Anderson (2014). ENMeval: An R package for conducting spatially independent evaluations and estimating optimal model complexity for ecological niche models. Methods in Ecology and Evolution.
- Roosbeh Valavi, Jane Elith, José Lahoz-Monfort and Gurutzeta Guillera-Arroita (2018). blockCV: Spatial and environmental blocking for k-fold cross-validation. <https://github.com/rvalavi/blockCV>.

### See Also

[randomFolds](#).

## Examples

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

## Train a Maxent model
model <- train(method = "Maxent",
              data = data,
              fc = "1",
              reg = 1.5,
              iter = 700)

# Add samples to background. This should be done preparing the data before
# training the model without using
data <- addSamplesToBg(data)
model <- train("Maxent",
              data = data)

## Train a Maxnet model
model <- train(method = "Maxnet",
              data = data,
              fc = "1q",
              reg = 1.5)

## Cross Validation
# Create 4 random folds splitting only the presence data
folds <- randomFolds(data,
                    k = 4,
                    only_presence = TRUE)

model <- train(method = "Maxnet",
              data = data,
              fc = "1",
              reg = 0.8,
              folds = folds)

## Not run:
# Run only if you have the package ENMeval installed
```

```

## Block partition using the ENMeval package
require(ENMeval)
block_folds <- get.block(occ = data@coords[data@pa == 1, ],
                        bg.coords = data@coords[data@pa == 0, ])

model <- train(method = "Maxnet",
              data = data,
              fc = "1",
              reg = 0.8,
              folds = block_folds)

## Checkerboard1 partition using the ENMeval package
cb_folds <- get.checkerboard1(occ = data@coords[data@pa == 1, ],
                             env = predictors,
                             bg.coords = data@coords[data@pa == 0, ],
                             aggregation.factor = 4)

model <- train(method = "Maxnet",
              data = data,
              fc = "1",
              reg = 0.8,
              folds = cb_folds)

## Environmental block using the blockCV package
# Run only if you have the package blockCV
require(blockCV)
# Create sf object
sf_df <- sf::st_as_sf(cbind(data@coords, pa = data@pa),
                    coords = c("X", "Y"),
                    crs = terra::crs(predictors,
                                       proj = TRUE))

# Spatial blocks
spatial_folds <- cv_spatial(x = sf_df,
                           column = "pa",
                           rows_cols = c(8, 10),
                           k = 5,
                           hexagon = FALSE,
                           selection = "systematic")

model <- train(method = "Maxnet",
              data = data,
              fc = "1",
              reg = 0.8,
              folds = spatial_folds)

## End(Not run)

## Train presence absence models
# Prepare presence and absence locations
p_coords <- virtualSp$presence
a_coords <- virtualSp$absence
# Create SWD object
data <- prepareSWD(species = "Virtual species",

```

```
        p = p_coords,
        a = a_coords,
        env = predictors[[1:5]])

## Train an Artificial Neural Network model
model <- train("ANN",
              data = data,
              size = 10)

## Train a Random Forest model
model <- train("RF",
              data = data,
              ntree = 300)

## Train a Boosted Regression Tree model
model <- train("BRT",
              data = data,
              n.trees = 300,
              shrinkage = 0.001)

## Multiple methods trained together with default arguments
output <- train(method = c("ANN", "BRT", "RF"),
               data = data,
               size = 10)

output$ANN
output$BRT
output$RF

## Multiple methods trained together passing extra arguments
output <- train(method = c("ANN", "BRT", "RF"),
               data = data,
               size = 10,
               ntree = 300,
               n.trees = 300,
               shrinkage = 0.001)

output
```

---

trainValTest

*Train, Validation and Test datasets*

---

## Description

Split a dataset randomly in training and testing datasets or training, validation and testing datasets.

## Usage

```
trainValTest(x, test, val = 0, only_presence = FALSE, seed = NULL)
```



**Arguments**

x	<b>SWD</b> object containing the data that have to be split in training, validation and testing datasets.
test	numeric. The percentage of data withhold for testing.
val	numeric. The percentage of data withhold for validation, default is 0.
only_presence	logical. If TRUE the split is done only for the presence locations and all the background locations are included in each partition, used manly for presence-only methods, default is FALSE.
seed	numeric. The value used to set the seed in order to have consistent results, default is NULL.

**Details**

When `only_presence = FALSE`, the proportion of presence and absence is preserved.

**Value**

A list with the training, validation and testing or training and testing **SWD** objects accordingly.

**Author(s)**

Sergio Vignali

**Examples**

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

# Split presence locations in training (80%) and testing (20%) datasets
# and splitting only the presence locations
datasets <- trainValTest(data,
                        test = 0.2,
                        only_presence = TRUE)

train <- datasets[[1]]
test <- datasets[[2]]
```

```
# Split presence locations in training (60%), validation (20%) and testing
# (20%) datasets and splitting the presence and the absence locations
datasets <- trainValTest(data,
                        val = 0.2,
                        test = 0.2)

train <- datasets[[1]]
val <- datasets[[2]]
test <- datasets[[3]]
```

---

tss

*True Skill Statistics*

---

### Description

Compute the max TSS of a given model.

### Usage

```
tss(model, test = NULL)
```

### Arguments

**model** [SDMmodel](#) or [SDMmodelCV](#) object.

**test** [SWD](#) object when **model** is an [SDMmodel](#) object; logical or [SWD](#) object when **model** is an [SDMmodelCV](#) object. If not provided it computes the training TSS, see details.

### Details

For [SDMmodelCV](#) objects, the function computes the mean of the training TSS values of the k-folds. If **test** = TRUE it computes the mean of the testing TSS values for the k-folds. If **test** is an [SWD](#) object, it computes the mean TSS values for the provided testing dataset.

### Value

The value of the TSS of the given model.

### Author(s)

Sergio Vignali

### References

Allouche O., Tsoar A., Kadmon R., (2006). Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). *Journal of Applied Ecology*, 43(6), 1223–1232.

**See Also**

[aicc](#) and [auc](#).

**Examples**

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

# Split presence locations in training (80%) and testing (20%) datasets
datasets <- trainValTest(data,
                       test = 0.2,
                       only_presence = TRUE)

train <- datasets[[1]]
test <- datasets[[2]]

# Train a model
model <- train(method = "Maxnet",
              data = train,
              fc = "1")

# Compute the training TSS
tss(model)

# Compute the testing TSS
tss(model,
     test = test)

# Same example but using cross validation instead of training and
# testing datasets. Create 4 random folds splitting only the presence
# locations
folds = randomFolds(train,
                   k = 4,
                   only_presence = TRUE)

model <- train(method = "Maxnet",
              data = train,
              fc = "1",
```

```
        folds = folds)

# Compute the training TSS
tss(model)

# Compute the testing TSS
tss(model,
      test = TRUE)

# Compute the TSS for the held apart testing dataset
tss(model,
      test = test)
```

---

varImp

*Variable Importance*

---

## Description

The function randomly permutes one variable at time (using training and absence/background datasets) and computes the decrease in training AUC. The result is normalized to percentages. Same implementation of MaxEnt java software but with the additional possibility of running several permutations to obtain a better estimate of the permutation importance. In case of more than one permutation (default is 10) the average of the decrease in training AUC is computed.

## Usage

```
varImp(model, permut = 10, progress = TRUE)
```

## Arguments

model	<a href="#">SDMmodel</a> or <a href="#">SDMmodelCV</a> object.
permut	integer. Number of permutations.
progress	logical. If TRUE shows a progress bar.

## Details

Note that it could return values slightly different from MaxEnt Java software due to a different random permutation.

For [SDMmodelCV](#) objects the function returns the average and the standard deviation of the permutation importances of the single models.

## Value

data.frame with the ordered permutation importance.

## Author(s)

Sergio Vignali

**Examples**

```

# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

# Split presence locations in training (80%) and testing (20%) datasets
datasets <- trainValTest(data,
                        test = 0.2,
                        only_presence = TRUE)

train <- datasets[[1]]
test <- datasets[[2]]

# Train a model
model <- train(method = "Maxnet",
              data = train,
              fc = "1")

# Compute variable importance
vi <- varImp(model,
            permut = 5)

vi

# Same example but using cross validation instead of training and testing
# datasets
# Create 4 random folds splitting only the presence locations
folds = randomFolds(data,
                  k = 4,
                  only_presence = TRUE)

model <- train(method = "Maxnet",
              data = data,
              fc = "1",
              folds = folds)

# Compute variable importance
vi <- varImp(model,
            permut = 5)

vi

```

## Description

The function performs a data-driven variable selection. Starting from the provided model it iterates through all the variables starting from the one with the highest contribution (permutation importance or maxent percent contribution). If the variable is correlated with other variables (according to the given method and threshold) it performs a Jackknife test and among the correlated variables it removes the one that results in the best performing model when removed (according to the given metric for the training dataset). The process is repeated until the remaining variables are not highly correlated anymore.

## Usage

```
varSel(
  model,
  metric,
  bg4cor,
  test = NULL,
  env = NULL,
  method = "spearman",
  cor_th = 0.7,
  permut = 10,
  use_pc = FALSE,
  interactive = TRUE,
  progress = TRUE,
  verbose = TRUE
)
```

## Arguments

model	<a href="#">SDMmodel</a> or <a href="#">SDMmodelCV</a> object.
metric	character. The metric used to evaluate the models, possible values are: "auc", "tss" and "aicc".
bg4cor	<a href="#">SWD</a> object. Background locations used to test the correlation between environmental variables.
test	<a href="#">SWD</a> . Test dataset used to evaluate the model, not used with aicc and <a href="#">SDMmodelCV</a> objects.
env	<a href="#">rast</a> containing the environmental variables, used only with "aicc".
method	character. The method used to compute the correlation matrix.
cor_th	numeric. The correlation threshold used to select highly correlated variables.
permut	integer. Number of permutations.

use_pc	logical, use percent contribution. If TRUE and the model is trained using the <a href="#">Maxent</a> method, the algorithm uses the percent contribution computed by Maxent software to score the variable importance.
interactive	logical. If FALSE the interactive chart is not created.
progress	logical. If TRUE shows a progress bar.
verbose	logical. If TRUE prints informative messages.

### Details

An interactive chart showing in real-time the steps performed by the algorithm is displayed in the Viewer pane.

To find highly correlated variables the following formula is used:

$$|coef.f| \leq cor.th$$

### Value

The [SDMmodel](#) or [SDMmodelCV](#) object trained using the selected variables.

### Author(s)

Sergio Vignali

### Examples

```
# Acquire environmental variables
files <- list.files(path = file.path(system.file(package = "dismo"), "ex"),
                  pattern = "grd",
                  full.names = TRUE)

predictors <- terra::rast(files)

# Prepare presence and background locations
p_coords <- virtualSp$presence
bg_coords <- virtualSp$background

# Create SWD object
data <- prepareSWD(species = "Virtual species",
                  p = p_coords,
                  a = bg_coords,
                  env = predictors,
                  categorical = "biome")

# Split presence locations in training (80%) and testing (20%) datasets
datasets <- trainValTest(data,
                        test = 0.2,
                        only_presence = TRUE)

train <- datasets[[1]]
test <- datasets[[2]]

# Train a model
```

```

model <- train(method = "Maxnet",
               data = train,
               fc = "1")

# Prepare background locations to test autocorrelation, this usually gives a
# warning message given that less than 10000 points can be randomly sampled
bg_coords <- terra::spatSample(predictors,
                               size = 9000,
                               method = "random",
                               na.rm = TRUE,
                               xy = TRUE,
                               values = FALSE)

bg <- prepareSWD(species = "Virtual species",
                 a = bg_coords,
                 env = predictors,
                 categorical = "biome")

## Not run:
# Remove variables with correlation higher than 0.7 accounting for the AUC,
# in the following example the variable importance is computed as permutation
# importance
vs <- varSel(model,
             metric = "auc",
             bg4cor = bg,
             test = test,
             cor_th = 0.7,
             permut = 1)

vs

# Remove variables with correlation higher than 0.7 accounting for the TSS,
# in the following example the variable importance is the MaxEnt percent
# contribution
# Train a model
model <- train(method = "Maxent",
               data = train,
               fc = "1")

vs <- varSel(model,
             metric = "tss",
             bg4cor = bg,
             test = test,
             cor_th = 0.7,
             use_pc = TRUE)

vs

# Remove variables with correlation higher than 0.7 accounting for the aicc,
# in the following example the variable importance is the MaxEnt percent
# contribution
vs <- varSel(model,
             metric = "aicc",
             bg4cor = bg,
             cor_th = 0.7,

```



```
                use_pc = TRUE,  
                env = predictors)  
vs  
## End(Not run)
```

---

virtualSp

*Virtual Species*

---

### Description

Dataset containing a random generated virtual species. The purpose of this dataset is to demonstrate the use of the functions included in the package.

### Usage

```
virtualSp
```

### Format

A list with five elements:

**presence** 400 random generated coordinates for the presence locations.

**absence** 300 random generated coordinates for the absence locations.

**background** 5000 random generated coordinates for the background locations.

**pa\_map** Presence absence map used to extract the presence and absence locations.

**prob\_map** Probability map of the random generated virtual species.

### Details

The random species has been generated using the package **virtualespecies**.

### References

Leroy, B. , Meynard, C. N., Bellard, C. and Courchamp, F. (2016), virtualespecies, an R package to generate virtual species distributions. *Ecography*, 39: 599-607. doi:10.1111/ecog.01388

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