# Package ‘modEvA’

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**Description** Analyses species distribution models and evaluates their performance. It includes functions for variation partitioning, extracting variable importance, computing several metrics of model discrimination and calibration performance, optimizing prediction thresholds based on a number of criteria, performing multivariate environmental similarity surface (MESS) analysis, and displaying various analytical plots. Initially described in Barbosa et al. (2013) <doi:10.1111/ddi.12100>.  

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Model Evaluation and Analysis

Description

The modEvA package can analyse species distribution models and evaluate their performance. It includes functions for performing variation partitioning; calculating several measures of model discrimination, classification, explanatory power, and calibration; optimizing prediction thresholds based on a number of criteria; performing multivariate environmental similarity surface (MESS) analysis; and displaying various analytical plots.
modEvA-package

Details
Author(s)
Barbosa A.M., Brown J.A., Jimenez-Valverde A., Real R.
A. Marcia Barbosa <ana.marcia.barbosa@gmail.com>

References

See Also
PresenceAbsence, ROCR, verification, Metrics

Examples
# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]

# plot this model:
plotGLM(model = mod)

# compute the Root Mean Square Error of the model:
RMSE(model = mod)

# extract variable importance from the model:
varImp(model = mod)

# calculate the area under the ROC curve for the model:
AUC(model = mod)

# calculate some threshold-based measures for this model:
threshMeasures(model = mod, thresh = 0.5)
threshMeasures(model = mod, thresh = "preval")

# calculate optimal thresholds based on several criteria:
optiThresh(model = mod, measures = c("CCR", "Sensitivity", "kappa", "TSS"),
ylim = c(0, 1), pch = 20, cex = 0.5)
applyThreshold

Apply threshold(s) to model predictions

Description

This function applies a threshold value to the continuous predictions of a model, converting them to binary predictions: 1 for values above the threshold, and 0 for values below it. If two thresholds are provided (e.g. to separate high, low and intermediate predictions), the result is 0 below the lowest threshold, 1 above the highest threshold, and 0.5 between them.

Usage

applyThreshold(model = NULL, obs = NULL, pred = NULL, thresh, right = FALSE, interval = 0.01, quant = 0, na.rm = TRUE, verbosity = 2)

Arguments

model a binary-response model object of class "glm", "gam", "gbm", "randomForest" or "bart". If this argument is provided, 'obs' and 'pred' will be extracted with mod2obspred. Alternatively, you can input the 'obs' and 'pred' arguments instead of 'model'.

obs alternatively to 'model' and together with 'pred', a numeric vector of observed presences (1) and absences (0) of a binary response variable. Alternatively (and if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, respectively, the x (longitude) and y (latitude) coordinates of the presence points, in which case the 'obs' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

dpred alternatively to 'model' and together with 'obs', a vector with the corresponding predicted values of presence probability, habitat suitability, environmental favourability or alike. Must be of the same length and in the same order as 'obs'. Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of the predicted values for the entire evaluation region, in which case the 'pred'
applyThreshold

vector will be extracted with `ptsrast2obspredd`. This argument is ignored if 'model' is provided.

**thresh**
numeric vector of length 1 or 2, containing the threshold value(s) with which to reclassify 'pred', or the criteria under which to compute these thresholds – run `modEvAmethods("getThreshold")` for available options, and see Details in `getThreshold` for their description.

**right**
logical value indicating if the interval should be closed on the right (and open on the left) or vice versa, i.e., if predictions equalling the threshold value(s) should be classified as lower rather than higher. The default is FALSE.

**interval**
Argument to pass to `optiThresh` indicating the interval between the thresholds to test, if 'thresh' implies optimizing a threshold-based measure. The default is 0.01. Smaller values may provide more precise results but take longer to compute.

**quant**
Numeric value indicating the proportion of presences to discard if any of 'thresh' is "MTP" (minimum training presence). With the default value 0, MTP will be the threshold at which all observed presences are classified as such; with e.g. quant=0.05, MTP will be the threshold at which 5% presences will be classified as absences.

**na.rm**
Logical value indicating whether NA values should be ignored. Defaults to TRUE.

**verbosity**
integer value indicating the amount of messages to print. Defaults to 2, for the maximum amount of messages.

**Details**
Several criteria have been proposed for selecting thresholds with which to convert continuous model predictions (of presence probability, habitat suitability or alike) into binary predictions of presence or absence. A threshold is required for computing threshold-based model evaluation metrics, such as those in `threshMeasures`. This function reclassifies the predictions of a model given one or two numeric thresholds, or one or two threshold selection criteria implemented in `getThreshold`.

**Value**
This function returns an object of the same class as 'pred' with the reclassified values after application of the threshold.

**Author(s)**
A. Marcia Barbosa

**See Also**
`getThreshold`, `threshMeasures`
Examples

# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]
applyThreshold(model = mod, thresh = "maxTSS")

# you can also use applyThreshold with vectors of observed and predicted values:
presabs <- mod$y
prediction <- mod$fitted.values
applyThreshold(pred = prediction, thresh = 0.5)
applyThreshold(pred = prediction, thresh = c(0.2, 0.8))
applyThreshold(pred = prediction, thresh = "meanPred")
applyThreshold(obs = presabs, pred = prediction, thresh = "preval")
applyThreshold(obs = presabs, pred = prediction, thresh = "MTP")
applyThreshold(obs = presabs, pred = prediction, thresh = "MTP", quant = 0.05)

# 'obs' can also be a table of presence point coordinates
# and 'pred' a SpatRaster of predicted values

---

arrangePlots  

Arrange plots

Description

Get an appropriate row/column combination (for \texttt{par(mfrow)}) for arranging a given number of plots within a plotting window.

Usage

\texttt{arrangePlots(n.plots, landscape = FALSE)}

Arguments

\texttt{n.plots}  

number of plots to be placed in the graphics device.

\texttt{landscape}  

logical, whether the plotting window should be landscape/horizontal (number of columns larger than the number of rows) or not. The value does not make a difference if the number of plots makes for a square plotting window.
Details

This function is used internally by optiThresh, but can also be useful outside it.

Value

An integer vector of the form c(nr, nc) indicating, respectively, the number of rows and of columns of plots to set in the graphics device.

Author(s)

A. Marcia Barbosa

See Also

plot, layout

Examples

arrangePlots(10)

arrangePlots(10, landscape = TRUE)

# a more practical example:
data(iris)

names(iris)

# say you want to plot all columns in a nicely arranged plotting window:

par(mfrow = arrangePlots(ncol(iris)))

for (i in 1:ncol(iris)) {
    plot(1:nrow(iris), iris[, i])
}

AUC

Area Under the Curve

Description

This function calculates the Area Under the Curve of the receiver operating characteristic (ROC) plot, or alternatively the precision-recall (PR) plot, for either a model object or two matching vectors of observed binary (1 for occurrence vs. 0 for non-occurrence) and predicted continuous (e.g. occurrence probability) values, respectively.
Usage

AUC(model = NULL, obs = NULL, pred = NULL, simplif = FALSE,
interval = 0.01, FPR.limits = c(0, 1), curve = "ROC",
method = NULL, plot = TRUE, diag = TRUE, diag.col = "grey",
diag.lty = 1, curve.col = "black", curve.lty = 1, curve.lwd = 2,
plot.values = TRUE, plot.digits = 3, plot.preds = FALSE,
grid = FALSE, grid.lty = 1, xlab = "auto", ylab = "auto",
ticks = FALSE, na.rm = TRUE, rm.dup = FALSE, ...)

Arguments

model
a binary-response model object of class "glm", "gam", "gbm", "randomForest" or "bart". If this argument is provided, 'obs' and 'pred' will be extracted with mod2obspred. Alternatively, you can input the 'obs' and 'pred' arguments instead of 'model'.

obs
alternatively to 'model' and together with 'pred', a numeric vector of observed presences (1) and absences (0) of a binary response variable. Alternatively (and if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, respectively, the x (longitude) and y (latitude) coordinates of the presence points, in which case the 'obs' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

pred
alternatively to 'model' and together with 'obs', a vector with the corresponding predicted values of presence probability, habitat suitability, environmental favourability or alike. Must be of the same length and in the same order as 'obs'. Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of the predicted values for the entire evaluation region, in which case the 'pred' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

simplif
logical, whether to use a faster version that returns only the AUC value (and the plot if 'plot = TRUE').

FPR.limits
(NOT YET IMPLEMENTED) numerical vector of length 2 indicating the limits of false positive rate between which to calculate a partial AUC. The default is c(0, 1), for considering the whole AUC. Pending implementation. Meanwhile, you can try e.g. the roc function in the pROC package.

curve
character indicating whether to compute the "ROC" (receiver operating characteristic) or the "PR" (precision-recall) curve.

interval
interval of threshold values at which to calculate the true and false positive rates. Defaults to 0.01 for relatively quick while still relatively accurate computation. Note that, if method = "rank" (the default if curve = "ROC"), this does not affect the obtained AUC value (although it can affect the size of the plotted curve, especially when prevalence is low), as the AUC is calculated with the Mann-Whitney-Wilcoxon statistic and is therefore threshold-independent. If method != "rank" (or, by extension, if curve = "PR" – see 'method' argument), setting 'interval' to smaller values will provide more accurate AUC values. The size of the 'interval' also affects the resulting 'meanPrecision', as this is averaged across all threshold values.
<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
<th>Default</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>method</td>
<td>character indicating with which method to calculate the AUC value. Available options are “rank” (the default and most accurate, but implemented only if curve = “ROC”) and “trapezoid” (the default if curve = “PR”). The latter is computed more accurately if ‘interval’ is decreased (see ‘interval’ argument).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>plot</td>
<td>logical, whether or not to plot the curve. Defaults to TRUE.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>diag</td>
<td>logical, whether or not to add the reference diagonal (if plot = TRUE).Defaults to TRUE.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>diag.col</td>
<td>line colour for the reference diagonal (if diag = TRUE).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>diag.lty</td>
<td>line type for the reference diagonal (if diag = TRUE).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>curve.col</td>
<td>line colour for the curve.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>curve.lty</td>
<td>line type for the curve.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>curve.lwd</td>
<td>line width for the curve.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>plot.values</td>
<td>logical, whether or not to show in the plot the values associated to the curve (e.g., the AUC). Defaults to TRUE.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>plot.digits</td>
<td>integer number indicating the number of digits to which the values in the plot should be rounded. Defaults to 3. This argument is ignored if ‘plot’ or ‘plot.values’ are set to FALSE.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>plot.preds</td>
<td>logical value indicating whether the proportions of ’pred’ values for each threshold should be plotted as proportionally sized blue circles. Can also be provided as a character vector specifying if the circles should be plotted on the “curve” (the default) and/or at the “bottom” of the plot. The default is FALSE for no circles, but it may be interesting to try it, especially if your curve has long straight lines or does not cover the full length of the plot.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>grid</td>
<td>logical, whether or not to add a grid to the plot, marking the analysed thresholds. Defaults to FALSE.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>grid.lty</td>
<td>line type for the grid (if grid = TRUE).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>xlab</td>
<td>label for the x axis. By default, a label is automatically generated according to the specified 'curve’.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ylab</td>
<td>label for the y axis. By default, a label is automatically generated according to the specified 'curve’.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ticks</td>
<td>logical, whether or not to add blue tick marks at the bottom of the plot to mark the thresholds at which there were values from which to to draw the curve. Defaults to FALSE.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>na.rm</td>
<td>Logical value indicating if missing values should be ignored in computations. The default is TRUE.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rm.dup</td>
<td>If TRUE and if ’pred’ is a SpatRaster and if there are repeated points within the same pixel, a maximum of one point per pixel is used to compute the presences. See examples in ptsrast2obspred. The default is FALSE.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>further arguments to be passed to the plot function.</td>
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<td></td>
</tr>
</tbody>
</table>
Details

In the case of the "ROC" curve (the default), the AUC is a measure of the overall discrimination power of the predictions, or the probability that an occurrence site has a higher predicted value than a non-occurrence site. It can thus be calculated with the Wilcoxon rank sum statistic, as is done with the default method="rank". There's also an option to compute, instead of the ROC curve, the precision-recall ("PR") curve, which is more robust to imbalanced data, e.g. species rarity (Sofaer et al. 2019), as it doesn't value true negatives.

If 'curve' is set to "PR", or if 'method' is manually set to "trapezoid", the AUC value will be more accurate if 'interval' is decreased (see 'method' and 'interval' arguments above). The plotted curve will also be more accurate with smaller 'interval' values, especially for imbalanced datasets (which can cause an apparent disagreement between the look of the curve and the actual value of the AUC).

Mind that the AUC has been widely criticized (e.g. Lobo et al. 2008, Jimenez-Valverde et al. 2013), but is still among the most widely used metrics in model evaluation. It is highly correlated with species prevalence (as are all model discrimination and classification metrics), so prevalence is also output by the AUC function (if simplif = FALSE, the default) for reference.

Although there are functions to calculate the AUC in other R packages (e.g. ROCR, Presence-Absence, verification, Epi, PRROC, PerfMeas, precrec), the AUC function is more compatible with the remaining functions in modEvA, and it can be applied not only to a set of observed vs. predicted values, but also directly to a model object of class "glm", "gam", "gbm", "randomForest" or "bart".

Value

If simplif = TRUE, the function returns only the AUC value (a numeric value between 0 and 1). Otherwise (the default), it returns a list with the following components:

- thresholds: a data frame of the true and false positives, the sensitivity, specificity and recall of the predictions, and the number of predicted values at each analysed threshold.
- N: the total number of observations.
- prevalence: the proportion of presences (i.e., ones) in the data (which correlates with the AUC of the "ROC" plot).
- AUC: the value of the AUC.
- AUChratio: the ratio of the obtained AUC value to the null expectation (0.5).
- meanPrecision: the arithmetic mean of precision (proportion of predicted presences actually observed as presences) across all threshold values (defined by 'interval'). It is close to the AUC of the precision-recall (PR) curve.
- GiniCoefficient: the Gini coefficient, measured as the area between the ROC curve and the diagonal divided by the area of the upper triangle (2*AUC-1).

Author(s)

A. Marcia Barbosa
References


See Also

threshMeasures

Examples

# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]

# compute the AUC:
AUC(model = mod)
AUC(model = mod, simplif = TRUE)
AUC(model = mod, curve = "PR")
AUC(model = mod, interval = 0.1, grid = TRUE)
AUC(model = mod, plot.preds = TRUE)
AUC(model = mod, ticks = TRUE)
AUC(model = mod, plot.preds = c("curve", "bottom"))

# you can also use vectors of observed and predicted values
# instead of a model object:
presabs <- mod$y
prediction <- mod$fitted.values
AUC(obs = presabs, pred = prediction)

# 'obs' can also be a table of presence point coordinates
# and 'pred' a SpatRaster of predicted values
Description
This function computes the (continuous) Boyce index (Boyce 2002; Hirzel et al. 2006) for either:
1) a model object; or 2) two paired numeric vectors of observed (binary, 1 for occurrence vs. 0 for
no occurrence records) and predicted (continuous, e.g. occurrence probability) values; or 3) a set of
presence point coordinates and a raster map with the predicted values for the entire model evaluation
area. This metric is designed for evaluating model predictions against presence/background data
(i.e. presence/available, where "available" includes both presences and absences; Boyce 2002), so
the function uses the model predictions for the presence sites (ones) against the predictions for the
entire dataset (ones and zeros).

Usage
Boyce(model = NULL, obs = NULL, pred = NULL, n.bins = NA,
bin.width = "default", res = 100, method = "spearman", rm.dup.classes = FALSE,
rm.dup.points = FALSE, plot = TRUE, plot.lines = TRUE, plot.values = TRUE,
plot.digits = 3, na.rm = TRUE, ...)

Arguments
model a binary-response model object of class "glm", "gam", "gbm", "randomForest"
or "bart". If this argument is provided, 'obs' and 'pred' will be extracted with
mod2obspred. Alternatively, you can input the 'obs' and 'pred' arguments (e.g.
for external test data) instead of 'model'.
obs alternatively to 'model' and together with 'pred', a numeric vector of observed
presences (1) and absences (0) of a binary response variable. Alternatively (and
if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, re-
spectively, the x (longitude) and y (latitude) coordinates of the presence points,
in which case the 'obs' vector will be extracted with ptsrast2obspred. This
argument is ignored if 'model' is provided.
pred alternatively to 'model' and together with 'obs', a vector with the correspond-
ing predicted values of presence probability, habitat suitability, environmental
favourability or alike. Must be of the same length and in the same order as 'obs'.
Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of
the predicted values for the entire evaluation region, in which case the 'pred'
vector will be extracted with ptsrast2obspred. This argument is ignored if
'model' is provided.
n.bins number of classes or bins (e.g. 10) in which to group the 'pred' values, or a
vector with the bin thresholds. If n.bins = NA (the default), a moving window
is used (see next parameters), so as to compute the "continuous Boyce index"
(Hirzel et al. 2006).
bin.width width of the moving window (if n.bins = NA), in the units of 'pred' (e.g. 0.1).
By default, it is 1/10th of the 'pred' range).
The Boyce index is the correlation between model predictions and area-adjusted frequencies (i.e., observed vs. expected proportion of occurrences) along different prediction classes (bins). In other words, it measures how model predictions differ from a random distribution of the observed presences across the prediction gradient (Boyce et al. 2002). It can take values between -1 and 1. Positive values indicate that presences are more frequent than expected by chance (given availability) in areas with higher predicted values. Values close to zero mean that predictions are no better than random (i.e., presences are distributed among prediction classes as expected by chance), and negative values indicate counter predictions (i.e., presences are more frequent in areas with lower predicted values).

The R code is largely based on the 'ecospat.boyce' function in the ecospat package (version 3.2.1), but it is modified to match the input types in the remaining functions of 'modEvA', and to return a more complete and informative output.

This function returns a list with the following components:

- **bins**: a data frame with the number of values in each bin, their median and range of predicted values, and the corresponding predicted/expected ratio of presences.
- **B**: the numeric value of the Boyce index, i.e., the coefficient of correlation between the median predicted value in each bin and the corresponding predicted/expected ratio.

Details

The Boyce index is the correlation between model predictions and area-adjusted frequencies (i.e., observed vs. expected proportion of occurrences) along different prediction classes (bins). In other words, it measures how model predictions differ from a random distribution of the observed presences across the prediction gradient (Boyce et al. 2002). It can take values between -1 and 1. Positive values indicate that presences are more frequent than expected by chance (given availability) in areas with higher predicted values. Values close to zero mean that predictions are no better than random (i.e., presences are distributed among prediction classes as expected by chance), and negative values indicate counter predictions (i.e., presences are more frequent in areas with lower predicted values).

The R code is largely based on the 'ecospat.boyce' function in the ecospat package (version 3.2.1), but it is modified to match the input types in the remaining functions of 'modEvA', and to return a more complete and informative output.

Value

This function returns a list with the following components:

- **bins**: a data frame with the number of values in each bin, their median and range of predicted values, and the corresponding predicted/expected ratio of presences.
- **B**: the numeric value of the Boyce index, i.e., the coefficient of correlation between the median predicted value in each bin and the corresponding predicted/expected ratio.
If plot=TRUE (the default), the function also plots the predicted/expected ratio for the utilized bins along the prediction range. A good model should yield a monotonically increasing curve (but see Note).

**Note**

This index is designed for evaluating predictions of habitat suitability, not presence probability (which also depends on the species' presence/absence ratio: rare species do not usually show high proportions of presences, even in highly suitable areas). If your predictions are of presence probability with a prevalence different from 50% presences, you should convert those predictions e.g. with the Fav function of package fuzzySim, before evaluating them with the Boyce index.

In bins with overly small sample sizes, the comparison between median prediction and random expectation may not be meaningful, although these bins will equally contribute to the overall Boyce index. When there are bins with less than 30 values, a warning is emitted and their points are plotted in red, but mind that 30 is a largely arbitrary number. See the $bins$bin.N section of the console output, and use the 'bin.width' argument to enlarge the bins.

**Author(s)**

A. Marcia Barbosa, with significant chunks of code from the 'ecospat::ecospat.boyce' function by Blaise Petitpierre and Frank Breiner (ecospat package version 3.2.1).

**References**


**Examples**

```r
# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]

# compute the Boyce index:
Boyce(model = mod, main = "My model Boyce plot")
Boyce(model = mod, main = "My model Boyce plot", rm.dup.classes = TRUE)

# you can also use vectors of observed and predicted values
# instead of a model object:
presabs <- mod$y
prediction <- mod$fitted.values
Boyce(obs = presabs, pred = prediction)
```
confusionLabel

Label predictions according to their confusion matrix category

Description

This function labels the (typically continuous) predictions of a binary-response model according to their confusion matrix categories, i.e., it classifies each prediction into a false positive, false negative, true positive or true negative, given a user-defined threshold value.

Usage

confusionLabel(model = NULL, obs = NULL, pred = NULL, thresh, interval = 0.01, quant = 0, verbosity = 2, na.rm = FALSE, rm.dup = FALSE, plot = TRUE, ...)

Arguments

model a binary-response model object of class "glm", "gam", "gbm", "randomForest" or "bart". If this argument is provided, 'obs' and 'pred' will be extracted with mod2obspred. Alternatively, you can input the 'obs' and 'pred' arguments (e.g. for external test data) instead of 'model'.

obs alternatively to 'model' and together with 'pred', a numeric vector of observed presences (1) and absences (0) of a binary response variable. Alternatively (and if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, respectively, the x (longitude) and y (latitude) coordinates of the presence points, in which case the 'obs' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

pred alternatively to 'model' and together with 'obs', a vector with the corresponding predicted values of presence probability, habitat suitability, environmental favourability or alike. Must be of the same length and in the same order as 'obs'. Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of the predicted values for the entire evaluation region, in which case the 'pred' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

thresh numeric value of the threshold to separate predicted presences from predicted absences; can be "preval", to use the prevalence of 'obs' (or of the response variable in 'model') as the threshold, or any real number between 0 and 1. See Details in threshMeasures for an informed choice.

interval numeric value, used if 'thresh' is a threshold optimization method such as "maxKappa" or "maxTSS", indicating the interval between the thresholds to test. The default is 0.01. Smaller values may provide more precise results but take longer to compute.
confusionLabel numeric value indicating the proportion of presences to discard if thresh="MTP" (minimum training presence). With the default value 0, MTP will be the threshold at which all observed presences are classified as such; with e.g. quant=0.05, MTP will be the threshold at which 5% presences will be classified as absences.

verbosity integer specifying the amount of messages to display. Defaults to the maximum implemented; lower numbers (down to 0) decrease the number of messages.

na.rm logical argument indicating whether to remove (with a warning saying how many) rows with NA in any of the 'obs' or 'pred' values. The default is FALSE.

rm.dup if TRUE and if 'pred' is a SpatRaster and if there are repeated points within the same pixel, a maximum of one point per pixel is used to compute the presences. See examples in ptsrast2obspred. The default is FALSE.

plot if TRUE (the default) and if 'pred' is a SpatRaster, the output (also a SpatRaster) is automatically plotted. Map categories have a set colour table, built with terra::coltab().

... additional arguments to pass to terra::plot() (if 'pred' is a SpatRaster and plot=TRUE), such as 'mar', 'axes' or 'legend'.

Value
This function returns a character vector (or a categorical SpatRaster, if `pred` is of that class) of the same length as `pred`, or of the same number of rows as the data in `model`, containing the confusion matrix label for each value.

Author(s)
A. Marcia Barbosa

See Also
threshMeasures, confusionMatrix

Examples
# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]

confusionLabel(model = mod, thresh = 0.5)

# you can instead use vectors of observed and predicted values:
presabs <- mod$y
prediction <- mod$fitted.values

confusionLabel(obs = presabs, pred = prediction, thresh = 0.5)
confusionMatrix

# 'obs' can also be a table of presence point coordinates
# and 'pred' a SpatRaster of predicted values

Description

This function computes the confusion (or contingency) matrix for a binary-response model, containing the numbers of false positives, false negatives, true positives and true negatives, given a user-defined threshold value.

Usage

confusionMatrix(model = NULL, obs = NULL, pred = NULL, thresh, interval = 0.01, quant = 0, verbosity = 2, na.rm = TRUE, rm.dup = FALSE, plot = FALSE, classes = FALSE, ...)

Arguments

model a binary-response model object of class "glm", "gam", "gbm", "randomForest" or "bart". If this argument is provided, 'obs' and 'pred' will be extracted with mod2obspred. Alternatively, you can input the 'obs' and 'pred' arguments (e.g. for external test data) instead of 'model'.

obs alternatively to 'model' and together with 'pred', a numeric vector of observed presences (1) and absences (0) of a binary response variable. Alternatively (and if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, respectively, the x (longitude) and y (latitude) coordinates of the presence points, in which case the 'obs' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

pred alternatively to 'model' and together with 'obs', a vector with the corresponding predicted values of presence probability, habitat suitability, environmental favourability or alike. Must be of the same length and in the same order as 'obs'. Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of the predicted values for the entire evaluation region, in which case the 'pred' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

thresh numeric value of the threshold to separate predicted presences from predicted absences; can be "preval", to use the prevalence of 'obs' (or of the response variable in 'model') as the threshold, or any real number between 0 and 1. See Details in threshMeasures for an informed choice.

interval numeric value, used if 'thresh' is a threshold optimization method such as "maxKappa" or "maxTSS", indicating the interval between the thresholds to test. The default is 0.01. Smaller values may provide more precise results but take longer to compute.
**quant**

numeric value indicating the proportion of presences to discard if `thresh=\"MTP\"` (minimum training presence). With the default value 0, MTP will be the threshold at which all observed presences are classified as such; with e.g. `quant=0.05`, MTP will be the threshold at which 5% presences will be classified as absences.

**verbosity**

integer specifying the amount of messages to display. Defaults to the maximum implemented; lower numbers (down to 0) decrease the number of messages.

**na.rm**

logical argument indicating whether to remove (with a warning saying how many) rows with NA in any of the \'obs\' or \'pred\' values. The default is FALSE.

**rm.dup**

if TRUE and if \'pred\' is a SpatRaster and if there are repeated points within the same pixel, a maximum of one point per pixel is used to compute the presences. See examples in `ptsrast2obspred`. The default is FALSE.

**plot**

logical argument indicating whether to also plot the matrix as an image. The default is FALSE (for back-compatibility).

**classes**

logical argument indicating whether the matrix image (if plot=TRUE) should have qualitative colours, matching the output of `confusionLabel` for SpatRasters. The default is FALSE, in which case the colours are proportional to the values in each section of the matrix, and the palette can be user-specified with the \'col\' argument for \'plot\' (see Examples).

... some additional arguments can be passed to `image` (and through to `plot`) if plot=TRUE, such as \'main\', \'font.main\' or \'cex.main\' (not \'axes\', \'xlab\' or \'ylab\', which are already defined by `confusionMatrix`).

**Value**

This function returns a data frame containing the four values of the confusion matrix.

**Author(s)**

A. Marcia Barbosa

**See Also**

`threshMeasures`, `confusionLabel`

**Examples**

```r
# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]

confusionMatrix(model = mod, thresh = 0.5)

confusionMatrix(model = mod, thresh = 0.5, plot = TRUE)

confusionMatrix(model = mod, thresh = 0.5, plot = TRUE,
col = hcl.colors(100, \"blues\"))
```
confusionMatrix(model = mod, thresh = 0.5, plot = TRUE, classes = TRUE, main = "Confusion matrix")

# you can instead use vectors of observed and predicted values:
presabs <- mod$y
prediction <- mod$fitted.values
confusionMatrix(obs = presabs, pred = prediction, thresh = 0.5, plot = TRUE)

# 'obs' can also be a table of presence point coordinates
# and 'pred' a SpatRaster of predicted values

<table>
<thead>
<tr>
<th>Dsquared</th>
<th>Explained deviance</th>
</tr>
</thead>
</table>

**Description**

This function computes the (adjusted) amount of deviance accounted for by a model, given a model object or a set of observed and predicted values.

**Usage**

Dsquared(model = NULL, obs = NULL, pred = NULL, family = NULL, adjust = FALSE, npar = NULL, na.rm = TRUE, rm.dup = FALSE, dismo.version = FALSE)

**Arguments**

- **model**: a model object of class implemented in mod2obspred. If this argument is provided, 'obs' and 'pred' will be extracted with that function. Alternatively, you can input the 'obs' and 'pred' arguments instead of 'model'.
- **obs**: alternatively to 'model' and together with 'pred', a numeric vector of observed values of the response variable. Alternatively (and if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, respectively, the x (longitude) and y (latitude) coordinates of presence points, in which case the 'obs' vector of presences and absences will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.
- **pred**: alternatively to 'model' and together with 'obs', a vector with the corresponding predicted values, of the same length and in the same order as 'obs'. Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of the predicted values for the entire evaluation region, in which case the 'pred' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.
family  
a character vector (i.e. in quotes) of length 1 specifying the family of the model that generated the 'pred' values. This argument is ignored if model is provided and is of a class for which family provides a result; otherwise (i.e. if 'obs' and 'pred' are provided rather than a model object), family can be specified by the user, or (if left NULL) will be guessed (with a message) given the values of the response variable.

adjust  
logical, whether or not to adjust the D-squared value for the number of observations and parameters in the model (see Details). The default is FALSE; TRUE requires either providing the model object of class GLM, or specifying the number of parameters in the model that produced the pred values.

npar  
integer value indicating the number of parameters in the model. This argument is ignored and taken from model if this argument is provided and of class GLM, or if adjust = FALSE.

na.rm  
Logical value indicating whether missing values should be ignored in computations. Defaults to TRUE.

rm.dup  
If TRUE and if 'pred' is a SpatRaster and if there are repeated points within the same pixel, a maximum of one point per pixel is used to compute the presences. See examples in ptsrast2obspred. The default is FALSE.

dismo.version  
Logical value indicating whether the deviance should be computed with code from the dismo::calc.deviance() function. The default is FALSE, for back-compatibility.

Details

Linear models have an R-squared value (commonly provided with the model summary) which measures the proportion of variation that the model accounts for. For generalized linear models (GLMs) and others based on non-continuous response variables, an equivalent is the amount of deviance accounted for (D-squared; Guisan & Zimmermann 2000), though this value is not routinely provided with the model summary. The Dsquared function calculates it as the proportion of the null deviance (i.e. the deviance of a model with no predictor variables) that is accounted for by the model. There is also an option to compute the adjusted D-squared, which takes into account the number of observations and the number of parameters, thus allowing direct comparison among the output for different models (Weisberg 1980, Guisan & Zimmermann 2000).

The function computes the mean residual deviance (as in the calc.deviance function of package dismo) of the observed (response) against the predicted values, and the mean deviance of a null model (with no predictor variables), i.e. of the response against the mean of the response. Finally, it gets the explained deviance as (null-residual)/null.

Value

The function returns a numeric value indicating the (optionally adjusted) proportion of deviance accounted for by the input model predictions.

Author(s)

A. Marcia Barbosa, with parts of code from 'dismo::calc.deviance' by John R. Leathwick and Jane Elith
References


See Also

plotGLM, RsqGLM, dismo::calc.deviance

Examples

# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]

Dsquared(model = mod)
Dsquared(model = mod, adjust = TRUE)

# you can also use Dsquared with vectors of observed and predicted values
# instead of with a model object:

presabs <- mod$y
prediction <- mod$fitted.values
parameters <- attributes(logLik(mod))$df

Dsquared(obs = presabs, pred = prediction, family = "binomial")

Dsquared(obs = presabs, pred = prediction, family = "binomial",
adjust = TRUE, npar = parameters)

# 'obs' can also be a table of presence point coordinates
# and 'pred' a SpatRaster of predicted values

---

evaluate  Evaluate a model based on the elements of a confusion matrix.

Description

This function evaluates the classification performance of a model based on the values of a confusion matrix obtained at a particular threshold.

Usage

evaluate(a, b, c, d, N = NULL, measure = "CCR")
**Arguments**

- **a**: number of correctly predicted presences
- **b**: number of absences incorrectly predicted as presences
- **c**: number of presences incorrectly predicted as absences
- **d**: number of correctly predicted absences
- **N**: total number of cases. If NULL (the default), it is calculated automatically by adding up a, b, c and d.
- **measure**: a character vector of length 1 indicating the evaluation measure to use. Type `modEvAmethods("threshMeasures")` for available options.

**Details**

A number of measures can be used to evaluate continuous model predictions against observed binary occurrence data (Fielding & Bell 1997; Liu et al. 2011; Barbosa et al. 2013; Leroy et al. 2018). The ’evaluate’ function can calculate a few threshold-based classification measures from the values of a confusion matrix obtained at a particular threshold. The ’evaluate’ function is used internally by `threshMeasures`. It can also be accessed directly by the user, but it is usually more practical to use ’threshMeasures’, which calculates the confusion matrix automatically.

**Value**

The value of the specified evaluation measure.

**Note**

Some measures (e.g. NMI, odds ratio) don’t work with zeros in (some parts of) the confusion matrix. Also, TSS and NMI are not symmetrical, i.e. "obs" vs "pred" is different from "pred" vs "obs".

**Author(s)**

A. Marcia Barbosa

**References**


evenness

See Also

threshMeasures

Examples

```r
evaluate(23, 44, 21, 34)
evaluate(23, 44, 21, 34, measure = "TSS")
```

evenness

**Evenness in a binary vector.**

Description

For building and evaluating species distribution models, the proportion of presences (prevalence) of a species and the balance between the number of presences and absences may be issues to take into account (e.g. Jimenez-Valverde & Lobo 2006, Barbosa et al. 2013). The evenness function calculates the presence-absence balance in a binary (e.g., presence/absence) vector.

Usage

```r
evenness(obs)
```

Arguments

- `obs`:
  a vector of binary observations (e.g. 1 or 0, male or female, disease or no disease, etc.)

Value

A number ranging between 0 when all values are the same, and 1 when there are the same number of cases with each value in `obs`.

Author(s)

A. Marcia Barbosa

References


See Also

prevalence
**getBins**

Get bins of continuous values.

**Description**

Get continuous predicted values into bins according to specific criteria.

**Usage**

```r
getBins(model = NULL, obs = NULL, pred = NULL, id = NULL,
bin.method, n.bins = 10, fixed.bin.size = FALSE, min.bin.size = 15,
min.prob.interval = 0.1, quantile.type = 7, simplif = FALSE,
verbosity = 2, na.rm = TRUE, rm.dup = FALSE)
```

**Arguments**

- **model**: a binary-response model object of class "glm", "gam", "gbm", "randomForest" or "bart". If this argument is provided, 'obs' and 'pred' will be extracted with `mod2obspred`. Alternatively, you can input the 'obs' and 'pred' arguments instead of 'model'.

- **obs**: alternatively to 'model' and together with 'pred', a numeric vector of observed presences (1) and absences (0) of a binary response variable. Alternatively (and if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, respectively, the x (longitude) and y (latitude) coordinates of the presence points, in which case the 'obs' vector will be extracted with `ptsrast2obspred`. This argument is ignored if 'model' is provided.

- **pred**: alternatively to 'model' and together with 'obs', a vector with the corresponding predicted values of presence probability, habitat suitability, environmental favourability or alike. Must be of the same length and in the same order as 'obs'. Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of the predicted values for the entire evaluation region, in which case the 'pred' vector will be extracted with `ptsrast2obspred`. This argument is ignored if 'model' is provided.
getBins

id
optional vector of row identifiers; must be of the same length and in the same
order of obs and pred (or of the cases used to build model)

bin.method
the method with which to divide the values into bins. Type modEvAMethods("getBins") for available options and see Details for more information on
these methods.

n.bins
the number of bins in which to divide the data.

fixed.bin.size
logical, whether all bins should have (approximately) the same size.

min.bin.size
integer value defining the minimum number of observations to include in each
bin. The default is 15, the minimum required for accurate comparisons within

min.prob.interval
minimum range of probability values in each bin. The default is 0.1.

quantile.type
argument to pass to quantile specifying the algorithm to use if bin.method =
"quantiles". The default is 7 (the quantile default in R), but check out other
types, e.g. 3 (used by SAS), 6 (used by Minitab and SPSS) or 5 (appropriate for
deciles, which correspond to the default n.bins = 10).

simplif
logical, whether to calculate a faster, simplified version (used internally in other
functions). The default is FALSE.

verbosity
integer specifying the amount of messages or warnings to display. Defaults to
the maximum implemented; lower numbers (down to 0) decrease the number of
messages.

na.rm
logical argument indicating whether to remove (with a warning saying how
many) rows with NA in any of the 'obs' or 'pred' values. The default is TRUE,
as some 'bin.method' options will fail if there are NAs.

rm.dup
If TRUE and if 'pred' is a SpatRaster and if there are repeated points within the
same pixel, a maximum of one point per pixel is used to compute the presences.
See examples in ptsrast2obspred. The default is FALSE.

Details

Mind that different bin.methods can lead to visibly different results regarding the bins and any
operations that depend on them (such as HLfit). Currently available bin.methods are:
- round.prob: probability values are rounded to the number of digits of min.prob.interval -
e.g., if min.prob.interval = 0.1 (the default), values under 0.05 get into bin 1 (rounded probability =
0), values between 0.05 and 0.15 get into bin 2 (rounded probability = 0.1), etc. until values with
probability over 0.95, which get into bin 11. Arguments n.bins, fixed.bin.size and min.bin.size are
ignored by this bin.method.
- prob.bins: probability values are grouped into bins of the given probability intervals - e.g., if
min.prob.interval = 0.1 (the default), bin 1 gets the values between 0 and 0.1, bin 2 gets the values
between 0.1 and 0.2, etc. until bin 10 which gets the values between 0.9 and 1. Arguments n.bins,
fixed.bin.size and min.bin.size are ignored by this bin.method.
- size.bins: probability values are grouped into bins of (approximately) equal size, defined by
argument min.bin.size. Arguments n.bins and min.prob.interval are ignored by this bin.method.
- n.bins: probability values are divided into the number of bins given by argument n.bins, and their
sizes may or may not be forced to be (approximately) equal, depending on argument fixed.bin.size
getBins

(which is FALSE by default). Arguments min.bin.size and min.prob.interval are ignored by this bin.method.

- quantiles: probability values are divided using R function `quantile`, with probability cutpoints defined by the given n.bins (i.e., deciles by default), and with the quantile algorithm defined by argument quantile.type. Arguments fixed.bin.size, min.bin.size and min.prob.interval are ignored by this bin.method.

Value

The output of `getBins` is a list with the following components:

- `prob.bin`: the first and last value of each bin
- `bins.table`: a data frame with the sample size, number of presences, number of absences, prevalence, mean and median probability, and the difference between predicted and observed values (mean probability - observed prevalence) in each bin.
- `N`: the total number of observations in the analysis.
- `n.bins`: the total number of bins obtained.

Note

This function is still under development and may fail for some datasets and binning methods (e.g., ties may sometimes preclude binning under some bin.methods). Fixes and further binning methods are in preparation. Feedback is welcome.

Author(s)

A. Marcia Barbosa

References


See Also

`HLfit`

Examples

```r
# load sample models:
data(rotif.mods)
# choose a particular model to play with:
```
mod <- rotif.mods$models[[1]]

# try getBins using different binning methods:
getBins(model = mod, bin.method = "quantiles")
getBins(model = mod, bin.method = "n.bins")
getBins(model = mod, bin.method = "n.bins", fixed.bin.size = TRUE)

getModEqn

Get model equation

Description
This function retrieves the equation of a model, to print or apply elsewhere.

Usage
getModEqn(model, type = "Y", digits = NULL, prefix = NULL, suffix = NULL)

Arguments
model a model object of class `lm` or `glm`.
type the type of equation to get; can be either "Y" (the default, for the linear model equation), "P" (for probability) or "F" (for favourability).
digits the number of significant digits to which to round the coefficient estimates in the equation.
prefix the prefix to add to each variable name in the equation.
suffix the suffix to add to each variable name in the equation.

Details
The summary of a model in R gives you a table of the coefficient estimates and other parameters. Sometimes it may be useful to have a string of text with the model’s equation, so that you can present it in an article (e.g. Real et al. 2005) or apply it in a (raster map) calculation, either in R (although here you can usually use the ‘predict’ function for this) or in a GIS software (e.g. Barbosa et al. 2010). The getModEqn function gets this equation for linear or generalized linear models.

By default it prints the “Y” linear equation, but for generalized linear models you can also set type = "P" (for the equation of probability) or type = "F" (for favourability, which modifies the intercept to eliminate the effect of modelled prevalence - see Real et al. 2006).

If the variables to which you want to apply the model have a prefix or suffix (e.g. something like prefix = "raster.stack$" for the R ‘raster’ or ‘terra’ package, or prefix = "mydata$" for a data frame, or suffix = "@1" in QGIS, or suffix = "@mapset" in GRASS), you can get these in the equation too, using the prefix and/or the suffix argument.
getThreshold

Value

A character string of the model equation.

Author(s)

A. Marcia Barbosa

References


Examples

# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]

getModEqn(mod)

getModEqn(mod, type = "P", digits = 3, suffix = "@mapset")

getModEqn(mod, type = "F", digits = 2)

getThreshold

Prediction threshold for a given criterion

Description

This function computes the prediction threshold under a given criterion.

Usage

getThreshold(model = NULL, obs = NULL, pred = NULL, threshMethod, interval = 0.01, quant = 0, na.rm = TRUE)
getThreshold

Arguments

model a binary-response model object of class "glm", "gam", "gbm", "randomForest" or "bart". If this argument is provided, 'obs' and 'pred' will be extracted with mod2obspred. Alternatively, you can input the 'obs' and 'pred' arguments instead of 'model'.

obs alternatively to 'model' and together with 'pred', a numeric vector of observed presences (1) and absences (0) of a binary response variable. Alternatively (and if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, respectively, the x (longitude) and y (latitude) coordinates of the presence points, in which case the 'obs' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

pred alternatively to 'model' and together with 'obs', a vector with the corresponding predicted values of presence probability, habitat suitability, environmental favourability or alike. Must be of the same length and in the same order as 'obs'. Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of the predicted values for the entire evaluation region, in which case the 'pred' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

threshMethod Criterion under which to compute the threshold. Run modEvAmethods("getThreshold") for available options.

interval Argument to pass to optiThresh indicating the interval between the thresholds to test. The default is 0.01. Smaller values may provide more precise results but take longer to compute.

quant Numeric value indicating the proportion of presences to discard if threshMethod="MTP" (minimum training presence). With the default value 0, MTP will be the threshold at which all observed presences are classified as such; with e.g. quant=0.05, MTP will be the threshold at which 5% presences will be classified as absences.

na.rm Logical value indicating whether NA values should be ignored. Defaults to TRUE.

Details

Several criteria have been proposed for selecting a threshold with which to convert continuous model predictions (of presence probability, habitat suitability or alike) into binary predictions of presence or absence. Such threshold is required for computing threshold-based model evaluation metrics, such as those in threshMeasures. This function implements a few of these threshold selection criteria, including those outlined in Liu et al. (2005, 2013) and a couple more:

- "preval", "trainPrev": prevalence (proportion of presences) in the supplied 'model' or 'obs'
- "meanPred": mean predicted value in the supplied 'model' or 'pred'
- "midPoint": median predicted value in the supplied 'model' or 'pred'
- "maxKappa": threshold that maximizes Cohen's kappa
- "maxCCR", "maxOA", "maxOPS": threshold that maximizes the Correct Classification Rate, aka Overall Accuracy, aka Overall Prediction Success
- "maxF": threshold that maximizes the F value
- "maxSSS": threshold that maximizes the sum of sensitivity and specificity
- "maxTSS": threshold that maximizes the True Skill Statistic
- "maxSPR": threshold that maximizes the sum of precision and recall
- "minDSS": threshold that minimizes the difference between sensitivity and specificity
- "minDPR": threshold that minimizes the difference between precision and recall
- "minD01": threshold that minimizes the distance between the ROC curve and the 0,1 point
- "minD11": threshold that minimizes the distance between the PR curve and the 1,1 point
- "equalPrev": predicted and observed prevalence equalization
- "MTP": minimum training presence, or the lowest predicted value where presence is recorded in 'obs' or 'model'. Optionally, with the 'quant' argument, this threshold leaves out predicted values lower than the value for the lowest specified proportion of presences

**Value**

This function returns a numeric value indicating the threshold selected under the specified 'threshMethod'.

**Author(s)**

A. Marcia Barbosa

**References**


**See Also**

threshMeasures, optiThresh

**Examples**

```r
# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]

getThreshold(model = mod, threshMethod = "maxTSS")

# you can also use getThreshold with vectors of observed and predicted values
# instead of with a model object:
presabs <- mod$y
prediction <- mod$fitted.values
```
getThreshold(obs = presabs, pred = prediction, threshMethod = "maxTSS")

getThreshold(obs = presabs, pred = prediction, threshMethod = "MTP")

getThreshold(obs = presabs, pred = prediction, threshMethod = "MTP", quant = 0.05)

# 'obs' can also be a table of presence point coordinates
# and 'pred' a SpatRaster of predicted values

---

**HLfit**

**Hosmer-Lemeshow goodness of fit**

**Description**

This function calculates a model’s calibration performance (reliability) with the Hosmer & Lemeshow goodness-of-fit statistic, which compares predicted probability to observed occurrence frequency at each portion of the probability range.

**Usage**

```r
HLfit(model = NULL, obs = NULL, pred = NULL, bin.method,
      n.bins = 10, fixed.bin.size = FALSE, min.bin.size = 15,
      min.prob.interval = 0.1, quantile.type = 7, simplif = FALSE,
      verbosity = 2, alpha = 0.05, plot = TRUE, plot.values = TRUE,
      plot.bin.size = TRUE, xlab = "Predicted probability",
      ylab = "Observed prevalence", na.rm = TRUE, rm.dup = FALSE, ...)
```

**Arguments**

- **model**: a binary-response model object of class "glm", "gam", "gbm", "randomForest" or "bart". If this argument is provided, 'obs' and 'pred' will be extracted with `mod2obspred`. Alternatively, you can input the 'obs' and 'pred' arguments instead of 'model'.

- **obs**: alternatively to 'model' and together with 'pred', a numeric vector of observed presences (1) and absences (0) of a binary response variable. Alternatively (and if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, respectively, the x (longitude) and y (latitude) coordinates of the presence points, in which case the 'obs' vector will be extracted with `ptsrast2obspred`. This argument is ignored if 'model' is provided.

- **pred**: alternatively to 'model' and together with 'obs', a vector with the corresponding predicted values of presence probability, habitat suitability, environmental favourability or alike. Must be of the same length and in the same order as 'obs'. Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of the predicted values for the entire evaluation region, in which case the 'pred' vector will be extracted with `ptsrast2obspred`. This argument is ignored if 'model' is provided.
bin.method  argument to pass to `getBins` specifying the method for grouping the records into bins within which to compare predicted probability to observed prevalence; type `modEvAmethods("getBins")` for available options, and see Details for more information.

n.bins  argument to pass to `getBins` specifying the number of bins to use if `bin.method = n.bins` or `bin.method = quantiles`. The default is 10.

fixed.bin.size  argument to pass to `getBins`, a logical value indicating whether to force bins to have (approximately) the same size. The default is FALSE.

min.bin.size  argument to pass to `getBins` specifying the minimum number of records in each bin. The default is 15, the minimum required for accurate comparisons within bins (Jovani & Tella 2006, Jimenez-Valverde et al. 2013).

min.prob.interval  argument to pass to `getBins` specifying the minimum interval (range) of probability values within each bin. The default is 0.1.

quantile.type  argument to pass to `quantile` specifying the algorithm to use if `bin.method = "quantiles"`. The default is 7 (the `quantile` default in R), but check out other types, e.g. 3 (used by SAS), 6 (used by Minitab and SPSS) or 5 (appropriate for deciles, which correspond to the default `n.bins = 10`).

simplif  logical, whether to perform a faster simplified version returning only the basic statistics. The default is FALSE.

verbosity  integer specifying the amount of messages or warnings to display. Defaults to the maximum implemented; lower numbers (down to 0) decrease the number of messages.

alpha  alpha value for confidence intervals if `plot = TRUE`.

plot  logical, whether to produce a plot of the results. The default is TRUE.

plot.values  logical, whether to report measure values in the plot. The default is TRUE.

plot.bin.size  logical, whether to report bin sizes in the plot. The default is TRUE.

xlab  label for the x axis.

ylab  label for the y axis.

na.rm  Logical value indicating whether missing values should be ignored in computations. Defaults to TRUE.

rm.dup  If TRUE and if `pred` is a SpatRaster and if there are repeated points within the same pixel, a maximum of one point per pixel is used to compute the presences. See examples in `ptsrast2obspred`. The default is FALSE.

...  further arguments to pass to the `plot` function.

Details

Most of the commonly used measures for evaluating model performance focus on the discrimination or the classification capacity, i.e., how well the model is capable of distinguishing or classifying presences and absences (often after the model’s continuous predictions of presence probability or alike are converted to binary predictions of presence or absence). However, there is another important facet of model evaluation: calibration or reliability, i.e., the relationship between predicted probability and observed occurrence frequency (Pearce & Ferrier 2000; Jimenez-Valverde et al.
The `HLfit` function measures model reliability with the Hosmer & Lemeshow goodness-of-fit statistic (Hosmer & Lemeshow 1980).

Note that this statistic has strong limitations and caveats (see e.g. http://www.statisticalhorizons.com/hosmer-lemeshow, Allison 2014), mainly due to the need to group the values into bins within which to compare probability and prevalence, and the strong influence of the binning method on the results. The 'HLfit' function can use several binning methods, which are implemented and roughly explained in the `getBins` function and can be accessed by typing `modEvAmethods("getBins")`. You should try 'HLfit' with different binning methods to see how if the results are robust.

**Value**

'HLfit' returns a list with the following components:

- **bins.table**: a data frame of the obtained bins and the values resulting from the hosmer-Lemeshow goodness-of-fit analysis.
- **chi.sq**: the value of the Chi-squared test.
- **DF**: the number of degrees of freedom.
- **p.value**: the p-value of the Hosmer-Lemeshow test. Note that this is one of those tests for which higher p-values are better.
- **RMSE**: the root mean squared error.

**Note**

The 4 lines of code from "observed" to "p.value" were adapted from the 'hosmerlem' function available at http://www.stat.sc.edu/~hitchcock/diseaseoutbreakRexample704.txt. The plotting code was loosely based on the calibration.plot function in package PresenceAbsence. 'HLfit' still needs some code simplification, and may fail for some datasets and binning methods. Fixes are being applied. Feedback is welcome.

**Author(s)**

A. Marcia Barbosa

**References**


See Also

getBins, MillerCalib

Examples

# load sample models:

data(rotif.mods)

# choose a particular model to play with:

mod <- rotif.mods$models[[1]]

# try HLfit using different binning methods:

HLfit(model = mod, bin.method = "round.prob",
main = "HL GOF with round.prob (n=10)")

HLfit(model = mod, bin.method = "prob.bins",
main = "HL GOF with prob.bins (n=10)")

HLfit(model = mod, bin.method = "size.bins",
main = "HL GOF with size.bins (min size=15)"

HLfit(model = mod, bin.method = "size.bins", min.bin.size = 30,
main = "HL GOF with size.bins min size 30"

HLfit(model = mod, bin.method = "n.bins",
main = "HL GOF with 10 bins"

HLfit(model = mod, bin.method = "n.bins", fixed.bin.size = TRUE,
main = "HL GOF with 10 bins of fixed size"

HLfit(model = mod, bin.method = "n.bins", n.bins = 20,
main = "HL GOF with 20 bins"

HLfit(model = mod, bin.method = "quantiles",
main = "HL GOF with quantile bins (n=10)"

HLfit(model = mod, bin.method = "quantiles", n.bins = 20,
main = "HL GOF with quantile bins (n=20)"

# you can also use 'predPlot' with vectors of observed and predicted values
# instead of a model object:

presabs <- mod$y
prediction <- mod$fitted.values

HLfit(obs = presabs, pred = prediction, bin.method = "round.prob")
inputMunch

Munch inputs into 'obs' and 'pred' vectors

Description

This function is used internally by many other functions in this package to check and extract the 'obs' and 'pred' vectors from the user inputs.

Usage

inputMunch(model = NULL, obs = NULL, pred = NULL, rm.dup = FALSE, na.rm = FALSE, verbosity = 2)

Arguments

model: a binary-response model object of class "glm", "gam", "gbm", "randomForest" or "bart". If this argument is provided, 'obs' and 'pred' will be extracted with mod2obspred. Alternatively, you can input the 'obs' and 'pred' arguments (e.g. for external test data) instead of 'model'.

obs: alternatively to 'model' and together with 'pred', a numeric vector of observed presences (1) and absences (0) of a binary response variable. Alternatively (and if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, respectively, the x (longitude) and y (latitude) coordinates of the presence points, in which case the 'obs' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

pred: alternatively to 'model' and together with 'obs', a vector with the corresponding predicted values of presence probability, habitat suitability, environmental favourability or alike. Must be of the same length and in the same order as 'obs'. Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of the predicted values for the entire evaluation region, in which case the 'pred' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

rm.dup: logical argument to be passed to ptsrast2obspred indicating whether repeated points within the same pixel should be removed. The default is FALSE.

na.rm: logical argument indicating whether to remove (with a warning saying how many) rows with NA in any of the resulting 'obs' or 'pred' values. The default is FALSE.

verbosity: integer value indicating the amount of messages to display. Defaults to 2, for the maximum amount of messages.
Value

This function returns a two-column data frame containing the 'obs' and 'pred' values, or an error message if inputs are not as required.

Author(s)

A. Marcia Barbosa

Description

This function creates a lollipop chart from a (optionally named) numeric vector.

Usage

lollipop(x, names = NULL, ymin = 0, sticks = TRUE, col = "royalblue", grid = TRUE, cex = 1, cex.axis = 1, las = 2, ...)

Arguments

x a numeric vector.

names a vector of the same length as 'x' with the names to be plotted below the lollipops. If this argument is left NULL and 'x' has names, then these will be used.

ymin numeric value for the lower limit of the y axis. The default is zero. If set to NA, the minimum of 'x' will be used.

sticks logical value indicating whether the sticks of the lollipops should be drawn. The default is TRUE.

col colour for the lollipops.

grid logical, whether or not to add a grid to the plot. The default is TRUE.

cex numeric value indicating the size of the lollipops. Will be passed as 'cex' to 'points' and as 'lwd' to 'arrows' (the lines or lollipop sticks).

cex.axis numeric value indicating the size of the x and y axis labels.

las argument to pass to par indicating the orientation of the axis labels.

... additional arguments that can be used for the plot, e.g. 'main'.

Details

According to modern data viz recommendations, lollipop charts are generally a better alternative to bar charts, as they reduce the visual distortion caused by the length of the bars, making it easier to compare the values.
Value

This function produces a lollipop chart of the values in 'x'.

Author(s)

A. Marcia Barbosa

See Also

barplot

Examples

lollipop(mtcars[,1], names = rownames(mtcars), las = 2, ylab = names(mtcars)[1],
cex.axis = 0.6, main = "Lollipop chart")

lollipop(mtcars[,1], names = rownames(mtcars), las = 2, ylab = names(mtcars)[1],
cex.axis = 0.6, main = "Lollipop chart", ymin = NA)

MESS
Multivariate Environmental Similarity Surfaces based on a data frame

Description

This function performs the MESS analysis of Elith et al. (2010) to determine the extent of the environmental differences between model training and model projection (extrapolation) data. It is applicable to variables in a matrix or data frame.

Usage

MESS(V, P, id.col = NULL, verbosity = 2)

Arguments

V a matrix or data frame containing the variables (one in each column) in the training dataset.

P a matrix or data frame containing the same variables in the area to which the model(s) will be projected. Variables (columns) must be in the same order as in V, and colnames(P) must exist.

id.col optionally, the index number of a column containing the row identifiers in P. If provided, this column will be excluded from MESS calculations but included in the output.

verbosity Integer number indicating the amount of messages to display while computing the results. The default is to display all messages. Set verbosity=0 for no messages.
Details
When model predictions are projected into regions, times or spatial resolutions not analysed in the training data, it may be important to measure the similarity between the new environments and those in the training sample (Elith et al. 2010), as models are not so reliable when predicting outside their domain (Barbosa et al. 2009). The Multivariate Environmental Similarity Surfaces (MESS) analysis measures the similarity in the analysed variables between any given locality in the projection dataset and the localities in the reference (training) dataset (Elith et al. 2010).

MESS analysis is implemented in the MAXENT software (Phillips et al. 2006) and in the dismo R package, but there it requires input variables in raster format. This implies not only the use of complex spatial data structures, but also that the units of analysis are rectangular pixels, whereas we often need to model distribution data recorded on less regular units (e.g. provinces, river basins), or on equal-area cells that are not necessarily rectangular (e.g. UTM cells, equal-area hexagons or other geometric shapes). The MESS function computes this analysis for variables in a data frame, where localities (in rows) may be of any size or shape.

Value
The function returns a data frame with the same column names as P, plus a column named TOTAL, quantifying the similarity between each point in the projection dataset and those in the reference dataset. Negative values indicate localities that are environmentally dissimilar from the reference region. The last column, MoD, indicates which of the column names of P corresponds to the most dissimilar variable, i.e., the limiting factor or the variable that drives the MESS in that locality (Elith et al. 2010).

Note
Newer and apparently more complete methods for analysing environmental dissimilarities have been developed, such as extrapolation detection (ExDet; Mesgaran et al. 2014) and Mobility-Oriented Parity analysis (MOP; Owens et al. 2013).

Author(s)
Alberto Jimenez-Valverde, A. Marcia Barbosa

References

See Also

OA; mess in package dismo; ecospat.climan in package ecospat; kuenm_mop and kuenm_mmop in package kuenm

Examples

```r
## Not run:
# load package 'fuzzySim' and its sample data:
require(fuzzySim)
data(rotif.env)

# add a column specifying the hemisphere:
unique(rotif.env$CONTINENT)

rotif.env$HEMISPHERE <- "Eastern"

rotif.env$HEMISPHERE[rotif.env$CONTINENT %in% c("NORTHERN_AMERICA", "SOUTHERN_AMERICA") ] <- "Western"

head(rotif.env)

# perform a MESS analysis
# suppose you'll extrapolate models from the Western hemisphere (Americas) to the Eastern hemisphere (rest of the world):

names(rotif.env) # variables are in columns 5:17

west <- subset(rotif.env, HEMISPHERE == "Western", select = 5:17)
est <- subset(rotif.env, HEMISPHERE == "Eastern", select = 5:17)
est.with.ID <- subset(rotif.env, HEMISPHERE == "Eastern", select = c(1, 5:17))

head(east)
head(east.with.ID) # ID is in column 1

mess <- MESS(V = west, P = east)
mess.with.ID <- MESS(V = west, P = east.with.ID, id.col = 1)

head(mess)
head(mess.with.ID)

range(mess[, "TOTAL"])

## End(Not run)
```
MillerCalib

Miller's calibration statistics for logistic regression models

Description

This function calculates Miller's (1991) calibration statistics for a presence probability model – namely, the intercept and slope of a logistic regression of the response variable on the logit of predicted probabilities. Optionally and by default, it also plots the corresponding regression line over the reference diagonal (identity line). If the model is well calibrated, the line should lie along (or at least be nearly parallel to) the reference diagonal, i.e. the slope should ideally equal 1 (i.e., 45 degrees).

Usage

MillerCalib(model = NULL, obs = NULL, pred = NULL, plot = TRUE, line.col = "black", diag = TRUE, diag.col = "grey", plot.values = TRUE, digits = 2, xlab = "", ylab = "", main = "Miller calibration", na.rm = TRUE, rm.dup = FALSE, ...)

Arguments

model a binary-response model object of class "glm", "gam", "gbm", "randomForest" or "bart". If this argument is provided, 'obs' and 'pred' will be extracted with mod2obspred. Alternatively, you can input the 'obs' and 'pred' arguments instead of 'model'.

obs alternatively to 'model' and together with 'pred', a numeric vector of observed presences (1) and absences (0) of a binary response variable. Alternatively (and if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, respectively, the x (longitude) and y (latitude) coordinates of the presence points, in which case the 'obs' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

pred alternatively to 'model' and together with 'obs', a vector with the corresponding predicted values of presence probability, habitat suitability, environmental favourability or alike. Must be of the same length and in the same order as 'obs'. Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of the predicted values for the entire evaluation region, in which case the 'pred' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

plot logical, whether or not to produce a plot of the Miller regression line. Defaults to TRUE.

line.col colour for the Miller regression line (if plot = TRUE).

diag logical, whether or not to add the reference diagonal (if plot = TRUE). Defaults to TRUE.

diag.col line colour for the reference diagonal.
plot.values logical, whether or not to report the values of the intercept and slope on the plot. Defaults to TRUE.
digits integer number indicating the number of digits to which the values in the plot should be rounded. Defaults to 2. This argument is ignored if 'plot' or 'plot.values' are set to FALSE.
xlab label for the x axis.
ylab label for the y axis.
main title for the plot.
na.rm Logical value indicating whether missing values should be ignored in computations. Defaults to TRUE.
rm.dup If TRUE and if 'pred' is a SpatRaster and if there are repeated points within the same pixel, a maximum of one point per pixel is used to compute the presences. See examples in ptsrast2obspred. The default is FALSE.
... additional arguments to pass to plot.

Details

Calibration or reliability measures how a model’s predicted probabilities relate to observed species prevalence or proportion of presences in the modelled data (Pearce & Ferrier 2000; Wintle et al. 2005; Franklin 2010). If predictions are perfectly calibrated, the slope will equal 1 and the intercept will equal 0, so the model’s calibration line will perfectly overlap with the reference diagonal or identity line.

Note that Miller’s statistics assess the model globally: a model is well calibrated if the average of all predicted probabilities equals the proportion of presences in the modelled data. For logistic regression models, perfect calibration is always attained on the same data used for building the model (Miller 1991); Miller’s calibration statistics are mainly useful when projecting a model outside those training data.

Calibration can be separated into two measurable components, bias and spread, and a third component, unexplained error. Bias describes a consistent overestimate or underestimate of presence probability, which is reflected by a Miller intercept above or below 0 (i.e., a model line above or below the reference diagonal). Spread describes a departure of the model line from the 45-degree slope. A slope greater than 1 indicates that predicted values above 0.5 are underestimating, and values below 0.5 are overestimating, the probability of presence. A slope smaller than 1 (while greater than 0) implies that predicted values below 0.5 are underestimating, and values above 0.5 are overestimating, the probability of presence (Pearce & Ferrier 2000). A Miller slope very different from 1 indicates a poorly calibrated model. The unexplained error component can be assessed, though only in part, through residual analysis (Miller 1991; Pearce & Ferrier 2000).

While Miller’s calibration statistics were originally conceived for generalized linear models with binomial distribution and logit link (Miller 1991), they may also apply to other models that also estimate presence probability, including those that use different link functions such as probit or cloglog. Regardless of how they get there, these models attempt to estimate presence probabilities as well calibrated as possible, and the logit is the canonical link for the Bernoulli distribution which is appropriate for a binary response variable. Indeed, the Miller slope is visibly worse when those other link functions are used for computing it.

Miller’s calibration slope (though not the intercept) is also adequate to assess the calibration of other predictions related to presence probability, such as suitability and favourability (see e.g. ‘Fav’
function in the fuzzySim package). Indeed, the slope is the same for presence probability and its corresponding favourability value (see Examples, bottom).

Value

This function returns a list of two integer values:

intercept the calibration intercept.
slope the calibration slope.

If plot = TRUE, a plot will be produced with the model calibration line, optionally (if diag = TRUE) over the reference diagonal, and optionally (if plot.values = TRUE) with the intercept and slope values printed on it.

Author(s)

A. Marcia Barbosa

References


See Also

HLfit, Dsquared, RsqGLM, Boyce

Examples

# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]

MillerCalib(model = mod)
MillerCalib(model = mod, plot.values = FALSE)
MillerCalib(model = mod, main = "Model calibration line")

# you can also use MillerCalib with vectors of observed and predicted values
# instead of a model object:

MillerCalib(obs = mod$y, pred = mod$fitted.values)
mod2obspred

Extract observed and predicted values from a model object.

Description
This function takes a model object and returns the observed and (optionally) the fitted values in that model.

Usage
mod2obspred(model, obs.only = FALSE)

Arguments
model  
a model object of class "glm", "gam", "gbm", "randomForest" or "bart" from which the response variable and fitted (predicted) values can be extracted. Note that, for "randomForest" models, only the out-of-bag prediction is available from the model object (see ?predict.randomForest if you have that package installed), so here you’ll get different results if you provide ’model’ or the modelled ‘obs’ (and corresponding ’pred’) values.

obs.only  
logical value indicating whether only ’obs’ should be obtained (saves computing time when ’pred’ not needed – used e.g. by prevalence). Defaults to FALSE.

Value
A data frame with one column containing the observed and (if obs.only=FALSE, the default) another column containing the predicted values from ’model’.

Author(s)
A. Marcia Barbosa
modEvAmethods

See Also

prevalence

Examples

data(rotif.mods)
mod <- rotif.mods$models[[1]]
obspred <- mod2obspred(mod)
head(obspred)

modEvAmethods

Methods implemented in modEvA functions

Description

This function allows retrieving the methods available for some of the functions in modEvA, such as similarity, threshMeasures, optiThresh, multModEv, getThreshold and getBins.

Usage

modEvAmethods(fun)

Arguments

fun a character vector of length 1 specifying the name (in quotes) of the function for which to obtain the available methods. Must be one of “threshMeasures”, "optiThresh", "multModEv", "getThreshold" or "getBins".

Value

a character vector of the available methods for the specified function.

Author(s)

A. Marcia Barbosa

See Also

threshMeasures, optiThresh, getBins, multModEv

Examples

modEvAmethods("threshMeasures")
modEvAmethods("multModEv")
modEvAmethods("optiThresh")
modEvAmethods("getBins")
modEvAmethods("similarity")

### multModEv

*Multiple model evaluation*

#### Description

If you have a list of GLM model objects (created, e.g., with the `multGLM` function of the 'fuzzySim' R-Forge package), or a data frame with presence-absence data and the corresponding predicted values for a set of species, you can use the `multModEv` function to get a set of evaluation measures for all models simultaneously, as long as they all have the same sample size.

#### Usage

```r
multModEv(models = NULL, obs.data = NULL, pred.data = NULL,
          measures = modEvAmethods("multModEv"), standardize = FALSE,
          thresh = NULL, bin.method = NULL, verbosity = 0, ...)
```

#### Arguments

- **models**: a list of model object(s) of class "glm", all applied to the same data set. Evaluation is based on the cases included in the models.
- **obs.data**: a data frame with observed (training or test) binary data. This argument is ignored if 'models' is provided.
- **pred.data**: a data frame with the corresponding predicted (training or test) values, with both rows and columns in the same order as in 'obs.data'. This argument is ignored if 'models' is provided. Note that, for calibration measures (based on `HLfit` or `MillerCalib`), the results are only valid if the input predictions represent probability.
- **measures**: character vector of the evaluation measures to calculate. The default is all implemented measures, which you can check by typing `modEvAmethods("multModEv")`. But beware: calibration measures (i.e., HL and Miller) are only valid if your predicted values reflect actual presence probability (not favourability, habitat suitability or others); you should exclude them otherwise.
- **standardize**: logical, whether to standardize measures that vary between -1 and 1 to the 0-1 scale (see `standard01`). The default is FALSE.
- **thresh**: argument to pass to `threshMeasures` if any of 'measures' is calculated by that function. The default is NULL, but a valid method must be specified if any of 'measures' is threshold-based - i.e., any of those in 'modEvAmethods("threshMeasures")'.
- **bin.method**: the method with which to divide the data into groups or bins, for calibration or reliability measures such as `HLfit`. The default is NULL, but a valid method must be specified if 'measures' includes "HL" or "HL.p". Type `modEvAmethods("getBins")` for available options), and see `HLfit` and `getBins` for more information.
multModEv

verbosity   integer specifying the amount of messages or warnings to display. Defaults to
          0, but can also be 1 or 2 for more messages from the functions within.

... optional arguments to pass to HLfit (if "HL" or "HL.p" are included in 'mea-
     sures'), namely n.bins, fixed.bin.size, min.bin.size, min.prob.interval or quan-
     tile.type.

Value

A data frame with the value of each evaluation measure for each model.

Author(s)

A. Marcia Barbosa

See Also

threshMeasures

Examples

data(rotif.mods)

eval1 <- multModEv(models = rotif.mods$models[1:6], thresh = 0.5,
                    bin.method = "n.bins", fixed.bin.size = TRUE)

head(eval1)

eval2 <- multModEv(models = rotif.mods$models[1:6],
                    thresh = "preval", measures = c("AUC", "AUCPR", "CCR",
                    "Sensitivity", "TSS"))

head(eval2)

# you can also calculate evaluation measures for a set of
# observed vs predicted data, rather than from model objects:

obses <- sapply(rotif.mods$models, `[[`, "y")
preds <- sapply(rotif.mods$models, `[[`, "fitted.values")

eval3 <- multModEv(obs.data = obses[,1:4],
                  pred.data = preds[,1:4], thresh = "preval",
                  bin.method = "prob.bins")

head(eval3)
Overlap Analysis

Description

This function analyses the range of values of the given environmental variables at the sites where a species has been recorded present.

Usage

\texttt{OA(data, sp.cols, var.cols)}

Arguments

- \texttt{data} a data frame with your species’ occurrence data and the predictor variables.
- \texttt{sp.cols} index number of the column containing the occurrence data of the species to be modelled. Currently only one species can be analysed at a time.
- \texttt{var.cols} index numbers of the columns containing the predictor variables to be used.

Details

Overlap Analysis is one of the simplest forms of modelling species’ distributions. It assesses the ranges of values of the given environmental variables at the sites where a species has been recorded present, and predicts where that species should be able to occur based on those presence data (e.g. Brito et al. 1999, Arntzen & Teixeira 2006).

\texttt{OA} can also be useful when extrapolating models outside their original scope (geographical area, time period or spatial resolution), as it can identify which localities are within the model’s domain - i.e., within the analysed ranges of values of the variables, outside which the model may not be reliable (e.g. Barbosa et al. 2009). In this case, the response is not a species’ presence, but rather the sites that have been included in the model. See also the \texttt{MESS} function for a comparison between modelled and extrapolation environments.

Input data for the \texttt{OA} function are a vector or column with ones and zeros (presences vs. absences of a species if we want to model its occurrence, or modelled vs. non-modelled sites if we want to know which non-modelled sites are within the modelled range), and a matrix or data frame with the corresponding values of the environmental variables to consider (one variable in each column, values in rows).

Value

A binary vector with 1 where the values of all predictors lie within the ranges observed for the presence records, and 0 otherwise.

Author(s)

A. Marcia Barbosa
References


See Also

MESS

Examples

## Not run:
# load package 'fuzzySim' and its sample data:
require(fuzzySim)
data(rotif.env)
names(rotif.env)
OA(rotif.env, sp.cols = 18, var.cols = 5:17)
## End(Not run)

optiPair

Optimize the classification threshold for a pair of related model evaluation measures.

Description

This function can optimize a model’s classification threshold based on a pair of model evaluation measures that balance each other, such as sensitivity-specificity, precision-recall (i.e., positive predictive power vs. sensitivity), or omission-commission, or underprediction-overprediction (Fielding & Bell 1997; Liu et al. 2011; Barbosa et al. 2013). The function plots both measures of the given pair against all thresholds with a given interval, and calculates the optimal sum, difference and mean of the two measures.

Usage

optiPair(model = NULL, obs = NULL, pred = NULL, measures = c("Sensitivity", "Specificity"), interval = 0.01, plot = TRUE, plot.sum = FALSE, plot.diff = FALSE, ylim = NULL, na.rm = TRUE, exclude.zeros = TRUE, rm.dup = FALSE, ...)
Arguments

model  a binary-response model object of class "glm", "gam", "gbm", "randomForest" or "bart". If this argument is provided, 'obs' and 'pred' will be extracted with mod2obspred. Alternatively, you can input the 'obs' and 'pred' arguments instead of 'model'.

obs  alternatively to 'model' and together with 'pred', a numeric vector of observed presences (1) and absences (0) of a binary response variable. Alternatively (and if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, respectively, the x (longitude) and y (latitude) coordinates of the presence points, in which case the 'obs' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

pred  alternatively to 'model' and together with 'obs', a vector with the corresponding predicted values of presence probability, habitat suitability, environmental favourability or alike. Must be of the same length and in the same order as 'obs'. Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of the predicted values for the entire evaluation region, in which case the 'pred' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

measures  a character vector of length 2 indicating the pair of measures whose curves to plot and whose combined threshold to optimize. Available measures can be obtained with 'modEvAmethods("threshMeasures")', but note that this function expects you to use two measures that counter-balance one another, such as c("Sensitivity", "Specificity") [the default], c("Omission", "Commission"), or c("Precision", "Recall").

interval  the interval of thresholds at which to calculate the measures. The default is 0.01.

plot  logical indicating whether or not to plot the pair of measures.

plot.sum  logical, whether to plot the sum (+) of both measures in the pair. Defaults to FALSE.

plot.diff  logical, whether to plot the difference (-) between both measures in the pair. Defaults to FALSE.

ylim  a character vector of length 2 indicating the lower and upper limits for the y axis. The default is NULL for an automatic definition of 'ylim' based on the values of the measures and their sum and/or difference if any of these are set to TRUE.

na.rm  logical, whether NA values should be removed from the calculation of minimum/maximum/mean values to get the optimized measures. Defaults to TRUE.

exclude.zeros  logical, whether non-finite and zero values should be removed from the calculation of minimum/maximum/mean values to get the optimized measures. Defaults to TRUE.

rm.dup  If TRUE and if 'pred' is a SpatRaster and if there are repeated points within the same pixel, a maximum of one point per pixel is used to compute the presences. See examples in ptsrast2obspred. The default is FALSE.

...  additional arguments to be passed to the plot function.
Value
The output is a list with the following components:

- **measures.values**: a data frame with the values of the chosen pair of measures, as well as their difference, sum and mean, at each threshold.
- **MinDiff**: numeric value, the minimum difference between both measures.
- **ThreshDiff**: numeric value, the threshold that minimizes the difference between both measures.
- **MaxSum**: numeric value, the maximum sum of both measures.
- **ThreshSum**: numeric value, the threshold that maximizes the sum of both measures.
- **MaxMean**: numeric value, the maximum mean of both measures.
- **ThreshMean**: numeric value, the threshold that maximizes the mean of both measures.

If plot=TRUE (the default), a plot is also produced with the value of each of 'measures' at each threshold, and horizontal and vertical lines marking, respectively, the threshold and value at which the difference between the two 'measures' is minimal.

Author(s)
A. Marcia Barbosa

References


See Also
- optiThresh, threshMeasures

Examples
```r
# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]

optiPair(model = mod)

optiPair(model = mod, measures = c("Precision", "Recall"))
```
optiPair(model = mod, measures = c("UPR", "OPR"))

optiPair(model = mod, measures = c("CCR", "F1score"))

# you can also use 'optiPair' with vectors of observed
# and predicted values, instead of a model object:
optiPair(obs = mod$y, pred = mod$fitted.values)

# 'obs' can also be a table of presence point coordinates
# and 'pred' a SpatRaster of predicted values

---

doctible: optiThresh

Optimize threshold for model evaluation.

Description

The 'optiThresh' function calculates optimal thresholds for a number of model evaluation measures
(see threshMeasures). Optimization is given for each measure, and/or for all measures according
to particular criteria (e.g. Jimenez-Valverde & Lobo 2007; Liu et al. 2005; Nenzen & Araujo 2011).
Results are given numerically and in plots.

Usage

optiThresh(model = NULL, obs = NULL, pred = NULL, interval = 0.01,
measures = c(modEvAmethods("threshMeasures"), modEvAmethods("similarity")),
optimize = modEvAmethods("optiThresh"), simplif = FALSE, plot = TRUE,
sep.plots = FALSE, xlab = "Threshold", na.rm = TRUE, rm.dup = FALSE, ...)

Arguments

model a binary-response model object of class "glm", "gam", "gbm", "randomForest"
or "bart". If this argument is provided, 'obs' and 'pred' will be extracted with
mod2obspred. Alternatively, you can input the 'obs' and 'pred' arguments in- stead of 'model'.

obs alternatively to 'model' and together with 'pred', a numeric vector of observed
presences (1) and absences (0) of a binary response variable. Alternatively (and
if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, re- spectively, the x (longitude) and y (latitude) coordinates of the presence points,
in which case the 'obs' vector will be extracted with ptsrast2obspred. This
argument is ignored if 'model' is provided.

pred alternatively to 'model' and together with 'obs', a vector with the corresponding predicted values of presence probability, habitat suitability, environmental
favourability or alike. Must be of the same length and in the same order as 'obs'.
Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of
the predicted values for the entire evaluation region, in which case the 'pred' vector will be extracted with `ptsrast2obspred`. This argument is ignored if 'model' is provided.

`interval` numeric value between 0 and 1 indicating the interval between the thresholds at which to calculate the evaluation measures. Defaults to 0.01.

`measures` character vector indicating the names of the model evaluation measures for which to calculate optimal thresholds. The default is using all measures available in `c(modEvAmethods("threshMeasures"), modEvAmethods("similarity"))`.

`optimize` character vector indicating the threshold optimization criteria to use; "each" calculates the optimal threshold for each model evaluation measure, while the remaining options optimize all measures according to the specified criterion. The default is using all criteria available in `modEvAmethods("optiThresh")`.

`simplif` logical, whether to calculate a faster simplified version. Used internally in other functions.

`plot` logical, whether to plot the values of each evaluation measure at all thresholds.

`sep.plots` logical. If TRUE, each plot is presented separately (you need to be recording R plot history to be able to browse through them all); if FALSE (the default), all plots are presented together in the same plotting window.

`xlab` character vector indicating the label of the x axis.

`na.rm` Logical value indicating whether missing values should be ignored in computations. Defaults to TRUE.

`rm.dup` If TRUE and if 'pred' is a SpatRaster and if there are repeated points within the same pixel, a maximum of one point per pixel is used to compute the presences. See examples in `ptsrast2obspred`. The default is FALSE.

`...` additional arguments to pass to `plot`.

**Value**

This function returns a list with the following components:

- `all.thresholds` a data frame with the values of all analysed measures at all analysed thresholds.
- `optimals.each` if "each" is among the threshold criteria specified in 'optimize', `optimals.each` is output as a data frame with the value of each measure at its optimal threshold, as well as the type of optimal for that measure (which may be the maximum for measures of goodness such as "Sensitivity", or the minimum for measures of badness such as "Omission").
- `optimals.criteria` a data frame with the values of measure at the threshold that maximizes each of the criteria specified in 'optimize' (except for "each", see above).

**Note**

"Sensitivity" is the same as "Recall", and "PPP" (positive predictive power) is the same as "Precision". "F1score" is the harmonic mean of precision and recall.
Note

Some measures cannot be calculated for thresholds at which there are zeros in the confusion matrix, hence the eventual 'NaN' or 'Inf' in results. Also, optimization may be deceiving for some measures; use 'plot = TRUE' and inspect the plot(s).

Author(s)

A. Marcia Barbosa

References


See Also

threshMeasures, optiPair

Examples

# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]

## Not run:
optiThresh(model = mod)
## End(Not run)

# change some of the parameters:
optiThresh(model = mod, pch = 20,
measures = c("CCR", "Sensitivity", "kappa", "TSS", "Jaccard", "F1score"),
ylim = c(0, 1))

# you can also use optiThresh with vectors of observed and predicted
# values instead of with a model object:

## Not run:
optiThresh(obs = mod$y, pred = mod$fitted.values, pch = 20)
## End(Not run)
plotGLM

Plot a generalized linear model

Description

This function plots the observed (presence/absence) data and the predicted (probability) values of a Generalized Linear Model against the y regression equation (logit) values. Only logistic regression (binomial response, logit link) is currently implemented.

Usage

plotGLM(model = NULL, obs = NULL, pred = NULL, link = "logit", plot.values = TRUE, plot.digits = 3, xlab = "Logit (Y)", ylab = "Predicted probability", main = "Model plot", na.rm = TRUE, rm.dup = FALSE, ...)

Arguments

- **model**: a binary-response model object of class "glm". If this argument is provided, 'obs' and 'pred' will be extracted with mod2obspred. Alternatively, you can input the 'obs' and 'pred' arguments instead of 'model'.
- **obs**: alternatively to 'model' and together with 'pred', a numeric vector of observed presences (1) and absences (0) of a binary response variable. Alternatively (and if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, respectively, the x (longitude) and y (latitude) coordinates of the presence points, in which case the 'obs' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.
- **pred**: alternatively to 'model' and together with 'obs', a vector with the corresponding predicted values of presence probability, habitat suitability, environmental favourability or alike. Must be of the same length and in the same order as 'obs'. Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of the predicted values for the entire evaluation region, in which case the 'pred' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.
- **link**: the link function of the GLM; only 'logit' (the default) is implemented.
- **plot.values**: logical, whether to include in the plot diagnostic values such as explained deviance (calculated with the Dsquared function) and pseudo-R-squared measures (calculated with the RsqGLM function). Defaults to TRUE.
- **plot.digits**: integer number indicating the number of digits to which the values in the plot should be rounded (if 'plot.values = TRUE'). Defaults to 3.
- **xlab**: character string specifying the label for the x axis.
plotGLM

ylab character string specifying the label for the y axis.
main character string specifying the title for the plot.
na.rm Logical value indicating whether missing values should be ignored in computations. Defaults to TRUE.
rm.dup If TRUE and if 'pred' is a SpatRaster and if there are repeated points within the same pixel, a maximum of one point per pixel is used to compute the presences. See examples in ptsrast2obspred. The default is FALSE.
...
additional arguments to pass to plot.

Value

This function outputs a plot of model predictions against observations.

Author(s)

A. Marcia Barbosa

References


See Also

predPlot, predDensity

Examples

# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]

plotGLM(model = mod)
plotGLM(model = mod, plot.values = FALSE)

# you can also use 'plotGLM' with vectors of observed and # predicted values instead of with a model object:
plotGLM(obs = mod$y, pred = mod$fitted.values)

# 'obs' can also be a table of presence point coordinates # and 'pred' a SpatRaster of predicted values
predDensity

Plot the density of predicted values for presences and absences.

Description

This function produces a histogram and/or a kernel density plot of predicted values for a binary-response model, possibly separately for the observed presences and absences, given a model object or a vector of predicted values and (optionally) a vector of the corresponding observed values. When there are multiple predicted values for each site, it can also plot a confidence interval.

Usage

predDensity(model = NULL, obs = NULL, pred = NULL, separate = TRUE, type = "both", ci = NA, legend.pos = "topright", main = "Density of predicted values", na.rm = TRUE, rm.dup = FALSE, ...)

Arguments

model a binary-response model object of class "glm", "gam", "gbm", "randomForest" or "bart". If this argument is provided, 'obs' and 'pred' will be extracted with mod2obspred. Alternatively, you can input the 'pred' (and optionally 'obs') argument(s) instead of 'model'.

obs alternatively to 'model' and together with 'pred', an optional numeric vector (in the same order of 'pred') of observed presences (1) and absences (0) of a binary response variable. Alternatively (and if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, respectively, the x (longitude) and y (latitude) coordinates of the presence points, in which case the 'obs' vector will be extracted with ptsrast2obspred. This argument may be omitted (to show the density plot of all 'pred' values combined), and it is ignored if 'model' is provided.

pred alternatively to 'model', a vector of predicted values of presence probability, habitat suitability, environmental favourability or alike. Must be of the same length and in the same order as 'obs' (if the latter is provided). Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of the predicted values for the entire evaluation region, in which case the 'pred' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

separate logical value indicating whether prediction densities should be computed separately for observed presences (ones) and absences (zeros). Defaults to TRUE, but it is automatically changed to FALSE if either 'model' or 'obs' are not provided, or if 'ci' is not NULL.

type character vector specifying whether to produce a "histogram", a "density" plot, or "both" (the default). Partial argument matching is used.

.ci numeric value for a confidence interval to add to the plot, e.g. 0.95 for 95%. The default is NA.
predDensity

legend.pos  character specifying the position for the legend; NA or "n" for no legend. Position can be "topright" (the default), "topleft", "bottomright", "bottomleft", "top", "bottom", "left", "right", or "center". Partial argument matching is used.

main  main title for the plot.

na.rm  logical value indicating whether missing values should be ignored in computations. Defaults to TRUE.

rm.dup  if TRUE and if 'pred' is a SpatRaster and if there are repeated points within the same pixel, a maximum of one point per pixel is used to compute the presences. See examples in ptsrast2obspred. The default is FALSE.

...  additional arguments to pass to hist, e.g. 'breaks'.

Details

For more details, please refer to the documentation of the functions mentioned under "See Also".

Value

This function outputs and plots the object(s) specified in 'type' – by default, a density object and a histogram.

Author(s)

A. Marcia Barbosa

See Also

hist, density, predPlot

Examples

# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]

# compute predDensity with different parameters:
predDensity(model = mod)
predDensity(model = mod, breaks = seq(0, 1, by = 0.05))
predDensity(model = mod, type = "histogram")
predDensity(model = mod, type = "density")
predDensity(model = mod, ci = 0.975)
# you can also use 'predDensity' with vectors of
# observed and predicted values, instead of a model object:

presabs <- mod$y
prediction <- mod$fitted.values

predDensity(obs = presabs, pred = prediction)
predDensity(pred = prediction, ci = 0.95)

# 'obs' can also be a table of presence point coordinates
# and 'pred' a SpatRaster of predicted values

---

**predPlot**

*Plot predicted values for presences and absences, optionally classified according to a prediction threshold.*

### Description

This function plots predicted values separated into observed presences and absences and (optionally and by default) coloured according to whether they are above or below a given prediction threshold. The plot imitates (with permission from the author) one of the graphical outputs of the 'summary' of models built with the *embarcadero* package (Carlson, 2020), but it can be applied to other types of models or to a set of observed and predicted values, and it allows specifying a user-defined threshold.

### Usage

```r
predPlot(model = NULL, obs = NULL, pred = NULL, thresh = "preval",
         main = "Classified predicted values", legend.pos = "n", pch = 1, cex = 0.5,
         col = c("black", "grey"), na.rm = TRUE, rm.dup = FALSE, interval = 0.01,
         quant = 0)
```

### Arguments

- **model**
  - A binary-response model object of class "glm", "gam", "gbm", "randomForest" or "bart". If this argument is provided, 'obs' and 'pred' will be extracted with `mod2obspred`. Alternatively, you can input the 'obs' and 'pred' arguments instead of 'model'.

- **obs**
  - Alternatively to 'model' and together with 'pred', a numeric vector of observed presences (1) and absences (0) of a binary response variable. Alternatively (and if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, respectively, the x (longitude) and y (latitude) coordinates of the presence points, in which case the 'obs' vector will be extracted with `ptsrast2obspred`. This argument is ignored if 'model' is provided.
pred alternatively to 'model' and together with 'obs', a vector with the correspon-
ding predicted values of presence probability, habitat suitability, environmental
favourability or alike. Must be of the same length and in the same order as 'obs'.
Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of
the predicted values for the entire evaluation region, in which case the 'pred'
vector will be extracted with ptsrast2obspred. This argument is ignored if
'model' is provided.

thresh threshold value to separate predicted presences from predicted absences in 'pred';
can be "preval" (the default), to use the prevalence (i.e. proportion of pres-
ences) in 'obs'; or any real number between 0 and 1; or any of the options
available on modEvAmethods("getThreshold") – see Details in getThreshold
for their description. This value, if not NA or NULL, will be used to draw a
vertical line on the plot and to colour the points (predicted values) according to
whether they fall above or below the threshold.

main Main title for the plot.

legend.pos character value specifying the position for the legend on the plot. Can be "bot-
tomleft", "bottom", "bottomright", "topleft", "left", "top", "topright", "right",
"center", or NA or "n" for no legend (the default). Partial argument matching is
used.

pch plotting character for the presences and absences (see par).

cex relative size of the plotting character (see par).

col vector of length 2 indicating the colours with which to plot predicted presences
and absences (points above and below the threshold), respectively. If 'thresh' is
NA or NULL, all points will have the first of the specified colours.

na.rm Logical value indicating whether missing values should be ignored in computa-
tions. Defaults to TRUE.

rm.dup If TRUE and if 'pred' is a SpatRaster and if there are repeated points within the
same pixel, a maximum of one point per pixel is used to compute the presences.
See examples in ptsrast2obspred. The default is FALSE.

interval Argument to pass to optiThresh indicating the interval between the thresholds
to test, if 'thresh' implies optimizing a threshold-based measure. The default is 0.01. Smaller values may provide more precise results but take longer to compute.

quant Numeric value indicating the proportion of presences to discard if thresh="MTP"
(minimum training presence). With the default value 0, MTP will be the thresh-
old at which all observed presences are classified as such; with e.g. quant=0.05,
MTP will be the threshold at which 5% presences will be classified as absences.

Value

This function outputs a plot as per 'Description'.

Note

Points are jittered randomly along the y axis to minimize visual overlap. So, each run of 'pred-
Plot' (unless you use set.seed first) will produce a different arrangement of points for the same
data, although their x-axis values are faithful.
predPlot

Author(s)

A. Marcia Barbosa

References


See Also

predDensity.plotGLM

Examples

# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]
predPlot(model = mod)
predPlot(model = mod, thresh = 0.5)

# you can first select a threshold optimized according to a particular metric:

## Not run:
threshold <- optiThresh(mod, measures = "TSS", optimize = "each")
threshold <- threshold$optimals.each[, "threshold"]
threshold
predPlot(model = mod, thresh = threshold)

## End(Not run)

# you can also use 'predPlot' with vectors of observed and predicted values
# instead of a model object:

presabs <- mod$y
prediction <- mod$fitted.values

predPlot(obs = presabs, pred = prediction)
predPlot(obs = presabs, pred = prediction, thresh = 0.5)

# 'obs' can also be a table of presence point coordinates
# and 'pred' a SpatRaster of predicted values
For building and evaluating species distribution models, the proportion of presences of the species may be an issue to take into account (e.g. Jimenez-Valverde & Lobo 2006, Barbosa et al. 2013). The `prevalence` function calculates this measure.

**Arguments**

- **obs**: a vector or a factor of binary observations (e.g. 1 vs. 0, male vs. female, disease vs. no disease, etc.). This argument is ignored if 'model' is provided.
- **model**: alternatively to 'obs', a binary-response model object of class "glm", "gam", "gbm", "randomForest" or "bart". If this argument is provided, 'obs' will be extracted with `mod2obspred`.
- **event**: the value whose prevalence we want to calculate (e.g. 1, "present", etc.). This argument is ignored if 'model' is provided.
- **na.rm**: logical, whether NA values should be excluded from the calculation. The default is TRUE.

**Value**

Numeric value of the prevalence of event in the `obs` vector.

**Author(s)**

A. Marcia Barbosa

**References**


**See Also**

`evenness`
Examples

# calculate prevalence from binary vectors:
(x <- rep(c(0, 1), each = 5))
(y <- c(rep(0, 3), rep(1, 7)))
(z <- c(rep(0, 7), rep(1, 3)))
prevalence(x)
prevalence(y)
prevalence(z)

(w <- c(rep("yes", 3), rep("nope", 7)))
prevalence(w, event = "yes")

# calculate prevalence from a model object:
data(rotif.mods)
prevalence(mod = rotif.mods$models[[1]])

Description

This function takes presence points or coordinates and a raster map of model predictions, and it returns a data frame with two columns containing, respectively, the observed (presence or no presence) and the predicted value for each pixel. Duplicate points (i.e., points falling in the same pixel, whether or not they have the exact same coordinates) can be kept or removed.

Usage

ptsrast2obspred(pts, rst, rm.dup = FALSE, na.rm = FALSE, verbosity = 2)

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pts</td>
<td>a 'SpatVector' map of the presence points, or a two-column matrix or data frame containing their x (longitude) and y (latitude) coordinates, respectively.</td>
</tr>
<tr>
<td>rst</td>
<td>a one-layer 'SpatRaster' map of the model predictions, in the same CRS as 'pts'. If you have a raster map in another format, you can try to convert it with 'terra::rast()'</td>
</tr>
</tbody>
</table>
ptsrast2obspred

rm.dup logical, whether repeated points within the same pixel should be removed. See Examples. The default is FALSE.

na.rm logical, whether presence points with missing or non-finite values of 'rst' should be excluded from the output. The default is FALSE.

verbosity integer value indicating the amount of messages to display. Defaults to 2, for the maximum amount of messages.

Value

This function outputs a data frame with one column containing the observed (1 for presence, 0 for absence) and another column containing the corresponding predicted values from 'rst'.

Author(s)

A. Marcia Barbosa

Examples

## Not run:
# you can run these examples if you have the 'terra' package installed

require(terra)

# get an example raster map:
rst <- terra::rast(system.file("ex/elev.tif", package = "terra"))
rst <- terra::aggregate(rst, 10)
plot(rst)

# generate some random presence points within it:
set.seed(8)
presences <- terra::spatSample(as.polygons(ext(rst)), 10)
plot(presences, add = TRUE)

# use 'ptsrast2obspred' on this points + raster data:

# without removing duplicates (the default):
obspred <- ptsrast2obspred(pts = crds(presences), rst = rst)
obspred
nrow(obspred) # you get as many 'obs' as pixels + additional points per pixel
sum(obspred$obs) # as many presences as points that overlay 'pred'

# with removal of duplicates:
obspred_rmdup <- ptsrast2obspred(pts = crds(presences), rst = rst[[1]],
rm.dup = TRUE) # you get as many 'obs' as pixels
obspred_rmdup
nrow(obspred_rmdup) # you get as many 'obs' as pixels
sum(obspred_rmdup$obs) # as many presences as pixels that contain (one or more) points

## End(Not run)
quantReclass

Reclassify continuous values based on quantiles

Description

This function takes the continuous predictions of a model of suitability (e.g. the continuous Bioclim
envelope model, computed by the bioclim function of the dismo package or the envelope function
of the predicts package), and reclassifies them according to their quantiles.

Usage

quantReclass(pred, by = 0.01, na.rm = TRUE)

Arguments

pred     a 'numeric' vector or a 'SpatRaster' map of predicted suitability values.
by      numeric value indicating which quantiles to compute, e.g. 0.01 for percentiles
     (the default), 0.1 for deciles, etc.
na.rm    logical value indicating whether NA values should be ignored when computing
     the quantiles. Defaults to TRUE.

Details

This function was created by Formoso-Freire et al. (accepted) to reclassify continuous Bioclim pre-
dictions into ranked suitability values, rescaling them into relative suitability. Modern implementa-
tions of Bioclim compute a percentile distribution of the values of each environmental variable at
species presence localities. Then, the closer to the 50th percentile (the median), the more suitable a
location is according to that variable (Hijmans et al. 2020; Hijmans 2023). However, the more vari-
ables are included in the model, the less suitable any location becomes, because it is less likely to be
close to the median for all variables. The proposed rescaling procedure removes the dependence of
Bioclim predictions on the number of variables included, and it has shown to provide more realistic
predictions (Formoso-Freire et al., accepted).

Value

This function returns an object of the same class as 'pred' with the reclassified values.

Author(s)

A. Marcia Barbosa, Victoria Formoso-Freire, Andres Baselga, Carola Gomez-Rodriguez

References

Formoso-Freire V., Barbosa A.M., Baselga A., Gomez-Rodriguez C. (accepted) Predicting the
spatio-temporal pattern of range expansion under lack of equilibrium with climate. Biological Con-
servation


See Also

getThreshold, bioclim in package dismo, envelope in package predicts

Examples

# simulate some sample data:
set.seed(2023)
bioclim_pred <- runif(n = 10, min = 0, max = 1)
bioclim_pred
quantReclass(pred = bioclim_pred, by = 0.1)

range01

Shrink or stretch a vector to make it range between 0 and 1

Description

This function re-scales a numeric vector so that it ranges between 0 and 1. So, the lowest value becomes 0, the highest becomes 1, and the ones in the middle retain their rank and relative difference.

Usage

range01(x, na.rm = TRUE)

Arguments

x a numeric vector.

na.rm logical, whether to remove NA values.

Details

This function was borrowed from http://stackoverflow.com/questions/5468280/scale-a-series-between-two-points-in-r/5468527#5468527 and adapted to handle also missing values.

Value

A numeric vector of the same length as the input, now with the values ranging from 0 to 1.

Author(s)

A. Marcia Barbosa
**RMSE**

See Also

standard01

Examples

```r
range01(0:10)

range01(-12.3 : 21.7)
```

---

**RMSE**

*Root mean square error*

---

**Description**

This function computes the root mean square error of a model object or a set of observed and predicted values or maps.

**Usage**

```r
RMSE(model = NULL, obs = NULL, pred = NULL, na.rm = TRUE, rm.dup = FALSE)
```

**Arguments**

- `model`:
  - a model object of class implemented in `mod2obspred`. If this argument is provided, `obs` and `pred` will be extracted with that function. Alternatively, you can input the `obs` and `pred` arguments instead of `model`.

- `obs`:
  - alternatively to `model` and together with `pred`, a numeric vector of observed values of the response variable. Alternatively (and if `pred` is a `SpatRaster`), a two-column matrix or data frame containing, respectively, the x (longitude) and y (latitude) coordinates of presence points, in which case the `obs` vector of presences and absences will be extracted with `ptsrast2obspred`. This argument is ignored if `model` is provided.

- `pred`:
  - alternatively to `model` and together with `obs`, a vector with the corresponding predicted values, of the same length and in the same order as `obs`. Alternatively (and if `obs` is a set of point coordinates), a `SpatRaster` map of the predicted values for the entire evaluation region, in which case the `pred` vector will be extracted with `ptsrast2obspred`. This argument is ignored if `model` is provided.

- `na.rm`:
  - Logical value indicating whether missing values should be ignored in computations. Defaults to TRUE.

- `rm.dup`:
  - If TRUE and if `pred` is a SpatRaster and if there are repeated points within the same pixel, a maximum of one point per pixel is used to compute the presences. See examples in `ptsrast2obspred`. The default is FALSE.
Details

The root mean square error is computed as the square root of the mean of the squared differences between observed and predicted values. It is (approximately) the same as the standard deviation of the model residuals (prediction errors), i.e., a measure of how spread out these residuals are, or how concentrated the observations are around the model prediction line. The smaller the RMSE, the better.

Value

The function returns a numeric value indicating the root mean square error of the model predictions.

Author(s)

A. Marcia Barbosa

References


See Also

plotGLM, RsqGLM, Dsquared

Examples

# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]

RMSE(model = mod)

# you can also use RMSE with vectors of observed and predicted values
# instead of with a model object:

presabs <- mod$y
prediction <- mod$fitted.values

RMSE(obs = presabs, pred = prediction)

# 'obs' can also be a table of presence point coordinates
# and 'pred' a SpatRaster of predicted values
Description

A set of generalized linear models of rotifer species distributions on TDWG level 4 regions of the world (Fontaneto et al. 2012), together with their predicted values. Mind that these models are provided just as sample data and have limited application, due to limitations in the underlying distribution records. See Details for more information.

Usage

data(rotif.mods)

Format

A list of 2 elements:

$ predictions: a data.frame with 291 observations of 60 variables, namely the presence probability (P) and environmental favourability (F) for each of 30 species of rotifers, obtained from the rotif.env dataset in the 'fuzzySim' R-Forge package

$ models: a list of the 30 generalized linear model (glm) objects which generated those predictions.

Details

These models were obtained with the 'multGLM' function and the rotif.env dataset from R-Forge package 'fuzzySim' using the following code:

```
require(fuzzySim)
data(rotif.env)
rotif.mods <- multGLM(data = rotif.env, sp.cols = 18:47, var.cols = 5:17, step = FALSE, trim = TRUE)
```

See package 'fuzzySim' (currently available on R-Forge at http://fuzzysim.r-forge.r-project.org) for more information on the source data that were used to build these models.

References


Examples

```
data(rotif.mods)
head(rotif.mods$predictions)
rotif.mods$models[[1]]
```
RsqGLM

R-squared measures for GLMs

Description

This function calculates some (pseudo) R-squared statistics for binomial Generalized Linear Models.

Usage

RsqGLM(model = NULL, obs = NULL, pred = NULL, use = "pairwise.complete.obs", plot = TRUE, plot.type = "lollipop", ...)

Arguments

model a binary-response model object of class "glm". Alternatively, you can input the 'obs' and 'pred' arguments instead of 'model'.

obs alternatively to 'model' and together with 'pred', a vector of observed presences (1) and absences (0) of a binary response variable. This argument is ignored if 'model' is provided.

pred alternatively to 'model' and together with 'obs', a vector with the corresponding predicted values of presence probability. Must be of the same length and in the same order as 'obs'. This argument is ignored if 'model' is provided.

use argument to be passed to cor for handling missing values.

plot logical value indicating whether or not to display a bar chart or (by default) a lollipop chart of the calculated measures.

plot.type character value indicating the type of plot to produce (if plot=TRUE). Can be "lollipop" (the default) or "barplot".

... additional arguments to pass to the plot function (see Examples).

Details

Implemented measures include the R-squareds of McFadden (1974), Cox-Snell (1989), Nagelkerke (1991, which corresponds to the corrected Cox-Snell, eliminating its upper bound), and Tjur (2009). See Allison (2014) for a brief review of these measures.

Value

The function returns a named list of the calculated R-squared values.

Note

Tjur's R-squared can only be calculated for models with binomial response variable; otherwise, NA will be returned.
RsqGLM

Author(s)

A. Marcia Barbosa

References


See Also

Dsquared, AUC, threshMeasures, HLfit

Examples

# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]
RsqGLM(model = mod)

# you can also use RsqGLM with vectors of observed and predicted values
# instead of a model object:
RsqGLM(obs = mod$y, pred = mod$fitted.values)

# plotting arguments can be modified:
par(mar = c(6, 3, 2, 1))
RsqGLM(obs = mod$y, pred = mod$fitted.values, col = "seagreen", border = NA, ylim = c(0, 1), main = "Pseudo-R-squared values")
**similarity**

**Similarity measures**

**Description**
This function computes similarity indices for evaluating the classification accuracy of a species distribution (or ecological niche, or bioclimatic envelope...) model against observed presence-absence data, upon the choice of a threshold value above which the model is considered to predict that the species is expected to be present rather than absent. These metrics were proposed for model evaluation by Li & Guo (2013) and Leroy et al. (2018) – see Details.

**Usage**

```r
similarity(model = NULL, obs = NULL, pred = NULL, thresh,
measures = modEvAmethods("similarity"), simplif = FALSE,
plot = TRUE, plot.type = "lollipop", plot.ordered = FALSE,
verbosity = 2, interval = 0.01, quant = 0, na.rm = TRUE, rm.dup = FALSE, ...)
```

**Arguments**
- **model**: a binary-response model object of class "glm", "gam", "gbm", "randomForest" or "bart". If this argument is provided, 'obs' and 'pred' will be extracted with `mod2obspred`. Alternatively, you can input the 'obs' and 'pred' arguments instead of 'model'.
- **obs**: alternatively to 'model' and together with 'pred', a numeric vector of observed presences (1) and absences (0) of a binary response variable. Alternatively (and if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, respectively, the x (longitude) and y (latitude) coordinates of the presence points, in which case the 'obs' vector will be extracted with `ptsrast2obspred`. This argument is ignored if 'model' is provided.
- **pred**: alternatively to 'model' and together with 'obs', a vector with the corresponding predicted values of presence probability, habitat suitability, environmental favourability or alike. Must be of the same length and in the same order as 'obs'. Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of the predicted values for the entire evaluation region, in which case the 'pred' vector will be extracted with `ptsrast2obspred`. This argument is ignored if 'model' is provided.
- **thresh**: threshold to separate predicted presences from predicted absences in 'model' or 'pred'; can be a numeric value between 0 and 1, or any of the options provided with `modEvAmethods("getThreshold")`. See Details in `getThreshold` for a description of the available options, and also Details below for a more informed choice.
- **measures**: character vector of the similarity indices to use. By default, all metrics available through `modEvAmethods("similarity")` are included.
- **simplif**: logical, whether to calculate a faster, simplified version. Used internally by other functions in the package. Defaults to FALSE.
plot logical, whether to produce a bar chart or (by default) a lollipop chart of the calculated measures. Defaults to TRUE.

plot.type character value indicating the type of plot to produce (if plot=TRUE). Can be "lollipop" (the default) or "barplot".

plot.ordered logical, whether to plot the measures in decreasing order rather than in input order. Defaults to FALSE.

verbosity integer specifying the amount of messages to display. Defaults to the maximum implemented; lower numbers (down to 0) decrease the number of messages.

interval Numeric value, used if 'thresh' is a threshold optimization method such as "maxKappa" or "maxTSS", indicating the interval between the thresholds to test. The default is 0.01. Smaller values may provide more precise results but take longer to compute.

quant Numeric value indicating the proportion of presences to discard if thresh="MTP" (minimum training presence). With the default value 0, MTP will be the threshold at which all observed presences are classified as such; with e.g. quant=0.05, MTP will be the threshold at which 5% presences will be classified as absences.

na.rm Logical value indicating whether missing values should be ignored in computations. Defaults to TRUE.

rm.dup  If TRUE and if 'pred' is a SpatRaster and if there are repeated points within the same pixel, a maximum of one point per pixel is used to compute the presences. See examples in ptsrast2obspred. The default is FALSE.

... additional arguments to be passed to the plot function, e.g. ylim=c(0, 1).

Details

Commonly used threshold-based metrics of model evaluation, such as the True Skill Statistic (TSS) implemented in the threshMeasures function, are conditioned by species prevalence in the modelled sample. To overcome this, Leroy et al. (2018) propose using the similiary indices of Sorensen and Jaccard for model evaluation, which they show to be (unlike the TSS) independent of prevalence. This function implements such indices in a model evaluation context.

Leroy et al. (2018) point out that Sorensen’s index is equivalent to the F-measure (or F1 score, which is also implemented in the threshMeasures function), and that Jaccard’s index is half the proxy of the F-measure previously proposed by Li & Guo (2013) for evaluating presence-background models.

Value

If 'simplif=TRUE', the output is a numeric matrix with the name and value of each measure. If 'simplif=FALSE' (the default), the output is a list with the following components:

N the number of observations (records) in the analysis.
Threshold the threshold value used to calculate the 'measures'.
similarity a numeric matrix with the name and value of each measure.

Author(s)

A. Marcia Barbosa
References

See Also
threshMeasures, optiThresh

Examples
# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]
similarity(model = mod, thresh = 0.5)
similarity(model = mod, thresh = 0.5, simplif = TRUE, ylim = c(0, 1))
similarity(model = mod, thresh = "maxJaccard")
# or thresh = "maxTSS", "MTP", etc.

# you can also use similarity with vectors of observed and
# predicted values instead of with a model object:
similarity(obs = mod$y, pred = mod$fitted.values, thresh = "maxJaccard")

# 'obs' can also be a table of presence point coordinates
# and 'pred' a SpatRaster of predicted values

---

**standard01**  
*Standardize to 0-1 (or vice-versa)*

Description
This function converts the score of a measure that ranges from -1 to 1 (e.g. a kappa or TSS value obtained for a model) into its (linearly) corresponding value in 0-to-1 scale, so that it can be compared directly with measures that range between 0 and 1 (such as CCR or AUC). It can also perform the conversion in the opposite direction.

Usage

```r
standard01(score, direction = c("-1+1to01", "01to-1+1"))
```
**Arguments**

- **score**: numeric value indicating the score of the measure of interest.
- **direction**: character value indicating the direction in which to perform the standardization. The default, "-1+1to01", can be switched to "01to-1+1".

**Details**

While most of the threshold-based measures of model evaluation range theoretically from 0 to 1, some of them (such as Cohen’s kappa and the true skill statistic, TSS) may range from -1 to 1 (Allouche et al. 2006). Thus, the values of different measures may not be directly comparable (Barbosa 2015). We do not usually get negative values of TSS or kappa (nor values under 0.5 for CCR or AUC, for example) because that only happens when model predictions perform worse than random guesses; still, such values are mathematically possible, and can occur e.g. when extrapolating models to regions where the species-environment relationships differ. This standardization is included as an option in the `threshMeasures` function.

**Value**

The numeric value of ‘score’ when re-scaled to the 0-to-1 (or to the -1 to +1) scale.

**Note**

Note that this is not the same as re-scaling a vector so that it ranges between 0 and 1, which is done by `range01`.

**Author(s)**

A. Marcia Barbosa

**References**


**See Also**

`threshMeasures`, `range01`

**Examples**

```r
standard01(0.6)

standard01(0.6, direction = "-1+1to01")

standard01(0.6, direction = "01to-1+1")
```
threshMeasures

Threshold-based measures of model evaluation

Description

This function calculates a number of measures for evaluating the classification accuracy of a species distribution (or ecological niche, or bioclimatic envelope...) model against observed presence-absence data (Fielding & Bell 1997; Liu et al. 2011; Barbosa et al. 2013), upon the choice of a threshold value above which the model is considered to predict that the species should be present.

Usage

threshMeasures(model = NULL, obs = NULL, pred = NULL, thresh, measures = modEvAmethods("threshMeasures")
[-grep("OddsRatio", modEvAmethods("threshMeasures"))], simplif = FALSE,
plot = TRUE, plot.type = "lollipop", plot.ordered = FALSE, standardize = TRUE,
verbosity = 2, interval = 0.01, quant = 0, na.rm = TRUE, rm.dup = FALSE, ...)

Arguments

model a binary-response model object of class "glm", "gam", "gbm", "randomForest" or "bart". If this argument is provided, 'obs' and 'pred' will be extracted with mod2obspred. Alternatively, you can input the 'obs' and 'pred' arguments instead of 'model'.

obs alternatively to 'model' and together with 'pred', a numeric vector of observed presences (1) and absences (0) of a binary response variable. Alternatively (and if 'pred' is a 'SpatRaster'), a two-column matrix or data frame containing, respectively, the x (longitude) and y (latitude) coordinates of the presence points, in which case the 'obs' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

pred alternatively to 'model' and together with 'obs', a vector with the corresponding predicted values of presence probability, habitat suitability, environmental favourability or alike. Must be of the same length and in the same order as 'obs'. Alternatively (and if 'obs' is a set of point coordinates), a 'SpatRaster' map of the predicted values for the entire evaluation region, in which case the 'pred' vector will be extracted with ptsrast2obspred. This argument is ignored if 'model' is provided.

thresh threshold to separate predicted presences from predicted absences in 'model' or 'pred'; can be a numeric value between 0 and 1, or any of the options provided with modEvAmethods("getThreshold"). See Details in getThreshold for a description of the available options, and also Details below for a more informed choice.

measures character vector of the evaluation metrics to use. By default, all metrics available through modEvAmethods("threshMeasures") are included, except for "Oddsratio" which usually yields overly large values that stand out in the plot.
threshMeasures

threshMeasures

simplif logical, whether to calculate a faster, simplified version. Used internally by other functions in the package. Defaults to FALSE.

plot logical, whether to produce a bar chart or (by default) a lollipop chart of the calculated measures. Defaults to TRUE.

plot.type character value indicating the type of plot to produce (if plot=TRUE). Can be "lollipop" (the default) or "barplot".

plot.ordered logical, whether to plot the measures in decreasing order rather than in input order. Defaults to FALSE.

standardize logical, whether to change measures that may range between -1 and +1 (namely kappa and TSS) to their corresponding value in the 0-to-1 scale (skappa and sTSS), so that they can compare directly to other measures (see standard01). The default is TRUE, but a message is displayed to inform the user about it.

verbosity integer specifying the amount of messages to display. Defaults to the maximum implemented; lower numbers (down to 0) decrease the number of messages.

interval Numeric value, used if 'thresh' is a threshold optimization method such as "maxKappa" or "maxTSS", indicating the interval between the thresholds to test. The default is 0.01. Smaller values may provide more precise results but take longer to compute.

quant Numeric value indicating the proportion of presences to discard if thresh="MTP" (minimum training presence). With the default value 0, MTP will be the threshold at which all observed presences are classified as such; with e.g. quant=0.05, MTP will be the threshold at which 5% presences will be classified as absences.

na.rm Logical value indicating whether missing values should be ignored in computations. Defaults to TRUE.

rm.dup If TRUE and if 'pred' is a SpatRaster and if there are repeated points within the same pixel, a maximum of one point per pixel is used to compute the presences. See examples in ptsrast2obspred. The default is FALSE.

... additional arguments to be passed to the plot function.

Details

The threshold value can be chosen according to a number of criteria (see e.g. Liu et al. 2005, 2013; Jimenez-Valverde & Lobo 2007; Nenzen & Araujo 2011). You can choose a fixed numeric value, or set 'thresh' to "preval" (species' prevalence or proportion of presences in the data input to this function), or calculate optimal threshold values according to different criteria with the getThreshold, optiThresh or optiPair function. If you are using "environmental favourability" as input 'pred' data (Real et al. 2006; see 'Fav' function in R package fuzzySim), then the 0.5 threshold equates to using training prevalence in logistic regression (GLM with binomial error distribution and logit link function).

While most of these threshold-based measures range from 0 to 1, some of them (such as kappa and TSS) may range from -1 to 1 (Allouche et al. 2006), so their raw scores are not directly comparable. 'threshMeasures' includes an option (used by default) to standardize these measures to 0-1 (Barbosa 2015) using the standard01 function, so that you obtain the standardized versions skappa and sTSS.

This function can also be used to calculate the agreement between different presence-absence (or other types of binary) data, as e.g. Barbosa et al. (2012) did for comparing mammal distribution
threshMeasures

data from atlas and range maps. Notice, however, that some of these measures, such as TSS or NMI, are not symmetrical (obs vs. pred is different from pred vs. obs).

Value

If 'simplif=TRUE', the output is a numeric matrix with the name and value of each measure. If 'simplif=FALSE' (the default), the output is a list with the following components:

- **N**: the number of observations (records) in the analysis.
- **Prevalence**: the prevalence (proportion of presences) in 'obs'.
- **Threshold**: the threshold value used to calculate the 'measures'.
- **ConfusionMatrix**: the confusion matrix obtained with the used threshold.
- **ThreshMeasures**: a numeric matrix with the name and value of each measure.

Note

"Sensitivity" is the same as "Recall", and "PPP" (positive predictive power) is the same as "Precision". Some of these measures (like NMI, UPR, OPR, PPP, NPP) cannot be calculated for thresholds at which there are zeros in the confusion matrix, so they can yield NaN values.

Author(s)

A. Marcia Barbosa

References


See Also

optiThresh, optiPair, AUC

Examples

# load sample models:
data(rotif.mods)

# choose a particular model to play with:
mod <- rotif.mods$models[[1]]

threshMeasures(model = mod, simplif = TRUE, thresh = 0.5)
threshMeasures(model = mod, thresh = "preval")
threshMeasures(model = mod, plot.ordered = TRUE, thresh = "preval")
threshMeasures(model = mod, measures = c("CCR", "TSS", "kappa"), thresh = "preval")
threshMeasures(model = mod, plot.ordered = TRUE, thresh = "preval")

# you can also use threshMeasures with vectors of observed and predicted values instead of with a model object:
threshMeasures(obs = mod$y, pred = mod$fitted.values, thresh = "preval")

# 'obs' can also be a table of presence point coordinates
# and 'pred' a SpatRaster of predicted values

---

**varImp**

*Variable importance.*

**Description**

This function gets, and optionally plots, variable importance for an input model object of an implemented class.
Usage

varImp(model, imp.type = "each", reorder = TRUE, group.cats = FALSE, plot = TRUE, plot.type = "lollipop", error.bars = "sd", ylim = "auto", col = c("#4477aa", "#ee6677"), plot.points = TRUE, legend = TRUE, grid = TRUE, ...) 

Arguments

model a binary-response model object of class "glm" (of stats), "gbm" (of gbm), "randomForest" (of randomForest), "bart" (of package dbarts), "pbart" or "lbart" (of package BART), or a list produced by function "probit_flexBART" of package flexBART.

imp.type character value indicating the type of variable importance to output, i.e. the metric with which importance is measured. Currently the only option is "each", to extract the measure provided within each model object. Note that this is inconsistent across model classes – see Details.

reorder logical value indicating whether to sort the variables in decreasing order of importance. TRUE by default, but automatically set to FALSE if 'model' is a 'flexBART' output, as these do not currently carry variable names. If FALSE, the variables retain their input order.

group.cats logical value indicating whether to aggregate all factor levels of each (one-hot encoded) categorical variable into a single variable, by summing up their proportions of branches used. Used if 'model' is of class 'bart', 'pbart' or 'lbart', in whose outputs the contributions of categorical variables are split by their factor levels. The default is FALSE. Note that this may incorrectly group variables that have the same name with a different numeric suffix (e.g. "soil_type_1", "soil_type_2"), so revise your results if you set this to TRUE.

plot logical value indicating whether to produce a plot with the results. The default is TRUE.

plot.type character value indicating the type of plot to produce (if plot=TRUE). Can be "lollipop" (the default), "barplot", or "boxplot". Note that the latter is only useful when 'model' contains several importance values per variable (i.e. for models of class "bart").

error.bars character value indicating the type of error metric to compute (and plot, if plot=TRUE) if the input contains the necessary information (i.e., for models of class "bart") and if the 'plot.type' is appropriate (i.e. "lollipop" or "barplot"). Can be "sd" (the default) for the standard deviation; "range" for the minimum and maximum value across the ones available; a numeric value between 0 and 1 for the corresponding confidence interval (e.g. 0.95 for 95%), computed with quantile; or NA for no error.bars.

ylim either a numeric vector of length 2 specifying the limits (minimum, maximum) for the y axis, or "auto" (the default) to fit the axis to the existing values.

col character or integer vector of length 1 or 2 specifying the plotting colours (if plot=TRUE) for the variables with positive and negative effect on the response, when this info is available (e.g. for models of class "glm").
plot.points logical, whether or not to add to the plot the individual importance points (rather than just the mean importance value, and the error bar if error.bars=TRUE) for each variable. By default it is TRUE (following Weissgerber et al. 2015), but it only holds for model objects that include several possible importance values per variable (i.e. BART models).

legend logical, whether or not to draw a legend. Used only if plot=TRUE and if the output includes negative values (i.e., if 'model' is of class 'GLM' and has variables with positive and negative coefficients).

grid logical, whether or not to add a grid to the plot. The default is TRUE.

... additional arguments that can be used for the plot (depending on 'plot.type'), e.g. 'main', 'cex.axis' (for lollipop or boxplot) or 'cex.names' (for barplot).

Details

Variable importance in a model of class "glm" obtained with the glm function can be measured by the magnitude of the absolute z-value test statistic, which is provided with summary(model). The 'varImp' function outputs the absolute z value of each variable, and in the plot (by default) uses different colours for variables with positive and negative relationships with the response.

If the input model is of class "gbm" of the gbm package, variable importance is obtained from summary.gbm(model) and divided by 100 to get the result as a proportion rather than a percentage.

If the input model is of class "randomForest" of the randomForest package, variable importance is obtained with model$importance.

If the input model is of class "bart" of the dbarts package, or of class "pbart" or "lbart" of the BART package, or a list produced by function "probit_flexBART" of the flexBART package, variable importance is obtained as the mean number of tree splits each variable was chosen for. If 'error.bars' is not NA, the error is also computed according to the specified metric ("sd" or standard deviation by default).

Value

This function outputs, and optionally plots, a named numeric vector of variable importance, as measured by 'imp.type' (see Details). If the model is Bayesian (BART) and 'error.bars' is not NA, the output is a row-named data frame with the mean and the lower and upper bounds of the error bars of variable importance.

Note that variable names can currently not be provided for 'flexBART' models, as the object does not include them. The names will match c(colnames(X_cont_train), colnames(X_cat_train)) in the inputs that were provided to 'flexBART'.

Author(s)

A. Marcia Barbosa

References

Description

This function performs variation partitioning (Borcard et al. 1992) among two factors (e.g. Ribas et al. 2006) or three factors (e.g. Real et al. 2003) for either linear regression models (LM) or generalized linear models (GLM).

Usage

varPart(A, B, C = NA, AB, AC = NA, BC = NA, ABC = NA, model.type = NULL, A.name = "Factor A", B.name = "Factor B", C.name = "Factor C", model = NULL, groups = NULL, pred.type = "Y", cor.method = "pearson", return.models = FALSE, plot = TRUE, plot.digits = 3, cex.names = 1.5, cex.values = 1.2, main = "", cex.main = 2, plot.unexpl = TRUE, colr = FALSE)

Arguments

A numeric value of the R-squared of the regression of the response variable on the variables related to factor 'A'. NOTE: INSTEAD of this and the next 10 arguments, you can use arguments 'model' and 'groups' below.

B numeric value of the R-squared of the regression of the response variable on the variables related to factor 'B'
varPart

C (optionally, if there are 3 factors) numeric value of the R-squared of the regression of the response on the variables related to factor 'C'

AB numeric value of the R-squared of the regression of the response on the variables of factors 'A' and 'B' simultaneously

AC (if there are 3 factors) numeric value of the R-squared of the regression of the response on the variables of factors 'A' and 'C' simultaneously

BC (if there are 3 factors) numeric value of the R-squared of the regression of the response on the variables of factors 'B' and 'C' simultaneously

ABC (if there are 3 factors) numeric value of the R-squared of the regression of the response on the variables of factors 'A', 'B' and 'C' simultaneously

model.type deprecated argument, kept here for back-compatibility

A.name character string indicating the name of factor 'A'

B.name character string indicating the name of factor 'B'

C.name character string indicating the name of factor 'C' (if there are 3 factors)

model a model object of class 'glm' (for linear models, instead of 'lm' you can use 'glm' with family=gaussian). If this argument is provided, all previous arguments are ignored, as they are computed instead from 'model' and 'groups'.

groups data frame with 2 columns, the 1st one containing the names of the variables, and the 2nd one containing the names of the factors in which they should be grouped (e.g. climatic, human, topographic) for the variation partitioning. This argument is required (and only used) if 'model' is provided.

pred.type character value specifying the type of predictions among which to calculate the R-squared values, or squared correlations. Can be "Y" (the default) for the 'link' function (in the scale of the predictor variables), "P" for using the 'response' (e.g. in the scale of probability for models of family binomial), or "F" for using favourability (i.e., probability after removing the effect of modelled prevalence, as in the 'Fav' function of package fuzzySim); see Details. This argument is only used if 'model' is provided.

cor.method character value to pass to the 'method' argument of cor specifying the correlation coefficient to use. The default is "pearson". This argument is only used if 'model' is provided.

return.models logical value indicating whether to include in the output the model obtained for each group of variables. The default is FALSE. This argument is only used if 'model' is provided.

plot logical, whether to plot the variation partitioning diagram. The default is TRUE.

plot.digits integer value of the number of digits to which to round the values in the plot. The default is 3.

cex.names numeric value indicating character expansion factor to define the size of the names of the factors displayed in the plot.

cex.values numeric value indicating character expansion factor to define the size of the values displayed in the plot.

main optional character string indicating the main title for the plot. The default is empty.
cex.main numeric value indicating character expansion factor to define the font size of the plot title (if provided).

plot.unexpl logical value indicating whether the amount of unexplained variation should be included in the plot. The default is TRUE.

colr logical value indicating whether or not to colour the circles in the plot. The default is FALSE for back-compatibility.

Details
If you have linear models (i.e. GLMs of family Gaussian), input data for 'varPart' are the coefficients of determination (R-squared values) of the linear regressions of the response variable on all the variables in the model, on the variables related to each particular factor, and (when there are 3 factors) on the variables related to each pair of factors. The outputs are the amounts of variance explained exclusively by each factor, the amounts explained exclusively by the overlapping effects of each pair of factors, and the amount explained by the overlap of the 3 factors if this is the case (e.g. Real et al. 2003). The amount of variation not explained by the complete model is also provided.

If you have generalized linear models (GLMs) such as logistic regression (see glm), you have no true R-squared values; inputs can then be the squared coefficients of correlation between the model predictions given by each factor (or pair of factors) and the predictions of the complete model. Predictions can be probability (e.g. Munoz & Real 2006), favourability (Baez et al. 2012, Estrada et al. 2016), or the 'logit' linear predictor (Real et al. 2013); the correlation coefficient can be e.g. Pearson's (Munoz & Real 2006) or Spearman's (Baez et al. 2012). An adjusted R-squared can also be used (De Araujo et al. 2014). In GLMs, the "total variation" (AB or ABC, depending on whether you have two or three factors) is 1 (correlation of the predictions of the complete model with themselves), and output values are not the total amounts of variance (of the response variable) explained by variable groups and their overlaps, but rather their proportional contribution to the total variation explained by the model.

Value
This function returns a data frame indicating the proportion of variance accounted for by each of the factors or groups, and (if 'plot = TRUE') a Venn diagram of the contributions of each factor or overlap. If 'return.models=TRUE', the output includes also the model obtained for each group of variables.

Note
These results derive from arithmetic operations between your input values, and they always sum up to 1; if your input is incorrect, the results will be incorrect as well, even if they sum up to 1.

This function had a bug up to modEvA version 0.8: a badly placed line break prevented the ABC overlap from being calculated correctly. Thanks to Jurica Levatic for pointing this out and helping to solve it!

Oswald van Ginkel also suggested a fix to some plotting awkwardness when using only two factors, and a nice option for colouring the plot. Many thanks!

Author(s)
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References


Examples

# if you have a linear model (LM), use (non-adjusted) R-squared values
# for each factor and for their combinations as inputs:

# with 2 factors:
varPart(A = 0.456, B = 0.315, AB = 0.852, A.name = "Spatial", B.name = "Environmental", main = "Small whale")

# with 3 factors:
varPart(A = 0.456, B = 0.315, C = 0.281, AB = 0.051, BC = 0.444,
AC = 0.569, ABC = 0.624, A.name = "Spatial", B.name = "Human", C.name = "Environmental", main = "Small whale")

varPart(A = 0.456, B = 0.315, C = 0.281, AB = 0.051, BC = 0.444,
AC = 0.569, ABC = 0.624, A.name = "Spatial", B.name = "Human", C.name = "Environmental", main = "Small whale", colr = TRUE)
# if you have a generalized linear model (GLM),
# you can use squared Pearson correlation coefficients of the
# predictions of each factor with those of the complete model:

varPart(A = (-0.005)^2, B = 0.698^2, C = 0.922^2, AB = 0.696^2,
BC = 0.994^2, AC = 0.953^2, ABC = 1, A.name = "Topographic",
B.name = "Climatic", C.name = "Geographic", main = "Big bird")

# but "Unexplained variation" can be deceiving in these cases
# (see Details); try also adding 'plot.unexpl = FALSE'

# if you have a model object and a table classifying the variables into groups:

data(rotif.mods)
mod <- rotif.mods$models[[2]]

head(mod$model)
vars <- colnames(mod$model)[-1]
vars
var_groups <- data.frame(vars = vars, groups = c("Spatial", "Spatial",
"Climate", "Climate", "Climate", "Human"))
var_groups

varPart(model = mod, groups = var_groups)
varPart(model = mod, groups = var_groups, pred.type = "P", colr = TRUE)
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