Package 'flashlight'

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Title Shed Light on Black Box Machine Learning Models

Version 0.9.0

Description Shed light on black box machine learning models by the help of model performance, variable importance, global surrogate models, ICE profiles, partial dependence (Friedman J. H. (2001) <doi:10.1214/aos/1013203451>), accumulated local effects (Apley D. W. (2016) <arXiv:1612.08468>), further effects plots, interaction strength, and variable contribution breakdown (Gosiewska and Biecek (2019) <arxiv:1903.11420>). All tools are implemented to work with case weights and allow for stratified analysis. Furthermore, multiple flashlights can be combined and analyzed together.

License GPL (>= 2)

Depends R (>= 3.2.0)

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Imports cowplot, dplyr (>= 1.1.0), ggplot2, MetricsWeighted (>= 0.3.0), rlang (>= 0.3.0), rpart, rpart.plot, stats, tibble, tidyr (>= 1.0.0), tidyselect, utils, withr

URL https://github.com/mayer79/flashlight

BugReports https://github.com/mayer79/flashlight/issues

Suggests knitr, rmarkdown, testthat (>= 3.0.0)

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Author Michael Mayer [aut, cre, cph]

Maintainer Michael Mayer <mayermichael79@gmail.com>

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R topics documented:

add_shap *DEPRECATED - Add SHAP values to (multi-)flashlight*

Description

The function calls `light_breakdown()` for `n_shap` observations and adds the resulting (approximate) SHAP decompositions as static element "shap" to the (multi)-flashlight for further analyses.

Usage

```
add_shap(x, ...)

## Default S3 method:
add_shap(x, ...)

## S3 method for class 'flashlight'
add_shap(
  x,
  v = NULL,
  visit_strategy = c("permutation", "importance", "v"),
  n_shap = 200,
  n_max = Inf,
  n_perm = 12,
  seed = NULL,
  use_linkinv = FALSE,
  verbose = TRUE,
  ...
)

## S3 method for class 'multiflashlight'
add_shap(x, ...)
```

Arguments

`x`	An object of class "flashlight" or "multiflashlight".
`...`	Further arguments passed from or to other methods.
`v`	Vector of variables to assess contribution for. Defaults to all except those specified by "y", "w" and "by".
`visit_strategy`	In what sequence should variables be visited? By `n_perm` "permutation" (slow), by "importance" (fast), or as "v" (not recommended).
`n_shap`	Number of SHAP decompositions to calculate.
`n_max`	Maximum number of rows in `data` to consider in the reference data. Set to lower value if `data` is large.
`n_perm`	Number of permutations of random visit sequences. Only used if `visit_strategy = "permutation"`.

seed	An integer random seed.
use_linkinv	Should retransformation function be applied? We suggest to keep the default (FALSE) as the values can be retransformed later.
verbose	Should progress bar be shown? Default is TRUE.

Details

We offer two approximations to SHAP: For visit_strategy = "importance", the breakdown algorithm (see reference) is used with importance based visit order. Use the default visit_strategy = "permutation" to run breakdown for multiple random permutations, averaging the results. This approximation will be closer to exact SHAP values, but very slow. Most available arguments can be chosen to reduce computation time.

Value

An object of class "flashlight" or "multiflashlight" with additional element "shap" of class "shap" (and "list").

Methods (by class)

- add_shap(default): Default method not implemented yet.
- add_shap(flashlight): Variable attribution to single observation for a flashlight.
- add_shap(multiflashlight): Add SHAP to multiflashlight.

References

A. Gosiewska and P. Biecek (2019). IBREAKDOWN: Uncertainty of model explanations for non-additive predictive models. ArXiv <arxiv.org/abs/1903.11420>.

Examples

```
## Not run:
fit <- lm(Sepal.Length ~ . + Petal.Length:Species, data = iris)
x <- flashlight(model = fit, label = "lm", data = iris, y = "Sepal.Length")
x <- add_shap(x)
is.shap(x$shap)
plot(light_importance(x, type = "shap"))
plot(light_scatter(x, type = "shap", v = "Petal.Length"))
plot(light_scatter(x, type = "shap", v = "Petal.Length", by = "Species"))

## End(Not run)
```

all_identical *all_identical*

Description

Checks if an aspect is identical for all elements in a nested list. The aspect is specified by `fun`, e.g., `[[`, followed by the element name to compare.

Usage

```
all_identical(x, fun, ...)
```

Arguments

`x`	A nested list of objects.
`fun`	Function used to extract information of each element of `x`.
`...`	Further arguments passed to `fun()`.

Value

A logical vector of length one.

Examples

```
x <- list(a = 1, b = 2)
y <- list(a = 1, b = 3)
all_identical(list(x, y), `[[`, "a")
all_identical(list(x, y), `[[`, "b")
```

auto_cut *Discretizes a Vector*

Description

This function takes a vector `x` and returns a list with information on disretized version of `x`. The construction of level names can be controlled by passing `...` arguments to `formatC()`.

Usage

```
auto_cut(
  x,
  breaks = NULL,
  n_bins = 27L,
  cut_type = c("equal", "quantile"),
  x_name = "value",
  level_name = "level",
  ...
)
```

Arguments

x	A vector.
breaks	An optional vector of breaks. Only relevant for numeric x.
n_bins	If x is numeric and no breaks are provided, this is the maximum number of bins allowed or to be created (approximately).
cut_type	For the default type "equal", bins of equal width are created by pretty(). Choose "quantile" to create quantile bins.
x_name	Column name with the values of x in the output.
level_name	Column name with the bin labels of x in the output.
...	Further arguments passed to cut3().

Value

A list with the following elements:

- data: A data.frame with colums x_name and level_name each with the same length as x. The column x_name has values in output bin_means while the column level_name has values in bin_labels.
- breaks: A vector of increasing and unique breaks used to cut a numeric x with too many distinct levels. NULL otherwise.
- bin_means: The midpoints of subsequent breaks, or if there are no breaks in the output, factor levels or distinct values of x.
- bin_labels: Break labels of the form "(low, high]" if there are breaks in the output, otherwise the same as bin_means. Same order as bin_means.

Examples

```
auto_cut(1:10, n_bins = 3)
auto_cut(c(NA, 1:10), n_bins = 3)
auto_cut(1:10, breaks = 3:4, n_bins = 3)
auto_cut(1:10, n_bins = 3, cut_type = "quantile")
auto_cut(LETTERS[4:1], n_bins = 2)
auto_cut(factor(LETTERS[1:4], LETTERS[4:1]), n_bins = 2)
auto_cut(990:1100, n_bins = 3, big.mark = "'", format = "fg")
auto_cut(c(0.0001, 0.0002, 0.0003, 0.005), n_bins = 3, format = "fg")
```

---

cut3 *Modified cut*

Description

Slightly modified version of cut.default(). Both modifications refer to the construction of break labels. Firstly, ... arguments are passed to formatC() in formatting the numbers in the labels. Secondly, a separator between the two numbers can be specified with default ", ".

Usage

```
cut3(
  x,
  breaks,
  labels = NULL,
  include.lowest = FALSE,
  right = TRUE,
  dig.lab = 3L,
  ordered_result = FALSE,
  sep = ", ",
  ...
)
```

Arguments

x	Numeric vector.
breaks	Numeric vector of cut points or a single number specifying the number of intervals desired.
labels	Labels for the levels of the final categories.
include.lowest	Flag if minimum value should be added to intervals of type "(,]" (or maximum for "[,)").
right	Flag if intervals should be closed to the right or left.
dig.lab	Number of significant digits passed to formatC().
ordered_result	Flag if resulting output vector should be ordered.
sep	Separater between from-to labels.
...	Arguments passed to formatC().

Value

Vector of the same length as x.

Examples

```
x <- 998:1001
cut3(x, breaks = 2)
cut3(x, breaks = 2, big.mark = "'", sep = ":")
```

---

flashlight *Create or Update a flashlight*

Description

Creates or updates a "flashlight" object. If a flashlight is to be created, all arguments are optional except label. If a flashlight is to be updated, all arguments are optional up to x (the flashlight to be updated).

Usage

```
flashlight(x, ...)

## Default S3 method:
flashlight(
  x,
  model = NULL,
  data = NULL,
  y = NULL,
  predict_function = stats::predict,
  linkinv = function(z) z,
  w = NULL,
  by = NULL,
  metrics = list(rmse = MetricsWeighted::rmse),
  label = NULL,
  shap = NULL,
  ...
)

## S3 method for class 'flashlight'
flashlight(x, check = TRUE, ...)
```

Arguments

x	An object of class "flashlight". If not provided, a new flashlight is created based on further input. Otherwise, x is updated based on further input.
...	Arguments passed from or to other functions.
model	A fitted model of any type. Most models require a customized predict_function.
data	A data.frame or tibble used as basis for calculations.
y	Variable name of response.
predict_function	A real valued function with two arguments: A model and a data of the same structure as data. Only the order of the two arguments matter, not their names.
linkinv	An inverse transformation function applied after predict_function.
w	A variable name of case weights.
by	A character vector with names of grouping variables.
metrics	A named list of metrics. Here, a metric is a function with exactly four arguments: actual, predicted, w (case weights) and ... like those in package MetricsWeighted.
label	Name of the flashlight. Required.
shap	An optional shap object. Typically added by calling add_shap().
check	When updating the flashlight: Should internal checks be performed? Default is TRUE.

Value

An object of class "flashlight" (and `list`) containing each input (except `x`) as element.

Methods (by class)

- `flashlight(default)`: Used to create a flashlight object. No `x` has to be passed in this case.
- `flashlight(flashlight)`: Used to update an existing flashlight object.

See Also

`multiflashlight()`

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
(fl <- flashlight(model = fit, data = iris, y = "Sepal.Length", label = "ols"))
(fl_updated <- flashlight(fl, linkinv = exp))
```

---

grouped_center *Grouped, weighted mean centering*

Description

Centers a numeric variable within optional groups and optional weights. The order of values is unchanged.

Usage

```
grouped_center(data, x, w = NULL, by = NULL, ...)
```

Arguments

`data`	A `data.frame`.
`x`	Variable name in `data` to center.
`w`	Optional name of the column in `data` with case weights.
`by`	An optional vector of column names in `data` used to group the results.
`...`	Additional arguments passed to mean calculation (e.g. `na.rm = TRUE`).

Value

A numeric vector with centered values in column `x`.

Examples

```
ir <- data.frame(iris, w = 1)
mean(grouped_center(ir, "Sepal.Width"))
rowsum(grouped_center(ir, "Sepal.Width", by = "Species"), ir$Species)
mean(grouped_center(ir, "Sepal.Width", w = "w"))
rowsum(grouped_center(ir, "Sepal.Width", by = "Species", w = "w"), ir$Species)
```

grouped_counts *Grouped count*

Description

Calculates weighted counts grouped by optional columns.

Usage

```
grouped_counts(data, by = NULL, w = NULL, value_name = "n", ...)
```

Arguments

data	A data.frame.
by	An optional vector of column names in data used to group the results.
w	Optional name of the column in data with case weights.
value_name	Name of the resulting column with counts.
...	Arguments passed to sum() (only if weights are provided).

Value

A data.frame with columns by and value_name.

Examples

```
grouped_counts(iris)
grouped_counts(iris, by = "Species")
grouped_counts(iris, w = "Petal.Length")
grouped_counts(iris, by = "Species", w = "Petal.Length")
```

grouped_stats *Grouped Weighted Means, Quartiles, or Variances*

Description

Calculates weighted means, quartiles, or variances (and counts) of a variable grouped by optional columns. By default, counts are not weighted, even if there is a weighting variable.

Usage

```
grouped_stats(
  data,
  x,
  w = NULL,
  by = NULL,
  stats = c("mean", "quartiles", "variance"),
  counts = TRUE,
  counts_weighted = FALSE,
  counts_name = "counts",
  value_name = x,
  q1_name = "q1",
  q3_name = "q3",
  ...
)
```

Arguments

data	A data.frame.
x	Variable name in data to summarize.
w	Optional name of the column in data with case weights.
by	An optional vector of column names in data used to group the results.
stats	Statistic to calculate: "mean", "quartiles", or "variance".
counts	Should group counts be added?
counts_weighted	Should counts be weighted by the case weights? If TRUE, the sum of w is returned by group.
counts_name	Name of column in the resulting data.frame containing the counts.
value_name	Name of the resulting column with mean, median, or variance.
q1_name	Name of the resulting column with first quartile values. Only relevant if stats = "quartiles".
q3_name	Name of the resulting column with third quartile values. Only relevant if stats = "quartiles".
...	Additional arguments passed to corresponding weighted_*() functions in MetricsWeighted.

Value

A data.frame with columns by, x, and optionally counts_name.

Examples

```
grouped_stats(iris, "Sepal.Width")
grouped_stats(iris, "Sepal.Width", stats = "quartiles")
grouped_stats(iris, "Sepal.Width", stats = "variance")
grouped_stats(iris, "Sepal.Width", w = "Petal.Width", counts_weighted = TRUE)
grouped_stats(iris, "Sepal.Width", by = "Species")
```

`grouped_weighted_mean` *Fast Grouped Weighted Mean*

Description

Fast version of `grouped_stats(..., counts = FALSE)`. Works if there is at most one "by" variable.

Usage

```
grouped_weighted_mean(
  data,
  x,
  w = NULL,
  by = NULL,
  na.rm = TRUE,
  value_name = x
)
```

Arguments

`data`	A `data.frame`.
`x`	Variable name in `data` to summarize.
`w`	Optional name of the column in `data` with case weights.
`by`	An optional vector of column names in `data` used to group the results.
`na.rm`	Should missing values in `x` be removed?
`value_name`	Name of the resulting column with means.

Value

A `data.frame` with grouped weighted means.

Examples

```
n <- 100
data <- data.frame(
  x = rnorm(n),
  w = runif(n),
  group = factor(sample(1:3, n, TRUE))
)
grouped_weighted_mean(data, x = "x", w = "w", by = "group")
```

`is.flashlight` *Check functions for flashlight Classes*

Description

Checks if an object inherits specific class relevant for the flashlight package.

Usage

```
is.flashlight(x)

is.multiflashlight(x)

is.light(x)

is.light_performance(x)

is.light_performance_multi(x)

is.light_importance(x)

is.light_importance_multi(x)

is.light_breakdown(x)

is.light_breakdown_multi(x)

is.light_ice(x)

is.light_ice_multi(x)

is.light_profile(x)

is.light_profile_multi(x)

is.light_profile2d(x)

is.light_profile2d_multi(x)

is.light_effects(x)

is.light_effects_multi(x)

is.shap(x)

is.light_scatter(x)
```

```
is.light_scatter_multi(x)

is.light_global_surrogate(x)

is.light_global_surrogate_multi(x)
```

Arguments

x	Any object.

Value

A logical vector of length one.

Functions

- `is.multiflashlight()`: Check for multiflashlight object.
- `is.light()`: Check for light object.
- `is.light_performance()`: Check for light_performance object.
- `is.light_performance_multi()`: Check for light_performance_multi object.
- `is.light_importance()`: Check for light_importance object.
- `is.light_importance_multi()`: Check for light_importance_multi object.
- `is.light_breakdown()`: Check for light_breakdown object.
- `is.light_breakdown_multi()`: Check for light_breakdown_multi object.
- `is.light_ice()`: Check for light_ice object.
- `is.light_ice_multi()`: Check for light_ice_multi object.
- `is.light_profile()`: Check for light_profile object.
- `is.light_profile_multi()`: Check for light_profile_multi object.
- `is.light_profile2d()`: Check for light_profile2d object.
- `is.light_profile2d_multi()`: Check for light_profile2d_multi object.
- `is.light_effects()`: Check for light_effects object.
- `is.light_effects_multi()`: Check for light_effects_multi object.
- `is.shap()`: Check for shap object.
- `is.light_scatter()`: Check for light_scatter object.
- `is.light_scatter_multi()`: Check for light_scatter_multi object.
- `is.light_global_surrogate()`: Check for light_global_surrogate object.
- `is.light_global_surrogate_multi()`: Check for light_global_surrogate_multi object.

Examples

```
a <- flashlight(label = "a")
is.flashlight(a)
is.flashlight("a")
```

light_breakdown *Variable Contribution Breakdown for Single Observation*

Description

Calculates sequential additive variable contributions (approximate SHAP) to the prediction of a single observation, see Gosiewska and Biecek (see reference) and the details below.

Usage

```
light_breakdown(x, ...)

## Default S3 method:
light_breakdown(x, ...)

## S3 method for class 'flashlight'
light_breakdown(
  x,
  new_obs,
  data = x$data,
  by = x$by,
  v = NULL,
  visit_strategy = c("importance", "permutation", "v"),
  n_max = Inf,
  n_perm = 20,
  seed = NULL,
  use_linkinv = FALSE,
  description = TRUE,
  digits = 2,
  ...
)

## S3 method for class 'multiflashlight'
light_breakdown(x, ...)
```

Arguments

x	An object of class "flashlight" or "multiflashlight".
...	Further arguments passed to prettyNum() to format numbers in description text.
new_obs	One single new observation to calculate variable attribution for. Needs to be a data.frame of same structure as data.
data	An optional data.frame.
by	An optional vector of column names used to filter data for rows with equal values in "by" variables as new_obs.
v	Vector of variable names to assess contribution for. Defaults to all except those specified by "y", "w" and "by".

visit_strategy	In what sequence should variables be visited? By "importance", by n_perm "permutation" or as "v" (see Details).
n_max	Maximum number of rows in data to consider in the reference data. Set to lower value if data is large.
n_perm	Number of permutations of random visit sequences. Only used if visit_strategy = "permutation".
seed	An integer random seed used to shuffle rows if n_max is smaller than the number of rows in data.
use_linkinv	Should retransformation function be applied? Default is FALSE.
description	Should descriptions be added? Default is TRUE.
digits	Passed to prettyNum() to format numbers in description text.

Details

The breakdown algorithm works as follows: First, the visit order $(x_1, ..., x_m)$ of the variables v is specified. Then, in the query data, the column x_1 is set to the value of x_1 of the single observation new_obs to be explained. The change in the (weighted) average prediction on data measures the contribution of x_1 on the prediction of new_obs. This procedure is iterated over all x_i until eventually, all rows in data are identical to new_obs.

A complication with this approach is that the visit order is relevant, at least for non-additive models. Ideally, the algorithm could be repeated for all possible permutations of v and its results averaged per variable. This is basically what SHAP values do, see the reference below for an explanation. Unfortunately, there is no efficient way to do this in a model agnostic way.

We offer two visit strategies to approximate SHAP:

1. "importance": Using the short-cut described in the reference below: The variables are sorted by the size of their contribution in the same way as the breakdown algorithm but without iteration, i.e., starting from the original query data for each variable x_i.
2. "permutation": Averages contributions from a small number of random permutations of v.

Note that the minimum required elements in the (multi-)flashlight are a "predict_function", "model", and "data". The latter can also directly be passed to light_breakdown(). Note that by default, no retransformation function is applied.

Value

An object of class "light_breakdown" with the following elements:

- data A tibble with results. Can be used to build fully customized visualizations. Column names can be controlled by options(flashlight.column_name).
- by Same as input by.

Methods (by class)

- light_breakdown(default): Default method not implemented yet.
- light_breakdown(flashlight): Variable attribution to single observation for a flashlight.
- light_breakdown(multiflashlight): Variable attribution to single observation for a multiflashlight.

References

A. Gosiewska and P. Biecek (2019). IBREAKDOWN: Uncertainty of model explanations for non-additive predictive models. ArXiv.

See Also

`plot.light_breakdown()`

Examples

```
fit <- lm(Sepal.Length ~ . + Petal.Length:Species, data = iris)
fl <- flashlight(model = fit, label = "lm", data = iris, y = "Sepal.Length")
light_breakdown(fl, new_obs = iris[1, ])
```

`light_check` *Check flashlight*

Description

Checks if an object of class "flashlight" or "multiflashlight" is consistently defined.

Usage

```
light_check(x, ...)

## Default S3 method:
light_check(x, ...)

## S3 method for class 'flashlight'
light_check(x, ...)

## S3 method for class 'multiflashlight'
light_check(x, ...)
```

Arguments

x	An object of class "flashlight" or "multiflashlight".
...	Further arguments passed from or to other methods.

Value

The input x or an error message.

Methods (by class)

- `light_check(default)`: Default check method not implemented yet.
- `light_check(flashlight)`: Checks if a flashlight object is consistently defined.
- `light_check(multiflashlight)`: Checks if a multiflashlight object is consistently defined.

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
fit_log <- lm(log(Sepal.Length) ~ ., data = iris)
fl <- flashlight(fit, data = iris, y = "Sepal.Length", label = "ols")
fl_log <- flashlight(fit_log,  y = "Sepal.Length", label = "ols", linkinv = exp)
light_check(fl)
light_check(fl_log)
```

`light_combine` *Combine Objects*

Description

Combines a list of similar objects each of class "light" by row binding `data.frame` slots and retaining the other slots from the first list element.

Usage

```
light_combine(x, ...)

## Default S3 method:
light_combine(x, ...)

## S3 method for class 'light'
light_combine(x, new_class = NULL, ...)

## S3 method for class 'list'
light_combine(x, new_class = NULL, ...)
```

Arguments

`x`	A list of objects of the same class.
`...`	Further arguments passed from or to other methods.
`new_class`	An optional vector with additional class names to be added to the output.

Value

If `x` is a list, an object like each element but with unioned rows in data slots.

Methods (by class)

- `light_combine(default)`: Default method not implemented yet.
- `light_combine(light)`: Since there is nothing to combine, the input is returned except for additional classes.
- `light_combine(list)`: Combine a list of similar light objects.

Examples

```
fit_lm <- lm(Sepal.Length ~ ., data = iris)
fit_glm <- glm(Sepal.Length ~ ., family = Gamma(link = "log"), data = iris)
mod_lm <- flashlight(model = fit_lm, label = "lm", data = iris, y = "Sepal.Length")
mod_glm <- flashlight(
  model = fit_glm,
  label = "glm",
  data = iris,
  y = "Sepal.Length",
  predict_function = function(object, newdata)
    predict(object, newdata, type = "response")
)
mods <- multiflashlight(list(mod_lm, mod_glm))
perf_lm <- light_performance(mod_lm)
perf_glm <- light_performance(mod_glm)
manual_comb <- light_combine(
  list(perf_lm, perf_glm),
  new_class = "light_performance_multi"
)
auto_comb <- light_performance(mods)
all.equal(manual_comb, auto_comb)
```

---

light_effects *Combination of Response, Predicted, Partial Dependence, and ALE profiles.*

Description

Calculates response- prediction-, partial dependence, and ALE profiles of a (multi-)flashlight with respect to a covariable v.

Usage

```
light_effects(x, ...)

## Default S3 method:
light_effects(x, ...)

## S3 method for class 'flashlight'
light_effects(
  x,
  v,
  data = NULL,
  by = x$by,
  stats = c("mean", "quartiles"),
  breaks = NULL,
  n_bins = 11L,
  cut_type = c("equal", "quantile"),
```

```
  use_linkinv = TRUE,
  counts_weighted = FALSE,
  v_labels = TRUE,
  pred = NULL,
  pd_indices = NULL,
  pd_n_max = 1000L,
  pd_seed = NULL,
  ale_two_sided = TRUE,
  ...
)

## S3 method for class 'multiflashlight'
light_effects(
  x,
  v,
  data = NULL,
  breaks = NULL,
  n_bins = 11L,
  cut_type = c("equal", "quantile"),
  ...
)
```

Arguments

x	An object of class "flashlight" or "multiflashlight".
...	Further arguments passed to cut3() in forming the cut breaks of the v variable.
v	The variable name to be profiled.
data	An optional data.frame. Not used for type = "shap".
by	An optional vector of column names used to additionally group the results.
stats	Statistic to calculate for the response profile: "mean" or "quartiles".
breaks	Cut breaks for a numeric v. Used to overwrite automatic binning via n_bins and cut_type. Ignored if v is not numeric.
n_bins	Approximate number of unique values to evaluate for numeric v. Ignored if v is not numeric or if breaks is specified.
cut_type	Should a numeric v be cut into "equal" or "quantile" bins? Ignored if v is not numeric or if breaks is specified.
use_linkinv	Should retransformation function be applied? Default is TRUE. Not used for type "shap".
counts_weighted	Should counts be weighted by the case weights? If TRUE, the sum of w is returned by group.
v_labels	If FALSE, return group centers of v instead of labels. Only relevant if v is numeric with many distinct values. In that case useful for instance when different flashlights use different data sets.

pred	Optional vector with predictions (after application of inverse link). Can be used to avoid recalculation of predictions over and over if the functions is to be repeatedly called for different v and predictions are computationally expensive to make. Not implemented for multiflashlight.
pd_indices	A vector of row numbers to consider in calculating partial dependence profiles and "ale".
pd_n_max	Maximum number of ICE profiles to calculate (will be randomly picked from data) for partial dependence and ALE.
pd_seed	Integer random seed used to select ICE profiles for partial dependence and ALE.
ale_two_sided	If TRUE, v is continuous and breaks are passed or being calculated, then two-sided derivatives are calculated for ALE instead of left derivatives. More specifically: Usually, local effects at value x are calculated using points in $[x - e, x]$. Set ale_two_sided = TRUE to use points in $[x - e/2, x + e/2]$.

Details

Note that ALE profiles are being calibrated by (weighted) average predictions. The resulting level might be quite different from the one of the partial dependence profiles.

Value

An object of class "light_effects" with the following elements:

- response: A tibble containing the response profiles. Column names can be controlled by options(flashlight.column_name).
- predicted: A tibble containing the prediction profiles.
- pd: A tibble containing the partial dependence profiles.
- ale: A tibble containing the ALE profiles.
- by: Same as input by.
- v: The variable(s) evaluated.
- stats: Same as input stats.

Methods (by class)

- light_effects(default): Default method.
- light_effects(flashlight): Profiles for a flashlight object.
- light_effects(multiflashlight): Effect profiles for a multiflashlight object.

See Also

light_profile(), plot.light_effects()

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
fl <- flashlight(model = fit, label = "iris", data = iris, y = "Sepal.Length")
light_effects(fl, v = "Species")
```

`light_global_surrogate` *Global Surrogate Tree*

Description

Model predictions are modelled by a single decision tree, serving as an easy to interprete surrogate to the original model. As suggested in Molnar (see reference below), the quality of the surrogate tree can be measured by its R-squared. The size of the tree can be modified by passing `...` arguments to `rpart::rpart()`.

Usage

```
light_global_surrogate(x, ...)

## Default S3 method:
light_global_surrogate(x, ...)

## S3 method for class 'flashlight'
light_global_surrogate(
  x,
  data = x$data,
  by = x$by,
  v = NULL,
  use_linkinv = TRUE,
  n_max = Inf,
  seed = NULL,
  keep_max_levels = 4L,
  ...
)

## S3 method for class 'multiflashlight'
light_global_surrogate(x, ...)
```

Arguments

`x`	An object of class "flashlight" or "multiflashlight".
`...`	Arguments passed to `rpart::rpart()`, such as `maxdepth`.
`data`	An optional `data.frame`.
`by`	An optional vector of column names used to additionally group the results. For each group, a separate tree is grown.
`v`	Vector of variables used in the surrogate model. Defaults to all variables in `data` except "by", "w" and "y".
`use_linkinv`	Should retransformation function be applied? Default is `TRUE`.
`n_max`	Maximum number of data rows to consider to build the tree.

seed An integer random seed used to select data rows if n_max is lower than the number of data rows.

keep_max_levels
Number of levels of categorical and factor variables to keep. Other levels are combined to a level "Other". This prevents rpart::rpart() to take too long to split non-numeric variables with many levels.

Value

An object of class "light_global_surrogate" with the following elements:

- data A tibble with results. Can be used to build fully customized visualizations. Column names can be controlled by options(flashlight.column_name).
- by Same as input by.

Methods (by class)

- light_global_surrogate(default): Default method not implemented yet.
- light_global_surrogate(flashlight): Surrogate model for a flashlight.
- light_global_surrogate(multiflashlight): Surrogate model for a multiflashlight.

References

Molnar C. (2019). Interpretable Machine Learning.

See Also

plot.light_global_surrogate()

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
x <- flashlight(model = fit, label = "lm", data = iris)
light_global_surrogate(x)
```

---

light_ice *Individual Conditional Expectation (ICE)*

Description

Generates Individual Conditional Expectation (ICE) profiles. An ICE profile shows how the prediction of an observation changes if one or multiple variables are systematically changed across its ranges, holding all other values fixed (see the reference below for details). The curves can be centered in order to increase visibility of interaction effects.

Usage

```
light_ice(x, ...)

## Default S3 method:
light_ice(x, ...)

## S3 method for class 'flashlight'
light_ice(
  x,
  v = NULL,
  data = x$data,
  by = x$by,
  evaluate_at = NULL,
  breaks = NULL,
  grid = NULL,
  n_bins = 27L,
  cut_type = c("equal", "quantile"),
  indices = NULL,
  n_max = 20L,
  seed = NULL,
  use_linkinv = TRUE,
  center = c("no", "first", "middle", "last", "mean", "0"),
  ...
)

## S3 method for class 'multiflashlight'
light_ice(x, ...)
```

Arguments

x	An object of class "flashlight" or "multiflashlight".
...	Further arguments passed to or from other methods.
v	The variable name to be profiled.
data	An optional data.frame.
by	An optional vector of column names used to additionally group the results.
evaluate_at	Vector with values of v used to evaluate the profile.
breaks	Cut breaks for a numeric v. Used to overwrite automatic binning via n_bins and cut_type. Ignored if v is not numeric or if grid or evaluate_at are specified.
grid	A data.frame with evaluation grid. For instance, can be generated by expand.grid().
n_bins	Approximate number of unique values to evaluate for numeric v. Ignored if v is not numeric or if breaks, grid or evaluate_at are specified.
cut_type	Should a numeric v be cut into "equal" or "quantile" bins? Ignored if v is not numeric or if breaks, grid or evaluate_at are specified.
indices	A vector of row numbers to consider.

n_max	If indices is not given, maximum number of rows to consider. Will be randomly picked from data if necessary.
seed	An integer random seed.
use_linkinv	Should retransformation function be applied? Default is TRUE.
center	How should curves be centered? • Default is "no". • Choose "first", "middle", or "last" to 0-center at specific evaluation points. • Choose "mean" to center all profiles at the within-group means. • Choose "0" to mean-center curves at 0.

Details

There are two ways to specify the variable(s) to be profiled.

1. Pass the variable name via v and an optional vector with evaluation points evaluate_at (or breaks). This works for dependence on a single variable.
2. More general: Specify any grid as a data.frame with one or more columns. For instance, it can be generated by a call to expand.grid().

The minimum required elements in the (multi-)flashlight are "predict_function", "model", "linkinv" and "data", where the latest can be passed on the fly.

Which rows in data are profiled? This is specified by indices. If not given and n_max is smaller than the number of rows in data, then row indices will be sampled randomly from data. If the same rows should be used for all flashlights in a multiflashlight, there are two options: Either pass a seed or a vector of indices used to select rows. In both cases, data should be the same for all flashlights considered.

Value

An object of class "light_ice" with the following elements:

- data A tibble containing the results. Can be used to build fully customized visualizations. Column names can be controlled by options(flashlight.column_name).
- by Same as input by.
- v The variable(s) evaluated.
- center How centering was done.

Methods (by class)

- light_ice(default): Default method not implemented yet.
- light_ice(flashlight): ICE profiles for a flashlight object.
- light_ice(multiflashlight): ICE profiles for a multiflashlight object.

References

Goldstein, A. et al. (2015). Peeking inside the black box: Visualizing statistical learning with plots of individual conditional expectation. Journal of Computational and Graphical Statistics, 24:1 <doi.org/10.1080/10618600.2014.907095>.

See Also

light_profile(), plot.light_ice()

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
fl <- flashlight(model = fit, label = "lm", data = iris)
light_ice(fl, v = "Species")
```

---

light_importance *Variable Importance*

Description

Two algorithms to calculate variable importance are available:

1. Permutation importance, and
2. SHAP importance

Algorithm 1 measures importance of variable v as the drop in performance by permuting the values of v, see Fisher et al. 2018 (reference below). Algorithm 2 measures variable importance by averaging absolute SHAP values.

Usage

```
light_importance(x, ...)

## Default S3 method:
light_importance(x, ...)

## S3 method for class 'flashlight'
light_importance(
  x,
  data = x$data,
  by = x$by,
  type = c("permutation", "shap"),
  v = NULL,
  n_max = Inf,
  seed = NULL,
  m_repetitions = 1L,
  metric = x$metrics[1L],
  lower_is_better = TRUE,
  use_linkinv = FALSE,
  ...
)

## S3 method for class 'multiflashlight'
light_importance(x, ...)
```

Arguments

x	An object of class "flashlight" or "multiflashlight".
...	Further arguments passed to light_performance(). Not used for type = "shap".
data	An optional data.frame. Not used for type = "shap".
by	An optional vector of column names used to additionally group the results.
type	Type of importance: "permutation" (default) or "shap". "shap" is only available if a "shap" object is contained in x.
v	Vector of variable names to assess importance for. Defaults to all variables in data except "by" and "y".
n_max	Maximum number of rows to consider. Not used for type = "shap".
seed	An integer random seed used to select and shuffle rows. Not used for type = "shap".
m_repetitions	Number of permutations. Defaults to 1. A value above 1 provides more stable estimates of variable importance and allows the calculation of standard errors measuring the uncertainty from permuting. Not used for type = "shap".
metric	An optional named list of length one with a metric as element. Defaults to the first metric in the flashlight. The metric needs to be a function with at least four arguments: actual, predicted, case weights w and .... Irrelevant for type = "shap".
lower_is_better	Logical flag indicating if lower values in the metric are better or not. If set to FALSE, the increase in metric is multiplied by -1. Not used for type = "shap".
use_linkinv	Should retransformation function be applied? Default is FALSE. Not uses for type = "shap".

Details

For Algorithm 1, the minimum required elements in the (multi-)flashlight are "y", "predict_function", "model", "data" and "metrics". For Algorithm 2, the only required element is "shap". Call add_shap() once to add such object.

Note: The values of the permutation Algorithm 1. are on the scale of the selected metric. For SHAP Algorithm 2, the values are on the scale of absolute values of the predictions.

Value

An object of class "light_importance" with the following elements:

- data A tibble with results. Can be used to build fully customized visualizations. Column names can be controlled by options(flashlight.column_name).
- by Same as input by.
- type Same as input type. For information only.

Methods (by class)

- `light_importance(default)`: Default method not implemented yet.
- `light_importance(flashlight)`: Variable importance for a flashlight.
- `light_importance(multiflashlight)`: Variable importance for a multiflashlight.

References

Fisher A., Rudin C., Dominici F. (2018). All Models are Wrong but many are Useful: Variable Importance for Black-Box, Proprietary, or Misspecified Prediction Models, using Model Class Reliance. Arxiv.

See Also

`most_important()`, `plot.light_importance()`

Examples

```
fit <- lm(Sepal.Length ~ Petal.Length, data = iris)
fl <- flashlight(model = fit, label = "full", data = iris, y = "Sepal.Length")
light_importance(fl)
```

---

light_interaction *Interaction Strength*

Description

This function provides Friedman's H statistic for overall interaction strength per covariable as well as its version for pairwise interactions, see the reference below.

Usage

```
light_interaction(x, ...)

## Default S3 method:
light_interaction(x, ...)

## S3 method for class 'flashlight'
light_interaction(
  x,
  data = x$data,
  by = x$by,
  v = NULL,
  pairwise = FALSE,
  type = c("H", "ice"),
  normalize = TRUE,
  take_sqrt = TRUE,
  grid_size = 200L,
```

```
  n_max = 1000L,
  seed = NULL,
  use_linkinv = FALSE,
  ...
)

## S3 method for class 'multiflashlight'
light_interaction(x, ...)
```

Arguments

x	An object of class "flashlight" or "multiflashlight".
...	Further arguments passed to or from other methods.
data	An optional data.frame.
by	An optional vector of column names used to additionally group the results.
v	Vector of variable names to be assessed.
pairwise	Should overall interaction strength per variable be shown or pairwise interactions? Defaults to FALSE.
type	Are measures based on Friedman's H statistic ("H") or on "ice" curves? Option "ice" is available only if pairwise = FALSE.
normalize	Should the variances explained be normalized? Default is TRUE in order to reproduce Friedman's H statistic.
take_sqrt	In order to reproduce Friedman's H statistic, resulting values are root transformed. Set to FALSE if squared values should be returned.
grid_size	Grid size used to form the outer product. Will be randomly picked from data (after limiting to n_max).
n_max	Maximum number of data rows to consider. Will be randomly picked from data if necessary.
seed	An integer random seed used for subsampling.
use_linkinv	Should retransformation function be applied? Default is FALSE.

Details

As a fast alternative to assess overall interaction strength, with type = "ice", the function offers a method based on centered ICE curves: The corresponding H* statistic measures how much of the variability of a c-ICE curve is unexplained by the main effect. As for Friedman's H statistic, it can be useful to consider unnormalized or squared values (see Details below).

Friedman's H statistic relates the interaction strength of a variable (pair) to the total effect strength of that variable (pair) based on partial dependence curves. Due to this normalization step, even variables with low importance can have high values for H. The function light_interaction() offers the option to skip normalization in order to have a more direct comparison of the interaction effects across variable (pairs). The values of such unnormalized H statistics are on the scale of the response variable. Use take_sqrt = FALSE to return squared values of H. Note that in general, for each variable (pair), predictions are done on a data set with grid_size * n_max, so be cautious

with increasing the defaults too much. Still, even with larger `grid_size` and `n_max`, there might be considerable variation across different runs, thus, setting a seed is recommended.

The minimum required elements in the (multi-) flashlight are a "predict_function", "model", and "data".

Value

An object of class "light_importance" with the following elements:

- `data` A tibble containing the results. Can be used to build fully customized visualizations. Column names can be controlled by `options(flashlight.column_name)`.
- `by` Same as input `by`.
- `type` Same as input `type`. For information only.

Methods (by class)

- `light_interaction(default)`: Default method not implemented yet.
- `light_interaction(flashlight)`: Interaction strengths for a flashlight object.
- `light_interaction(multiflashlight)`: for a multiflashlight object.

References

Friedman, J. H. and Popescu, B. E. (2008). "Predictive learning via rule ensembles." The Annals of Applied Statistics. JSTOR, 916–54.

See Also

`light_ice()`

Examples

```
v <- c("Petal.Length", "Petal.Width")
fit_add <- stats::lm(Sepal.Length ~ Petal.Length + Petal.Width, data = iris)
fit_nonadd <- stats::lm(Sepal.Length ~ Petal.Length * Petal.Width, data = iris)
fl_add <- flashlight(model = fit_add, label = "additive")
fl_nonadd <- flashlight(model = fit_nonadd, label = "nonadditive")
fls <- multiflashlight(list(fl_add, fl_nonadd), data = iris)
plot(st <- light_interaction(fls, v = v), fill = "darkgreen")
plot(light_interaction(fls, v = v, pairwise = TRUE), fill = "darkgreen")
plot(st <- light_interaction(fls, v = v, by = "Species"), fill = "darkgreen")
```

`light_performance` *Model Performance of Flashlight*

Description

Calculates performance of a flashlight with respect to one or more performance measure.

Usage

```
light_performance(x, ...)

## Default S3 method:
light_performance(x, ...)

## S3 method for class 'flashlight'
light_performance(
  x,
  data = x$data,
  by = x$by,
  metrics = x$metrics,
  use_linkinv = FALSE,
  ...
)

## S3 method for class 'multiflashlight'
light_performance(x, ...)
```

Arguments

`x`	An object of class "flashlight" or "multiflashlight".
`...`	Arguments passed from or to other functions.
`data`	An optional `data.frame`.
`by`	An optional vector of column names used to additionally group the results. Will overwrite `x$by`.
`metrics`	An optional named list with metrics. Each metric takes at least four arguments: actual, predicted, case weights w and `....`
`use_linkinv`	Should retransformation function be applied? Default is `FALSE`.

Details

The minimal required elements in the (multi-) flashlight are "y", "predict_function", "model", "data" and "metrics". The latter two can also directly be passed to `light_performance()`. Note that by default, no retransformation function is applied.

Value

An object of class "light_performance" with the following elements:

- `data`: A tibble containing the results. Can be used to build fully customized visualizations. Column names can be controlled by `options(flashlight.column_name)`.
- by Same as input by.

Methods (by class)

- `light_performance(default)`: Default method not implemented yet.
- `light_performance(flashlight)`: Model performance of flashlight object.
- `light_performance(multiflashlight)`: Model performance of multiflashlight object.

See Also

`plot.light_performance()`

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
fl <- flashlight(model = fit, label = "lm", data = iris, y = "Sepal.Length")
light_performance(fl)
light_performance(fl, by = "Species")
```

---

light_profile *Partial Dependence and other Profiles*

Description

Calculates different types of profiles across covariable values. By default, partial dependence profiles are calculated (see Friedman). Other options are profiles of ALE (accumulated local effects, see Apley), response, predicted values ("M plots" or "marginal plots", see Apley), residuals, and shap. The results are aggregated either by (weighted) means or by (weighted) quartiles.

Note that ALE profiles are calibrated by (weighted) average predictions. In contrast to the suggestions in Apley, we calculate ALE profiles of factors in the same order as the factor levels. They are not being reordered based on similiarity of other variables.

Usage

```
light_profile(x, ...)

## Default S3 method:
light_profile(x, ...)

## S3 method for class 'flashlight'
light_profile(
```

```
  x,
  v = NULL,
  data = NULL,
  by = x$by,
 type = c("partial dependence", "ale", "predicted", "response", "residual", "shap"),
  stats = c("mean", "quartiles"),
  breaks = NULL,
  n_bins = 11L,
  cut_type = c("equal", "quantile"),
  use_linkinv = TRUE,
  counts = TRUE,
  counts_weighted = FALSE,
  v_labels = TRUE,
  pred = NULL,
  pd_evaluate_at = NULL,
  pd_grid = NULL,
  pd_indices = NULL,
  pd_n_max = 1000L,
  pd_seed = NULL,
  pd_center = c("no", "first", "middle", "last", "mean", "0"),
  ale_two_sided = FALSE,
  ...
)

## S3 method for class 'multiflashlight'
light_profile(
  x,
  v = NULL,
  data = NULL,
 type = c("partial dependence", "ale", "predicted", "response", "residual", "shap"),
  breaks = NULL,
  n_bins = 11L,
  cut_type = c("equal", "quantile"),
  pd_evaluate_at = NULL,
  pd_grid = NULL,
  ...
)
```

Arguments

x	An object of class "flashlight" or "multiflashlight".
...	Further arguments passed to cut3() in forming the cut breaks of the v variable.
v	The variable name to be profiled.
data	An optional data.frame. Not used for type = "shap".
by	An optional vector of column names used to additionally group the results.
type	Type of the profile: Either "partial dependence", "ale", "predicted", "response", "residual", or "shap".

`stats` Statistic to calculate: "mean" or "quartiles". For ALE profiles, only "mean" makes sense.

`breaks` Cut breaks for a numeric `v`. Used to overwrite automatic binning via `n_bins` and `cut_type`. Ignored if `v` is not numeric.

`n_bins` Approximate number of unique values to evaluate for numeric `v`. Ignored if `v` is not numeric or if `breaks` is specified.

`cut_type` Should a numeric `v` be cut into "equal" or "quantile" bins? Ignored if `v` is not numeric or if `breaks` is specified.

`use_linkinv` Should retransformation function be applied? Default is `TRUE`. Not used for type "shap".

`counts` Should observation counts be added?

`counts_weighted`
If `counts` = `TRUE`: Should counts be weighted by the case weights? If `TRUE`, the sum of `w` is returned by group.

`v_labels` If `FALSE`, return group centers of `v` instead of labels. Only relevant for types "response", "predicted" or "residual" and if `v` is being binned. In that case useful, for instance, if different flashlights use different data sets and bin labels would not match.

`pred` Optional vector with predictions (after application of inverse link). Can be used to avoid recalculation of predictions over and over if the functions is to be repeatedly called for different `v` and predictions are computationally expensive to make. Not implemented for multiflashlight.

`pd_evaluate_at` Vector with values of `v` used to evaluate the profile. Only relevant for type = "partial dependence" and "ale".

`pd_grid` A `data.frame` with grid values, e.g., generated by `expand.grid()`. Only used for type = "partial dependence".

`pd_indices` A vector of row numbers to consider in calculating partial dependence profiles and "ale".

`pd_n_max` Maximum number of ICE profiles to calculate (will be randomly picked from `data`) for partial dependence and ALE.

`pd_seed` Integer random seed used to select ICE profiles for partial dependence and ALE.

`pd_center` How should ICE curves be centered?

- Default is "no".
- Choose "first", "middle", or "last" to 0-center at specific evaluation points.
- Choose "mean" to center all profiles at the within-group means.
- Choose "0" to mean-center curves at 0. Only relevant for partial dependence.

`ale_two_sided` If `TRUE`, `v` is continuous and `breaks` are passed or being calculated, then two-sided derivatives are calculated for ALE instead of left derivatives. More specifically: Usually, local effects at value x are calculated using points in $[x - e, x]$. Set `ale_two_sided` = `TRUE` to use points in $[x - e/2, x + e/2]$.

Details

Numeric covariables `v` with more than `n_bins` disjoint values are binned into `n_bins` bins. Alternatively, `breaks` can be provided to specify the binning. For partial dependence profiles (and partly also ALE profiles), this behaviour can be overwritten either by providing a vector of evaluation points (`pd_evaluate_at`) or an evaluation `pd_grid`. By the latter we mean a data frame with column name(s) with a (multi-)variate evaluation grid.

For partial dependence, ALE, and prediction profiles, "model", "predict_function", "linkinv" and "data" are required. For response profiles its "y", "linkinv" and "data", and for shap profiles it is just "shap". "data" can be passed on the fly.

Value

An object of class "light_profile" with the following elements:

- `data` A tibble containing results. Can be used to build fully customized visualizations. Column names can be controlled by `options(flashlight.column_name)`.
- `by` Names of group by variable.
- `v` The variable(s) evaluated.
- `type` Same as input `type`. For information only.
- `stats` Same as input `stats`.

Methods (by class)

- `light_profile(default)`: Default method not implemented yet.
- `light_profile(flashlight)`: Profiles for flashlight.
- `light_profile(multiflashlight)`: Profiles for multiflashlight.

References

- Friedman J. H. (2001). Greedy function approximation: A gradient boosting machine. The Annals of Statistics, 29:1189–1232.
- Apley D. W. (2016). Visualizing the effects of predictor variables in black box supervised learning models.

See Also

`light_effects()`, `plot.light_profile()`

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
fl <- flashlight(model = fit, label = "iris", data = iris, y = "Sepal.Length")
light_profile(fl, v = "Species")
light_profile(fl, v = "Petal.Width", type = "residual")
```

light_profile2d *2D Partial Dependence and other 2D Profiles*

Description

Calculates different types of 2D-profiles across two variables. By default, partial dependence profiles are calculated (see Friedman). Other options are response, predicted values, residuals, and shap. The results are aggregated by (weighted) means.

Usage

```
light_profile2d(x, ...)

## Default S3 method:
light_profile2d(x, ...)

## S3 method for class 'flashlight'
light_profile2d(
  x,
  v = NULL,
  data = NULL,
  by = x$by,
  type = c("partial dependence", "predicted", "response", "residual", "shap"),
  breaks = NULL,
  n_bins = 11L,
  cut_type = "equal",
  use_linkinv = TRUE,
  counts = TRUE,
  counts_weighted = FALSE,
  pd_evaluate_at = NULL,
  pd_grid = NULL,
  pd_indices = NULL,
  pd_n_max = 1000L,
  pd_seed = NULL,
  ...
)

## S3 method for class 'multiflashlight'
light_profile2d(
  x,
  v = NULL,
  data = NULL,
  type = c("partial dependence", "predicted", "response", "residual", "shap"),
  breaks = NULL,
  n_bins = 11L,
  cut_type = "equal",
  pd_evaluate_at = NULL,
```

```
  pd_grid = NULL,
  ...
)
```

Arguments

x	An object of class "flashlight" or "multiflashlight".
...	Further arguments passed to cut3() in forming the cut breaks of the v variables. Not relevant for partial dependence profiles.
v	A vector of exactly two variable names to be profiled.
data	An optional data.frame. Not used for type = "shap".
by	An optional vector of column names used to additionally group the results.
type	Type of the profile: Either "partial dependence", "predicted", "response", "residual", or "shap".
breaks	Named list of cut breaks specifying how to bin one or more numeric variables. Used to overwrite automatic binning via n_bins and cut_type. Ignored for non-numeric v.
n_bins	Approximate number of unique values to evaluate for numeric v. Can be an unnamed vector of length 2 to distinguish between v.
cut_type	Should numeric v be cut into "equal" or "quantile" bins? Can be an unnamed vector of length 2 to distinguish between v.
use_linkinv	Should retransformation function be applied? Default is TRUE. Not used for type "shap".
counts	Should observation counts be added?
counts_weighted	If counts is TRUE: Should counts be weighted by the case weights? If TRUE, the sum of w is returned by group.
pd_evaluate_at	An named list of evaluation points for one or more variables. Only relevant for type = "partial dependence".
pd_grid	An evaluation data.frame with exactly two columns, e.g., generated by expand.grid(). Only used for type = "partial dependence". Offers maximal flexibility.
pd_indices	A vector of row numbers to consider in calculating partial dependence profiles. Only used for type = "partial dependence".
pd_n_max	Maximum number of ICE profiles to calculate (will be randomly picked from data). Only used for type = "partial dependence".
pd_seed	Integer random seed used to select ICE profiles. Only used for type = "partial dependence".

Details

Different binning options are available, see arguments below. For high resolution partial dependence plots, it might be necessary to specify breaks, pd_evaluate_at or pd_grid in order to avoid empty parts in the plot. A high value of n_bins might not have the desired effect as it internally capped at the number of distinct values of a variable.

For partial dependence and prediction profiles, "model", "predict_function", "linkinv" and "data" are required. For response profiles it is "y", "linkinv" and "data" and for shap profiles it is just "shap". "data" can be passed on the fly.

Value

An object of class "light_profile2d" with the following elements:

- `data` A tibble containing results. Can be used to build fully customized visualizations. Column names can be controlled by `options(flashlight.column_name)`.
- by Names of group by variables.
- v The two variable names evaluated.
- `type` Same as input `type`. For information only.

Methods (by class)

- `light_profile2d(default)`: Default method not implemented yet.
- `light_profile2d(flashlight)`: 2D profiles for flashlight.
- `light_profile2d(multiflashlight)`: 2D profiles for multiflashlight.

References

Friedman J. H. (2001). Greedy function approximation: A gradient boosting machine. The Annals of Statistics, 29:1189–1232.

See Also

`light_profile()`, `plot.light_profile2d()`

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
fl <- flashlight(model = fit, label = "iris", data = iris, y = "Sepal.Length")
light_profile2d(fl, v = c("Petal.Length", "Species"))
```

---

light_recode *Recode Factor Columns*

Description

Recodes factor levels of columns in data slots of an object of class "light".

Usage

```
light_recode(x, ...)

## Default S3 method:
light_recode(x, ...)

## S3 method for class 'light'
light_recode(x, what, levels, labels, ...)
```

Arguments

x	An object of class "light".
...	Further arguments passed to factor.
what	Column identifier to be recoded, e.g., "type". For backward compatibility, also the option identifier (e.g. "type_name") can be passed.
levels	Current levels/values of type_name column (in desired order).
labels	New levels of type_name column in same order as levels.

Value

x with new factor levels of type_name column.

Methods (by class)

- light_recode(default): Default method not implemented yet.
- light_recode(light): Recoding factors in data slots of "light" object.

See Also

plot.light_effects().

Examples

```
fit_full <- lm(Sepal.Length ~ ., data = iris)
fit_part <- lm(Sepal.Length ~ Petal.Length, data = iris)
mod_full <- flashlight(
  model = fit_full, label = "full", data = iris, y = "Sepal.Length"
)
mod_part <- flashlight(
  model = fit_part, label = "part", data = iris, y = "Sepal.Length"
)
mods <- multiflashlight(list(mod_full, mod_part))
eff <- light_effects(mods, v = "Species")
eff <- light_recode(
  eff,
  what = "type_name",
  levels = c("response", "predicted", "partial dependence", "ale"),
  labels = c("Observed", "Fitted", "PD", "ALE")
)
plot(eff, use = "all")
```

`light_scatter` *Scatter*

Description

This function prepares values for drawing a scatter plot of predicted values, responses, residuals, or SHAP values against a selected variable.

Usage

```
light_scatter(x, ...)

## Default S3 method:
light_scatter(x, ...)

## S3 method for class 'flashlight'
light_scatter(
  x,
  v,
  data = x$data,
  by = x$by,
  type = c("predicted", "response", "residual", "shap"),
  use_linkinv = TRUE,
  n_max = 400,
  seed = NULL,
  ...
)

## S3 method for class 'multiflashlight'
light_scatter(x, ...)
```

Arguments

`x`	An object of class "flashlight" or "multiflashlight".
`...`	Further arguments passed from or to other methods.
`v`	The variable name to be shown on the x-axis.
`data`	An optional `data.frame`. Not relevant for `type = "shap"`.
`by`	An optional vector of column names used to additionally group the results.
`type`	Type of the profile: Either "predicted", "response", "residual", or "shap".
`use_linkinv`	Should retransformation function be applied? Default is `TRUE`. Not used for `type = "shap"`.
`n_max`	Maximum number of data rows to select. Will be randomly picked from the relevant data.
`seed`	An integer random seed used for subsampling.

Value

An object of class "light_scatter" with the following elements:

- `data`: A tibble with results. Can be used to build fully customized visualizations. Column names can be controlled by `options(flashlight.column_name)`.
- `by`: Same as input `by`.
- `v`: The variable evaluated.
- `type`: Same as input `type`. For information only.

Methods (by class)

- `light_scatter(default)`: Default method not implemented yet.
- `light_scatter(flashlight)`: Variable profile for a flashlight.
- `light_scatter(multiflashlight)`: light_scatter for a multiflashlight.

See Also

`plot.light_scatter()`

Examples

```
fit_a <- lm(Sepal.Length ~ . -Petal.Length, data = iris)
fit_b <- lm(Sepal.Length ~ ., data = iris)
fl_a <- flashlight(model = fit_a, label = "without Petal.Length")
fl_b <- flashlight(model = fit_b, label = "all")
fls <- multiflashlight(list(fl_a, fl_b), data = iris, y = "Sepal.Length")
pr <- light_scatter(fls, v = "Petal.Length")
plot(
  light_scatter(fls, "Petal.Length", by = "Species", type = "residual"),
  alpha = 0.2
)
```

`most_important` *Most Important Variables.*

Description

Returns the most important variable names sorted descendingly.

Usage

```
most_important(x, top_m = Inf)

## Default S3 method:
most_important(x, top_m = Inf)

## S3 method for class 'light_importance'
most_important(x, top_m = Inf)
```

Arguments

x	An object of class "light_importance".
top_m	Maximum number of important variables to be returned. Defaults to Inf, i.e., return all variables in descending order of importance.

Value

A character vector of variable names sorted in descending order by importance.

Methods (by class)

- most_important(default): Default method not implemented yet.
- most_important(light_importance): Extracts most important variables from an object of class "light_importance".

See Also

light_importance()

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
fl <- flashlight(model = fit, label = "ols", data = iris, y = "Sepal.Length")
(imp <- light_importance(fl, seed = 4))
most_important(imp)
most_important(imp, 2)
```

---

multiflashlight *Create or Update a multiflashlight*

Description

Combines a list of flashlights to an object of class "multiflashlight" and/or updates a multiflashlight.

Usage

```
multiflashlight(x, ...)

## Default S3 method:
multiflashlight(x, ...)

## S3 method for class 'flashlight'
multiflashlight(x, ...)

## S3 method for class 'list'
multiflashlight(x, ...)

## S3 method for class 'multiflashlight'
multiflashlight(x, ...)
```

Arguments

x	An object of class "multiflashlight", "flashlight" or a list of flashlights.
...	Optional arguments in the flashlights to update, see examples.

Value

An object of class "multiflashlight" (a named list of flashlight objects).

Methods (by class)

- `multiflashlight(default)`: Used to create a flashlight object. No `x` has to be passed in this case.
- `multiflashlight(flashlight)`: Updates an existing flashlight object and turns into a multiflashlight.
- `multiflashlight(list)`: Creates (and updates) a multiflashlight from a list of flashlights.
- `multiflashlight(multiflashlight)`: Updates an object of class "multiflashlight".

See Also

`flashlight()`

Examples

```
fit_lm <- lm(Sepal.Length ~ ., data = iris)
fit_glm <- glm(Sepal.Length ~ ., family = Gamma(link = log), data = iris)
mod_lm <- flashlight(model = fit_lm, label = "lm")
mod_glm <- flashlight(model = fit_glm, label = "glm")
(mods <- multiflashlight(list(mod_lm, mod_glm)))
```

---

plot.light_breakdown *Visualize Variable Contribution Breakdown for Single Observation*

Description

Minimal visualization of an object of class "light_breakdown" as waterfall plot. The object returned is of class "ggplot" and can be further customized.

Usage

```
## S3 method for class 'light_breakdown'
plot(x, facet_scales = "free", facet_ncol = 1, rotate_x = FALSE, ...)
```

Arguments

x	An object of class "light_breakdown".
facet_scales	Scales argument passed to ggplot2::facet_wrap().
facet_ncol	ncol argument passed to ggplot2::facet_wrap().
rotate_x	Should x axis labels be rotated by 45 degrees?
...	Further arguments passed to ggplot2::geom_label().

Details

The waterfall plot is to be read from top to bottom. The first line describes the (weighted) average prediction in the query data used to start with. Then, each additional line shows how the prediction changes due to the impact of the corresponding variable. The last line finally shows the original prediction of the selected observation. Multiple flashlights are shown in different facets. Positive and negative impacts are visualized with different colors.

Value

An object of class "ggplot".

See Also

light_breakdown()

Examples

```
fit <- lm(Sepal.Length ~ . + Petal.Length:Species, data = iris)
fl <- flashlight(model = fit, label = "lm", data = iris, y = "Sepal.Length")
plot(light_breakdown(fl, new_obs = iris[1, ]))
```

---

plot.light_effects *Visualize Multiple Types of Profiles Together*

Description

Visualizes response-, prediction-, partial dependence, and/or ALE profiles of a (multi-)flashlight with respect to a covariable v. Different flashlights or a single flashlight with one "by" variable are separated by a facet wrap.

Usage

```
## S3 method for class 'light_effects'
plot(
  x,
  use = c("response", "predicted", "pd"),
  zero_counts = TRUE,
  size_factor = 1,
```

```
  facet_scales = "free_x",
  facet_nrow = 1L,
  rotate_x = TRUE,
  show_points = TRUE,
  ...
)
```

Arguments

x	An object of class "light_effects".
use	A vector of elements to show. Any subset of ("response", "predicted", "pd", "ale") or "all". Defaults to all except "ale"
zero_counts	Logical flag if 0 count levels should be shown on the x axis.
size_factor	Factor used to enlarge default size/linewidth in ggplot2::geom_point() and ggplot2::geom_line().
facet_scales	Scales argument passed to ggplot2::facet_wrap().
facet_nrow	Number of rows in ggplot2::facet_wrap(). Must be 1 if plot_counts() should be used.
rotate_x	Should x axis labels be rotated by 45 degrees?
show_points	Should points be added to the line (default is TRUE).
...	Further arguments passed to geoms.

Value

An object of class "ggplot".

See Also

light_effects(), plot_counts()

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
fl <- flashlight(model = fit, label = "iris", data = iris, y = "Sepal.Length")
plot(light_effects(fl, v = "Species"))
```

---

plot.light_global_surrogate

Plot Global Surrogate Trees

Description

Use rpart.plot::rpart.plot() to visualize trees fitted by light_global_surrogate().

Usage

```
## S3 method for class 'light_global_surrogate'
plot(x, type = 5, auto_main = TRUE, mfrow = NULL, ...)
```

Arguments

x	An object of class "light_global_surrogate".
type	Plot type, see help of rpart.plot::rpart.plot(). Default is 5.
auto_main	Automatic plot titles (only if multiple trees are shown).
mfrow	If multiple trees are shown in the same figure: what value of mfrow to use in graphics::par()?
...	Further arguments passed to rpart.plot::rpart.plot().

Value

An object of class "ggplot".

See Also

light_global_surrogate()

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
x <- flashlight(model = fit, label = "lm", data = iris)
plot(light_global_surrogate(x))
```

---

plot.light_ice *Visualize ICE profiles*

Description

Minimal visualization of an object of class "light_ice" as ggplot2::geom_line(). The object returned is of class "ggplot" and can be further customized.

Usage

```
## S3 method for class 'light_ice'
plot(x, facet_scales = "fixed", rotate_x = FALSE, ...)
```

Arguments

x	An object of class "light_ice".
facet_scales	Scales argument passed to ggplot2::facet_wrap().
rotate_x	Should x axis labels be rotated by 45 degrees?
...	Further arguments passed to ggplot2::geom_line().

Details

Each observation is visualized by a line. The first "by" variable is represented by the color, a second "by" variable or a multiflashlight by facets.

Value

An object of class "ggplot".

See Also

light_ice()

Examples

```
fit_full <- lm(Sepal.Length ~ ., data = iris)
fit_part <- lm(Sepal.Length ~ Petal.Length, data = iris)
mod_full <- flashlight(model = fit_full, label = "full", data = iris)
mod_part <- flashlight(model = fit_part, label = "part", data = iris)
mods <- multiflashlight(list(mod_full, mod_part))
plot(light_ice(mod_full, v = "Species"), alpha = 0.2)
indices <- (1:15) * 10
plot(light_ice(mods, v = "Species", indices = indices))
plot(light_ice(mods, v = "Species", indices = indices, center = "first"))
plot(light_ice(mods, v = "Petal.Width", by = "Species", n_bins = 5, indices = indices))
```

---

plot.light_importance *Visualize Variable Importance*

Description

Minimal visualization of an object of class "light_importance" via ggplot2::geom_bar(). If available, standard errors are added by ggplot2::geom_errorbar(). The object returned is of class "ggplot" and can be further customized.

Usage

```
## S3 method for class 'light_importance'
plot(
  x,
  top_m = Inf,
  swap_dim = FALSE,
  facet_scales = "fixed",
  rotate_x = FALSE,
  error_bars = TRUE,
  ...
)
```

Arguments

x	An object of class "light_importance".
top_m	Maximum number of important variables to be returned.
swap_dim	If multiflashlight and one "by" variable or single flashlight with two "by" variables, swap the role of dodge/fill variable and facet variable. If multiflashlight or one "by" variable, use facets instead of colors.
facet_scales	Scales argument passed to ggplot2::facet_wrap().
rotate_x	Should x axis labels be rotated by 45 degrees?
error_bars	Should error bars be added? Defaults to TRUE. Only available if light_importance() was run with multiple permutations by setting m_repetitions > 1.
...	Further arguments passed to ggplot2::geom_bar().

Details

The plot is organized as a bar plot with variable names as x-aesthetic. Up to two additional dimensions (multiflashlight and one "by" variable or single flashlight with two "by" variables) can be visualized by facetting and dodge/fill. Set swap_dim = FALSE to revert the role of these two dimensions. One single additional dimension is visualized by a facet wrap, or - if swap_dim = FALSE - by dodge/fill.

Value

An object of class "ggplot".

See Also

light_importance()

Examples

```
fit_full <- lm(Sepal.Length ~ ., data = iris)
fit_part <- lm(Sepal.Length ~ Petal.Length, data = iris)
mod_full <- flashlight(model = fit_full, label = "full", data = iris, y = "Sepal.Length")
mod_part <- flashlight(model = fit_part, label = "part", data = iris, y = "Sepal.Length")
mods <- multiflashlight(list(mod_full, mod_part), by = "Species")
plot(light_importance(mod_part, m_repetitions = 4), fill = "darkred")
plot(light_importance(mods), swap_dim = TRUE)
```

---

plot.light_performance

Visualize Model Performance

Description

Minimal visualization of an object of class "light_performance" as ggplot2::geom_bar(). The object returned has class "ggplot", and can be further customized.

Usage

```
## S3 method for class 'light_performance'
plot(
  x,
  swap_dim = FALSE,
  geom = c("bar", "point"),
  facet_scales = "free_y",
  rotate_x = FALSE,
  ...
)
```

Arguments

x	An object of class "light_performance".
swap_dim	Should representation of dimensions (either two "by" variables or one "by" variable and multiflashlight) of x aesthetic and dodge fill aesthetic be swapped? Default is FALSE.
geom	Geometry of plot (either "bar" or "point")
facet_scales	Scales argument passed to ggplot2::facet_wrap().
rotate_x	Should x axis labels be rotated by 45 degrees?
...	Further arguments passed to ggplot2::geom_bar() or ggplot2::geom_point().

Details

The plot is organized as a bar plot as follows: For flashlights without "by" variable specified, a single bar is drawn. Otherwise, the "by" variable (or the flashlight label if there is no "by" variable) is represented by the "x" aesthetic.

The flashlight label (in case of one "by" variable) is represented by dodged bars. This strategy makes sure that performance of different flashlights can be compared easiest. Set "swap_dim = TRUE" to revert the role of dodging and x aesthetic. Different metrics are always represented by facets.

Value

An object of class "ggplot".

See Also

light_performance()

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
fl <- flashlight(model = fit, label = "ols", data = iris, y = "Sepal.Length")
plot(light_performance(fl, by = "Species"), fill = "darkred")
```

plot.light_profile *Visualize Profiles, e.g. Partial Dependence*

Description

Minimal visualization of an object of class "light_profile". The object returned is of class "ggplot" and can be further customized.

Usage

```
## S3 method for class 'light_profile'
plot(
  x,
  swap_dim = FALSE,
  facet_scales = "free_x",
  rotate_x = x$type != "partial dependence",
  show_points = TRUE,
  ...
)
```

Arguments

x	An object of class "light_profile".
swap_dim	If multiflashlight and one "by" variable or single flashlight with two "by" variables, swap the role of dodge/fill variable and facet variable. If multiflashlight or one "by" variable, use facets instead of colors.
facet_scales	Scales argument passed to ggplot2::facet_wrap().
rotate_x	Should x axis labels be rotated by 45 degrees?
show_points	Should points be added to the line (default is TRUE).
...	Further arguments passed to ggplot2::geom_point() or ggplot2::geom_line().

Details

Either lines and points are plotted (if stats = "mean") or quartile boxes. If there is a "by" variable or a multiflashlight, this first dimension is represented by color (or if swap_dim = TRUE by facets). If there are two "by" variables or a multiflashlight with one "by" variable, the first "by" variable is visualized as color, while the second one or the multiflashlight is shown via facet (change with swap_dim).

Value

An object of class "ggplot".

See Also

light_profile(), plot.light_effects()

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
fl <- flashlight(model = fit, label = "iris", data = iris, y = "Sepal.Length")
plot(light_profile(fl, v = "Species"))
plot(light_profile(fl, v = "Petal.Width", by = "Species", evaluate_at = 2:4))
plot(light_profile(fl, v = "Petal.Width", type = "predicted"))
```

---

plot.light_profile2d *Visualize 2D-Profiles, e.g., of Partial Dependence*

Description

Minimal visualization of an object of class "light_profile2d". The object returned is of class "ggplot" and can be further customized.

Usage

```
## S3 method for class 'light_profile2d'
plot(x, swap_dim = FALSE, rotate_x = TRUE, numeric_as_factor = FALSE, ...)
```

Arguments

x	An object of class "light_profile2d".
swap_dim	Swap the ggplot2::facet_grid() dimensions.
rotate_x	Should the x axis labels be rotated by 45 degrees? Default is TRUE.
numeric_as_factor	Should numeric x and y values be converted to factors first? Default is FALSE. Useful if cut_type was not set to "equal".
...	Further arguments passed to ggplot2::geom_tile().

Details

The main geometry is ggplot2::geom_tile(). Additional dimensions ("by" variable(s) and/or multiflashlight) are represented by facet_wrap/grid. For all types of profiles except "partial dependence", it is natural to see empty parts in the plot. These are combinations of the v variables that do not appear in the data. Even for type "partial dependence", such gaps can occur, e.g. for cut_type = "quantile" or if n_bins are larger than the number of distinct values of a v variable. Such gaps can be suppressed by setting numeric_as_factor = TRUE or by using the arguments breaks, pd_evaluate_at or pd_grid in light_profile2d().

Value

An object of class "ggplot".

See Also

light_profile2d()

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
fl <- flashlight(model = fit, label = "iris", data = iris, y = "Sepal.Length")
plot(light_profile2d(fl, v = c("Petal.Length", "Species")))
```

`plot.light_scatter` *Scatter Plot*

Description

Values are plotted against a variable. The object returned is of class "ggplot" and can be further customized. To avoid overplotting, try `alpha = 0.2` or `position = "jitter"`.

Usage

```
## S3 method for class 'light_scatter'
plot(x, swap_dim = FALSE, facet_scales = "free_x", rotate_x = FALSE, ...)
```

Arguments

`x`	An object of class "light_scatter".
`swap_dim`	If multiflashlight and one "by" variable, or single flashlight with two "by" variables, swap the role of color variable and facet variable. If multiflashlight or one "by" variable, use colors instead of facets.
`facet_scales`	Scales argument passed to `ggplot2::facet_wrap()`.
`rotate_x`	Should x axis labels be rotated by 45 degrees?
`...`	Further arguments passed to `ggplot2::geom_point()`. Typical arguments would be `alpha = 0.2` or `position = "jitter"` to avoid overplotting.

Value

An object of class "ggplot".

See Also

`light_scatter()`

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
fl <- flashlight(model = fit, label = "ols", data = iris)
plot(light_scatter(fl, v = "Petal.Length", by = "Species"), alpha = 0.2)
```

plot_counts *DEPRECATED - Add Counts to Effects Plot*

Description

Add counts as labelled bar plot on top of light_effects plot.

Usage

```
plot_counts(
  p,
  x,
  text_size = 3,
  facet_scales = "free_x",
  show_labels = TRUE,
  big.mark = "'",
  scientific = FALSE,
  digits = 0,
  ...
)
```

Arguments

p	The result of plot.light_effects().
x	An object of class "light_effects".
text_size	Size of count labels.
facet_scales	Scales argument passed to ggplot2::facet_wrap().
show_labels	Should count labels be added as text?
big.mark	Parameter passed to format() the labels. Default is "'".
scientific	Parameter passed to format() the labels. Default is FALSE.
digits	Used to round the labels. Default is 0.
...	Further arguments passed to ggplot2::geom_bar().

Details

Experimental. Uses package ggpubr to rearrange the figure. Thus, the resulting plot cannot be easily modified. Furthermore, adding counts only works if the legend in plot.light_effects() is not placed on the left or right side of the plot. It has to be placed inside or at the bottom.

Value

An object of class "ggplot".

See Also

plot.light_effects()

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
fl <- flashlight(model = fit, label = "iris", data = iris, y = "Sepal.Length")
x <- light_effects(fl, v = "Species")
plot_counts(plot(x), x, width = 0.3, alpha = 0.2)
```

`predict.flashlight` *Predictions for flashlight*

Description

Predict method for an object of class "flashlight". Pass additional elements to update the flashlight, typically `data`.

Usage

```
## S3 method for class 'flashlight'
predict(object, ...)
```

Arguments

`object`	An object of class "flashlight".
`...`	Arguments used to update the flashlight.

Value

A vector with predictions.

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
fl <- flashlight(model = fit, data = iris, y = "Sepal.Length", label = "ols")
predict(fl)[1:5]
predict(fl, data = iris[1:5, ])
```

`predict.multiflashlight`
Predictions for multiflashlight

Description

Predict method for an object of class "multiflashlight". Pass additional elements to update the flashlight, typically `data`.

Usage

```
## S3 method for class 'multiflashlight'
predict(object, ...)
```

Arguments

object	An object of class "multiflashlight".
...	Arguments used to update the multiflashlight.

Value

A named list of prediction vectors.

Examples

```
fit_part <- lm(Sepal.Length ~ Petal.Length, data = iris)
fit_full <- lm(Sepal.Length ~ ., data = iris)
mod_full <- flashlight(model = fit_full, label = "full")
mod_part <- flashlight(model = fit_part, label = "part")
mods <- multiflashlight(list(mod_full, mod_part), data = iris, y = "Sepal.Length")
predict(mods, data = iris[1:5, ])
```

---

print.flashlight *Prints a flashlight*

Description

Print method for an object of class "flashlight".

Usage

```
## S3 method for class 'flashlight'
print(x, ...)
```

Arguments

x	A on object of class "flashlight".
...	Further arguments passed from other methods.

Value

Invisibly, the input is returned.

See Also

flashlight()

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
x <- flashlight(model = fit, label = "lm", y = "Sepal.Length", data = iris)
x
```

`print.light` *Prints light Object*

Description

Print method for an object of class "light".

Usage

```
## S3 method for class 'light'
print(x, ...)
```

Arguments

`x`	A on object of class "light".
`...`	Further arguments passed from other methods.

Value

Invisibly, the input is returned.

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
fl <- flashlight(model = fit, label = "lm", y = "Sepal.Length", data = iris)
light_performance(fl, v = "Species")
```

`print.multiflashlight` *Prints a multiflashlight*

Description

Print method for an object of class "multiflashlight".

Usage

```
## S3 method for class 'multiflashlight'
print(x, ...)
```

Arguments

x	An object of class "multiflashlight".
...	Further arguments passed to print.flashlight().

Value

Invisibly, the input is returned.

See Also

multiflashlight()

Examples

```
fit_lm <- lm(Sepal.Length ~ ., data = iris)
fit_glm <- glm(Sepal.Length ~ ., family = Gamma(link = log), data = iris)
fl_lm <- flashlight(model = fit_lm, label = "lm")
fl_glm <- flashlight(model = fit_glm, label = "glm")
multiflashlight(list(fl_lm, fl_glm), data = iris)
```

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residuals.flashlight *Residuals for flashlight*

Description

Residuals method for an object of class "flashlight". Pass additional elements to update the flashlight before calculation of residuals.

Usage

```
## S3 method for class 'flashlight'
residuals(object, ...)
```

Arguments

object	An object of class "flashlight".
...	Arguments used to update the flashlight before calculating the residuals.

Value

A numeric vector with residuals.

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
x <- flashlight(model = fit, data = iris, y = "Sepal.Length", label = "ols")
residuals(x)[1:5]
```

residuals.multiflashlight *Residuals for multiflashlight*

Description

Residuals method for an object of class "multiflashlight". Pass additional elements to update the multiflashlight before calculation of residuals.

Usage

```
## S3 method for class 'multiflashlight'
residuals(object, ...)
```

Arguments

object	An object of class "multiflashlight".
...	Arguments used to update the multiflashlight before calculating the residuals.

Value

A named list with residuals per flashlight.

Examples

```
fit_part <- lm(Sepal.Length ~ Petal.Length, data = iris)
fit_full <- lm(Sepal.Length ~ ., data = iris)
mod_full <- flashlight(model = fit_full, label = "full")
mod_part <- flashlight(model = fit_part, label = "part")
mods <- multiflashlight(list(mod_full, mod_part), data = iris, y = "Sepal.Length")
residuals(mods, data = head(iris))
```

response *Response of multi/-flashlight*

Description

Extracts response from object of class "flashlight".

Usage

```
response(object, ...)

## Default S3 method:
response(object, ...)

## S3 method for class 'flashlight'
response(object, ...)

## S3 method for class 'multiflashlight'
response(object, ...)
```

Arguments

`object`	An object of class "flashlight".
`...`	Arguments used to update the flashlight before extracting the response.

Value

A numeric vector of responses.

Methods (by class)

- `response(default)`: Default method not implemented yet.
- `response(flashlight)`: Extract response from flashlight object.
- `response(multiflashlight)`: Extract responses from multiflashlight object.

Examples

```
fit <- lm(Sepal.Length ~ ., data = iris)
(fl <- flashlight(model = fit, data = iris, y = "Sepal.Length", label = "ols"))
response(fl)[1:5]
response(fl, data = iris[1:5, ])
response(fl, data = iris[1:5, ], linkinv = exp)
```

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