

Package ‘ingredients’

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Title Effects and Importances of Model Ingredients

Version 0.4

Description Collection of tools for assessment of feature importance and feature effects.

Key functions are:

feature_importance() for assessment of global level feature importance,

ceteris_paribus() for calculation of the what-if plots,

partial_dependency() for partial dependency plots,

conditional_dependency() for conditional dependency plots,

accumulated_dependency() for accumulated local effects plots,

aggregate_profiles() and cluster_profiles() for aggregation of ceteris paribus profiles,

generic_print() and plot() for better usability of selected explainers,

generic_plotD3() for interactive, D3 based explanations, and

generic_describe() for explanations in natural language.

The package 'ingredients' is a part of the 'DrWhy.AI' universe (Biecek 2018) <arXiv:1806.08915>.

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License GPL

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accumulated_dependency

Accumulated Local Effects Profiles aka ALEPlots

Description

Accumulated Local Effects Profiles accumulate local changes in Ceteris Paribus Profiles. Function [accumulated_dependency](#) calls [ceteris_paribus](#) and then [aggregate_profiles](#).

Usage

```

accumulated_dependency(x, ...)

## S3 method for class 'explainer'
accumulated_dependency(x, variables = NULL,
  N = 500, variable_splits = NULL, grid_points = 101, ...,
  variable_type = "numerical")

## Default S3 method:
accumulated_dependency(x, data,
  predict_function = predict, label = class(x)[1], variables = NULL,
  N = 500, variable_splits = NULL, grid_points = 101, ...,
  variable_type = "numerical")

## S3 method for class 'ceteris_paribus_explainer'
accumulated_dependency(x, ...,
  variables = NULL)

```

Arguments

x	an explainer created with function <code>DALEX::explain()</code> , an object of the class <code>ceteris_paribus_explainer</code> or a model to be explained.
...	other parameters
variables	names of variables for which profiles shall be calculated. Will be passed to calculate_variable_split . If <code>NULL</code> then all variables from the validation data will be used.
N	number of observations used for calculation of partial dependency profiles. By default, 500 observations will be chosen randomly.
variable_splits	named list of splits for variables, in most cases created with calculate_variable_split . If <code>NULL</code> then it will be calculated based on validation data available in the explainer.
grid_points	number of points for profile. Will be passed to calculate_variable_split .
variable_type	a character. If "numerical" then only numerical variables will be calculated. If "categorical" then only categorical variables will be calculated.
data	validation dataset Will be extracted from x if it's an explainer NOTE: It is best when target variable is not present in the data
predict_function	predict function Will be extracted from x if it's an explainer
label	name of the model. By default it's extracted from the class attribute of the model

Details

Find more details in the [Accumulated Local Dependency Chapter](#).

Value

an object of the class `aggregated_profiles_explainer`

References

ALEPlot: Accumulated Local Effects (ALE) Plots and Partial Dependence (PD) Plots <https://cran.r-project.org/package=ALEPlot>, Predictive Models: Visual Exploration, Explanation and Debugging https://pbiecek.github.io/PM_VEE

Examples

```
library("DALEX")

model_titanic_glm <- glm(survived ~ gender + age + fare,
                        data = titanic_imputed, family = "binomial")

explain_titanic_glm <- explain(model_titanic_glm,
                              data = titanic_imputed[,-8],
                              y = titanic_imputed[,8],
                              verbose = FALSE)

adp_glm <- accumulated_dependency(explain_titanic_glm,
                                 N = 150, variables = c("age", "fare"))

head(adp_glm)
plot(adp_glm)

library("randomForest")

model_titanic_rf <- randomForest(survived ~., data = titanic_imputed)

explain_titanic_rf <- explain(model_titanic_rf,
                              data = titanic_imputed[,-8],
                              y = titanic_imputed[,8],
                              verbose = FALSE)

adp_rf <- accumulated_dependency(explain_titanic_rf, N = 200, variable_type = "numerical")
plot(adp_rf)

adp_rf <- accumulated_dependency(explain_titanic_rf, N = 200, variable_type = "categorical")
plotD3(adp_rf, variable_type = "categorical", label_margin = 80, scale_plot = TRUE)
```

Description

The function `aggregate_profiles()` calculates an aggregate of ceteris paribus profiles. It can be: Partial Dependency Profile (average across Ceteris Paribus Profiles), Conditional Dependency Profile (local weighted average across Ceteris Paribus Profiles) or Accumulated Local Dependency Profile (cummulated average local changes in Ceteris Paribus Profiles).

Usage

```
aggregate_profiles(x, ..., variable_type = "numerical", groups = NULL,
  type = "partial", variables = NULL)
```

Arguments

<code>x</code>	a ceteris paribus explainer produced with function <code>ceteris_paribus()</code>
<code>...</code>	other explainers that shall be calculated together
<code>variable_type</code>	a character. If <code>numerical</code> then only numerical variables will be calculated. If <code>categorical</code> then only categorical variables will be calculated.
<code>groups</code>	a variable name that will be used for grouping. By default <code>NULL</code> which means that no groups shall be calculated
<code>type</code>	either <code>partial/conditional/accumulated</code> for parital dependence, conditional profiles of accumulated local effects
<code>variables</code>	if not <code>NULL</code> then aggregate only for selected variables will be calculated

Value

an object of the class `aggregated_profiles_explainer`

References

Predictive Models: Visual Exploration, Explanation and Debugging https://pbiemek.github.io/PM_VEE

Examples

```
library("DALEX")
library("randomForest")

model_titanic_rf <- randomForest(survived ~ ., data = titanic_imputed)

explain_titanic_rf <- explain(model_titanic_rf,
  data = titanic_imputed[,-8],
  y = titanic_imputed[,8])

selected_passangers <- select_sample(titanic_imputed, n = 100)
cp_rf <- ceteris_paribus(explain_titanic_rf, selected_passangers)
head(cp_rf)

# continouse variable
pdp_rf_p <- aggregate_profiles(cp_rf, variables = "age", type = "partial")
```

```

pdp_rf_p$`_label_` <- "RF_partial"
pdp_rf_c <- aggregate_profiles(cp_rf, variables = "age", type = "conditional")
pdp_rf_c$`_label_` <- "RF_conditional"
pdp_rf_a <- aggregate_profiles(cp_rf, variables = "age", type = "accumulated")
pdp_rf_a$`_label_` <- "RF_accumulated"

plot(pdp_rf_p, pdp_rf_c, pdp_rf_a, color = "_label_")

pdp_rf <- aggregate_profiles(cp_rf, variables = "age",
                             groups = "gender")

head(pdp_rf)
plot(cp_rf, variables = "age") +
  show_observations(cp_rf, variables = "age") +
  show_rugs(cp_rf, variables = "age", color = "red") +
  show_aggregated_profiles(pdp_rf, size = 3, color = "_label_")

# categorical variable
pdp_rf_p <- aggregate_profiles(cp_rf, variables = "class",
                              variable_type = "categorical", type = "partial")
pdp_rf_p$`_label_` <- "RF_partial"
pdp_rf_c <- aggregate_profiles(cp_rf, variables = "class",
                              variable_type = "categorical", type = "conditional")
pdp_rf_c$`_label_` <- "RF_conditional"
pdp_rf_a <- aggregate_profiles(cp_rf, variables = "class",
                              variable_type = "categorical", type = "accumulated")
pdp_rf_a$`_label_` <- "RF_accumulated"
plot(pdp_rf_p, pdp_rf_c, pdp_rf_a, color = "_label_")

# or maybe flipped?
library(ggplot2)
plot(pdp_rf_p, pdp_rf_c, pdp_rf_a, color = "_label_") + coord_flip()

pdp_rf <- aggregate_profiles(cp_rf, variables = "class", variable_type = "categorical",
                             groups = "gender")

head(pdp_rf)
plot(pdp_rf, variables = "class")
# or maybe flipped?
plot(pdp_rf, variables = "class") + coord_flip()

```

Description

Oscillations are proxies for local feature importance at the instance level. Find more details in [Ceteris Paribus Oscillations Chapter](#).

Usage

```
calculate_oscillations(x, sort = TRUE, ...)
```

Arguments

x	a ceteris_paribus explainer produced with the ceteris_paribus() function
sort	a logical value. If TRUE then rows are sorted along the oscillations
...	other arguments

Value

an object of the class ceteris_paribus_oscillations

References

Predictive Models: Visual Exploration, Explanation and Debugging https://pbiecek.github.io/PM_VEE

Examples

```
library("DALEX")
# smaller data, quicker example
titanic_small <- select_sample(titanic_imputed, n = 500, seed = 1313)

# build a model
model_titanic_glm <- glm(survived ~ gender + age + fare,
                        data = titanic_small, family = "binomial")

explain_titanic_glm <- explain(model_titanic_glm,
                              data = titanic_small[,-8],
                              y = titanic_small[,8])

cp_rf <- ceteris_paribus(explain_titanic_glm, titanic_small[1,])

calculate_oscillations(cp_rf)

library("randomForest")

apartments_rf_model <- randomForest(m2.price ~ construction.year + surface + floor +
                                   no.rooms + district, data = apartments)

explainer_rf <- explain(apartments_rf_model,
                       data = apartments_test[,-1],
                       y = apartments_test$m2.price)
```

```
apartment <- apartments_test[1,]
cp_rf <- ceteris_paribus(explainer_rf, apartment)
calculate_oscillations(cp_rf)
```

calculate_variable_profile

Internal Function for Individual Variable Profiles

Description

This function calculates individual variable profiles (ceteris paribus profiles), i.e. series of predictions from a model calculated for observations with altered single coordinate.

Usage

```
calculate_variable_profile(data, variable_splits, model,
  predict_function = predict, ...)
```

Default S3 method:

```
calculate_variable_profile(data, variable_splits, model,
  predict_function = predict, ...)
```

Arguments

data	set of observations. Profile will be calculated for every observation (every row)
variable_splits	named list of vectors. Elements of the list are vectors with points in which profiles should be calculated. See an example for more details.
model	a model that will be passed to the predict_function
predict_function	function that takes data and model and returns numeric predictions. Note that the ... arguments will be passed to this function.
...	other parameters that will be passed to the predict_function

Details

Note that [calculate_variable_profile](#) function is S3 generic. If you want to work on non standard data sources (like H2O ddf, external databases) you should overload it.

Value

a data frame with profiles for selected variables and selected observations

References

Predictive Models: Visual Exploration, Explanation and Debugging https://pbiecek.github.io/PM_VEE

calculate_variable_split

Internal Function for Split Points for Selected Variables

Description

This function calculate candidate splits for each selected variable. For numerical variables splits are calculated as percentiles (in general uniform quantiles of the length `grid_points`). For all other variables splits are calculated as unique values.

Usage

```
calculate_variable_split(data, variables = colnames(data),  
  grid_points = 101)
```

```
## Default S3 method:  
calculate_variable_split(data,  
  variables = colnames(data), grid_points = 101)
```

Arguments

<code>data</code>	validation dataset. Is used to determine distribution of observations.
<code>variables</code>	names of variables for which splits shall be calculated
<code>grid_points</code>	number of points used for response path

Details

Note that `calculate_variable_split` function is S3 generic. If you want to work on non standard data sources (like H2O ddf, external databases) you should overload it.

Value

A named list with splits for selected variables

ceteris_paribus

Ceteris Paribus Profiles aka Individual Variable Profiles

Description

This explainer works for individual observations. For each observation it calculates Ceteris Paribus Profiles for selected variables. Such profiles can be used to hypothesize about model results if selected variable is changed. For this reason it is also called 'What-If Profiles'.

Usage

```
ceteris_paribus(x, ...)

## S3 method for class 'explainer'
ceteris_paribus(x, new_observation, y = NULL,
  variables = NULL, variable_splits = NULL, grid_points = 101, ...)

## Default S3 method:
ceteris_paribus(x, data, predict_function = predict,
  new_observation, y = NULL, variables = NULL,
  variable_splits = NULL, grid_points = 101, label = class(x)[1],
  ...)
```

Arguments

x	an explainer created with the DALEX::explain() function, or a model to be explained.
...	other parameters
new_observation	a new observation with columns that corresponds to variables used in the model
y	true labels for new_observation. If specified then will be added to ceteris paribus plots. NOTE: It is best when target variable is not present in the new_observation
variables	names of variables for which profiles shall be calculated. Will be passed to calculate_variable_split . If NULL then all variables from the validation data will be used.
variable_splits	named list of splits for variables, in most cases created with calculate_variable_split . If NULL then it will be calculated based on validation data available in the explainer.
grid_points	maximum number of points for profile calculations. Note that the final number of points may be lower than grid_points, eg. if there is not enough unique values for a given variable. Will be passed to calculate_variable_split .
data	validation dataset. It will be extracted from x if it's an explainer NOTE: It is best when target variable is not present in the data

predict_function	predict function. It will be extracted from <code>x</code> if it's an explainer
label	name of the model. By default it's extracted from the <code>class</code> attribute of the model

Details

Find more details in [Ceteris Paribus Chapter](#).

Value

an object of the class `ceteris_paribus_explainer`.

References

Predictive Models: Visual Exploration, Explanation and Debugging https://pbiemek.github.io/PM_VEE

Examples

```
library("DALEX")
# smaller data, quicker example
titanic_small <- select_sample(titanic_imputed, n = 500, seed = 1313)

# build a model
model_titanic_glm <- glm(survived ~ gender + age + fare,
                        data = titanic_small,
                        family = "binomial")

explain_titanic_glm <- explain(model_titanic_glm,
                              data = titanic_small[,-8],
                              y = titanic_small[,8],
                              verbose = FALSE)

cp_rf <- ceteris_paribus(explain_titanic_glm, titanic_small[1,])
cp_rf

plot(cp_rf, variables = "age")

library("randomForest")
model_titanic_rf <- randomForest(survived ~., data = titanic_imputed)

explain_titanic_rf <- explain(model_titanic_rf,
                              data = titanic_imputed[,-8],
                              y = titanic_imputed[,8],
                              label = "Random Forest v7",
                              verbose = FALSE)

# select few passangers
selected_passangers <- select_sample(titanic_imputed, n = 20)
```

```
cp_rf <- ceteris_paribus(explain_titanic_rf, selected_passangers)
cp_rf

plot(cp_rf, variables = "age") +
  show_observations(cp_rf, variables = "age") +
  show_rugs(cp_rf, variables = "age", color = "red")
```

ceteris_paribus_2d *Ceteris Paribus 2D Plot*

Description

This function calculates ceteris paribus profiles for grid of values spanned by two variables. It may be useful to identify or present interactions between two variables.

Usage

```
ceteris_paribus_2d(explainer, observation, grid_points = 101,
  variables = NULL)
```

Arguments

explainer	a model to be explained, preprocessed by the DALEX::explain() function
observation	a new observation for which predictions need to be explained
grid_points	number of points used for response path. Will be used for both variables
variables	if specified, then only these variables will be explained

Details

Find more details in [Ceteris Paribus 2D](#).

Value

an object of the class ceteris_paribus_2d_explainer.

Examples

```
library("DALEX")

model_titanic_glm <- glm(survived ~ age + fare,
  data = titanic_imputed, family = "binomial")

explain_titanic_glm <- explain(model_titanic_glm,
  data = titanic_imputed[,-8],
  y = titanic_imputed[,8])
```

```

cp_rf <- ceteris_paribus_2d(explain_titanic_glm, titanic_imputed[1,],
                           variables = c("age", "fare", "sibsp"))
head(cp_rf)

plot(cp_rf)

library("randomForest")
set.seed(59)

apartments_rf_model <- randomForest(m2.price ~., data = apartments)

explainer_rf <- explain(apartments_rf_model,
                       data = apartments_test[,-1],
                       y = apartments_test[,1])

new_apartment <- apartments_test[1,]
new_apartment

wi_rf_2d <- ceteris_paribus_2d(explainer_rf, observation = new_apartment,
                              variables = c("surface", "floor", "no.rooms"))
head(wi_rf_2d)
plot(wi_rf_2d)

```

cluster_profiles *Cluster Ceteris Paribus Profiles*

Description

This function calculates aggregates of ceteris paribus profiles based on hierarchical clustering.

Usage

```

cluster_profiles(x, ..., aggregate_function = mean,
                variable_type = "numerical", center = FALSE, k = 3,
                variables = NULL)

```

Arguments

x	a ceteris paribus explainer produced with function <code>ceteris_paribus()</code>
...	other explainers that shall be plotted together
aggregate_function	a function for profile aggregation. By default it's mean
variable_type	a character. If numerical then only numerical variables will be computed. If categorical then only categorical variables will be computed.
center	shall profiles be centered before clustering
k	number of clusters for the <code>hclust</code> function
variables	if not NULL then only variables will be presented

Details

Find more details in the [Clustering Profiles Chapter](#).

Value

an object of the class `aggregated_profiles_explainer`

References

Predictive Models: Visual Exploration, Explanation and Debugging https://pbiecek.github.io/PM_VEE

Examples

```
library("DALEX")

selected_passangers <- select_sample(titanic_imputed, n = 100)
model_titanic_glm <- glm(survived ~ gender + age + fare,
                        data = titanic_imputed, family = "binomial")

explain_titanic_glm <- explain(model_titanic_glm,
                             data = titanic_imputed[,-8],
                             y = titanic_imputed[,8])

cp_rf <- ceteris_paribus(explain_titanic_glm, selected_passangers)
clust_rf <- cluster_profiles(cp_rf, k = 3, variables = "age")
plot(clust_rf)

library("randomForest")
model_titanic_rf <- randomForest(survived ~., data = titanic_imputed)
model_titanic_rf

explain_titanic_rf <- explain(model_titanic_rf,
                             data = titanic_imputed[,-8],
                             y = titanic_imputed[,8],
                             label = "Random Forest v7")

cp_rf <- ceteris_paribus(explain_titanic_rf, selected_passangers)
cp_rf

pdp_rf <- aggregate_profiles(cp_rf, variables = "age")
head(pdp_rf)
clust_rf <- cluster_profiles(cp_rf, k = 3, variables = "age")
head(clust_rf)

plot(clust_rf, color = "_label_") +
  show_aggregated_profiles(pdp_rf, color = "black", size = 3)

plot(cp_rf, color = "grey", variables = "age") +
  show_aggregated_profiles(clust_rf, color = "_label_", size = 2)
```

```
clust_rf <- cluster_profiles(cp_rf, k = 3, center = TRUE, variables = "age")
head(clust_rf)
```

conditional_dependency

Conditional Dependency Profiles

Description

Conditional Dependency Profiles (aka Local Profiles) average locally Ceteris Paribus Profiles. Function 'conditional_dependency' calls 'ceteris_paribus' and then 'aggregate_profiles'.

Usage

```
conditional_dependency(x, ...)

## S3 method for class 'explainer'
conditional_dependency(x, variables = NULL,
  N = 500, variable_splits = NULL, grid_points = 101, ...,
  variable_type = "numerical")

## Default S3 method:
conditional_dependency(x, data,
  predict_function = predict, label = class(x)[1], variables = NULL,
  N = 500, variable_splits = NULL, grid_points = 101, ...,
  variable_type = "numerical")

## S3 method for class 'ceteris_paribus_explainer'
conditional_dependency(x, ...,
  variables = NULL)

local_dependency(x, ...)
```

Arguments

x	an explainer created with function DALEX::explain(), an object of the class ceteris_paribus_explainer or a model to be explained.
...	other parameters
variables	names of variables for which profiles shall be calculated. Will be passed to calculate_variable_split . If NULL then all variables from the validation data will be used.
N	number of observations used for calculation of partial dependency profiles. By default 500.
variable_splits	named list of splits for variables, in most cases created with calculate_variable_split . If NULL then it will be calculated based on validation data available in the explainer.

grid_points	number of points for profile. Will be passed to <code>calculate_variable_split</code> .
variable_type	a character. If numerical then only numerical variables will be calculated. If categorical then only categorical variables will be calculated.
data	validation dataset, will be extracted from <code>x</code> if it's an explainer NOTE: It is best when target variable is not present in the data
predict_function	predict function, will be extracted from <code>x</code> if it's an explainer
label	name of the model. By default it's extracted from the <code>class</code> attribute of the model

Details

Find more details in [Local Dependency Profiles Chapter](#).

Value

an object of the class `aggregated_profile_explainer`

References

Predictive Models: Visual Exploration, Explanation and Debugging https://pbiecek.github.io/PM_VEE

Examples

```
library("DALEX")

model_titanic_glm <- glm(survived ~ gender + age + fare,
                        data = titanic_imputed, family = "binomial")

explain_titanic_glm <- explain(model_titanic_glm,
                              data = titanic_imputed[,-8],
                              y = titanic_imputed[,8],
                              verbose = FALSE)

cdp_glm <- conditional_dependency(explain_titanic_glm,
                                N = 150, variables = c("age", "fare"))

head(cdp_glm)
plot(cdp_glm)

library("randomForest")

model_titanic_rf <- randomForest(survived ~., data = titanic_imputed)

explain_titanic_rf <- explain(model_titanic_rf,
                              data = titanic_imputed[,-8],
                              y = titanic_imputed[,8],
                              verbose = FALSE)
```



```
cdp_rf <- conditional_dependency(explain_titanic_rf, N = 200, variable_type = "numerical")
plot(cdp_rf)
```

```
cdp_rf <- conditional_dependency(explain_titanic_rf, N = 200, variable_type = "categorical")
plotD3(cdp_rf, variable_type = "categorical", label_margin = 80, scale_plot = TRUE)
```

```
describe.partial_dependency_explainer
```

Natural language description of feature importance explainer

Description

Generic function `describe` generates a natural language description of `ceteris_paribus()`, `aggregated_profiles()` and `feature_importance()` explanations what enhances their interpretability.

Usage

```
## S3 method for class 'partial_dependency_explainer'
describe(x,
  nonsignificance_treshold = 0.15, ..., display_values = FALSE,
  display_numbers = FALSE, variables = NULL, label = "prediction")

describe(x, ...)

## S3 method for class 'ceteris_paribus_explainer'
describe(x,
  nonsignificance_treshold = 0.15, ..., display_values = FALSE,
  display_numbers = FALSE, variables = NULL, label = "prediction")

## S3 method for class 'feature_importance_explainer'
describe(x,
  nonsignificance_treshold = 0.15, ...)
```

Arguments

<code>x</code>	a ceteris paribus explanation produced with function <code>ceteris_paribus()</code>
<code>nonsignificance_treshold</code>	a parameter specifying a treshold for variable importance
<code>...</code>	other arguments
<code>display_values</code>	allows for displaying variable values
<code>display_numbers</code>	allows for displaying numerical values
<code>variables</code>	a character of a single variable name to be described
<code>label</code>	label for model's prediction

Details

Function `describe.ceteris_paribus()` generates a natural language description of ceteris paribus profile. The description summarizes variable values, that would change model's prediction at most. If a ceteris paribus profile for multiple variables is passed, `variables` must specify a single variable to be described. Works only for a ceteris paribus profile for one observation. In current version only categorical values are described. For `display_numbers = TRUE` three most important variable values are displayed, while `display_numbers = FALSE` displays all the important variables, however without further details.

Function `describe.ceteris_paribus()` generates a natural language description of ceteris paribus profile. The description summarizes variable values, that would change model's prediction at most. If a ceteris paribus profile for multiple variables is passed, `variables` must specify a single variable to be described. Works only for a ceteris paribus profile for one observation. For `display_numbers = TRUE` three most important variable values are displayed, while `display_numbers = FALSE` displays all the important variables, however without further details.

Function `describe.feature_importance_explainer()` generates a natural language description of feature importance explanation. It prints the number of important variables, that have significant dropout difference from the full model, depending on `nonsignificance_threshold`. The description prints the three most important variables for the model's prediction. The current design of DALEX explainer does not allow for displaying variables values.

Examples

```
library("DALEX")
library("randomForest")

model_titanic_rf <- randomForest(survived ~., data = titanic_imputed)

explain_titanic_rf <- explain(model_titanic_rf,
                             data = titanic_imputed[,-8],
                             y = titanic_imputed[,8],
                             label = "rf")

selected_passangers <- select_sample(titanic_imputed, n = 10)
cp_rf <- ceteris_paribus(explain_titanic_rf, selected_passangers)
pdp <- aggregate_profiles(cp_rf, type = "partial", variable_type = "categorical")
describe(pdp, variables = "gender")

library("DALEX")
library("randomForest")

model_titanic_rf <- randomForest(survived ~., data = titanic_imputed)

explain_titanic_rf <- explain(model_titanic_rf,
                             data = titanic_imputed[,-8],
                             y = titanic_imputed[,8],
                             label = "rf")

selected_passanger <- select_sample(titanic_imputed, n = 1, seed = 123)
cp_rf <- ceteris_paribus(explain_titanic_rf, selected_passanger)
```

```

plot(cp_rf, variable_type = "categorical")
describe(cp_rf, variables = "class", label = "the predicted probability")

library("DALEX")

lm_model <- lm(m2.price~., data = apartments)
explainer_lm <- explain(lm_model, data = apartments[,-1], y = apartments[,1])

fi_lm <- feature_importance(explainer_lm, loss_function = loss_root_mean_square)

plot(fi_lm)
describe(fi_lm)

```

feature_importance	<i>Feature Importance</i>
--------------------	---------------------------

Description

This function calculates permutation based feature importance. For this reason it is also called the Variable Dropout Plot.

Usage

```

feature_importance(x, ...)

## S3 method for class 'explainer'
feature_importance(x,
  loss_function = loss_root_mean_square, ..., type = c("raw", "ratio",
  "difference"), n_sample = NULL, B = 1,
  keep_raw_permutations = NULL, variables = NULL,
  variable_groups = NULL, label = NULL)

## Default S3 method:
feature_importance(x, data, y,
  predict_function = predict, loss_function = loss_root_mean_square,
  ..., label = class(x)[1], type = c("raw", "ratio", "difference"),
  n_sample = NULL, B = 1, keep_raw_permutations = NULL,
  variables = NULL, variable_groups = NULL)

```

Arguments

x	an explainer created with function <code>DALEX::explain()</code> , or a model to be explained.
...	other parameters
loss_function	a function that will be used to assess variable importance


```
fi_glm <- feature_importance(explain_titanic_glm)
plot(fi_glm)

fi_glm_joint1 <- feature_importance(explain_titanic_glm,
  variable_groups = list("demographics" = c("gender", "age"),
    "ticket_type" = c("fare")),
  label = "lm 2 groups")

plot(fi_glm_joint1)

fi_glm_joint2 <- feature_importance(explain_titanic_glm,
  variable_groups = list("demographics" = c("gender", "age"),
    "wealth" = c("fare", "class"),
    "family" = c("sibsp", "parch"),
    "embarked" = "embarked"),
  label = "lm 5 groups")

plot(fi_glm_joint2, fi_glm_joint1)

explain_titanic_glm

library("randomForest")

model_titanic_rf <- randomForest(survived ~., data = titanic_imputed)

explain_titanic_rf <- explain(model_titanic_rf,
  data = titanic_imputed[,-8],
  y = titanic_imputed[,8])

fi_rf <- feature_importance(explain_titanic_rf)
plot(fi_rf)

fi_rf <- feature_importance(explain_titanic_rf, B = 5) # 5 replications
plot(fi_rf)

fi_rf_group <- feature_importance(explain_titanic_rf,
  variable_groups = list("demographics" = c("gender", "age"),
    "wealth" = c("fare", "class"),
    "family" = c("sibsp", "parch"),
    "embarked" = "embarked"),
  label = "rf 4 groups")

plot(fi_rf_group, fi_rf)

HR_rf_model <- randomForest(status ~., data = HR, ntree = 100)

explainer_rf <- explain(HR_rf_model, data = HR, y = HR$status,
  verbose = FALSE, precalculate = FALSE)

fi_rf <- feature_importance(explainer_rf, type = "raw",
  loss_function = loss_cross_entropy)

head(fi_rf)
```

```

plot(fi_rf)

HR_glm_model <- glm(status == "fired"~., data = HR, family = "binomial")
explainer_glm <- explain(HR_glm_model, data = HR, y = HR$status == "fired")
fi_glm <- feature_importance(explainer_glm, type = "raw",
                             loss_function = loss_root_mean_square)

head(fi_glm)
plot(fi_glm)

library("xgboost")
model_martix_train <- model.matrix(status == "fired" ~ . -1, HR)
data_train <- xgb.DMatrix(model_martix_train, label = HR$status == "fired")
param <- list(max_depth = 2, eta = 1, silent = 1, nthread = 2,
              objective = "binary:logistic", eval_metric = "auc")
HR_xgb_model <- xgb.train(param, data_train, nrounds = 50)

explainer_xgb <- explain(HR_xgb_model, data = model_martix_train,
                        y = HR$status == "fired", label = "xgboost")

fi_xgb <- feature_importance(explainer_xgb, type = "raw")
head(fi_xgb)
plot(fi_xgb, fi_glm)

```

partial_dependency *Partial Dependency Profiles*

Description

Partial Dependency Profiles are averages from Ceteris Paribus Profiles. Function `partial_dependency` calls `ceteris_paribus` and then `aggregate_profiles`.

Usage

```

partial_dependency(x, ...)

## S3 method for class 'explainer'
partial_dependency(x, variables = NULL, N = 500,
                  variable_splits = NULL, grid_points = 101, ...,
                  variable_type = "numerical")

## Default S3 method:
partial_dependency(x, data, predict_function = predict,
                  label = class(x)[1], variables = NULL, grid_points = 101,
                  variable_splits = NULL, N = 500, ..., variable_type = "numerical")

## S3 method for class 'ceteris_paribus_explainer'
partial_dependency(x, ...,
                  variables = NULL)

```

Arguments

x	an explainer created with function <code>DALEX::explain()</code> , an object of the class <code>ceteris_paribus_explainer</code> or a model to be explained.
...	other parameters
variables	names of variables for which profiles shall be calculated. Will be passed to <code>calculate_variable_split</code> . If <code>NULL</code> then all variables from the validation data will be used.
N	number of observations used for calculation of partial dependency profiles. By default 500.
variable_splits	named list of splits for variables, in most cases created with <code>calculate_variable_split</code> . If <code>NULL</code> then it will be calculated based on validation data available in the explainer.
grid_points	number of points for profile. Will be passed to <code>calculate_variable_split</code> .
variable_type	a character. If <code>numerical</code> then only numerical variables will be calculated. If <code>categorical</code> then only categorical variables will be calculated.
data	validation dataset, will be extracted from x if it's an explainer NOTE: It is best when target variable is not present in the data
predict_function	predict function, will be extracted from x if it's an explainer
label	name of the model. By default it's extracted from the class attribute of the model

Details

Find more details in the [Partial Dependence Profiles Chapter](#).

Value

an object of the class `aggregated_profiles_explainer`

References

Predictive Models: Visual Exploration, Explanation and Debugging https://pbiemek.github.io/PM_VEE

Examples

```
library("DALEX")

model_titanic_glm <- glm(survived ~ gender + age + fare,
                        data = titanic_imputed, family = "binomial")

explain_titanic_glm <- explain(model_titanic_glm,
                              data = titanic_imputed[,-8],
                              y = titanic_imputed[,8],
                              verbose = FALSE)
```

```

pdp_glm <- partial_dependency(explain_titanic_glm,
                             N = 50, variables = c("age", "fare"))
head(pdp_glm)
plot(pdp_glm)

library("randomForest")

model_titanic_rf <- randomForest(survived ~., data = titanic_imputed)

explain_titanic_rf <- explain(model_titanic_rf,
                             data = titanic_imputed[,-8],
                             y = titanic_imputed[,8],
                             verbose = FALSE)

pdp_rf <- partial_dependency(explain_titanic_rf, variable_type = "numerical")
plot(pdp_rf)

pdp_rf <- partial_dependency(explain_titanic_rf, variable_type = "categorical")
plotD3(pdp_rf, variable_type = "categorical", label_margin = 80, scale_plot = TRUE)

```

```
plot.agggregated_profiles_explainer
```

Plots Aggregated Profiles

Description

Function `plot.agggregated_profiles_explainer` plots partial dependency plot or accumulated effect plot. It works in a similar way to `plot.ceteris_paribus`, but instead of individual profiles show average profiles for each variable listed in the `variables` vector.

Usage

```

## S3 method for class 'agggregated_profiles_explainer'
plot(x, ..., size = 1,
     alpha = 1, color = "_label_", facet_ncol = NULL,
     variables = NULL)

```

Arguments

<code>x</code>	a ceteris paribus explainer produced with function <code>aggregate_profiles()</code>
<code>...</code>	other explainers that shall be plotted together
<code>size</code>	a numeric. Size of lines to be plotted
<code>alpha</code>	a numeric between 0 and 1. Opacity of lines
<code>color</code>	a character. Either name of a color or name of a variable that should be used for coloring

facet_ncol number of columns for the `facet_wrap`
 variables if not NULL then only variables will be presented

Value

a ggplot2 object

References

Predictive Models: Visual Exploration, Explanation and Debugging https://pbiecek.github.io/PM_VEE

Examples

```
library("DALEX")

model_titanic_glm <- glm(survived ~ gender + age + fare,
                        data = titanic_imputed, family = "binomial")

explain_titanic_glm <- explain(model_titanic_glm,
                              data = titanic_imputed[,-8],
                              y = titanic_imputed[,8],
                              verbose = FALSE)

pdp_rf_p <- partial_dependency(explain_titanic_glm, N = 50)
pdp_rf_p$`_label_` <- "RF_partial"
pdp_rf_l <- conditional_dependency(explain_titanic_glm, N = 50)
pdp_rf_l$`_label_` <- "RF_local"
pdp_rf_a <- accumulated_dependency(explain_titanic_glm, N = 50)
pdp_rf_a$`_label_` <- "RF_accumulated"
head(pdp_rf_p)
plot(pdp_rf_p, pdp_rf_l, pdp_rf_a, color = "_label_")

library("randomForest")

model_titanic_rf <- randomForest(survived ~., data = titanic_imputed)

explain_titanic_rf <- explain(model_titanic_rf,
                              data = titanic_imputed[,-8],
                              y = titanic_imputed[,8],
                              label = "Random Forest v7",
                              verbose = FALSE)

selected_passangers <- select_sample(titanic_imputed, n = 100)
cp_rf <- ceteris_paribus(explain_titanic_rf, selected_passangers)
cp_rf

pdp_rf_p <- aggregate_profiles(cp_rf, variables = "age", type = "partial")
pdp_rf_p$`_label_` <- "RF_partial"
pdp_rf_c <- aggregate_profiles(cp_rf, variables = "age", type = "conditional")
pdp_rf_c$`_label_` <- "RF_conditional"
```

```

pdp_rf_a <- aggregate_profiles(cp_rf, variables = "age", type = "accumulated")
pdp_rf_a$`_label_` <- "RF_accumulated"

head(pdp_rf_p)
plot(pdp_rf_p)
plot(pdp_rf_p, pdp_rf_c, pdp_rf_a)

plot(cp_rf, variables = "age") +
  show_observations(cp_rf, variables = "age") +
  show_rugs(cp_rf, variables = "age", color = "red") +
  show_aggregated_profiles(pdp_rf_p, size = 2)

```

```
plot.ceteris_paribus_2d_explainer
```

Plot Ceteris Paribus 2D Explanations

Description

This function plots What-If Plots for a single prediction / observation.

Usage

```

## S3 method for class 'ceteris_paribus_2d_explainer'
plot(x, ..., facet_ncol = NULL,
     add_raster = TRUE, add_contour = TRUE, bins = 3,
     add_observation = TRUE, pch = "+", size = 6)

```

Arguments

<code>x</code>	a ceteris paribus explainer produced with the <code>ceteris_paribus_2d()</code> function
<code>...</code>	currently will be ignored
<code>facet_ncol</code>	number of columns for the facet_wrap
<code>add_raster</code>	if TRUE then <code>geom_raster</code> will be added to present levels with diverging colors
<code>add_contour</code>	if TRUE then <code>geom_contour</code> will be added to present contours
<code>bins</code>	number of contours to be added
<code>add_observation</code>	if TRUE then <code>geom_point</code> will be added to present observation that is explained
<code>pch</code>	character, symbol used to plot observations
<code>size</code>	numeric, size of individual datapoints

Value

a `ggplot2` object

References

Predictive Models: Visual Exploration, Explanation and Debugging https://pbiemek.github.io/PM_VEE

Examples

```
library("DALEX")
library("randomForest")

apartments_rf_model <- randomForest(m2.price ~., data = apartments)

explainer_rf <- explain(apartments_rf_model,
                       data = apartments_test[,-1],
                       y = apartments_test[,1],
                       verbose = FALSE)

new_apartment <- apartments_test[1,]
new_apartment

wi_rf_2d <- ceteris_paribus_2d(explainer_rf, observation = new_apartment)
head(wi_rf_2d)

plot(wi_rf_2d)
plot(wi_rf_2d, add_contour = FALSE)
plot(wi_rf_2d, add_observation = FALSE)
plot(wi_rf_2d, add_raster = FALSE)

# HR data
model <- randomForest(status ~ gender + age + hours + evaluation + salary, data = HR)

pred1 <- function(m, x) predict(m, x, type = "prob")[,1]

explainer_rf_fired <- explain(model,
                              data = HR[,1:5],
                              y = HR$status == "fired",
                              predict_function = pred1,
                              label = "fired")

new_emp <- HR[1,]
new_emp

wi_rf_2d <- ceteris_paribus_2d(explainer_rf_fired, observation = new_emp)
head(wi_rf_2d)

plot(wi_rf_2d)
```

Description

Function `plot.ceteris_paribus_explainer` plots Individual Variable Profiles for selected observations. Various parameters help to decide what should be plotted, profiles, aggregated profiles, points or rugs.

Find more details in [Ceteris Paribus Chapter](#).

Usage

```
## S3 method for class 'ceteris_paribus_explainer'
plot(x, ..., size = 1, alpha = 1,
     color = "#46bac2", variable_type = "numerical", facet_ncol = NULL,
     variables = NULL)
```

Arguments

<code>x</code>	a ceteris paribus explainer produced with function <code>ceteris_paribus()</code>
<code>...</code>	other explainers that shall be plotted together
<code>size</code>	a numeric. Size of lines to be plotted
<code>alpha</code>	a numeric between 0 and 1. Opacity of lines
<code>color</code>	a character. Either name of a color or name of a variable that should be used for coloring
<code>variable_type</code>	a character. If <code>numerical</code> then only numerical variables will be plotted. If <code>categorical</code> then only categorical variables will be plotted.
<code>facet_ncol</code>	number of columns for the facet_wrap
<code>variables</code>	if not <code>NULL</code> then only variables will be presented

Value

a `ggplot2` object

References

Predictive Models: Visual Exploration, Explanation and Debugging https://pbiemek.github.io/PM_VEE

Examples

```
library("DALEX")

model_titanic_glm <- glm(survived ~ gender + age + fare,
                       data = titanic_imputed, family = "binomial")

explain_titanic_glm <- explain(model_titanic_glm,
                             data = titanic_imputed[,-8],
                             y = titanic_imputed[,8],
                             verbose = FALSE)
```

```

cp_rf <- ceteris_paribus(explain_titanic_glm, titanic_imputed[1,])
cp_rf

plot(cp_rf, variables = "age")

library("randomForest")
model_titanic_rf <- randomForest(survived ~., data = titanic_imputed)

explain_titanic_rf <- explain(model_titanic_rf,
                             data = titanic_imputed[,-8],
                             y = titanic_imputed[,8],
                             label = "Random Forest v7",
                             verbose = FALSE)

selected_passangers <- select_sample(titanic_imputed, n = 100)

cp_rf <- ceteris_paribus(explain_titanic_rf, selected_passangers)
cp_rf

plot(cp_rf, variables = "age") +
  show_observations(cp_rf, variables = "age") +
  show_rugs(cp_rf, variables = "age", color = "red")

selected_passangers <- select_sample(titanic_imputed, n = 1)
selected_passangers

cp_rf <- ceteris_paribus(explain_titanic_rf, selected_passangers)

plot(cp_rf) +
  show_observations(cp_rf)

plot(cp_rf, variables = "age") +
  show_observations(cp_rf, variables = "age")

plot(cp_rf, variables = "class")
plot(cp_rf, variables = c("class", "embarked"), facet_ncol = 1)
plotD3(cp_rf, variables = c("class", "embarked", "gender"),
       variable_type = "categorical", scale_plot = TRUE,
       label_margin = 70)

```

plot.ceteris_paribus_oscillations

Plot Ceteris Paribus Oscillations

Description

This function plots local variable importance plots calculated as oscillations in the Ceteris Paribus Profiles.

Usage

```
## S3 method for class 'ceteris_paribus_oscillations'  
plot(x, ..., bar_width = 10)
```

Arguments

x	a ceteris paribus oscillation explainer produced with function <code>calculate_oscillations()</code>
...	other explainers that shall be plotted together
bar_width	width of bars. By default 10

Value

a ggplot2 object

References

Predictive Models: Visual Exploration, Explanation and Debugging https://pbiemek.github.io/PM_VEE

Examples

```
library("DALEX")  
  
library("randomForest")  
  
apartments_rf_model <- randomForest(m2.price ~., data = apartments)  
  
explainer_rf <- explain(apartments_rf_model,  
                        data = apartments_test[,-1],  
                        y = apartments_test[,1])  
  
apartment <- apartments_test[1:2,]  
  
cp_rf <- ceteris_paribus(explainer_rf, apartment)  
plot(cp_rf, color = "_ids_")  
  
vips <- calculate_oscillations(cp_rf)  
vips  
  
plot(vips)
```

```
plot.feature_importance_explainer
```

Plots Feature Importance

Description

This function plots variable importance calculated as changes in the loss function after variable drops. It uses output from feature_importance function that corresponds to permutation based measure of variable importance. Variables are sorted in the same order in all panels. The order depends on the average drop out loss. In different panels variable contributions may not look like sorted if variable importance is different in different models.

Usage

```
## S3 method for class 'feature_importance_explainer'  
plot(x, ..., max_vars = NULL,  
      bar_width = 10)
```

Arguments

x	a feature importance explainer produced with the feature_importance() function
...	other explainers that shall be plotted together
max_vars	maximum number of variables that shall be presented for for each model. By default NULL what means all variables
bar_width	width of bars. By default 10

Details

Find more details in the [Feature Importance Chapter](#).

Value

a ggplot2 object

References

Predictive Models: Visual Exploration, Explanation and Debugging https://piecek.github.io/PM_VEE

Examples

```
library("DALEX")  
  
model_titanic_glm <- glm(survived ~ gender + age + fare,  
                        data = titanic_imputed, family = "binomial")
```

```
explain_titanic_glm <- explain(model_titanic_glm,
                              data = titanic_imputed[,-8],
                              y = titanic_imputed[,8])

fi_rf <- feature_importance(explain_titanic_glm)
plot(fi_rf)

library("randomForest")

model_titanic_rf <- randomForest(survived ~., data = titanic_imputed)

explain_titanic_rf <- explain(model_titanic_rf,
                              data = titanic_imputed[,-8],
                              y = titanic_imputed[,8])

fi_rf <- feature_importance(explain_titanic_rf)
plot(fi_rf)

HR_rf_model <- randomForest(status~., data = HR, ntree = 100)

explainer_rf <- explain(HR_rf_model, data = HR, y = HR$status,
                       verbose = FALSE, precalculate = FALSE)

fi_rf <- feature_importance(explainer_rf, type = "raw",
                           loss_function = loss_cross_entropy)
head(fi_rf)
plot(fi_rf)

HR_glm_model <- glm(status == "fired"~., data = HR, family = "binomial")
explainer_glm <- explain(HR_glm_model, data = HR, y = HR$status == "fired")

fi_glm <- feature_importance(explainer_glm, type = "raw",
                             loss_function = loss_root_mean_square)
head(fi_glm)
plot(fi_glm)

library("xgboost")

model_martix_train <- model.matrix(status == "fired" ~ . -1, HR)
data_train <- xgb.DMatrix(model_martix_train, label = HR$status == "fired")

param <- list(max_depth = 2, eta = 1, silent = 1, nthread = 2,
              objective = "binary:logistic", eval_metric = "auc")

HR_xgb_model <- xgb.train(param, data_train, nrounds = 50)

explainer_xgb <- explain(HR_xgb_model, data = model_martix_train,
                        y = HR$status == "fired", label = "xgboost")

fi_xgb <- feature_importance(explainer_xgb, type = "raw")

head(fi_xgb)
```



```
plot(fi_glm, fi_xgb, bar_width = 5)
```

plotD3

Plots Ceteris Paribus Profiles in D3 with r2d3 Package.

Description

Function `plotD3.ceteris_paribus_explainer` plots Individual Variable Profiles for selected observations. It uses output from `ceteris_paribus` function. Various parameters help to decide what should be plotted, profiles, aggregated profiles, points or rugs.

Find more details in [Ceteris Paribus Chapter](#).

Usage

```
plotD3(x, ...)

## S3 method for class 'ceteris_paribus_explainer'
plotD3(x, ..., size = 2, alpha = 1,
       color = "#46bac2", variable_type = "numerical", facet_ncol = 2,
       scale_plot = FALSE, variables = NULL,
       chart_title = "Ceteris Paribus Profiles", label_margin = 60,
       show_observations = TRUE, show_rugs = TRUE)
```

Arguments

<code>x</code>	a ceteris paribus explainer produced with function <code>ceteris_paribus()</code>
<code>...</code>	other explainers that shall be plotted together
<code>size</code>	a numeric. Set width of lines
<code>alpha</code>	a numeric between 0 and 1. Opacity of lines
<code>color</code>	a character. Set line color
<code>variable_type</code>	a character. If "numerical" then only numerical variables will be plotted. If "categorical" then only categorical variables will be plotted.
<code>facet_ncol</code>	number of columns for the <code>facet_wrap</code>
<code>scale_plot</code>	a logical. If TRUE, the height of plot scales with window size. By default it's FALSE
<code>variables</code>	if not NULL then only variables will be presented
<code>chart_title</code>	a character. Set custom title
<code>label_margin</code>	a numeric. Set width of label margins in categorical type
<code>show_observations</code>	a logical. Adds observations layer to a plot. By default it's TRUE
<code>show_rugs</code>	a logical. Adds rugs layer to a plot. By default it's TRUE

Value

a r2d3 object.

Examples

```
library("DALEX")
library("randomForest")

model_titanic_rf <- randomForest(survived ~., data = titanic_imputed)

explain_titanic_rf <- explain(model_titanic_rf,
                             data = titanic_imputed[,-8],
                             y = titanic_imputed[,8],
                             label = "rf")

selected_passangers <- select_sample(titanic_imputed, n = 10)
cp_rf <- ceteris_paribus(explain_titanic_rf, selected_passangers)

plotD3(cp_rf, variables = c("age", "parch", "fare", "sibsp"),
       facet_ncol = 2, scale_plot = TRUE)

selected_passanger <- select_sample(titanic_imputed, n = 1)
cp_rf <- ceteris_paribus(explain_titanic_rf, selected_passanger)

plotD3(cp_rf, variables = c("class", "embarked", "gender", "sibsp"),
       facet_ncol = 2, variable_type = "categorical", label_margin = 100, scale_plot = TRUE)
```

plotD3.agggregated_profiles_explainer

Plots Aggregated Ceteris Paribus Profiles in D3 with r2d3 Package.

Description

Function `plotD3.agggregated_profiles_explainer` plots an aggregate of ceteris paribus profiles. It works in a similar way to `plotD3.ceteris_paribus_explainer` but, instead of individual profiles, show average profiles for each variable listed in the `variables` vector.

Find more details in [Ceteris Paribus Chapter](#).

Usage

```
## S3 method for class 'agggregated_profiles_explainer'
plotD3(x, ..., size = 2,
       alpha = 1, color = "#46bac2", variable_type = "numerical",
       facet_ncol = 2, scale_plot = FALSE, variables = NULL,
       chart_title = "Aggregated Profiles", label_margin = 60)
```

Arguments

x	a aggregated profiles explainer produced with function <code>aggregate_profiles()</code>
...	other explainers that shall be plotted together
size	a numeric. Set width of lines
alpha	a numeric between 0 and 1. Opacity of lines
color	a character. Set line/bar color
variable_type	a character. If "numerical" then only numerical variables will be plotted. If "categorical" then only categorical variables will be plotted.
facet_ncol	number of columns for the <code>facet_wrap</code>
scale_plot	a logical. If TRUE, the height of plot scales with window size. By default it's FALSE
variables	if not NULL then only variables will be presented
chart_title	a character. Set custom title
label_margin	a numeric. Set width of label margins in categorical type

Value

a r2d3 object.

References

Predictive Models: Visual Exploration, Explanation and Debugging https://pbiemek.github.io/PM_VEE

Examples

```
library("DALEX")
library("randomForest")

# smaller data, quicker example
titanic_small <- select_sample(titanic_imputed, n = 500, seed = 1313)

# build a model
model_titanic_rf <- randomForest(survived ~., data = titanic_small)

explain_titanic_rf <- explain(model_titanic_rf,
                             data = titanic_small[,-8],
                             y = titanic_small[,8],
                             label = "Random Forest v7")

selected_passangers <- select_sample(titanic_small, n = 100)
cp_rf <- ceteris_paribus(explain_titanic_rf, selected_passangers)

pdp_rf_p <- aggregate_profiles(cp_rf, type = "partial", variable_type = "numerical")
pdp_rf_p$`_label_` <- "RF_partial"
pdp_rf_c <- aggregate_profiles(cp_rf, type = "conditional", variable_type = "numerical")
pdp_rf_c$`_label_` <- "RF_conditional"
```

```

pdp_rf_a <- aggregate_profiles(cp_rf, type = "accumulated", variable_type = "numerical")
pdp_rf_a$`_label_` <- "RF_accumulated"

plotD3(pdp_rf_p, pdp_rf_c, pdp_rf_a, variable_type = "numerical", scale_plot = TRUE)

pdp <- aggregate_profiles(cp_rf, type = "partial", variable_type = "categorical")
pdp$`_label_` <- "RF_partial"

plotD3(pdp, variables = c("gender", "class"), variable_type = "categorical", label_margin = 70)

```

```
plotD3.feature_importance_explainer
```

Plot Feature Importance Objects in D3 with r2d3 Package.

Description

Function `plotD3.feature_importance_explainer` plots dropouts for variables used in the model. It uses output from `feature_importance` function that corresponds to permutation based measure of feature importance. Variables are sorted in the same order in all panels. The order depends on the average drop out loss. In different panels variable contributions may not look like sorted if variable importance is different in different models.

Usage

```

## S3 method for class 'feature_importance_explainer'
plotD3(x, ..., max_vars = NULL,
       bar_width = 12, split = "model", scale_height = FALSE,
       margin = 0.15, chart_title = "Feature importance")

```

Arguments

<code>x</code>	a feature importance explainer produced with the <code>feature_importance()</code> function
<code>...</code>	other explainers that shall be plotted together
<code>max_vars</code>	maximum number of variables that shall be presented for for each model. By default NULL which means all variables
<code>bar_width</code>	width of bars in px. By default 12px
<code>split</code>	either "model" or "feature" determines the plot layout
<code>scale_height</code>	a logical. If TRUE, the height of plot scales with window size. By default it's FALSE
<code>margin</code>	extend x axis domain range to adjust the plot. Usually value between 0.1 and 0.3, by default it's 0.15
<code>chart_title</code>	a character. Set custom title

Value

a r2d3 object.

Examples

```
library("DALEX")

lm_model <- lm(m2.price ~., data = apartments)
explainer_lm <- explain(lm_model,
  data = apartments[,-1],
  y = apartments[,1],
  verbose = FALSE)

fi_lm <- feature_importance(explainer_lm, loss_function = loss_root_mean_square)

head(fi_lm)
plotD3(fi_lm)

## Not run:
library("randomForest")

rf_model <- randomForest(m2.price~., data = apartments)

explainer_rf <- explain(rf_model,
  data = apartments[,-1],
  y = apartments[,1],
  label = "rf", verbose = FALSE)

fi_rf <- feature_importance(explainer_rf, loss_function = loss_root_mean_square)

head(fi_rf)
plotD3(fi_lm, fi_rf)

plotD3(fi_lm, fi_rf, split = "feature")

plotD3(fi_lm, fi_rf, max_vars = 3, bar_width = 16, scale_height = TRUE)
plotD3(fi_lm, fi_rf, max_vars = 3, bar_width = 16, split = "feature", scale_height = TRUE)
plotD3(fi_lm, margin = 0.2)

## End(Not run)
```

print.agggregated_profiles_explainer
Prints Aggregated Profiles

Description

Prints Aggregated Profiles

Usage

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

Arguments

x an individual variable profile explainer produced with the `aggregate_profiles()` function

... other arguments that will be passed to `head()`

Examples

```
library("DALEX")  
  
model_titanic_glm <- glm(survived ~ gender + age + fare,  
                          data = titanic_imputed, family = "binomial")  
  
explain_titanic_glm <- explain(model_titanic_glm,  
                              data = titanic_imputed[,-8],  
                              y = titanic_imputed[,8])  
  
selected_passangers <- select_sample(titanic_imputed, n = 100)  
cp_rf <- ceteris_paribus(explain_titanic_glm, selected_passangers)  
  
head(cp_rf)  
  
pdp_rf <- aggregate_profiles(cp_rf, variables = "age")  
head(pdp_rf)  
  
library("randomForest")  
  
model_titanic_rf <- randomForest(survived ~., data = titanic_imputed)  
  
explain_titanic_rf <- explain(model_titanic_rf,  
                              data = titanic_imputed[,-8],  
                              y = titanic_imputed[,8],  
                              verbose = FALSE, precalculate = FALSE)  
  
cp_rf <- ceteris_paribus(explain_titanic_rf, selected_passangers)  
cp_rf  
  
pdp_rf <- aggregate_profiles(cp_rf, variables = "age")  
head(pdp_rf)
```

```
print.ceteris_paribus_explainer
  Prints Individual Variable Explainer Summary
```

Description

Prints Individual Variable Explainer Summary

Usage

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

Arguments

x	an individual variable profile explainer produced with the ceteris_paribus() function
...	other arguments that will be passed to head()

Examples

```
library("DALEX")
library("randomForest")

apartments_rf_model <- randomForest(m2.price ~., data = apartments)

explainer_rf <- explain(apartments_rf_model,
  data = apartments_test[,-1],
  y = apartments_test[,1])

apartments_small <- select_sample(apartments_test, 10)

cp_rf <- ceteris_paribus(explainer_rf, apartments_small)
cp_rf
```

```
select_neighbours      Select Subset of Rows Closest to a Specified Observation
```

Description

Function [select_neighbours](#) selects subset of rows from data set. This is useful if data is large and we need just a sample to calculate profiles.

Usage

```
select_neighbours(observation, data, variables = NULL,
  distance = gower::gower_dist, n = 20, frac = NULL)
```

Arguments

observation	single observation
data	set of observations
variables	names of variables that shall be used for calculation of distance. By default these are all variables present in data and observation
distance	the distance function, by default the gower_dist() function.
n	number of neighbours to select
frac	if n is not specified (NULL), then will be calculated as frac * number of rows in data. Either n or frac need to be specified.

Details

Note that select_neighbours() function is S3 generic. If you want to work on non standard data sources (like H2O ddf, external databases) you should overload it.

Value

a data frame with selected rows

Examples

```
library("DALEX")

new_apartment <- apartments[1,]
small_apartments <- select_neighbours(new_apartment, apartments_test, n = 10)

new_apartment
small_apartments
```

select_sample	<i>Select Subset of Rows</i>
---------------	------------------------------

Description

Function [select_sample](#) selects subset of rows from data set. This is useful if data is large and we need just a sample to calculate profiles.

Usage

```
select_sample(data, n = 100, seed = 1313)
```


Arguments

data	set of observations. Profile will be calculated for every observation (every row)
n	number of observations to select.
seed	seed for random number generator.

Details

Note that `select_subsample()` function is S3 generic. If you want to work on non standard data sources (like H2O ddf, external databases) you should overload it.

Value

a data frame with selected rows

Examples

```
library("DALEX")

small_apartments <- select_sample(apartments_test)
head(small_apartments)
```

show_aggregated_profiles

Adds a Layer with Aggregated Profiles

Description

Function `show_aggregated_profiles` adds a layer to a plot created with `plot.ceteris_paribus_explainer`.

Usage

```
show_aggregated_profiles(x, ..., size = 0.5, alpha = 1,
  color = "#371ea3", variables = NULL)
```

Arguments

x	a ceteris paribus explainer produced with function <code>ceteris_paribus()</code>
...	other explainers that shall be plotted together
size	a numeric. Size of lines to be plotted
alpha	a numeric between 0 and 1. Opacity of lines
color	a character. Either name of a color or name of a variable that should be used for coloring
variables	if not NULL then only variables will be presented

Value

a ggplot2 layer

Examples

```
library("DALEX")

selected_passangers <- select_sample(titanic_imputed, n = 100)

model_titanic_glm <- glm(survived ~ gender + age + fare,
                        data = titanic_imputed, family = "binomial")

explain_titanic_glm <- explain(model_titanic_glm,
                              data = titanic_imputed[, -8],
                              y = titanic_imputed[, 8])

cp_rf <- ceteris_paribus(explain_titanic_glm, selected_passangers)

pdp_rf <- aggregate_profiles(cp_rf, type = "partial", variables = "age")

plot(cp_rf, variables = "age") +
  show_observations(cp_rf, variables = "age") +
  show_aggregated_profiles(pdp_rf, size = 3)

library("randomForest")

model_titanic_rf <- randomForest(survived ~., data = titanic_imputed)

explain_titanic_rf <- explain(model_titanic_rf,
                              data = titanic_imputed[, -8],
                              y = titanic_imputed[, 8],
                              verbose = FALSE, precalculate = FALSE)

cp_rf <- ceteris_paribus(explain_titanic_rf, selected_passangers)
cp_rf

pdp_rf <- aggregate_profiles(cp_rf, type = "partial", variables = "age")
head(pdp_rf)

plot(cp_rf, variables = "age") +
  show_observations(cp_rf, variables = "age") +
  show_rugs(cp_rf, variables = "age", color = "red") +
  show_aggregated_profiles(pdp_rf, size = 3)
```

show_observations

Adds a Layer with Observations to a Profile Plot

Description

Function `show_observations` adds a layer to a plot created with `plot.ceteris_paribus_explainer` for selected observations. Various parameters help to decide what should be plotted, profiles, aggregated profiles, points or rugs.

Usage

```
show_observations(x, ..., size = 2, alpha = 1, color = "#371ea3",  
  variable_type = "numerical", variables = NULL)
```

Arguments

<code>x</code>	a ceteris paribus explainer produced with function <code>ceteris_paribus()</code>
<code>...</code>	other explainers that shall be plotted together
<code>size</code>	a numeric. Size of lines to be plotted
<code>alpha</code>	a numeric between 0 and 1. Opacity of lines
<code>color</code>	a character. Either name of a color or name of a variable that should be used for coloring
<code>variable_type</code>	a character. If <code>numerical</code> then only numerical variables will be plotted. If <code>categorical</code> then only categorical variables will be plotted.
<code>variables</code>	if not <code>NULL</code> then only variables will be presented

Value

a `ggplot2` layer

Examples

```
library("DALEX")  
library("randomForest")  
  
rf_model <- randomForest(survived ~.,  
  data = titanic_imputed)  
  
explainer_rf <- explain(rf_model,  
  data = titanic_imputed[,-8],  
  y = titanic_imputed[,8],  
  label = "RF", verbose = FALSE)  
  
selected_passangers <- select_sample(titanic_imputed, n = 100)  
cp_rf <- ceteris_paribus(explainer_rf, selected_passangers)  
cp_rf  
  
plot(cp_rf, variables = "age", color = "grey") +  
  show_observations(cp_rf, variables = "age", color = "black") +  
  show_rugs(cp_rf, variables = "age", color = "red")
```

show_profiles	<i>Adds a Layer with Profiles</i>
---------------	-----------------------------------

Description

Function `show_profiles` adds a layer to a plot created with `plot.ceteris_paribus_explainer`.

Usage

```
show_profiles(x, ..., size = 0.5, alpha = 1, color = "#371ea3",
             variables = NULL)
```

Arguments

<code>x</code>	a ceteris paribus explainer produced with function <code>ceteris_paribus()</code>
<code>...</code>	other explainers that shall be plotted together
<code>size</code>	a numeric. Size of lines to be plotted
<code>alpha</code>	a numeric between 0 and 1. Opacity of lines
<code>color</code>	a character. Either name of a color or name of a variable that should be used for coloring
<code>variables</code>	if not NULL then only variables will be presented

Value

a ggplot2 layer

Examples

```
library("DALEX")

selected_passangers <- select_sample(titanic_imputed, n = 100)
selected_john <- titanic_imputed[1,]

model_titanic_glm <- glm(survived ~ gender + age + fare,
                       data = titanic_imputed, family = "binomial")

explain_titanic_glm <- explain(model_titanic_glm,
                             data = titanic_imputed[,-8],
                             y = titanic_imputed[,8],
                             label = "cool_model", verbose = FALSE)

cp_rf <- ceteris_paribus(explain_titanic_glm, selected_passangers)
cp_rf_john <- ceteris_paribus(explain_titanic_glm, selected_john)
plot(cp_rf, variables = "age") +
  show_profiles(cp_rf_john, variables = "age", size = 2)
```

```

library("randomForest")

model_titanic_rf <- randomForest(survived ~., data = titanic_imputed)

explain_titanic_rf <- explain(model_titanic_rf,
                             data = titanic_imputed[,-8],
                             y = titanic_imputed[,8],
                             verbose = FALSE, precalculate = FALSE)

cp_rf <- ceteris_paribus(explain_titanic_rf, selected_passangers)
cp_rf_john <- ceteris_paribus(explain_titanic_rf, selected_john)

cp_rf

pdp_rf <- aggregate_profiles(cp_rf, variables = "age")
head(pdp_rf)

plot(cp_rf, variables = "age") +
  show_observations(cp_rf, variables = "age") +
  show_rugs(cp_rf, variables = "age", color = "red") +
  show_profiles(cp_rf_john, variables = "age", color = "red", size = 2)

```

show_residuals	<i>Adds a Layer with Residuals to a Profile Plot</i>
----------------	------------------------------------------------------

Description

Function `show_residuals` adds a layer to a plot created with `plot.ceteris_paribus_explainer` for selected observations. Note that the `y` argument has to be specified in the `ceteris_paribus` function.

Usage

```
show_residuals(x, ..., size = 0.75, alpha = 1, color = c(`TRUE` =
  "#371ea3", `FALSE` = "#f05a71"), variables = NULL)
```

Arguments

<code>x</code>	a ceteris paribus explainer produced with function <code>ceteris_paribus()</code> . Note that <code>y</code> parameter shall be supplied in this function.
<code>...</code>	other explainers that shall be plotted together
<code>size</code>	a numeric. Size of lines to be plotted
<code>alpha</code>	a numeric between 0 and 1. Opacity of lines
<code>color</code>	a character. Either name of a color or name of a variable that should be used for coloring
<code>variables</code>	if not NULL then only variables will be presented

Value

a ggplot2 layer

Examples

```
library("DALEX")
library("randomForest")

model_titanic_rf <- randomForest(survived ~., data = titanic_imputed, ntree = 500)

explain_titanic_rf <- explain(model_titanic_rf,
                             data = titanic_imputed[,-8],
                             y = titanic_imputed[,8],
                             label = "Random Forest v7")

johnny_d <- data.frame(
  class = factor("1st", levels = c("1st", "2nd", "3rd", "deck crew", "engineering crew",
                                   "restaurant staff", "victualling crew")),
  gender = factor("male", levels = c("female", "male")),
  age = 8,
  sibsp = 0,
  parch = 0,
  fare = 72,
  embarked = factor("Southampton", levels = c("Belfast", "Cherbourg", "Queenstown", "Southampton"))
)

johnny_neighbours <- select_neighbours(data = titanic_imputed,
                                       observation = johnny_d,
                                       variables = c("age", "gender", "class",
                                                     "fare", "sibsp", "parch"),
                                       n = 10)

cp_neighbours <- ceteris_paribus(explain_titanic_rf,
                                 johnny_neighbours,
                                 y = johnny_neighbours$survived == "yes",
                                 variable_splits = list(age = seq(0,70, length.out = 1000)))

plot(cp_neighbours, variables = "age") +
  show_observations(cp_neighbours, variables = "age")

cp_johny <- ceteris_paribus(explain_titanic_rf, johnny_d,
                           variable_splits = list(age = seq(0,70, length.out = 1000)))

plot(cp_johny, variables = "age", size = 1.5, color = "#8bdcbf") +
  show_profiles(cp_neighbours, variables = "age", color = "#ceced9") +
  show_observations(cp_johny, variables = "age", size = 5, color = "#371ea3") +
  show_residuals(cp_neighbours, variables = "age")
```

show_rugs	<i>Adds a Layer with Rugs to a Profile Plot</i>
-----------	-------------------------------------------------

Description

Function `show_rugs` adds a layer to a plot created with `plot.ceteris_paribus_explainer` for selected observations. Various parameters help to decide what should be plotted, profiles, aggregated profiles, points or rugs.

Usage

```
show_rugs(x, ..., size = 0.5, alpha = 1, color = "#371ea3",
          variable_type = "numerical", sides = "b", variables = NULL)
```

Arguments

<code>x</code>	a ceteris paribus explainer produced with function <code>ceteris_paribus()</code>
<code>...</code>	other explainers that shall be plotted together
<code>size</code>	a numeric. Size of lines to be plotted
<code>alpha</code>	a numeric between 0 and 1. Opacity of lines
<code>color</code>	a character. Either name of a color or name of a variable that should be used for coloring
<code>variable_type</code>	a character. If <code>numerical</code> then only numerical variables will be plotted. If <code>categorical</code> then only categorical variables will be plotted.
<code>sides</code>	a string containing any of "trbl", for top, right, bottom, and left. Passed to <code>geom_rug</code> .
<code>variables</code>	if not <code>NULL</code> then only variables will be presented

Value

a `ggplot2` layer

Examples

```
library("DALEX")
library("randomForest")

rf_model <- randomForest(survived ~., data = titanic_imputed)

explainer_rf <- explain(rf_model, data = titanic_imputed[,-8],
                      y = titanic_imputed[,8],
                      label = "RF", verbose = FALSE)

selected_passangers <- select_sample(titanic_imputed, n = 100)
cp_rf <- ceteris_paribus(explainer_rf, selected_passangers)
cp_rf
```

```
plot(cp_rf, variables = "age", color = "grey") +  
show_observations(cp_rf, variables = "age", color = "black") +  
  show_rugs(cp_rf, variables = "age", color = "red")
```


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