Package 'eVCGsampler'

December 19, 2025

Type Package

Title VCG Sampling using Energy-Based Covariate Balancing

Version 0.9.2

Description
Provides a principled framework for sampling Virtual Control Group (VCG) using energy distance-based covariate balancing. The package offers visualization tools to assess covariate balance and includes a permutation test to evaluate the statistical significance of observed deviations.

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Encoding UTF-8

RoxygenNote 7.3.3

Depends ggplot2

Imports ggforce, osqp, patchwork

Suggests knitr, rmarkdown

VignetteBuilder knitr

NeedsCompilation no

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Repository CRAN

Date/Publication 2025-12-19 20:10:17 UTC

Contents

`BestVCGsize` *The function attempts to find the optimal size for VCG.*

Description

The function tries out different sizes of VCG and searches for the smallest distance.

Usage

```
BestVCGsize(formula, data = data, plot = TRUE)
```

Arguments

`formula`	A formula specifying the treated and covariates, e.g., 'treated ~ cov1 + cov2 | stratum'. The treated variable must be binary (0=pool, 1=treated)
`data`	A data frame containing the variables specified in the formula.
`plot`	Logical. If 'TRUE', returns a ggplot2 plot. Default: TRUE

Details

It is only intended for exploratory purposes, as the VCG size is normally given. But it can be used to see how well the given size fits. The recommendation for VCG size is based solely on distance and does not take into account other aspects such as power or validity.

Value

If 'plot = TRUE', returns a list with:

`optimal_n`	The estimated optimal VCG size (integer).
`plot`	A ggplot2 object visualizing the energy distance curve and plateau.

Examples

```
set.seed(2342)
dat <- data.frame(
  treat = rep(0:1, c(50, 30)),
  cov1 = c(rnorm(50, 11, 2),  rnorm(30, 10, 1)),
  cov2 = c(rnorm(50, 12, 2),  rnorm(30, 10, 1)),
  cov3 = c(rnorm(50, 9,  2),  rnorm(30, 10, 1))
)
 BestVCGsize(treat ~ cov1 + cov2 + cov3, data=dat)
```

combine_data *Combine data from pool and treated groups*

Description

If your data is stored in separate files, you can use this function to merge them.

Usage

```
combine_data(POOL_data, TG_data, indicator_name = "treated")
```

Arguments

POOL_data	Data frame with POOL data, where you want to sample from.
TG_data	Data frame with TG (treated groups) data, all treated groups together!
indicator_name	Name of the variable that is created for further use in the package, Default: 'treated'

Value

Data frame with all covariates that were present in both files and with new indicator factor POOL vs TG

Examples

```
pool_data <- data.frame(
  cov1   = rnorm(100, 11, 2),
  cov2   = rnorm(100, 11, 2),
  cov3   = rnorm(100, 11, 2),
  sex    = rbinom(100, 1, 0.5))

tg_data <- data.frame(
  cov2   = rnorm(20, 12, 1),
  cov3   = rnorm(20, 12, 1),
  cov4   = rnorm(20, 12, 1),
  sex    = rbinom(20, 1, 0.5))

 dx <- combine_data(pool_data, tg_data)
 str(dx)
```

`energy_distance` *Compute Energy Distance Between Two Groups*

Description

Calculates the energy distance between two groups.

Usage

```
energy_distance(formula, data, standardized = TRUE)
```

Arguments

`formula`	A formula specifying the treated and covariates, e.g., 'treated ~ cov1 + cov2'. The treated variable must be binary (0=pool, 1=treated)
`data`	A data frame containing the variables specified in the formula.
`standardized`	If TRUE, the standardized energy distance that lies in the range 0 to 1 is returned, the so-called E-coefficient. If FALSE, not scaled energy distance is returned that can be >1.

Details

Energy distance is a non-parametric measure of distributional difference. It is sensitive to differences in location, scale, and shape between groups. Before calculation, the covariates are scaled to a mean value of 0 and a standard deviation of 1.

Value

A numeric value representing the energy distance between the two groups.

Examples

```
dat <- data.frame(
 treated = rep(0:1, c(50, 30)),
 age    = c(rnorm(50, 5, 2),   rnorm(30, 5, 1)),
 weight = c(rnorm(50, 11, 2),  rnorm(30, 10, 1)),
 class  = c(rbinom(50, 3, 0.6),   rbinom(30, 3, 0.4))
 )

 energy_distance(treated ~ age + weight + class, data=dat)
```

`energy_test` *Permutation Energy Test for Covariate Imbalance*

Description

Performs a permutation-based energy distance test to assess whether two groups (defined by a binary treated variable) are balanced across a set of covariates. Optionally, it visualizes the distribution of permuted energy distances and highlights the observed test statistic and critical value.

Usage

```
energy_test(formula, data, alpha = 0.05, R = 2000, plot = TRUE)
```

Arguments

`formula`	A formula specifying the treated and covariates, e.g., 'treated ~ cov1 + cov2 | stratum'.
`data`	A data frame containing the variables specified in the formula.
`alpha`	Significance level for the test (default is 0.05).
`R`	Number of permutations to perform (default is 2000).
`plot`	Logical. If 'TRUE', returns a ggplot2 visualization of the permutation distribution.

Details

The energy distance is a non-parametric measure of distributional difference. This test evaluates whether the covariate distributions between two groups are statistically distinguishable. A small p-value indicates imbalance between groups. A one-sided test is used because the energy distance is strictly positive; only values greater than the observed statistic in the permutation distribution are relevant.

Value

If 'plot = TRUE', returns a list with:

- A list of class '"htest"' containing:
  - 'p.value': The permutation p-value.
  - 'estimate': The observed energy distance.
  - 'critical.value': The critical value at the specified alpha level.
  - 'alternative': The alternative hypothesis ("one.sided").
  - 'method': Description of the test.
  - 'n.permutations': Number of permutations performed.
  - 'permutations': Vector of permuted energy distances.
- A ggplot2 object showing the histogram of permuted distances, with vertical lines for the observed statistic and critical value.

If 'plot = FALSE', returns only the '"htest"' result list.

See Also

element

Examples

```
dat <- data.frame(
 treated = rep(0:1, c(50, 30)),
 age    = c(rnorm(50, 5, 2),   rnorm(30, 5, 1)),
 weight = c(rnorm(50, 11, 2),  rnorm(30, 10, 1)),
 class  = c(rbinom(50, 3, 0.6),   rbinom(30, 3, 0.4))
 )

 energy_test(treated ~ age + weight + class, data=dat, R = 500)
```

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multiSampler *Multi-Sample VCG Generator and Overlap Visualization*

Description

Repeatedly samples VCGs (via 'VCG_sampler' and 'random=TRUE') from the pool, optionally plots the overlap of VCGs.

Usage

```
multiSampler(formula, data, n, c_w = NULL, Nsamples = 20, plot = TRUE)
```

Arguments

formula	A formula specifying the treated and covariates, e.g., 'treated ~ cov1 + cov2'. The treated variable must be binary (0=pool, 1=treated)
data	A data frame containing the variables specified in the formula.
n	Integer. Number of observations to sample from the pool. Or a vector of n for each stratum.
c_w	Optional: Vector of positive weights for covariates, reflecting the relative importance of the covariates for the balancing.
Nsamples	Number of VCGs to generate (default is 20).
plot	Logical; if 'TRUE', returns a ggplot2 plot showing the overlap of VCGs (default is 'TRUE').

Details

The function repeatedly calls 'VCG_sampler' with 'random' set to TRUE to generate multiple VCG groups. It calculates the frequency of selection for each observation and computes the average percentage of overlapping observations. This function should only be used if you really need multiple VCG, e.g. for PoC studies. It is not intended for selecting one VCG from them afterwards! In this case, the VCG_sampler function should be used directly and only one VCG should be generated.

Value

If ‘plot = TRUE‘, returns a list with:

data The original data frame with additional VCG columns (‘VCG_1‘, ..., ‘VCG_Nsamples‘).

p A ‘ggplot2‘ object showing the number of times each observation was selected across VCG samples.

If ‘plot = FALSE‘, returns the modified data frame only.

Examples

```
dat <- data.frame(
treat = rep(0:1, c(50, 30)),
cov_1 = c(rnorm(50, 5, 2),   rnorm(30, 5, 1)),
cov_2 = c(rnorm(50, 11, 2),  rnorm(30, 10, 1))
)

result <- multiSampler(treat ~ cov_1 + cov_2, data = dat, n = 10, Nsamples = 10)
```

`plot_var` *Visualize Covariate Distribution Across TG, VCG, and POOL*

Description

Creates a plot to compare the distribution of a selected variable across three groups: TG (treated groups), VCG (virtual control group), and POOL (data pool).

Usage

```
plot_var(data, what = NULL, stratum = "in_stratum", group = "VCG", title = "")
```

Arguments

`data`	A balanced data frame (output of the VCG_sampler function)
`what`	A string specifying the name of the variable to be visualized.
`stratum`	A string specifying the name of the stratum variable (default is ‘"in_stratum"‘)
`group`	A string specifying the column name used to define group membership (default is ‘"VCG"‘).
`title`	Optional title for the plot.

Details

The function uses energy distance to quantify distributional differences between groups. For continuous variables, it overlays dashed lines for TG group statistics (mean, min, max) and displays sample sizes. For categorical variables, it uses color-coded bars and cumulative proportion lines to highlight imbalance.

Value

A ggplot2 object showing either:

- A boxplot for continuous variables (more than 4 unique values).
- A proportional bar chart for categorical variables (2–4 unique values).

Examples

```
dat   <- data.frame(
  cov1  = rnorm(50, 10, 1),
  cov2  = rnorm(50, 7,  1),
  cov3  = rnorm(50, 5,  1),
  treated = rep(c(0, 1), c(35, 15))
)
  out <- VCG_sampler(treated ~ cov1 + cov2 + cov3, data=dat, n=5, plot=FALSE)
  plot_var(out, what='cov1', group='VCG')
  plot_var(out, what='cov2', group='VCG')
```

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robust_scale *Robust Scaling of Numeric and Categorical Variables*

Description

Applies robust scaling to numeric and categorical variables. For numeric variables, the function centers by the median and scales by the MAD. For categorical variables with 2–4 unique levels, it applies a custom transformation to map them to numeric values.

Usage

```
robust_scale(x, group)
```

Arguments

x	A numeric vector, factor, matrix, or data frame. If a matrix or data frame is provided, scaling is applied column-wise.
group	vector indicating which group is the TG to scale to

Details

This function is designed to make numeric and categorical variables comparable. This is an internal function that should not be used by package users.

Value

A scaled numeric vector or a data frame with scaled columns.

Examples

```
dat<-data.frame(x=rnorm(100, 10, 3), sex=factor(rbinom(100, 1, 0.5), labels=c("M","F")))

x<- robust_scale(dat$x, dat$sex)
round(median(x), 2)
round(mad(x), 2)
```

`VCG_sampler` *VCG Sampler for Energy Distance Balancing*

Description

This function performs energy distance based balancing and selects a subset from pool based on energy distance to approximate a randomized control trial. Optionally, it visualizes the balancing results.

Usage

```
VCG_sampler(formula, data, n, c_w = NULL, random = FALSE, plot = TRUE)
```

Arguments

`formula`	A formula specifying the treated indicator and covariates, e.g., 'treated ~ cov1 + cov2 | stratum'. The treated variable must be binary (0=pool, 1=treated)
`data`	A data frame containing the variables specified in the formula.
`n`	Integer. Number of observations to sample from the pool, or a vector of n for each stratum
`c_w`	Optional: Vector of positive weights for covariates, reflecting the relative importance of the covariates for balancing.
`random`	Logical. If 'TRUE', the distance is used as the probability for selecting the observation; otherwise, the nearest observations are used (deterministic). Default: FALSE
`plot`	Logical. If 'TRUE', returns a visualization of the balancing effect.

Details

If random is set to FALSE, the function selects the top 'n' units from the pool with the lowest energy distance and assigns them to the VCG group. If random is set to TRUE, the function samples 'n' units from pool with sampling probability inversely proportional to energy distance. The quality of covariate balancing is visualized using differences in medians and median absolute deviations (MADs). Permutation ellipses are generated by randomly permuting the pool and treated groups to estimate usual (random) variability. Only the X and Y axes are computed directly; the ellipse is interpolated between the axes. This method is intended as a visual approximation rather than a precise statistical test.

Value

If ‘plot = TRUE‘, returns a list with:

- A data frame with added columns:
  - ‘VCG‘: Indicator for selected pool units. VCG==1 indicates the VCG selected.
  - ‘e_weights‘: Energy weights used for selection
  - ‘<treated>_balanced‘: A factor indicating balanced treated assignment.
- A ggplot2 object showing the median and MAD differences before and after balancing, with a 95

If ‘plot = FALSE‘, returns only the modified data frame.

Examples

```
dat   <- data.frame(
  cov1  = rnorm(50, 10, 1),
  cov2  = rnorm(50, 7,  1),
  cov3  = rnorm(50, 5,  1),
  treated = rep(c(0, 1), c(35, 15))
)
  VCG_sampler(treated ~ cov1 + cov2 + cov3, data=dat, n=5)
```

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