

Package ‘autoMR’

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Type Package

Title Automated Mendelian Randomization Workflows and Visualizations

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Description Provides tools to summarize, analyze, and visualize results from Mendelian randomization studies using summarized genetic association data. The package includes functions for generating forest plots and scatter plots at the single-nucleotide polymorphism and Mendelian randomization method levels, and for fitting multiple estimators in a unified workflow, including inverse-variance weighted estimation, Mendelian randomization Egger regression, the weighted median estimator, the robust adjusted profile score, Mendelian randomization pleiotropy residual sum and outlier, Mendelian randomization with the genotype recoding invariance property, and a Bayesian horseshoe method. Related methods are described by Burgess (2013) <doi:10.1002/gepi.21758>, Bowden (2015) <doi:10.1093/ije/dyv080>, Bowden (2016) <doi:10.1002/gepi.21965>, Zhao (2020) <doi:10.1214/19-AOS1866>, Verbanck (2018) <doi:10.1038/s41588-018-0099-7>, Dudbridge (2025) <doi:10.1371/journal.pgen.1011967>, and Grant and Burgess (2024) <doi:10.1016/j.ajhg.2023.12.002>. Related open-source software includes 'TwoSampleMR' <<https://github.com/MRCIEU/TwoSampleMR>>, 'mr.raps' <<https://github.com/qingyuanzhao/mr.raps>>, 'MR-PRESSO' <<https://github.com/rondolab/MR-PRESSO>>, and 'MR-Horse' <<https://github.com/aj-grant/mrhorse>>.

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URL <https://github.com/KelinZhong/autoMR>

BugReports <https://github.com/KelinZhong/autoMR/issues>

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export_forest_plots *Export MR Forest Plots to Disk*

Description

Saves plots stored in a GWASForestPlots or MRForestPlots object to a directory using `ggplot2::ggsave()`. You can export all plots or filter to a specific outcome, a specific exposure, or a specific outcome-exposure pair.

Usage

```

export_forest_plots(
  object,
  save_dir = tempdir(),
  file_type = "png",
  width = 8,
  height = 6,
  dpi = 300,
  outcome = NULL,
  exposure = NULL
)

## S4 method for signature 'GWASForestPlots'
export_forest_plots(
  object,
  save_dir = tempdir(),
  file_type = "png",
  width = 8,
  height = 6,
  dpi = 300,
  outcome = NULL,
  exposure = NULL
)

## S4 method for signature 'MRForestPlots'
export_forest_plots(
  object,
  save_dir = tempdir(),
  file_type = "png",
  width = 8,
  height = 6,
  dpi = 300,
  outcome = NULL,
  exposure = NULL
)

```

Arguments

object	A GWASForestPlots or MRForestPlots object returned by GWAS_forest() or MR_forest().
save_dir	Character string; directory to write files into. Must already exist. Defaults to tempdir().
file_type	Character string; output format passed to ggplot2::ggsave(). One of "pdf", "png", "jpeg", or "tiff". Default is "png".
width	Numeric; plot width in inches. Default is 8.
height	Numeric; plot height in inches. Default is 6.
dpi	Integer; resolution in dots per inch (ignored for PDF). Default is 300.

outcome	Optional character string; if supplied, only plots whose outcome matches this value are exported.
exposure	Optional character string; if supplied, only plots whose exposure matches this value are exported.

Details

Filtering logic:

- **Both outcome and exposure supplied** — exports the single plot for that exact pair.
- **outcome only** — exports all exposures for that outcome.
- **exposure only** — exports all outcomes for that exposure.
- **Neither supplied** — exports every plot in the object.

File names are prefixed with `Instrument_forest_` for `GWASForestPlots` objects and `Method_forest_` for `MRForestPlots` objects, followed by `<Outcome>_<Exposure>.<file_type>` with spaces replaced by underscores.

Value

Invisibly returns object so calls can be chained.

Methods (by class)

- `export_forest_plots(GWASForestPlots)`: Method for `GWASForestPlots`.
- `export_forest_plots(MRForestPlots)`: Method for `MRForestPlots`.

Examples

```
data("fi_49item")
input1 <- harmonize_mr_data(df = fi_49item)$input_df
outcome1 <- run_mr_analysis(MR_input_data = input1)

gwas_plots <- GWAS_forest(MR_input_data = input1, report_form = "Beta")
mr_plots <- MR_forest(summary_df = outcome1, effect = "Beta")

# Inspect what is stored; for fi_49item both objects print:
# [1] fi_49item :: Zn

# Retrieve the exact outcome/exposure labels stored in the object
gwas_out <- gwas_plots@outcomes[1] # "fi_49item"
gwas_exp <- gwas_plots@exposures[1] # "Zn"
mr_out <- mr_plots@outcomes[1] # "fi_49item"
mr_exp <- mr_plots@exposures[1] # "Zn"

# Export all instrument-level plots as PDF (commented - writes to disk)
export_forest_plots(gwas_plots, save_dir = tempdir())

# Export one outcome only
export_forest_plots(gwas_plots, save_dir = tempdir(), outcome = gwas_out)
```

```
# Export one exposure only
export_forest_plots(mr_plots, save_dir = tempdir(), exposure = mr_exp)

# Export one specific pair
export_forest_plots(mr_plots, save_dir = tempdir(), outcome = mr_out, exposure = mr_exp)
```

export_scatter_plots *Export MR Scatter Plots to Disk*

Description

Saves plots stored in an MRScatterPlots object to a directory. You can export all plots or filter to a specific outcome, a specific exposure, or a specific outcome-exposure pair.

Usage

```
export_scatter_plots(
  object,
  save_dir = tempdir(),
  file_type = "png",
  width = 8,
  height = 6,
  outcome = NULL,
  exposure = NULL
)

## S4 method for signature 'MRScatterPlots'
export_scatter_plots(
  object,
  save_dir = tempdir(),
  file_type = "png",
  width = 8,
  height = 6,
  outcome = NULL,
  exposure = NULL
)
```

Arguments

object	An MRScatterPlots object returned by plot_mr_scatter().
save_dir	Character string; directory to write files into. Must exist. Defaults to tempdir().
file_type	Character string; output format passed to the corresponding grDevices device. One of "pdf", "png", "jpeg", or "tiff". Default is "png".
width	Numeric; plot width in inches. Default is 8.
height	Numeric; plot height in inches. Default is 6.

outcome	Optional character string; if supplied, only plots whose outcome matches this value are exported.
exposure	Optional character string; if supplied, only plots whose exposure matches this value are exported.

Details

Filtering logic:

- **Both outcome and exposure supplied** — exports the single plot for that exact pair.
- **outcome only** — exports all exposures for that outcome.
- **exposure only** — exports all outcomes for that exposure.
- **Neither supplied** — exports every plot in the object.

File names follow the pattern Scatter_<Outcome>_<Exposure>.<file_type> with spaces replaced by underscores.

Value

Invisibly returns object so calls can be chained.

Methods (by class)

- `export_scatter_plots(MRScatterPlots)`: Method for MRScatterPlots.

Examples

```
data("fi_49item")
input1 <- harmonize_mr_data(df = fi_49item)$input_df
outcome1 <- run_mr_analysis(MR_input_data = input1)
plots <- plot_mr_scatter(MR_input_data = input1, summary_df = outcome1)

# Inspect what is stored; for fi_49item this prints:
# [1] fi_49item :: Zn
#' # Retrieve the exact outcome/exposure labels stored in the object
out_name <- plots@outcomes[1] # "fi_49item"
exp_name <- plots@exposures[1] # "Zn"

# Export all plots to tempdir() (commented - writes to disk)
export_scatter_plots(plots, save_dir = tempdir())

# Export one outcome only
export_scatter_plots(plots, save_dir = tempdir(), outcome = out_name)

# Export one exposure only
export_scatter_plots(plots, save_dir = tempdir(), exposure = exp_name)

# Export one specific pair
export_scatter_plots(plots, save_dir = tempdir(), outcome = out_name, exposure = exp_name)
```

fi_49item	<i>Frailty Index Dataset (49-items)</i>
-----------	---

Description

A dataset containing variables used to compute a 49-item frailty index (FI). The exact variables/columns depend on your project definitions.

Format

A data frame.

format_mr_input	<i>Format vectors into a Mendelian Randomization input data frame</i>
-----------------	---

Description

Assembles raw vectors into a working data frame, aligns outcome alleles to the exposure strand (Step 1), then standardizes the sign of beta_exposure (Step 2). Returns both a full working data frame (check_df) and a slim, renamed input data frame (input_df), mirroring the output of harmonize_mr_data().

Usage

```
format_mr_input(  
  Instrument,  
  beta_exposure,  
  se_exposure,  
  beta_outcome,  
  se_outcome,  
  Outcome,  
  Exposure,  
  ALLELE1 = NULL,  
  ALLELE0 = NULL,  
  A1FREQ = NULL,  
  ALLELE1_outcome = NULL,  
  ALLELE0_outcome = NULL,  
  A1FREQ_outcome = NULL,  
  beta_sign = c("positive", "negative")  
)
```

Arguments

Instrument	Character vector of instrument/SNP identifiers.
beta_exposure	Numeric vector of exposure effects.
se_exposure	Numeric vector of exposure standard errors.
beta_outcome	Numeric vector of outcome effects.
se_outcome	Numeric vector of outcome standard errors.
Outcome	Character string or vector for outcome names (Mandatory).
Exposure	Character string or vector for exposure names (Mandatory).
ALLELE1	Optional character vector for non-effect alleles (NEA) on the exposure strand (ALLELE1 = NEA_exposure).
ALLELE0	Optional character vector for effect alleles (EA) on the exposure strand (ALLELE0 = EA_exposure).
A1FREQ	Optional numeric vector for effect allele frequencies (exposure dataset).
ALLELE1_outcome	Optional character vector for non-effect alleles in the outcome dataset. If NULL, assumed identical to ALLELE1.
ALLELE0_outcome	Optional character vector for effect alleles in the outcome dataset. If NULL, assumed identical to ALLELE0.
A1FREQ_outcome	Optional numeric vector for effect allele frequencies in the outcome dataset.
beta_sign	Character string controlling the target sign for beta_outcome. One of "positive" (default, forces beta_outcome >= 0) or "negative" (forces beta_outcome <= 0). When a row is flipped, beta_exposure is negated as a side effect and all allele columns are swapped consistently. Ignored when no allele columns are supplied (strand identity is unknown without allele information).

Value

A named list with two elements:

`check_df` Full working data frame retaining all allele columns (NEA_exposure, EA_exposure, NEA_outcome, EA_outcome, A1FREQ_exposure, A1FREQ_outcome) after harmonization. Useful for quality-checking the harmonization results.

`input_df` Slim data frame ready for MR analysis, with columns: Instrument, beta_exposure, se_exposure, beta_outcome, se_outcome, Outcome, Exposure, ALLELE1, ALLELE0, A1FREQ.

Examples

```
data("fi_49item")

# Without allele columns
result1 <- format_mr_input(
  Instrument = fi_49item$Instrument,
  beta_exposure = fi_49item$beta_exposure,
  se_exposure = fi_49item$se_exposure,
```

```

    beta_outcome = fi_49item$beta_outcome,
    se_outcome   = fi_49item$se_outcome,
    Outcome      = fi_49item$Outcome,
    Exposure     = fi_49item$Exposure
  )
  head(result1$input_df)

# With allele columns (enables alignment + sign standardization)
result2 <- format_mr_input(
  Instrument      = fi_49item$Instrument,
  beta_exposure  = fi_49item$beta_exposure,
  se_exposure    = fi_49item$se_exposure,
  beta_outcome   = fi_49item$beta_outcome,
  se_outcome    = fi_49item$se_outcome,
  Outcome        = fi_49item$Outcome,
  Exposure       = fi_49item$Exposure,
  ALLELE1       = fi_49item$NEA_exposure,
  ALLELE0       = fi_49item$EA_exposure,
  A1FREQ        = fi_49item$A1FREQ_exposure,
  ALLELE1_outcome = fi_49item$NEA_outcome,
  ALLELE0_outcome = fi_49item$EA_outcome,
  A1FREQ_outcome = fi_49item$A1FREQ_outcome
)
  head(result2$check_df)
  head(result2$input_df)

# Force all exposure betas to be negative
result3 <- format_mr_input(
  Instrument      = fi_49item$Instrument,
  beta_exposure  = fi_49item$beta_exposure,
  se_exposure    = fi_49item$se_exposure,
  beta_outcome   = fi_49item$beta_outcome,
  se_outcome    = fi_49item$se_outcome,
  Outcome        = fi_49item$Outcome,
  Exposure       = fi_49item$Exposure,
  ALLELE1       = fi_49item$NEA_exposure,
  ALLELE0       = fi_49item$EA_exposure,
  beta_sign      = "negative"
)
  head(result3$input_df)

```

fried_frailty

Fried Frailty Phenotype Dataset

Description

A dataset containing variables used to compute Fried frailty phenotype measures. The exact variables/columns depend on your project definitions.

Format

A data frame.

GWASForestPlots-class *S4 class to store instrument-level MR forest plots*

Description

A GWASForestPlots object is returned by `GWAS_forest()`. It holds one `ggplot` object per outcome-exposure pair — each plot shows per-instrument (SNP-level) causal estimates alongside a pooled IVW estimate — together with the metadata needed to filter and export subsets.

Slots

`plots` Named list of `ggplot` objects. Names follow the pattern "Outcome::Exposure".

`outcomes` Character vector of outcome labels, parallel to `plots`.

`exposures` Character vector of exposure labels, parallel to `plots`.

Methods

`export_forest_plots(object, save_dir, file_type, width, height, dpi, outcome, exposure)`
Saves plots to disk. Optionally filter by outcome, exposure, or both to export a subset.

GWAS_forest *Generate Instrument-level Forest Plots for Mendelian Randomization*

Description

Creates a forest plot for each instrument (SNP) within the MR analysis, including a pooled IVW estimate at the top for comparison.

Usage

```
GWAS_forest(
  MR_input_data,
  report_form,
  xlim_custom = NULL,
  dot_size = 2,
  axis_text_size = 10,
  axis_title_size = 12,
  digits = 2,
  plot_width = 8,
  plot_height = 6,
  label_text_size = 3
)
```

Arguments

MR_input_data	Harmonised MR input data frame. Must contain Outcome, Exposure, Instrument, beta_exposure, se_exposure, beta_outcome, and se_outcome columns.
report_form	Character string or vector indicating the standard output scale for each outcome (e.g., "Beta", "OR", "HR"). Defaults to "Beta".
xlim_custom	Optional numeric vector of length 2 providing custom limits for the x-axis. If NULL, limits are determined by the data.
dot_size	Numeric value specifying the size of the points. Default is 2.
axis_text_size	Numeric value specifying the font size for axis labels. Default is 10.
axis_title_size	Numeric value specifying the font size for axis titles. Default is 12.
digits	Integer specifying the number of decimal places for labels. Default is 2.
plot_width	Numeric value specifying the width of exported plot file. Default is 8.
plot_height	Numeric value specifying the height of exported plot file. Default is 6.
label_text_size	Numeric value specifying the size of estimate labels (Beta/OR/HR and 95 percent CI) shown on the plot. Default is 3.

Value

A GWASForestPlots object containing one ggplot per outcome-exposure pair, with instrument-level (SNP) causal estimates and a pooled IVW estimate. Use `export_forest_plots()` to write plots to disk with optional filtering.

Examples

```
data("merged_data")
input3 <- harmonize_mr_data(df = merged_data)$input_df

gwas_plots <- GWAS_forest(
  MR_input_data = input3,
  report_form   = c("Beta", "OR"),
  xlim_custom   = NULL,
  dot_size      = 2,
  axis_text_size = 10,
  axis_title_size = 12,
  digits        = 2,
  plot_width    = 8,
  plot_height   = 6,
  label_text_size = 3
)

# Retrieve the exact outcome/exposure labels stored in the object
out_name <- gwas_plots@outcomes[1] # "fi_49item"
exp_name <- gwas_plots@exposures[1] # "Zn"

# Export all instrument-level plots as PNG (commented - writes to disk)
# export_forest_plots(gwas_plots, save_dir = tempdir(), file_type = "jpeg")
```

```

# Export plots for one outcome only
# export_forest_plots(gwas_plots, save_dir = tempdir(), outcome = out_name)

# Export plots for one exposure only
# export_forest_plots(gwas_plots, save_dir = tempdir(), exposure = exp_name)

# Export one specific outcome-exposure pair
# export_forest_plots(gwas_plots, save_dir = tempdir(), outcome = out_name, exposure = exp_name)

```

harmonize_mr_data	<i>Harmonize exposure and outcome SNP data</i>
-------------------	--

Description

Takes a data frame that already contains all required MR columns, aligns outcome alleles to the exposure strand (Step 1), then standardizes the sign of beta_exposure (Step 2). Returns both a full working data frame (check_df) and a slim, renamed input data frame (input_df), mirroring the output of format_mr_input().

Usage

```

harmonize_mr_data(
  df,
  Outcome = NULL,
  Exposure = NULL,
  beta_sign = c("positive", "negative")
)

```

Arguments

df	Data frame containing required columns: beta_exposure, se_exposure, beta_outcome, se_outcome, Outcome, Exposure. Allele columns may be supplied as NEA_exposure/EA_exposure/NEA_ or as ALLELE1 (NEA) / ALLELE0 (EA) which are treated as exposure alleles.
Outcome	Optional; character string to set as the Outcome name when the column is absent from df.
Exposure	Optional; character string to set as the Exposure name when the column is absent from df.
beta_sign	Character string controlling the target sign for beta_outcome after harmonization. One of "positive" (default, forces beta_outcome >= 0) or "negative" (forces beta_outcome <= 0). When a row is flipped, beta_exposure is negated as a side effect and all allele columns are swapped consistently.

Value

A named list with two elements:

`check_df` Full working data frame retaining all allele columns after harmonization. Useful for quality-checking results.

`input_df` Slim data frame ready for MR analysis, with columns: `Instrument`, `beta_exposure`, `se_exposure`, `beta_outcome`, `se_outcome`, `Outcome`, `Exposure`, `ALLELE1`, `ALLELE0`, `A1FREQ`.

Examples

```
result1 <- harmonize_mr_data(df = fi_49item)
head(result1$check_df)
head(result1$input_df)

# Force all exposure betas to be negative
result2 <- harmonize_mr_data(df = fi_49item, beta_sign = "negative")
head(result2$input_df)
```

merged_data	<i>Merged Frailty Index Dataset (49-items and fried frailty)</i>
-------------	--

Description

A dataset containing variables used to compute a 49-item frailty index (FI) and Fried frailty. The exact variables/columns depend on your project definitions.

Format

A data frame.

MRForestPlots-class	<i>S4 class to store method-level MR forest plots</i>
---------------------	---

Description

An MRForestPlots object is returned by `MR_forest()`. It holds one ggplot object per outcome-exposure pair — each plot compares causal estimates across MR methods (IVW, RAPS, Egger, etc.) — together with the metadata needed to filter and export subsets.

Slots

`plots` Named list of ggplot objects. Names follow the pattern `"Outcome::Exposure"`.

`outcomes` Character vector of outcome labels, parallel to `plots`.

`exposures` Character vector of exposure labels, parallel to `plots`.

Methods

`export_forest_plots(object, save_dir, file_type, width, height, dpi, outcome, exposure)`
Saves plots to disk. Optionally filter by outcome, exposure, or both to export a subset.

MRScatterPlots-class *S4 class to store MR scatter plots*

Description

An MRScatterPlots object is returned by `plot_mr_scatter()`. It holds one plot-parameter list per outcome-exposure pair, together with the metadata needed to filter and export subsets of plots.

Slots

`plots` Named list of plot-parameter lists. Names follow the pattern "Outcome::Exposure".
`outcomes` Character vector of outcome labels, parallel to plots.
`exposures` Character vector of exposure labels, parallel to plots.

Methods

`export_scatter_plots(object, save_dir, file_type, width, height, outcome, exposure)`
Saves plots to disk. Optionally filter by outcome, exposure, or both to export a subset.

MR_forest *Generate Forest Plots across Multiple MR Methods*

Description

Creates a forest plot comparing causal estimates across different MR methods (e.g., IVW, RAPS, Egger).

Usage

```
MR_forest(
  summary_df,
  effect,
  custom_xlim = NULL,
  dot_size = 3,
  axis_text_size = 10,
  axis_title_size = 12,
  pval_text_size = 3,
  plot_width = 8,
  plot_height = 6,
  clamp_nonpositive = FALSE
)
```

Arguments

summary_df	MR results data frame, typically the output from run_mr_analysis().
effect	Character string or vector indicating the effect scale ("Beta", "OR", or "HR").
custom_xlim	Optional numeric vector of length 2 for x-axis limits.
dot_size	Numeric value specifying the point size. Default is 3.
axis_text_size	Numeric value for axis font size.
axis_title_size	Numeric value for title font size.
pval_text_size	Numeric value for p-value label size.
plot_width	Width of exported plot.
plot_height	Height of exported plot.
clamp_nonpositive	Logical; whether non-positive estimates should be clamped to a small positive value before log-transformation.

Value

An MRForestPlots object containing one ggplot per outcome-exposure pair, with causal estimates compared across MR methods. Use export_forest_plots() to write plots to disk with optional filtering.

Examples

```

data("merged_data")
input3 <- harmonize_mr_data(df = merged_data)$input_df
outcome3 <- run_mr_analysis(
  MR_input_data = input3,
  outcome.form = c("Beta", "OR"),
  use_ivw = TRUE,
  use_raps = TRUE,
  use_median = TRUE,
  use_egger = TRUE,
  use_mr_presso = TRUE,
  use_mr_horse = TRUE,
  use_mr_grip = TRUE,
  NbDistribution = 1000,
  SignifThreshold = 0.05,
  mr_horse_n_iter = 5000,
  mr_horse_n_burnin = 1000,
  mr_grip_parameters = NULL
)

mr_plots <- MR_forest(
  summary_df = outcome3,
  effect = c("Beta", "OR"),
  custom_xlim = NULL,
  dot_size = 3,
  axis_text_size = 10,

```

```

    axis_title_size = 12,
    pval_text_size  = 3,
    plot_width      = 8,
    plot_height     = 6,
    clamp_nonpositive = FALSE
  )

  # Retrieve the exact outcome/exposure labels stored in the object
  out_name <- mr_plots@outcomes[1] # "fi_49item"
  exp_name <- mr_plots@exposures[1] # "Zn"

  # Export all method-level plots as PDF (commented - writes to disk)
  export_forest_plots(mr_plots, save_dir = tempdir(), file_type = "png")

  # Export plots for one outcome only
  export_forest_plots(mr_plots, save_dir = tempdir(), outcome = out_name)

  # Export plots for one exposure only
  export_forest_plots(mr_plots, save_dir = tempdir(), exposure = exp_name)

  # Export one specific outcome-exposure pair
  export_forest_plots(mr_plots, save_dir = tempdir(), outcome = out_name, exposure = exp_name)

```

plot_mr_scatter

Plot MR Scatter Plots for Multiple Outcomes and Exposures

Description

Generates one scatter plot per outcome-exposure pair using base R graphics, with a regression line overlaid for each requested Mendelian Randomization (MR) method. Plot parameters are stored in an MRScatterPlots S4 object and rendered on demand at export time, so no files are written to disk during this call.

Usage

```

plot_mr_scatter(
  MR_input_data,
  plot.xlab = "Exposure",
  plot.ylab = "Outcome",
  methods.plot = c("IVW", "RAPS", "Egger", "PRESSO", "Horse", "GRIP"),
  NbDistribution_presso = 1000,
  SignifThreshold_presso = 0.05,
  mr_horse_n_iter = 5000,
  mr_horse_n_burnin = 1000,
  show.legend = TRUE,
  summary_df = NULL,
  effect_scale = "Beta",
  use_df_results = TRUE
)

```

Arguments

MR_input_data	Harmonised MR input data frame. Must contain Outcome and Exposure columns.
plot.xlab	Character string; prefix for the x-axis label. Default is "Exposure".
plot.ylab	Character string; prefix for the y-axis label. Default is "Outcome".
methods.plot	Character vector of MR methods to overlay as regression lines. Supported values: "IVW", "RAPS", "Egger", "PRESSO", "Horse", "GRIP".
NbDistribution_presso	Integer; number of simulated distributions for on-the-fly MR-PRESSO calculation. Default is 1000.
SignifThreshold_presso	Numeric; significance threshold for on-the-fly MR-PRESSO outlier test. Default is 0.05.
mr_horse_n_iter	Integer; number of Markov chain Monte Carlo (MCMC) iterations for on-the-fly MR-Horse. Default is 5000.
mr_horse_n_burnin	Integer; number of MCMC burn-in samples for on-the-fly MR-Horse. Default is 1000.
show.legend	Logical; whether to annotate each plot with method labels, beta estimates, and p-values. Default is TRUE.
summary_df	Optional data frame of pre-calculated results from run_mr_analysis(). When supplied together with use_df_results = TRUE, avoids re-running the analysis.
effect_scale	Character string matching the scale used in summary_df: "Beta", "OR", or "HR". Default is "Beta".
use_df_results	Logical; if TRUE and summary_df is provided, method slopes are read from summary_df instead of being re-calculated. Default is TRUE.

Value

An MRScatterPlots object containing one recordedplot per outcome-exposure pair, together with outcome and exposure metadata. Use export_scatter_plots() to write plots to disk with optional filtering by outcome, exposure, or both.

Examples

```
data("merged_data")
input3 <- harmonize_mr_data(df = merged_data)$input_df
outcome3 <- run_mr_analysis(
  MR_input_data      = input3,
  outcome.form       = c("Beta", "OR"),
  use_ivw            = TRUE,
  use_raps           = FALSE,
  use_median         = FALSE,
  use_egger          = FALSE,
  use_mr_presso     = FALSE,
  use_mr_horse       = FALSE,
  use_mr_grip        = FALSE,
```

```

    NbDistribution      = 1000,
    SignifThreshold    = 0.05,
    mr_horse_n_iter    = 5000,
    mr_horse_n_burnin  = 1000,
    mr_grip_parameters = NULL
  )

# Pass pre-calculated results to avoid rerunning the analysis
plots <- plot_mr_scatter(
  MR_input_data = input3,
  summary_df    = outcome3,
  use_df_results = TRUE
)

# Inspect the object; for fi_49item this prints:
# [1] fi_49item :: Zn

# Retrieve the exact outcome/exposure labels stored in the object
out_name <- plots@outcomes[1] # "fi_49item"
exp_name <- plots@exposures[1] # "Zn"

# Export all plots as PDF (commented - writes to disk)
export_scatter_plots(plots, save_dir = tempdir(), file_type = "pdf")

# Export one outcome only
export_scatter_plots(plots, save_dir = tempdir(), outcome = out_name)

# Export one exposure only
export_scatter_plots(plots, save_dir = tempdir(), exposure = exp_name)

# Export one specific pair
# export_scatter_plots(plots, save_dir = tempdir(), outcome = out_name, exposure = exp_name)

# Export as PNG instead
export_scatter_plots(plots, save_dir = tempdir(), file_type = "png")

```

run_mr_analysis

Run MR Analysis for Multiple Outcomes

Description

Performs causal inference analysis using multiple Mendelian Randomization (MR) methods across one or more outcomes and exposures. Returns a combined results data frame. To save the output, use standard R functions such as `write.csv()` or `saveRDS()` on the returned object.

Usage

```
run_mr_analysis(
```

```

MR_input_data,
outcome.form = NULL,
use_ivw = TRUE,
use_raps = TRUE,
use_median = TRUE,
use_egger = TRUE,
use_mr_presso = TRUE,
use_mr_horse = TRUE,
use_mr_grip = TRUE,
NbDistribution = 1000,
SignifThreshold = 0.05,
mr_horse_n_iter = 5000,
mr_horse_n_burnin = 1000,
mr_grip_parameters = NULL
)

```

Arguments

MR_input_data	Harmonised MR input data frame. Must contain Outcome and Exposure columns.
outcome.form	Character vector indicating the effect scale for each outcome: "Beta", "OR" (odds ratio), or "HR" (hazard ratio). A single value is recycled across all outcomes. Defaults to "Beta".
use_ivw	Logical; whether to run the Inverse Variance Weighted (IVW) method. Default is TRUE.
use_raps	Logical; whether to run the Robust Adjusted Profile Score (MR-RAPS) method. Default is TRUE.
use_median	Logical; whether to run the Weighted Median method. Default is TRUE.
use_egger	Logical; whether to run MR-Egger regression. Default is TRUE.
use_mr_presso	Logical; whether to run the Mendelian Randomization Pleiotropy RESidual Sum and Outlier (MR-PRESSO) method. Default is TRUE.
use_mr_horse	Logical; whether to run the MR-Horse method. Default is TRUE.
use_mr_grip	Logical; whether to run the Generalized Regression with Instrument Pairs (MR-GRIP) method. Default is TRUE.
NbDistribution	Integer; number of simulated distributions for MR-PRESSO. Default is 1000.
SignifThreshold	Numeric; significance threshold for the MR-PRESSO outlier test. Default is 0.05.
mr_horse_n_iter	Integer; number of Markov chain Monte Carlo (MCMC) iterations for MR-Horse. Default is 5000.
mr_horse_n_burnin	Integer; number of MCMC burn-in samples for MR-Horse. Default is 1000.
mr_grip_parameters	List of additional parameters passed to MR-GRIP. If NULL, default parameters are used.

Value

A data frame combining results across all outcomes and exposures. Each row represents one outcome-exposure pair. Columns include estimates, confidence intervals (CI), and p-values for each method, together with diagnostic flags (e.g., F-statistic below 10, significant heterogeneity). Use `write.csv()` or `saveRDS()` to save the returned object.

Examples

```
data("fi_49item")
input1 <- harmonize_mr_data(df = fi_49item)$input_df
outcome1 <- run_mr_analysis(
  MR_input_data      = input1,
  outcome.form       = "Beta",
  use_ivw            = TRUE,
  use_raps           = FALSE,
  use_median         = FALSE,
  use_egger          = FALSE,
  use_mr_presso     = FALSE,
  use_mr_horse       = FALSE,
  use_mr_grip        = FALSE,
  NbDistribution     = 1000,
  SignifThreshold   = 0.05,
  mr_horse_n_iter    = 5000,
  mr_horse_n_burnin = 1000,
  mr_grip_parameters = NULL
)
```

```
data("fried_frailty")
input2 <- harmonize_mr_data(df = fried_frailty)$input_df
outcome2 <- run_mr_analysis(
  MR_input_data      = input2,
  outcome.form       = "OR",
  use_ivw            = TRUE,
  use_raps           = TRUE,
  use_median         = TRUE,
  use_egger          = TRUE,
  use_mr_presso     = TRUE,
  use_mr_horse       = TRUE,
  use_mr_grip        = TRUE,
  NbDistribution     = 1000,
  SignifThreshold   = 0.05,
  mr_horse_n_iter    = 5000,
  mr_horse_n_burnin = 1000,
  mr_grip_parameters = NULL
)
```

```
data("merged_data")
input3 <- harmonize_mr_data(df = merged_data)$input_df
outcome3 <- run_mr_analysis(
```

```

MR_input_data      = input3,
outcome.form       = c("Beta", "OR"), ## First outcome use Beta and second outcome use OR
use_ivw            = TRUE,
use_raps           = TRUE,
use_median         = TRUE,
use_egger          = TRUE,
use_mr_presso     = TRUE,
use_mr_horse      = TRUE,
use_mr_grip       = TRUE,
NbDistribution     = 1000,
SignifThreshold   = 0.05,
mr_horse_n_iter   = 5000,
mr_horse_n_burnin = 1000,
mr_grip_parameters = NULL
)

```

showplot

Display MR Plots on Screen

Description

Renders plots stored in an MRScatterPlots, GWASForestPlots, or MRForestPlots object to the active graphics device. You can display all plots or filter to a specific outcome, exposure, or outcome-exposure pair.

Usage

```
showplot(object, outcome = NULL, exposure = NULL)
```

```
## S4 method for signature 'MRScatterPlots'
showplot(object, outcome = NULL, exposure = NULL)
```

```
## S4 method for signature 'GWASForestPlots'
showplot(object, outcome = NULL, exposure = NULL)
```

```
## S4 method for signature 'MRForestPlots'
showplot(object, outcome = NULL, exposure = NULL)
```

Arguments

object	An MRScatterPlots, GWASForestPlots, or MRForestPlots object.
outcome	Optional character string; if supplied, only plots whose outcome matches this value are displayed.
exposure	Optional character string; if supplied, only plots whose exposure matches this value are displayed.

Details

Filtering logic:

- **Both outcome and exposure supplied** — displays the single plot for that exact pair.
- **outcome only** — displays all exposures for that outcome.
- **exposure only** — displays all outcomes for that exposure.
- **Neither supplied** — displays every plot in the object.

Value

Invisibly returns object.

Methods (by class)

- `showplot(MRScatterPlots)`: Display scatter plots from an `MRScatterPlots` object.
- `showplot(GWASForestPlots)`: Display forest plots from a `GWASForestPlots` object.
- `showplot(MRForestPlots)`: Display forest plots from an `MRForestPlots` object.

Examples

```
data("fi_49item")
input1 <- harmonize_mr_data(df = fi_49item)$input_df
outcome1 <- run_mr_analysis(MR_input_data = input1)

# Scatter plots
scatter <- plot_mr_scatter(MR_input_data = input1, summary_df = outcome1)
showplot(scatter)
showplot(scatter, outcome = "fi_49item")
showplot(scatter, outcome = "fi_49item", exposure = "Zn")

# GWAS forest plots
gwas_plots <- GWAS_forest(MR_input_data = input1, report_form = "Beta")
showplot(gwas_plots)
showplot(gwas_plots, exposure = "Zn")

# MR forest plots
mr_plots <- MR_forest(summary_df = outcome1, effect = "Beta")
showplot(mr_plots)
showplot(mr_plots, outcome = "fi_49item", exposure = "Zn")
```

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