Package 'getmstatistic'

July 22, 2025

Title Quantifying Systematic Heterogeneity in Meta-Analysis

Version 0.2.2

Description Quantifying systematic heterogeneity in meta-analysis using R. The M statistic aggregates heterogeneity information across multiple variants to, identify systematic heterogeneity patterns and their direction of effect in meta-analysis. It's primary use is to identify outlier studies, which either show ``null'' effects or consistently show stronger or weaker genetic effects than average across, the panel of variants examined in a GWAS meta-analysis. In contrast to conventional heterogeneity metrics (Q-statistic, I-squared and tau-squared) which measure random heterogeneity at individual variants, M measures systematic (non-random) heterogeneity across multiple independently associated variants. Systematic heterogeneity can arise in a meta-analysis due to differences in the study characteristics of participating studies. Some of the differences may include: ancestry, allele frequencies, phenotype definition, age-of-disease onset, family-history, gender, linkage disequilibrium and quality control thresholds. See <https://magosil86.github.io/getmstatistic/> for statistical statistical theory, documentation and examples.

Depends R (>= 3.1.0)

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URL https://magosil86.github.io/getmstatistic/

BugReports https://github.com/magosil86/getmstatistic/issues

LazyData true

Imports ggplot2 (>= 1.0.1), gridExtra (>= 0.9.1), gtable (>= 0.1.2), metafor (>= 1.9-6), psych (>= 1.5.1), stargazer (>= 5.1)

Suggests foreign (>= 0.8-62), knitr (>= 1.10.5), testthat, covr, rmarkdown

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VignetteBuilder knitr

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Contents

`draw_table` *Helper function to draw table grobs.*

Description

`draw_table()` Pre and post version: 2.0.0 gridExtra packages handle drawing tables differently. `draw_table()` determines the installed version of gridExtra and applies the appropriate syntax. If gridExtra version < 2.0.0 then it uses old gridExtra syntax to build table Grob(graphical object) else uses new syntax. `draw_table()`

Usage

```
draw_table(body, heading, ...)
```

Arguments

`body`	A dataframe. Table body.
`heading`	A string. Table title.
`...`	Further arguments to control the gtable.

Details

prints tables without rownames.

Acknowledgements

Thanks to Ryan Welch, https://github.com/welchr/LocusZoom/issues/16

Examples

```
library(gridExtra)

## Not run:

# Table of iris values
iris_dframe <- head(iris)
title_iris_dframe <- paste("Table: Length and width measurements (cm) of sepals and petals,",
                           "for 50 flowers from 3 species of iris (setosa, versicolor,",
                           "and virginica).\n", sep = " ")
# Wrap title text at column 60
title_iris_dframe <- sapply(strwrap(title_iris_dframe, width = 60, simplify = FALSE),
                            paste, collapse = "\n")
# Draw table
table_influential_studies <- draw_table(body = iris_dframe, heading = title_iris_dframe)

# Table of mtcars values
mtcars_dframe <- head(mtcars)
title_mtcars_dframe <- paste("Table: Motor Trend US magazine (1974) automobile statistics",
                          "for fuel consumption, \nautomobile design and performance.\n",
                             sep = " ")
# Wrap title text at column 60
title_mtcars_dframe <- sapply(strwrap(title_mtcars_dframe, width = 60, simplify = FALSE),
                              paste, collapse = "\n")
# Draw table
table_influential_studies <- draw_table(body = mtcars_dframe, heading = title_mtcars_dframe)

## End(Not run)
```

`getmstatistic` *Quantifying Systematic Heterogeneity in Meta-Analysis.*

Description

`getmstatistic` computes *M* statistics to assess the contribution of each participating study in a meta-analysis. The *M* statistic aggregates heterogeneity information across multiple variants to, identify systematic heterogeneity patterns and their direction of effect in meta-analysis. It's primary use is to identify outlier studies, which either show "null" effects or consistently show stronger or weaker genetic effects than average, across the panel of variants examined in a GWAS meta-analysis.

Usage

```
getmstatistic(beta_in, lambda_se_in, study_names_in, variant_names_in, ...)

## Default S3 method:
getmstatistic(
  beta_in,
  lambda_se_in,
```

```
  study_names_in,
  variant_names_in,
  save_dir = getwd(),
  tau2_method = "DL",
  x_axis_increment_in = 0.02,
  x_axis_round_in = 2,
  produce_plots = TRUE,
  verbose_output = FALSE,
  ...
)
```

Arguments

beta_in	A numeric vector of study effect-sizes e.g. log odds-ratios.
lambda_se_in	A numeric vector of standard errors, genomically corrected at study-level.
study_names_in	A character vector of study names.
variant_names_in	A character vector of variant names e.g. rsIDs.
...	Further arguments.
save_dir	A character scalar specifying a path to the directory where plots should be stored (optional). Required if produce_plots = TRUE.
tau2_method	A character scalar, method to estimate heterogeneity: either "DL" or "REML" (Optional). Note: The REML method uses the iterative Fisher scoring algorithm (step length = 0.5, maximum iterations = 10000) to estimate tau2.
x_axis_increment_in	A numeric scalar, value by which x-axis of M scatterplot will be incremented (Optional).
x_axis_round_in	A numeric scalar, value to which x-axis labels of M scatterplot will be rounded (Optional).
produce_plots	A boolean to generate plots (optional).
verbose_output	An optional boolean to display intermediate output.

Details

In contrast to conventional heterogeneity metrics (Q-statistic, I-squared and tau-squared) which measure random heterogeneity at individual variants, *M* measures systematic (non-random) heterogeneity across multiple independently associated variants.

Systematic heterogeneity can arise in a meta-analysis due to differences in the study characteristics of participating studies. Some of the differences may include: ancestry, allele frequencies, phenotype definition, age-of-disease onset, family-history, gender, linkage disequilibrium and quality control thresholds. See the getmstatistic website for statistical theory, documentation and examples.

`getmstatistic` uses summary data i.e. study effect-sizes and their corresponding standard errors to calculate *M* statistics (One *M* for each study in the meta-analysis).

In particular, `getmstatistic` employs the inverse-variance weighted random effects regression model provided in the `metafor` R package to extract SPREs (standardized predicted random effects) which are then aggregated to formulate *M* statistics.

Value

Returns a list containing:

- Mstatistic_expected_mean , A numeric scalar for the expected mean for M
- Mstatistic_expected_sd , A numeric scalar for the expected standard deviation for M
- number_studies , A numeric scalar for the number of studies
- number_variants , A numeric scalar for the number of variants
- Mstatistic_crit_alpha_0_05 , A numeric scalar of the critical M value at the 5 percent significance level.
- M_dataset (dataframe) A dataset of the computed M statistics, which includes the following fields:
  - M , Mstatistic
  - M_sd , standard deviation of M
  - M_se , standard error of M
  - lowerbound , lowerbound of M 95
  - upperbound , upperbound of M 95
  - bonfpvalue , 2-sided bonferroni pvalues of M
  - qvalue , false discovery rate adjusted pvalues of M
  - tau2 , tau_squared, DL estimates of between-study heterogeneity
  - I2 , I_squared, proportion of total variation due to between study variance
  - Q , Cochran's Q
  - xb , fitted values excluding random effects
  - usta , standardized predicted random effect (SPRE)
  - xbu , fitted values including random effects
  - stdxbu , standard error of prediction (fitted values) including random effects
  - hat , diagonal elements of the projection hat matrix
  - study , study numbers
  - snp , variant numbers
  - beta_mean , average variant effect size
  - oddsratio , average variant effect size as oddsratio
  - beta_n , number of variants in each study
- influential_studies_0_05 (dataframe) A dataset of influential studies significant at the 5 percent level.
- weaker_studies_0_05 (dataframe) A dataset of under-performing studies significant at the 5 percent level.

Methods (by class)

- `default`: Computes M statistics

See Also

`rma.uni` function in `metafor` for random effects model, and https://magosil86.github.io/getmstatistic/ for getmstatistic website.

Examples

```
library(getmstatistic)
library(gridExtra)


# Basic M analysis using the heartgenes214 dataset.
# heartgenes214 is a multi-ethnic GWAS meta-analysis dataset for coronary artery disease.
# To learn more about the heartgenes214 dataset ?heartgenes214

# Running an M analysis on 20 GWAS significant variants (p < 5e-08) in the first 10 studies

heartgenes44_10studies <- subset(heartgenes214, studies <= 10 & fdr214_gwas46 == 2)
heartgenes20_10studies <- subset(heartgenes44_10studies,
    variants %in% unique(heartgenes44_10studies$variants)[1:20])

# Set directory to store plots, this can be a temporary directory
# or a path to a directory of choice e.g. plots_dir <- "~/Downloads"
plots_dir <- tempdir()

getmstatistic_results <- getmstatistic(heartgenes20_10studies$beta_flipped,
                                       heartgenes20_10studies$gcse,
                                       heartgenes20_10studies$variants,
                                       heartgenes20_10studies$studies,
                                       save_dir = plots_dir)
getmstatistic_results

# Explore results generated by getmstatistic function

# Retrieve dataset of M statistics
dframe <- getmstatistic_results$M_dataset



str(dframe)


# Retrieve dataset of stronger than average studies (significant at 5% level)
getmstatistic_results$influential_studies_0_05

# Retrieve dataset of weaker than average studies (significant at 5% level)
getmstatistic_results$weaker_studies_0_05

# Retrieve number of studies and variants
getmstatistic_results$number_studies
getmstatistic_results$number_variants

# Retrieve expected mean, sd and critical M value at 5% significance level
getmstatistic_results$M_expected_mean
getmstatistic_results$M_expected_sd
getmstatistic_results$M_crit_alpha_0_05

# To view plots stored in a temporary directory, call `tempdir()` to view the directory path
```

```
tempdir()


# Additional examples: These take a little bit longer to run

## Not run:

# Set directory to store plots, this can be a temporary directory
# or a path to a directory of choice e.g. plots_dir <- "~/Downloads"
plots_dir <- tempdir()

# Run M analysis on all 214 lead variants
# heartgenes214 is a multi-ethnic GWAS meta-analysis dataset for coronary artery disease.
getmstatistic_results <- getmstatistic(heartgenes214$beta_flipped,
                                       heartgenes214$gcse,
                                       heartgenes214$variants,
                                       heartgenes214$studies,
                                       save_dir = plots_dir)
getmstatistic_results


# Subset the GWAS significant variants (p < 5e-08) in heartgenes214
heartgenes44 <- subset(heartgenes214, heartgenes214$fdr214_gwas46 == 2)

# Exploring getmstatistic options:
#     Estimate heterogeneity using "REML", default is "DL"
#     Modify x-axis of M scatterplot
#     Run M analysis verbosely
getmstatistic_results <- getmstatistic(heartgenes44$beta_flipped,
                                       heartgenes44$gcse,
                                       heartgenes44$variants,
                                       heartgenes44$studies,
                                       save_dir = plots_dir,
                                       tau2_method = "REML",
                                       x_axis_increment_in = 0.03,
                                       x_axis_round_in = 3,
                                       produce_plots = TRUE,
                                       verbose_output = TRUE)
getmstatistic_results



## End(Not run)
```

---

heartgenes214 *heartgenes214.*

Description

heartgenes214 is a multi-ethnic GWAS meta-analysis dataset for coronary artery disease.

Usage

```
heartgenes214
```

Format

A data frame with seven variables:

`beta_flipped` Effect-sizes expressed as log odds ratios. Numeric

`gcse` Standard errors

`studies` Names of participating studies

`variants` Names of genetic variants/SNPs

`cases` Number of cases in each participating study

`controls` Number of controls in each participating study

`fdr214_gwas46` Flag indicating GWAS significant variants, 1: Not GWAS-significant, 2: GWAS-significant

Details

It comprises summary data (effect-sizes and their corresponding standard errors) for 48 studies (68,801 cases and 123,504 controls), at 214 lead variants independently associated with coronary artery disease (P < 0.00005, FDR < 5%). Of the 214 lead variants, 44 are genome-wide significant (p < 5e-08). The meta-analysis dataset is based on individuals of: African American, Hispanic American, East Asian, South Asian, Middle Eastern and European ancestry.

The study effect-sizes have been flipped to ensure alignment of the effect alleles.

Standard errors were genomically corrected at the study-level.

Source

Magosi LE, Goel A, Hopewell JC, Farrall M, on behalf of the CARDIoGRAMplusC4D Consortium (2017) Identifying systematic heterogeneity patterns in genetic association meta-analysis studies. PLoS Genet 13(5): e1006755. https://doi.org/10.1371/journal.pgen.1006755.

https://magosil86.github.io/getmstatistic/

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