Package ‘decoupleR’

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Type Package

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Description Many methods allow us to extract biological activities from omics data using information from prior knowledge resources, reducing the dimensionality for increased statistical power and better interpretability. Here, we present decoupleR, a Bioconductor package containing different statistical methods to extract these signatures within a unified framework. decoupleR allows the user to flexibly test any method with any resource. It incorporates methods that take into account the sign and weight of network interactions. decoupleR can be used with any omic, as long as its features can be linked to a biological process based on prior knowledge. For example, in transcriptomics gene sets regulated by a transcription factor, or in phospho-proteomics phosphosites that are targeted by a kinase.

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decoupleR-package

decoupleR: Ensemble of computational methods to infer biological activities from omics data

Description

Many methods allow us to extract biological activities from omics data using information from prior knowledge resources, reducing the dimensionality for increased statistical power and better interpretability. Here, we present decoupleR, a Bioconductor package containing different statistical methods to extract these signatures within a unified framework. decoupleR allows the user to flexibly test any method with any resource. It incorporates methods that take into account the sign and weight of network interactions. decoupleR can be used with any omic, as long as its features can be linked to a biological process based on prior knowledge. For example, in transcriptomics gene sets regulated by a transcription factor, or in phospho-proteomics phosphosites that are targeted by a kinase.

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See Also

Useful links:
• https://saezlab.github.io/decoupleR/
• Report bugs at https://github.com/saezlab/decoupleR/issues

.decoupler_mat_format  DecoupleR mat format

Description
DecoupleR mat format

Arguments
mat  Matrix to evaluate (e.g. expression matrix). Target nodes in rows and conditions in columns. rownames(mat) must have at least one intersection with the elements in network .target column.

See Also
Other decoupleR formats: .decoupler_network_format

.decoupler_network_format  DecoupleR network format

Description
A network passed to any run_ method in the package must contain at least two attributes: .source and .target. In addition, the methods must map their corresponding metadata associated with their edges.

Arguments
network  Tibble or dataframe with edges and it’s associated metadata.
.source  Column with source nodes.
.target  Column with target nodes.
.mor  Column with edge mode of regulation (i.e. mor).
.likelihood  Deprecated argument. Now it will always be set to 1.
Details

- All the attributes to be mapped are prefixed by .
- The idea of using this type of mapping is to provide flexibility to different types of networks, be they regulatory, metabolic, or of any other type. This way, you should only consider having your network or networks in a long format and these can easily be manipulated by functions within the tidyverse ecosystem.

See Also

Other decoupleR formats: .decoupler_mat_format

Description

- If center is true, then the expression values are centered by the mean of expression across the samples.

Usage

.\fit_preprocessing(network, mat, center, na.rm, sparse)

Arguments

- network: Tibble or dataframe with edges and it’s associated metadata.
- mat: Matrix to evaluate (e.g. expression matrix). Target nodes in rows and conditions in columns. rownames(mat) must have at least one intersection with the elements in network .target column.
- center: Logical value indicating if mat must be centered by base::rowMeans()?
- na.rm: Should missing values (including NaN) be omitted from the calculations of base::rowMeans()?
- sparse: Deprecated parameter.

Value

A named list of matrices to evaluate in methods that fit models, like .mlm_analysis().

- mat: Features as rows and samples as columns.
- mor_mat: Features as rows and columns as source.

Examples

inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")
matt <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))
net <- rename_net(net, source, target, mor)
.\fit_preprocessing(net, mat, center = FALSE, na.rm = FALSE, sparse = FALSE)
### check_corr

**Check correlation (colinearity)**

**Description**

Checks the correlation across the regulators in a network.

**Usage**

```r
check_corr(
  network,
  .source = "source",
  .target = "target",
  .mor = "mor",
  .likelihood = NULL
)
```

**Arguments**

- **network**: Tibble or dataframe with edges and it's associated metadata.
- **.source**: Column with source nodes.
- **.target**: Column with target nodes.
- **.mor**: Column with edge mode of regulation (i.e. mor).
- **.likelihood**: Deprecated argument. Now it will always be set to 1.

**Value**

Correlation pairs tibble.

**Examples**

```r
inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")
net <- readRDS(file.path(inputs_dir, "net.rds"))
check_corr(net, .source='source')
```

---

### convert_f_defaults

**Rename columns and add defaults values if column not present**

**Description**

`convert_f_defaults()` combine the `dplyr::rename()` way of working and with the `tibble::add_column()` to add columns with default values in case they don’t exist after renaming data.
Usage

convert_f_defaults(.data, ..., .def_col_val = c(), .use_dots = TRUE)

Arguments

.data A data frame, data frame extension (e.g. a tibble), or a lazy data frame (e.g. from dbplyr or dtplyr). See Methods, below, for more details.

... For rename(): <tidy-select> Use new_name = old_name to rename selected variables.
For rename_with(): additional arguments passed onto .fn.

.def_col_val Named vector with columns with default values if none exist after rename.

.use_dots Should a dot prefix be added to renamed variables? This will allow swapping of columns.

Details

The objective of using .use_dots is to be able to swap columns which, by default, is not allowed by the dplyr::rename() function. The same behavior can be replicated by simply using the dplyr::select(), however, the select evaluation allows much more flexibility so that unexpected results could be obtained. Despite this, a future implementation will consider this form of execution to allow renaming the same column to multiple ones (i.e. extend dataframe extension).

Value

An object of the same type as .data. The output has the following properties:

• Rows are not affected.
• Column names are changed.
• Column order is the same as that of the function call.

Examples

df <- tibble::tibble(x = 1, y = 2, z = 3)

# Rename columns
df <- tibble::tibble(x = 1, y = 2)
convert_f_defaults(
  .data = df,
  new_x = x,
  new_y = y,
  new_z = NULL,
  .def_col_val = c(new_z = 3)
)
Evaluate multiple statistics with same input data

decouple

Description

Calculate the source activity per sample out of a gene expression matrix by coupling a regulatory network with a variety of statistics.

Usage

decouple(
    mat,
    network,
    .source = .data$source,
    .target = .data$target,
    statistics = NULL,
    args = list(NULL),
    consensus_score = TRUE,
    consensus_stats = NULL,
    include_time = FALSE,
    show_toy_call = FALSE,
    minsize = 5
)

Arguments

mat  Matrix to evaluate (e.g. expression matrix). Target nodes in rows and conditions in columns. rownames(mat) must have at least one intersection with the elements in network .target column.

network  Tibble or dataframe with edges and it’s associated metadata.

.source  Column with source nodes.

.target  Column with target nodes.

statistics  Statistical methods to be run sequentially. If none are provided, only top performer methods are run (mlm, ulm and wsum).

args  A list of argument-lists the same length as statistics (or length 1). The default argument, list(NULL), will be recycled to the same length as statistics, and will call each function with no arguments (apart from mat, network, .source and .target).

consensus_score  Boolean whether to run a consensus score between methods.

consensus_stats  List of estimate names to use for the calculation of the consensus score. This is used to filter out extra estimations from some methods, for example wsum returns wsum, corr_wsum and norm_wsum. If none are provided, and also no statistics where provided, only top performer methods are used (mlm, ulm and norm_wsum). Else, it will use all available estimates after running all methods in the statistics argument.
include_time Should the time per statistic evaluated be informed?
show_toy_call The call of each statistic must be informed?
minsize Integer indicating the minimum number of targets per source.

Value
A long format tibble of the enrichment scores for each source across the samples. Resulting tibble contains the following columns:

1. run_id: Indicates the order in which the methods have been executed.
2. statistic: Indicates which method is associated with which score.
3. source: Source nodes of network.
4. condition: Condition representing each column of mat.
5. score: Regulatory activity (enrichment score).
6. statistic_time: If requested, internal execution time indicator.
7. p_value: p-value (if available) of the obtained score.

See Also
Other decoupleR statistics: run_aucell(), run_fgsea(), run_gsva(), run_mdt(), run_mlm(), run_ora(), run_udt(), run_ulm(), run_viper(), run_wmean(), run_wsum()

Examples
if (FALSE) {
  inputs_dir <- system.file("testdata", "inputs", package = "decoupleR"

mat <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))

decouple(
  mat = mat,
  network = net,
  .source = "source",
  .target = "target",
  statistics = c("gsva", "wmean", "wsum", "ulm", "aucell"),
  args = list(
    gsva = list(verbos = FALSE),
    wmean = list(.mor = "mor", .likelihood = "likelihood"),
    wsum = list(.mor = "mor"),
    ulm = list(.mor = "mor")
  ),
  minsize = 0
)
**extract_sets**

*Extract sets*

**Description**

Extracts feature sets from a renamed network (see `rename_net`).

**Usage**

`extract_sets(network)`

**Arguments**

- `network`: Tibble or dataframe with edges and it's associated metadata.

**Examples**

```r
inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")
mat <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))
net <- rename_net(net, source, target, mor)
extract_sets(net)
```

---

**filt_minsize**

*Filter sources with minsize targets*

**Description**

Filter sources of a net with less than minsize targets

**Usage**

`filt_minsize(mat_f_names, network, minsize = 5)`

**Arguments**

- `mat_f_names`: Feature names of mat.
- `network`: Tibble or dataframe with edges and it’s associated metadata.
- `minsize`: Integer indicating the minimum number of targets per source.

**Value**

Filtered network.
**Examples**

```r
inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")
mat <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))
net <- rename_net(net, source, target, mor)
filt_minsize(rownames(mat), net, minsize = 4)
```

---

**get_collectri**  
*CollecTRI gene regulatory network. Wrapper to access CollecTRI gene regulatory network. CollecTRI is a comprehensive resource containing a curated collection of transcription factors (TFs) and their target genes. It is an expansion of DoRothEA. Each interaction is weighted by its mode of regulation (either positive or negative).*

**Description**

CollecTRI gene regulatory network. Wrapper to access CollecTRI gene regulatory network. CollecTRI is a comprehensive resource containing a curated collection of transcription factors (TFs) and their target genes. It is an expansion of DoRothEA. Each interaction is weighted by its mode of regulation (either positive or negative).

**Usage**

```r
get_collectri(organism = "human", split_complexes = FALSE)
```

**Arguments**

- **organism**  
  Which organism to use. Only human and mouse are available.

- **split_complexes**  
  Whether to split complexes into subunits. By default complexes are kept as they are.

**Examples**

```r
collectri <- get_collectri(organism="human", split_complexes=FALSE)
```

---

**get_dorothea**  
*DoRothEA gene regulatory network.*

**Description**

Wrapper to access DoRothEA gene regulatory network. DoRothEA is a comprehensive resource containing a curated collection of transcription factors (TFs) and their target genes. Each interaction is weighted by its mode of regulation (either positive or negative) and by its confidence level.
get_ksn_omnipath

Usage

get_dorothea(
  organism = "human",
  levels = c("A", "B", "C"),
  weight_dict = list(A = 1, B = 2, C = 3, D = 4)
)

Arguments

  organism  Which organism to use. Only human and mouse are available.
  levels    List of confidence levels to return. Goes from A to D, A being the most confident and D being the less.
  weight_dict Dictionary of values to divide the mode of regulation (-1 or 1), one for each confidence level. Bigger values will generate weights close to zero.

Examples

dorothea <- get_dorothea(organism='human', levels=c('A', 'B', 'C'))

get_ksn_omnipath  OmniPath kinase-substrate network

Description

Retrieve a ready to use, curated kinase-substrate Network from the OmniPath database.

Usage

get_ksn_omnipath(...)

Arguments

...  Passed to OmnipathR::import_omnipath_enzsub.

Details

Import enzyme-PTM network from OmniPath, then filter out anything that is not phospho or dephosphorilation. Then format the columns for use with decoupleR functions.
get_profile_of

Complete a data frame with missing combinations of data

Description

Turns implicit missing values into explicit missing values. This is a wrapper around expand(), dplyr::full_join() and replace_na() that’s useful for completing missing combinations of data.

Usage

generate_profile_of(data, sources, values_fill = NA)

Arguments

data A data frame.
sources A named vector or list with the values to expand and get profile.
values_fill Optionally, a (scalar) value that specifies what each value should be filled in with when missing.

This can be a named list if you want to apply different fill values to different value columns.

Value

A data frame with the expanded grid of the values passed in sources and filled as specified in the fill argument.

See Also

complete expand

Examples

## Not run:
library(dplyr, warn.conflicts = FALSE)
df <- tibble(
  group = c(1:2, 1),
  item_id = c(1:2, 2),
  item_name = c("a", "b", "b"),
  value1 = 1:3,
  value2 = 4:6
)
to_get_profile <- list(group = c(1, 2, 3), item_id = c(1, 2))

# This will add the combinations of group 3 with the id of the items
df %>% get_profile_of(sources = to_get_profile)
# You can also choose to fill in missing values
# This only fill with "Unknown" the NA values of the column item_name
df %>% get_profile_of(
  sources = to_get_profile,
  values_fill = list(item_name = "Unknown")
)

# Replace all NAs with "Unknown"
df %>% get_profile_of(sources = to_get_profile, values_fill = "Unknown")
## End(Not run)

---

**get_progeny**

Pathway RespOnsive GENes for activity inference (PROGENy).

### Description

Wrapper to access PROGENy model gene weights. Each pathway is defined with a collection of target genes, each interaction has an associated p-value and weight. The top significant interactions per pathway are returned.

### Usage

```r
get_progeny(organism = "human", top = 500)
```

### Arguments

- `organism`  
  Which organism to use. Only human and mouse are available.

- `top`  
  Number of genes per pathway to return.

### Examples

```r
progeny <- get_progeny(organism = 'human', top = 500)
```

---

**get_resource**

Wrapper to access resources inside Omnipath. This wrapper allows to easily query different prior knowledge resources. To check available resources run decoupleR::show_resources(). For more information visit the official website for Omnipath.

### Description

Wrapper to access resources inside Omnipath. This wrapper allows to easily query different prior knowledge resources. To check available resources run decoupleR::show_resources(). For more information visit the official website for Omnipath.
get_toy_data

Usage

get_resource(name)

Arguments

name Name of the resource to query.

Examples

df <- decoupleR::get_resource('SIGNOR')

get_toy_data

Generate a toy mat and network.

Description

Generate a toy mat and network.

Usage

get_toy_data(n_samples = 24, seed = 42)

Arguments

n_samples Number of samples to simulate.
seed A single value, interpreted as an integer, or NULL for random number generation.

Value

List containing mat and network.

Examples

data <- get_toy_data()
mat <- data$mat
network <- data$network
intersect_regulons  
**Intersect network target features with input matrix.**

**Description**

Keep only edges which its target features belong to the input matrix.

**Usage**

```
intersect_regulons(mat, network, .source, .target, minsize)
```

**Arguments**

- `mat`: Matrix to evaluate (e.g. expression matrix). Target nodes in rows and conditions in columns. `rownames(mat)` must have at least one intersection with the elements in `network .target` column.
- `network`: Tibble or dataframe with edges and it’s associated metadata.
- `.source`: Column with source nodes.
- `.target`: Column with target nodes.
- `minsize`: Minimum number of targets per source allowed.

**Value**

Filtered tibble.

**Examples**

```
inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")
mat <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))
intersect_regulons(mat, net, source, target, minsize=4)
```

---

**pivot_wider_profile  
Pivot a data frame to wider and convert it to matrix**

**Description**

Generates a kind of table where the rows come from `id_cols`, the columns from `names_from` and the values from `values_from`. 
**Usage**

```r
pivot_wider_profile(
    data,
    id_cols,
    names_from,
    values_from,
    values_fill = NA,
    to_matrix = FALSE,
    to_sparse = FALSE,
    ...)
```

**Arguments**

- **data**
  A data frame to pivot.

- **id_cols**
  
  A set of columns that uniquely identify each observation. Typically used when you have redundant variables, i.e., variables whose values are perfectly correlated with existing variables. Defaults to all columns in `data` except for the columns specified through `names_from` and `values_from`. If a tidyselect expression is supplied, it will be evaluated on `data` after removing the columns specified through `names_from` and `values_from`.

- **names_from, values_from**
  
  A pair of arguments describing which column (or columns) to get the name of the output column (`names_from`), and which column (or columns) to get the cell values from (`values_from`). If `values_from` contains multiple values, the value will be added to the front of the output column.

- **values_fill**
  Optionally, a (scalar) value that specifies what each value should be filled in with when missing. This can be a named list if you want to apply different fill values to different value columns.

- **to_matrix**
  Logical value indicating if the result should be a matrix. Parameter is ignored in case `sparse` is `TRUE`.

- **to_sparse**
  Logical value indicating whether the resulting matrix should be sparse or not.

- **...**
  Additional arguments passed on to methods.

**Details**

In the current state of the function, to ensure its operation, the `id_cols` parameter is a single selector.

**Value**

"widened" data; it is increasing the number of columns and decreasing the number of rows.
### Examples

```r
## Not run:
df <- tibble::tibble(
  tf = c("tf_1", "tf_1", "tf_2", "tf_2"),
  gene = c("gene_1", "gene_2", "gene_1", "gene_2"),
  mor = c(1, -1, 1, -1)
)

# Return a tibble
pivot_wider_profile(
  data = df,
  id_cols = tf,
  names_from = gene,
  values_from = mor
)

# Return a matrix
pivot_wider_profile(
  data = df,
  id_cols = tf,
  names_from = gene,
  values_from = mor,
  to_matrix = TRUE
)

# Return a sparse Matrix of class "dgCMatrix"
pivot_wider_profile(
  data = df,
  id_cols = tf,
  names_from = gene,
  values_from = mor,
  to_sparse = TRUE
)

## End(Not run)
```

### randomize_matrix

Randomize matrix

#### Description

Utility function used in functions that require permutations of the expression matrix

#### Usage

```r
randomize_matrix(mat, randomize_type = c("rows", "cols_independently"))
```

#### Arguments

- `mat`: Matrix to randomize.
- `randomize_type`: How to randomize.
rename_net

Value

Randomized matrix

Examples

```r
## Not run:
mat <- matrix(seq_len(9), ncol = 3)
mat

set.seed(42)
randomize_matrix(mat, randomize_type = "rows")

set.seed(42)
randomize_matrix(mat, randomize_type = "cols_independently")

## End(Not run)
```

rename_net  Rename network

Description

Renames a given network to these column names: .source, .target, .mor. If .mor is not provided, then the function sets them to default values.

Usage

```r
rename_net(
  network,
  .source,
  .target,
  .mor = NULL,
  .likelihood = NULL,
  def_mor = 1
)
```

Arguments

- `network`: Tibble or dataframe with edges and it’s associated metadata.
- `source`: Column with source nodes.
- `target`: Column with target nodes.
- `mor`: Column with edge mode of regulation (i.e. mor).
- `likelihood`: Deprecated argument. Now it will always be set to 1.
- `def_mor`: Default value for .mor when not provided.
Examples

```r
inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")
mat <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))
rename_net(net, source, target, mor)
```

---

**run_aucell**

**AUCell**

---

### Description

Calculates regulatory activities using AUCell.

### Usage

```r
run_aucell(
  mat, 
  network, 
  .source = .data$source, 
  .target = .data$target, 
  aucMaxRank = ceiling(0.05 * nrow(rankings)), 
  nproc = 4, 
  seed = 42, 
  minsize = 5
)
```

### Arguments

- **mat**: Matrix to evaluate (e.g. expression matrix). Target nodes in rows and conditions in columns. `rownames(mat)` must have at least one intersection with the elements in `network .target` column.
- **network**: Tibble or dataframe with edges and it's associated metadata.
- **.source**: Column with source nodes.
- **.target**: Column with target nodes.
- **aucMaxRank**: Threshold to calculate the AUC.
- **nproc**: Number of cores to use for computation.
- **seed**: A single value, interpreted as an integer, or NULL for random number generation.
- **minsize**: Integer indicating the minimum number of targets per source.
Details

AUCell (Aibar et al., 2017) uses the Area Under the Curve (AUC) to calculate whether a set of targets is enriched within the molecular readouts of each sample. To do so, AUCell first ranks the molecular features of each sample from highest to lowest value, resolving ties randomly. Then, an AUC can be calculated using by default the top 5% molecular features in the ranking. Therefore, this metric, aucell, represents the proportion of abundant molecular features in the target set, and their relative abundance value compared to the other features within the sample.


See Also

Other decoupleR statistics: decouple(), run_fgsea(), run_gsva(), run_mdt(), run_mlm(), run_ora(), run_udt(), run_ulm(), run_viper(), run_wmean(), run_wsum()

Examples

```r
inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")

mat <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))

run_aucell(mat, net, minsize=0, nproc=1, aucMaxRank=3)
```

---

**run_consensus**

<table>
<thead>
<tr>
<th>Consensus score between methods</th>
</tr>
</thead>
</table>

Description

Function to generate a consensus score between methods from the result of the decouple function.

Usage

```
run_consensus(df, include_time = FALSE, seed = NULL)
```

Arguments

- `df` decouple data frame result
- `include_time` Should the time per statistic evaluated be informed?
- `seed` Deprecated parameter.

Value

Updated tibble with the computed consensus score between methods
Examples
inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")
mat <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))

results <- decouple(
  mat = mat,
  network = net,
  .source = "source",
  .target = "target",
  statistics = c("wmean", "ulm"),
  args = list(
    wmean = list(.mor = "mor", .likelihood = "likelihood"),
    ulm = list(.mor = "mor", .likelihood = "likelihood")
  ),
  consensus_score = FALSE,
  minsize = 0
)
run_consensus(results)

run_fgsea

Fast Gene Set Enrichment Analysis (FGSEA)

Description
Calculates regulatory activities using FGSEA.

Usage
run_fgsea(
  mat,
  network,
  .source = .data$source,
  .target = .data$target,
  times = 100,
  nproc = 4,
  seed = 42,
  minsize = 5,
  ...
)

Arguments
mat Matrix to evaluate (e.g. expression matrix). Target nodes in rows and conditions in columns. rownames(mat) must have at least one intersection with the elements in network .target column.

network Tibble or dataframe with edges and it’s associated metadata.

.source Column with source nodes.
.target  Column with target nodes.
times  How many permutations to do?
nproc  Number of cores to use for computation.
seed  A single value, interpreted as an integer, or NULL.
minsize  Integer indicating the minimum number of targets per source.
  ...  Arguments passed on to fgsea::fgseaMultilevel
sampleSize  The size of a random set of genes which in turn has size = pathwaySize
minSize  Minimal size of a gene set to test. All pathways below the threshold are excluded.
maxSize  Maximal size of a gene set to test. All pathways above the threshold are excluded.
eps  This parameter sets the boundary for calculating the p value.
scoreType  This parameter defines the GSEA score type. Possible options are ("std", "pos", "neg")
gseaParam  GSEA parameter value, all gene-level stats are raised to the power of 'gseaParam' before calculation of GSEA enrichment scores.
BPPARAM  Parallelization parameter used in bplapply. Can be used to specify cluster to run. If not initialized explicitly or by setting 'nproc' default value 'bpparam()' is used.
absEps  deprecated, use 'eps' parameter instead

Details

GSEA (Aravind et al., 2005) starts by transforming the input molecular readouts in mat to ranks for each sample. Then, an enrichment score $\text{fgsea}$ is calculated by walking down the list of features, increasing a running-sum statistic when a feature in the target feature set is encountered and decreasing it when it is not. The final score is the maximum deviation from zero encountered in the random walk. Finally, a normalized score $\text{norm fgsea}$, can be obtained by computing the z-score of the estimate compared to a null distribution obtained from $N$ random permutations. The used implementation is taken from the package fgsea (Korotkevich et al., 2021).


Value

A long format tibble of the enrichment scores for each source across the samples. Resulting tibble contains the following columns:

1. statistic: Indicates which method is associated with which score.
2. source: Source nodes of network.
3. condition: Condition representing each column of mat.
4. score: Regulatory activity (enrichment score).
run_gsva

See Also

Other decoupleR statistics: decouple(), run_aucell(), run_gsva(), run_mdt(), run_mlm(), run_ora(), run_udt(), run_ulm(), run_viper(), run_wmean(), run_wsum()

Examples

inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")
mat <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))
run_fgsea(mat, net, minsize=0, nproc=1)

run_gsva  

Gene Set Variation Analysis (GSVA)

Description

Calculates regulatory activities using GSVA.

Usage

run_gsva(
  mat,
  network,
  .source = .data$source,
  .target = .data$target,
  verbose = FALSE,
  method = "gsva",
  minsize = 5,
  ...)

Arguments

mat  
Matrix to evaluate (e.g. expression matrix). Target nodes in rows and conditions in columns. rownames(mat) must have at least one intersection with the elements in network .target column.

network  
Tibble or dataframe with edges and it’s associated metadata.

[source]  
Column with source nodes.

target  
Column with target nodes.

verbose  
Gives information about each calculation step. Default: FALSE.

method  
Method to employ in the estimation of gene-set enrichment. scores per sample. By default this is set to gsva (Hänzelmann et al., 2013).

minsize  
Integer indicating the minimum number of targets per source.

...  
Arguments passed on to GSVA::gsva
Details

GSVA (Hänzelmann et al., 2013) starts by transforming the input molecular readouts in mat to a readout-level statistic using Gaussian kernel estimation of the cumulative density function. Then, readout-level statistics are ranked per sample and normalized to up-weight the two tails of the rank distribution. Afterwards, an enrichment score gsva is calculated using a running sum statistic that is normalized by subtracting the largest negative estimate from the largest positive one.


Value

A long format tibble of the enrichment scores for each source across the samples. Resulting tibble contains the following columns:

1. statistic: Indicates which method is associated with which score.
2. source: Source nodes of network.
3. condition: Condition representing each column of mat.
4. score: Regulatory activity (enrichment score).

See Also

Other decoupleR statistics: decouple(), run_aucell(), run_fgsea(), run_mdt(), run_mlm(), run_ora(), run_udt(), run_ulf(), run_viper(), run_wmean(), run_wsum()

Examples

```r
inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")
mat <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))
run_gsva(mat, net, minsize=0, verbose = FALSE)
```

---

**run_mdt**  
**Multivariate Decision Trees (MDT)**

Description

Calculates regulatory activities using MDT.
run_mdt

Usage

run_mdt(
  mat,
  network,
  .source = .data$source,
  .target = .data$target,
  .mor = .data$mor,
  .likelihood = .data$likelihood,
  sparse = FALSE,
  center = FALSE,
  na.rm = FALSE,
  trees = 10,
  min_n = 20,
  nproc = 4,
  seed = 42,
  minsize = 5
)

Arguments

mat Matrix to evaluate (e.g. expression matrix). Target nodes in rows and conditions in columns. rownames(mat) must have at least one intersection with the elements in network .target column.

network Tibble or dataframe with edges and it’s associated metadata.

.source Column with source nodes.

.target Column with target nodes.

.mor Column with edge mode of regulation (i.e. mor).

.likelihood Deprecated argument. Now it will always be set to 1.

.sparse Deprecated parameter.

center Logical value indicating if mat must be centered by base::rowMeans().

.na.rm Should missing values (including NaN) be omitted from the calculations of base::rowMeans()?

trees An integer for the number of trees contained in the ensemble.

.min_n An integer for the minimum number of data points in a node that are required for the node to be split further.

.nproc Number of cores to use for computation.

.seed A single value, interpreted as an integer, or NULL for random number generation.

.minsize Integer indicating the minimum number of targets per source.

Details

MDT fits a multivariate regression random forest for each sample, where the observed molecular readouts in mat are the response variable and the regulator weights in net are the covariates. Target features with no associated weight are set to zero. The obtained feature importances from the fitted model are the activities mdt of the regulators in net.
run_mlm

**Value**
A long format tibble of the enrichment scores for each source across the samples. Resulting tibble contains the following columns:

1. statistic: Indicates which method is associated with which score.
2. source: Source nodes of network.
3. condition: Condition representing each column of mat.
4. score: Regulatory activity (enrichment score).

**See Also**
Other decoupleR statistics: **decouple(), run_aucell(), run_fgsea(), run_gsva(), run_mlm(), run_ora(), run_udt(), run_ulm(), run_viper(), run_wmean(), run_wsum()**

**Examples**
```r
inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")
mat <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))
run_mdt(mat, net, minsize=0)
```

---

**run_mlm**

*Multivariate Linear Model (MLM)*

**Description**
Calculates regulatory activities using MLM.

**Usage**
```r
run_mlm(
  mat,
  network,
  .source = .data$source,
  .target = .data$target,
  .mor = .data$mor,
  .likelihood = .data$likelihood,
  sparse = FALSE,
  center = FALSE,
  na.rm = FALSE,
  minsize = 5
)
```
Arguments

mat        Matrix to evaluate (e.g. expression matrix). Target nodes in rows and conditions in columns. rownames(mat) must have at least one intersection with the elements in network .target column.

network    Tibble or dataframe with edges and its associated metadata.

.source    Column with source nodes.

.target    Column with target nodes.

.mor       Column with edge mode of regulation (i.e. mor).

.likelihood Deprecated argument. Now it will always be set to 1.

.sparse    Deprecated parameter.

.center    Logical value indicating if mat must be centered by base::rowMeans()?

.na.rm     Should missing values (including NaN) be omitted from the calculations of base::rowMeans()? 

.minsize   Integer indicating the minimum number of targets per source.

Details

MLM fits a multivariate linear model for each sample, where the observed molecular readouts in mat are the response variable and the regulator weights in net are the covariates. Target features with no associated weight are set to zero. The obtained t-values from the fitted model are the activities (mlm) of the regulators in net.

Value

A long format tibble of the enrichment scores for each source across the samples. Resulting tibble contains the following columns:

1. statistic: Indicates which method is associated with which score.
2. source: Source nodes of network.
3. condition: Condition representing each column of mat.
4. score: Regulatory activity (enrichment score).

See Also

Other decoupleR statistics: decouple(), run_aucell(), run_fgsea(), run_gsva(), run_mdt(), run_ora(), run_udt(), run_uml(), run_viper(), run_wmean(), run_wsum()

Examples

```r
inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")

mat <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))

run_mlm(mat, net, minsize=0)
```
Over Representation Analysis (ORA)

Description

Calculates regulatory activities using ORA.

Usage

```r
run_ora(
  mat,
  network,
  .source = .data$source,
  .target = .data$target,
  n_up = ceiling(0.05 * nrow(mat)),
  n_bottom = 0,
  n_background = 20000,
  with_ties = TRUE,
  seed = 42,
  minsize = 5,
  ...
)
```

Arguments

- `mat` Matrix to evaluate (e.g. expression matrix). Target nodes in rows and conditions in columns. `rownames(mat)` must have at least one intersection with the elements in `network\.target` column.
- `network` Tibble or dataframe with edges and it’s associated metadata.
- `.source` Column with source nodes.
- `.target` Column with target nodes.
- `n_up` Integer indicating the number of top targets to slice from mat.
- `n_bottom` Integer indicating the number of bottom targets to slice from mat.
- `n_background` Integer indicating the background size of the sliced targets. If not specified the number of background targets is determined by the total number of unique targets in the union of `mat` and `network`.
- `with_ties` Should ties be kept together? The default, TRUE, may return more rows than you request. Use FALSE to ignore ties, and return the first `n` rows.
- `seed` A single value, interpreted as an integer, or NULL for random number generation.
- `minsize` Integer indicating the minimum number of targets per source.
- `...` Arguments passed on to `stats::fisher.test`
workspace  an integer specifying the size of the workspace used in the network algorithm. In units of 4 bytes. Only used for non-simulated p-values larger than $2 \times 2$ tables. Since R version 3.5.0, this also increases the internal stack size which allows larger problems to be solved, however sometimes needing hours. In such cases, simulate.p.values=TRUE may be more reasonable.

hybrid  a logical. Only used for larger than $2 \times 2$ tables, in which cases it indicates whether the exact probabilities (default) or a hybrid approximation thereof should be computed.

hybridPars  a numeric vector of length 3, by default describing “Cochran’s conditions” for the validity of the chisquare approximation, see ‘Details’.

control  a list with named components for low level algorithm control. At present the only one used is "mult", a positive integer $\geq 2$ with default 30 used only for larger than $2 \times 2$ tables. This says how many times as much space should be allocated to paths as to keys: see file ‘fexact.c’ in the sources of this package.

or  the hypothesized odds ratio. Only used in the $2 \times 2$ case.

alternative  indicates the alternative hypothesis and must be one of "two.sided", "greater" or "less". You can specify just the initial letter. Only used in the $2 \times 2$ case.

conf.int  logical indicating if a confidence interval for the odds ratio in a $2 \times 2$ table should be computed (and returned).

conf.level  confidence level for the returned confidence interval. Only used in the $2 \times 2$ case and if conf.int = TRUE.

simulate.p.value  a logical indicating whether to compute p-values by Monte Carlo simulation, in larger than $2 \times 2$ tables.

B  an integer specifying the number of replicates used in the Monte Carlo test.

Details

ORA measures the overlap between the target feature set and a list of most altered molecular features in mat. The most altered molecular features can be selected from the top and or bottom of the molecular readout distribution, by default it is the top 5% positive values. With these, a contingency table is build and a one-tailed Fisher's exact test is computed to determine if a regulator's set of features are over-represented in the selected features from the data. The resulting score, ora, is the minus log10 of the obtained p-value.

Value

A long format tibble of the enrichment scores for each source across the samples. Resulting tibble contains the following columns:

1. statistic: Indicates which method is associated with which score.
2. source: Source nodes of network.
3. condition: Condition representing each column of mat.
4. score: Regulatory activity (enrichment score).
See Also

Other decoupleR statistics: decouple(), run_aucell(), run_fgsea(), run_gsva(), run_mdt(), run_mlm(), run_udt(), run_ulm(), run_viper(), run_wmean(), run_wsum()

Examples

```r
inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")
mat <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))
run_ora(mat, net, minsize=0)
```

---

**run_udt**

*Univariate Decision Tree (UDT)*

**Description**

Calculates regulatory activities by using UDT.

**Usage**

```r
run_udt(
  mat,  
  network,  
  .source = .data$s-source,  
  .target = .data$s-target,  
  .mor = .data$s-mor,  
  .likelihood = .data$s-likelihood,  
  sparse = FALSE,  
  center = FALSE,  
  na.rm = FALSE,  
  min_n = 20,  
  seed = 42,  
  minsize = 5  
)
```

**Arguments**

- **mat**: Matrix to evaluate (e.g. expression matrix). Target nodes in rows and conditions in columns. `rownames(mat)` must have at least one intersection with the elements in `network .target` column.
- **network**: Tibble or dataframe with edges and it’s associated metadata.
- **.source**: Column with source nodes.
- **.target**: Column with target nodes.
- **.mor**: Column with edge mode of regulation (i.e. mor).
.likelihood Deprecated argument. Now it will always be set to 1.
sparse Deprecated parameter.
center Logical value indicating if mat must be centered by `base::rowMeans()`.
na.rm Should missing values (including NaN) be omitted from the calculations of `base::rowMeans()`?
min_n An integer for the minimum number of data points in a node that are required for the node to be split further.
seed A single value, interpreted as an integer, or NULL for random number generation.
minsize Integer indicating the minimum number of targets per source.

Details

UDT fits a single regression decision tree for each sample and regulator, where the observed molecular readouts in mat are the response variable and the regulator weights in net are the explanatory one. Target features with no associated weight are set to zero. The obtained feature importance from the fitted model is the activity `udt` of a given regulator.

Value

A long format tibble of the enrichment scores for each source across the samples. Resulting tibble contains the following columns:

1. statistic: Indicates which method is associated with which score.
2. source: Source nodes of network.
3. condition: Condition representing each column of mat.
4. score: Regulatory activity (enrichment score).

See Also

Other decoupleR statistics: `decouple()`, `run_aucell()`, `run_fgsea()`, `run_gsva()`, `run_mdt()`, `run_mlm()`, `run_ora()`, `run_ulm()`, `run_viper()`, `run_wmean()`, `run_wsum()`

Examples

```r
inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")

mat <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))

run_udt(mat, net, minsize=0)
```
Description

Calculates regulatory activities using ULM.

Usage

run_ulm(
  mat,
  network,
  .source = .data$source,
  .target = .data$target,
  .mor = .data$mor,
  .likelihood = .data$likelihood,
  sparse = FALSE,
  center = FALSE,
  na.rm = FALSE,
  minsize = 5
)

Arguments

- **mat**: Matrix to evaluate (e.g., expression matrix). Target nodes in rows and conditions in columns. `rownames(mat)` must have at least one intersection with the elements in `network .target` column.
- **network**: Tibble or dataframe with edges and its associated metadata.
- **.source**: Column with source nodes.
- **.target**: Column with target nodes.
- **.mor**: Column with edge mode of regulation (i.e., mor).
- **.likelihood**: Deprecated argument. Now it will always be set to 1.
- **sparse**: Deprecated parameter.
- **center**: Logical value indicating if `mat` must be centered by `base::rowMeans()`.
- **na.rm**: Should missing values (including NaN) be omitted from the calculations of `base::rowMeans()`?
- **minsize**: Integer indicating the minimum number of targets per source.

Details

ULM fits a linear model for each sample and regulator, where the observed molecular readouts in `mat` are the response variable and the regulator weights in `net` are the explanatory one. Target features with no associated weight are set to zero. The obtained t-value from the fitted model is the activity `ulm` of a given regulator.
Value

A long format tibble of the enrichment scores for each source across the samples. Resulting tibble contains the following columns:

1. statistic: Indicates which method is associated with which score.
2. source: Source nodes of network.
3. condition: Condition representing each column of mat.
4. score: Regulatory activity (enrichment score).

See Also

Other decoupleR statistics: `decouple()`, `run_aucell()`, `run_fgsea()`, `run_gsva()`, `run_mdt()`, `run_mlm()`, `run_ora()`, `run_udt()`, `run_viper()`, `run_wmean()`, `run_wsum()`

Examples

```r
inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")

mat <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))

run_viper(mat, net, minsize=0)
```

Description

Calculates regulatory activities using VIPER.

Usage

```r
run_viper(
  mat,
  network,
  .source = .data$source,
  .target = .data$target,
  .mor = .data$mor,
  .likelihood = .data$likelihood,
  verbose = FALSE,
  minsize = 5,
  pleiotropy = TRUE,
  eset.filter = FALSE,
  ...
)
```
Arguments

- **mat**: Matrix to evaluate (e.g., expression matrix). Target nodes in rows and conditions in columns. `rownames(mat)` must have at least one intersection with the elements in `network.target` column.
- **network**: Tibble or dataframe with edges and its associated metadata.
- **.source**: Column with source nodes.
- **.target**: Column with target nodes.
- **.mor**: Column with edge mode of regulation (i.e., `mor`).
- **.likelihood**: Deprecated argument. Now it will always be set to 1.
- **verbose**: Logical, whether progression messages should be printed in the terminal.
- **minsize**: Integer indicating the minimum number of targets per source.
- **pleiotropy**: Logical, whether correction for pleiotropic regulation should be performed.
- **eset.filter**: Logical, whether the dataset should be limited only to the genes represented in the interactome.

... Arguments passed on to `viper::viper`

- **dnull**: Numeric matrix for the null model, usually generated by `nullTtest`
- **nes**: Logical, whether the enrichment score reported should be normalized
- **method**: Character string indicating the method for computing the single samples signature, either `scale`, `rank`, `mad`, `ttest` or `none`
- **bootstraps**: Integer indicating the number of bootstraps iterations to perform. Only the `scale` method is implemented with bootstraps.
- **adaptive.size**: Logical, whether the weighting scores should be taken into account for computing the regulon size
- **pleiotropyArgs**: list of 5 numbers for the pleiotropy correction indicating: regulators p-value threshold, pleiotropic interaction p-value threshold, minimum number of targets in the overlap between pleiotropic regulators, penalty for the pleiotropic interactions and the method for computing the pleiotropy, either absolute or adaptive
- **cores**: Integer indicating the number of cores to use (only 1 in Windows-based systems)

Details

VIPER (Alvarez et al., 2016) estimates biological activities by performing a three-tailed enrichment score calculation. For further information check the supplementary information of the decoupler manuscript or the original publication.


Value

A long format tibble of the enrichment scores for each source across the samples. Resulting tibble contains the following columns:
1. statistic: Indicates which method is associated with which score.
2. source: Source nodes of network.
3. condition: Condition representing each column of mat.
4. score: Regulatory activity (enrichment score).

See Also

Other decoupleR statistics: `decouple()`, `run_aucell()`, `run_fgsea()`, `run_gsva()`, `run_mdt()`, `run_mlm()`, `run_ora()`, `run_udt()`, `run_ulm()`, `run_wmean()`, `run_wsum()`

Examples

```r
inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")
mat <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))
run_viper(mat, net, minsize=0, verbose = FALSE)
```

---

**run_wmean**

**Weighted Mean (WMEAN)**

**Description**

Calculates regulatory activities using WMEAN.

**Usage**

```r
run_wmean(
  mat,
  network,
  .source = .data$source,
  .target = .data$target,
  .mor = .data$mor,
  .likelihood = .data$likelihood,
  times = 100,
  seed = 42,
  sparse = TRUE,
  randomize_type = "rows",
  minsize = 5
)
```
Arguments

mat Matrix to evaluate (e.g. expression matrix). Target nodes in rows and conditions in columns. rownames(mat) must have at least one intersection with the elements in network .target column.

network Tibble or dataframe with edges and it's associated metadata.

[source] Column with source nodes.

[target] Column with target nodes.

[mor] Column with edge mode of regulation (i.e. mor).

[likelihood] Deprecated argument. Now it will always be set to 1.

times How many permutations to do?

[seed] A single value, interpreted as an integer, or NULL for random number generation.

[sparse] Should the matrices used for the calculation be sparse?

[randomize_type] How to randomize the expression matrix.

[minsize] Integer indicating the minimum number of targets per source.

Details

WMEAN infers regulator activities by first multiplying each target feature by its associated weight which then are summed to an enrichment score wmean. Furthermore, permutations of random target features can be performed to obtain a null distribution that can be used to compute a z-score norm_wmean, or a corrected estimate corr_wmean by multiplying wmean by the minus log10 of the obtained empirical p-value.

Value

A long format tibble of the enrichment scores for each source across the samples. Resulting tibble contains the following columns:

1. statistic: Indicates which method is associated with which score.
2. source: Source nodes of network.
3. condition: Condition representing each column of mat.
4. score: Regulatory activity (enrichment score).
5. p_value: p-value for the score of the method.

See Also

Other decoupleR statistics: decouple(), run_aucell(), run_fgsea(), run_gsve(), run_mdt(), run_mlm(), run_ora(), run_udt(), run_ulp(), run_viper(), run_wsum()
**Examples**

```r
inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")

mat <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))

run_wmean(mat, net, minsize=0)
```

---

**Weighted Sum (WSUM)**

**Description**

Calculates regulatory activities using WSUM.

**Usage**

```r
run_wsum(
  mat,
  network,
  .source = .data$source,
  .target = .data$target,
  .mor = .data$mor,
  .likelihood = .data$likelihood,
  times = 100,
  seed = 42,
  sparse = TRUE,
  randomize_type = "rows",
  minsize = 5
)
```

**Arguments**

- **mat**: Matrix to evaluate (e.g. expression matrix). Target nodes in rows and conditions in columns. `rownames(mat)` must have at least one intersection with the elements in `network$.target` column.
- **network**: Tibble or dataframe with edges and it’s associated metadata.
- **.source**: Column with source nodes.
- **.target**: Column with target nodes.
- **.mor**: Column with edge mode of regulation (i.e. mor).
- **.likelihood**: Deprecated argument. Now it will always be set to 1.
- **times**: How many permutations to do?
- **seed**: A single value, interpreted as an integer, or NULL for random number generation.
- **sparse**: Should the matrices used for the calculation be sparse?
- **randomize_type**: How to randomize the expression matrix.
- **minsize**: Integer indicating the minimum number of targets per source.
**Details**

WSUM infers regulator activities by first multiplying each target feature by its associated weight which then are summed to an enrichment score \( wsum \). Furthermore, permutations of random target features can be performed to obtain a null distribution that can be used to compute a z-score \( \text{norm}_wsum \), or a corrected estimate \( \text{corr}_wsum \) by multiplying \( wsum \) by the minus log10 of the obtained empirical p-value.

**Value**

A long format tibble of the enrichment scores for each source across the samples. Resulting tibble contains the following columns:

1. **statistic**: Indicates which method is associated with which score.
2. **source**: Source nodes of network.
3. **condition**: Condition representing each column of \( \text{mat} \).
4. **score**: Regulatory activity (enrichment score).
5. **p_value**: p-value for the score of the method.

**See Also**

Other decoupleR statistics: `decouple()`, `run_aucell()`, `run_fgsea()`, `run_gsva()`, `run_mdt()`, `run_mlm()`, `run_ora()`, `run_udt()`, `run.ulm()`, `run.viper()`, `run.wmean()`

**Examples**

```r
inputs_dir <- system.file("testdata", "inputs", package = "decoupleR")

mat <- readRDS(file.path(inputs_dir, "mat.rds"))
net <- readRDS(file.path(inputs_dir, "net.rds"))
run_wsum(mat, net, minsize=0)
```

---

**Description**

Prints the methods available in decoupleR. The first column correspond to the function name in decoupleR and the second to the method’s full name.

**Usage**

`show_methods()`

**Examples**

`show_methods()`
show_resources  

*Shows available resources in Omnipath. For more information visit the official website for R [https://omnipathdb.org/Omnipath](https://omnipathdb.org/Omnipath).*

**Description**

Shows available resources in Omnipath. For more information visit the official website for Omnipath.

**Usage**

`show_resources()`

**Examples**

```
decoupleR::show_resources()
```

---

**tidyeval**  

*Tidy eval helpers*

**Description**

- `rlang::sym()` creates a symbol from a string and `sym()` creates a list of symbols from a character vector.
- `enquo()` and `enquos()` delay the execution of one or several function arguments. `enquo()` returns a single quoted expression, which is like a blueprint for the delayed computation. `enquos()` returns a list of such quoted expressions.
- `expr()` quotes a new expression *locally*. It is mostly useful to build new expressions around arguments captured with `enquo()` or `enquos()`: `expr(mean(!enquo(arg), na.rm = TRUE))`.
- `rlang::as_name()` transforms a quoted variable name into a string. Supplying something else than a quoted variable name is an error.

That’s unlike `rlang::as_label()` which also returns a single string but supports any kind of R object as input, including quoted function calls and vectors. Its purpose is to summarise that object into a single label. That label is often suitable as a default name.

If you don’t know what a quoted expression contains (for instance expressions captured with `enquo()` could be a variable name, a call to a function, or an unquoted constant), then use `as_label()`. If you know you have quoted a simple variable name, or would like to enforce this, use `as_name()`.

To learn more about tidy eval and how to use these tools, visit [https://tidyeval.tidyverse.org](https://tidyeval.tidyverse.org) and the Metaprogramming section of Advanced R.

**Examples**

```
if (FALSE) {
  help("nse-defuse", package = "rlang")
}
```
Pipe operator

Description

See magrittr::%>% for details.

Usage

lhs %>% rhs

Value

Pipe an object forward into a function or call expression.

Examples

c(1, 2, 3) %>% sum()
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