Package: metamorphr (via r-universe)

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Title Tidy and Streamlined Metabolomics Data Workflows

Version 0.5.0

Description Facilitate tasks typically encountered during metabolomics data analysis including data import, filtering, missing value imputation (Stacklies et al. (2007) <doi:10.1093/bioinformatics/btm069>, Stekhoven et al. (2012) <doi:10.1093/bioinformatics/btr597>, Tibshirani et al. (2017) <doi:10.18129/B9.BIOC.IMPUTE>, Troyanskaya et al. (2001) <doi:10.1093/bioinformatics/17.6.520>), normalization (Bolstad et al. (2003) <doi:10.1093/bioinformatics/19.2.185>, Dieterle et al. (2006) <doi:10.1021/ac051632c>, Zhao et al. (2020) <doi:10.1038/s41598-020-72664-6>) transformation, centering and scaling (Van Den Berg et al. (2006) <doi:10.1186/1471-2164-7-142>) as well as statistical tests and plotting. 'metamorphr' introduces a tidy (Wickham et al. (2019) <doi:10.21105/joss.01686>) format for metabolomics data and is designed to make it easier to build elaborate analysis workflows and to integrate them with 'tidyverse' packages including 'dplyr' and 'ggplot2'.

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Imports broom, crayon, dplyr, ggplot2, impute, lifecycle, magrittr, missForest, pcaMethods, purrr, readr, rlang, stats, stringi, tibble, tidyr, utils, vctrs, withr

Depends R (>= 3.5)

LazyData true

Suggests knitr, qsmooth, rmarkdown, stringr, testthat (>= 3.0.0)

Config/testthat/edition 3

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BugReports https://github.com/yasche/metamorphr/issues

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`atoms` *A tibble containing the NIST standard atomic weights*

Description

The data set contains the atomic weights of the elements and their isotopes. It is used to calculate the exact mass in `formula_to_mass` but can also be used as a reference.

description

Usage

```
atoms
```

Format

`atoms`:

A data frame with 442 rows and 7 columns:

Number The atomic number of the element in the periodic table.

Element The element.

Isotope The mass number of the specific isotope.

Symbol The atomic symbol. Either only the letter (for standard isotopes) or the mass number followed by the symbol (for special isotopes).

Weight The monoisotopic mass of the isotope.

Composition The fraction of the isotope in the naturally occuring element.

Standard_Weight The standard atomic weight of the element. It is the sum of the product of the `Weight` and `Composition` column for each element. Where no composition is available, the weight of the IUPAC "ATOMIC WEIGHTS OF THE ELEMENTS 2023" table was used. See the Source section for more information. ...

Source

The table was retrieved from the National Institute of Standards and Technology (NIST) at https://physics.nist.gov/cgi-bin/Compositions/stand_alone.pl, accesed in October 2025, and enriched with data from the IUPAC "ATOMIC WEIGHTS OF THE ELEMENTS 2023" table at https://iupac.qmul.ac.uk/AtWt/, accesed in October 2025

`calc_km` *Calculate the Kendrick mass*

Description

Calculate the Kendrick mass for a given mass (or m/z) and repeating unit. The Kendrick mass is a rescaled mass, that usually sets CH2 = 14 but other repeating units can also be used. It is usefull for the visual identification of potential homologues. See the References section for more information. The Kendrick mass is not to be confused with the Kendrick mass defect (KMD, `calc_kmd`) and the nominal Kendrick mass (`calc_nominal_km`).

Usage

```
calc_km(mass, repeating_unit = "CH2")
```

Arguments

`mass`	A molecular mass (or m/z).
`repeating_unit`	The formula of the repeating unit, given as a string.

Value

The Kendrick mass.

References

- Kendrick mass on Wikipedia
- Edward Kendrick, *Anal. Chem.* **1963**, *35*, 2146–2154.
- C. A. Hughey, C. L. Hendrickson, R. P. Rodgers, A. G. Marshall, K. Qian, *Anal. Chem.* **2001**, *73*, 4676–4681.

Examples

```
# Calculate the Kendrick masses for two measured masses with
# CH2 as the repeating unit.
# See Hughey et al. in the References section above

calc_km(c(351.3269, 365.3425))

# Construct a KMD plot from m/z values.
# RT is mapped to color and the feature-wise maximum intensity to size.
# Note that in the publication by Hughey et al., the nominal Kendrick mass
# is used on the x-axis instead of the exact Kendrick mass.
# See ?calc_nominal_km.

toy_metaboscape %>%
  dplyr::group_by(UID, `m/z`, RT) %>%
  dplyr::summarise(max_int = max(Intensity, na.rm = TRUE)) %>%
  dplyr::ungroup() %>%
  dplyr::mutate(KMD = calc_kmd(`m/z`),
                KM = calc_km(`m/z`)) %>%
  ggplot2::ggplot(ggplot2::aes(x = KM,
                               y = KMD,
                               size = max_int,
                               color = RT)) +
    ggplot2::geom_point()
```

`calc_kmd` *Calculate the Kendrick mass defect (KMD)*

Description

The Kendrick mass defect (KMD) is calculated by subtracting the Kendrick mass (`calc_km`) from the nominal Kendrick mass (`calc_nominal_km`). See the References section for more information.

Usage

```
calc_kmd(mass, repeating_unit = "CH2")
```

Arguments

`mass`	A molecular mass (or m/z).
`repeating_unit`	The formula of the repeating unit, given as a string.

Value

The Kendrick mass defect (KMD)

References

- Kendrick mass on Wikipedia
- Edward Kendrick, *Anal. Chem.* **1963**, *35*, 2146–2154.
- C. A. Hughey, C. L. Hendrickson, R. P. Rodgers, A. G. Marshall, K. Qian, *Anal. Chem.* **2001**, *73*, 4676–4681.

Examples

```
# Calculate the Kendrick mass defects for two measured masses with
# CH2 as the repeating unit.
# See Hughey et al. in the References section above

calc_kmd(c(351.3269, 365.3425))

# Construct a KMD plot from m/z values.
# RT is mapped to color and the feature-wise maximum intensity to size.

toy_metaboscape %>%
  dplyr::group_by(UID, `m/z`, RT) %>%
  dplyr::summarise(max_int = max(Intensity, na.rm = TRUE)) %>%
  dplyr::ungroup() %>%
  dplyr::mutate(KMD = calc_kmd(`m/z`),
                `nominal KM` = calc_nominal_km(`m/z`)) %>%
  ggplot2::ggplot(ggplot2::aes(x = `nominal KM`,
                               y = KMD,
                               size = max_int,
                               color = RT)) +
    ggplot2::geom_point()
```

---

calc_neutral_loss *Calculate neutral losses from precursor ion mass and fragment ion masses*

Description

[Deprecated]

`calc_neutral_loss()` is fully replaced by `msn_calc_nl`.

Calculate neutral loss spectra for all ions with available MSn spectra in `data`. To calculate neutral losses, MSn spectra are required. See `read_mgf`. This step is required for subsequent filtering based on neutral losses (`filter_neutral_loss`). Resulting neutral loss spectra are stored in tibbles in a new list column named `Neutral_Loss`.

Usage

```
calc_neutral_loss(data, m_z_col)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.
`m_z_col`	Which column holds the precursor m/z? Uses `args_data_masking`.

Value

A tibble with added neutral loss spectra. A new list column is created named `Neutral_Loss`.

Examples

```
toy_mgf %>%
  calc_neutral_loss(m_z_col = PEPMASS)
```

`calc_nominal_km` *Calculate the nominal Kendrick mass*

Description

The nominal Kendrick mass is the Kendrick mass (`calc_km`), rounded up to the nearest whole number. The nominal Kendrick mass and the Kendrick mass are both required to calculate the Kendrick mass defect (KMD). The nominal Kendrick mass is not to be confused with the Kendrick mass defect (`calc_kmd`) and the Kendrick mass (`calc_km`).

Usage

```
calc_nominal_km(mass, repeating_unit = "CH2")
```

Arguments

`mass`	A molecular mass (or m/z).
`repeating_unit`	The formula of the repeating unit, given as a string.

Value

The nominal Kendrick mass.

References

- Kendrick mass on Wikipedia
- Edward Kendrick, *Anal. Chem.* **1963**, *35*, 2146–2154.
- C. A. Hughey, C. L. Hendrickson, R. P. Rodgers, A. G. Marshall, K. Qian, *Anal. Chem.* **2001**, *73*, 4676–4681.

Examples

```
# Calculate the nominal Kendrick masses for two measured masses with
# CH2 as the repeating unit.
# See Hughey et al. in the References section above

calc_nominal_km(c(351.3269, 365.3425))

# Construct a KMD plot from m/z values.
# RT is mapped to color and the feature-wise maximum intensity to size.

toy_metaboscape %>%
  dplyr::group_by(UID, `m/z`, RT) %>%
  dplyr::summarise(max_int = max(Intensity, na.rm = TRUE)) %>%
  dplyr::ungroup() %>%
  dplyr::mutate(KMD = calc_kmd(`m/z`),
                `nominal KM` = calc_nominal_km(`m/z`)) %>%
  ggplot2::ggplot(ggplot2::aes(x = `nominal KM`,
                               y = KMD,
                               size = max_int,
                               color = RT)) +
    ggplot2::geom_point()
```

`collapse_max` *Collapse intensities of technical replicates by calculating their maximum*

Description

Calculates the minimum of the intensity of technical replicates (e.g., if the same sample was injected multiple times or if multiple workups have been performed on the same starting material). The function assigns new sample names by joining either group and replicate name, or if a batch column is specified group, replicate and batch together with a specified separator. Due to the nature of the function, sample and feature metadata columns will be dropped unless they are specified with the according arguments.

Usage

```
collapse_max(
  data,
  group_column = .data$Group,
  replicate_column = .data$Replicate,
```

```
  batch_column = .data$Batch,
  feature_metadata_cols = "Feature",
  sample_metadata_cols = NULL,
  separator = "_"
)
```

Arguments

data	A tidy tibble created by read_featuretable.
group_column	Which column should be used for grouping? Usually grouping_column = Group. Uses args_data_masking.
replicate_column	Which column contains replicate information? Usually replicate_column = Replicate. Uses args_data_masking.
batch_column	Which column contains batch information? If all samples belong to the same batch (i.e., they all have the same batch identifier in the batch_column) it will have no effect on the calculation. Usually batch_column = Batch. Uses args_data_masking.
feature_metadata_cols	A character or character vector containing the names of the feature metadata columns. They are usually created when reading the feature table with read_featuretable. Feature metadata columns not specified here will be dropped.
sample_metadata_cols	A character or character vector containing the names of the sample metadata columns. They are usually created when joining the metadata with join_metadata. Sample metadata columns not specified here will be dropped, except for group_column, replicate_column and batch_column if specified.
separator	Separator used for joining group and replicate, or group, batch and replicate together to create the new sample names. The new sample names will be Group name, separator, Batch name, separator, Replicate name, or Group name, separator, Replicate name, in case all samples belong to the same batch (i.e., they all have the same batch identifier in the batch_column).

Value

A tibble with intensities of technical replicates collapsed.

Examples

```
# uses a slightly modified version of toy_metaboscape_metadata
collapse_toy_metaboscape_metadata <- toy_metaboscape_metadata
collapse_toy_metaboscape_metadata$Replicate <- 1

toy_metaboscape %>%
  join_metadata(collapse_toy_metaboscape_metadata) %>%
  impute_lod() %>%
  collapse_max(group_column = Group, replicate_column = Replicate)
```

collapse_mean *Collapse intensities of technical replicates by calculating their mean*

Description

Calculates the mean of the intensity of technical replicates (e.g., if the same sample was injected multiple times or if multiple workups have been performed on the same starting material). The function assigns new sample names by joining either group and replicate name, or if a batch column is specified group, replicate and batch together with a specified separator. Due to the nature of the function, sample and feature metadata columns will be dropped unless they are specified with the according arguments.

Usage

```
collapse_mean(
  data,
  group_column = .data$Group,
  replicate_column = .data$Replicate,
  batch_column = .data$Batch,
  feature_metadata_cols = "Feature",
  sample_metadata_cols = NULL,
  separator = "_"
)
```

Arguments

data	A tidy tibble created by read_featuretable.
group_column	Which column should be used for grouping? Usually grouping_column = Group. Uses args_data_masking.
replicate_column	Which column contains replicate information? Usually replicate_column = Replicate. Uses args_data_masking.
batch_column	Which column contains batch information? If all samples belong to the same batch (i.e., they all have the same batch identifier in the batch_column) it will have no effect on the calculation. Usually batch_column = Batch. Uses args_data_masking.
feature_metadata_cols	A character or character vector containing the names of the feature metadata columns. They are usually created when reading the feature table with read_featuretable. Feature metadata columns not specified here will be dropped.
sample_metadata_cols	A character or character vector containing the names of the sample metadata columns. They are usually created when joining the metadata with join_metadata. Sample metadata columns not specified here will be dropped, except for group_column, replicate_column and batch_column if specified.

separator — Separator used for joining group and replicate, or group, batch and replicate together to create the new sample names. The new sample names will be Group name, separator, Batch name, separator, Replicate name, or Group name, separator, Replicate name, in case all samples belong to the same batch (i.e., they all have the same batch identifier in the batch_column).

Value

A tibble with intensities of technical replicates collapsed.

Examples

```
# uses a slightly modified version of toy_metaboscape_metadata
collapse_toy_metaboscape_metadata <- toy_metaboscape_metadata
collapse_toy_metaboscape_metadata$Replicate <- 1

toy_metaboscape %>%
  join_metadata(collapse_toy_metaboscape_metadata) %>%
  impute_lod() %>%
  collapse_mean(group_column = Group, replicate_column = Replicate)
```

---

collapse_median *Collapse intensities of technical replicates by calculating their median*

Description

Calculates the median of the intensity of technical replicates (e.g., if the same sample was injected multiple times or if multiple workups have been performed on the same starting material). The function assigns new sample names by joining either group and replicate name, or if a batch column is specified group, replicate and batch together with a specified separator. Due to the nature of the function, sample and feature metadata columns will be dropped unless they are specified with the according arguments.

Usage

```
collapse_median(
  data,
  group_column = .data$Group,
  replicate_column = .data$Replicate,
  batch_column = .data$Batch,
  feature_metadata_cols = "Feature",
  sample_metadata_cols = NULL,
  separator = "_"
)
```

Arguments

data	A tidy tibble created by read_featuretable.
group_column	Which column should be used for grouping? Usually grouping_column = Group. Uses args_data_masking.
replicate_column	Which column contains replicate information? Usually replicate_column = Replicate. Uses args_data_masking.
batch_column	Which column contains batch information? If all samples belong to the same batch (i.e., they all have the same batch identifier in the batch_column) it will have no effect on the calculation. Usually batch_column = Batch. Uses args_data_masking.
feature_metadata_cols	A character or character vector containing the names of the feature metadata columns. They are usually created when reading the feature table with read_featuretable. Feature metadata columns not specified here will be dropped.
sample_metadata_cols	A character or character vector containing the names of the sample metadata columns. They are usually created when joining the metadata with join_metadata. Sample metadata columns not specified here will be dropped, except for group_column, replicate_column and batch_column if specified.
separator	Separator used for joining group and replicate, or group, batch and replicate together to create the new sample names. The new sample names will be Group name, separator, Batch name, separator, Replicate name, or Group name, separator, Replicate name, in case all samples belong to the same batch (i.e., they all have the same batch identifier in the batch_column).

Value

A tibble with intensities of technical replicates collapsed.

Examples

```
# uses a slightly modified version of toy_metaboscape_metadata
collapse_toy_metaboscape_metadata <- toy_metaboscape_metadata
collapse_toy_metaboscape_metadata$Replicate <- 1

toy_metaboscape %>%
  join_metadata(collapse_toy_metaboscape_metadata) %>%
  impute_lod() %>%
  collapse_median(group_column = Group, replicate_column = Replicate)
```

collapse_min *Collapse intensities of technical replicates by calculating their minimum*

Description

Calculates the minimum of the intensity of technical replicates (e.g., if the same sample was injected multiple times or if multiple workups have been performed on the same starting material). The function assigns new sample names by joining either group and replicate name, or if a batch column is specified group, replicate and batch together with a specified separator. Due to the nature of the function, sample and feature metadata columns will be dropped unless they are specified with the according arguments.

Usage

```
collapse_min(
  data,
  group_column = .data$Group,
  replicate_column = .data$Replicate,
  batch_column = .data$Batch,
  feature_metadata_cols = "Feature",
  sample_metadata_cols = NULL,
  separator = "_"
)
```

Arguments

data	A tidy tibble created by read_featuretable.
group_column	Which column should be used for grouping? Usually grouping_column = Group. Uses args_data_masking.
replicate_column	Which column contains replicate information? Usually replicate_column = Replicate. Uses args_data_masking.
batch_column	Which column contains batch information? If all samples belong to the same batch (i.e., they all have the same batch identifier in the batch_column) it will have no effect on the calculation. Usually batch_column = Batch. Uses args_data_masking.
feature_metadata_cols	A character or character vector containing the names of the feature metadata columns. They are usually created when reading the feature table with read_featuretable. Feature metadata columns not specified here will be dropped.
sample_metadata_cols	A character or character vector containing the names of the sample metadata columns. They are usually created when joining the metadata with join_metadata. Sample metadata columns not specified here will be dropped, except for group_column, replicate_column and batch_column if specified.

separator — Separator used for joining group and replicate, or group, batch and replicate together to create the new sample names. The new sample names will be Group name, separator, Batch name, separator, Replicate name, or Group name, separator, Replicate name, in case all samples belong to the same batch (i.e., they all have the same batch identifier in the batch_column).

Value

A tibble with intensities of technical replicates collapsed.

Examples

```
# uses a slightly modified version of toy_metaboscape_metadata
collapse_toy_metaboscape_metadata <- toy_metaboscape_metadata
collapse_toy_metaboscape_metadata$Replicate <- 1

toy_metaboscape %>%
  join_metadata(collapse_toy_metaboscape_metadata) %>%
  impute_lod() %>%
  collapse_min(group_column = Group, replicate_column = Replicate)
```

---

convert_from_matrix *Convert a wide matrix to a tidy tibble*

Description

This functions transforms a matrix holding a wide feature table into a "long" and tidy tibble to use it with functions provided in the metamorphr package. convert_from_matrix works with objects of class matrix. To convert a data frame or tibble, see convert_from_wide.

Usage

```
convert_from_matrix(data, samples_in_cols = TRUE)
```

Arguments

data — A feature table matrix in wide format. To convert a wide data frame, see convert_from_wide.

samples_in_cols — TRUE if samples are in columns and features in rows, FALSE if it is reversed. See examples for more information.

Value

A tidy tibble.

Examples

```
# Using a small fictional data set
dataset <- matrix(1:9, ncol = 3)
colnames(dataset) <- paste0("sample", 1:3)
rownames(dataset) <- paste0("feature", 1:3)


# Example 1: Samples in columns
dataset
convert_from_matrix(dataset)

# Example 2: Samples in rows
dataset_transposed <- t(dataset)
dataset_transposed

convert_from_matrix(dataset, samples_in_cols = FALSE)
```

---

convert_from_wide *Convert a wide feature table to a tidy tibble*

Description

Feature tables are usually stored in a "wide" data format where sample names are stored in columns and features are stored in rows. This functions transforms those feature tables into a "long" and tidy data format to use it with functions provided in the `metamorphr` package. `convert_from_wide` works with tibbles and data frames. To convert a matrix, see `convert_from_matrix`.

Usage

```
convert_from_wide(data, label_col = 1, metadata_cols = NULL)
```

Arguments

`data`	A feature table data frame or tibble in wide format. To convert a matrix, see `convert_from_matrix`.
`label_col`	The index or name of the column that will be used to label Features. For example an identifier (*e.g.*, KEGG, CAS, HMDB) or a *m/z*-RT pair.
`metadata_cols`	The index/indices or name(s) of column(s) that hold additional feature metadata (*e.g.*, retention times, additional identifiers or *m/z* values).

Value

A tidy tibble.

Examples

```
featuretable_path <- system.file("extdata", "toy_metaboscape.csv", package = "metamorphr")
featuretable_wide <- read.csv(featuretable_path)

convert_from_wide(featuretable_wide, metadata_cols = 2:5)
```

`convert_to_fa` *Convert a tidy tibble into a format compatible with the "Functional Analysis" module in 'MetaboAnalyst'*

Description

Creates a tibble with columns `m.z`, `p.value`, `t.score` and optionally `r.t` to use in the "Functional Analysis" module in 'MetaboAnalyst'. Metrics are calculated using a `t.test`.

Usage

```
convert_to_fa(
  data,
  m_z_col,
  rt_col = NULL,
  group_column,
  groups_to_compare,
  batch_column = NULL,
  batch = NULL,
  adjust_p = FALSE,
  log2_before = FALSE,
  ...
)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.
`m_z_col`	Which column holds the precursor m/z? Uses `args_data_masking`.
`rt_col`	Optional. Which column holds the precursor retention times? Uses `args_data_masking`.
`group_column`	Which column should be used for grouping? Usually `group_column = Group`. Uses `args_data_masking`.
`groups_to_compare`	Names of the groups which should be compared as a character vector. Those are the group names in the `group_column`. They are usually provided in the form of a metadata tibble and joined via `join_metadata`.
`batch_column`	Which column contains the batch information? Usually `batch_column = Batch`. Only relevant if `data` contains multiple batches. For example, if `data` contains 2 batches and each batch contains measurements of separate controls, `group_column` and `batch` arguments should be provided. Otherwise controls

	of both batches will be considered when calculating the *p*-value and log2 fold change. Uses args_data_masking.
batch	The names of the batch(es) that should be included when calculating *p*-value and log2 fold change.
adjust_p	Should the *p*-value be adjusted? Can be either FALSE, (the default) in case no adjustment should be made or any or the name from p.adjust.methods (e.g., adjust_p = "fdr").
log2_before	A logical. Should the data be log2 transformed prior to calculating the *p*-values?
...	Arguments passed on to t.test. If none are provided (the default), a Welch Two Sample *t*-test will be performed.

Value

A tibble with columns m.z, p.value, t.score and optionally r.t.

Examples

```
# Without optional retention time column
toy_metaboscape %>%
  join_metadata(toy_metaboscape_metadata) %>%
  convert_to_fa(group_column = Group,
                groups_to_compare = c("control", "treatment"),
                return_tbl = TRUE,
                alternative = "two.sided",
                m_z_col = `m/z`)

# With optional retention time column
toy_metaboscape %>%
  join_metadata(toy_metaboscape_metadata) %>%
  convert_to_fa(group_column = Group,
                groups_to_compare = c("control", "treatment"),
                return_tbl = TRUE,
                m_z_col = `m/z`,
                rt_col = RT)
```

---

create_metadata_skeleton

Create a blank metadata skeleton

Description

Takes a tidy tibble created by metamorphr::read_featuretable() and returns an empty tibble for sample metadata. The tibble can either be populated directly in R or exported and edited by hand (*e.g.* in Excel). Metadata are necessary for several downstream functions. **More columns may be added if necessary**.

Usage

```
create_metadata_skeleton(data)
```

Arguments

data	A tidy tibble created by `metamorphr::read_featuretable()`.

Value

An empty tibble structure with the necessary columns for metadata:

Sample The sample name

Group To which group does the samples belong? For example a treatment or a background. Note that additional columns with additional grouping information can be freely added if necessary.

Replicate If multiple technical replicates exist in the data set, they must have the same value for Replicate and the same value for Group so that they can be collapsed. Examples for technical replicates are: the same sample was injected multiple times or workup was performed multiple times with the same starting material. If no technical replicates exist, set `Replicate = 1` for all samples.

Batch The batch in which the samples were prepared or measured. If only one batch exists, set `Batch = 1` for all samples.

Factor A sample-specific factor, for example dry weight or protein content. ...

Examples

```
featuretable_path <- system.file("extdata", "toy_metaboscape.csv", package = "metamorphr")
metadata <- read_featuretable(featuretable_path, metadata_cols = 2:5) %>%
  create_metadata_skeleton()
```

---

filter_blank *Filter Features based on their occurrence in blank samples*

Description

Filters Features based on their occurrence in blank samples. For example, if `min_frac = 3` the maximum intensity in samples must be at least 3 times as high as in blanks for a Feature not to be filtered out.

Usage

```
filter_blank(
  data,
  blank_samples,
  min_frac = 3,
  blank_as_group = FALSE,
  group_column = NULL
)
```

Arguments

data	A tidy tibble created by read_featuretable.
blank_samples	Defines the blanks. If blank_as_group = FALSE a character vector containing the names of the blank samples as in the Sample column of data. If blank_as_group = TRUE the name(s) of the group(s) that define blanks, as in the Group column of data. The latter can only be used if sample metadata is provided.
min_frac	A numeric defining how many times higher the maximum intensity in samples must be in relation to blanks.
blank_as_group	A logical indicating if blank_samples are the names of samples or group(s).
group_column	Only relevant if blank_as_group = TRUE. Which column should be used for grouping blank and non-blank samples? Usually group_column = Group. Uses args_data_masking.

Value

A filtered tibble.

Examples

```
# Example 1: Define blanks by sample name
toy_metaboscape %>%
  filter_blank(blank_samples = c("Blank1", "Blank2"), blank_as_group = FALSE, min_frac = 3)

# Example 2: Define blanks by group name
# toy_metaboscape %>%
#  join_metadata(toy_metaboscape_metadata) %>%
#  filter_blank(blank_samples = "blank",
#               blank_as_group = TRUE,
#               min_frac = 3,
#               group_column = Group)
```

---

filter_cv *Filter Features based on their coefficient of variation*

Description

Filters Features based on their coefficient of variation (CV). The CV is defined as $CV = \frac{s_i}{\overline{x_i}}$ with s_i = Standard deviation of sample i and $\overline{x_i}$ = Mean of sample i.

Usage

```
filter_cv(
  data,
  reference_samples,
  max_cv = 0.2,
  ref_as_group = FALSE,
```

```
  group_column = NULL,
  na_as_zero = TRUE
)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.
`reference_samples`	The names of the samples or group which will be used to calculate the CV of a feature. Usually Quality Control samples.
`max_cv`	The maximum allowed CV. 0.2 is a reasonable start.
`ref_as_group`	A logical indicating if `reference_samples` are the names of samples or group(s).
`group_column`	Only relevant if `ref_as_group = TRUE`. Which column should be used for grouping reference and non-reference samples? Usually `group_column = Group`. Uses `args_data_masking`.
`na_as_zero`	Should `NA` be replaced with 0 prior to calculation? Under the hood `filter_cv` calculates the CV by `stats::sd(..., na.rm = TRUE) / mean(..., na.rm = TRUE)`. If there are 3 samples to calculate the CV from and 2 of them are `NA` for a specific feature, then the CV for that Feature will be `NA` if `na_as_zero = FALSE`. This might lead to problems. `na_as_zero = TRUE` is the safer pick. Zeros will be replaced with `NA` after calculation no matter if it is `TRUE` or `FALSE`.

Value

A filtered tibble.

References

Coefficient of Variation on Wikipedia

Examples

```
# Example 1: Define reference samples by sample names
toy_metaboscape %>%
  filter_cv(max_cv = 0.2, reference_samples = c("QC1", "QC2", "QC3"))

# Example 2: Define reference samples by group name
toy_metaboscape %>%
  join_metadata(toy_metaboscape_metadata) %>%
 filter_cv(max_cv = 0.2, reference_samples = "QC", ref_as_group = TRUE, group_column = Group)
```

`filter_global_mv` *Filter Features based on the absolute number or fraction of samples it was found in*

Description

Filters features based on the number or fraction of samples they are found in. This is usually one of the first steps in metabolomics data analysis and often already performed when the feature table is first created from the raw spectral files..

Usage

```
filter_global_mv(data, min_found = 0.5, fraction = TRUE)
```

Arguments

`data`	A tidy tibble created by `metamorphr::read_featuretable()`.
`min_found`	In how many samples must a Feature be found? If `fraction == TRUE`, a value between 0 and 1 (*e.g.*, 0.5 if a Feature must be found in at least half the samples). If `fraction == FALSE` the absolute maximum number of samples (*e.g.*, 5 if a specific Feature must be found in at least 5 samples).
`fraction`	Either `TRUE` or `FALSE`. Should `min_found` be the absolute number of samples or a fraction?

Value

A filtered tibble.

Examples

```
# Example 1: A feature must be found in at least 50 % of the samples
toy_metaboscape %>%
  filter_global_mv(min_found = 0.5)

# Example 2: A feature must be found in at least 8 samples
toy_metaboscape %>%
  filter_global_mv(min_found = 8, fraction = FALSE)
```

`filter_grouped_mv` *Group-based feature filtering*

Description

Similar to `filter_global_mv` it filters features that are found in a specified number of samples. The key difference is that `filter_grouped_mv()` takes groups into consideration and therefore needs sample metadata. For example, if `fraction = TRUE` and `min_found = 0.5`, a feature must be found in at least 50 % of the samples of at least 1 group. It is very similar to the *Filter features by occurrences in groups* option in Bruker MetaboScape.

Usage

```
filter_grouped_mv(
  data,
  min_found = 0.5,
  group_column = .data$Group,
  fraction = TRUE
)
```

Arguments

`data`	A tidy tibble created by `read_featuretable` with added sample metadata. See ?`create_metadata_skeleton` for help.
`min_found`	Defines in how many samples of at least 1 group a Feature must be found not to be filtered out. If `fraction == TRUE`, a value between 0 and 1 (*e.g.*, 0.5 if a Feature must be found in at least half the samples of at least 1 group). If `fraction == FALSE` the absolute maximum number of samples (*e.g.*, 5 if a specific Feature must be found in at least 5 samples of at least 1 group).
`group_column`	Which column should be used for grouping? Usually `group_column = Group`. Uses `args_data_masking`.
`fraction`	Either `TRUE` or `FALSE`. Should `min_found` be the absolute number of samples or a fraction?

Value

A filtered tibble.

Examples

```
# A Feature must be found in all samples of at least 1 group.
toy_metaboscape %>%
  join_metadata(toy_metaboscape_metadata) %>%
  filter_grouped_mv(min_found = 1, group_column = Group)
```

filter_msn *Filter Features based on occurrence of fragment ions*

Description

Filters Features based on the presence of MSn fragments. This can help, for example with the identification of potential homologous molecules.

Usage

```
filter_msn(
  data,
  fragments,
  min_found,
  tolerance = 5,
  tolerance_type = "ppm",
  show_progress = TRUE
)
```

Arguments

data	A data frame containing MSn spectra.
fragments	A numeric. Exact mass of the fragment(s) to filter by.
min_found	How many of the fragments must be found in order to keep the row? If min_found = length(fragments), all fragments must be found.
tolerance	A numeric. The tolerance to apply to the fragments. Either an absolute value in Da (if tolerance_type = "absolute") or in ppm (if tolerance_type = "ppm").
tolerance_type	Either "absolute" or "ppm". Should the tolerance be an absolute value or in ppm?
show_progress	A logical indicating whether the progress of the filtering should be printed to the console. Only important for large tibbles.

Value

A filtered tibble.

Examples

```
# all of the given fragments (3) must be found
# returns the first row of toy_mgf
toy_mgf %>%
  filter_msn(fragments = c(12.3456, 23.4567, 34.5678), min_found = 3)

# all of the given fragments (3) must be found
# returns an empty tibble because the third fragment
```

```
# of row 1 (34.5678)
# is outside of the tolerance (5 ppm):
# Lower bound:
# 34.5688 - 34.5688 * 5 / 1000000 = 34.5686
# Upper bound:
# 34.5688 + 34.5688 * 5 / 1000000 = 34.5690
toy_mgf %>%
  filter_msn(fragments = c(12.3456, 23.4567, 34.5688), min_found = 3)

# only 2 of the 3 fragments must be found
# returns the first row of toy_mgf
toy_mgf %>%
  filter_msn(fragments = c(12.3456, 23.4567, 34.5688), min_found = 2)
```

`filter_mz` *Filter Features based on their mass-to-charge ratios*

Description

Facilitates filtering by given mass-to-charge ratios (m/z) with a defined tolerance. Can also be used to filter based on exact mass.

Usage

```
filter_mz(data, m_z_col, masses, tolerance = 5, tolerance_type = "ppm")
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.
`m_z_col`	Which column holds the precursor m/z (or exact mass)? Uses `args_data_masking`.
`masses`	The mass(es) to filter by.
`tolerance`	A numeric. The tolerance to apply to the masses Either an absolute value in Da (if `tolerance_type = "absolute"`) or in ppm (if `tolerance_type = "ppm"`).
`tolerance_type`	Either `"absolute"` or `"ppm"`. Should the tolerance be an absolute value or in ppm?

Value

A filtered tibble.

Examples

```
# Use a tolerance of plus or minus 5 ppm
toy_metaboscape %>%
  filter_mz(m_z_col = `m/z`, 162.1132, tolerance = 5, tolerance_type = "ppm")

# Use a tolerance of plus or minus 0.005 Da
toy_metaboscape %>%
  filter_mz(m_z_col = `m/z`, 162.1132, tolerance = 0.005, tolerance_type = "absolute")
```

`filter_neutral_loss` *Filter Features based on occurrence of neutral losses*

Description

The occurrence of characteristic neutral losses can help with the putative annotation of molecules. See the Reference section for an example.

Usage

```
filter_neutral_loss(
  data,
  losses,
  min_found,
  tolerance = 10,
  tolerance_type = "ppm",
  show_progress = TRUE
)
```

Arguments

`data`	A data frame containing MSn spectra.
`losses`	A numeric. Exact mass of the fragment(s) to filter by.
`min_found`	How many of the `fragments` must be found in order to keep the row? If `min_found = length(fragments)`, all fragments must be found.
`tolerance`	A numeric. The tolerance to apply to the fragments. Either an absolute value in Da (if `tolerance_type = "absolute"`) or in ppm (if `tolerance_type = "ppm"`).
`tolerance_type`	Either `"absolute"` or `"ppm"`. Should the tolerance be an absolute value or in ppm?
`show_progress`	A `logical` indicating whether the progress of the filtering should be printed to the console. Only important for large tibbles.

Value

A filtered tibble.

References

- A. Brink, F. Fontaine, M. Marschmann, B. Steinhuber, E. N. Cece, I. Zamora, A. Pähler, *Rapid Commun. Mass Spectrom.* **2014**, *28*, 2695–2703, DOI 10.1002/rcm.7062.

Examples

```
# neutral losses must be calculated first
toy_mgf_nl <- toy_mgf %>%
  calc_neutral_loss(m_z_col = PEPMASS)

# all of the given losses (3) must be found
# returns the first row of toy_mgf
toy_mgf_nl %>%
  filter_neutral_loss(losses = c(11.1111, 22.2222, 33.3333), min_found = 3)

# all of the given fragments (3) must be found
# returns an empty tibble because the third loss
# of row 1 (33.3333)
# is outside of the tolerance (10 ppm):
# Lower bound:
# 33.4333 - 33.4333 * 5 / 1000000 = 33.4333
# Upper bound:
# 33.4333 + 33.4333 * 5 / 1000000 = 33.4336
toy_mgf_nl %>%
  filter_neutral_loss(losses = c(11.1111, 22.2222, 33.4333), min_found = 3)

# only 2 of the 3 fragments must be found
# returns the first row of toy_mgf
toy_mgf_nl %>%
  filter_neutral_loss(losses = c(11.1111, 22.2222, 33.4333), min_found = 2)
```

`formula_to_mass` *Calculate the monoisotopic mass from a given formula*

Description

Calculates the monoisotopic mass from a given formula. If only the element symbols are provided, the calculated mass corresponds to that of a molecule made up from the most abundant isotopes. Other isotopes can also be provided (e.g., 13C, instead of the naturally most abundant 12C). See the samples for details.

Usage

```
formula_to_mass(formula)
```

Arguments

`formula`	A formula as a string.

Value

The monoisotopic mass of the formula.

Examples

```
# The monoisotopic mass is calculated with the most abundant isotopes
# if only the element symbols are provided:
formula_to_mass("CH4")
formula_to_mass("NH3")
formula_to_mass("C10H17N3O6S")

# Other isotopes can be provided as follows:
formula_to_mass("[13C]H4")
formula_to_mass("[15N]H3")

# Every isotope, including the most abundant ones, can be named explicitly.
# Compare:
formula_to_mass("[14N][1H]3")
formula_to_mass("NH3")

# The function also supports brackets and nested brackets:
formula_to_mass("(CH3)2")
formula_to_mass("(((CH3)2N)3C)2")
formula_to_mass("((([13C]H3)2N)3C)2")
```

---

impute_bpca *Impute missing values using Bayesian PCA*

Description

One of several PCA-based imputation methods. Basically a wrapper around `pcaMethods::pca(method = "bpca")`. For a detailed discussion, see the `vignette("pcaMethods")` and `vignette("missingValues", "pcaMethods")` as well as the References section.

Important Note

`impute_bpca()` depends on the `pcaMethods` package from Bioconductor. If `metamorphr` was installed via `install.packages()`, dependencies from Bioconductor were not automatically installed. When `impute_bpca()` is called without the `pcaMethods` package installed, you should be asked if you want to install `pak` and `pcaMethods`. If you want to use `impute_bpca()` you have to install those. In case you run into trouble with the automatic installation, please install `pcaMethods` manually. See pcaMethods – a Bioconductor package providing PCA methods for incomplete data.

Usage

```
impute_bpca(data, n_pcs = 2, center = TRUE, scale = "none", direction = 2)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.
`n_pcs`	The number of PCs to calculate.
`center`	Should `data` be mean centered? See `prep` for details.
`scale`	Should `data` be scaled? See `prep` for details.

`direction` Either `1` or `2`. `1` runs a PCA on a matrix with samples in columns and features in rows and `2` runs a PCA on a matrix with features in columns and samples in rows. Both are valid according to this discussion on GitHub but give **different results**.

Value

A tibble with imputed missing values.

References

- H. R. Wolfram Stacklies, **2017**, DOI 10.18129/B9.BIOC.PCAMETHODS.
- W. Stacklies, H. Redestig, M. Scholz, D. Walther, J. Selbig, *Bioinformatics* **2007**, *23*, 1164–1167, DOI 10.1093/bioinformatics/btm069.

Examples

```
toy_metaboscape %>%
  impute_bpca()
```

---

impute_global_lowest *Impute missing values by replacing them with the lowest observed intensity (global)*

Description

Replace missing intensity values (`NA`) with the lowest observed intensity.

Usage

```
impute_global_lowest(data)
```

Arguments

`data` A tidy tibble created by `read_featuretable`.

Value

A tibble with imputed missing values.

Examples

```
toy_metaboscape %>%
  impute_global_lowest()
```

impute_knn *Impute missing values using nearest neighbor averaging*

Description

Basically a wrapper function around `impute::impute.knn`. Imputes missing values using the k-th nearest neighbor algorithm.

Note that the function ln-transforms the data prior to imputation and transforms it back to the original scale afterwards. **Please do not do it manually prior to calling `impute_knn()`!** See References for more information.

Important Note

`impute_knn()` depends on the `impute` package from Bioconductor. If `metamorphr` was installed via `install.packages()`, dependencies from Bioconductor were not automatically installed. When `impute_knn()` is called without the `impute` package installed, you should be asked if you want to install `pak` and `impute`. If you want to use `impute_knn()` you have to install those. In case you run into trouble with the automatic installation, please install `impute` manually. See impute: Imputation for microarray data for instructions on manual installation.

Usage

```
impute_knn(data, quietly = TRUE, ...)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.
`quietly`	`TRUE` or `FALSE`. Should messages and warnings from `impute.knn` be printed to the console?
`...`	Additional parameters passed to `impute.knn`.

Value

A tibble with imputed missing values.

References

- Robert Tibshirani, Trevor Hastie, **2017**, DOI 10.18129/B9.BIOC.IMPUTE.
- J. Khan, J. S. Wei, M. Ringnér, L. H. Saal, M. Ladanyi, F. Westermann, F. Berthold, M. Schwab, C. R. Antonescu, C. Peterson, P. S. Meltzer, *Nat Med* **2001**, *7*, 673–679, DOI 10.1038/89044.

Examples

```
toy_metaboscape %>%
  impute_knn()
```

`impute_lls` *Impute missing values using Local Least Squares (LLS)*

Description

Basically a wrapper around `pcaMethods::llsImpute`. For a detailed discussion, see the `vignette("pcaMethods")` and `vignette("missingValues", "pcaMethods")` as well as the References section.

Important Note `impute_lls()` depends on the `pcaMethods` package from Bioconductor. If `metamorphr` was installed via `install.packages()`, dependencies from Bioconductor were not automatically installed. When `impute_svd()` is called without the `pcaMethods` package installed, you should be asked if you want to install `pak` and `pcaMethods`. If you want to use `impute_lls()` you have to install those. In case you run into trouble with the automatic installation, please install `pcaMethods` manually. See pcaMethods – a Bioconductor package providing PCA methods for incomplete data for instructions on manual installation.

Usage

```
impute_lls(
  data,
  correlation = "pearson",
  complete_genes = FALSE,
  center = FALSE,
  cluster_size = 10
)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.
`correlation`	The method used to calculate correlations between features. One of `"pearson"`, `"spearman"` or `"kendall"`. See `cor`.
`complete_genes`	If `TRUE` only complete features will be used for regression, if `FALSE`, all will be used.
`center`	Should `data` be mean centered? See `prep` for details.
`cluster_size`	The number of similar features used for regression.

Value

A tibble with imputed missing values.

References

- H. R. Wolfram Stacklies, **2017**, DOI 10.18129/B9.BIOC.PCAMETHODS.
- W. Stacklies, H. Redestig, M. Scholz, D. Walther, J. Selbig, *Bioinformatics* **2007**, *23*, 1164–1167, DOI 10.1093/bioinformatics/btm069.

Examples

```
# The cluster size must be reduced because
# the data set is too small for the default (10)

toy_metaboscape %>%
  impute_lls(complete_genes = TRUE, cluster_size = 5)
```

`impute_lod` *Impute missing values by replacing them with the Feature 'Limit of Detection'*

Description

Replace missing intensity values (NA) by what is assumed to be the detector limit of detection (LoD). It is estimated by dividing the Feature minimum by the provided denominator, usually 5. See the References section for more information.

Usage

```
impute_lod(data, div_by = 5)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.
`div_by`	A numeric value that specifies by which number the Feature minimum will be divided

Value

A tibble with imputed missing values.

References

LoD on OmicsForum

Examples

```
toy_metaboscape %>%
  impute_lod()
```

impute_mean *Impute missing values by replacing them with the Feature mean*

Description

Replace missing intensity values (NA) with the Feature mean of non-NA values. For example, if a Feature has the measured intensities NA, 1, NA, 3, 2 in samples 1-5, the intensities after impute_mean() would be 2, 1, 2, 3, 2.

Usage

```
impute_mean(data)
```

Arguments

data	A tidy tibble created by read_featuretable.

Value

A tibble with imputed missing values.

Examples

```
toy_metaboscape %>%
  impute_mean()
```

impute_median *Impute missing values by replacing them with the Feature median*

Description

Replace missing intensity values (NA) with the Feature median of non-NA values. For example, if a Feature has the measured intensities NA, 1, NA, 3, 2 in samples 1-5, the intensities after impute_median() would be 2, 1, 2, 3, 2.

Usage

```
impute_median(data)
```

Arguments

data	A tidy tibble created by read_featuretable.

Value

A tibble with imputed missing values.

Examples

```
toy_metaboscape %>%
  impute_median()
```

`impute_min` *Impute missing values by replacing them with the Feature minimum*

Description

Replace missing intensity values (`NA`) with the Feature minimum of non-`NA` values.

Usage

```
impute_min(data)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.

Value

A tibble with imputed missing values.

Examples

```
toy_metaboscape %>%
  impute_min()
```

`impute_nipals` *Impute missing values using NIPALS PCA*

Description

One of several PCA-based imputation methods. Basically a wrapper around `pcaMethods::pca(method = "nipals")`. For a detailed discussion, see the `vignette("pcaMethods")` and `vignette("missingValues", "pcaMethods")` as well as the References section.

Important Note

`impute_nipals()` depends on the `pcaMethods` package from Bioconductor. If `metamorphr` was installed via `install.packages()`, dependencies from Bioconductor were not automatically installed. When `impute_nipals()` is called without the `pcaMethods` package installed, you should be asked if you want to install `pak` and `pcaMethods`. If you want to use `impute_nipals()` you have to install those. In case you run into trouble with the automatic installation, please install `pcaMethods` manually. See pcaMethods – a Bioconductor package providing PCA methods for incomplete data for instructions on manual installation.

Usage

```
impute_nipals(data, n_pcs = 2, center = TRUE, scale = "none", direction = 2)
```

Arguments

data	A tidy tibble created by read_featuretable.
n_pcs	The number of PCs to calculate.
center	Should data be mean centered? See prep for details.
scale	Should data be scaled? See prep for details.
direction	Either 1 or 2. 1 runs a PCA on a matrix with samples in columns and features in rows and 2 runs a PCA on a matrix with features in columns and samples in rows. Both are valid according to this discussion on GitHub but give **different results**.

Value

A tibble with imputed missing values.

References

- H. R. Wolfram Stacklies, **2017**, DOI 10.18129/B9.BIOC.PCAMETHODS.
- W. Stacklies, H. Redestig, M. Scholz, D. Walther, J. Selbig, *Bioinformatics* **2007**, *23*, 1164–1167, DOI 10.1093/bioinformatics/btm069.

Examples

```
toy_metaboscape %>%
  impute_nipals()
```

---

impute_ppca *Impute missing values using Probabilistic PCA*

Description

One of several PCA-based imputation methods. Basically a wrapper around pcaMethods::pca(method = "ppca"). For a detailed discussion, see the vignette("pcaMethods") and vignette("missingValues", "pcaMethods") as well as the References section. In the underlying function (pcaMethods::pca(method = "ppca")), the order of columns has an influence on the outcome. Therefore, calling pcaMethods::pca(method = "ppca") on a matrix and calling metamorphr::impute() on a tidy tibble might give different results, even though they contain the same data. That is because under the hood, the tibble is transformed to a matrix prior to calling pcaMethods::pca(method = "ppca") and you have limited influence on the column order of the resulting matrix.

Important Note

impute_ppca() depends on the pcaMethods package from Bioconductor. If metamorphr was installed via install.packages(), dependencies from Bioconductor were not automatically installed. When impute_ppca() is called without the pcaMethods package installed, you should be

asked if you want to install pak and pcaMethods. If you want to use impute_ppca() you have to install those. In case you run into trouble with the automatic installation, please install pcaMethods manually. See pcaMethods – a Bioconductor package providing PCA methods for incomplete data for instructions on manual installation.

Usage

```
impute_ppca(
  data,
  n_pcs = 2,
  center = TRUE,
  scale = "none",
  direction = 2,
  random_seed = 1L
)
```

Arguments

data	A tidy tibble created by read_featuretable.
n_pcs	The number of PCs to calculate.
center	Should data be mean centered? See prep for details.
scale	Should data be scaled? See prep for details.
direction	Either 1 or 2. 1 runs a PCA on a matrix with samples in columns and features in rows and 2 runs a PCA on a matrix with features in columns and samples in rows. Both are valid according to this discussion on GitHub but give **different results**.
random_seed	An integer used as seed for the random number generator.

Value

A tibble with imputed missing values.

References

- H. R. Wolfram Stacklies, **2017**, DOI 10.18129/B9.BIOC.PCAMETHODS.
- W. Stacklies, H. Redestig, M. Scholz, D. Walther, J. Selbig, *Bioinformatics* **2007**, *23*, 1164–1167, DOI 10.1093/bioinformatics/btm069.

Examples

```
toy_metaboscape %>%
  impute_ppca()
```

`impute_rf` *Impute missing values using random forest*

Description

Basically a wrapper function around `missForest::missForest`. Imputes missing values using the random forest algorithm.

Usage

```
impute_rf(data, random_seed = 1L, ...)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.
`random_seed`	A seed for the random number generator. Can be an integer or `NULL` (in case no particular seed should be used) but for reproducibility reasons it is **strongly advised** to provide an integer.
`...`	Additional parameters passed to `missForest`.

Value

A tibble with imputed missing values.

References

- **missForest** on CRAN
- D. J. Stekhoven, P. Bühlmann, *Bioinformatics* **2012**, *28*, 112–118, DOI 10.1093/bioinformatics/btr597.

Examples

```
toy_metaboscape %>%
  impute_rf()
```

`impute_svd` *Impute missing values using Singular Value Decomposition (SVD)*

Description

Basically a wrapper around `pcaMethods::pca(method = "svdImpute")`. For a detailed discussion, see the `vignette("pcaMethods")` and `vignette("missingValues", "pcaMethods")` as well as the References section.

Important Note `impute_svd()` depends on the `pcaMethods` package from Bioconductor. If `metamorphr` was installed via `install.packages()`, dependencies from Bioconductor were not automatically installed. When `impute_svd()` is called without the `pcaMethods` package installed, you should be asked if you want to install `pak` and `pcaMethods`. If you want to use `impute_svd()` you have to install those. In case you run into trouble with the automatic installation, please install `pcaMethods` manually. See pcaMethods – a Bioconductor package providing PCA methods for incomplete data for instructions on manual installation.

Usage

```
impute_svd(data, n_pcs = 2, center = TRUE, scale = "none", direction = 2)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.
`n_pcs`	The number of PCs to calculate.
`center`	Should `data` be mean centered? See `prep` for details.
`scale`	Should `data` be scaled? See `prep` for details.
`direction`	Either `1` or `2`. `1` runs `pcaMethods::pca(method = "svdImpute")` on a matrix with samples in columns and features in rows and `2` runs `pcaMethods::pca(method = "svdImpute")` on a matrix with features in columns and samples in rows. Both are valid according to this discussion on GitHub but give **different results**.

Value

A tibble with imputed missing values.

References

- H. R. Wolfram Stacklies, **2017**, DOI 10.18129/B9.BIOC.PCAMETHODS.
- W. Stacklies, H. Redestig, M. Scholz, D. Walther, J. Selbig, *Bioinformatics* **2007**, *23*, 1164–1167, DOI 10.1093/bioinformatics/btm069.
- O. Troyanskaya, M. Cantor, G. Sherlock, P. Brown, T. Hastie, R. Tibshirani, D. Botstein, R. B. Altman, *Bioinformatics* **2001**, *17*, 520–525, DOI 10.1093/bioinformatics/17.6.520.

Examples

```
toy_metaboscape %>%
  impute_svd()
```

impute_user_value *Impute missing values by replacing them with a user-provided value*

Description

Replace missing intensity values (NA) with a user-provided value (e.g., 1).

Usage

```
impute_user_value(data, value)
```

Arguments

data	A tidy tibble created by read_featuretable.
value	Numeric that replaces missing values

Value

A tibble with imputed missing values.

Examples

```
toy_metaboscape %>%
  impute_user_value(value = 1)
```

join_metadata *Join a featuretable and sample metadata*

Description

Joins a featuretable and associated sample metadata. Basically a wrapper around left_join where by = "Sample".

Usage

```
join_metadata(data, metadata)
```

Arguments

data	A feature table created with read_featuretable
metadata	Sample metadata created with create_metadata_skeleton

Value

A tibble with added sample metadata.

Examples

```
toy_metaboscape %>%
  join_metadata(toy_metaboscape_metadata)
```

`msn_calc_nl` *Calculate neutral losses from precursor ion mass and fragment ion masses*

Description

Calculate neutral loss spectra for all ions with available MSn spectra in `data`. To calculate neutral losses, MSn spectra are required. See `read_mgf`. This step is required for subsequent filtering based on neutral losses (`filter_neutral_loss`). Resulting neutral loss spectra are stored in tibbles in a new list column named `Neutral_Loss`.

Usage

```
msn_calc_nl(data, m_z_col)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.
`m_z_col`	Which column holds the precursor m/z? Uses `args_data_masking`.

Value

A tibble with added neutral loss spectra. A new list column is created named `Neutral_Loss`.

Examples

```
toy_mgf %>%
  msn_calc_nl(m_z_col = PEPMASS)
```

`msn_scale` *Scale intensities in MSn spectra to the highest value within each spectrum*

Description

Scale the intensity of each peak in an MSn spectrum to that of the highest peak. MSn spectra are required to use this function. See `read_mgf`.

Important Note

Please note that existing MSn spectra in `data` will be overwritten.

Usage

```
msn_scale(data, scale_to = 100)
```

Arguments

data	A tidy tibble created by read_featuretable.
scale_to	A numeric that specifies to which number the highest signal in each spectrum will be scaled.

Value

A tibble with scaled MSn spectra.

Examples

```
toy_mgf %>%
  msn_scale()
```

---

normalize_cyclic_loess

Normalize intensities across samples using cyclic LOESS normalization

---

Description

The steps the algorithm takes are the following:

1. log2 transform the intensities
2. Choose 2 samples to generate an MA-plot from
3. Fit a LOESS curve
4. Subtract half of the difference between the predicted value and the true value from the intensity of sample 1 and add the same amount to the intensity of Sample 2
5. Repeat for all unique combinations of samples
6. Repeat all steps until the model converges or n_iter is reached.

Convergence is assumed if the confidence intervals of all LOESS smooths include the 0 line. If fixed_iter = TRUE, the algorithm will perform exactly n_iter iterations. If fixed_iter = FALSE, the algorithm will perform a maximum of n_iter iterations.

See the reference section for details.

Usage

```
normalize_cyclic_loess(
  data,
  n_iter = 3,
  fixed_iter = TRUE,
  loess_span = 0.7,
  level = 0.95,
  verbose = FALSE,
  ...
)
```

Arguments

data	A tidy tibble created by read_featuretable.
n_iter	The number of iterations to perform. If fixed_iter = TRUE exactly n_iter will be performed. If fixed_iter = FALSE a maximum of n_iter will be performed and the algorithm will stop whether convergence is reached or not.
fixed_iter	Should a fixed number of iterations be performed?
loess_span	The span of the LOESS fit. A larger span produces a smoother line.
level	The confidence level for the convergence criterion. Note that a a larger confidence level produces larger confidence intervals and therefore the algorithm stops earlier.
verbose	TRUE or FALSE. Should messages be printed to the console?
...	Arguments passed onto loess. For example, degree = 1, family = "symmetric", iterations = 4, s produces a LOWESS fit.

Value

A tibble with intensities normalized across samples.

References

- B. M. Bolstad, R. A. Irizarry, M. Åstrand, T. P. Speed, *Bioinformatics* **2003**, *19*, 185–193, DOI 10.1093/bioinformatics/19.2.185.
- Karla Ballman, Diane Grill, Ann Oberg, Terry Therneau, "Faster cyclic loess: normalizing DNA arrays via linear models" can be found under https://www.mayo.edu/research/documents/biostat-68pdf/doc-10027897, 2004.
- K. V. Ballman, D. E. Grill, A. L. Oberg, T. M. Therneau, *Bioinformatics* **2004**, *20*, 2778–2786, DOI 10.1093/bioinformatics/bth327.

Examples

```
toy_metaboscape %>%
  impute_lod() %>%
  normalize_cyclic_loess()
```

normalize_factor *Normalize intensities across samples using a normalization factor*

Description

Normalization is done by dividing the intensity by a sample-specific factor (e.g., weight, protein or DNA content). This function requires a sample-specific factor, usually supplied via the `Factor` column from the sample metadata. See the Examples section for details.

Usage

```
normalize_factor(data, factor_column = .data$Factor)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.
`factor_column`	Which column contains the sample-specific factor? Usually `factor_column = Factor`. Uses `args_data_masking`.

Value

A tibble with intensities normalized across samples.

Examples

```
toy_metaboscape %>%
  join_metadata(toy_metaboscape_metadata) %>%
  normalize_factor()
```

normalize_median *Normalize intensities across samples by dividing by the sample median*

Description

Normalize across samples by dividing feature intensities by the sample median, making the median 1 in all samples. See References for more information.

Usage

```
normalize_median(data)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.

Value

A tibble with intensities normalized across samples.

References

T. Ramirez, A. Strigun, A. Verlohner, H.-A. Huener, E. Peter, M. Herold, N. Bordag, W. Mellert, T. Walk, M. Spitzer, X. Jiang, S. Sperber, T. Hofmann, T. Hartung, H. Kamp, B. Van Ravenzwaay, *Arch Toxicol* **2018**, *92*, 893–906, DOI 10.1007/s00204-017-2079-6.

Examples

```
toy_metaboscape %>%
  normalize_median()
```

`normalize_pqn` *Normalize intensities across samples using a Probabilistic Quotient Normalization (PQN)*

Description

This method was originally developed for H-NMR spectra of complex biofluids but has been adapted for other 'omics data. It aims to eliminate dilution effects by calculating the most probable dilution factor for each sample, relative to one or more reference samples. See references for more details.

Usage

```
normalize_pqn(
  data,
  fn = "median",
  normalize_sum = TRUE,
  reference_samples = NULL,
  ref_as_group = FALSE,
  group_column = NULL
)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.
`fn`	Which function should be used to calculate the reference spectrum from the reference samples? Can be either "mean" or "median".
`normalize_sum`	A logical indicating whether a sum normalization (aka total area normalization) should be performed prior to PQN. It is recommended to do so and other packages (e.g., **KODAMA**) also perform a sum normalization prior to PQN.

`reference_samples`
: Either `NULL` or a character or character vector containing the sample(s) to calculate the reference spectrum from. In the original publication, it is advised to calculate the median of control samples. If `NULL`, all samples will be used to calculate the reference spectrum.

`ref_as_group`
: A logical indicating if `reference_samples` are the names of samples or group(s).

`group_column`
: Only relevant if `ref_as_group = TRUE`. Which column should be used for grouping reference and non-reference samples? Usually `group_column = Group`. Uses `args_data_masking`.

Value

A tibble with intensities normalized across samples.

References

- F. Dieterle, A. Ross, G. Schlotterbeck, H. Senn, *Anal. Chem.* **2006**, *78*, 4281–4290, DOI 10.1021/ac051632c.

Examples

```
# specify the reference samples with their sample names
toy_metaboscape %>%
  impute_lod() %>%
  normalize_pqn(reference_samples = c("QC1", "QC2", "QC3"))

# specify the reference samples with their group names
toy_metaboscape %>%
  join_metadata(toy_metaboscape_metadata) %>%
  impute_lod() %>%
  normalize_pqn(reference_samples = c("QC"), ref_as_group = TRUE, group_column = Group)
```

`normalize_quantile_all`
: *Normalize intensities across samples using standard Quantile Normalization*

Description

This is the standard approach for Quantile Normalization. Other sub-flavors are also available:

- `normalize_quantile_group`
- `normalize_quantile_batch`
- `normalize_quantile_smooth`

See References for more information.

Usage

```
normalize_quantile_all(data)
```

Arguments

data	A tidy tibble created by read_featuretable.

Value

A tibble with intensities normalized across samples.

References

Y. Zhao, L. Wong, W. W. B. Goh, *Sci Rep* **2020**, *10*, 15534, DOI 10.1038/s41598-020-72664-6.

Examples

```
toy_metaboscape %>%
  normalize_quantile_all()
```

---

normalize_quantile_batch

Normalize intensities across samples using grouped Quantile Normalization with multiple batches

---

Description

This function performs a Quantile Normalization on each sub-group and batch in the data set. **It therefore requires grouping information**. See Examples for more information. This approach might perform better than the standard approach, normalize_quantile_all, if sub-groups are very different (e.g., when comparing cancer vs. normal tissue).

Other sub-flavors are also available:

- normalize_quantile_all
- normalize_quantile_batch
- normalize_quantile_smooth

See References for more information. Note that it is equivalent to the 'Discrete' normalization in Zhao *et al.* but has been renamed for internal consistency.

Usage

```
normalize_quantile_batch(
  data,
  group_column = .data$Group,
  batch_column = .data$Batch
)
```

Arguments

data	A tidy tibble created by read_featuretable.
group_column	Which column should be used for grouping? Usually grouping_column = Group. Uses args_data_masking.
batch_column	Which column contains the batch information? Usually grouping_column = Batch. Uses args_data_masking.

Value

A tibble with intensities normalized across samples.

References

Y. Zhao, L. Wong, W. W. B. Goh, *Sci Rep* **2020**, *10*, 15534, DOI 10.1038/s41598-020-72664-6.

Examples

```
toy_metaboscape %>%
  # Metadata, including grouping and batch information,
  # must be added before using normalize_quantile_batch()
  join_metadata(toy_metaboscape_metadata) %>%
  normalize_quantile_batch(group_column = Group, batch_column = Batch)
```

---

normalize_quantile_group

Normalize intensities across samples using grouped Quantile Normalization

---

Description

This function performs a Quantile Normalization on each sub-group in the data set. **It therefore requires grouping information**. See Examples for more information. This approach might perform better than the standard approach, normalize_quantile_all, if sub-groups are very different (e.g., when comparing cancer vs. normal tissue).

Other sub-flavors are also available:

- normalize_quantile_all
- normalize_quantile_batch
- normalize_quantile_smooth

See References for more information. Note that it is equivalent to the 'Class-specific' normalization in Zhao *et al.* but has been renamed for internal consistency.

Usage

```
normalize_quantile_group(data, group_column = .data$Group)
```

Arguments

data	A tidy tibble created by read_featuretable.
group_column	Which column should be used for grouping? Usually grouping_column = Group. Uses args_data_masking.

Value

A tibble with intensities normalized across samples.

References

Y. Zhao, L. Wong, W. W. B. Goh, *Sci Rep* **2020**, *10*, 15534, DOI 10.1038/s41598-020-72664-6.

Examples

```
toy_metaboscape %>%
 # Metadata, including grouping information, must be added before using normalize_quantile_group()
  join_metadata(toy_metaboscape_metadata) %>%
  normalize_quantile_group(group_column = Group)
```

---

normalize_quantile_smooth

Normalize intensities across samples using smooth Quantile Normalization (qsmooth)

Description

This function performs a smooth Quantile Normalization on each sub-group in the data set (qsmooth). **It therefore requires grouping information**. See Examples for more information. This approach might perform better than the standard approach, normalize_quantile_all, if subgroups are very different (e.g., when comparing cancer vs. normal tissue). The result lies somewhere between normalize_quantile_group and normalize_quantile_all. Basically a re-implementation of Hicks *et al.* (2018).

Usage

```
normalize_quantile_smooth(
  data,
  group_column = .data$Group,
  rolling_window = 0.05
)
```

Arguments

data	A tidy tibble created by read_featuretable.
group_column	Which column should be used for grouping? Usually grouping_column = Group. Uses args_data_masking.
rolling_window	normalize_quantile_smooth uses a rolling window median to eliminate isolated outliers. This argument specifies the size of the rolling window as a fraction of the number of unique features in data. For example, if there are 100 features in data and rolling_window = 0.05, the rolling median will be calculated from 5 features. Set rolling_window = 0 to disable.

Value

A tibble with intensities normalized across samples.

References

- S. C. Hicks, K. Okrah, J. N. Paulson, J. Quackenbush, R. A. Irizarry, H. C. Bravo, *Biostatistics* **2018**, *19*, 185–198, DOI 10.1093/biostatistics/kxx028.
- Y. Zhao, L. Wong, W. W. B. Goh, *Sci Rep* **2020**, *10*, 15534, DOI 10.1038/s41598-020-72664-6.

Examples

```
toy_metaboscape %>%
 # Metadata, including grouping information, must be added before using normalize_quantile_group()
  join_metadata(toy_metaboscape_metadata) %>%
  normalize_quantile_smooth(group_column = Group)
```

---

normalize_ref *Normalize intensities across samples using a reference feature*

Description

Performs a normalization based on a reference feature, for example an internal standard. Divides the Intensities of all features by the Intensity of the reference feature in that sample and multiplies them with a constant value, making the Intensity of the reference feature the same in each sample.

Usage

```
normalize_ref(
  data,
  reference_feature,
  identifier_column,
  reference_feature_intensity = 1
)
```

Arguments

data	A tidy tibble created by read_featuretable.
reference_feature	An identifier for the reference feature. Must be unique. It is recommended to use the UID.
identifier_column	The column in which to look for the reference feature. It is recommended to use identifier_column = UID
reference_feature_intensity	Either a constant value with which the intensity of each feature is multiplied or a function (e.g., mean, median, min, max). If a function is provided, it will use that function on the Intensities of the reference feature in all samples before normalization and multiply the intensity of each feature with that value after dividing by the Intensity of the reference feature. For example, if reference_feature_intensity = mean, it calculates the mean of the Intensities of the reference features across samples before normalization. It then divides the Intensity of each feature by the Intensity of the reference feature in that sample. Finally, it multiplies each Intensity with the mean of the Intensities of the reference features prior to normalization.

Value

A tibble with intensities normalized across samples.

Examples

```
# Divide by the reference feature and make its Intensity 1000 in each sample
toy_metaboscape %>%
  impute_lod() %>%
 normalize_ref(reference_feature = 2, identifier_column = UID, reference_feature_intensity = 1000)

# Divide by the reference feature and make its Intensity the mean of intensities
# of the reference features before normalization
toy_metaboscape %>%
  impute_lod() %>%
 normalize_ref(reference_feature = 2, identifier_column = UID, reference_feature_intensity = mean)
```

---

normalize_sum *Normalize intensities across samples by dividing by the sample sum*

Description

Normalize across samples by dividing feature intensities by the sum of all intensities in a sample, making the sum 1 in all samples.

Important Note

Intensities of individual features will be very small after this normalization approach. It is therefore advised to multiply all intensities with a fixed number (e.g., 1000) after normalization. See this discussion on OMICSForum.ca and the examples below for further information.

Usage

```
normalize_sum(data)
```

Arguments

data	A tidy tibble created by read_featuretable.

Value

A tibble with intensities normalized across samples.

Examples

```
# Example 1: Normalization only
toy_metaboscape %>%
  normalize_sum()

# Example 2: Multiply with 1000 after normalization
toy_metaboscape %>%
  normalize_sum() %>%
  dplyr::mutate(Intensity = .data$Intensity * 1000)
```

---

plot_pca *Draws a scores or loadings plot or performs calculations necessary to draw them manually*

Description

Performs PCA and creates a Scores or Loadings plot. Basically a wrapper around pcaMethods::pca The plot is drawn with ggplot2 and can therefore be easily manipulated afterwards (e.g., changing the theme or the axis labels). Please note that the function is intended to be easy to use and beginner friendly and therefore offers limited ability to fine-tune certain parameters of the resulting plot. If you wish to draw the plot yourself, you can set return_tbl = TRUE. In this case, a tibble is returned instead of a ggplot2 object which you can use to create a plot yourself.

Important Note

plot_pca() depends on the pcaMethods package from Bioconductor. If metamorphr was installed via install.packages(), dependencies from Bioconductor were not automatically installed. When plot_pca() is called without the pcaMethods package installed, you should be asked if you want to install pak and pcaMethods. If you want to use plot_pca() you have to install those. In case you run into trouble with the automatic installation, please install pcaMethods manually. See pcaMethods – a Bioconductor package providing PCA methods for incomplete data for instructions on manual installation.

Usage

```
plot_pca(
  data,
  method = "svd",
  what = "scores",
  n_pcs = 2,
  pcs = c(1, 2),
  center = TRUE,
  group_column = NULL,
  name_column = NULL,
  return_tbl = FALSE,
  verbose = FALSE
)
```

Arguments

data	A tidy tibble created by read_featuretable.
method	A character specifying one of the available methods ("svd", "nipals", "rnipals", "bpca", "ppca", "svdImpute", "robustPca", "nlpca", "llsImpute", "llsImputeAll"). If the default is used ("svd") an SVD PCA will be done, in case data does not contain missing values, or a NIPALS PCA if data does contain missing values.
what	Specifies what should be returned. Either "scores" or "loadings".
n_pcs	The number of PCs to calculate.
pcs	A vector containing 2 integers that specifies the PCs to plot. Only relevant if return_tbl = FALSE. The following condition applies: max(pcs) <= n_pcs.
center	Should data be mean centered? See prep for details.
group_column	Either NULL or a column in data (e.g., group_column = Group). If provided, the dots in the scores plot will be colored according to their group. Only relevant if what = "scores".
name_column	Either NULL or a column in data (e.g., name_column = Feature). If provided, feature names are preserved in the resulting tibble. Only relevant if what = "loadings" & return_tbl = TRUE.
return_tbl	A logical. If FALSE, returns a ggplot2 object, if TRUE returns a tibble which can be used to draw the plot manually to have more control.
verbose	Should outputs from pca be printed to the console?

Value

Either a Scores or Loadings Plot in the form of a ggplot2 object or a tibble.

Examples

```
# Draw a Scores Plot
toy_metaboscape %>%
  impute_lod() %>%
  join_metadata(toy_metaboscape_metadata) %>%
```

```
  plot_pca(what = "scores", group_column = Group)

# Draw a Loadings Plot
toy_metaboscape %>%
  impute_lod() %>%
  join_metadata(toy_metaboscape_metadata) %>%
  plot_pca(what = "loadings", name_column = Feature)
```

`plot_volcano` *Draws a Volcano Plot or performs calculations necessary to draw one manually*

Description

Performs necessary calculations (i.e., calculate *p*-values and log2-fold changes) and creates a basic Volcano Plot. The plot is drawn with ggplot2 and can therefore be easily manipulated afterwards (e.g., changing the theme or the axis labels). Please note that the function is intended to be easy to use and beginner friendly and therefore offers limited ability to fine-tune certain parameters of the resulting plot. If you wish to draw the plot yourself, you can set `return_tbl = TRUE`. In this case, a tibble is returned instead of a ggplot2 object which you can use to create a plot yourself. A Volcano Plot is used to compare two groups. Therefore grouping information must be provided. See `join_metadata` for more information.

Usage

```
plot_volcano(
  data,
  group_column,
  name_column,
  groups_to_compare,
  batch_column = NULL,
  batch = NULL,
  log2fc_cutoff = 1,
  p_value_cutoff = 0.05,
  colors = list(sig_up = "darkred", sig_down = "darkblue", not_sig_up = "grey",
    not_sig_down = "grey", not_sig = "grey"),
  adjust_p = FALSE,
  log2_before = FALSE,
  return_tbl = FALSE,
  ...
)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.
`group_column`	Which column should be used for grouping? Usually `group_column = Group`. Uses `args_data_masking`.

name_column — Which column contains the feature names? Can for example be name_column = UID or name_column = Feature. Uses args_data_masking.

groups_to_compare — Names of the groups which should be compared as a character vector. Those are the group names in the group_column. They are usually provided in the form of a metadata tibble and joined via join_metadata.

batch_column — Which column contains the batch information? Usually batch_column = Batch. Only relevant if data contains multiple batches. For example, if data contains 2 batches and each batch contains measurements of separate controls, group_column and batch arguments should be provided. Otherwise controls of both batches will be considered when calculating the *p*-value and log2 fold change. Uses args_data_masking.

batch — The names of the batch(es) that should be included when calculating *p*-value and log2 fold change.

log2fc_cutoff — A numeric. What cutoff should be used for the log2 fold change? Traditionally, this is set to 1 which corresponds to a doubling or halving of intensity or area compared to a control. This is only important for assignment to groups and colors defined in the colors argument.

p_value_cutoff — A numeric. What cutoff should be used for the *p*-value? Traditionally, this is set to 0.05. This is only important for assignment to groups and colors defined in the colors argument. Note that this is not the -log10 transformed value.

colors — A named list for coloring the dots in the Volcano Plot or NULL in case the points should not be colored. The list must contain colors for the following groups: sig_up, sig_down, not_sig_up, not_sig_down and not_sig.

adjust_p — Should the *p*-value be adjusted? Can be either FALSE, (the default) in case no adjustment should be made or any or the name from p.adjust.methods (e.g., adjust_p = "fdr").

log2_before — A logical. Should the data be log2 transformed prior to calculating the *p*-values?

return_tbl — A logical. If FALSE, returns a ggplot2 object, if TRUE returns a tibble which can be used to draw the plot manually to have more control.

... — Arguments passed on to t.test. If none are provided (the default), a Welch Two Sample *t*-test will be performed.

Value

Either a Volcano Plot in the form of a ggplot2 object or a tibble.

Examples

```
# returns a Volcano Plot in the form of a ggplot2 object
toy_metaboscape %>%
  impute_lod() %>%
  join_metadata(toy_metaboscape_metadata) %>%
  plot_volcano(
    group_column = Group,
    name_column = Feature,
    groups_to_compare = c("control", "treatment")
```

```
  )

# returns a tibble to draw the plot manually
toy_metaboscape %>%
  impute_lod() %>%
  join_metadata(toy_metaboscape_metadata) %>%
  plot_volcano(
    group_column = Group,
    name_column = Feature,
    groups_to_compare = c("control", "treatment"),
    return_tbl = TRUE
  )
```

`read_featuretable` *Read a feature table into a tidy tibble*

Description

Basically a wrapper around `readr::read_delim()` but performs some initial tidying operations such as `gather()` rearranging columns. The `label_col` will be renamed to *Feature*.

Usage

```
read_featuretable(
  file,
  delim = ",",
  label_col = 1,
  metadata_cols = NULL,
  remove_empty_cols = FALSE,
  show_removed_cols = TRUE,
  ...
)
```

Arguments

`file`	A path to a file but can also be a connection or literal data.
`delim`	The field separator or delimiter. For example "," in csv files.
`label_col`	The index or name (as a character) of the column that will be used to label Features. For example an identifier (*e.g.*, KEGG, CAS, HMDB) or a *m/z*-RT pair.
`metadata_cols`	The index/indices or name(s) of column(s) that hold additional feature metadata (*e.g.*, retention times, additional identifiers or *m/z* values).
`remove_empty_cols`	Either `TRUE` or `FALSE`. Should empty columns be removed after reading the feature table? For a more fine-grained control, you can use a combination of `read_delim`, `remove_empty_cols` and `convert_from_wide`.See the respective function documentation for more details.

show_removed_cols
: Only relevant if `remove_empty_cols = TRUE`. If `TRUE` prints a message that shows which columns were removed.

...
: Additional arguments passed on to `readr::read_delim()`

Value

A tidy tibble.

References

- H. Wickham, *J. Stat. Soft.* **2014**, *59*, DOI 10.18637/jss.v059.i10.
- H. Wickham, M. Averick, J. Bryan, W. Chang, L. McGowan, R. François, G. Grolemund, A. Hayes, L. Henry, J. Hester, M. Kuhn, T. Pedersen, E. Miller, S. Bache, K. Müller, J. Ooms, D. Robinson, D. Seidel, V. Spinu, K. Takahashi, D. Vaughan, C. Wilke, K. Woo, H. Yutani, *JOSS* **2019**, *4*, 1686, DOI 10.21105/joss.01686.
- "12 Tidy data | R for Data Science," can be found under https://r4ds.had.co.nz/tidy-data.html, **2023**.

Examples

```
# Read a toy dataset in the format produced with Bruker MetaboScape (Version 2021).
featuretable_path <- system.file("extdata", "toy_metaboscape.csv", package = "metamorphr")

# Example 1: Provide indices for metadata_cols
featuretable <- read_featuretable(featuretable_path, metadata_cols = 2:5)

featuretable

# Example 2: Provide a name for label_col and indices for metadata_cols
featuretable <- read_featuretable(
  featuretable_path,
  label_col = "m/z",
  metadata_cols = c(1, 2, 4, 5)
)

featuretable

# Example 3: Provide names for both, label_col and metadata_cols
featuretable <- read_featuretable(
  featuretable_path,
  label_col = "m/z",
  metadata_cols = c("Bucket label", "RT", "Name", "Formula")
)

featuretable
```

`read_featuretable_mzmine` *Read a 'full_feature_table' from 'mzmine' into a tidy tibble*

Description

Similar to `read_featuretable` but specifically for full_feature_table' files created with 'mzmine'. For more information, see the 'mzmine' documentation.

Usage

```
read_featuretable_mzmine(
  file,
  intensity = "height",
  field_separator = ",",
  label_col = 1,
  import_datafile_cols = FALSE,
  remove_empty_cols = FALSE,
  show_removed_cols = TRUE
)
```

Arguments

`file`	A path to a file but can also be a connection or literal data.
`intensity`	A character that specifies what should be used as the (semi-)quantitative measure. Either `"height"` or `"area"`.
`field_separator`	The field separator as specified in 'mzmine'. Usually `","` if the file is in common CSV format.
`label_col`	The index or name (as a character) of the column that will be used to label Features. For example an identifier (*e.g.*, KEGG, CAS, HMDB) or a *m/z*-RT pair.
`import_datafile_cols`	Should columns that begin with `datafile:` be imported? Those columns contain sample-specific information, for example the retention time of a feature measured in a specific sample. Usually, this information is not necessary for downstream analysis but it can be used for quality control purposes. If `TRUE`, `datafile:` columns are imported and the sample names are removed from the column names. This allows for tidy storage of the information in one column per variable.
`remove_empty_cols`	Either `TRUE` or `FALSE`. Should empty columns be removed after reading the feature table? For a more fine-grained control, you can use a combination of `read_delim`, `remove_empty_cols` and `convert_from_wide`.See the respective function documentation for more details.

show_removed_cols
: Only relevant if remove_empty_cols = TRUE. If TRUE prints a message that shows which columns were removed.

Value

A tidy tibble.

References

- H. Wickham, *J. Stat. Soft.* **2014**, *59*, DOI 10.18637/jss.v059.i10.
- H. Wickham, M. Averick, J. Bryan, W. Chang, L. McGowan, R. François, G. Grolemund, A. Hayes, L. Henry, J. Hester, M. Kuhn, T. Pedersen, E. Miller, S. Bache, K. Müller, J. Ooms, D. Robinson, D. Seidel, V. Spinu, K. Takahashi, D. Vaughan, C. Wilke, K. Woo, H. Yutani, *JOSS* **2019**, *4*, 1686, DOI 10.21105/joss.01686.
- "12 Tidy data | R for Data Science," can be found under https://r4ds.had.co.nz/tidy-data.html, **2023**.

Examples

```
# Read a toy dataset in the format produced with mzmine.

featuretable_path <- system.file("extdata", "toy_mzmine.csv", package = "metamorphr")

# Example 1: Use feature height as the metric
featuretable <- read_featuretable_mzmine(
  featuretable_path,
  intensity = "height"
)

featuretable

# Example 2: Use the 'mz' column as a Feature label
featuretable <- read_featuretable_mzmine(
  featuretable_path,
  label_col = "mz"
)

featuretable
```

---

read_mgf *Read a MGF file into a tidy tibble*

Description

MGF files allow the storage of MS/MS spectra. This function reads them into a tidy tibble. Each variable is stored in a column and each ion (observation) is stored in a separate row. MS/MS spectra are stored in a list column named MSn. Please note that MGF files are software-specific so the variables and their names may vary. This function was developed with the GNPS file format exported from mzmine in mind. If you encounter any bugs please report them: https://github.com/yasche/metamorphr/issues

Usage

```
read_mgf(file, show_progress = TRUE)
```

Arguments

file	The path to the MGF file.
show_progress	A logical indicating whether the progress of the import should be printed to the console. Only important for large MGF files.

Value

A tidy tibble holding MS/MS spectra.

Examples

```
mgf_path <- system.file("extdata", "toy_mgf.mgf", package = "metamorphr")
read_mgf(mgf_path)
```

---

remove_empty_cols *Remove empty columns from a tibble or data frame*

Description

Remove empty columns (i.e., columns that *only* contain NA) from a tibble or data frame.

Usage

```
remove_empty_cols(data, always_keep = NULL, show_removed_cols = TRUE)
```

Arguments

data	A tibble or data frame in wide format.
always_keep	Specify columns that should *always* be kept, regardless if they only contain NA or not. Columns can be specified as a vector with column indices (e.g., c(1, 2)), column names as characters (e.g., c("a", "b")), as symbols (e.g., c(a, b)), or combinations thereof (e.g., c(1, b))
show_removed_cols	If TRUE prints a message that shows which columns were removed.

Value

A tibble or data frame in wide format without empty columns.

Examples

```
# Columns `a` and `d` contains only `NA` and should be removed
na_tibble <- tibble::tibble(
  a = c(NA, NA, NA),
  b = c(1, 2, 3),
  c = c(NA, 2, 3),
  d = c(NA, NA, 3),
  e = c(NA, NA, NA)
)

remove_empty_cols(na_tibble)

# Columns `a` and `d` contains only `NA` but `a` should be kept anyways
remove_empty_cols(na_tibble, always_keep = a)
```

---

scale_auto *Scale intensities of features using autoscale*

Description

Scales the intensities of all features using

$$\widetilde{x}_{ij} = \frac{x_{ij} - \overline{x}_i}{s_i}$$

where $\widetilde{x}_{ij}$ is the intensity of sample j, feature i after scaling, x_{ij} is the intensity of sample j, feature i before scaling, $\overline{x}_i$ is the mean of intensities of feature i across all samples and s_i is the standard deviation of intensities of feature i across all samples. In other words, it subtracts the mean intensity of a feature across samples from the intensities of that feature in each sample and divides by the standard deviation of that feature. For more information, see the reference section.

Usage

```
scale_auto(data)
```

Arguments

data	A tidy tibble created by read_featuretable.

Value

A tibble with autoscaled intensities.

References

- R. A. Van Den Berg, H. C. Hoefsloot, J. A. Westerhuis, A. K. Smilde, M. J. Van Der Werf, *BMC Genomics* **2006**, *7*, 142, DOI 10.1186/1471-2164-7-142.

Examples

```
toy_metaboscape %>%
  scale_auto()
```

`scale_center` *Center intensities of features around zero*

Description

Centers the intensities of all features around zero using

$$\widetilde{x}_{ij} = x_{ij} - \overline{x}_i$$

where $\widetilde{x}_{ij}$ is the intensity of sample j, feature i after scaling, x_{ij} is the intensity of sample j, feature i before scaling and $\overline{x}_i$ is the mean of intensities of feature i across all samples. In other words, it subtracts the mean intensity of a feature across samples from the intensities of that feature in each sample. For more information, see the reference section.

Usage

```
scale_center(data)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.

Value

A tibble with intensities scaled around zero.

References

- R. A. Van Den Berg, H. C. Hoefsloot, J. A. Westerhuis, A. K. Smilde, M. J. Van Der Werf, *BMC Genomics* **2006**, *7*, 142, DOI 10.1186/1471-2164-7-142.

Examples

```
toy_metaboscape %>%
  scale_center()
```

`scale_level` *Scale intensities of features using level scaling*

Description

Scales the intensities of all features using

$$\widetilde{x}_{ij} = \frac{x_{ij} - \overline{x}_i}{\overline{x}_i}$$

where $\widetilde{x}_{ij}$ is the intensity of sample j, feature i after scaling, x_{ij} is the intensity of sample j, feature i before scaling and $\overline{x}_i$ is the mean of intensities of feature i across all samples

In other words, it performs centering (`scale_center`) and divides by the feature mean, thereby focusing on the relative intensity.

Usage

```
scale_level(data)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.

Value

A tibble with level scaled intensities.

References

- R. A. Van Den Berg, H. C. Hoefsloot, J. A. Westerhuis, A. K. Smilde, M. J. Van Der Werf, *BMC Genomics* **2006**, *7*, 142, DOI 10.1186/1471-2164-7-142.

Examples

```
toy_metaboscape %>%
  impute_lod() %>%
  scale_level()
```

`scale_pareto` *Scale intensities of features using Pareto scaling*

Description

Scales the intensities of all features using

$$\widetilde{x}_{ij} = \frac{x_{ij} - \overline{x}_i}{\sqrt{s_i}}$$

where $\widetilde{x}_{ij}$ is the intensity of sample j, feature i after scaling, x_{ij} is the intensity of sample j, feature i before scaling, $\overline{x}_i$ is the mean of intensities of feature i across all samples and $\sqrt{s_i}$ is the square root of the standard deviation of intensities of feature i across all samples. In other words, it subtracts the mean intensity of a feature across samples from the intensities of that feature in each sample and divides by the square root of the standard deviation of that feature. For more information, see the reference section.

Usage

```
scale_pareto(data)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.

Value

A tibble with autoscaled intensities.

References

- R. A. Van Den Berg, H. C. Hoefsloot, J. A. Westerhuis, A. K. Smilde, M. J. Van Der Werf, *BMC Genomics* **2006**, *7*, 142, DOI 10.1186/1471-2164-7-142.

Examples

```
toy_metaboscape %>%
  scale_pareto()
```

scale_range *Scale intensities of features using range scaling*

Description

Scales the intensities of all features using

$$\widetilde{x}_{ij} = \frac{x_{ij} - \overline{x}_i}{x_{i,max} - x_{i,min}}$$

where $\widetilde{x}_{ij}$ is the intensity of sample j, feature i after scaling, x_{ij} is the intensity of sample j, feature i before scaling, $\overline{x}_i$ is the mean of intensities of feature i across all samples, $x_{i,max}$ is the maximum intensity of feature i across all samples and $x_{i,min}$ is the minimum intensity of feature i across all samples. In other words, it subtracts the mean intensity of a feature across samples from the intensities of that feature in each sample and divides by the range of that feature. For more information, see the reference section.

Usage

```
scale_range(data)
```

Arguments

data	A tidy tibble created by read_featuretable.

Value

A tibble with range scaled intensities.

References

- R. A. Van Den Berg, H. C. Hoefsloot, J. A. Westerhuis, A. K. Smilde, M. J. Van Der Werf, *BMC Genomics* **2006**, *7*, 142, DOI 10.1186/1471-2164-7-142.

Examples

```
toy_metaboscape %>%
  scale_range()
```

`scale_vast` *Scale intensities of features using vast scaling*

Description

Scales the intensities of all features using

$$\widetilde{x}_{ij} = \frac{x_{ij} - \overline{x}_i}{s_i} \cdot \frac{\overline{x}_i}{s_i}$$

where $\widetilde{x}_{ij}$ is the intensity of sample j, feature i after scaling, x_{ij} is the intensity of sample j, feature i before scaling, $\overline{x}_i$ is the mean of intensities of feature i across all samples and s_i is the standard deviation of intensities of feature i across all samples. Note that $\frac{\overline{x}_i}{s_i} = \frac{1}{CV}$ where CV is the coefficient of variation across all samples. `scale_vast_grouped` is a variation of this function that uses a group-specific coefficient of variation. In other words, it performs autoscaling (`scale_auto`) and divides by the coefficient of variation, thereby reducing the importance of features with a poor reproducibility.

Usage

```
scale_vast(data)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.

Value

A tibble with vast scaled intensities.

References

- R. A. Van Den Berg, H. C. Hoefsloot, J. A. Westerhuis, A. K. Smilde, M. J. Van Der Werf, *BMC Genomics* **2006**, *7*, 142, DOI 10.1186/1471-2164-7-142.
- J. Sun, Y. Xia, *Genes & Diseases* **2024**, *11*, 100979, DOI 10.1016/j.gendis.2023.04.018.

Examples

```
toy_metaboscape %>%
  scale_vast()
```

scale_vast_grouped *Scale intensities of features using grouped vast scaling*

Description

A variation of scale_vast but uses a group-specific coefficient of variation and therefore requires group information. See scale_vast and the References section for more information.

Usage

```
scale_vast_grouped(data, group_column = .data$Group)
```

Arguments

data	A tidy tibble created by read_featuretable.
group_column	Which column should be used for grouping? Usually grouping_column = Group. Uses args_data_masking.

Value

A tibble with vast scaled intensities.

References

- R. A. Van Den Berg, H. C. Hoefsloot, J. A. Westerhuis, A. K. Smilde, M. J. Van Der Werf, *BMC Genomics* **2006**, *7*, 142, DOI 10.1186/1471-2164-7-142.

Examples

```
toy_metaboscape %>%
  join_metadata(toy_metaboscape_metadata) %>%
  scale_vast_grouped()
```

summary_featuretable *General information about a feature table and sample-wise summary*

Description

Information about a feature table. Prints information to the console (number of samples, number of features and if applicable number of groups, replicates and batches) and returns a sample-wise summary as a list.

Usage

```
summary_featuretable(
  data,
  n_samples_max = 5,
  n_features_max = 5,
  n_groups_max = 5,
  n_batches_max = 5
)
```

Arguments

data	A tidy tibble created by read_featuretable.
n_samples_max	How many Samples should be printed to the console?
n_features_max	How many Features should be printed to the console?
n_groups_max	How many groups should be printed to the console?
n_batches_max	How many Batches should be printed to the console?

Value

A sample-wise summary as a list.

Examples

```
toy_metaboscape %>%
  join_metadata(toy_metaboscape_metadata) %>%
  summary_featuretable()
```

---

toy_metaboscape *A small toy data set created from a feature table in MetaboScape style*

Description

The raw feature table is also included. This tibble can be reproduced with `metamorphr::read_featuretable(system.file "toy_metaboscape.csv", package = "metamorphr"), metadata_cols = 2:5)`.

Usage

```
toy_metaboscape
```

Format

`toy_metaboscape`**:**

A data frame with 110 rows and 8 columns:

UID A unique identifier for each Feature. This column is automatically generated by `metamorphr::read_featuretable(` when the feature table is imported.

Feature A label given to each Feature for easier identification. The column of the original feature table that is used to generate the Feature column is specified with the `label_col` argument of `metamorphr::read_featuretable()`.

Sample Sample name. Column names in the original feature table.

Intensity Measured intensity (or area).

RT Retention time. Feature metadata and therefore not really necessary.

m/z Mass over charge. Feature metadata and therefore not really necessary.

Name Feature name. Feature metadata and therefore not really necessary.

Formula Chemical formula. Feature metadata and therefore not really necessary. ...

Source

This data set contains fictional data!

`toy_metaboscape_metadata`
Sample metadata for the fictional dataset `toy_metaboscape`

Description

Data was generated with `metamorphr::create_metadata_skeleton()` and can be reproduced with `metamorphr::toy_metaboscape %>% create_metadata_skeleton()`.'

Usage

```
toy_metaboscape_metadata
```

Format

`toy_metaboscape_metadata`**:**

A data frame with 11 rows and 5 columns:

Sample The sample name

Group To which group does the samples belong? For example a treatment or a background. Note that additional columns with additional grouping information can be freely added if necessary.

Replicate The replicate.

Batch The batch in which the samples were prepared or measured.

Factor A sample-specific factor, for example dry weight or protein content. ...

Source

This data set contains fictional data!

toy_mgf *A small toy data set containing MSn spectra*

Description

Data was generated with `metamorphr::read_mgf()` and can be reproduced with This tibble can be reproduced with `metamorphr::read_mgf(system.file("extdata", "toy_mgf.mgf", package = "metamorphr"))`.

Usage

```
toy_mgf
```

Format

`toy_mgf`**:**

A data frame with 3 rows and 5 columns:

VARIABLEONE A fictional variable.

VARIABLETWO A fictional variable.

VARIABLETHREE A fictional variable.

PEPMASS The precursor ion m/z.

MSn A list column containing MSn spectra. ...

Source

This data set contains fictional data!

transform_log *Transforms the intensities by calculating their log*

Description

Log-transforms intensities. The default (base = 10) calculates the log10. This transformation can help reduce heteroscedasticity. See references for more information.

Usage

```
transform_log(data, base = 10)
```

Arguments

`data`	A tidy tibble created by `read_featuretable`.
`base`	Which base should be used for the log-transformation. The default (10) means that log10 values of the intensities are calculated.

Value

A tibble with log-transformed intensities.

References

- R. A. Van Den Berg, H. C. Hoefsloot, J. A. Westerhuis, A. K. Smilde, M. J. Van Der Werf, *BMC Genomics* **2006**, *7*, 142, DOI 10.1186/1471-2164-7-142.

Examples

```
toy_metaboscape %>%
  impute_lod() %>%
  transform_log()
```

---

transform_power *Transforms the intensities by calculating their* n*th root*

Description

Calculates the *n*th root of intensities with x^(1/n). The default (n = 2) calculates the square root. This transformation can help reduce heteroscedasticity. See references for more information.

Usage

```
transform_power(data, n = 2)
```

Arguments

data	A tidy tibble created by read_featuretable.
n	The *n*th root to calculate.

Value

A tibble with power-transformed intensities.

References

- R. A. Van Den Berg, H. C. Hoefsloot, J. A. Westerhuis, A. K. Smilde, M. J. Van Der Werf, *BMC Genomics* **2006**, *7*, 142, DOI 10.1186/1471-2164-7-142.

Examples

```
toy_metaboscape %>%
  impute_lod() %>%
  transform_power()
```

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