Package ‘metabCombiner’

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Title Method for Combining LC-MS Metabolomics Feature Measurements

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Description This package aligns LC-HRMS metabolomics datasets acquired from biologically similar specimens analyzed under similar, but not necessarily identical, conditions. Peak-picked and simply aligned metabolomics feature tables (consisting of m/z, rt, and per-sample abundance measurements, plus optional identifiers & adduct annotations) are accepted as input. The package outputs a combined table of feature pair alignments, organized into groups of similar m/z, and ranked by a similarity score. Input tables are assumed to be acquired using similar (but not necessarily identical) analytical methods.

Depends R (>= 4.0)

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Suggests knitr, rmarkdown, testthat, BiocStyle

BugReports https://www.github.com/hhabra/metabCombiner/issues

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adductData

Retrieve Adduct Annotations

Description

This retrieves user-assigned adduct annotations from one or all constituent datasets of a metabCombiner object.

Usage

adductData(object, data = NULL)

## S4 method for signature 'metabCombiner'
adductData(object, data = NULL)

Arguments

object metabCombiner object
data dataset identifier to extract information from; if NULL, extracts information from all datasets
Value

data frame of adduct annotations

Examples

data(plasma30)
data(plasma20)

p30 <- metabData(head(plasma30,500), samples = "CHEAR")
p20 <- metabData(head(plasma20,500), samples = "Red")

p.comb <- metabCombiner(p30, p20, xid = "p30", yid = "p20")

##retrieve all adduct data
adducts <- adductData(p.comb, data = NULL)

##retrieve adduct data from p30
adducts <- adductData(p.comb, data = "p30")

---

adjustData  Process and Filter Metabolomics Feature Lists

Description

adjustData contains a set of pre-analysis steps for processing LC-MS metabolomics feature tables individually

Usage

adjustData(Data, misspc, measure, rtmin, rtmax, zero, duplicate)

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>a metabData object.</td>
</tr>
<tr>
<td>misspc</td>
<td>Numeric. Threshold missingness percentage for analysis.</td>
</tr>
<tr>
<td>measure</td>
<td>Character. Choice of central abundance measure; either &quot;median&quot; or &quot;mean&quot;.</td>
</tr>
<tr>
<td>rtmin</td>
<td>Numeric. Minimum retention time for analysis.</td>
</tr>
<tr>
<td>rtmax</td>
<td>Numeric. Maximum retention time for analysis.</td>
</tr>
<tr>
<td>zero</td>
<td>Logical. Whether to consider zero values as missing.</td>
</tr>
<tr>
<td>duplicate</td>
<td>Ordered numeric pair (m/z, rt) tolerance parameters for duplicate feature search.</td>
</tr>
</tbody>
</table>
Details

The pre-analysis adjustment steps include: 1) Restriction to a feature retention time range \( rt_{\text{min}} \leq rt \leq rt_{\text{max}} \) 2) Removal of features with missingness percentage exceeding \( \text{misspc} \) 3) Removal of duplicate metabolomics features.

After processing, abundance quantile (Q) values are calculated between 0 & 1 for the remaining features, as ranked by the \text{measure} argument, unless provided by the user.

Value

Updated \text{metabData} object. The \text{data} field is processed by the listed steps and \text{stats} list updated to contain feature statistics.

See Also

\text{metabData}, \text{filterRT}

---

**batchCombine**

*Stepwise Multi-batch LC-MS Alignment*

Description

This is a method for aligning multiple batches of a single metabolomics experiment in a stepwise manner using the \text{metabCombiner} workflow. The input is a list of \text{metabData} objects corresponding to the batch data frames arranged in sequential order (i.e. batch 1, 2, ..., N), and parameter lists for each step; the output is an aligned feature table and a \text{metabCombiner} object composed from the input batches.

Usage

```r
batchCombine(
    batches,
    binGap = 0.005,
    fitMethod = "gam",
    means = list(mz = TRUE, rt = TRUE, Q = TRUE),
    union = FALSE,
    anchorParam = selectAnchorsParam(),
    fitParam = fitgamParam(),
    scoreParam = calcScoresParam(B = 30),
    reduceParam = reduceTableParam()
)
```

Arguments

- **batches**: list of \text{metabData} objects corresponding to each LC-MS batch
- **binGap**: numeric parameter used for grouping features by m/z. See \?mzGroup for more details.
fitMethod  RT spline-fitting method, either "gam" or "loess"
means     logical. Option to take average m/z, rt, and/or Q from metabCombiner. May be a 3-length vector, single value (TRUE/FALSE), or a list with names "mz", "rt", "Q" as names.
union     logical. If FALSE, only feature present in all batches will be in the final result. If TRUE, features missing in at least one batch are included. The mean m/z, RT, and Q values imputed for matching in each step.
anchorParam list of parameter values for selectAnchors() function
fitParam   list of parameter values for fit_gam() or fit_loess()
scoreParam list of parameter values for calcScores()
reduceParam list of parameter values for reduceTable()

Details
Retention time drifting is commonly observed in large-scale LC-MS experiments in which samples are analyzed in multiple batches. Conventional LC-MS pre-processing approaches may effectively align features detected in samples from within a single batch, but fail in many cases to account for inter-batch drifting, leading to misaligned features.

batchCombine assumes that each batch has been previously processed separately using conventional LC-MS pre-processing approaches (e.g. XCMS), and can be represented as a data frame. Each batch data feature table must be filtered and formatted as a metabData object and the batches must be arranged as a list in sequential order of acquisition.

batchCombine applies the metabCombine wrapper function to successive pairs of metabolomics batches in a stepwise manner. Each iteration consists of the key steps in the package workflow (feature m/z grouping, anchor selection, retention time spline fitting, pairwise scoring, & table reduction). The first two batches are aligned together, then the combined results are aligned with the third batch, and so forth. Parameters for each sub-method are arranged in list format, with their respective defaults (e.g. fitgamParam() lists the default values for the fit_gam function).

Following each iteration, m/z, rt, and Q values from the combined dataset may be averaged to use for comparison with the next batch’s feature quantitative descriptors, if the means argument is set to TRUE; if set to FALSE, feature information is drawn from the latter of the previously combined batches, identical to the manner in which id & adduct descriptors are drawn.

Value

object metabCombiner object of the final alignment; x is set to the penultimate batch and y is set to the final batch

table combined feature table consisting of feature descriptor values followed by per-sample abundances and extra columns

Note
batchCombine is designed for aligning multi-batch datasets, i.e. where each batch is acquired in a roughly identical manner. It is not for disparately acquired LC-MS datasets (e.g. from different instruments, chromatographic systems, laboratories, etc.).
calcScores

See Also

metabCombine

Examples

# identically formatted batches in list form
data(metabBatches)

# obtain list of metabData objects
batchdata <- lapply(metabBatches, metabData, samples = "POOL",
                   extra = "SAMP", zero = TRUE)

# recommended: give each batch dataset a unique name
names(batchdata) <- paste("exb", seq_along(batchdata), sep = "")

# customize main workflow parameter lists
saparam <- selectAnchorsParam(tolmz = 0.002, tolQ = 0.2, tolrtq = 0.1)
fgparam <- fitgamParam(k = 20, iterFilter = 1)
csparam <- calcScoresParam(A = 70, B = 35, C = 0.3)
rtparam <- reduceTableParam(minScore = 0.5, maxRTerr = 0.33)

# run batchCombine program
combinedRes <- batchCombine(batches = batchdata, binGap = 0.0075,
                             means = list('mz' = TRUE, 'rt' = FALSE, 'Q' = FALSE),
                             anchorParam = saparam, fitParam = fgparam,
                             scoreParam = csparam, reduceParam = rtparam)

cTable <- combinedRes$table
object <- combinedRes$object

# if names were set earlier, the names should be returned by this
datasets(object)

calcScores

Compute Feature Similarity Scores

Description

Calculates a pairwise similarity (between 0 & 1) between all grouped features in metabCombiner object. The similarity score calculation is described in scorePairs.

Usage

calcScores(
    object,
    A = 75,
calcScores

B = 10,
C = 0.25,
f = c("gam", "loess"),
groups = NULL,
useAdduct = FALSE,
adduct = 1.25,
usePPM = FALSE,
brackets_ignore = c("", "[", ")
)

Arguments

object metabCombiner object.
A Numeric weight for penalizing m/z differences.
B Numeric weight for penalizing differences between fitted & observed retention times
C Numeric weight for differences in Q (abundance quantiles).
fit Character. Choice of fitted rt model, "gam" or "loess."
groups integer. Vector of feature groups to score. If set to NULL (default), will compute scores for all feature groups.
useAdduct logical. Option to penalize mismatches in (non-empty, non-bracketed) adduct column annotations.
adduct numeric. If useAdduct is TRUE, divides score of mismatched, non-empty and non-bracketed adduct column labels by this value.
usePPM logical. Option to use relative (as opposed to absolute) m/z differences in score computations.
brackets_ignore If useAdduct = TRUE, bracketed adduct character strings of these types will be ignored according to this argument

Details

This function updates the rtProj, score, rankX, and rankY columns in the combinedTable report. First, using the RT mapping model computed in the previous step(s), rt values are projected onto rty. Then similarity scores are calculated based on m/z, rt (fitted vs observed), and Q differences, with multiplicative weight penalties A, B, and C.

If the datasets contain representative set of shared identities (idx = idy), evaluateParams provides some guidance on appropriate A, B, and C values to use. In testing, the best values for A should lie between 50 and 120, according to mass accuracy; B should lie between 5 and 15 depending on fitting accuracy (higher if datasets processed under roughly identical conditions) ; C should vary between 0 and 1, depending on sample similarity. See examples below.

If using ppm (usePPM = TRUE), do not use the above guidelines for A values. The suggested range is between 0.01 and 0.05, though this hasn’t been thoroughly tested yet. Also, if using adduct information (useAdduct = TRUE), the score is divided by the numeric adduct argument if non-empty and non-bracketed adduct values do not match. Be sure that adduct annotations are accurate before using this functionality.
calcScoresParam

Value

metabCombiner object with updated combinedTable. rtProj column will contain fitted retention times determined from previously computed model; score will contain computed pairwise similarity scores of feature pairs; rankX & rankY are the integer ranks of scores for x & y features in descending order.

See Also

evaluateParams, scorePairs

Examples

data(plasma30)
data(plasma20)
p30 <- metabData(plasma30, samples = "CHEAR")
p20 <- metabData(plasma20, samples = "Red", rtmax = 17.25)
p.comb <- metabCombiner(xdata = p30, ydata = p20, binGap = 0.0075)

p.comb <- selectAnchors(p.comb, tolmz = 0.003, tolQ = 0.3, windy = 0.02)
p.comb <- fit_gam(p.comb, k = 20, iterFilter = 1, family = "gaussian")

#example: moderate m/z deviation, accurate rt fit, high sample similarity
p.comb <- calcScores(p.comb, A = 90, B = 14, C = 0.8, useAdduct = FALSE,
groups = NULL, fit = "gam", usePPM = FALSE)
cTable = combinedTable(p.comb)  #to view results

#example 2: high m/z deviation, moderate rt fit, low sample similarity
p.comb <- calcScores(p.comb, A = 50, B = 8, C = 0.2)

#example 3: low m/z deviation, poor rt fit, moderate sample similarity
p.comb <- calcScores(p.comb, A = 120, B = 5, C = 0.5)

#example 4: using ppm for mass deviation; note different A value
p.comb <- calcScores(p.comb, A = 0.05, B = 14, C = 0.5, usePPM = TRUE)

#example 5: limiting to specific m/z groups 1-1000
p.comb <- calcScores(p.comb, A = 90, B = 14, C = 0.5, groups = seq(1,1000))

#example 6: using adduct information
p.comb <- calcScores(p.comb, A = 90, B = 14, C = 0.5, useAdduct = TRUE,
adduct = 1.25)
calcScoresParam

Description

List of default parameters for score calculation step of main package workflow. See help(calcScores) or ?calcScores for details.

Usage

calcScoresParam(
  A = 75,
  B = 10,
  C = 0.25,
  fit = "gam",
  groups = NULL,
  usePPM = FALSE,
  useAdduct = FALSE,
  adduct = 1.25,
  brackets_ignore = c("", ",", ":")
)

Arguments

A  m/z difference specific weight; default: 75
B  RT prediction error specific weight; default: 10
C  Q difference specific weight; default: 0.25
fit choice of fitted model ("gam" or "loess"); default: "gam"
groups choice of m/z groups to score
usePPM choice to use PPM for m/z differences; default: FALSE
useAdduct choice to use adduct strings in scoring; default: FALSE
adduct value divisor for mismatched adduct strings; default: 1.25
brackets_ignore bracket types for ignoring string comparisons

Value

list of calcScores parameters

See Also

calcScores, metabCombine

Examples

cs_param <- calcScoresParam(A = 60, B = 15, C = 0.3)

cs_param <- calcScoresParam(A = 0.1, B = 20, C = 0.2, usePPM = TRUE)
**combineData**

*Obtain All Feature Data*

**Description**

Obtain all meta-data (m/z, RT, Q, id, adduct) alongside their respective sample (+ extra) values for aligned features. This is a (quasi)merge of the `linkcombinedTable` and `linkfeatData` tables and methods.

**Usage**

```r
combineData(object)
```

## S4 method for signature 'metabCombiner'

```r
combineData(object)
```

**Arguments**

- `object` metabCombiner object

**Value**

A data.frame containing meta-data columns as well as sample + extra columns for each of the constituent data sets.

**Examples**

```r
data(plasma30)
data(plasma20)
p30 <- metabData(head(plasma30, 500), samples = "CHEAR")
p20 <- metabData(head(plasma20, 500), samples = "Red")
p.comb <- metabCombiner(p30, p20)
p.comb.table <- combineData(p.comb)
```

---

**combinedTable**

*Obtain Feature Alignment Report*

**Description**

Obtain constructed table reporting every feature pair alignment.
Usage

combinedTable(object)

## S4 method for signature 'metabCombiner'
combinedTable(object)

Arguments

object metabCombiner object.

Value

Feature Pair Alignment report data frame. The columns of the report are as follows:

- idx: Identities of features from dataset X
- idy: Identities of features from dataset Y
- mzx: m/z values of features from dataset X
- mzy: m/z values of features from dataset Y
- rtx: retention time values of features from dataset X
- rty: retention time values of features from dataset Y
- rtProj: model-projected (X->Y) retention times values
- Qx: abundance quantile values of features from dataset X
- Qy: abundance quantile values of features from dataset Y
- group: m/z feature group of feature pairing
- score: computed similarity scores of feature pairing
- rankX: ranking of pairing score for X dataset features
- rankY: ranking of pairing score for Y dataset features
- adductX: adduct label of features from dataset X
- adductY: adduct label of features from dataset Y
- ...: Sample and extra columns from both datasets X & Y

Examples

data(plasma30)
data(plasma20)
p30 <- metabData(head(plasma30,500), samples = "CHEAR")
p20 <- metabData(head(plasma20,500), samples = "Red")
p.comb <- metabCombiner(p30, p20)
p.comb.table <- combinedTable(p.comb)
**combinerCheck**

Obtain Errors for metabCombiner Object Checks

**Description**

This function stores and returns a customized error message when checking the validity of certain objects.

**Usage**

```r
combinerCheck(errNo, type, error = "stop")
```

**Arguments**

- `errNo`: integer error code.
- `type`: character object type (either "combinedTable", "metabCombiner" or "metabData")
- `error`: character. If "stop", gives an error message; if "warning", provides a warning message; if "silent", returns silently

**Details**

In certain functions, an object must be checked for correctness. A metabData must have a properly formatted dataset with the correct column names & types. A metabCombiner must have properly formatted combinedTable, with expected names and columns. If one of these conditions is not met, a non-zero numeric code is returned and this function is used to print a specific error message corresponding to the appropriate object and error code.

**Value**

A customized error message for specific object check.

**crossValFit**

Cross Validation for Model Fits

**Description**

Helper function for `fit_gam()` & `fit_loess()`. Determines optimal value of k basis functions for Generalized Additive Model fits or span for loess fits from among user-defined choices, using a 10-fold cross validation minimizing mean squared error.
Usage

crossValFit(
  rts,
  fit,
  vals,
  bs,
  family,
  m,
  method,
  optimizer,
  control,
  message,
  ...
)

Arguments

rts data.frame of ordered pair retention times
fit Either "gam" for GAM fits, or "loess" for loess fits
vals numeric vector: k values for GAM fits, spans for loess fits. Best value chosen by 10-fold cross validation.
bs character. Choice of spline method, either "bs" or "ps"
family character. Choice of mgcv family; see: ?mgcv::family.mgcv
m integer. Basis and penalty order for GAM; see ?mgcv::s
method character. Smoothing parameter estimation method; see: ?mgcv::gam
optimizer character. Method to optimize smoothing parameter; see: ?mgcv::gam
control control parameters for loess fits; see: ?loess.control
message Option to print message indicating function progress
...
Other arguments passed to mgcv::gam.

Value

Optimal parameter value as determined by 10-fold cross validation

datasets Obtain Dataset IDs

Description

Each dataset in a metabCombiner object is represented by a character identifier. The datasets slot contains all these ids in a single vector, which can be obtained in sequential order with this accessor method
detectFields

Usage

datasets(object, list = FALSE)

## S4 method for signature 'metabCombiner'
datasets(object, list = FALSE)

Arguments

object metabCombiner object
list logical, option to return in list format (TRUE) vs character vector format (FALSE)

Value

character vector of dataset identifiers

Examples

data(plasma30)
data(plasma20)
p30 <- metabData(head(plasma30,500), samples = "CHEAR")
p20 <- metabData(head(plasma20,500), samples = "Red")
p.comb <- metabCombiner(p30, p20, xid = "p30", yid = "p20")
##datasets extraction: expect "p30", "p20"
sets <- datasets(p.comb, list = FALSE)

detectFields

Detect metabData Input Columns

Description

This function ensures that metabolomics datasets used as inputs for the program possess all of the required fields, plus any optional columns that may appear in the final report table.

Usage

detectFields(Data, table, mz, rt, id, adduct, samples, extra, Q)

Arguments

Data a metabData object.
table data frame containing metabolomics features or path to metabolomics data file.
mz Character name(s) / regular expressions associated with data column containing m/z values. The first column whose name contains this expression will be selected for analysis.
**rt** Character name(s) / regular expression associated with data column containing retention time values. The first column whose name contains this expression will be selected for analysis.

**id** Character name(s) or regular expression associated with data column containing metabolomics feature identifiers. The first column whose name contains this expression will be selected for analysis.

**adduct** Character name(s) or regular expression associated with data column containing adduct, formula, or additional annotations. The first column whose name contains this expression will be selected for analysis.

**samples** Character name(s) or regular expression associated with data column containing metabolomics feature identifiers. The first column whose name contains this expression will be selected for analysis.

**extra** Character names of columns containing additional feature information, e.g. non-analyzed sample values. All columns containing these keywords are selected for analysis.

**Q** Character name(s) or regular expression associated with numeric feature abundance quantiles.

**Value**

an initialized and formatted `metabData` object.

---

**evaluateParams** 
Evaluate Similarity Score Parameters

**Description**

This function provides a method for guiding selection of suitable values for A, B, & C weight arguments in the `calcScores` method, based on the similarity scores of shared identified compounds. Datasets must have at least one identity in common (i.e. idx = idy, case-insensitive), and preferably more than 10.

**Usage**

```r
evaluateParams(
  object,
  A = seq(60, 150, by = 10),
  B = seq(6, 15),
  C = seq(0.1, 0.5, by = 0.1),
  fit = c("gam", "loess"),
  usePPM = FALSE,
  minScore = 0.5,
  penalty = 5,
  groups = NULL,
  brackets_ignore = c("", ",", ";")
)
```
### evaluateParams

**Arguments**

- **object**: metabCombiner object
- **A**: Numeric weights for penalizing m/z differences.
- **B**: Numeric weights for penalizing differences between fitted & observed retention times
- **C**: Numeric weight for differences in Q (abundance quantiles).
- **fit**: Character. Choice of fitted rt model, "gam" or "loess."
- **usePPM**: logical. Option to use relative parts per million (ppm) as opposed to absolute m/z differences in score computations.
- **minScore**: numeric minimum score to count towards objective function calculation for known matching features (idx = idy) and mismatches.
- **penalty**: numeric. Subtractive mismatch penalty.
- **groups**: integer. Vector of feature groups to score. If set to NULL (default), will compute scores for all feature groups.
- **brackets_ignore**: bracketed identity and adduct character strings of these types will be ignored according to this argument

### Details

This uses an objective function, based on the accurate and inaccurate alignments of shared pre-identified compounds. For more details, see: `objective`.

### Value

A data frame with the following columns:

- **A**: m/z weight values
- **B**: rt weight values
- **C**: Q weight values
- **totalScore**: objective function evaluation of (A,B,C) weights

### Note

In contrast to `calcScores` function, A, B, & C take numeric vectors as input, as opposed to constants. The total number of rows in the output will be equal to the products of the lengths of these input vectors

### See Also

`calcScores, objective`
Examples

```r
data(plasma30)
data(plasma20)

p30 <- metabData(plasma30, samples = "CHEAR")
p20 <- metabData(plasma20, samples = "Red", rtmax = 17.25)
p.comb <- metabCombiner(xdata = p30, ydata = p20, binGap = 0.0075)

p.comb <- selectAnchors(p.comb, windx = 0.03, windy = 0.02)
p.comb <- fit_gam(p.comb, k = 20, iterFilter = 2)

#example 1
scores <- evaluateParams(p.comb, A = seq(60,100,10), B = seq(10,15), C = 0.5,
                          minScore = 0.7, penalty = 10)

#example 2: limiting to groups 1-2000
scores <- evaluateParams(p.comb, minScore = 0.5, groups = seq(1,2000))
```

---

**featData**

*Obtain Feature Metadata*

**Description**

This method retrieves all feature meta-data or that of one data set. The rowIDs identically correspond to the rows from the `combinedTable` data frame.

**Usage**

```r
featData(object, data = NULL)
```

## S4 method for signature 'metabCombiner'

```r
featData(object, data = NULL)
```

**Arguments**

- `object`: a `metabCombiner` object
- `data`: character dataset identifier

**Details**

`metabCombiner` objects organized metabolomics feature information in the "featData" slot. This table and method is primarily useful for alignment analyses involving three or more data sets.

**Value**

data frame of feature metadata from one or all datasets
Examples

data(plasma30)
data(plasma20)

p30 <- metabData(head(plasma30,500), samples = "CHEAR")
p20 <- metabData(head(plasma20,500), samples = "Red")

p.comb <- metabCombiner(p30, p20, xid = "p30", yid = "p20")

#full metadata extraction
fdata <- featData(p.comb, data = NULL)

#single dataset feature information extraction
fdata <- featData(p.comb, data = "p20")

filterAnchors Filter Outlier Ordered Pairs

Description

Helper function for fit_gam & fit_loess. It filters the set of ordered pairs using the residuals calculated from multiple GAM / loess fits.

Usage

filterAnchors(
    rts,
    fit,
    vals,
    outlier,
    coef,
    iterFilter,
    prop,
    bs,
    m,
    family,
    method,
    optimizer,
    control,
    message,
    ...
)

Arguments

rts Data frame of ordered retention time pairs.
fit Either "gam" for GAM fits, or "loess" for loess fits
vals  numeric values: k values for GAM fits, spans for loess fits
outlier  Thresholding method for outlier detection. If "MAD", the threshold is the mean absolute deviation (MAD) times \( \text{coef} \); if "boxplot", the threshold is \( \text{coef} \) times IQR plus 3rd quartile of a model’s absolute residual values.
coef  numeric (> 1) multiplier for determining thresholds for outliers (see outlier argument)
iterFilter  integer number of outlier filtering iterations
prop  numeric. A point is excluded if deemed a residual in more than this proportion of fits. Must be between 0 & 1.
bs  character. Choice of spline method from mgcv; either "bs" or "ps"
m  integer. Basis and penalty order for GAM; see \texttt{mgcv::s}
family  character. Choice of mgcv family; see: \texttt{mgcv::family.mgcv}
method  character. Smoothing parameter estimation method; see: \texttt{mgcv::gam}
optimizerv  character. Method to optimize smoothing parameter; see: \texttt{mgcv::gam}
control  control parameters for loess fits; see: \texttt{loess.control}
message  Option to print message indicating function progress
...  other arguments passed to \texttt{mgcv::gam}.

Value

anchor rts data frame with updated weights.

filtered  Retrieve Filtered Features

Description

Returns a data frame of metabolomics features eliminated in the \texttt{metabData} step. Features are returned based on the specific filter used for their elimination (RT, missingness, or duplicates).

Usage

\[
\text{filtered}(\text{object, type = c("rt", "duplicates", "missing")})
\]

\[
\#	ext{ S4 method for signature 'metabData'}
\text{filtered}(\text{object, type = c("rt", "missing", "duplicates")})
\]

Arguments

\begin{itemize}
\item \textbf{object} metabData object
\item \textbf{type} one of three filter types used for feature removal
\end{itemize}

Value

data frame of features removed due to specified filter
Examples

data(plasma20)

p20 <- metabData(plasma20, samples = "CHEAR", zero = TRUE, misspc = 20, rtmax = 17)

filtered_by_rt <- filtered(p20, type = "rt")

filtered_by_missingness <- filtered(p20, type = "missing")

filterRT

Filter Features by Retention Time Range

Description

Restricts input metabolomics feature table in metabData object to a range of retention times defined by rtmin & rtmax.

Usage

filterRT(data, rtmin, rtmax)

Arguments

data formatted metabolomics data frame.

rtmin lower range of retention times for analysis. If "min", defaults to minimum observed retention time.

rtmax upper range of retention times for analysis. If "max", defaults to maximum observed retention time.

Details

Retention time restriction is often recommended to aid the analysis of comparable metabolomics datasets. The beginning and end of a chromatogram typically contain features that do not correspond with true biological compounds derived from the sample. rtmin and rtmax should be set slightly before and slightly after the first and last commonly observed metabolites, respectively.

Value

A data frame of metabolomics features, limited to time window rtmin ≤ rt ≤ rtmax)
List fit_gam Defaults

Description

List of default parameters for GAM fitting step of main package workflow, which can be used as input for the wrapper functions. See help(fit_gam) or ?fit_gam for more details.

Usage

```r
fitgamParam(
  useID = FALSE,
  k = seq(10, 20, 2),
  iterFilter = 2,
  outlier = "MAD",
  coef = 2,
  prop = 0.5,
  weights = 1,
  bs = "bs",
  family = "scat",
  m = c(3, 2),
  method = "REML",
  rtx = c("min", "max"),
  rty = c("min", "max"),
  optimizer = "newton",
  message = TRUE
)
```

Arguments

- **useID**: choice of preserving identity-based anchors; default: FALSE
- **k**: values for GAM basis dimension k
- **iterFilter**: number of outlier filtering iterations; default: 2
- **outlier**: outlier filtering method (either "MAD" (mean absolute deviation) or "boxplot"); default: "MAD"
- **coef**: outlier filtering coefficient; default: 2
- **prop**: minimum proportion of fits in which a point can be a flagged outlier; default: 0.5
- **weights**: optional supplied weights to individual points; default: 1
- **bs**: choice of spline type ("bs" or "ps"); default: "bs"
- **family**: choice of family ("scat" or "gaussian"); default: "scat"
- **m**: basis and penalty order; default: c(3,2)
- **method**: smoothing parameter estimation method; default: "REML"
- **rtx**: ordered pair of endpoints for rtx; default: ("min", "max")
**fitloessParam**

- **rty**: ordered pair of endpoints for rty; default: ("min", "max")
- **optimizer**: numerical optimization for GAM; default: "newton"
- **message**: option to print progress message; default: TRUE

**Value**

list of fit_gam parameters

**See Also**

fit_gam, metabCombine

**Examples**

```r
fitParam <- fitgamParam(k = c(12, 14, 18, 20), iterFilter = 1, bs = "ps",
                         family = "gaussian", method = "GCV.Cp")
```

---

**Description**

List of default parameters for loess fitting step of main package workflow, See help(fit_loess) or ?fit_loess for more details.

**Usage**

```r
fitloessParam(
  useID = FALSE,
  spans = seq(0.2, 0.3, by = 0.02),
  outlier = "MAD",
  coef = 2,
  iterFilter = 2,
  prop = 0.5,
  weights = 1,
  message = TRUE,
  rtx = c("min", "max"),
  rty = c("min", "max"),
  control = loess.control(surface = "direct", iterations = 10)
)
```
Arguments

- **useID**: choice of preserving identity-based anchors; default: FALSE
- **spans**: values for span parameter which controls degree of smoothing
- **outlier**: outlier filtering method (either "MAD" or "boxplot"); default: "MAD"
- **coef**: outlier filtering coefficient; default: 2
- **iterFilter**: number of outlier filtering iterations; default: 2
- **prop**: minimum proportion of fits where a point can be a flagged outlier; default: 0.5
- **weights**: optional supplied weights to individual points; default: 1
- **message**: option to print progress message; default: TRUE
- **rtx**: ordered pair of endpoints for rtx; default: ("min", "max")
- **rty**: ordered pair of endpoints for rty; default: ("min", "max")
- **control**: loess-specific control parameters; see: \?loess.control

Value

list of fit_loess parameters:

See Also

- **fit_loess**, **metabCombine**

Examples

```r
fitParam <- fitloessParam(spans = c(0.2, 0.25, 0.3), outlier = "boxplot", iterFilter = 3, coef = 1.5, message = FALSE, control = loess.control(iterations = 4))
```

Description

Fits a (penalized) basis splines curve through a set of ordered pair retention times, modeling one set of retention times (rty) as a function on the other set (rtx). Outlier filtering iterations are performed first, then with the remaining points, the best value of parameter k is selected through 10-fold cross validation.
Usage

```r
fit_gam(
  object,
  useID = FALSE,
  k = seq(10, 20, 2),
  iterFilter = 2,
  outlier = c("MAD", "boxplot"),
  coef = 2,
  prop = 0.5,
  weights = 1,
  bs = c("bs", "ps"),
  m = c(3, 2),
  family = c("scat", "gaussian"),
  method = "REML",
  rtx = c("min", "max"),
  rty = c("min", "max"),
  optimizer = "newton",
  message = TRUE,
  ...
)
```

Arguments

- **object**: a `metabCombiner` object.
- **useID**: logical. If set to TRUE, matched ID anchors detected from previous step will never be flagged as outliers.
- **k**: integer k values controlling the dimension of the basis of the GAM fit (see: `?mgcv::s`). Best value chosen by 10-fold cross validation.
- **iterFilter**: integer number of outlier filtering iterations to perform.
- **outlier**: Thresholding method for outlier detection. If "MAD", the threshold is the mean absolute deviation (MAD) times coef; if "boxplot", the threshold is coef times IQR plus 3rd quartile of a model's absolute residual values.
- **coef**: numeric (> 1) multiplier for determining thresholds for outliers (see `outlier` argument).
- **prop**: numeric. A point is excluded if deemed a residual in more than this proportion of fits. Must be between 0 & 1.
- **weights**: Optional user supplied weights for each ordered pair. Must be of length equal to number of anchors (n) or a divisor of (n + 2).
- **bs**: character. Choice of spline method from `mgcv`, either "bs" (basis splines) or "ps" (penalized basis splines).
- **m**: integer. Basis and penalty order for GAM; see `?mgcv::s`.
- **family**: character. Choice of `mgcv` family; see: `?mgcv::family.mgcv`.
- **method**: character smoothing parameter estimation method; see: `?mgcv::gam`.
- **rtx**: ordered pair of endpoints for rtx; if "max" or "min", gives the maximum or minimum rtx, respectively, as model endpoints for rtx.
The minimum and maximum retention times from both input datasets are included in the set as ordered pairs \((\min_{\text{rtx}}, \min_{\text{rty}})\) & \((\max_{\text{rtx}}, \max_{\text{rty}})\). The weights argument initially determines the contribution of each point to the model fits; they are equally weighed by default, but can be changed using an \(n+2\) length vector, where \(n\) is the number of ordered pairs and the first and last of the weights determines the contribution of the min and max ordered pairs; by default, all weights are initially set to 1 for equal contribution of each point.

The model complexity is determined by \(k\). Multiple values of \(k\) are allowed, with the best value chosen by 10 fold cross validation. Before this happens, certain ordered pairs are removed based on the model errors. In each iteration, a GAM is fit using each selected value of \(k\). Depending on the outlier argument, a point is "removed" from the model (i.e. its corresponding weight set to 0) if its residual is above the threshold for a proportion of fitted models, as determined by \(\text{prop}\). If an anchor is an "identity" \((\text{id}_x = \text{id}_y\), detected in the \text{selectAnchors} by setting \text{useID} to TRUE\), then setting \text{useID} here prevents its removal.

Other arguments, e.g. \text{family}, \text{m}, \text{optimizer}, \text{bs}, and \text{method} are GAM specific parameters from the \text{mgcv} R package. The \text{family} option is currently limited to the "scat" (scaled t) and "gaussian" families; scat family model fits are more robust to outliers than gaussian fits, but compute much slower. Type of splines are currently limited to basis splines ("bs" or "ps").

Value

\text{metabCombiner} with a fitted GAM model object

See Also

\text{selectAnchors}, \text{fit_loess},

Examples

```r
data(plasma30)
data(plasma20)
p30 <- metabData(plasma30, samples = "CHEAR")
p20 <- metabData(plasma20, samples = "Red", rmax = 17.25)
p.comb = metabCombiner(xdata = p30, ydata = p20, binGap = 0.0075)
p.comb = selectAnchors(p.comb, tolmz = 0.003, tolQ = 0.3, windy = 0.02)
anchors = getAnchors(p.comb)

#version 1: using faster, but less robust, gaussian family
p.comb = fit_gam(p.comb, k = c(10,12,15,17,20), prop = 0.5,
```

```
```
fit_loess: Fit RT Projection Model With LOESS

Description

Fits a local regression smoothing spline through a set of ordered pair retention times. Modeling one set of retention times (rty) as a function on the other set (rtx). Filtering iterations of high residual points are performed first. Multiple acceptable values of \( \text{span} \) can be used, with one value selected through 10-fold cross validation.

Usage

fit_loess(
  object,
  useID = FALSE,
  spans = seq(0.2, 0.3, by = 0.02),
  outlier = c("MAD", "boxplot"),
  coef = 2,
  iterFilter = 2,
  prop = 0.5,
  weights = 1,
  rtx = c("min", "max"),
  rty = c("min", "max"),
)

#version 2: using slower, but more robust, scat family
p.comb = fit_gam(p.comb, k = seq(12,20,2), family = "scat",
  iterFilter = 1, coef = 3, method = "GCV.Cp")

#version 3 (with identities)
p.comb = selectAnchors(p.comb, useID = TRUE)
anchors = getAnchors(p.comb)
p.comb = fit_gam(p.comb, useID = TRUE, k = seq(12,20,2), iterFilter = 1)

#version 4 (using identities and weights)
weights = ifelse(anchors$labels == "I", 2, 1)
p.comb = fit_gam(p.comb, useID = TRUE, k = seq(12,20,2),
  iterFilter = 1, weights = weights)

#version 5 (using boxplot-based outlier detection
p.comb = fit_gam(p.comb, k = seq(12,20,2), outlier = "boxplot", coef = 1.5)

#to preview result of fit_gam
plot(p.comb, pch = 19, outlier = "h", xlab = "CHEAR Plasma (30 min)",
  ylab = "Red-Cross Plasma (20 min)", main = "Example GAM Fit")
message = TRUE,
control = loess.control(surface = "direct", iterations = 10)
)

Arguments

object a metabCombiner object.
useID logical. If set to TRUE, matched ID anchors detected from previous step will never be flagged outliers.
spans numeric span values (between 0 & 1) used for loess fits
outlier Thresholding method for outlier detection. If "MAD", the threshold is the mean absolute deviation (MAD) times coef; if "boxplot", the threshold is coef times IQR plus 3rd quartile of a model’s absolute residual values.
coef numeric (> 1) multiplier for determining thresholds for outliers (see outlier argument)
iterFilter integer number of outlier filtering iterations to perform
prop numeric. A point is excluded if deemed a residual in more than this proportion of fits. Must be between 0 & 1.
weights Optional user supplied weights for each ordered pair. Must be of length equal to number of anchors (n) or a divisor of (n + 2)
rtx ordered pair of endpoints for rtx; if "max" or "min", gives the maximum or minimum rtx, respectively, as model endpoints for rtx
rty ordered pair of endpoints for rty; if "max" or "min", gives the maximum or minimum rtx, respectively, as model endpoints for rty
message Option to print message indicating function progress
control control parameters for loess fits; see: ?loess.control

Value

metabCombiner object with model slot updated to contain a fitted loess model

See Also

selectAnchors, fit_gam

Examples

data(plasma30)
data(plasma20)
p30 <- metabData(plasma30, samples = "CHEAR")
p20 <- metabData(plasma20, samples = "Red", rtxmax = 17.25)
p.comb = metabCombiner(xdata = p30, ydata = p20, binGap = 0.0075)
p.comb = selectAnchors(p.comb, tolmz = 0.003, tolQ = 0.3, windy = 0.02)
#version 1
p.comb = fit_loess(p.comb, spans = seq(0.2,0.3,0.02), iterFilter = 1)
#version 2 (using weights)
anchors = getAnchors(p.comb)
weights = c(2, rep(1, nrow(anchors)), 2)  # weight = 2 to boundary points
p.comb = fit_loess(p.comb, spans = seq(0.2, 0.3, 0.02), weights = weights)

#version 3 (using identities)
p.comb = selectAnchors(p.comb, useID = TRUE, tolmz = 0.003)
p.comb = fit_loess(p.comb, spans = seq(0.2, 0.3, 0.02), useID = TRUE)

# to preview result of fit_loess
plot(p.comb, fit = "loess", xlab = "CHEAR Plasma (30 min)",
     ylab = "Red-Cross Plasma (20 min)", pch = 19,
     main = "Example fit_loess Result Fit")

getAnchors

\textit{Get Ordered Retention Time Pairs}

\section*{Description}

Returns the data frame of feature alignments used to anchor the retention time projection model, constructed by \texttt{selectAnchors}.

\section*{Usage}

getAnchors(object)

\section*{Arguments}

\begin{itemize}
  \item \texttt{object} metabCombiner object
\end{itemize}

\section*{Value}

Data frame of anchor features

\section*{See Also}

selectAnchors

\section*{Examples}

data(plasma30)
data(plasma20)
p30 <- metabData(plasma30, samples = "CHEAR")
```r
p20 <- metabData(plasma20, samples = "Red")
p.comb <- metabCombiner(p30, p20)
p.comb <- selectAnchors(p.comb, windx = 0.05, windy = 0.03)
anchors <- getAnchors(p.comb)
```

---

**getCoefficients**

*Obtain Last-Used Score Coefficients*

**Description**

Provides the last used weight arguments from `calcScores()` function. Returns empty list if `calcScores()` has not yet been called.

**Usage**

```r
coefficients(object)
```

## S4 method for signature 'metabCombiner'

```r
coefficients(object)
```

**Arguments**

- `object`: metabCombiner object

**Value**

A list of the last used weight parameters:

- **A**: Specific weight penalizing feature m/z differences
- **B**: Specific weight penalizing retention time projection error
- **C**: Specific weight penalizing differences in abundance quantiles

**Examples**

```r
data(plasma30)
data(plasma20)
p30 <- metabData(plasma30, samples = "CHEAR")
p20 <- metabData(plasma20, samples = "Red")
p.comb <- metabCombiner(p30, p20)
p.comb <- selectAnchors(p.comb, windx = 0.05, windy = 0.04, tolrq = 0.15)
p.comb <- fit_gam(p.comb, k = 20, iterFilter = 1, family = "gaussian")
p.comb <- calcScores(p.comb, A = 90, B = 14, C = 0.5)
getCoefficients(p.comb)
```
**getData**

*Get Processed Dataset*

**Description**

The `metabData` constructor creates a formatted dataset from the input, which may be accessed using this method.

**Usage**

```r
data(object)
```

```r
## S4 method for signature 'metabData'
data(object)
```

**Arguments**

- `object` metabData object

**Value**

Single Metabolomics Data Frame

**Examples**

```r
data(plasma30)
p30 <- metabData(plasma30, samples = "CHEAR")
data <- getData(p30)
```

---

**getExtra**

*Get Extra Data Column Names*

**Description**

Get Extra Data Column Names

**Usage**

```r
data(object, data = NULL)
```

```r
## S4 method for signature 'metabCombiner'
data(object, data = NULL)
```

```r
## S4 method for signature 'metabData'
data(object)
```

```r
## S4 method for signature 'metabExtract'
data(object)
```

---
getModel

Arguments

object metabCombiner or metabData object
data dataset identifier for metabCombiner objects

Value

character vector of extra column names

Examples

data(plasma30)
p30 <- metabData(plasma30, samples = "CHEAR", extra = "Red")
getExtra(p30)

getModel (Get Fitted RT Model)

Description

Returns the last fitted RT projection model from a metabCombiner object of type "gam" or "loess".

Usage

getModel(object, fit = c("gam", "loess"))

## S4 method for signature 'metabCombiner'
getModel(object, fit = c("gam", "loess"))

Arguments

object metabCombiner object
fit Choice of model, "gam" or "loess"

Value

nonlinear retention time fit object

See Also

fit_gam, fit_loess
getSamples

Examples

data(plasma30)
data(plasma20)
p30 <- metabData(plasma30, samples = "CHEAR")
p20 <- metabData(plasma20, samples = "Red", rtmax = 17.25)
p.comb <- metabCombiner(xdata = p30, ydata = p20, binGap = 0.005)
p.comb <- selectAnchors(p.comb, tolrtq = 0.15, tolQ = 0.2, windy = 0.02)
p.comb <- fit_gam(p.comb, iterFilter = 1, k = 20, family = "gaussian")
p.comb <- fit_loess(p.comb, iterFilter = 1, spans = 0.2)
model.gam <- getModel(p.comb, fit = "gam")
model.loess <- getModel(p.comb, fit = "loess")

getSamples

Get Sample Names From metabCombiner or metabData Object

Description

Returns the sample names from one of the two datasets used in metabCombiner analysis, denoted as 'x' or 'y.'

Usage

getSamples(object, data = NULL)

## S4 method for signature 'metabCombiner'
getSamples(object, data = NULL)

## S4 method for signature 'metabData'
getSamples(object)

Arguments

object metabCombiner or metabData object
data dataset identifier for metabCombiner objects

Value

character vector of sample names. For metabCombiner objects these may come from the 'x' dataset (if data = "x") or the 'y' dataset (if data = "y").

Examples

data(plasma30)
data(plasma20)
p30 <- metabData(plasma30, samples = "CHEAR")
p20 <- metabData(plasma20, samples = "Red", rtmax = 17.25)
getStats

p.comb <- metabCombiner(xdata = p30, ydata = p20)

getSamples(p30)
getSamples(p.comb, data = "x")  # equivalent to previous
getSamples(p20)
getSamples(p.comb, data = "y")  # equivalent to previous

---

getStats  
Get Object Statistics

Description

Prints out a list of object-specific statistics for both metabCombiner and metabData objects

Usage

getStats(object)

### S4 method for signature 'metabCombiner'
getStats(object)

### S4 method for signature 'metabData'
getStats(object)

Arguments

object  metabCombiner or metabData object

Value

list of object-specific statistics

Methods (by class)

- metabCombiner: Method for 'metabCombiner' object

Examples

data(plasma30)
data(plasma20)
p30 <- metabData(plasma30, samples = "CHEAR")
p20 <- metabData(plasma20, samples = "Red", rtmax = 17.25)

getStats(p30)  # metabData stats

p.comb <- metabCombiner(xdata = p30, ydata = p20, binGap = 0.005)
p.comb <- selectAnchors(p.comb, tolmz = 0.003, tolQ = 0.3, windy = 0.02)
idData <- fit_gam(p.comb, iterFilter = 1, k = 20)
getStats(p.comb) #metabCombiner stats

idData

Retrieve Feature Identities

Description
This retrieves user-assigned feature identities from one or all constituent datasets of a metabCombiner object

Usage
idData(object, data = NULL)
## S4 method for signature 'metabCombiner'
idData(object, data = NULL)

Arguments

<table>
<thead>
<tr>
<th>object</th>
<th>metabCombiner object</th>
</tr>
</thead>
<tbody>
<tr>
<td>data</td>
<td>dataset identifier to extract information from; if NULL, extracts information from all datasets</td>
</tr>
</tbody>
</table>

Value
data frame of feature identities

Examples
data(plasma30)
data(plasma20)
p30 <- metabData(head(plasma30,500), samples = "CHEAR")
p20 <- metabData(head(plasma20,500), samples = "Red")
p.comb <- metabCombiner(p30, p20, xid = "p30", yid = "p20")

##retrieve all ids
ids <- idData(p.comb, data = NULL)

##retrieve ids from p30
ids <- idData(p.comb, data = "p30")
identityAnchorSelection

Select Matching Ids as Anchors

Description

This is an optional helper function for selectAnchors. Uses identities to guide selection of ordered retention time pairs. If useID option is set to TRUE, it will select pairs of features with matching ID character strings before proceeding with iterative anchor selection.

Usage

identityAnchorSelection(cTable, windx, windy, useID, brackets)

Arguments

cTable data frame, contains only feature ids, mzs, rts, Qs, & labels
windx numeric positive retention time exclusion window in X dataset
windy numeric positive retention time exclusion window in Y dataset
useID logical. Operation proceeds if TRUE, terminates otherwise.
brackets If useID = TRUE, bracketed identity strings of the types included in this argument will be ignored

Details

Identity anchors are allowed to violate constraints of m/z, Q, and rtq difference tolerances, and will not be removed if they fall within a rt exclusion window of other features. If a name appears more than once, only the pair with the highest relative abundance is selected.

Value

combinedTable with updated anchor labels

See Also

selectAnchors
isCombinedTable  

**Determine combinedTable Validity**

**Description**

Checks whether input object is a valid metaData. Returns an integer code if invalid. Function is used alongside combinerCheck.

**Usage**

isCombinedTable(object)

**Arguments**

- object: Any R object.

**Details**

A proper combinedTable must have these characteristics to be deemed valid for metabCombiner operations:

1) It must be a data.frame with at least 16 columns and at least 1 row
2) The first 16 columns must be named "rowID", "idx", "idy", "mzx", "mzy", "rtx", "rty", "rtProj", "Qx", "Qy", "group", "score", "rankX", "rankY", "adductx", & "adducty" in this exact order
3) The first 16 columns must be of class: "numeric", "character", "numeric", "numeric", "numeric", "numeric", "numeric", "numeric", "numeric", "numeric", "integer", "integer", "integer", "character", "character"
4) The group column must have no missing or negative values

Failing any one of these criteria causes an error

**Value**

0 if object is a valid Combiner Table; an integer code otherwise

---

isMetabCombiner  

**Determine if object is a valid metabCombiner object**

**Description**

Checks whether input object is a valid metabCombiner. Returns an integer code if invalid. Function is used alongside combinerCheck.

**Usage**

isMetabCombiner(object)
### Arguments

**object**  
Any R object.

### Value

0 if object is a valid metabData object; an integer code otherwise.

---

**isMetabData**  
*Determine validity of input metabData object*

### Description

Checks whether input object is a valid metabData. Returns an integer code if invalid. Function is used alongside combinerCheck.

### Usage

`isMetabData(object)`

### Arguments

**object**  
Any R object

### Value

0 if object is a valid metabData object; an integer code otherwise.

---

**iterativeAnchorSelection**  
*Iterative Selection of Ordered Pairs*

### Description

This is a helper function for selectAnchors. Anchors are iteratively selected from highly abundant feature pairs, subject to feature m/z, rt, & Q constraints set by the user.

### Usage

`iterativeAnchorSelection(cTable, windx, windy, swap = FALSE)`
Arguments

cTable data frame, contains only feature ids, mzs, rts, Qs, & labels
windx numeric positive retention time exclusion window in X dataset.
windy numeric positive retention time exclusion window in Y dataset.
swap logical. When FALSE, searches for abundant features in dataset X, complemented by dataset Y features; when TRUE, searches for abundant features in dataset Y, complemented by dataset X features.

Value
data frame of anchor feature alignments.

See Also

selectAnchors

Description

This is a method for annotating removable, conflicting, and identity-matched feature pair alignment (FPA) rows in the combinedTable report. Simple thresholds for score, rank, retention time error and delta score can computationally reduce the set of possible FPAs to the most likely feature matches. FPAs falling within some small delta score or mz/rt of the top-ranked pair are organized into subgroups to facilitate inspection. Automated reduction to 1-1 pairs is also possible with this function.

reduceTable behaves identically to labelRows, but with a focus on automated table reduction. Rank threshold defaults in reduceTable are also stricter than in labelRows.

Usage

labelRows(
  object,
  useID = FALSE,
  minScore = 0.5,
  maxRankX = 3,
  maxRankY = 3,
  delta = 0.1,
  method = c("score", "mzrt"),
  maxRTerr = 10,
  resolveConflicts = FALSE,
  rtOrder = TRUE,
  remove = FALSE,
  balanced = TRUE,
  brackets_ignore = c("", ",", "{")
reduceTable(
  object,
  useID = FALSE,
  maxRankX = 2,
  maxRankY = 2,
  minScore = 0.5,
  delta = 0.1,
  method = c("score", "mzrt"),
  maxRTerr = 10,
  rtOrder = TRUE,
  brackets_ignore = c(",", ":[", ":")
)

Arguments

object Either a metabCombiner object or combinedTable
useID option to annotate identity-matched strings as "IDENTITY"
minScore numeric minimum allowable score (between 0 & 1) for metabolomics feature pair alignments
maxRankX integer maximum allowable rank for X dataset features.
maxRankY integer maximum allowable rank for Y dataset features.
delta numeric score or mz/rt distances used to define subgroups. If method = "score", a value (between 0 & 1) score difference between a pair of conflicting FPAs. If method = "mzrt", a length 4 numeric: (m/z, rt, m/z, rt) tolerances, the first pair for X dataset features and the second pair for Y dataset features.
method Conflict detection method. If equal to "score" (default), assigns a conflict subgroup if score of lower-ranking FPA is within some tolerance of higher-ranking FPA. If set to "mzrt", assigns a conflicting subgroup if within a small m/z & rt distance of the top-ranked FPA.
maxRTerr numeric maximum allowable error between model-projected retention time (rt-Proj) and observed retention time (rtY)
resolveConflicts logical option to computationally resolve conflicting rows to a final set of 1-1 feature pair alignments
rtOrder logical. If resolveConflicts set to TRUE, then this imposes retention order consistency on rows deemed "RESOLVED" within subgroups.
remove Logical. Option to keep or discard rows deemed removable.
balanced Logical. Optional processing of "balanced" groups, defined as groups with an equal number of features from input datasets where all features have a 1-1 match.
brackets_ignore character. If useID = TRUE, bracketed identity strings of the types in this argument will be ignored
Details

metabCombiner initially reports all possible feature pairings in the rows of the combinedTable report. Most of these are misalignments that require removal. This function is used to automate this reduction process by labeling rows as removable or conflicting, based on certain conditions, and is performed after computing similarity scores.

A label may take on one of four values:

a) "": No determination made  
b) "IDENTITY": an alignment with matching identity "idx & idy" strings  
c) "REMOVE": a row determined to be a misalignment  
d) "CONFLICT": competing alignments for one or multiple shared features

The labeling rules are as follows:

1) Groups determined to be 'balanced': label rows with rankX > 1 & rankY > 1 "REMOVE" irrespective of delta criteria  
2) Rows with a score < minScore: label "REMOVE"  
3) Rows with rankX > maxRankX and/or rankY > maxRankY: label "REMOVE"  
4) Conflicting subgroup assignment as determined by method & delta arguments. Conflicting alignments following outside delta thresholds: labeled "REMOVE". Otherwise, they are assigned a "CONFLICT" label and subgroup number.  
5) If useID argument set to TRUE, rows with matching idx & idy strings are labeled "IDENTITY". These rows are not changed to "REMOVE" or "CONFLICT" irrespective of subsequent criteria.

Value

updated combinedTable or metabCombiner object. The table will have three new columns:

- labels: characterization of feature alignments as described
- subgroup: conflicting subgroup number of feature alignments
- alt: alternate subgroup for rows in multiple feature pair conflicts

Examples

#required steps prior to function use
data(plasma30)
data(plasma20)
p30 <- metabData(plasma30, samples = "CHEAR")
p20 <- metabData(plasma20, samples = "Red", rtmax = 17.25)
p.comb <- metabCombiner(xdata = p30, ydata = p20, binGap = 0.0075)
p.comb <- selectAnchors(p.comb, tolmz = 0.003, tolQ = 0.3, windy = 0.02)
p.comb <- fit_gam(p.comb, k = 20, iterFilter = 1)
p.comb <- calcScores(p.comb, A = 90, B = 14, C = 0.5)

##applies labels, but maintains all rows
p.comb <- labelRows(p.comb, maxRankX = 2, maxRankY = 2, maxRTerr = 0.5, delta = 0.1, resolveConflicts = FALSE, remove = FALSE)

##automatically resolve conflicts and filter to 1-1 feature pairs
p.comb.2 <- labelRows(p.comb, resolveConflicts = FALSE, remove = FALSE)

#this is identical to the previous command
p.comb.2 <- reduceTable(p.comb)
p.comb <- labelRows(p.comb, method = "mzrt", delta = c(0.005, 0.5, 0.005, 0.3))

# this function may be applied to combinedTable inputs as well
cTable <- cbind.data.frame(combinedTable(p.comb), featData(p.comb))

lTable <- labelRows(cTable, maxRankX = 3, maxRankY = 2, minScore = 0.5,
                     method = "score", maxRTerr = 0.5, delta = 0.2)

labelRowsParam List labelRows & reduceTable Defaults

Description
List of default parameters for combinedTable row annotation and removal. See help(labelRows) or ?labelRows for more details. reduceTableParam loads parameters for the more automated reduceTable function.

Usage
labelRowsParam(
  useID = FALSE,
  maxRankX = 3,
  maxRankY = 3,
  minScore = 0.5,
  method = "score",
  delta = 0.1,
  maxRTerr = 10,
  resolveConflicts = FALSE,
  rtOrder = TRUE,
  remove = FALSE,
  balanced = TRUE,
  brackets_ignore = c("\“, \[", "\{")
)

reduceTableParam(
  useID = FALSE,
  maxRankX = 2,
  maxRankY = 2,
  minScore = 0.5,
  maxRTerr = 10,
  delta = 0.1,
  rtOrder = TRUE,
  method = "score",
  brackets_ignore = c("\“, \[", "\{")
)
Arguments

- **useID**
  - Option to annotate identity-matched strings as IDENTITY; default: FALSE
- **maxRankX**
  - Maximum rank allowable for X features
- **maxRankY**
  - Maximum rank allowable for Y features
- **minScore**
  - Minimum score threshold; default: 0.5
- **method**
  - Thresholding method for subgroup detection ("score" or "mzrt"); default: "score"
- **delta**
  - Score distance or mz/rt difference tolerances for subgrouping; default: 0.1
- **maxRTerr**
  - Maximum allowable difference between predicted RT (rtProj) & observed RT (rty); default: 10 minutes
- **resolveConflicts**
  - Logical. If TRUE, automatically resolves subgroups to 1-1 feature pair alignments
- **rtOrder**
  - Logical. If TRUE and resolveConflicts is TRUE, imposes retention order condition on paired alignments
- **remove**
  - Option to eliminate rows determined as removable; default: FALSE
- **balanced**
  - Option to reduce balanced groups; default: TRUE
- **bracketsIgnore**
  - Bracket types for ignoring string comparisons

Value

List of labelRows parameters

See Also

- `labelRows`, `metabCombine`, `batchCombine`, `reduceTable`

Examples

```r
lrParams <- labelRowsParam(maxRankX = 2, maxRankY = 2, delta = 0.1, 
maxRTerr = 0.5)
```

Description

An example multi-batch LC-MS metabolomics analysis of human plasma, used to demonstrate `batchCombine`. Due to the large size of the full experimental data, only three of the batches are loaded here with a subset of the samples and features from each batch.

Usage

```r
data(metabBatches)
```
Format

A list containing three identically formatted data frames

**Description**

`metabCombine` wraps the five main `metabCombiner` workflow steps into a single wrapper function. Parameter list arguments organize program parameters by constituent package functions.

**Usage**

```r
metabCombine(
  xdata,
  ydata,
  binGap = 0.005,
  xid = NULL,
  yid = NULL,
  means = list(mz = FALSE, rt = FALSE, Q = FALSE),
  fitMethod = "gam",
  rtOrder = TRUE,
  union = FALSE,
  impute = FALSE,
  anchorParam = selectAnchorsParam(),
  fitParam = fitgamParam(),
  scoreParam = calcScoresParam(),
  labelParam = labelRowsParam()
)
```

**Arguments**

- `xdata`: metabData object. One of two datasets to be combined.
- `ydata`: metabData object. One of two datasets to be combined.
- `binGap`: numeric parameter used for grouping features by m/z. See ?mzGroup for more details.
- `xid`: character identifier of xdata. If `xdata` is a metabData, assigns a new ID for this dataset; if `xdata` is a metabCombiner, must be assigned to one of the existing dataset IDs. See details for more information.
- `yid`: character identifier of ydata. If `ydata` is a metabData, assigns a new ID for this dataset; if `ydata` is a metabCombiner, must be assigned to one of the existing dataset IDs. See details for more information.
- `means`: logical. Option to take average m/z, rt, and/or Q from `metabComber`. May be a vector (length = 3), single value (TRUE/FALSE), or a list with names "mz", "rt", "Q" as names.
metabCombine

fitMethod: RT spline-fitting method, either "gam" or "loess"
rtOrder: logical. If set to TRUE, retention order consistency expected when resolving conflicting alignments for metabCombiner object inputs.
union: logical. Option to include non-matched features in final combinedTable results
impute: logical. If TRUE, imputes the mean mz/rt/Q values for missing features in metabCombiner object inputs before use in alignment (not recommended for disparate data alignment); if FALSE, features with missing information are dropped.
anchorParam: list of parameter values for selectAnchors() function
fitParam: list of parameter values for fit_gam() or fit_loess()
scoreParam: list of parameter values for calcScores()
labelParam: list of parameter values for labelRows()

Details
The five main steps in metabCombine are 1) m/z grouping & combined table construction, 2) selection of ordered pair RT anchors, 3) nonlinear spline (Basis Spline GAM or LOESS) fitting to predict RTs, 4) score calculation and feature pair alignment ranking, 5) combined table row annotation and reduction. metaData arguments xdata & ydata and m/z grouping binGap are required for step 1.

Steps 2-5 are handled by anchors, fit, scores, & labels, respectively, with lists containing the argument values for each step expected for these arguments. selectAnchorsParam, fitgamParam, fitloessParam, calcScoresParam, & labelRowsParam load the default program values of selectAnchors, fit_gam, fit_loess, calcScores & labelRows, respectively. These program arguments should be modified as necessary for the datasets used for analysis.

By default, the RT fitting method (fitMethod) is set to "gam", which means the argument fit is a list of parameters for fit_gam; if the (fitMethod) argument is set to "loess", then the fit argument expects a list of fit_loess parameters.

Value
a metabCombiner object following complete analysis

See Also
selectAnchorsParam, fitgamParam, calcScoresParam, labelRowsParam, fitloessParam

Examples

data("plasma20")
data("plasma30")
p30 <- metabData(plasma30, samples = "CHEAR")
p20 <- metabData(plasma20, samples = "Red", rtmax = 17.25)

#parameter lists:
saParam <- selectAnchorsParam(tolrtq = 0.2, windy = 0.02, tolmz = 0.002)
fitParam <- fitgamParam(k = seq(12,15), iterFilter = 1, outlier = "boxplot", family = "gaussian", prop = 0.6, coef = 1.5)
scoreParam <- calcScoresParam(A = 75, B = 15, C = 0.3)
labelParam <- labelRowsParam(maxRankX = 2, maxRankY = 2, delta = 0.1)

#metabCombine wrapper
p.combined <- metabCombine(xdata = p30, ydata = p20, binGap = 0.0075,
                           anchorParam = saParam, fitParam = fitParam,
                           scoreParam = scoreParam, labelParam = labelParam)

##to view results
p.combined.table <- combinedTable(p.combined)

---

**metabCombiner**

*Form a metabCombiner object.*

**Description**

This constructs an object of type metabCombiner from a pair of metabolomics datasets, formatted as either metabData (single-dataset class) or metabCombiner (combined-dataset class). An initial table of possible feature pair alignments is constructed by grouping features into m/z groups controlled by the binGap argument.

**Usage**

```r
metabCombiner(
  xdata,  # metabData or metabCombiner object
  ydata,  # metabData or metabCombiner object
  binGap = 0.005,  # numeric parameter used for grouping features by m/z. See ?mzGroup for more details.
  xid = NULL,  # character. If xdata is a metabData, assigns a new identifier for this dataset; if xdata is a metabCombiner, selects one of the existing dataset IDs to represent xdata. See details for more information.
  yid = NULL,
  means = list(mz = FALSE, rt = FALSE, Q = FALSE),
  rtOrder = TRUE,
  impute = FALSE
)
```

**Arguments**

- `xdata`: metabData or metabCombiner object
- `ydata`: metabData or metabCombiner object
- `binGap`: numeric parameter used for grouping features by m/z. See ?mzGroup for more details.
- `xid`: character. If xdata is a metabData, assigns a new identifier for this dataset; if xdata is a metabCombiner, selects one of the existing dataset IDs to represent xdata. See details for more information.
- `yid`: character
- `means`: list with options `mz`, `rt`, `Q`
- `rtOrder`: logical
- `impute`: logical
**metabCombiner**

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>yid</strong></td>
<td>character. If ydata is a metabData, assigns a new identifier for this dataset; if ydata is a metabCombiner, selects one of the existing dataset IDs to represent ydata. See details for more information.</td>
</tr>
<tr>
<td><strong>means</strong></td>
<td>logical. Option to take average m/z, rt, and/or Q from metabComber. May be a vector (length = 3), a single value (TRUE/FALSE), or a list with names &quot;mz&quot;, &quot;rt&quot;, &quot;Q&quot; as names.</td>
</tr>
<tr>
<td><strong>rtOrder</strong></td>
<td>logical. If set to TRUE, retention order consistency expected when resolving conflicting alignments for metabCombiner object inputs.</td>
</tr>
<tr>
<td><strong>impute</strong></td>
<td>logical. If TRUE, imputes the mean m/z/rt/Q values for missing features in metabCombiner object inputs before use in alignment (not recommended for disparate data alignment); if FALSE, features with missing information are dropped.</td>
</tr>
</tbody>
</table>

### Details

This function serves as a constructor of the metabCombiner combined dataset class and the entry point to the main workflow for pairwise dataset alignment. Two arguments must be specified, xdata and ydata, which must be either metabData or metabCombiner objects. There are four scenarios listed here:

1) If xdata & ydata are metabData objects, a new metabCombiner object is constructed with an alignment of this pair. New character identifiers are assigned to each dataset (xid & yid, respectively); if these are unassigned, then "1" and "2" will be their respective ids. xdata & ydata will be the active "dataset x" and "dataset y" used for the paired alignment.

2) If xdata is a metabCombiner and ydata is a metabData, then the result is the existing metabCombiner xdata augmented by an additional dataset, ydata. One set of meta-data (id, m/z, rt, Q, adduct labels) from xdata is used for alignment with the respective information from ydata, which is controlled by the xid argument; see the **datasets** method for extracting existing dataset ids. A new identifier yid is assigned to ydata, which must be distinct from the current dataset identifier.

3) If xdata is a metabData and ydata is a metabCombiner, then a similar process to #2 occurs, with xdata augmented to the existing ydata object and one of the constituent dataset’s meta-data is accessed, as controlled by the yid argument. One major difference is that rts of ydata serve as the "reference" or dependent variable in the spline-fitting step.

4) If xdata and ydata are both metabCombiner objects, the resulting metabCombiner object aligns information from both combined datasets. As before, one set of values contained in xdata (specified by xid argument) is used to align to the values from ydata (controlled by yid argument). The samples and extra columns are concatenated from all datasets.

For metabCombiner object inputs, the full workflow (**selectAnchors**, **fit_gam**/**fit_loess**, **calcScores**, **labelRows**) must be performed before further alignment. If not completed already, features are pared down to 1-1 alignments via the resolveConflicts approach (see: help(resolveRows)). Features may not be used more than twice and will be removed if they are detected as duplicates.

The mean of the numeric fields (m/z, rt, Q) from all constituent datasets can be used in alignment in place of values from a single dataset. These are controlled by the means argument. By default this is a list value with "mz", "rt" and "Q" as names, but may also accept a single logical or a length-3 logical vector. If set to a single logical value, then all three fields are averaged (TRUE) or not averaged (FALSE). If a three-length argument is supplied (e.g. c(TRUE, FALSE, FALSE)), then the values correspond to m/z, rt, and Q respectively. RT averaging is generally not recommended for disparate data alignment.
If missing features have been incorporated into the `metabCombiner`, they can be imputed using the average m/z, rt, and Q values for that feature in datasets in which it is present by setting `impute` to TRUE. Likewise, this option is not recommended for disparate data alignment.

**Value**

A `metabCombiner` object constructed from `xdata` and `ydata`, with features grouped by m/z according to the `binGap` argument.

**Note**

If using a `metabCombiner` object as input, only one row is allowed per feature corresponding to its first appearance. It is strongly recommended to reduce the table to 1-1 paired matches prior to aligning it with a new dataset.

**Examples**

```r
data(plasma30)
data(plasma20)

p30 <- metabData(plasma30, samples = "CHEAR")
p20 <- metabData(plasma20, samples = "Red", rtmax = 17.25)

p.comb = metabCombiner(xdata = p30, ydata = p20, binGap = 0.0075, 
                        xid = "p30", yid = "p20")
```

---

**Description**

This is the main object for the `metabCombiner` package workflow. This object holds a combined feature table, along with a retention time warping model, the ordered pair anchors used to generate this model, important information organized by dataset, and key object statistics.

**Slots**

- `combinedTable` data frame displaying all feature pair alignments, combining measurements of all possible shared compounds
- `featData` data frame of feature metadata (id, m/z, rt, Q, adduct)
- `anchors` data frame of feature pairs used for RT warping model
- `model` list containing the last fitted nonlinear model(s)
- `datasets` list of constituent datasets from `xdata` & `ydata` inputs
- `xy` current X & Y datasets
- `nonmatched` list of data frames consisting of nonmatched features
coefficients list of last used A,B,C similarity weight values
samples list of sample name vectors from input datasets
extra list of extra column name vectors from input datasets
stats set of useful metabCombiner statistics

---

**metabData**

*Constructor for the metabData object.*

**Description**

This is a constructor for objects of type metabData.

**Usage**

```r
metabData(
  table,
  mz = "mz",
  rt = "rt",
  id = "id",
  adduct = "adduct",
  samples = NULL,
  Q = NULL,
  extra = NULL,
  rtmin = "min",
  rtmax = "max",
  misspc = 50,
  measure = c("median", "mean"),
  zero = FALSE,
  duplicate = opts.duplicate()
)
```

**Arguments**

- **table**
  Path to file containing feature table or data.frame object containing features

- **mz**
  Character name(s) or regular expression associated with data column containing m/z values. The first column whose name contains this expression will be selected for analysis.

- **rt**
  Character name(s) or regular expression associated with data column containing retention time values. The first column whose name contains this expression will be selected for analysis.

- **id**
  Character name(s) or regular expression associated with data column containing metabolomics feature identifiers. The first column whose name contains this expression will be selected for analysis.

- **adduct**
  Character name(s) or regular expression associated with data column containing adduct or chemical formula annotations. The first column whose name contains this expression will be selected for analysis.
samples  Character name(s) or regular expression associated with data columns. All numeric columns whose names contain these keywords are selected for analysis. If no keywords given, program searches longest stretch of remaining numeric columns.

Q  Character name(s) or regular expression associated with numeric feature abundance quantiles. If NULL, abundance quantiles are calculated from sample intensities.

extra  Character names of columns containing additional feature information, e.g. non-analyzed sample values. All columns containing these keywords selected and will be displayed in the final output.

rtmin  Numeric. Minimum retention time for analysis.

rtmax  Numeric. Maximum retention time for analysis.

misspc  Numeric. Threshold missingness percentage for analysis.

measure  Central sample abundance measure, either "median" or "mean".

zero  Logical. Whether to consider zero values as missing.

duplicate  list of duplicate feature removal parameters. (see: opts.duplicate)

Details

Processed metabolomics feature table must contain columns for m/z, rt, and numeric sample intensities. Some optional fields such as identity id and adduct label columns may also be supplied. Non-analyzed columns can be included into the final output by specifying the names of these columns in the extra argument. All required arguments are checked for validity (e.g. no negative m/z or rt values, each column is used at most once, column types are valid, etc...).

Following this is a pre-analysis filtering of rows that are either: 1) Outside of a specified retention time range (rtmin, rtmax), 2) Missing in excess of misspc percent of analyzed samples, or 3) deemed duplicates by small pairwise <m/z, rt> differences. See: opts.duplicate on duplicate feature removal.

Remaining features are ranked by abundance quantiles, Q, using a central measure, either "median" or "mean." Alternatively, the abundance quantiles column can be specified in the argument Q.

Value

An object of class metabData containing the specific information specified by mz, rt, samples, id, adduct, Q, and extra arguments, and adjusted by pre-processing steps.

Examples

data(plasma30)
data(plasma20)

#samples: CHEAR; RedCross samples non-analyzed "extra" columns
p30 <- metabData(plasma30, mz = "mz", rt = "rt", id = "identity",
adduct = "adduct", samples = "CHEAR", extra = "RedCross")

getSamples(p30)  #should print names of 5 CHEAR Sample column names
getExtra(p30)  #should print names of 5 Red Cross Sample column names
# equivalent to above
p30 <- metabData(plasma30, id = "id", samples = "CHEAR", extra = "Red")

# analyzing Red Cross samples with retention time limitations (0.5-17.5min)
p20 <- metabData(plasma20, samples = "Red", rtmin = 0.5, rtmax = 17.5)
data = getData(p20)
range(data$rt)

# using regular expressions for field searches
p30 <- metabData(plasma30, id = "identity|id|ID", samples = ".[3-5]$")
getSamples(p30)  # should print all column names ending in .3, .4, .5

---

**metabData-class**

'**metabData**' **Single Metabolomics Dataset Class**

**Description**

This class is designed to process and format input metabolomics feature tables. It stores the information from individual metabolomics datasets, including the formatted feature table, sample names, and feature statistics.

**Slots**

- `data` formatted metabolomics data frame.
- `samples` character vector of analyzed sample names
- `extra` character vector of non-analyzed columns names
- `stats` A list of dataset statistics
- `filtered` A list of filtered dataset features

**mzData**

*Retrieve m/z Values*

**Description**

This retrieves feature m/z values from one or all constituent datasets of a **metabCombiner** object. Alternatively, the average m/z value can be retrieved.

**Usage**

mzData(object, data = NULL, value = c("obs", "mean"))

## S4 method for signature '**metabCombiner**'
mzData(object, data = NULL, value = c("observed", "mean"))
Arguments

object metabCombiner object
data dataset identifier to extract information from; if NULL, extracts data frame information from all datasets
value Either "obs" (observed - default option) or "mean" value

Value
data frame of m/z values (if NULL) or single vector of m/z values
data(plasma30) data(plasma20)
p30 <- metabData(head(plasma30,500), samples = "CH30") p20 <- metabData(head(plasma20,500), samples = "Red") p.comb <- metabCombiner(p30, p20, xid = "p30", yid = "p20")

##retrieve all m/z mzd <- mzData(p.comb, data = NULL)
##retrieve m/z from p30 mzd <- mzData(p.comb, data = "p30")
##retrieve mean m/z mzd <- mzData(p.comb, value = "mean")

mzGroup

Binning of mass spectral features in m/z dimension

Description

Features in two input feature lists are grouped by their m/z values.

Usage

mzGroup(xset, yset, binGap)

Arguments

xset data frame containing metabolomics features
yset data frame containing metabolomics features
binGap numeric gap value between consecutive sorted & pooled feature m/z values.

Details

The m/z values from both datasets are pooled, sorted, and binned by the binGap argument. Feature groups form when there is at least one pair of features from both datasets whose consecutive difference is less than binGap. Grouped features are joined together in combinedTable data report.

Value

list object containing updated xset & yset with group information
Get Nonmatched Features

Description

Features that lack any counterparts in the complementary dataset may be obtained from this method. If data is set to "x" or "y", will retrieve data from the current X or Y dataset, respectively. If data is set to NULL, will retrieve the list of nonmatched features.

Usage

nonmatched(object, data = "x")

## S4 method for signature 'metabCombiner'
nonmatched(object, data = "x")

Arguments

object metabCombiner object
data dataset identifier for metabCombiner objects; if NULL, returns full list of nonmatched features

Value

Data frame of non-matched features corresponding to data argument

Examples

data(plasma30)
data(plasma20)
p30 <- metabData(head(plasma30, 500), samples = "CHEAR")
p20 <- metabData(head(plasma20, 500), samples = "Red", rtmax = 17.25)
p.comb <- metabCombiner(xdata = p30, ydata = p20, binGap = 0.005)

nnmx <- nonmatched(p.comb, data = "x")
nnmy <- nonmatched(p.comb, data = "y")
## Weight Parameter Objective Function

### Description
This function evaluates the A, B, C weight parameters in terms of score separability of matching versus mismatching compound alignments. Higher objective function value imply a superior weight parameter selection.

### Usage
```r
objective(
  cTable, idtable, A, B, C, minScore, mzdiff, rtdiff, qdiff, rtrange, adductdiff, penalty, matches, mismatches
)
```

### Arguments
- **cTable**: data frame. Abridged `metabCombiner` report table.
- **idtable**: data frame containing all evaluated identities
- **A**: Numeric weight for penalizing m/z differences.
- **B**: Numeric weight for penalizing differences between fitted & observed retention times
- **C**: Numeric weight for differences in Q (abundance quantiles).
- **minScore**: numeric. Minimum score to count towards objective value.
- **mzdiff**: numeric differences between feature m/z values
- **rtdiff**: Differences between model-projected retention time value & observed retention time
- **qdiff**: Difference between feature quantile Q values.
- **rtrange**: range of dataset Y retention times
- **adductdiff**: Numeric divisors of computed score when non-empty adduct labels do not match
- **penalty**: positive numeric penalty wherever $S(i,j) > S(i,i), i /= j$
matches  integer row indices of identity matches
mismatches list of integer identity row mismatches for each identity

Details

First, the similarity scores between all grouped features are calculated as described in `scorePairs`.
Then, the objective value for a similarity S is evaluated as:

$$ OBJ(S) = \sum h(S(i, i)) - h(S(i, j)) - p(S(i, i) > S(i, j)) $$

- $S(i, i)$ represents the similarity between correct identity alignments
- $S(i, j)$, represents the maximum similarity of i to grouped feature j, i =/= j (the highest-scoring misalignment)
- $h(x) = x$ if $x > \text{minScore}$, 0 otherwise
- $p(\text{COND}) = 0$ if the condition is true, and a penalty value otherwise

This is summed over all labeled compound identities (e.g. idx = idy) shared between input datasets.

Value

A numeric value quantifying total separability of compound match similarity scores from mismatch scores, given A,B,C values.

__opts.duplicate__  Duplicate Feature Detection Parameters

Description

Lists the parameters for detection of two or more rows that represent the same entity, based on similar m/z and retention time values.

Usage

```r
opts.duplicate(
  mz = 0.0025,
  rt = 0.05,
  resolve = c("single", "merge"),
  weighted = FALSE
)
```

Arguments

- `mz`  m/z tolerance for duplicate feature detection
- `rt`  RT tolerance for duplicate feature
- `resolve` character. Either "single" (default) or "merge".
- `weighted` logical. Option to weight m/z, RT, Q by mean abundance of each row (TRUE) or take single representative values (FALSE).
Details

The presence of duplicate features has negative consequences for the LC-MS alignment task. The package offers several options for resolving the issue of feature duplication. Pairwise m/z and RT tolerances define which features are to be considered as duplicates within a single data set. Setting mz or rt to 0 skips duplicate feature filtering altogether.

When duplicates are detected, either a single master copy is retained (resolve = "single") or merged into a single row (resolve = "merge"). The master copy is the copy with lower proportion of missingness, followed by the most abundant (by median or mean). If missingness and abundance is equivalent for duplicates, the first copy that appears is retained. The "merge" option fuses duplicate feature rows, with quantitative descriptors (m/z, RT) either calculated as a weighted average (weighted = TRUE) or otherwise taken from the top representative row; id and adduct values are concatenated; the maximum feature value is used for each sample; and all ‘extra’ values are taken from the ‘master copy’ row, similar to the "single" option.

Examples

data(plasma20)
pars.duplicate <- opts.duplicate(mz = 0.01, rt = 0.05, resolve = "single")
p20 <- metabData(plasma20, samples = "Red", duplicate = pars.duplicate)

#to prevent removal of duplicate features
p20 <- metabData(plasma20, samples = "Red", duplicate = opts.duplicate(0))

##merge option
pars.duplicate <- opts.duplicate(mz = 0.01, rt = 0.05, resolve = "merge")
p20 <- metabData(plasma20, samples = "Red", duplicate = pars.duplicate)

plasma20

20 minute LC-MS Analysis of Human Plasma

Description

An example metabolomics analysis of human plasma from Red Cross and CHEAR cohorts, plus pooled aliquots and blanks, acquired with a 20 minute total Reversed-Phase Liquid Chromatography & QTOF-MS instrument in the positive ionization mode.

Usage

data(plasma20)

Format

A data frame with 8910 rows and 22 columns.
30 minute LC-MS Analysis of Human Plasma

Description

An example metabolomics analysis of human plasma from Red Cross and CHEAR cohorts, plus pooled aliquots and blanks, acquired with a 30 minute total Reversed-Phase Liquid Chromatography and a QTOF-MS instrument in the positive ionization mode.

Usage

data(plasma30)

Format

A data frame with 8286 rows and 22 columns

plot,metabCombiner,ANY-method

Plot metabCombiner Fits

Description

This is a plotting method for metabCombiner objects. It displays ordered pairs and a curve fit computed using fit_gam or fit_loess, using base R graphics.

Usage

## S4 method for signature 'metabCombiner,ANY'
plot(x, y, ...)

plot_fit(
  object,
  fit = c("gam", "loess"),
  pcol = "black",
  lcol = "red",
  lwd = 3,
 pch = 19,
  outlier = "show",
  ocol = "springgreen4",
  legend = c("anchor", "outlier"),
  ...
)
Arguments

- `x` metabCombiner object
- `y` ... Other variables passed into graphics::plot
- `fit` choice of model (either "gam" or "loess").
- `pcol` color of the normal points (ordered RT pair) in the plot
- `lcol` color of the fitted line in the plot
- `lwd` line width of the curve fit between anchor points
- `pch` plot character type; see ?graphics::par for details
- `outlier` display option for outliers. If "show" or "s", treats outlier points like normal anchors; if "remove" or "r", removes outlier points from the plot; if "highlight" or "h", displays outliers with a different color and associated legend.
- `ocol` color of the outlier points; outlier argument must be set to "highlight" or "h"
- `legend` length-2 character vector indicating point labels in the legend if outlier argument set to "highlight" or "h"

Value

no values returned

Examples

data(plasma30)
data(plasma20)
p30 <- metabData(plasma30, samples = "CHEAR")
p20 <- metabData(plasma20, samples = "Red", rtmax = 17.25)
p.comb = metabCombiner(xdata = p30, ydata = p20, binGap = 0.0075)
p.comb = selectAnchors(p.comb, tolmz = 0.003, tolQ = 0.3, windy = 0.02)
p.comb = fit_gam(p.comb, k = 20, iterFilter = 1, family = "gaussian")

##plot of GAM fit
plot(p.comb, main = "Example GAM Fit Plot", xlab = "X Dataset RTs", ylab = "Y Dataset RTs", pcol = "red", lcol = "blue", lwd = 5, fit = "gam", outliers = "remove")

grid(lwd = 2, lty = 3) #adding gridlines
QData

Retrieve Relative Abundance Values

Description
This retrieves feature Q values from one or all constituent dataset features of a metabCombiner object. Alternatively, the average Q value can be retrieved.

Usage
QData(object, data = NULL, value = c("obs", "mean"))

## S4 method for signature 'metabCombiner'
QData(object, data = NULL, value = c("observed", "mean"))

Arguments
- object: metabCombiner object
- data: dataset identifier to extract information from; if NULL, extracts information from all datasets
- value: Either "obs" (observed - default option) or "mean" average value

Value
data frame or vector of relative ranked abundance (Q) values
data(plasma30) data(plasma20)
p30 <- metabData(head(plasma30,500), samples = "CHEAR") p20 <- metabData(head(plasma20,500), samples = "Red") p.comb <- metabCombiner(p30, p20, xid = "p30", yid = "p20")
##retrieve all Q Q <- QData(p.comb, data = NULL)
##retrieve Q from p30 Q <- QData(p.comb, data = "p30")
##retrieve mean Q Q <- QData(p.comb, value = "mean")

resolveRows

Resolve Conflicting Alignment Subgroups

Description
This method resolves conflicting feature pair assignments (labeled as "CONFLICT") to obtain 1-1 feature matches in the combinedTable results report.

Usage
resolveRows(fields, rtOrder)
rtData

Retrieve Retention Time Values

Description

This retrieves feature RT values from one or all constituent dataset features of a metabCombiner object. Alternatively, the average RT value can be retrieved.

Usage

rtData(object, data = NULL, value = c("obs", "mean"))

## S4 method for signature 'metabCombiner'
rtData(object, data = NULL, value = c("observed", "mean"))

Arguments

- **object**: metabCombiner object
- **data**: dataset identifier to extract information from; if NULL, extracts information from all datasets
- **value**: Either "obs" (observed - default option) or "mean"

Value

data frame or vector of retention time values

Arguments

- **fields**: data frame containing the main
- **rtOrder**: logical option to impose RT order for resolving subgroups

Details

This is called from within labelRows (with argument resolveConflicts set to TRUE), reduceTable, & metabCombiner (using metabCombiner object inputs). The method determines which combination of unique feature pairs has the highest sum of scores ("resolveScore") within each subgroup. By default, these combinations of feature pairs must have consistency in their retention time order (rtOrder = TRUE). The combination of 1-1 feature pair alignments with the highest resolveScore within the subgroups are annotated as "RESOLVED", with the remaining unannotated rows labeled as "REMOVE" (or removed outright by other package functions). Feature pairs belonging to multiple subgroup (alt > 0) are labeled as REMOVE.

Value

data frame of combinedTable fields, replacing "CONFLICT" labels with "RESOLVED" or "REMOVE", depending on the computations performed.
scorePairs

Examples

```r
data(plasma30)
data(plasma20)

p30 <- metabData(head(plasma30, 500), samples = "CHEAR")
p20 <- metabData(head(plasma20, 500), samples = "Red")
p.comb <- metabCombiner(p30, p20, xid = "p30", yid = "p20")

# retrieve all RTs
rt <- rtData(p.comb, data = NULL)

# retrieve RTs from p30
rt <- rtData(p.comb, data = "p30")

# retrieve mean RT
rt <- rtData(p.comb, value = "mean")
```

scorePairs

*Calculate Pairwise Alignment Scores*

Description

Helper function for `calcScores` & `evaluateParams`. Calculates a pairwise similarity score between grouped features using differences in m/z, rt, and Q.

Usage

```r
scorePairs(A, B, C, mzdiff, rtdiff, qdiff, rtrange, adductdiff)
```

Arguments

- **A**: Numeric weight for penalizing m/z differences.
- **B**: Numeric weight for penalizing differences between fitted & observed retention times.
- **C**: Numeric weight for differences in Q (abundance quantiles).
- **mzdiff**: Numeric differences between feature m/z values
- **rtdiff**: Differences between model-projected retention time value & observed retention time
- **qdiff**: Difference between feature quantile Q values
- **rtrange**: Range of dataset Y retention times
- **adductdiff**: Numeric divisors of computed score when non-empty adduct labels do not match
Details

The score between two grouped features x & y is calculated as:

\[ S = -\exp(-A|mzx - mzy| - B|rt - rtproj|/rtrange - C|Qx - Qy|) \]

where \( mzx \) & \( Qx \) correspond to the m/z and abundance quantile values of feature x; \( mzy, rt, \) and \( Qy \) correspond to the m/z, retention time, and quantile values of feature y; \( rtproj \) is the model-projected retention time of feature x onto the Y dataset chromatogram and \( rtrange \) is the retention time range of the Y dataset chromatogram. A, B, C are non-negative constant weight parameters for penalizing m/z, rt, and Q differences. Values between 0 (no confidence alignment) and 1 (high confidence alignment).

Value

Numeric similarity score between 0 & 1

---

selectAnchors  
**Select Anchors for Nonlinear RT Model**

Description

A subset of possible alignments in the combinedTable are used as ordered pairs to anchor a retention time projection model. Alignments of abundant features are prominent targets for anchor selection, but shared identified features (i.e. feature pairs where idx = idy) may be used.

Usage

```r
selectAnchors(
    object,
    useID = FALSE,
    tolmz = 0.003,
    tolQ = 0.3,
    tolrtq = 0.3,
    windx = 0.03,
    windy = 0.03,
    brackets_ignore = c("\", "[", "{")
)
```

Arguments

- **object**: metabCombiner object.
- **useID**: logical. Option to first search for IDs as anchors.
- **tolmz**: numeric. m/z tolerance for prospective anchors
- **tolQ**: numeric. Quantile Q tolerance for prospective anchors
- **tolrtq**: numeric. Linear RT quantile tolerance for prospective anchors.
selectAnchors

windx numeric. Retention time exclusion window around each anchor in X dataset. Optimal values are between 0.01 and 0.05 min (1-3s)

windy numeric. Retention time exclusion window around each anchor in dataset Y. Optimal values are between 0.01 and 0.05 min (1-3s)

brackets_ignore If useID = TRUE, bracketed identity strings of the types included in this argument will be ignored.

Details

In order to map between two sets of retention times, a set of ordered pairs need to be selected for the spline fit. This function relies on mutually abundant features to select these ordered pairs. In iterative steps, the most abundant (as indicated by Q value) in one dataset is selected along with its counterpart, and all features within some retention time window specified by windx & windy arguments are excluded. This process is repeated until all features have been considered.

tolQ & tolmz arguments restrict to feature pairs that have differences in Q & m/z within these tolerances. tolrtq further limits to feature pairs those with relative differences in linear retention time quantiles, calculated as \( rtqx = (rtx - \text{min}(rtx))/(\text{max}(rtx) - \text{min}(rtx)) \) & \( rtry = (rty - \text{min}(rty))/(\text{max}(rty) - \text{min}(rty)) \)

Shared identities (in which idx & idy columns have matching, non-empty & non-bracketed strings) may be used if useID is set to TRUE. In this case, shared identities will be searched first and will not be subject to any of the restrictions in m/z, Q, or rt. The iterative process proceeds after processing of shared identities.

Value

metabCombiner object with updated anchors slot. This is a data.frame of feature pairs that shall be used to map between retention times using a GAM or LOESS model.

idx identities of features from dataset X

idy identities of features from dataset Y

mzx m/z values of features from dataset X

mzy m/z values of features from dataset Y

rtx retention time values of features from dataset X

rty retention time values of features from dataset Y

rtProj model-projected retention time values from X to Y

Qx abundance quantile values of features from dataset X

Qy abundance quantile values of features from dataset Y

adductX adduct label of features from dataset X

adductY adduct label of features from dataset Y

group m/z feature group of feature pairing

labels anchor labels; "I" for identity, "A" for normal anchors
selectAnchorsParam

List selectAnchors Defaults

Description

List of default parameters for anchor selection step of main package workflow, which can be used as input for the wrapper functions. See help(selectAnchors) or ?selectAnchors for more details.

Usage

selectAnchorsParam(
  useID = FALSE,
  tolmz = 0.003,
  tolQ = 0.3,
  tolrtq = 0.3,
  windx = 0.03,
  windy = 0.03,
  brackets_ignore = c("\"", "\[", "\{")
)
Arguments

- `useID` Choice of using IDs for anchor selection; default: FALSE
- `tolmz` m/z tolerance for ordered pair features; default: 0.003
- `tolQ` Q tolerance for ordered pair features; default: 0.3
- `tolrtq` RT quantile tolerance for ordered pair features; default: 0.5
- `windx` X feature RT window parameter. Default: 0.03
- `windy` Y feature RT window parameter. Default: 0.03

- `brackets_ignore` bracket types for ignoring string comparisons

Value

list of selectAnchors parameters

See Also

selectAnchors, metabCombine

Examples

```r
sa_param <- selectAnchorsParam(tolmz = 0.002, tolQ = 0.2, windy = 0.02)
```

Description

This method updates the feature list (featData) and aligned table (combinedTable) within a metabCombiner object. Manual changes to the (combinedTable) as well as unmatched X & Y dataset features can be incorporated into the object and the corresponding results. This function is typically paired with `reduceTable` or other forms of table reduction performed by the user.

Usage

```r
updateTables(object, xdata = NULL, ydata = NULL, combinedTable = NULL)
```

Arguments

- `object` metabCombiner object to be updated
- `xdata` metabData or metabCombiner object originally used to construct the object argument
- `ydata` metabData or metabCombiner object originally used to construct the object argument
- `combinedTable` merged table which may be altered by the user. This must have the combinedTable format to be valid (see: ?isCombinedTable)
Details

There are two points where features can be removed from the combinedTable report: during m/z grouping and during the table reduction step. It is also possible for user-specified changes to the report to remove certain features entirely. This function allows for the missed features to be brought back into the table as non-matched entities. For xdata features, the Y columns will be entirely missing values, and ydata features will have missing X information. The feature data (featData) will also be updated for use in subsequent alignments, but only features present in the representative dataset will be retained by default.

Value

metabCombiner object with updates to combinedTable to include features that have been missed or changes by the user.

Note

Duplicated sample & extra column names cannot be copied from the original data they feature in, therefore they are left as missing values.

Examples

data(plasma30)
data(plasma20)
p30 <- metabData(plasma30, samples = "CHEAR")
p20 <- metabData(plasma20, samples = "Red")
p.comb <- metabCombiner(xdata = p30, ydata = p20, xid = "p30", yid = "p20", binGap = 0.0075)

# extracting, modifying, and updating combinedTable
ctable <- combinedTable(p.comb)
cTable <- dplyr::filter(cTable, rty < 17.25)
p.comb <- updateTables(p.comb, combinedTable = cTable)

p.comb <- selectAnchors(p.comb, tolmz = 0.003, tolq = 0.3, windy = 0.02)
p.comb <- fit_gam(p.comb, k = 20, iterFilter = 1)
p.comb <- calcScores(p.comb, A = 90, B = 14, C = 0.5)
p.comb <- reduceTable(p.comb, delta = 0.2, maxRTerr = 0.5)

# updating to include features removed from xdata & ydata
p.comb <- updateTables(p.comb, xdata = p30, ydata = p20)

# view results
cTable <- combinedTable(p.comb)
fd <- featData(p.comb)
Description

Prints a combinedTable report to a file, specified by file argument. Output file has an empty line between each separate m/z group for ease of viewing.

Usage

write2file(object, file, sep = ",")

Arguments

- object: metabCombiner object or combinedTable
- file: character string naming the output file path
- sep: Character field separator. Values within each row are separated by this character.

Value

no values returned

Examples

data(plasma30)
data(plasma20)

p30 <- metabData(plasma30, samples = "CHEAR")
p20 <- metabData(plasma20, samples = "Red", rtmax = 17.25)
p.comb <- metabCombiner(xdata = p30, ydata = p20, binGap = 0.0075)

p.comb <- selectAnchors(p.comb, tolmz = 0.003, tolrtq = 0.3, windy = 0.02)
p.comb <- fit_gam(p.comb, k = 20, iterFilter = 1)
p.comb <- calcScores(p.comb, A = 90, B = 14, C = 0.5)
p.comb <- labelRows(p.comb, maxRankX = 2, maxRankY = 2, remove = TRUE)

###using metabCombiner object as input
write2file(p.comb, file = "plasma-combined.csv", sep = ",")

###using combinedTable report and feature data as input
cTable <- combinedTable(p.comb)
write2file(cTable, file = "plasma-combined.txt", sep = "\t")
Obtain x & y Data Identifiers

Description

metabCombiner alignment is performed in a pairwise manner between two datasets generically termed "x" & "y". These methods print the identifier(s) associated with datasets X and Y, contained within the xy slot of a constructed metabCombiner object.

Usage

x(object)
xy(object)
y(object)

## S4 method for signature 'metabCombiner'
x(object)

## S4 method for signature 'metabCombiner'
xy(object)

## S4 method for signature 'metabCombiner'
y(object)

Arguments

object metabCombiner object

Value

character X or Y dataset identifiers
data(plasma30) data(plasma20)
p30 <- metabData(head(plasma30,500), samples = "CHEAR") p20 <- metabData(head(plasma20,500), samples = "Red") p.comb <- metabCombiner(p30, p20, xid = "p30", yid = "p20")

#expected: "p30" x(p.comb)
#expected: "p20" y(p.comb)
#list of x & y data descriptors xy(p.comb)
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