

# Package ‘qPLEXanalyzer’

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qPLEXanalyzer-package *Tools for qPLEX-RIME data analysis*

---

## Description

Tools for quantitative proteomics data analysis generated from qPLEX-RIME method The package offers the following functionalities Data processing, normalization & analysis:

- `convertToMSnset`: Converts quantitative data to a MSnSet
- `summarizeIntensities`: Summarizes multiple peptide measurements for a protein
- `normalizeQuantiles`: Performs quantile normalization on the peptides/proteins intensities

- `normalizeScaling`: Performs scaling normalization on the peptides/proteins intensities (mean, median or sum)
- `groupScaling`: Performs scaling normalization on the peptides/proteins intensities within group (median or mean)
- `rowScaling`: Normalization by scaling peptide/protein intensity across all samples
- `regressIntensity`: Performs linear regression on protein intensities based on selected protein
- `coefVar`: Calculating the coefficient of variation by utilizing expression data within individual sample groups
- `computeDiffStats`: Compute differential statistics for the given contrasts
- `getContrastResults`: Get differential statistics results for given contrast

#### Visualization:

- `assignColours`: Assigns colours to samples in groups
- `corrPlot`: Correlation plot of all the samples
- `coveragePlot`: Computes and display protein sequence coverage of
- `hierarchicalPlot`: Hierarchical clustering plot of all the samples
- `intensityBoxplot`: Intensity distribution boxplot of all the samples
- `intensityPlot`: Intensity distribution plot of all the samples
- `maVolPlot`: MA or Volcano plot of differential analysis results
- `pcaPlot`: PCA plot of all the samples
- `peptideIntensityPlot`: Peptide intensity distribution plot of specific protein
- `plotMeanVar`: Computes and plots mean-variance for samples in MSnSet
- `rliPlot`: Relative intensity plot of all the samples selected protein in proteomics experiment

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#### See Also

Useful links:

- Report bugs at <https://github.com/crukci-bioinformatics/qPLEXanalyzer/issues>

---

|               |                                             |
|---------------|---------------------------------------------|
| assignColours | <i>Assigns colours to samples in groups</i> |
|---------------|---------------------------------------------|

---

### Description

Assigns colours to samples in groups for plotting

### Usage

```
assignColours(MSnSetObj, colourBy = "SampleGroup")
```

### Arguments

|           |                                                                          |
|-----------|--------------------------------------------------------------------------|
| MSnSetObj | MSnSet; an object of class MSnSet                                        |
| colourBy  | character: column name from pData(MSnSetObj) to use for coloring samples |

### Value

A character vector of colors for samples.

### Examples

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
  metadata=exp3_OHT_ESR1$metadata_qPLEX1,
  indExpData=c(7:16), Sequences=2, Accessions=6)
sampleColours <- assignColours(MSnSet_data)
```

---

|         |                                                                                                               |
|---------|---------------------------------------------------------------------------------------------------------------|
| coefVar | <i>Calculating the coefficient of variation by utilizing expression data within individual sample groups.</i> |
|---------|---------------------------------------------------------------------------------------------------------------|

---

### Description

Calculating the coefficient of variation by utilizing peptide/protein expression data within individual sample groups.

### Usage

```
coefVar(MSnSetObj)
```

### Arguments

|           |                                   |
|-----------|-----------------------------------|
| MSnSetObj | MSnSet; an object of class MSnSet |
|-----------|-----------------------------------|

## Details

In this approach, we calculate distributions of the coefficient of variation (CV) for the dataset. The CVs are determined based on peptides or proteins intensities within each sample group, and the results are visualized through boxplots and cumulative fraction plots for each sample group.

## Value

An object of class `list` consisting of object of class `ggplot`)

## Examples

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)
exprs(MSnSet_data) <- exprs(MSnSet_data)+1.1
res <- coefVar(MSnSet_data)
```

---

|                  |                                        |
|------------------|----------------------------------------|
| computeDiffStats | <i>Compute differential statistics</i> |
|------------------|----------------------------------------|

---

## Description

Compute differential statistics on the given contrasts, based on [limma](#) functions.

## Usage

```
computeDiffStats(
  MSnSetObj,
  batchEffect = NULL,
  transform = TRUE,
  contrasts,
  trend = TRUE,
  robust = TRUE
)
```

## Arguments

|             |                                                                                        |
|-------------|----------------------------------------------------------------------------------------|
| MSnSetObj   | MSnSet; An object of class MSnSet                                                      |
| batchEffect | character; vector of variable(s) to correct for batch effect, Default : "Sample-Group" |
| transform   | logical; apply log2 transformation to the raw intensities                              |
| contrasts   | character; named character vector of contrasts for differential statistics             |
| trend       | logical; TRUE or FALSE                                                                 |
| robust      | logical; TRUE or FALSE                                                                 |

## Details

A statistical analysis for the identification of differentially regulated or bound proteins is carried out using limma based analysis. It uses linear models to assess differential expression in the context of multifactor designed experiments. Firstly, a linear model is fitted for each protein where the model includes variables for each group and MS run. Then, log2 fold changes between comparisons are estimated. Multiple testing correction of p-values are applied using the Benjamini-Hochberg method to control the false discovery rate (FDR).

In order to correct for batch effect, variable(s) can be defined. It should corresponds to a column name in pData(MSnSetObj). The default variable is "SampleGroup" that distinguish between two groups. If more variables are defined they are added to default.

## Value

A list object containing three components: MSnSetObj of class MSnSet (see [MSnSet-class](#)) object), fittedLM (fitted linear model) and fittedContrasts. This object should be input into getContrastResults function to get differential results. See [eBayes](#) function of [limma](#) for more details on differential statistics.

## Examples

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                              metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                              indExpData=c(7:16),
                              Sequences=2,
                              Accessions=6)
MSnset_norm <- groupScaling(MSnSet_data, scalingFunction=median)
MSnset_Pnorm <- summarizeIntensities(MSnset_norm, sum, human_anno)
contrasts <- c(tam.24h_vs_vehicle = "tam.24h - vehicle",
               tam.6h_vs_vehicle = "tam.6h - vehicle")
diffstats <- computeDiffStats(MSnSetObj=MSnset_Pnorm, contrasts=contrasts)
```

---

convertToMSnset

*Converts proteomics TMT intensity data to MSnSet*

---

## Description

Converts processed TMT peptide intensities to MSnSet

## Usage

```
convertToMSnset(
  ExpObj,
  metadata,
  indExpData,
  Sequences = NULL,
```

```

    Accessions,
    type = "peptide",
    rmMissing = TRUE
  )

```

## Arguments

|            |                                                                                                   |
|------------|---------------------------------------------------------------------------------------------------|
| ExpObj     | data.frame; a data.frame consisting of quantitative peptide intensities and peptide annotation    |
| metadata   | data.frame; a data.frame describing the samples                                                   |
| indExpData | numeric; a numeric vector indicating the column indexes of intensities in ExpObj                  |
| Sequences  | numeric; a numeric value indicating the index of column consisting of peptide sequence in ExpObj  |
| Accessions | numeric; a numeric value indicating the index of column consisting of protein accession in ExpObj |
| type       | character; what type of data set to create, either 'peptide' or 'protein'                         |
| rmMissing  | logical; TRUE or FALSE to indicate whether to remove missing data or not                          |

## Details

This function builds an object of class MSnSet from a dataframe consisting of quantitative proteomics intensities data and a meta-data describing the samples information. This function creates an MSnSet object from the intensities and metadata file. The metadata must contain "Sample-Name", "SampleGroup", "BioRep" and "TechRep" columns. The function can be used for either peptide intensities or data that has already been summarized to protein level. The type argument should be set to 'protein' for the latter.

## Value

An object of class MSnSet (see [MSnSet-class](#)) object).

## Examples

```

data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)

```

corrPlot

*Correlation plot***Description**

Computes and display correlation plot for samples within MSnSet

**Usage**

```
corrPlot(
  MSnSetObj,
  addValues = TRUE,
  title = "",
  low_cor_colour = "#FFFFFF",
  high_cor_colour = "#B90505",
  low_cor_limit = 0,
  high_cor_limit = 1,
  textsize = 3
)
```

**Arguments**

|                 |                                                      |
|-----------------|------------------------------------------------------|
| MSnSetObj       | MSnSet; an object of class MSnSet                    |
| addValues       | logical: adds correlation values to the plot         |
| title           | character; title of the plot                         |
| low_cor_colour  | colour; colour for lowest correlation in scale       |
| high_cor_colour | colour; colour for highest correlation in scale      |
| low_cor_limit   | numeric; lower limit for correlation in colour scale |
| high_cor_limit  | numeric; upper limit for correlation in colour scale |
| textsize        | integer: set the size of correlation values text     |

**Value**

An object created by ggplot

**Examples**

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
  metadata=exp3_OHT_ESR1$metadata_qPLEX1,
  indExpData=c(7:16),
  Sequences=2,
  Accessions=6)
corrPlot(MSnSet_data, addValues=TRUE, title="Correlation plot")
```

```
# change colours
corrPlot(MSnSet_data, addValues=TRUE, title="Correlation plot",
         low_cor_colour="yellow", high_cor_colour="pink")
```

---

|              |                                       |
|--------------|---------------------------------------|
| coveragePlot | <i>Plot peptide sequence coverage</i> |
|--------------|---------------------------------------|

---

## Description

Computes and displays peptide sequence coverage in proteomics experiment

## Usage

```
coveragePlot(MSnSetObj, ProteinID, ProteinName, fastaFile, myCol = "brown")
```

## Arguments

|             |                                           |
|-------------|-------------------------------------------|
| MSnSetObj   | MSnSet: an object of class MSnSet         |
| ProteinID   | character: Uniprot ID of the protein      |
| ProteinName | character: name of the protein            |
| fastaFile   | character: fasta file of protein sequence |
| myCol       | colour: colour for plotting               |

## Details

In the qPLEX-RIME experiment it is imperative for bait protein to have good sequence coverage. This function plots the protein sequence coverage of the bait protein in the qPLEX-RIME experiment. It requires the fasta sequence file of bait protein as input to generate the plot.

## Value

An object created by ggplot

## Examples

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)
mySequenceFile <- system.file('extdata',
                              "P03372.fasta",
                              package="qPLEXanalyzer")
coveragePlot(MSnSet_data,
```

```
ProteinID="P03372",
ProteinName="ERa",
fastaFile=mySequenceFile)
```

---

|                   |                                  |
|-------------------|----------------------------------|
| ER_ARID1A_KO_MCF7 | <i>ER_ARID1A_KO_MCF7 dataset</i> |
|-------------------|----------------------------------|

---

### Description

Five ER qPLEX-RIME (9plex) experiments were performed on two wild type clones, two ARID1A knockout clones and one parental cell line with Tamoxifen treatment in MCF7 cell lines.

### Format

An object of class `list` related to peptides quantification. It consists of qPLEX-RIME data from five experimental runs. Each run contains 9 samples divided into nine conditions (T\_14, V\_14, T\_11, V\_11, ECACC.T, ECACC.V, T\_221, V\_221 and Ref).

### Value

An object of class `list` related to peptides quantification.

---

|            |                           |
|------------|---------------------------|
| exp2_Xlink | <i>exp2_Xlink dataset</i> |
|------------|---------------------------|

---

### Description

An ER qPLEX-RIME experiment was performed to compare two different methods of crosslinking. MCF7 cells were double crosslinked with DSG/formaldehyde (double) or with formaldehyde alone (single). Four biological replicates were obtained for each condition along with two IgG pooled samples from each replicate.

### Format

An object of class `list` related to peptides quantification. It consists of qPLEX-RIME data of 10 samples divided into three conditions (FA, DSG.FA and IgG).

### Value

An object of class `list` related to peptides quantification.

---

exp3\_OHT\_ESR1*exp3\_OHT\_ESR1 dataset*

---

**Description**

Three ER qPLEX-RIME (10plex) experiments were performed to investigate the dynamics of the ER complex assembly upon 4-hydroxytamoxifen (OHT) treatment at 2h, 6h and 24h or at 24h post-treatment with the drug-vehicle alone (ethanol). Two biological replicates of each condition were included in each experiment to finally consider a total of six replicates per time point. Additionally, MCF7 cells were treated with OHT or ethanol and cross-linked at 24h post-treatment in each experiment to be used for mock IgG pull-downs and to enable discrimination of non-specific binding in the same experiment. This is a timecourse experiment to study the effect of tamoxifen in ER interactome using qPLEX-RIME method.

**Format**

An object of class `list` related to peptides quantification. It consists of qPLEX-RIME data from three experimental runs. Each run contains 10 samples divided into five conditions (IgG, vehicle, tam.2h, tam.6h and tam.24h).

**Value**

An object of class `list` related to peptides quantification.

---

getContrastResults*Get differential statistics results*

---

**Description**

Get differential statistics results for given contrasts.

**Usage**

```
getContrastResults(  
  diffstats,  
  contrast,  
  controlGroup = NULL,  
  transform = TRUE,  
  writeFile = FALSE  
)
```

**Arguments**

|              |                                                                                       |
|--------------|---------------------------------------------------------------------------------------|
| diffstats    | list; output of computeDiffStats function                                             |
| contrast     | character; contrast of interest for which to retrieve differential statistics results |
| controlGroup | character; control group such as IgG                                                  |
| transform    | logical; apply log2 transformation to the raw intensities                             |
| writeFile    | logical; whether to write the results into a text file                                |

**Value**

A `data.frame` object and text file containing the result of the differential statistics.

**Examples**

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnSet(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)
MSnset_norm <- groupScaling(MSnSet_data, scalingFunction=median)
MSnset_Pnorm <- summarizeIntensities(MSnset_norm, sum, human_anno)
contrasts <- c(tam.24h_vs_vehicle = "tam.24h - vehicle")
diffstats <- computeDiffStats(MSnset_Pnorm, contrasts=contrasts)
diffexp <- getContrastResults(diffstats=diffstats, contrast=contrasts)
```

---

|              |                                              |
|--------------|----------------------------------------------|
| groupScaling | <i>Normalization by scaling within group</i> |
|--------------|----------------------------------------------|

---

**Description**

Performs scaling normalization on the intensities within group (median or mean)

**Usage**

```
groupScaling(
  MSnSetObj,
  scalingFunction = median,
  groupingColumn = "SampleGroup"
)
```

**Arguments**

|                 |                                                                              |
|-----------------|------------------------------------------------------------------------------|
| MSnSetObj       | MSnSet; an object of class MSnSet                                            |
| scalingFunction | function; median or mean                                                     |
| groupingColumn  | character; the feature on which groups would be based; default="SampleGroup" |

**Details**

In this normalization method the central tendencies (mean or median) of the samples within groups are aligned. The argument "groupingColumn" is used to define separate groups to normalize. The function takes one of the column of pData(data) as the variable for classifying group. The default variable is "SampleGroup". It is imperative in qPLEX-RIME experiment to define IgG as a separate group and normalize it separately from others. You could add a column into the metadata to define this classification.

**Value**

An object of class MSnSet (see [MSnSet-class](#))

**Examples**

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnSet(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)
MSnset_norm <- groupScaling(MSnSet_data,
                             scalingFunction=median,
                             groupingColumn="SampleGroup")
```

---

|                  |                                     |
|------------------|-------------------------------------|
| hierarchicalPlot | <i>Hierarchical clustering plot</i> |
|------------------|-------------------------------------|

---

**Description**

Computes and displays hierarchical clustering plot for samples in MSnSet

**Usage**

```
hierarchicalPlot(
  MSnSetObj,
  sampleColours = NULL,
  colourBy = "SampleGroup",
  horizontal = TRUE,
  title = ""
)
```

**Arguments**

|               |                                                                                            |
|---------------|--------------------------------------------------------------------------------------------|
| MSnSetObj     | MSnSet; an object of class MSnSet                                                          |
| sampleColours | character: a named vector of colors for samples, names should be values of colourBy column |

|            |                                                                          |
|------------|--------------------------------------------------------------------------|
| colourBy   | character: column name from pData(MSnSetObj) to use for coloring samples |
| horizontal | logical: define orientation of the dendrogram                            |
| title      | character: the main title for the dendrogram                             |

**Value**

An object created by ggplot

**Examples**

```
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)
exprs(MSnSet_data) <- exprs(MSnSet_data)+0.01
hierarchicalPlot(MSnSet_data, title="qPLEX_RIME_ER")
```

---

|            |                           |
|------------|---------------------------|
| human_anno | <i>human_anno dataset</i> |
|------------|---------------------------|

---

**Description**

Uniprot Human protein annotation table.

**Format**

An object of class [data.frame](#) consisting of uniprot human protein annotation.

---

|                  |                                       |
|------------------|---------------------------------------|
| intensityBoxplot | <i>Intensity Distribution boxplot</i> |
|------------------|---------------------------------------|

---

**Description**

Intensity distribution boxplot of all the samples

**Usage**

```
intensityBoxplot(
  MSnSetObj,
  title = "",
  sampleColours = NULL,
  colourBy = "SampleGroup"
)
```

**Arguments**

|               |                                                                          |
|---------------|--------------------------------------------------------------------------|
| MSnSetObj     | MSnSet; an object of class MSnSet                                        |
| title         | character; title of the plot                                             |
| sampleColours | character: a named character vector of colors for samples                |
| colourBy      | character: column name from pData(MSnSetObj) to use for coloring samples |

**Details**

The column provided to the colourBy argument will be used to colour the samples. The colours will be determined using the function [assignColours](#), alternatively the user may specify a named vector of colours using the sampleColours argument. The names of the sampleColours vector should match the unique values in the colourBy column.

**Value**

An object created by ggplot

**Examples**

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)
intensityBoxplot(MSnSet_data, title = "qPLEX_RIME_ER")

# custom colours
customCols <- rainbow(length(unique(pData(MSnSet_data)$SampleGroup)))
names(customCols) <- unique(pData(MSnSet_data)$SampleGroup)
intensityBoxplot(MSnSet_data,
                 title = "qPLEX_RIME_ER",
                 sampleColours = customCols)
```

---

intensityPlot

*Intensity Distribution Plot*


---

**Description**

Intensity distribution plot of all the samples

**Usage**

```
intensityPlot(
  MSnSetObj,
  sampleColours = NULL,
  title = "",
  colourBy = "SampleGroup",
  transform = TRUE,
  xlab = "log2(intensity)",
  trFunc = log2xplus1
)
```

**Arguments**

|               |                                                                          |
|---------------|--------------------------------------------------------------------------|
| MSnSetObj     | MSnSet; an object of class MSnSet                                        |
| sampleColours | character: a vector of colors for samples                                |
| title         | character: title for the plot                                            |
| colourBy      | character: column name from pData(MSnSetObj) to use for coloring samples |
| transform     | logical: whether to log transform intensities                            |
| xlab          | character: label for x-axis                                              |
| trFunc        | func: internal helper function for log transformation                    |

**Details**

The column provided to the colourBy argument will be used to colour the samples. The colours will be determined using the function [assignColours](#), alternatively the user may specify a named vector of colours using the sampleColours argument. The names of the sampleColours vector should match the unique values in the colourBy column.

**Value**

An object created by ggplot

**Examples**

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)
intensityPlot(MSnSet_data, title = "qPLEX_RIME_ER")

# custom colours
customCols <- rainbow(length(unique(pData(MSnSet_data)$SampleGroup)))
names(customCols) <- unique(pData(MSnSet_data)$SampleGroup)
intensityPlot(MSnSet_data,
              title = "qPLEX_RIME_ER",
```

```
sampleColours = customCols)
```

IRSnorm

*Batch Correction by Internal Reference Scale*

## Description

Performs batch correction on multiple runs using an Internal Reference Scale sample.

## Usage

```
IRSnorm(MSnSetObj, IRSname = "RefPool", groupingColumn = "Plex")
```

## Arguments

|                |                                                                                    |
|----------------|------------------------------------------------------------------------------------|
| MSnSetObj      | MSnSet; an object of class MSnSet                                                  |
| IRSname        | character; name of the Reference group within the SampleGroup column               |
| groupingColumn | character; the pData(MSnSetObj) column name used to define batches; default="Plex" |

## Details

The Internal Reference Scale sample (IRS) should ideally be representative of the entire proteome detectable across all sample in the experiment, e.g. a pooled sample made up of aliquots of protein from all samples. The IRS is then run and measured in each TMT experiment. The normalization procedure makes measurements of the IRS from different TMT batches exactly the same, and puts all of the reporter ions on the same "intensity scale". The argument 'IRSname' is used to define the name of the Reference group within the SampleGroup column. The argument "groupingColumn" takes one of the column of pData(MSnSetObj) to define separate batches to correct; the default variable name is "Plex".

## Value

An object of class MSnSet (see [MSnSet-class](#))

## Examples

```
data(human_anno)
data(ER_ARID1A_KO_MCF7)
MSnset_SET1 <- convertToMSnset(ER_ARID1A_KO_MCF7$intensities_Set1,
                              metadata=ER_ARID1A_KO_MCF7$metadata_Set1,
                              indExpData=c(7:15),
                              Sequences=2,
                              Accessions=6)
MSnset_SET2 <- convertToMSnset(ER_ARID1A_KO_MCF7$intensities_Set2,
                              metadata=ER_ARID1A_KO_MCF7$metadata_Set2,
                              indExpData=c(7:15),
```

```

Sequences=2,
Accessions=6)
MSnset_SET3 <- convertToMSnset(ER_ARID1A_KO_MCF7$intensities_Set3,
                               metadata=ER_ARID1A_KO_MCF7$metadata_Set3,
                               indExpData=c(7:15),
                               Sequences=2,
                               Accessions=6)
MSnset_SET4 <- convertToMSnset(ER_ARID1A_KO_MCF7$intensities_Set4,
                               metadata=ER_ARID1A_KO_MCF7$metadata_Set4,
                               indExpData=c(7:14),
                               Sequences=2,
                               Accessions=6)
MSnset_SET5 <- convertToMSnset(ER_ARID1A_KO_MCF7$intensities_Set5,
                               metadata=ER_ARID1A_KO_MCF7$metadata_Set5,
                               indExpData=c(7:15),
                               Sequences=2,
                               Accessions=6)
MSnset_SET1_norm <- normalizeScaling(MSnset_SET1, median)
MSnset_SET2_norm <- normalizeScaling(MSnset_SET2, median)
MSnset_SET3_norm <- normalizeScaling(MSnset_SET3, median)
MSnset_SET4_norm <- normalizeScaling(MSnset_SET4, median)
MSnset_SET5_norm <- normalizeScaling(MSnset_SET5, median)
MSnset_SET1_Pnorm <- summarizeIntensities(MSnset_SET1_norm, sum, human_anno)
MSnset_SET2_Pnorm <- summarizeIntensities(MSnset_SET2_norm, sum, human_anno)
MSnset_SET3_Pnorm <- summarizeIntensities(MSnset_SET3_norm, sum, human_anno)
MSnset_SET4_Pnorm <- summarizeIntensities(MSnset_SET4_norm, sum, human_anno)
MSnset_SET5_Pnorm <- summarizeIntensities(MSnset_SET5_norm, sum, human_anno)
MSnset_SET1_Pnorm <- updateSampleNames(updateFvarLabels(MSnset_SET1_Pnorm))
MSnset_SET2_Pnorm <- updateSampleNames(updateFvarLabels(MSnset_SET2_Pnorm))
MSnset_SET3_Pnorm <- updateSampleNames(updateFvarLabels(MSnset_SET3_Pnorm))
MSnset_SET4_Pnorm <- updateSampleNames(updateFvarLabels(MSnset_SET4_Pnorm))
MSnset_SET5_Pnorm <- updateSampleNames(updateFvarLabels(MSnset_SET5_Pnorm))
MSnset_comb <- MSnbase::combine(MSnset_SET1_Pnorm,
                                MSnset_SET2_Pnorm,
                                MSnset_SET3_Pnorm,
                                MSnset_SET4_Pnorm,
                                MSnset_SET5_Pnorm)
tokeep <- complete.cases(fData(MSnset_comb))
MSnset_comb <- MSnset_comb[tokeep,]
sampleNames(MSnset_comb) <- pData(MSnset_comb)$SampleName
fData(MSnset_comb) <- fData(MSnset_comb)[,c(2,3,6)]
colnames(fData(MSnset_comb)) <- c("Sequences", "Modifications", "Accessions")
MSnset_comb_corr <- IRSnorm(MSnset_comb, IRSname="Ref", groupingColumn="Run")

```

---

maVolPlot

---

*MA or Volcano Plot*


---

## Description

MA or Volcano plot of differential statistics results

**Usage**

```
maVolPlot(
  diffstats,
  contrast,
  title = "",
  controlGroup = NULL,
  selectedGenes = NULL,
  fdrCutoff = 0.05,
  lfcCutoff = 1,
  controlLfcCutoff = 1,
  plotType = "MA"
)
```

**Arguments**

|                  |                                                                         |
|------------------|-------------------------------------------------------------------------|
| diffstats        | list; output of computeDiffStats function                               |
| contrast         | character; contrast of interest to plot differential statistics results |
| title            | character: title for the plot                                           |
| controlGroup     | character; control group such as IgG                                    |
| selectedGenes    | character: a vector defining genes to plot                              |
| fdrCutoff        | numeric: False Discovery Rate (adj.P.Val) cut off                       |
| lfcCutoff        | numeric: Log Fold Change (log2FC) cutoff for                            |
| controlLfcCutoff | numeric: only plot genes above controlLogFoldChange cutoff              |
| plotType         | character: which type of plot to generate: "MA" or "Volcano"            |

**Details**

Genes determined as significant according to the Log Fold Change and False Discovery Rate cutoffs are highlighted in red.

A user specified selection of genes can be highlighted by passing a character vector of Accessions to the selectedGenes argument. The contents of this vector will be matched with the Accessions column of the diffstats object to identify rows to highlight. These will be plotted in blue and labeled with the contents of the GeneSymbol column. Note that if the GeneSymbol for a selected gene is missing, no label will be apparent.

**Value**

An object created by ggplot

**Examples**

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
```

```

                                indExpData=c(7:16),
                                Sequences=2,
                                Accessions=6)
MSnset_norm <- groupScaling(MSnSet_data, scalingFunction=median)
MSnset_Pnorm <- summarizeIntensities(MSnset_norm, sum, human_anno)
contrasts <- c(tam.24h_vs_vehicle = "tam.24h - vehicle")
diffstats <- computeDiffStats(MSnset_Pnorm, contrasts=contrasts)
maVolPlot(diffstats, contrast = contrasts, plotType="MA")
maVolPlot(diffstats, contrast = contrasts, plotType="Volcano")

```

---

mergePeptides

---

*Merge identical modified peptides intensities*


---

## Description

Merge modified peptides with identical sequences to single peptide intensity. This function is especially useful for modified peptide enrichment based method such as phosphopeptide analysis.

## Usage

```
mergePeptides(MSnSetObj, summarizationFunction, annotation, keepCols = NULL)
```

## Arguments

|                       |                                                                                                                                                  |
|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| MSnSetObj             | MSnSet; an object of class MSnSet                                                                                                                |
| summarizationFunction | function; method used to aggregate the peptides. sum, mean or median                                                                             |
| annotation            | data.frame; a data.frame of protein annotation of four columns: "Accessions", "Gene", "Description" and "GeneSymbol"                             |
| keepCols              | a vector of additional columns from fData(MSnSetObj) to keep. either be a numeric vector of column indices or a character vector of column names |

## Details

Rows of the intensity matrix with identical peptide sequences are merged by summarising the intensities using summarizationFunction.

Columns specified with keepCols are retained in the final output. Non-unique entries in different rows are concatenated with ','.

## Value

An object of class MSnSet (see [MSnSet-class](#))

## Examples

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)
MSnset_P <- mergePeptides(MSnSet_data, sum, human_anno)
```

---

|            |                                                       |
|------------|-------------------------------------------------------|
| mergeSites | <i>Merge identical modification sites intensities</i> |
|------------|-------------------------------------------------------|

---

## Description

Merge peptides with identical modification sites to single site intensity. This function is especially useful for data based on enrichment of specific peptide modification.

## Usage

```
mergeSites(MSnSetObj, summarizationFunction, annotation, keepCols = NULL)
```

## Arguments

|                       |                                                                                                                                                  |
|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| MSnSetObj             | MSnSet; an object of class MSnSet                                                                                                                |
| summarizationFunction | function; method used to aggregate the peptides. sum, mean or median                                                                             |
| annotation            | data.frame; a data.frame of protein annotation of four columns: "Accessions", "Gene", "Description" and "GeneSymbol"                             |
| keepCols              | a vector of additional columns from fData(MSnSetObj) to keep. either be a numeric vector of column indices or a character vector of column names |

## Details

Rows of the intensity matrix with identical sites on same protein are merged by summarising the intensities using summarizationFunction. The merging will only take place if "Sites" and "Type" column are present in the fData(MSnSetObj). Sites contains the information of modified site position within the protein sequence and Type tells us about whether the modification is single (1xPhospho/Acetyl) or multi (2xPhospho/Acetyl).

Columns specified with keepCols are retained in the final output. Non-unique entries in different rows are concatenated with ','.

## Value

An object of class MSnSet (see [MSnSet-class](#))

**Examples**

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnSet(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)
#MSnset_P <- mergeSites(MSnSet_data, sum, human_anno)
```

---

|            |                           |
|------------|---------------------------|
| mouse_anno | <i>mouse_anno dataset</i> |
|------------|---------------------------|

---

**Description**

Uniprot Mouse protein annotation table.

**Format**

An object of class [data.frame](#) consisting of uniprot mouse protein annotation.

---

|                    |                               |
|--------------------|-------------------------------|
| normalizeQuantiles | <i>Quantile normalization</i> |
|--------------------|-------------------------------|

---

**Description**

Performs quantile normalization on the intensities within columns

**Usage**

```
normalizeQuantiles(MSnSetObj)
```

**Arguments**

MSnSetObj      MSnSet; an object of class MSnSet

**Details**

The peptide intensities are roughly replaced by the order statics on their abundance. This normalization technique has the effect of making the distributions of intensities from the different samples identical in terms of their statistical properties. It is the strongest normalization method and should be used carefully as it erases most of the difference between the samples.

**Value**

An object of class MSnSet (see [MSnSet-class](#))

## Examples

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)
MSnSet_norm <- normalizeQuantiles(MSnSet_data)
```

---

|                  |                                 |
|------------------|---------------------------------|
| normalizeScaling | <i>Normalization by scaling</i> |
|------------------|---------------------------------|

---

## Description

Performs scaling normalization on the peptide/protein intensities (median or mean)

## Usage

```
normalizeScaling(MSnSetObj, scalingFunction = median, ProteinId = NULL)
```

## Arguments

|                 |                                   |
|-----------------|-----------------------------------|
| MSnSetObj       | MSnSet; an object of class MSnSet |
| scalingFunction | function; median or mean          |
| ProteinId       | character; protein Id             |

## Details

In this normalization method the central tendencies (mean or median) of the samples are aligned. The central tendency for each sample is computed and log transformed. A scaling factor is determined by subtracting from each central tendency the mean of all the central tendencies. The raw intensities are then divided by the scaling factor to get normalized intensities.

The intensities can also be normalized based on the peptide intensities of a selected protein. For this the argument "ProteinId" allows you to define the protein that will be used for scaling the intensities.

## Value

An object of class MSnSet (see [MSnSet-class](#))

## Examples

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)
MSnSet_norm <- normalizeScaling(MSnSet_data, scalingFunction=median)
```

---

pcaPlot

*PCA plot*


---

## Description

PCA plots of the samples within MSnset

## Usage

```
pcaPlot(
  MSnSetObj,
  omitIgG = FALSE,
  sampleColours = NULL,
  transFunc = log2xplus1,
  transform = TRUE,
  colourBy = "SampleGroup",
  title = "",
  labelColumn = "BioRep",
  labelsSize = 4,
  pointsSize = 4,
  x.nudge = 4,
  x.PC = 1
)
```

## Arguments

|               |                                                                                                               |
|---------------|---------------------------------------------------------------------------------------------------------------|
| MSnSetObj     | MSnSet; an object of class MSnSet                                                                             |
| omitIgG       | Logical: whether to remove IgG from the PCA plot                                                              |
| sampleColours | character: A named vector of colours for samples                                                              |
| transFunc     | func: internal helper function for log transformation                                                         |
| transform     | logical: whether to log transform intensities                                                                 |
| colourBy      | character: column name to use for colouring samples from pData(MSnSetObj)                                     |
| title         | character: title for the plot                                                                                 |
| labelColumn   | character: column name from pData(MSnSetObj) to use for labelling points on the plot or "none" to omit labels |

|           |                                                                                                        |
|-----------|--------------------------------------------------------------------------------------------------------|
| labelsize | numeric: size of the labels                                                                            |
| pointsize | numeric: size of plotting points                                                                       |
| x.nudge   | numeric: distance to move labels along the x-axis away from the plotting points                        |
| x.PC      | numeric: The principle component to plot on the x-axis; the following PC will be plotted on the y-axis |

## Details

The column provided to the "colourBy" argument will be used to colour the samples. The colours will be determined using the function [assignColours](#), alternatively the user may specify a named vector of colours using the "sampleColours" argument. The names of the "sampleColours" vector should match the unique values in the "colourBy" column.

## Value

An object created by ggplot

## Examples

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)
exprs(MSnSet_data) <- exprs(MSnSet_data)+0.01
pcaPlot(MSnSet_data, omitIgG = TRUE, labelColumn = "BioRep")

# custom colours and PC2 v PC3
customCols <- rainbow(length(unique(pData(MSnSet_data)$SampleGroup)))
names(customCols) <- unique(pData(MSnSet_data)$SampleGroup)
pcaPlot(MSnSet_data,
        omitIgG = TRUE,
        labelColumn = "BioRep",
        sampleColours = customCols,
        x.PC=2)
```

---

peptideIntensityPlot    *Plot peptide intensities*

---

## Description

Plots all the peptide intensities for the selected protein

**Usage**

```
peptideIntensityPlot(
  MSnSetObj,
  ProteinID,
  ProteinName,
  combinedIntensities = NULL,
  selectedSequence = NULL,
  selectedModifications = NULL
)
```

**Arguments**

|                                    |                                                                                                   |
|------------------------------------|---------------------------------------------------------------------------------------------------|
| <code>MSnSetObj</code>             | <code>MSnSet</code> ; an object of class <code>MSnSet</code> containing peptide level intensities |
| <code>ProteinID</code>             | character: Uniprot ID of the protein                                                              |
| <code>ProteinName</code>           | character: name of the protein                                                                    |
| <code>combinedIntensities</code>   | <code>MSnSet</code> ; an object of class <code>MSnSet</code> containing protein level intensities |
| <code>selectedSequence</code>      | character: sequence present in the "Sequences" column in <code>fData(MSnSetObj)</code>            |
| <code>selectedModifications</code> | character: modification present in the "Modifications" column in <code>fData(MSnSetObj)</code>    |

**Details**

Providing a summarised protein level `MSnSet` object to the `combinedIntensities` argument will add a summed protein intensity trace to the plot along with the peptide intensities.

**Value**

An object created by `ggplot`

**Examples**

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                              metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                              indExpData=c(7:16),
                              Sequences=2,
                              Accessions=6)
MSnset_P <- summarizeIntensities(MSnSet_data, sum, human_anno)
peptideIntensityPlot(MSnSet_data,
                     combinedIntensities=MSnset_P,
                     ProteinID="P03372",
                     ProteinName= "ESR1")
```

---

|             |                           |
|-------------|---------------------------|
| plotMeanVar | <i>Mean variance plot</i> |
|-------------|---------------------------|

---

**Description**

Computes and plots variance v mean intensity for peptides in MSnset

**Usage**

```
plotMeanVar(MSnSetObj, title = "")
```

**Arguments**

|           |                                   |
|-----------|-----------------------------------|
| MSnSetObj | MSnSet; an object of class MSnSet |
| title     | character: title for the plot     |

**Value**

An object created by ggplot

**Examples**

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)
plotMeanVar(MSnSet_data, title="Mean_Variance")
```

---

|                  |                                  |
|------------------|----------------------------------|
| regressIntensity | <i>Regression based analysis</i> |
|------------------|----------------------------------|

---

**Description**

Performs linear regression on protein intensities based on selected protein (qPLEX-RIME bait)

**Usage**

```
regressIntensity(MSnSetObj, ProteinId, controlInd = NULL, plot = TRUE)
```

**Arguments**

|            |                                                     |
|------------|-----------------------------------------------------|
| MSnSetObj  | MSnSet; an object of class MSnSet                   |
| ProteinId  | character; Uniprot protein ID                       |
| controlInd | numeric; index of IgG within MSnSet                 |
| plot       | character; Whether or not to plot the QC histograms |

**Details**

This function performs regression based analysis upon protein intensities based on a selected protein. In qPLEX RIME this method could be used to regress out the effect of target protein on other interactors. This function corrects this dependency of many proteins on the target protein levels by linear regression. It sets the target protein levels as the independent variable (x) and each of the other proteins as the dependent variable (y). The resulting residuals of the linear regressions  $y=ax+b$  are the protein levels corrected for target protein dependency.

**Value**

An object of class MSnSet (see [MSnSet-class](#)). This consists of corrected protein levels. In addition, the function can also plot histograms of correlation of target protein with all other proteins before and after this correction.

**Examples**

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)
MSnset_P <- summarizeIntensities(MSnSet_data, sum, human_anno)
IgG_ind <- which(pData(MSnset_P)$SampleGroup == "IgG")
MSnset_reg <- regressIntensity(MSnset_P,
                              controlInd=IgG_ind,
                              ProteinId="P03372")
```

---

rliPlot

*Relative log intensity plot*


---

**Description**

Relative log intensity (RLI) plots of the samples within MSnset

**Usage**

```
rliPlot(
  MSnSetObj,
  title = "",
  sampleColours = NULL,
  colourBy = "SampleGroup",
  omitIgG = TRUE
)
```

**Arguments**

|               |                                                                           |
|---------------|---------------------------------------------------------------------------|
| MSnSetObj     | MSnSet; an object of class MSnSet                                         |
| title         | character: title for the plot                                             |
| sampleColours | character: a named vector of colours for samples                          |
| colourBy      | character: column name to use for colouring samples from pData(MSnSetObj) |
| omitIgG       | logical: whether to remove IgG from the RLI plot                          |

**Details**

An RLI-plot is a boxplot that can be used to visualise unwanted variation in a data set. It is similar to the relative log expression plot developed for microarray analysis - see Gandolfo and Speed (2018). Rather than examining gene expression, the RLI plot uses the MS intensities for each peptide or the summarised protein intensities.

The column provided to the colourBy argument will be used to colour the samples. The colours will be determined using the function `assignColours`, alternatively the user may specify a named vector of colours using the sampleColours argument. The names of the sampleColours vector should match the unique values in the colourBy column.

**Value**

An object created by ggplot

**References**

Gandolfo LC, Speed TP (2018) RLE plots: Visualizing unwanted variation in high dimensional data. PLoS ONE 13(2): e0191629. <https://doi.org/10.1371/journal.pone.0191629>

**Examples**

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)
rliPlot(MSnSet_data, title = "qPLEX_RIME_ER")
```

```
# custom colours
customCols <- rainbow(length(unique(pData(MSnSet_data)$SampleGroup)))
names(customCols) <- unique(pData(MSnSet_data)$SampleGroup)
rliPlot(MSnSet_data, title = "qPLEX_RIME_ER", sampleColours = customCols)
```

---

|            |                                                                              |
|------------|------------------------------------------------------------------------------|
| rowScaling | <i>Normalization by scaling peptide/protein intensity across all samples</i> |
|------------|------------------------------------------------------------------------------|

---

## Description

Divide each peptide/protein by the row mean/median and transform to log2

## Usage

```
rowScaling(MSnSetObj, scalingFunction)
```

## Arguments

|                 |                                   |
|-----------------|-----------------------------------|
| MSnSetObj       | MSnSet; an object of class MSnSet |
| scalingFunction | function; median or mean          |

## Value

An object of class MSnSet (see [MSnSet-class](#)).

## Examples

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)
MSnset_norm <- rowScaling(MSnSet_data, scalingFunction=median)
```

---

|                      |                                                    |
|----------------------|----------------------------------------------------|
| summarizeIntensities | <i>Summarizes peptides intensities to proteins</i> |
|----------------------|----------------------------------------------------|

---

**Description**

Summarizes multiple peptides intensities measurements to protein level.

**Usage**

```
summarizeIntensities(MSnSetObj, summarizationFunction, annotation)
```

**Arguments**

|                       |                                                                                                                      |
|-----------------------|----------------------------------------------------------------------------------------------------------------------|
| MSnSetObj             | MSnSet; an object of class MSnSet                                                                                    |
| summarizationFunction | function; method used to aggregate the peptides into proteins. Sum, mean or median                                   |
| annotation            | data.frame; a data.frame of protein annotation of four columns: "Accessions", "Gene", "Description" and "GeneSymbol" |

**Value**

An object of class MSnSet (see [MSnSet-class](#))

**Examples**

```
data(human_anno)
data(exp3_OHT_ESR1)
MSnSet_data <- convertToMSnset(exp3_OHT_ESR1$intensities_qPLEX1,
                               metadata=exp3_OHT_ESR1$metadata_qPLEX1,
                               indExpData=c(7:16),
                               Sequences=2,
                               Accessions=6)
MSnset_P <- summarizeIntensities(MSnSet_data, sum, human_anno)
```

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