

# Package ‘HTqPCR’

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**Type** Package

**Title** Automated analysis of high-throughput qPCR data

**Version** 1.65.0

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**Description** Analysis of Ct values from high throughput quantitative real-time PCR (qPCR) assays across multiple conditions or replicates. The input data can be from spatially-defined formats such as ABI TaqMan Low Density Arrays or OpenArray; LightCycler from Roche Applied Science; the CFX plates from Bio-Rad Laboratories; conventional 96- or 384-well plates; or microfluidic devices such as the Dynamic Arrays from Fluidigm Corporation. HTqPCR handles data loading, quality assessment, normalization, visualization and parametric or non-parametric testing for statistical significance in Ct values between features (e.g. genes, microRNAs).

**Reference** Heidi Dvinge and Paul Bertone (2009). HTqPCR: High-throughput analysis and visualization of quantitative real-time PCR data in R Bioinformatics.

**License** Artistic-2.0

**URL** <http://www.ebi.ac.uk/bertone/software>

**LazyLoad** yes

**Depends** Biobase, RColorBrewer, limma

**Suggests** statmod

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HTqPCR-package*Analysis of High-Throughput qPCR data (HTqPCR)*

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## Description

This package is for analysing high-throughput qPCR data. Focus is on data from Taqman Low Density Arrays, but any kind of qPCR performed across several samples is applicable. Cycle threshold (Ct) data from different cards (samples) is read in, normalised, processed and the genes are tested for differential expression across different samples. Results are visualised in various ways.

## Details

|           |            |
|-----------|------------|
| Package:  | HTqPCR     |
| Type:     | Package    |
| Version:  | 1.0        |
| Date:     | 2009-07-03 |
| License:  | Artistic   |
| LazyLoad: | yes        |
| Depends:  | methods    |

## Author(s)

Maintainer: Heidi Dvinge <hdvinge@fredhutch.org> Maintainer: Paul Bertone <bertone@ebi.ac.uk>

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cbind*Combine qPCRset objects*

---

## Description

Functions for combining multiple qPCRset objects into one, by either adding columns (samples) or rows (features).

## Usage

```
## S3 method for class 'qPCRset'
cbind(..., deparse.level = 1)
## S3 method for class 'qPCRset'
rbind(..., deparse.level = 1)
```

## Arguments

|               |                                                        |
|---------------|--------------------------------------------------------|
| ...           | qPCRset objects that are to be combined.               |
| deparse.level | not implemented currently. See <a href="#">cbind</a> . |

## Details

In some cases it might be desirable to merge multiple qPCRset objects, that have been read into R or processed individually. This can be done for either identical samples across multiple different cards (such as a 384 well plate), or if more samples have been run on cards with the same layout.

cbind combines data assuming that all experiments have been carried out on identical cards, i.e. that featureNames, featureType, featurePos and featureClass is identical across all the qPCRset objects. rbind combines data assuming that the same samples have been analysed using different qPCR cards.

For both functions, the getCtHistory of all the individual objects will be added to the combined qPCRset.

## Value

A combined qPCRset object.

## Author(s)

Heidi Dvinge

## See Also

[cbind](#)

---

changeCtLayout

*Changing the dimensions (rows x columns) of qPCRset objects*

---

## Description

A function for splitting up the individual qPCR cards, in case there are multiple samples present on each card. I.e. for cases where the layout isn't 1 sample x 384 features, but for example 4 samples x 96 features on each 384 well card.

## Usage

```
changeCtLayout(q, sample.order)
```

## Arguments

|              |                                                                                 |
|--------------|---------------------------------------------------------------------------------|
| q            | a qPCRset object.                                                               |
| sample.order | vector, same length as number of features on each card (e.g. 384). See details. |

## Details

The result from each qPCR run of a given card typically gets presented together, such as in a file with 384 lines, one per feature, for 384 well plates. However, some cards may contain multiple samples, such as commercial cards that are designed to be loaded with two separate samples and then include 192 individual features.

Per default, each card is read into the qPCRset object as consisting of a single sample, and hence one column in the Ct data matrix. When this is not the case, the data can subsequently be split into the correct features x samples (rows x columns) dimensions using this function. The parameter `sample.order` is a vector, that for each feature in the qPCRset indicates what sample it actually belongs to.

In the new qPCRset the samples (Ct columns) are ordered first by `sample.order` then by the original `sampleNames`, as shown in the examples below.

## Value

A qPCRset object like the input, but with the dimensions changed according to the new layout.

## Note

Since the actual biological samples are likely to differ on each card, after applying `changeCtLayout` renaming of the samples in qPCRset using `sampleNames` is advisable.

The features are assumed to be identical for all samples on a given card! I.e. if for example `sample.order=rep(c("A", "B"), each=192)`, then feature number 1 (the first for sample A) should be the same as feature number 193 (the first for sample B). The new `featureNames` are taken for those features listed as belonging to the first sample in `sample.order`.

## Author(s)

Heidi Dvinge

## Examples

```
# Example data
data(qPCRraw)
# With e.g. 2 or 4 samples per 384 well card.
sample2.order <- rep(c("subSampleA", "subSampleB"), each=192)
sample4.order <- rep(c("subA", "subB", "subC", "subD"), each=96)
# Splitting the data into all individual samples
qPCRnew2 <- changeCtLayout(qPCRraw, sample.order=sample2.order)
show(qPCRnew2)
qPCRnew4 <- changeCtLayout(qPCRraw, sample.order=sample4.order)
show(qPCRnew4)
sampleNames(qPCRnew4)
```

---

|           |                                     |
|-----------|-------------------------------------|
| clusterCt | <i>Clustering of qPCR Ct values</i> |
|-----------|-------------------------------------|

---

## Description

Hierarchical clustering of samples or genes from high-throughput qPCR experiments, such as the TaqMan Low Density Array platform. Individual clusters can be selected, and the features within them listed in the given order.

## Usage

```
clusterCt(q, main = NULL, type = "genes", dist = "pearson", xlab = "Cluster dendrogram", n.cluster, h.cl
```

## Arguments

|                             |                                                                                                                         |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------------|
| <code>q</code>              | object of class <code>qPCRset</code> .                                                                                  |
| <code>main</code>           | character string, plot title.                                                                                           |
| <code>type</code>           | character string, either "genes" (default) or "samples", indicating what is to be clustered.                            |
| <code>dist</code>           | character string, specifying whether to use "pearson" correlation (default) or "euclidean" distance for the clustering. |
| <code>xlab</code>           | character string, label for the x-axis.                                                                                 |
| <code>n.cluster</code>      | integer, the number of cluster to divide the dendrogram into. See details.                                              |
| <code>h.cluster</code>      | numeric, the height at which to cut the dendrogram into clusters. See details.                                          |
| <code>select.cluster</code> | logical, whether to select clusters interactively. See details.                                                         |
| <code>...</code>            | any other arguments will be passed to the plot function.                                                                |

## Details

This function may be used to cluster the Ct values and present the result as a dendrogram.

The `n.cluster` and `h.cluster` parameters are from the `rect.hclust` function and can be used to divide the dendrogram into subclusters based on either number of clusters or height of branch, drawing boxes around subclusters. The members of each cluster can be returned (see value). If `n.cluster` is specified `h.cluster` will be ignored.

If `select.cluster` is chosen individual subclusters can be selected and marked by a box by clicking on their highest common branch with the (first) mouse button. Multiple clusters can be selected until any mouse button other than the first is pressed, and the function can be used in conjunction with either `n.cluster` or `h.cluster`. The members of each cluster will likewise be returned, in the order they were selected.

## Value

A plot is created on the current graphics device. If any subclusters are marked, these will be returned invisibly in a list, with one component for each subcluster. The individual slots in the list contain the names of the genes, and their position in the original input data (row number).

**Author(s)**

Heidi Dvinge

**See Also**[hclust](#), [dist](#), [rect.hclust](#), [identify.hclust](#)**Examples**

```
# Load example data
data(qPCRraw)
# Clustering samples
clusterCt(qPCRraw, type="samples")
clusterCt(qPCRraw, type="samples", dist="euclidean")
# Clustering genes
clusterCt(qPCRraw, type="genes", cex=0.5)
clusterCt(qPCRraw, type="genes", h.cluster=1.5, cex=0.5)
cluster.list <- clusterCt(qPCRraw, type="genes", n.cluster=6, cex=0.5)
cluster.list[[1]]
```

filterCategory

*Filter Ct values based on their feature categories.***Description**

Ct values corresponding to selected feature categories will be replaced by NA. Generally, the feature categories indicate how reliable the values are.

**Usage**

```
filterCategory(q, na.categories = c("Unreliable", "Undetermined"))
```

**Arguments**

**q** a qPCRset object.

**na.categories** character vector, with the name(s) of the feature categories where Ct values will be considered NA.

**Value**

A qPCRset object like the input, but with the selected Ct values replaced by NAs

**Author(s)**

Heidi Dvinge

**See Also**

[setCategory](#) for adjusting the categories.

## Examples

```
data(qPCRraw)
qPCRraw2 <- setCategory(qPCRraw, groups=NULL)
x <- filterCategory(qPCRraw2)
summary(qPCRraw)
summary(x)
```

---

|              |                                                    |
|--------------|----------------------------------------------------|
| filterCtData | <i>Filter out features (genes) from qPCR data.</i> |
|--------------|----------------------------------------------------|

---

## Description

This function is for filtering Ct data from high-throughput qPCR platforms like the TaqMan Low Density Arrays. This can for example be done prior to analysing the statistical significance of the data, to remove genes where the results are of low quality, or that are not of interest to the analysis in question.

## Usage

```
filterCtData(q, remove.type, remove.name, remove.class, remove.category, n.category = 3, remove.IQR, verbose)
```

## Arguments

|                 |                                                                                                          |
|-----------------|----------------------------------------------------------------------------------------------------------|
| q               | object of class qPCRset.                                                                                 |
| remove.type     | character vector, the feature type(s) to be removed from the data object.                                |
| remove.name     | character vector, the feature name(s) to be removed from the data object.                                |
| remove.class    | character vector, the feature class(es) to be removed from the data object.                              |
| remove.category | character vector, the features categories(s) to be assessed across samples.                              |
| n.category      | numeric, all features with more than this number of remove.category across samples are removed.          |
| remove.IQR      | numeric, all features with an interquartile range (IQR) below this limit across samples will be removed. |
| verbose         | boolean, should some information be printed to the prompt.                                               |

## Details

This function may be used to exclude individual or small groups of features that are irrelevant to a given analysis. However, it can also be used on a more general basis, to for example split the data into separate qPCRset objects based on features with different characteristics, such as groups of markers or other gene classes present in featureClass.

remove.IQR can be used to exclude features that show only little variation across the samples. These are unlikely to be differentially expressed, so including them in downstream analysis such as limmaCtData or ttestCtData would result in a slight loss of power caused by the adjustment of p-values required due to multiple testing across all features.

**Value**

An object of class qPCRset like the input, but with the required features removed.

**Note**

After removing features the function `plotCtCard` will no longer work, since the number of features is now smaller than the card dimensions.

When using `remove.category` or `remove.IQR` and there are replicated features present on the array, it might no longer be possible to use the `ndups` parameter of `limmaCtData`, since the number of replicates isn't identical for each feature.

Filtering can be performed either before or after normalization, but in some cases normalization might be affected by this, for example if many features are removed, making it difficult to identify rank-invariant genes.

**Author(s)**

Heidi Dvinge

**Examples**

```
# Load some example data
data(qPCRpros)
show(qPCRpros)
# Filter based on different feature type
qFilt <- filterCtData(qPCRpros, remove.type=c("Endogenous Control"))
# Filter based on feature type and name
qFilt <- filterCtData(qPCRpros, remove.type=c("Endogenous Control"), remove.name=c("Gene1", "Gene20", "Gene30"))
# Filter based on feature class
qFilt <- filterCtData(qPCRpros, remove.class="Kinase")
# Filter based on feature categories, using two different cut-offs
qFilt <- filterCtData(qPCRpros, remove.category="Undetermined")
qFilt <- filterCtData(qPCRpros, remove.category="Undetermined", n.category=5)
# Remove features without much variation across samples
iqr <- apply(exprs(qPCRpros), 1, IQR, na.rm=TRUE)
hist(iqr, n=20)
qFilt <- filterCtData(qPCRpros, remove.IQR=2)
```

---

heatmapSig

*Heatmap of deltadeltaCt values from qPCR data.*


---

**Description**

Heatmap and clustering of deltadeltaCt values from different sample comparisons using qPCR data.

**Usage**

```
heatmapSig(qDE, comparison = "all", col, zero.center = TRUE, mar, dist = "pearson", ...)
```

**Arguments**

|             |                                                                                                                                             |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| qDE         | data.frame or list, as created by <code>ttestCtData</code> or <code>limmaCtData</code> .                                                    |
| comparison  | integers or the names of the comparisons to include in the plot. Defaults to all results in the qDE data, but a minimum of two is required. |
| col         | colour scheme to use for the plot.                                                                                                          |
| zero.center | logical, should the colour scale be centered around 0.                                                                                      |
| mar         | vector of length two, the bottom and right side margins of the heatmap.                                                                     |
| dist        | character string, either "pearson" (default) or "euclidean" indicating what type of distance is used for the clustering.                    |
| ...         | further arguments passed to <code>heatmap.2</code> .                                                                                        |

**Details**

This function can be useful if multiple conditions are compared, for detecting features with similar behaviour in comparisons, and look at the general level of up and down regulation.

**Value**

A plot if produced in the current graphics device.

**Author(s)**

Heidi Dvinge

**See Also**

[heatmap.2](#) for modifying the plot, and [ttestCtData](#) or [limmaCtData](#) for generating the data used for the plotting.

---

limmaCtData

*Differentially expressed features with qPCR: limma*


---

**Description**

Function for detecting differentially expressed genes from high-throughput qPCR Ct values, based on the framework from the `limma` package. Multiple comparisons can be performed, and across more than two groups of samples.

**Usage**

```
limmaCtData(q, design = NULL, contrasts, sort = TRUE, stringent = TRUE, ndups = 1, spacing = NULL, dupcon
```

**Arguments**

|                        |                                                                                                                                       |
|------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| <code>q</code>         | object of class <code>qPCRset</code> .                                                                                                |
| <code>design</code>    | matrix, design of the experiment rows corresponding to cards and columns to coefficients to be estimated. See details.                |
| <code>contrasts</code> | matrix, with columns containing contrasts. See details                                                                                |
| <code>sort</code>      | boolean, should the output be sorted by adjusted p-values.                                                                            |
| <code>stringent</code> | boolean, for flagging results as "Undetermined". See details.                                                                         |
| <code>ndups</code>     | integer, the number of times each feature is present on the card.                                                                     |
| <code>spacing</code>   | integer, the spacing between duplicate spots, <code>spacing=1</code> for consecutive spots                                            |
| <code>dupcor</code>    | list, the output from <code>duplicateCorrelation</code> . See details.                                                                |
| <code>...</code>       | any other arguments are passed to <code>lmFit</code> , <code>contrasts.fit</code> , <code>eBayes</code> or <code>decideTests</code> . |

**Details**

This function is a wrapper for the functions `lmFit`, `contrasts.fit` (if a contrast matrix is supplied) and `eBayes` from the `limma` package. See the help pages for these functions for more information about setting up the design and contrast matrices.

All results are assigned to a category, either "OK" or "Unreliable" depending on the input Ct values. If `stringent=TRUE` any unreliable or undetermined measurements among technical and biological replicates will result in the final result being "Undetermined". For `stringent=FALSE` the result will be "OK" unless at least half of the Ct values for a given gene are unreliable/undetermined.

Note that when there are replicated features in the samples, each feature is assumed to be present the same number of times, and with regular spacing between replicates. Reordering the sample by `featureNames` and setting `spacing=1` is recommendable.

If technical sample replicates are available, `dupcor` can be used. It is a list containing the estimated correlation between replicates. `limmaCtData` will then take this correlation into account when fitting a model for each gene. It can be calculate using the function [duplicateCorrelation](#). Technical replicates and duplicated spots can't be assessed at the same time though, so if `dupcor` is used, `ndups` should be 1.

**Value**

A list of `data.frames`, one for each column in `design`, or for each comparison in `contrasts` if this matrix is supplied. Each component of the list contains the result of the given comparisons, with one row per gene and has the columns:

|                          |                                                                                                                                                                                               |
|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>genes</code>       | Feature IDs.                                                                                                                                                                                  |
| <code>feature.pos</code> | The unique feature IDs from <code>featurePos</code> of the <code>q</code> object. Useful if replicates are not collapsed, in which case there might be several features with identical names. |
| <code>t.test</code>      | The result of the t-test.                                                                                                                                                                     |
| <code>p.value</code>     | The corresponding p.values.                                                                                                                                                                   |
| <code>adj.p.value</code> | P-values after correcting for multiple testing using the Benjamini-Holm method.                                                                                                               |
| <code>ddCt</code>        | The <code>deltadeltaCt</code> values.                                                                                                                                                         |

|                   |                                                                                                             |
|-------------------|-------------------------------------------------------------------------------------------------------------|
| FC                | The fold change; $2^{-(ddCt)}$ .                                                                            |
| meanTest          | The average Ct across the test samples for the given comparison.                                            |
| meanReference     | The average Ct across the reference samples for the given comparison.                                       |
| categoryTest      | The category of the Ct values ("OK", "Undetermined") across the test samples for the given comparison.      |
| categoryReference | The category of the Ct values ("OK", "Undetermined") across the reference samples for the given comparison. |

Also, the last item in the list is called "Summary", and it's the result of calling `decideTests` from `limma` on the fitted data. This is a data frame with one row per feature and one column per comparison, with down-regulation, no change and up-regulation marked by -1, 0 and 1.

### Author(s)

Heidi Dvinge

### References

Smyth, G. K. (2005). Limma: linear models for microarray data. In: Bioinformatics and Computational Biology Solutions using R and Bioconductor. R. Gentleman, V. Carey, S. Dudoit, R. Irizarry, W. Huber (eds), Springer, New York, pages 397–420.

### See Also

[lmFit](#), [contrasts.fit](#) and [ebayes](#) for more information about the underlying limma functions. [mannwhitneyCtData](#) and [ttestCtData](#) for other functions calculating differential expression of Ct data. [plotCtRQ](#), [heatmapSig](#) and [plotCtSignificance](#) can be used for visualising the results.

### Examples

```
# Load example preprocessed data
data(qPCRpros)
samples <- read.delim(file.path(system.file("exData", package="HTqPCR"), "files.txt"))
# Define design and contrasts
design <- model.matrix(~0+samples$Treatment)
colnames(design) <- c("Control", "LongStarve", "Starve")
contrasts <- makeContrasts(LongStarve-Control, LongStarve-Starve, Starve-Control, levels=design)
# The actual test
diff.exp <- limmaCtData(qPCRpros, design=design, contrasts=contrasts)
# Some of the results
diff.exp[["LongStarve - Control"]][1:10,]
```

---

mannwhitneyCtData      *Differentially expressed features with qPCR: Mann-Whitney*


---

## Description

Function for calculating p-values across two groups for the features present in high-throughput qPCR data, such as from TaqMan Low Density Arrays. Also known as two sample Wilcoxon test.

## Usage

```
mannwhitneyCtData(q, groups = NULL, calibrator, alternative = "two.sided", paired = FALSE, replicates =
```

## Arguments

|             |                                                                                                                                                             |
|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| q           | qPCRset object.                                                                                                                                             |
| groups      | factor, assigning each sample to one of two groups.                                                                                                         |
| calibrator  | which of the two groups is to be considered as the reference and not the test? Defaults to the first group in groups.                                       |
| alternative | character string (first letter is enough), specifying the alternative hypothesis, "two.sided" (default), "greater" or "less".                               |
| paired      | logical, should a paired t-test be used.                                                                                                                    |
| replicates  | logical, if replicated genes are present on the array, the statistics will be calculated for all the replicates combined, rather than the individual wells. |
| sort        | boolean, should the output be sorted by p-values.                                                                                                           |
| stringent   | boolean, for flagging results as "Undetermined". See details.                                                                                               |
| p.adjust    | character string, which method to use for p-value adjustment for multiple testing. See details.                                                             |
| ...         | any other arguments will be passed to the <a href="#">wilcox.test</a> function.                                                                             |

## Details

Once the Ct values have been normalised, differential expression can be calculated. This function deals with just the simple case, where there are two types of samples to compare. For a parametric test see `ttestCtData` and `limmaCtData` for more complex studies.

The underlying statistics is calculated by `wilcox.test`. Due to the high possibility of ties for each feature between samples, the test is run with `exact=FALSE`.

All results are assigned to a category, either "OK" or "Undetermined" depending on the input Ct values. If `stringent=TRUE` any unreliable or undetermined measurements among technical and biological replicates will result in the final result being "Undetermined". For `stringent=FALSE` the result will be "OK" unless at least half of the Ct values for a given gene are unreliable/undetermined.

The argument `p.adjust` is passed on to the [p.adjust](#) function. Options include e.g. "BH" (Benjamini & Hochberg, the default), "fdr" and "bonferroni". See [p.adjust](#) for more information on the individual methods.

**Value**

A data.frame containing the following information:

|                    |                                                                                                                 |
|--------------------|-----------------------------------------------------------------------------------------------------------------|
| genes              | The names of the features on the card.                                                                          |
| feature.pos        | The featurePos of the genes. If replicated genes are used, the feature positions will be concatenated together. |
| MB.test            | The name and value of the test statistic.                                                                       |
| p.value            | The corresponding p-value.                                                                                      |
| ddCt               | The delta delta Ct values.                                                                                      |
| FC                 | The fold change; $2^{(-ddCt)}$ .                                                                                |
| meanCalibrator     | The average expression level of each gene in the calibrator sample(s).                                          |
| meanTarget         | The average expression level of each gene in the target sample(s).                                              |
| categoryCalibrator | The category of the Ct values ("OK", "Undetermined") across the calibrator.                                     |
| categoryTarget     |                                                                                                                 |
|                    | Ditto for the target.                                                                                           |

**Author(s)**

Heidi Dvinge

**See Also**

[wilcox.test](#), [ttestCtData](#), [limmaCtData](#), [plotCtRQ](#) and [plotCtSignificance](#) can be used for visualising the results.

---

|                 |                                                   |
|-----------------|---------------------------------------------------|
| normalizeCtData | <i>Normalization of Ct values from qPCR data.</i> |
|-----------------|---------------------------------------------------|

---

**Description**

This function is for normalizing Ct data from high-throughput qPCR platforms like the TaqMan Low Density Arrays. Normalization can be either within or across different samples.

**Usage**

```
normalizeCtData(q, norm = "deltaCt", deltaCt.genes = NULL, scale.rank.samples, rank.type = "pseudo.med
```

**Arguments**

|      |                                                                                                                                                                                                                |
|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| q    | object of class qPCRset.                                                                                                                                                                                       |
| norm | character string with partial match allowed, the normalisation method to use. "deltaCt" (default) , "scale.rankinvariant", "norm.rankinvariant", "quantile" and "geometric.mean" are implemented. See details. |

|                                 |                                                                                                                                                                                                                                    |
|---------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>deltaCt.genes</code>      | character vector, the gene(s) to use for deltaCt normalization. Must correspond to some of the featureNames in <code>q</code> or <code>NULL</code> , in which case the endogenous controls from <code>featureType</code> are used. |
| <code>scale.rank.samples</code> | integer, for the "scale.rankinvariant" method, how many samples should a feature be rank invariant across to be included. Defaults to number of samples-1.                                                                         |
| <code>rank.type</code>          | string, the reference sample for the rank invariant normalisation. Either "pseudo.median" or "pseudo.mean" for using the median or mean across samples as a pseudo-reference sample.                                               |
| <code>Ct.max</code>             | numeric, Ct values above this will be ignored when identifying rank invariant genes.                                                                                                                                               |
| <code>geo.mean.ref</code>       | numeric, the reference sample to scale to for the "geometric.mean" method. Defaults to sample number 1.                                                                                                                            |
| <code>verbose</code>            | boolean, should some information be printed to the prompt.                                                                                                                                                                         |

## Details

"quantile" will make the expression distributions across all cards more or less identical. "deltaCt" calculates the standard deltaCt values, i.e. subtracts the mean of the chosen controls from all other values on the array. "scale.rankinvariant" sorts features from each sample based on Ct values, and identifies a set of features that remain rank invariant, i.e. whose ordering is constant. The average of these rank invariant features is then used to scale the Ct values on each array individually. "norm.rankinvariant" also identifies rank invariant features between each sample and a reference, and then uses these features to generate a normalisation curve individually for each sample by smoothing. "geometric.mean" calculates the geometric mean of all Ct values below Ct.max in each sample, and scales the Ct values accordingly.

For the rank invariant methods it can make a significant difference whether high Ct values, such as "40" or something else being used for undetermined Ct values is removed during the normalisation using the Ct.max parameter. "norm.rankinvariant" also depends on having enough rank invariant genes for generating a robust smoothing curve.

"quantile" is based on `normalizeQuantiles` from `limma`, and the rank invariant normalisations implement methods from `normalize.invariantset` in package `affy`.

The distribution of Ct values before/after normalisation can be assessed with the function `plotCtDensity`.

## Value

An object of class `qPCRset` like the input.

## Author(s)

Heidi Dvinge

## See Also

[normalize.invariantset](#) for the rank invariant normalisations, [normalizequantiles](#) and [plotCtDensity](#)

## Examples

```
# Load example data
data(qPCRraw)
# Perform different normalisations
dnorm <- normalizeCtData(qPCRraw, norm="deltaCt", deltaCt.genes="Gene1")
qnorm <- normalizeCtData(qPCRraw, norm="quantile")
nrnorm <- normalizeCtData(qPCRraw, norm="norm.rankinvariant")
srnorm <- normalizeCtData(qPCRraw, norm="scale.rankinvariant")
gnorm <- normalizeCtData(qPCRraw, norm="geometric.mean")
# Normalized versus raw data
cols <- rep(brewer.pal(6, "Spectral"), each=384)
plot(exprs(qPCRraw), exprs(dnorm), pch=20, col=cols, main="deltaCt normalization")
plot(exprs(qPCRraw), exprs(qnorm), pch=20, col=cols, main="Quantile normalization")
plot(exprs(qPCRraw), exprs(nrnorm), pch=20, col=cols, main="norm.rankinvariant")
plot(exprs(qPCRraw), exprs(srnorm), pch=20, col=cols, main="scale.rankinvariant")
plot(exprs(qPCRraw), exprs(gnorm), pch=20, col=cols, main="geometric.mean")
# With or without removing high Ct values
nrnorm <- normalizeCtData(qPCRraw, norm="norm.rankinvariant")
nrnorm2 <- normalizeCtData(qPCRraw, norm="norm.rankinvariant", Ct.max=40)
plot(exprs(nrnorm), exprs(nrnorm2), pch=20, col=cols, xlab="Ct.max = 35", ylab="Ct.max = 40")
# Distribution of the normalised data
par(mfrow=c(2,3), mar=c(3,3,2,1))
plotCtDensity(qPCRraw, main="Raw Ct values")
plotCtDensity(dnorm, main="deltaCt")
plotCtDensity(qnorm, main="quantile")
plotCtDensity(srnorm, main="scale.rankinvariant")
plotCtDensity(nrnorm, main="norm.rankinvariant")
plotCtDensity(gnorm, main="geometric.mean")
```

---

plotCtArray

*Image plot of qPCR Ct values from an array format*

---

## Description

Function for plotting high-throughput qPCR Ct values from a platform with a defined spatial layout, such as Fluidigm Dynamic Arrays (BioMark) or OpenArray from Applied Biosystems. The location of Ct values in the plot corresponds to the position of each well on the array.

## Usage

```
plotCtArray(q, plot = "Ct", main, col, col.range, na.col = "grey", na.value = 40, chamber.size, ...)
```

## Arguments

|                   |                                                                                               |
|-------------------|-----------------------------------------------------------------------------------------------|
| <code>q</code>    | object of class <code>qPCRset</code> .                                                        |
| <code>plot</code> | character string indicating what type of plot to produce. Currently only "Ct" is implemented. |
| <code>main</code> | character string, the title of the plot. Per default "Ct values".                             |

|                           |                                                                               |
|---------------------------|-------------------------------------------------------------------------------|
| <code>col</code>          | the name of a colour scheme.                                                  |
| <code>col.range</code>    | vector, the range of colours to use.                                          |
| <code>na.col</code>       | the colour used for well with NA (undetermined) Ct values.                    |
| <code>na.value</code>     | numeric, if NA has been replaced by an (arbitrary) high Ct value in the data. |
| <code>chamber.size</code> | numeric, for adjusting the size of the reaction chamber on the card.          |
| <code>...</code>          | any other arguments will be passed to the plot function.                      |

**Value**

A plot is created on the current graphics device.

**Author(s)**

Heidi Dvinge

**See Also**

[plotCtCard](#) for plotting data from other high-throughput qPCR platforms.

**Examples**

```
# Locate example data
exPath <- system.file("exData", package="HTqPCR")
exFiles <- "BioMark_sample.csv"
# Create qPCRset object
raw <- readCtData(exFiles, path=exPath, n.features=48, n.data=48, format="BioMark")
# Plot
plotCtArray(raw)
# Change colour and range
plotCtArray(raw, col=brewer.pal(11, "Spectral"), col.range=c(10,35))
```

---

plotCtBoxes

*Boxplots for qPCR Ct values.*

---

**Description**

Function for making boxplots of Ct values from high-throughput qPCR data. The boxes can be made either using all values on each card, or stratified by different feature information.

**Usage**

```
plotCtBoxes(q, cards = TRUE, xlab = "", col, main = NULL, names, stratify = "type", mar = c(7, 4, 3, 1), .
```

**Arguments**

|                       |                                                                                                                                                                                                            |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>q</code>        | object of class <code>qPCRset</code> .                                                                                                                                                                     |
| <code>cards</code>    | vector, the numbers of the cards to plot. Defaults to <code>TRUE</code> = all cards.                                                                                                                       |
| <code>xlab</code>     | character string, label for the x-axis.                                                                                                                                                                    |
| <code>col</code>      | vector of colours to use, defaults to different colour for each card.                                                                                                                                      |
| <code>main</code>     | character string, plot title.                                                                                                                                                                              |
| <code>names</code>    | vector, names to plot under the boxes. Defaults to sample names.                                                                                                                                           |
| <code>stratify</code> | character, specifying what to stratify the Ct values by. <code>NULL</code> , the default means no stratification, "type" is the feature types of the <code>qPCRset</code> , and "class" the feature class. |
| <code>mar</code>      | vector, the size of the margins. See <a href="#">par</a> for details.                                                                                                                                      |
| <code>...</code>      | any other arguments will be passed to the <code>boxplot</code> or <code>par</code> function.                                                                                                               |

**Details**

For the stratified plots all boxes with Ct values from the same card are plotted in identical colours. "type" and "class" are automatically extracted from the `qPCRset` using `featureType` and `featureClass`.

**Value**

A plot is created on the current graphics device.

**Author(s)**

Heidi Dvinge

**See Also**

[boxplot](#)

**Examples**

```
# Loading the data
data(qPCRraw)
# Make plot with all samples or just a few
plotCtBoxes(qPCRraw, stratify=NULL)
plotCtBoxes(qPCRraw, cards=c(1,4))
plotCtBoxes(qPCRraw, stratify="class")
```

plotCtCard

*Image plot of qPCR Ct values from a card format***Description**

Function for plotting high-throughput qPCR Ct values from a platform with a defined spatial layout, such as TaqMan Low Density Assay cards. The location of Ct values in the plot corresponds to the position of each well on the card.

**Usage**

```
plotCtCard(q, card = 1, plot = "Ct", main, nrow = 16, ncol = 24, col, col.range, na.col = "grey", na.value
```

**Arguments**

|             |                                                                                                                                                         |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| q           | object of class qPCRset.                                                                                                                                |
| card        | integer, the sample number to plot.                                                                                                                     |
| plot        | character string among "Ct", "flag", "type", "class") indicating what type of plot to produce. See Details for a longer description.                    |
| main        | character string, the title of the plot. Per default this is the sample name corresponding to card.                                                     |
| nrow        | integer, the number of rows on the card (16 for a standard 384 well format).                                                                            |
| ncol        | integer, the number of columns on the card (24 for a standard 384 well format).                                                                         |
| col         | vector of colors of the same length as the number of different groups for the categorical data, or the name of a colour scheme for the continuous data. |
| col.range   | vector, the range of colours to use.                                                                                                                    |
| na.col      | the colour used for well with NA (undetermined) Ct values.                                                                                              |
| na.value    | numeric, if NA has been replaced by an (arbitrary) high Ct value in the data.                                                                           |
| legend.cols | integer, how many columns should the legend text be split into (defaults to number of labels).                                                          |
| well.size   | numeric, for adjusting the size of the wells on the card.                                                                                               |
| zero.center | logical, should the colours be shifted to be zero-centered.                                                                                             |
| unR         | logical, should wells from the category "Unreliable" be crossed out.                                                                                    |
| unD         | logical, should wells from the category "Undetermined" be crossed out.                                                                                  |
| ...         | any other arguments will be passed to the plot and points functions.                                                                                    |

**Details**

This function may be used to plot the values of any well-specific information, such as the raw or normalized Ct values, or categorical data such as flag, gene class etc. The image follows the layout of an actual HTqPCR card.

If unR=TRUE these wells will be crossed out using a diagonal cross (X), whereas unD=TRUE will be marked with a horizontal/vertical cross.

**Value**

A plot is created on the current graphics device.

**Author(s)**

Heidi Dvinge

**See Also**

[image](#), and [plotCtArray](#) for plotting data from other high-throughput qPCR platforms (e.g. Fluidigm arrays).

**Examples**

```
# Load some example data
data(qPCRraw)
# Plot Ct values from first card
plotCtCard(qPCRraw)
plotCtCard(qPCRraw, card=2, col.range=c(10,35))
plotCtCard(qPCRraw, unR=TRUE, unD=TRUE)
# Other examples
plotCtCard(qPCRraw, plot="class")
plotCtCard(qPCRraw, plot="type")
plotCtCard(qPCRraw, plot="flag")
```

---

plotCtCategory

*Summarising the feature categories for Ct values.*


---

**Description**

This function will provide a summary of the featureCategory for a qPCRset. Focus can either be on categories across samples, or across features.

**Usage**

```
plotCtCategory(q, cards = TRUE, by.feature = FALSE, stratify, col, xlim, main, ...)
```

**Arguments**

|            |                                                                                                                                                                   |
|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| q          | object of class qPCRset.                                                                                                                                          |
| cards      | integers, the number of the cards (samples) to plot.                                                                                                              |
| by.feature | logical, should the categories be summarised for features rather than samples. See details.                                                                       |
| stratify   | character string, either "type" or "class" indicating if the categories should be stratified by featureType or featureClass of q. Ignored if by.features is TRUE. |

|      |                                                                                                                                                |
|------|------------------------------------------------------------------------------------------------------------------------------------------------|
| col  | vector with the colours to use for the categories. Default is green for "OK", yellow for "Unreliable" and red for "Undetermined". See details. |
| xlim | vector, the limits of the x-axis. If by.feature is FALSE, this can be used to adjust the size of the barplot to fit in the colour legend.      |
| main | character string, the title of the plot.                                                                                                       |
| ...  | further arguments passed to barplot or heatmap.                                                                                                |

### Details

This function is for generating two different types of plot. If by.feature=FALSE the number of each featureCategory will be counted for each card, and a barplot is made. If however by.feature=TRUE, then the categories for each feature across the selected cards will be clustered in a heatmap.

The colours given in col correspond to all the unique categories present in the entire featureCategory of q, even categories not represented for the samples selected by cards. Categories are sorted alphabetically, and colours assigned accordingly.

For by.feature=TRUE the plot can be modified extensively using calls to the underlying heatmap function, such as setting cexRow to adjust the size of row labels.

### Value

A figure is produced on the current graphics device.

### Author(s)

Heidi Dvinge

### See Also

[setCategory](#), and [heatmap](#) for the underlying plotting function for by.feature=TRUE.

### Examples

```
# Load example preprocessed data
data(qPCRpros)
# Plot categories for samples
plotCtCategory(qPCRpros)
plotCtCategory(qPCRpros, cards=1:3, stratify="class")
# Categories for features
plotCtCategory(qPCRpros, by.feature=TRUE)
```

---

`plotCtCor`*Correlation between Ct values from qPCR data*

---

**Description**

Function for plotting the correlation based on Ct values between samples containing high-throughput qPCR data.

**Usage**

```
plotCtCor(q, col, col.range = c(0, 1), main, mar, ...)
```

**Arguments**

|                        |                                                                            |
|------------------------|----------------------------------------------------------------------------|
| <code>q</code>         | object of class <code>qPCRset</code> .                                     |
| <code>col</code>       | vector of colours to use, defaults to a spectrum from red to blue/purple.  |
| <code>col.range</code> | vector, the range of colours to use.                                       |
| <code>main</code>      | character string, plot title.                                              |
| <code>mar</code>       | vector, the size of the borrom and right hand side margins.                |
| <code>...</code>       | any other arguments will be passed to the <code>heatmap.2</code> function. |

**Details**

This function may be used to cluster the samples based on Ct values and present the result in a heatmap. Per default the colours are a rainbow scale from 0 to 1.

The correlation is calculated as 1 - the 'Pearson' method. Prior to version 1.9.1 the value plotted was the correlation directly, rather than 1-correlation.

A standard heatmap is drawn, but this can be modified extensively using the arguments available in the `heatmap.2` function.

**Value**

A plot is created on the current graphics device.

**Author(s)**

Heidi Dvinge

**See Also**

[heatmap.2](#)

**Examples**

```
data(qPCRraw)
plotCtCor(qPCRraw)
plotCtCor(qPCRraw, col.range=c(0,0.6))
```

---

|               |                                              |
|---------------|----------------------------------------------|
| plotCtDensity | <i>Distribution plot for qPCR Ct values.</i> |
|---------------|----------------------------------------------|

---

**Description**

Function for plotting the density distribution of Ct values from high-throughput qPCR data.

**Usage**

```
plotCtDensity(q, cards = TRUE, xlab = "Ct", ylab = "Density", col, main = NULL, legend = TRUE, lwd = 2, ...)
```

**Arguments**

|        |                                                                          |
|--------|--------------------------------------------------------------------------|
| q      | object of class qPCRset.                                                 |
| cards  | vector, the numbers of the cards to plot. Defaults to TRUE = all cards.  |
| xlab   | character string, label for the x-axis.                                  |
| ylab   | character string, label for the y-axis.                                  |
| col    | vector of colours to use, defaults to different colour for each card.    |
| main   | character string, plot title.                                            |
| legend | logical, whether to include a colour legend or not.                      |
| lwd    | numeric, the width of the lines.                                         |
| ...    | any other arguments will be passed to the <code>matplot</code> function. |

**Details**

The distribution of Ct values in the qPCRset `q` is calculated using `density`.

**Value**

A plot is created on the current graphics device.

**Author(s)**

Heidi Dvinge

**See Also**

[matplot](#), [density](#)

**Examples**

```
# Loading the data
data(qPCRraw)
# Make plot with all samples or just a few
plotCtDensity(qPCRraw)
plotCtDensity(qPCRraw, cards=c(1,4))
```

---

|               |                                   |
|---------------|-----------------------------------|
| plotCtHeatmap | <i>Heatmap of qPCR Ct values.</i> |
|---------------|-----------------------------------|

---

## Description

Function for drawing a heatmap of Ct values from high-throughput qPCR experiments such as using TaqMan Low Density Arrays.

## Usage

```
plotCtHeatmap(q, main = NULL, col, col.range, dist = "pearson", zero.center, mar, gene.names, sample.names, ...)
```

## Arguments

|                           |                                                                                                                         |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------|
| <code>q</code>            | object of class <code>qPCRset</code> .                                                                                  |
| <code>main</code>         | character string, plot title.                                                                                           |
| <code>col</code>          | the colours to use. See details.                                                                                        |
| <code>col.range</code>    | vector, the range of colours to use.                                                                                    |
| <code>dist</code>         | character string, specifying whether to use "pearson" correlation (default) or "euclidean" distance for the clustering. |
| <code>zero.center</code>  | logical, should the colours be shifted to be zero-centered. See details.                                                |
| <code>mar</code>          | vector, the size of the borrom and right hand side margins.                                                             |
| <code>gene.names</code>   | character vector, names to replace the genes (rows) with. See details.                                                  |
| <code>sample.names</code> | character vector, names to replace the samples (columns) with. See details.                                             |
| <code>...</code>          | any other arguments will be passed to the <code>heatmap.2</code> function.                                              |

## Details

This function may be used to cluster the raw or normalized Ct values, and present the result in a heatmap.

The color range is used to represent the range of values for the statistic. If `col=NULL` the colour will be set to a spectrum from red to blue/purple, unless there are negative values in which case it goes red-yellow-green to reflect up and down regulation of genes. If `zero.center=NULL` then `zero.center` will automatically be set to `TRUE` to make the colour scale symmetric around 0.

Especially gene names will often not be readable in a standard size plotting device, and might therefore be removed. If `gene.names` or `sample.names` is set to a single character (such as "" for no naming), then this character will be repeated for all rows or columns.

A standard heatmap is drawn, but this can be modified extensively using the arguments available in the `heatmap.2` function.

## Value

A plot is created on the current graphics device.

**Author(s)**

Heidi Dvinge

**See Also**[heatmap.2](#)**Examples**

```
# Load example data
data(qPCRraw)
# Some standard heatmaps
plotCtHeatmap(qPCRraw, gene.names="")
plotCtHeatmap(qPCRraw, gene.names="", dist="euclidean", col.range=c(10,35))
plotCtHeatmap(qPCRraw, gene.names="", dist="euclidean", col=colorRampPalette(rev(brewer.pal(9, "YlGnBu")))(20))
```

plotCtHistogram

*Histogram of Ct values from qPCR experiments.***Description**

The distribution of Ct values for a selected qPCR sample is shown in a histogram.

**Usage**

```
plotCtHistogram(q, card = 1, xlab = "Ct", col, main, n = 30, ...)
```

**Arguments**

|      |                                                                      |
|------|----------------------------------------------------------------------|
| q    | an object of class qPCRset.                                          |
| card | integer, the number of the card (sample) to plot.                    |
| xlab | character string, the label for the x-axis.                          |
| col  | integer or character, the colour for the histogram.                  |
| main | character string, the plot title. Default is the name of the sample. |
| n    | integer, number of bins to divide the Ct values into.                |
| ...  | any other arguments are passed to hist.                              |

**Value**

A figure is generated in the current graphics device.

**Author(s)**

Heidi Dvinge

**See Also**

[plotCtDensity](#) or [plotCtBoxes](#) for including multiple samples in the same plot.

**Examples**

```
# Load example data
data(qPCRraw)
# Create the plots
plotCtHistogram(qPCRraw, card=2)
plotCtHistogram(qPCRraw, card=3, n=50, col="blue")
```

---

plotCtLines

*Plotting Ct values from qPCR across multiple samples.*


---

**Description**

This function is for displaying a set of features from a `qPCRset` across multiple samples, such as a timeseries or different treatments. Values for each feature are connected by lines, and the can be averaged across groups rather than shown for individual samples.

**Usage**

```
plotCtLines(q, genes, groups, col = brewer.pal(10, "Spectral"), xlab = "Sample", ylab = "Ct", legend = T)
```

**Arguments**

|                     |                                                                                                        |
|---------------------|--------------------------------------------------------------------------------------------------------|
| <code>q</code>      | object of class <code>qPCRset</code> .                                                                 |
| <code>genes</code>  | numeric or character vector, selected genes to make the plot for.                                      |
| <code>groups</code> | vector, the different groups that the samples in <code>q</code> belong to. See details.                |
| <code>col</code>    | vector, colours to use for the lines.                                                                  |
| <code>xlab</code>   | character string, label for the x-axis.                                                                |
| <code>ylab</code>   | character string, label for the y-axis.                                                                |
| <code>legend</code> | logical, whether to include a colour legend or not.                                                    |
| <code>lwd</code>    | numeric, the width of the lines.                                                                       |
| <code>lty</code>    | vector, line types to use. See <code>par</code> or <code>lines</code> for details.                     |
| <code>pch</code>    | vector, if <code>groups</code> is set, the point types that will be used for each feature in genes.    |
| <code>xlim</code>   | vector of length two, the limits for the x-axis. Mainly used for adjusting the position of the legend. |
| <code>...</code>    | any other arguments will be passed to the <code>matplot</code> function.                               |

**Details**

The default plot shows the Ct values across all samples in `q`, with lines connecting the samples. However, if `groups` is set the Ct values will be averaged within groups. Lines connect these averages, but the individual values are shown with different point types, as chosen in `pch`.

**Value**

A plot is created on the current graphics device.

**Author(s)**

Heidi Dvinge

**See Also**

[matplot](#)

**Examples**

```
# Load some example data
data(qPCRraw)
samples <- exFiles <- read.delim(file.path(system.file("exData", package="HTqPCR"), "files.txt"))
# Draw different plots
plotCtLines(qPCRraw, genes=1:10)
plotCtLines(qPCRraw, genes=1:10, groups=samples$Treatment, xlim=c(0,3))
feat <- as.numeric(as.factor(featureType(qPCRraw)[1:10]))
plotCtLines(qPCRraw, genes=1:10, col=feat)
```

---

plotCtOverview

*Overview plot of qPCR Ct values across multiple conditions.*

---

**Description**

Function for high-throughput qPCR data, for showing the average Ct values for features in a barplot, either for individual samples or averaged across biological or technical groups. If Ct values are shown, error bars can be included, or the Ct values can be displayed relative to a calibrator sample.

**Usage**

```
plotCtOverview(q, cards = TRUE, genes, groups, calibrator, replicates = TRUE, col, conf.int = FALSE, leg
```

**Arguments**

|                         |                                                                                                                       |
|-------------------------|-----------------------------------------------------------------------------------------------------------------------|
| <code>q</code>          | object of class <code>qPCRset</code> .                                                                                |
| <code>cards</code>      | integer, the cards (samples) to use. Defaults to all.                                                                 |
| <code>genes</code>      | vector selecting the features to show. See Details.                                                                   |
| <code>groups</code>     | vector with groups to average the samples across. If missing all the samples are displayed individually. See Details. |
| <code>calibrator</code> | the value in groups to use as calibrator sample. See Details.                                                         |
| <code>replicates</code> | logical, if should values from replicated features in each sample be collapsed or kept separate.                      |

|                       |                                                                                                                                                            |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>col</code>      | colours to use for each sample or group. Per default a maximum of 10 colours are used, so this parameter should be set if more than 10 groups are present. |
| <code>conf.int</code> | logical, should the 95 percent confidence interval be shown. See Details.                                                                                  |
| <code>legend</code>   | logical, should a legend be included in the plot.                                                                                                          |
| <code>...</code>      | further arguments passed to <code>barplot</code> .                                                                                                         |

## Details

If a calibrator is chosen all values will be displayed relative to this, i.e. as  $\text{Ct}(\text{sample}) - \text{Ct}(\text{calibrator})$ . If there is no calibrator, the full Ct values are shown, including 95% confidence interval if selected. For confidence intervals when there is a calibrator, it's the variation across  $\text{Ct}(\text{sample}) - \text{average}(\text{Ct}(\text{calibrator}))$  that is shown.

When setting `replicates=TRUE` it is often better to specify genes by name rather than selecting for example the first 10 features using `1:10`. This literally only takes the first 10 rows of the data, although some of these features might be replicated elsewhere in the data.

The purpose of `group` is to tell `plotCtOverview` if any of the samples should be treated as biological replicates, in addition to the technical replicates that might be present on each plate. With e.g. 4 samples and `groups=c("A", "B", "C", "D")` they're each treated individually, and only replicates features on each plate are considered. However, `groups=c("WT", "WT", "WT", "mutant")` means that the first 3 are treated as biological replicates; hence for each gene in the barplot there'll be one bar for WT and one for mutant.

## Value

A figure is produced in the current graphics device.

## Author(s)

Heidi Dvinge

## Examples

```
# Load example data
data(qPCRraw)
exPath <- system.file("exData", package="HTqPCR")
samples <- read.delim(file.path(exPath, "files.txt"))
# Show all samples for the first 10 genes
g <- featureNames(qPCRraw)[1:10]
plotCtOverview(qPCRraw, genes=g, xlim=c(0,90))
plotCtOverview(qPCRraw, genes=g, xlim=c(0,50), groups=samples$Treatment)
plotCtOverview(qPCRraw, genes=g, xlim=c(0,60), groups=samples$Treatment, conf.int=TRUE, ylim=c(0,55))
# Relative to a calibrator sample
plotCtOverview(qPCRraw, genes=g, groups=samples$Treatment, calibrator="Control")
plotCtOverview(qPCRraw, genes=g, groups=samples$Treatment, calibrator="Control", conf.int=TRUE, ylim=c(-0.5,0.5))
plotCtOverview(qPCRraw, genes=g, groups=samples$Treatment, calibrator="LongStarve")
```

plotCtPairs

*Pairwise scatterplot of multiple sets of Ct values from qPCR data.***Description**

Produces a plot of high-throughput qPCR Ct values from N number of samples plotted pairwise against each other in an N by N plot. The Ct values will be in the upper triangle, and the correlation between samples in the lower. Features can be marked based on for example feature class or type.

**Usage**

```
plotCtPairs(q, cards = TRUE, lower.panel = panel.Ct.cor, upper.panel = panel.Ct.scatter, Ct.max = 35, cex.cor = 1.2, cex.pch = 1.2, diag = FALSE, ...)
```

**Arguments**

|             |                                                                                                                                                                                        |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| q           | object of class qPCRset.                                                                                                                                                               |
| cards       | vector, the cards to plot against each other.                                                                                                                                          |
| lower.panel | function, to use for plotting the lower triangle.                                                                                                                                      |
| upper.panel | function, to use for plotting the upper triangle.                                                                                                                                      |
| Ct.max      | numeric, Ct values above this limit will be excluded when calculating the correlation.                                                                                                 |
| col         | vector with the colour(s) to use for the points, or a character string ("type" or "class") indicating whether points should be coloured according to featureType or featureClass of q. |
| pch         | integer or single character, which plotting symbol to use for the points.                                                                                                              |
| cex.cor     | numeric, the expansion factor for the text in panel.Ct.cor.                                                                                                                            |
| cex.pch     | numeric, the expansion factor for the points in panel.Ct.scatter.                                                                                                                      |
| diag        | logical, should the diagonal line y=x be plotted.                                                                                                                                      |
| ...         | any other arguments are passed to the panel function or pairs.                                                                                                                         |

**Details**

Per default, the lower panels contain the correlations between data sets. For each correlation all complete pairs are used, i.e. NAs are ignored. If there are no complete observations between two samples the correlation will be set to NA.

**Value**

A figure is generated in the current graphics device.

**Author(s)**

Heidi Dvinge

**See Also**

[pairs](#) or [plotCtScatter](#) for plotting just two samples.

**Examples**

```
# Load example data
data(qPCRraw)
# Various types of plot
plotCtPairs(qPCRraw, cards=1:4)
plotCtPairs(qPCRraw, col="black")
plotCtPairs(qPCRraw, Ct.max=40)
```

---

plotCtPCA

*PCA for qPCR Ct values.*

---

**Description**

Perform and plot a principal component analysis for high-throughput qPCR data from any platform, for doing clustering.

**Usage**

```
plotCtPCA(q, s.names, f.names, scale = TRUE, features = TRUE, col, cex = c(1, 1))
```

**Arguments**

|                       |                                                                                                                 |
|-----------------------|-----------------------------------------------------------------------------------------------------------------|
| <code>q</code>        | a matrix or an object of class <code>qPCRset</code> containing Ct values.                                       |
| <code>s.names</code>  | character vector, names of samples. See details.                                                                |
| <code>f.names</code>  | character vector, names of features. See details.                                                               |
| <code>scale</code>    | logical, should the variables be scaled to have unit variance. Passed on to <code>prcomp</code> .               |
| <code>features</code> | logical, should the features be plotted. See details.                                                           |
| <code>col</code>      | vector, the colours to use for the samples if <code>features=FALSE</code> .                                     |
| <code>cex</code>      | vector of length 2, the expansion to use for features and samples respectively if <code>features=FALSE</code> . |

**Details**

Per default the sample names from the `qPCRset` are used, however the feature names are replaced by "\*" to avoid cluttering the plot.

If `features=TRUE` then a biplot including all features is produced, with samples represented by vectors. I.e. both observations and variables are plotted, which can potentially be used to identify outliers among the features. For `features=FALSE` only the samples will be included in the plot. This might be more useful for clustering.

In case of high-throughput arrays, some samples may be all NAs. These are ignored during the PCA calculation.

**Value**

A plot is created on the current graphics device.

**Note**

This is still a work in progress, and the function is not particularly sophisticated. Suggestions/wishes are welcome though.

**Author(s)**

Heidi Dvinge

**See Also**

[prcomp](#), [biplot](#)

**Examples**

```
# Load example data
data(qPCRraw)
# Plot
plotCtPCA(qPCRraw)
# Include feature names; make them smaller
plotCtPCA(qPCRraw, f.names=featureNames(qPCRraw), cex=c(0.5,1))
# Plot only the samples
plotCtPCA(qPCRraw, features=FALSE)
```

---

plotCtReps

---

*Scatter plot of features analysed twice during each qPCR experiment.*


---

**Description**

In high-throughput qPCR data some features may be present twice on each card (sample). This function will make a scatter plot of one replicate versus the other for each sample individually, as well as mark genes with very deviating replicate values.

**Usage**

```
plotCtReps(q, card = 1, percent = 20, verbose = TRUE, col = 1, ...)
```

**Arguments**

|         |                                                                                                                         |
|---------|-------------------------------------------------------------------------------------------------------------------------|
| q       | object of class qPCRset.                                                                                                |
| card    | integer, the sample number to plot.                                                                                     |
| percent | numeric, features with replicate values differ more than this percentage from their average will be marked on the plot. |
| verbose | logical, should the deviating genes and their Ct values be printed to the terminal.                                     |
| col     | integer or character; the colour of the points in the scatter plot.                                                     |
| ...     | any other arguments are passed to <a href="#">plot</a> .                                                                |

**Details**

This function will look through the data in the qPCRset, find all genes with are presented twice on the array, and plot the Ct values of these replicated genes against each other. Whether a genes goes to the x or y-axis depends on the first occurrence of the gene names.

All genes where  $\text{abs}(\text{rep1}-\text{rep2}) > \text{percent}/100 * \text{replicate mean}$  will be marked by an open circle, and the gene names written in red letters.

**Value**

An plot is created on the current graphics device. Also, a data.frame with the names and values of deviating genes is returned invisibly.

**Author(s)**

Heidi Dvinge

**See Also**

[plot](#), and [par](#) for the plotting parameters.

**Examples**

```
# Load example data
data(qPCRraw)
# Plot replicates
plotCtReps(qPCRraw, card=1, percent=30)
plotCtReps(qPCRraw, card=2, percent=10)
reps <- plotCtReps(qPCRraw, card=2, percent=20)
reps
```

---

plotCtRQ

---

*Plot the relative quantification of Ct values from qPCR experiments.*


---

**Description**

Function for plotting the relative quantification (RQ) between two groups of data, whose Ct values have been tested for significant differential expression.

**Usage**

```
plotCtRQ(qDE, comparison = 1, genes, transform = "log2", p.val = 0.1, mark.sig = TRUE, p.sig = 0.05, p.val
```

**Arguments**

|            |                                                                                                                            |
|------------|----------------------------------------------------------------------------------------------------------------------------|
| qDE        | list or data.frame, the result from <code>ttestCtData</code> or <code>limmaCtData</code> .                                 |
| comparison | integer or character string, indicating which component to use if qDE is a list.                                           |
| genes      | numeric or character vector, selected genes to make the plot for.                                                          |
| transform  | character string, how should the data be displayed. Options are "none", "log2" or "log10". See details                     |
| p.val      | numeric between 0 and 1, if genes is not supplied all given with (adjusted) p-value below this threshold will be included. |
| mark.sig   | logical, should significant features be marked.                                                                            |
| p.sig      | numeric, the cut-off for significant p-values that will be marked by *.                                                    |
| p.very.sig | numeric, the cut-off for very significant p-values that will be marked by ".                                               |
| mark.un    | logical, should data with unreliable target or calibrator samples be marked. See details.                                  |
| un.tar     | colour to use for the undetermined targets. See details.                                                                   |
| un.cal     | colour to use for the undetermined calibrators. See details.                                                               |
| col        | vector, colours to use for the bars.                                                                                       |
| legend     | logical, should a legend be included in the barplot.                                                                       |
| xlim       | vector of length 2, the limits on the x-axis. Mainly used for moving the legend to the left of bars.                       |
| mar        | vector with 4 values, the size of the margins. See <code>par</code> for more info.                                         |
| main       | character string, the image title. Default to the name of the chosen comparison.                                           |
| ...        | any other arguments will be passed to the <code>barplot</code> function.                                                   |

**Details**

The relative quantification is calculated as  $RQ=2^{-ddCT}$ , where ddCT is the `deltadeltaCt` value.

If `mark.un=TRUE`, those bars where either the calibrator or target sample measurements were undetermined are marked using diagonal lines. Whether either of these are called undetermined (includes unreliable values) or not depends on all the input Ct values in `ttestCtData` or `limmaCtData`, and whether `stringent=TRUE` was used in these functions.

**Value**

A plot is created on the current graphics device.

**Author(s)**

Heidi Dvinge

**See Also**

[ttestCtData](#) and [limmaCtData](#) for testing the Ct data for differential expression.

---

|               |                                                             |
|---------------|-------------------------------------------------------------|
| plotCtScatter | <i>Scatterplot of two sets of Ct values from qPCR data.</i> |
|---------------|-------------------------------------------------------------|

---

## Description

Produces a plot of Ct values from two samples plotted against each other. Features can be marked based on for example feature class or type.

## Usage

```
plotCtScatter(q, cards = c(1, 2), col = "class", pch = 20, diag = FALSE, cor = TRUE, Ct.max = 35, legend =
```

## Arguments

|        |                                                                                                                                                                                         |
|--------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| q      | object of class qPCRset.                                                                                                                                                                |
| cards  | vector, the two cards to plot against each other.                                                                                                                                       |
| col    | vector with the colour(s) to use for the points, or a character string ("type" or "class") indicating whether points should be coloured according to featureType or featureClass of q.  |
| pch    | integer, the point type to use for the plot.                                                                                                                                            |
| diag   | logical, should the diagonal line y=x be plotted.                                                                                                                                       |
| cor    | logical, should information about the correlation between the two samples be included in the plot. The correlation is calculated both with and without removing Ct values above Ct.max. |
| Ct.max | numeric, all Ct values above this will be removed for calculating one of the correlations.                                                                                              |
| legend | logical, if col is either "type" or "class", should a colour legend for these be included.                                                                                              |
| ...    | any other arguments are passed to plot.                                                                                                                                                 |

## Value

A figure is generated in the current graphics device.

## Author(s)

Heidi Dvinge

## Examples

```
# Load example data
data(qPCRraw)
# Various types of plot
plotCtScatter(qPCRraw, cards=c(1,2))
plotCtScatter(qPCRraw, cards=c(1,4), col="type")
plotCtScatter(qPCRraw, cards=c(1,4), col="black", cor=FALSE, diag=TRUE)
```

---

plotCtSignificance      *Barplot with Ct values between genes from qPCR.*


---

## Description

Function for producing a barplot of the Ct values from high-throughput qPCR samples. A comparison is made between two groups which have been tested for differential expression, and all individual Ct values are shown, to identify potential outliers.

## Usage

```
plotCtSignificance(qDE, q, comparison = 1, genes, p.val = 0.1, groups, calibrator, target, p.sig = 0.05,
```

## Arguments

|            |                                                                                                                                                                                                                |
|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| qDE        | list or data.frame, the result from ttestCtData or limmaCtData.                                                                                                                                                |
| q          | the qPCRset data that was used for testing for differential expression.                                                                                                                                        |
| comparison | integer or character string, indicating which component to use if x is a list.                                                                                                                                 |
| genes      | numeric or character vector, selected genes to make the plot for.                                                                                                                                              |
| p.val      | numeric between 0 and 1, if genes is not supplied all given with (adjusted) p-value below this threshold will be included.                                                                                     |
| groups     | vector, the groups of all the samples in q.                                                                                                                                                                    |
| calibrator | character string, which of the groups is the calibrator.                                                                                                                                                       |
| target     | character string, which of the groups is the target.                                                                                                                                                           |
| p.sig      | numeric, the cut-off for significant p-values that will be marked by *.                                                                                                                                        |
| p.very.sig | numeric, the cut-off for very significant p-values that will be marked by ".                                                                                                                                   |
| mark.sig   | logical, should significant features be marked.                                                                                                                                                                |
| col        | vector, colours to use for the two sets of bars, one per sample type.                                                                                                                                          |
| un.col     | integer or character string, the colour to use for all Ct values that are "Unreliable" or "Undetermined".                                                                                                      |
| point.col  | integer or character string, the colour to use for all other Ct values.                                                                                                                                        |
| legend     | logical, should a legend be included in the barplot.                                                                                                                                                           |
| mar        | vector with 4 values, the size of the margins. See par for more info.                                                                                                                                          |
| main       | character string, the image title. Default to the name of the chosen comparison.                                                                                                                               |
| jitter     | numeric, between 0 and 1. If Ct values are very similar, the individual points might lie on top of each other in the bars. This adds a jittering factor along the x-axis. If 0 the points will all be aligned. |
| ...        | any other arguments will be passed to the barplot function.                                                                                                                                                    |

Details

This function will make a barplot with the average Ct values for the test and reference samples for the selected genes. All the individual Ct values are plotted on top of the bars though, and the "Unreliable" or "Undetermined" ones are marked, to do a visual assessment of the impact of non-valid measurements on the average.

It's up to the user to specify the correct calibrator and target for the given comparison; no checking is done.

Value

A plot is created on the current graphics device.

Author(s)

Heidi Dvinge

See Also

[barplot](#) and [plotCtRQ](#) or [plotCtOverview](#) for a plot of the relative quantification between samples.

---

|                 |                                                      |
|-----------------|------------------------------------------------------|
| plotCtVariation | <i>Plot variation in Ct values across replicates</i> |
|-----------------|------------------------------------------------------|

---

Description

Examine the variation in Ct values, either across features present multiple times on each card, or for within different groups of samples. The function supports both a summarised and a more detailed output.

Usage

```
plotCtVariation(q, cards = TRUE, variation = "var", type = "summary", sample.reps, feature.reps, log = F
```

Arguments

- q                    object of class qPCRset.
- cards                vector, the numbers of the cards to plot. Defaults to TRUE = all cards.
- variation           character string indication whether to calculate the variation, "var", or standard deviation, "sd".
- type                character string indicating whether to output the results in a summarised box-plot, "summary" or as a more detailed scatter plot, "detail". See Details and the examples.
- sample.reps        a vector grouping the samples (see Details). Overrides feature.reps.
- feature.reps        a vector grouping the features according to which are replicates. Per default featureNames(q) are used.

|                               |                                                                                                                                                        |
|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>log</code>              | logical, should the results be converted into log10 values.                                                                                            |
| <code>add.featurenames</code> | logical, if <code>type="detail"</code> should the names of each feature be added to the scatter plot.                                                  |
| <code>ylab</code>             | character, the label of the y-axis.                                                                                                                    |
| <code>n.col</code>            | integer, if <code>type="detail"</code> how many columns should the scatterplots be presented in. Defaults to 3, or <code>n.samples(q)</code> if $<3$ . |
| <code>...</code>              | further arguments passed to <code>boxplot</code> or <code>plot</code> .                                                                                |

## Details

It is often useful to examine the data to determine if some samples are inherently more variable than other, or if the concordance between replicates on each qPCR card is acceptable. Using `type="summary"` generates a boxplot with all the variation values, either across genes (if `sample.reps` is set) or with each samples (default, or if `feature.reps` is set). That way the general distribution of variation or standard deviation values can be compared quickly.

If it looks like there's an unacceptable (or interesting) difference in the variation, this can be further investigated using `type="detail"`. This will generate multiple sub-plots, containing a single scatterplot of variation versus mean for each gene (if `sample.reps` is set) or each sample (default, or if `feature.reps` is set). Including the mean in the plot can be used to assess heteroskedasticity in the data.

## Value

A plot is created on the current graphics device. The variation and mean across each type of replicate is returned invisibly in a list with "Var" and "Mean" slots.

## Author(s)

Heidi Dvinge

## See Also

[plotCtReps](#) for cases where the qPCR card only contains two replicates of each feature. [plotCVBoxes](#) for other ways of plotting variation within different groups.

## Examples

```
# Load some example data
data(qPCRraw)

# Detailed summary of variation versus mean Ct value for replicated features within each sample
plotCtVariation(qPCRraw, type="detail", log=TRUE)
plotCtVariation(qPCRraw, type="detail")
# Add feature names to see which the highly varying replicates are.
plotCtVariation(qPCRraw, type="detail", add.featurenames=TRUE, pch=" ", cex=0.8)
# Use different information to indicate which features are replicates
plotCtVariation(qPCRraw, type="detail", feature.reps=paste("test", rep(1:96, each=4)))
```

```
# Examine variation across samples for the first 9 features
plotCtVariation(qPCRraw[1:9,], type="detail", sample.reps=paste("mutant", rep(1:3,2)), add.featurenames=TRUE)

# Examine the output
test <- plotCtVariation(qPCRraw, variation="sd")
names(test)
head(test[["Var"]])
```

---

|             |                                           |
|-------------|-------------------------------------------|
| plotCVBoxes | <i>Boxplots of CV for qPCR Ct values.</i> |
|-------------|-------------------------------------------|

---

**Description**

Function that will calculate the coefficients of variation across selected qPCR data, and plot the results in a boxplot.

**Usage**

```
plotCVBoxes(q, cards = TRUE, xlab = "", ylab = "CV", col = brewer.pal(5, "Spectral"), main = NULL, strati
```

**Arguments**

|          |                                                                                                                                                                                |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| q        | object of class qPCRset.                                                                                                                                                       |
| cards    | vector, the numbers of the cards to plot. Defaults to TRUE = all cards.                                                                                                        |
| xlab     | character string, label for the x-axis.                                                                                                                                        |
| ylab     | character string, label for the y-axis.                                                                                                                                        |
| col      | vector of colours to use.                                                                                                                                                      |
| main     | character string, plot title.                                                                                                                                                  |
| stratify | character, specifying what to stratify the Ct values by. NULL, the default means no stratification, "type" is the feature types of the qPCRset, and "class" the feature class. |
| ...      | any other arguments will be passed to the boxplot function.                                                                                                                    |

**Details**

The CV is calculated across all the selected cards based on each well position, without taking possibly replicated genes on the cards into consideration. "type" and "class" are automatically extracted from the qPCRset using featureType and featureClass.

**Value**

A plot is created on the current graphics device. The CV values are returned invisibly.

**Author(s)**

Heidi Dvinge

**See Also**[boxplot](#)**Examples**

```
# Load example data
data(qPCRraw)
# Make plot with all samples or just a few
plotCVBoxes(qPCRraw)
plotCVBoxes(qPCRraw, cards=c(1,4))
plotCVBoxes(qPCRraw, stratify="class")
x <- plotCVBoxes(qPCRraw, stratify="type")
x[1:10]
```

qPCRpros

*Example processed qPCR data***Description**

Processed version of the raw data in qPCRraw, to be used as example data in the HTqPCR package. The data has been processed with `setCategory` to mark the feature categories, and with `normalizeCtData` using rank invariant normalisation.

**Usage**

```
data(qPCRpros)
```

**Format**

The format is: Formal class 'qPCRset' [package ".GlobalEnv"] with 8 slots ..@ CtHistory : 'data.frame': 3 obs. of 1 variable: .. .\$ history: chr [1:3] "readCtData(files = exFiles\$File, path = exPath)" "setCategory(q = qPCRraw, groups = exFiles\$Treatment)" "normalizeCtData(q = qPCRpros, norm = \"norm.rankinvariant\")" ..@ assayData :<environment: 0x1180c9400> ..@ phenoData :Formal class 'AnnotatedDataFrame' [package "Biobase"] with 4 slots ..@ varMetadata : 'data.frame': 1 obs. of 1 variable: .. .\$ labelDescription: chr "Sample numbering" ..@ data : 'data.frame': 6 obs. of 1 variable: .. .\$ sample: int [1:6] 1 2 3 4 5 6 ..@ dimLabels : chr [1:2] "sampleNames" "sampleColumns" ..@ .\_\_classVersion\_\_: Formal class 'Versions' [package "Biobase"] with 1 slots ..@ .Data: List of 1 .. .\$ : int [1:3] 1 1 0 ..@ featureData :Formal class 'AnnotatedDataFrame' [package "Biobase"] with 4 slots ..@ varMetadata : 'data.frame': 4 obs. of 1 variable: .. .\$ labelDescription: chr [1:4] NA NA NA NA ..@ data : 'data.frame': 384 obs. of 4 variables: .. .\$ featureNames: Factor w/ 191 levels "Gene1","Gene10",...: 1 104 115 126 137 148 159 170 181 2 ... .. .\$ featureType : Factor w/ 2 levels "Endogenous Control",...: 1 2 2 2 2 2 2 2 2 2 ... .. .\$ featurePos : Factor w/ 384 levels "A1","A10","A11",...: 1 12 18 19 20 21 22 23 24 2 ... .. .\$ featureClass: Factor w/ 3 levels "Kinase","Marker",...: 1 2 1 3 2 2 2 3 1 2 ... ..@ dimLabels : chr [1:2] "featureNames" "featureColumns" ..@ .\_\_classVersion\_\_: Formal class 'Versions' [package "Biobase"] with 1 slots ..@ .Data: List of 1 .. .\$ : int [1:3] 1 1 0 ..@ experimentData :Formal class 'MIAME' [package "Biobase"]

```
with 13 slots .. ..@ name : chr "" .. ..@ lab : chr "" .. ..@ contact : chr "" .. ..@ title : chr
"" .. ..@ abstract : chr "" .. ..@ url : chr "" .. ..@ pubMedIds : chr "" .. ..@ samples : list()
.. ..@ hybridizations : list() .. ..@ normControls : list() .. ..@ preprocessing : list() .. ..@
other : list() .. ..@ .__classVersion__:Formal class 'Versions' [package "Biobase"] with 1 slots ..
.. ..@ .Data:List of 2 .. .. ..$ : int [1:3] 1 0 0 .. .. ..$ : int [1:3] 1 1 0 .. ..@ annotation
: chr(0) .. ..@ protocolData :Formal class 'AnnotatedDataFrame' [package "Biobase"] with 4 slots
.. .. ..@ varMetadata : 'data.frame': 0 obs. of 1 variable: .. .. ..$ labelDescription: chr(0) ..
.. ..@ data : 'data.frame': 6 obs. of 0 variables .. .. ..@ dimLabels : chr [1:2] "sampleNames"
"sampleColumns" .. ..@ .__classVersion__:Formal class 'Versions' [package "Biobase"] with 1
slots .. .. ..@ .Data:List of 1 .. .. ..$ : int [1:3] 1 1 0 .. ..@ .__classVersion__:Formal class
'Versions' [package "Biobase"] with 1 slots .. .. ..@ .Data:List of 3 .. .. ..$ : int [1:3] 2 14 0 .. ..
..$ : int [1:3] 2 14 0 .. .. ..$ : int [1:3] 1 3 0
```

## Examples

```
data(qPCRpros)
```

---

qPCRraw

*Example raw qPCR data.*


---

## Description

Six qPCR samples, performed on the TaqMan Low Density Arrays from Applied Biosystem. Each sample contains 384 PCR reactions, and there are 3 different samples with 2 replicates each. To be used as example data in the HTqPCR package.

## Usage

```
data(qPCRraw)
```

## Format

The format is: Formal class 'qPCRset' [package ".GlobalEnv"] with 8 slots ..@ CtHistory : 'data.frame': 1 obs. of 1 variable: .. ..\$ history: chr "readCtData(files = exFiles\$File, path = exPath)" ..@ assayData :<environment: 0x118094e30> ..@ phenoData :Formal class 'AnnotatedDataFrame' [package "Biobase"] with 4 slots .. .. ..@ varMetadata : 'data.frame': 1 obs. of 1 variable: .. .. ..\$ labelDescription: chr "Sample numbering" .. .. ..@ data : 'data.frame': 6 obs. of 1 variable: .. .. ..\$ sample: int [1:6] 1 2 3 4 5 6 .. .. ..@ dimLabels : chr [1:2] "sampleNames" "sampleColumns" .. .. ..@ .\_\_classVersion\_\_:Formal class 'Versions' [package "Biobase"] with 1 slots .. .. ..@ .Data:List of 1 .. .. ..\$ : int [1:3] 1 1 0 ..@ featureData :Formal class 'AnnotatedDataFrame' [package "Biobase"] with 4 slots .. .. ..@ varMetadata : 'data.frame': 4 obs. of 1 variable: .. .. ..\$ labelDescription: chr [1:4] NA NA NA NA .. .. ..@ data : 'data.frame': 384 obs. of 4 variables: .. .. ..\$ featureNames: Factor w/ 191 levels "Gene1","Gene10",...: 1 104 115 126 137 148 159 170 181 2 ... .. ..\$ featureType : Factor w/ 2 levels "Endogenous Control",...: 1 2 2 2 2 2 2 2 2 2 ... .. ..\$ featurePos : Factor w/ 384 levels "A1","A10","A11",...: 1 12 18 19 20 21 22 23 24 2 ... .. ..\$ featureClass: Factor w/ 3 levels "Kinase","Marker",...: 1 2 1 3 2 2 2 3 1 2 ... .. ..@ dimLabels : chr [1:2] "featureNames" "featureColumns" .. .. ..@ .\_\_classVersion\_\_:Formal

```
class 'Versions' [package "Biobase"] with 1 slots .. ..@ .Data:List of 1 .. ..@ ..$ :
int [1:3] 1 1 0 ..@ experimentData :Formal class 'MIAME' [package "Biobase"] with 13 slots ..
..@ name : chr "" .. ..@ lab : chr "" .. ..@ contact : chr "" .. ..@ title : chr "" .. ..@
abstract : chr "" .. ..@ url : chr "" .. ..@ PubMedIds : chr "" .. ..@ samples : list() .. ..@
hybridizations : list() .. ..@ normControls : list() .. ..@ preprocessing : list() .. ..@ other :
list() .. ..@ __classVersion__:Formal class 'Versions' [package "Biobase"] with 1 slots .. ..@
..@ .Data:List of 2 .. ..@ ..$ : int [1:3] 1 0 0 .. ..@ ..$ : int [1:3] 1 1 0 ..@ annotation
: chr(0) ..@ protocolData :Formal class 'AnnotatedDataFrame' [package "Biobase"] with 4 slots
.. ..@ varMetadata : 'data.frame': 0 obs. of 1 variable: .. ..@ ..$ labelDescription: chr(0) ..
.. ..@ data : 'data.frame': 6 obs. of 0 variables .. ..@ dimLabels : chr [1:2] "sampleNames"
"sampleColumns" .. ..@ __classVersion__:Formal class 'Versions' [package "Biobase"] with 1
slots .. ..@ .Data:List of 1 .. ..@ ..$ : int [1:3] 1 1 0 ..@ __classVersion__:Formal class
'Versions' [package "Biobase"] with 1 slots .. ..@ .Data:List of 3 .. ..@ ..$ : int [1:3] 2 14 0 ..
..@ ..$ : int [1:3] 2 14 0 .. ..@ ..$ : int [1:3] 1 3 0
```

## Examples

```
data(qPCRraw)
```

|               |                        |
|---------------|------------------------|
| qPCRset-class | <i>Class "qPCRset"</i> |
|---------------|------------------------|

## Description

This is a class for containing the raw or normalized cycle threshold (Ct) values and some related quality information. It is suitable for TaqMan Low Density Arrays or any other type of (high-throughput) qPCR data, where gene expression is measured for any number of genes, across several samples/conditions. It inherits from [eSet](#) for microarray data.

## Objects from the Class

Objects can be created by calls of the form `new("qPCRset", assayData, phenoData, featureData, experimentData, annotation, protocolData, ...)` or using `readCtData`.

## Slots

**CtHistory:** Object of class "data.frame" indicating how the data has been read in, normalized, filtered etc. Gives the exact commands used during these operations.

**assayData:** Object of class "AssayData", containing the Ct values.

phenoData: Object of class "AnnotatedDataFrame", where information about samples can be added.

featureData: Object of class "AnnotatedDataFrame", where information about features can be added. If the object is from readCtData, the featureData will contain the columns 'featureName', 'featurePos' and 'featureType'.

**experimentData:** Object of class "MIAxE", where details about the experiment can be stored.

annotation: Object of class "character", where the name of the qPCR assay can be stored.

**protocolData:** Object of class "AnnotatedDataFrame", where details of the protocol can be stored.

**.\_\_classVersion\_\_:** Object of class "Versions".

Furthermore, the following information is contained within the object.

**flag:** Object of class "data.frame" containing the flag for each Ct value, as supplied by the input files.

**featureCategory:** Object of class "data.frame" representing the quality of the measurement for each Ct value, such as "OK", "Undetermined" or "Unreliable" if the Ct value is considered too high.

## Extends

Class "eSet", directly. Class "VersionedBiobase", by class "eSet", distance 2. Class "Versioned", by class "eSet", distance 3.

## Methods

**[ signature(x = "qPCRset"):** Subsets by genes or samples.

**exprs signature(object = "qPCRset"):** Extracts the Ct matrix. Is identical to getCt

**exprs<- signature(object = "qPCRset", value = "matrix"):** Replaces the Ct matrix. Is identical to setCt<-

**getCt signature(object = "qPCRset"):** Extracts the Ct matrix. Is identical to exprs.

**setCt<- signature(object = "qPCRset", value = "matrix"):** Replaces the Ct matrix. Is identical to exprs<-.

**featureNames signature(object = "qPCRset"):** Extracts the features (gene names) on the card.

**featureNames<- signature(object = "qPCRset", value = "character"):** Replaces the features (gene names) on the card.

**sampleNames signature(object = "qPCRset"):** Extracts the sample names.

**sampleNames<- signature(object = "qPCRset", value = "character"):** Replaces the sample names.

**featureType signature(object = "qPCRset"):** Extracts the different types of features on the card, such as controls and target genes.

**featureType<- signature(object = "qPCRset", value = "factor"):** Replaces the feature type for each gene.

**featurePos signature(object = "qPCRset"):** Extracts the position of each feature (gene) on the assay, representing the location "well" (such as well A1, A2, ...). If data does not come from a card format, the positions will be given consecutive names.

**featurePos<- signature(object = "qPCRset", value = "character"):** Replaces the position of each feature (gene) on the card.

**featureClass signature(object = "qPCRset"):** Extracts the feature class for each gene.

**featureClass<- signature(object = "qPCRset", value = "factor"):** Replaces the feature class for each gene, for example if it is a marker, transcription factor or similar.

**featureCategory signature(object = "qPCRset"):** Extracts the category of each Ct value.

**featureCategory<-** signature(object = "qPCRset", value = "data.frame"): Replaces the category of each Ct value.

**flag** signature(object = "qPCRset"): Extracts the flag of each Ct value.

**flag<-** signature(object = "qPCRset"): Replaces the flag of each Ct value.

**n.wells** signature(object = "qPCRset"): Extracts information about the number of wells on the card.

**n.samples** signature(object = "qPCRset"): Extracts information about the number of samples in the set.

**getCtHistory** signature(object = "qPCRset"): Extracts data frame containing information about the history of the object (which operations have been performed on it).

**setCtHistory<-** signature(object = "qPCRset"): Add information about the history of the object.

**show** signature(object = "qPCRset"): Displays some abbreviated information about the data object.

**summary** signature(object = "qPCRset"): Displays a summary of the Ct values from each sample.

### Author(s)

Heidi Dvinge

### Examples

```
# The data format
data(qPCRraw)
show(qPCRraw)
getCtHistory(qPCRraw)
showClass("qPCRset")
str(qPCRraw)
# Information about samples
phenoData(qPCRraw)
pData(qPCRraw)
pData(qPCRraw)[,"Rep"] <- c(1,1,2,2,3,3)
# Information about features
featureData(qPCRraw)
head(fData(qPCRraw))
```

---

readCtData

---

*Reading Ct values from qPCR experiments data into a qPCRset*


---

### Description

This function will read tab separated text files with Ct values and feature meta-data from high-throughput qPCR experiments into a qPCRset containing all the relevant information.

**Usage**

```
readCtData(files, path = NULL, n.features = 384, format="plain", column.info, flag, feature, type, posi
```

**Arguments**

|                                                |                                                                                                                                                                                                                                                                                                                                                                                          |
|------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>files</code>                             | character vector with the names of the files to be read.                                                                                                                                                                                                                                                                                                                                 |
| <code>path</code>                              | character string with the path to the folder containing the data files.                                                                                                                                                                                                                                                                                                                  |
| <code>n.features</code>                        | integer, number of features present on each array (e.g. 384). See details.                                                                                                                                                                                                                                                                                                               |
| <code>format</code>                            | character, the format of the input file. Options are "plain", "SDS", "LightCycler", "CFX", "OpenArray" and "BioMark". See Details.                                                                                                                                                                                                                                                       |
| <code>column.info</code>                       | list, indicating which column number or name the information of interest is in. It is set automatically by format, but this can be overridden manually. The names list slots can be 'flag', 'feature', 'position', 'type' and 'Ct'. See Details. Note than when indicating column names, these are sometimes changed by R to be syntactically valid, so replacing e.g. brackets by dots. |
| <code>flag, feature, Ct, type, position</code> | deprecated, use <code>column.info</code> instead.                                                                                                                                                                                                                                                                                                                                        |
| <code>header</code>                            | logical, does the file contain a header row or not. Only used for format="plain".                                                                                                                                                                                                                                                                                                        |
| <code>SDS</code>                               | deprecated, use format="SDS" instead.                                                                                                                                                                                                                                                                                                                                                    |
| <code>n.data</code>                            | integer vector, same length as <code>files</code> . Indicates the number of samples that are present in each file. For each file in <code>files</code> , <code>n.data*n.features</code> lines will be read.                                                                                                                                                                              |
| <code>samples</code>                           | character vector with names for each sample. Per default the file names are used.                                                                                                                                                                                                                                                                                                        |
| <code>na.value</code>                          | integer, a Ct value that will be assigned to all undetermined/NA wells.                                                                                                                                                                                                                                                                                                                  |
| <code>sample.info</code>                       | object of class <code>AnnotatedDataFrame</code> , given the <code>phenoData</code> of the object. Can be added later.                                                                                                                                                                                                                                                                    |
| <code>...</code>                               | any other arguments are passed to <a href="#">read.table</a> or <a href="#">read.csv</a> .                                                                                                                                                                                                                                                                                               |

**Details**

This is the main data input function for the HTqPCR package for analysing qPCR data. It extracts the threshold cycle, Ct value, of each well on the card, as well as information about the quality (e.g.~passed/failed) of the wells. The function is tuned for data from TaqMan Low Density Array cards, but can be used for any kind of qPCR data.

The information to be extracted is:

- `flag` integer indicating the number of column containing information about the flags.
- `feature` integer indicating the number of column containing information about the individual features (typically gene names).
- `type` integer indicating the number of column containing information about the type of each feature.
- `position` integer indicating the number of column containing information about the position of features on the card.
- `Ct` integer indicating the number of column containing information about the Ct values. Per default, this information is assumed to be in certain columns depending on the input format.

featureNames, featureType and featurePos will be extracted from the first file. If flag, type or position are not included into column.info, this means that this information is not available in the file. flag will then be set to "Passed", type to "Target" and position to "feature1", "feature2", ... etc until the end of the file. Especially position might not be available in case the data does not come from a card format, but it is required in subsequent functions in order to disambiguate in case some features are present multiple times.

format indicates the format of the input file. The options currently implemented are:

- plain A tab-separated text file, containing no header unless header=TRUE. The information extracted defaults to column.info=list(flag=4, feature=6, type=7, position=3, Ct=8).
- SDS An output file from the SDS Software program. This is often used for the TaqMan Low Density Arrays from Applied Biosystems, but can also be used for assays from other vendors, such as Exiqon. column.info is the same as for "plain".
- OpenArray The TaqMan OpenArray Real-Time PCR Plates. The information extracted defaults to column.info=list(flag="ThroughHole.Outlier", feature="Assay.Assay.ID", type="Assay.Assay.Type", position="ThroughHole.Address", Ct="ThroughHole.Ct").
- BioMark The BioMark HD System from Fluidigm, currently including the 48.48 and 96.96 assays. The information extracted defaults to column.info=list(flag="Call", feature="Name.1", position="ID", Ct="Value").
- CFX The CFX Automation System from Bio-Rad. The information extracted defaults to column.info=list(feature="Content", position="Well", Ct="Cq.Mean").
- LightCycler The LightCycler System from Roche Applied Science. The information extracted defaults to column.info=list(feature="Name", position="Pos", Ct="Cp").

The BioMark and OpenArray assays always contain information multiple samples on each assay, such as 48 features for 48 samples for the BioMark 48.48. The results across these samples are always present in a single file, e.g. with 48x48=2304 rows. Setting n.features=2304 will read in all the information and create a qPCRset object with dimensions 2304x1. Setting n.data=48 and n.features=48 will however automatically convert this into a 48x48 qPCRset. See openVignette(package="HTqPCR") for examples. The samples are being read in the order in which they're present in the file, i.e. from row 1 onwards, regardless of how they're loaded onto the particular platform.

If the data was analysed using for example SDS Software it may contain a variable length header specifying parameters for files that were analysed at the same time. If format="SDS" then readCtData will scan through the first 100 lines of each file, and skip all lines until (and including) the line beginning with "#", which is the header. The end of the file might also contain some plate ID information, but only the number of lines specified in n.features will be read.

n.features indicates the number of features present on each array. For example, for a 384 well plate with just 1 sample, the number would be 382. For a plate with 2 individual samples loaded onto it, n.features=196 and n.data=2. For 1 file with 5 plates and 2 samples per plate, the numbers are n.features=196 and n.data=10. n.features\*n.data must correspond to the total number of lines to be read from each file.

## Value

A "qPCRset" object.

Warnings

The files are all assumed to belong to the same design, i.e.~have the same features (genes) in them and in identical order.

Author(s)

Heidi Dvinge

See Also

[read.delim](#) for further information about reading in data, and "[qPCRset](#)" for a definition of the resulting object.

Examples

```
# Locate example data and create qPCRset object
exPath <- system.file("exData", package="HTqPCR")
exFiles <- read.delim(file.path(exPath, "files.txt"))
raw <- readCtData(files=exFiles$File, path=exPath)
# Example of adding missing information (random data in this case)
featureClass(raw) <- factor(rep(c("A", "B", "C"), each=384/3))
pData(raw)[,"rep"] <- c(1,1,2,2,3,3)

## See the package vignette for more examples, including different input formats.
```

---

|             |                                                       |
|-------------|-------------------------------------------------------|
| setCategory | <i>Assign categories to Ct values from qPCR data.</i> |
|-------------|-------------------------------------------------------|

---

Description

Data in qPCRset objects will have feature categories ("Unreliable", "Undetermined") assigned to them based on different Ct criteria.

Usage

```
setCategory(q, Ct.max = 35, Ct.min = 10, replicates = TRUE, quantile = 0.9, groups, flag = TRUE, flag.out
```

Arguments

|            |                                                                                                             |
|------------|-------------------------------------------------------------------------------------------------------------|
| q          | qPCRset object.                                                                                             |
| Ct.max     | numeric, the maximum tolerated Ct value. Everything above this will be "Undetermined".                      |
| Ct.min     | numeric, the minimum tolerated Ct value. Everything below this will be "Unreliable".                        |
| replicates | logical, should Ct values from genes replicated within each sample be collapsed for the standard deviation. |

|          |                                                                                                                                                                                    |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| quantile | numeric from 0 to 1, the quantile interval accepted for standard deviations. See details. NULL means that variation between replicates is not used for setting the categories.     |
| groups   | vector, grouping of cards, for example biological or technical replicates. NULL means that variation between groups or samples is not assessed, same as for setting quantile=NULL. |
| flag     | logical, should categories also be set to "Unreliable" according to the content of flag(q).                                                                                        |
| flag.out | character vector, if flag=TRUE, what are the flag(s) to be set as "Unreliable".                                                                                                    |
| verbose  | logical, should a summary about category counts per sample be printed to the prompt.                                                                                               |
| plot     | logical, should some plots of the standard deviations be created.                                                                                                                  |
| ...      | any other arguments are passed to plot.                                                                                                                                            |

### Details

Categories can be assigned to the featureCategory of the qPCRset using either just simple criteria (max/min of Ct values or flag of q) or by looking at the standard deviation of Ct values across biological and technical replicates for each gene.

When looking at replicates, the standard deviation and mean are calculated and a normal distribution following these parameters is generated. Individual Ct values that are outside the interval set by quantile are set as "Unreliable". So if e.g. quantile=90 the values outside the top 5% and lower 5% of the normal distribution with the given mean and standard deviation are removed.

"Undetermined" has priority over "Unreliable", so if a value is outside quantile but also above Ct.max it will be "Undetermined".

NB: When setting categories based on replicates, the Ct values are assumed to follow a normal distribution. This might not be the case if the number of samples within each group is small, and there are no replicates on the genes within each sample.

If the number of replicates vary significantly between biological groups, this will influence the thresholds used for determining the range of "OK" Ct values.

### Value

If plot=TRUE one figure per sample group is returned to the current graphics device. A qPCRset with the new feature categories is returned invisibly.

### Note

It's advised to try several different values for quantile, depending on the input data set. Using the function PlotCtCategory(..., by.feature=FALSE) or plotCtCategory(..., by.feature=TRUE) might help assess the result of different quantile choices.

### Author(s)

Heidi Dvinge

**See Also**

[filterCategory](#), [plotCtCategory](#)

**Examples**

```
# Load example data
data(qPCRraw)
exFiles <- read.delim(file.path(system.file("exData", package="HTqPCR"), "files.txt"))
# Set categories in various ways
setCategory(qPCRraw, flag=FALSE, quantile=NULL)
```

---

ttestCtData

*Differentially expressed features with qPCR: t-test*


---

**Description**

Function for calculating t-test and p-values across two groups for the features present in high-throughput qPCR data, such as from TaqMan Low Density Arrays.

**Usage**

```
ttestCtData(q, groups = NULL, calibrator, alternative = "two.sided", paired = FALSE, replicates = TRUE,
```

**Arguments**

|             |                                                                                                                                                             |
|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| q           | qPCRset object.                                                                                                                                             |
| groups      | factor, assigning each sample to one of two groups.                                                                                                         |
| calibrator  | which of the two groups is to be considered as the reference and not the test? Defaults to the first group in groups.                                       |
| alternative | character string (first letter is enough), specifying the alternative hypothesis, "two.sided" (default), "greater" or "less".                               |
| paired      | logical, should a paired t-test be used.                                                                                                                    |
| replicates  | logical, if replicated genes are present on the array, the statistics will be calculated for all the replicates combined, rather than the individual wells. |
| sort        | boolean, should the output be sorted by p-values.                                                                                                           |
| stringent   | boolean, for flagging results as "Undetermined". See details.                                                                                               |
| p.adjust    | character string, which method to use for p-value adjustment for multiple testing. See details.                                                             |
| ...         | any other arguments will be passed to the <a href="#">t.test</a> function.                                                                                  |

## Details

Once the Ct values have been normalised, differential expression can be calculated. This function deals with just the simple case, where there are two types of samples to compare. For more complex studies, see `limmaCtData`.

All results are assigned to a category, either "OK" or "Undetermined" depending on the input Ct values. If `stringent=TRUE` any unreliable or undetermined measurements among technical and biological replicates will result in the final result being "Undetermined". For `stringent=FALSE` the result will be "OK" unless at least half of the Ct values for a given gene are unreliable/undetermined.

The argument `p.adjust` is passed on to the [p.adjust](#) function. Options include e.g. "BH" (Benjamini & Hochberg, the default), "fdr" and "bonferroni". See [p.adjust](#) for more information on the individual methods.

## Value

A data.frame containing the following information:

|                                 |                                                                                                                 |
|---------------------------------|-----------------------------------------------------------------------------------------------------------------|
| <code>genes</code>              | The names of the features on the card.                                                                          |
| <code>feature.pos</code>        | The featurePos of the genes. If replicated genes are used, the feature positions will be concatenated together. |
| <code>t.test</code>             | The value of the t-test.                                                                                        |
| <code>p.value</code>            | The corresponding p-value.                                                                                      |
| <code>ddCt</code>               | The delta delta Ct values.                                                                                      |
| <code>FC</code>                 | The fold change; $2^{(-ddCt)}$ .                                                                                |
| <code>meanCalibrator</code>     | The average expression level of each gene in the calibrator sample(s).                                          |
| <code>meanTarget</code>         | The average expression level of each gene in the target sample(s).                                              |
| <code>categoryCalibrator</code> | The category of the Ct values ("OK", "Undetermined") across the calibrator.                                     |
| <code>categoryTarget</code>     | Ditto for the target.                                                                                           |

## Author(s)

Heidi Dvinge

## See Also

[t.test](#), [limmaCtData](#), [mannwhitneyCtData](#), [plotCtRQ](#) and [plotCtSignificance](#) can be used for visualising the results.

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