

Package ‘flowTime’

March 30, 2021

Title Annotation and analysis of biological dynamical systems using flow cytometry

Version 1.14.0

Description This package facilitates analysis of both timecourse and steady state flow cytometry experiments. This package was originally developed for quantifying the function of gene regulatory networks in yeast (strain W303) expressing fluorescent reporter proteins using BD Accuri C6 and SORP cytometers. However, the functions are for the most part general and may be adapted for analysis of other organisms using other flow cytometers. Functions in this package facilitate the annotation of flow cytometry data with experimental metadata, as often required for publication and general ease-of-reuse. Functions for creating, saving and loading gate sets are also included. In the past, we have typically generated summary statistics for each flowset for each timepoint and then annotated and analyzed these summary statistics. This method loses a great deal of the power that comes from the large amounts of individual cell data generated in flow cytometry, by essentially collapsing this data into a bulk measurement after subsetting. In addition to these summary functions, this package also contains functions to facilitate annotation and analysis of steady-state or time-lapse data utilizing all of the data collected from the thousands of individual cells in each sample.

Depends R (>= 3.4), flowCore

License Artistic-2.0

LazyData true

biocViews FlowCytometry, TimeCourse, Visualization, DataImport, CellBasedAssays, ImmunoOncology

Suggests knitr, rmarkdown, flowViz, ggplot2, BiocGenerics, stats, flowClust, openCyto, flowStats, ggcyto

Imports utils, dplyr (>= 1.0.0), tibble, magrittr, plyr, rlang

VignetteBuilder knitr

RoxygenNote 7.1.1

git_url <https://git.bioconductor.org/packages/flowTime>

git_branch RELEASE_3_12
git_last_commit 9398c74
git_last_commit_date 2020-10-27
Date/Publication 2021-03-29
Author R. Clay Wright [aut, cre],
 Nick Bolten [aut],
 Edith Pierre-Jerome [aut]
Maintainer R. Clay Wright <wright.clay@gmail.com>

R topics documented:

| | |
|----------------------------|-----------|
| addbs | 2 |
| addnorm | 3 |
| annotateFlowSet | 4 |
| createAnnotation | 5 |
| dipdoubletGate | 5 |
| dipsingletGate | 6 |
| flsummary | 6 |
| getTime | 7 |
| hapdoubletGate | 7 |
| hapsingletGate | 8 |
| loadGates | 8 |
| meanMedianSD | 9 |
| ploidy | 9 |
| polyGate | 10 |
| qaGating | 10 |
| read.plateSet | 11 |
| saveGates | 12 |
| steadyState | 13 |
| summarizeFlow | 13 |
| tidyFlow | 14 |
| yeastGate | 15 |
| Index | 16 |

| | |
|-------|---|
| addbs | <i>Add background subtraction to a summary data frame</i> |
|-------|---|

Description

Subtracts the background fluorescence of a given control strain from the chosen column.

Usage

```

addbs(
  flowData,
  column = "FL3.Amean",
  baseline_column = "strain",
  baseline = "noYFP"
)

```

Arguments

| | |
|-----------------|---|
| flowData | the summary data frame of flowSet to be background subtracted |
| column | the column containing the fluorescent measurement to be background subtracted |
| baseline_column | the column containing the name of the strain representing background fluorescent values |
| baseline | character the name of the strain representing background fluorescent values |

Value

A summary data frame with an additional column "column_bs" containing the background subtracted fluorescent values

Examples

```
dat<-read.flowSet(path=system.file("extdata", "tc_example",
package = "flowTime"),alter.names = TRUE)
annotation <- read.csv(system.file("extdata", "tc_example.csv",
package = "flowTime"))
annotation[which(annotation$treatment == 0), 'strain'] <- 'background'
adat <- annotateFlowSet(dat, annotation)
loadGates(gatesFile = 'C6Gates')
dat_sum <- summarizeFlow(adat, ploidy = 'diploid', only = 'singlets',
channel = 'FL1.A')
dat_sum <- addbs(dat_sum, column = "FL1.Amean", baseline = "background")
```

addnorm

Normalize fluorescence

Description

Produces a normalized fluorescence column 'normed'. Expects the 'FL1.A_bs' column to exist or a column to be specified. Has three different methods, version 1 and version 2, described in the script

Usage

```
addnorm(
  frame,
  factor_in = c("strain", "treatment"),
  method = 1,
  column = "FL3.Amean_bs"
)
```

Arguments

| | |
|-----------|--|
| frame | data frame of summary statistics to be normalized |
| factor_in | character vector containing the variables to split the data frame by |
| method | which normalization method to use, 1, 2 or 3. |
| column | character the column to apply the normalization to |

Details

Method 1, the default normalization method, takes the highest point in each dataset grouped by 'factor_in' and normalizes all values in the group by this point. This method is default because it works regardless of whether the data is a time series. Method 2 finds the mean value of all time points with time values less than 0 for each group and normalizes each group by this respective value. Requires a time series with negative time values to work. Method 3 fits a linear model to the pre-zero time points for each groups, infers the y-intercept, and normalizes using this intercept. Method 3 also requires a time series with negative time values to work.

Value

data frame containing the additional normalized variable

Examples

```
dat <- read.flowSet(path=system.file("extdata", "tc_example",
package = "flowTime"), alter.names = TRUE)
annotation <- read.csv(system.file("extdata", "tc_example.csv",
package = "flowTime"))
adat <- annotateFlowSet(dat, annotation)
loadGates(gatesFile = 'C6Gates')
dat_sum <- summarizeFlow(adat, ploidy = "diploid", only = "singlets",
channel = "FL1.A")
dat_sum <- addnorm(dat_sum, c("strain", "treatment"), method = 1,
column = "FL1.Amean")
```

annotateFlowSet

Annotate a flowSet with experimental metadata

Description

Add annotations to a flowSets phenoData and plate numbers, strain names, and treatment also set T0

Usage

```
annotateFlowSet(yourFlowSet, annotation_df, mergeBy = "name")
```

Arguments

| | |
|---------------|---|
| yourFlowSet | a flowSet with sampleNames of the format 'plate#_Well', we typically use the following code chunk to read data from individual plates as exported from BD Accuri C6 software. |
| annotation_df | A data frame with columns 'well', 'strain', 'treatment', containing all of the wells in the flowset labeled with the strain and treatment in that well. |
| mergeBy | the unique identifier column |

Value

An annotated flowSet

Examples

```
dat <- read.flowSet(path = system.file("extdata", "ss_example",
package = "flowTime"), alter.names = TRUE)
annotation <- read.csv(system.file("extdata", "ss_example.csv", package =
"flowTime"))
annotateFlowSet(dat, annotation, mergeBy = "name")
```

| | |
|------------------|---------------------------------------|
| createAnnotation | <i>Create an annotation dataframe</i> |
|------------------|---------------------------------------|

Description

Creates a data frame with rows containing the sample names of your flow set that can then be filled in with experimental metadata.

Usage

```
createAnnotation(yourFlowSet)
```

Arguments

yourFlowSet the flowSet to create an annotation data frame for

Value

annotation_df a data frame containing the sample names of your flow set

Examples

```
dat <- read.flowSet(path = system.file("extdata", "ss_example",
package = "flowTime"), alter.names = TRUE)
annotation <- createAnnotation(yourFlowSet = dat)
head(annotation)
```

| | |
|----------------|---|
| dipdoubletGate | <i>A gate for the set of all diploid doublets</i> |
|----------------|---|

Description

A gate for the set of all diploid doublets

Usage

```
data(dipdoubletGate)
```

Format

formal class polygonGate

| | |
|----------------|--|
| dipsingletGate | <i>A gate for the set of all diploid singlet yeast cells</i> |
|----------------|--|

Description

Typically set in FSC.A by FSC.H space Diploids are typically 5um x 6um ellipsoids while haploids are typically 4um x 4um spheroids. As a result, diploids are longer and you get a larger 'area/volume'.

Usage

```
data(dipsingletGate)
```

Format

```
formal class polygonGate
```

| | |
|-----------|--|
| flsummary | <i>Get summary statistics for fluorescence or other data channels of a flowSet</i> |
|-----------|--|

Description

Get summary statistics for fluorescence or other data channels of a flowSet

Usage

```
flsummary(flowset, channel)
```

Arguments

| | |
|---------|--|
| flowset | the flowSet to create summary statistics for |
| channel | option character vector of the data channel(s) to summarize. By default all channels will be summarized. Setting channels does not reduce computation time |

Value

A data frame containing summary statistics (mean, median, SD) for the specified fluorescent channel and time moments of the flowSet.

Examples

```
plate1 <- read.flowSet(path = system.file("extdata",
"ss_example", package = "flowTime"), alter.names = TRUE)
flsummary(flowset = plate1, channel = "FL1.A")
```

| | |
|---------|--|
| getTime | <i>Get the time at which at flowFrame began collection</i> |
|---------|--|

Description

Get the time at which at flowFrame began collection

Usage

```
getTime(flowframe)
```

Arguments

flowframe The flowFrame for which you would like the initial time

Value

numeric time value in minutes

Examples

```
plate1<-read.flowSet(path = system.file("extdata", "ss_example", package =  
"flowTime"),alter.names = TRUE)  
getTime(plate1$A01.fcs)
```

| | |
|----------------|---|
| hapdoubletGate | <i>A gate for the set of all haploid doublets</i> |
|----------------|---|

Description

A gate for the set of all haploid doublets

Usage

```
data(hapdoubletGate)
```

Format

formal class polygonGate

| | |
|----------------|---|
| hapsingletGate | <i>A gate for the set of all haploid singlets</i> |
|----------------|---|

Description

A gate for the set of all haploid singlets

Usage

```
data(hapsingletGate)
```

Format

formal class polygonGate

| | |
|-----------|-------------------------------|
| loadGates | <i>Load a yeast gate file</i> |
|-----------|-------------------------------|

Description

Loads a set of yeast gates into active memory to be used in analysis functions

Usage

```
loadGates(gatesFile = NULL, path = NULL, envir = environment())
```

Arguments

| | |
|-----------|---|
| gatesFile | the gates file to be loaded into memory, or path to the gates file |
| path | The path to the gates file. If 'NULL' this will look through lazy loaded data for the gatesFile |
| envir | The environment in which to load the gates |

Value

gate objects created in the current environment

Examples

```
loadGates(system.file("extdata/SORPGates.RData", package = "flowTime"))
```

| | |
|--------------|---|
| meanMedianSD | <i>Summary statistic columns for a flow frame</i> |
|--------------|---|

Description

Summary statistic columns for a flow frame

Usage

```
meanMedianSD(frame)
```

Arguments

frame a flowFrame

Value

a matrix with a single row for the flow frame and mean, median, and sd columns for each column of the expression measurements

Examples

```
plate1<-read.flowSet(path = system.file("extdata", "ss_example", package =  
"flowTime"), alter.names = TRUE)  
meanMedianSD(plate1@frames$A01.fcs)  
fsApply(plate1, meanMedianSD)
```

| | |
|--------|--|
| ploidy | <i>Guess the ploidy of a given flowframe</i> |
|--------|--|

Description

Use the FSC.A/FSC.H ratio. Diploids are typically 5um x 6um ellipsoids while haploids are typically 4um x 4um spheroids. As a result, diploids are longer and you get a larger 'area/volume' FSC.A. 'Width' might also be useful on certain cytometers.

Usage

```
ploidy(flowframe)
```

Arguments

flowframe the flowFrame you would like to identify the ploidy of

Value

"Diploid" or "Haploid" and the mean FSC.A/FSC.H quotient

Examples

```
dat <- read.flowSet(path = system.file("extdata", "ss_example",
package = "flowTime"), alter.names = TRUE)
ploidy(dat$A01.fcs)
```

polyGate*Create a polygon gate*

Description

Create a polygon gate

Usage

```
polyGate(x, y, filterID = "newGate", channels = c("FSC.A", "FSC.H"))
```

Arguments

| | |
|----------|---|
| x | a vector of x coordinates |
| y | a vector of y coordinates |
| filterID | name of the gate |
| channels | vector containing the channels matching the x and y coordinates above |

Value

a polygon gate object

Examples

```
polyGate(x = c(1,1,10000,10000), y = c(1,10000, 10000, 1), )
```

qaGating*Quality assurance check*

Description

Check whether a flowSet (or a single flowFrame) contains empty values, in which case normalization may fail (divide by zero). This is particularly useful for removing wash wells from a flowSet.

Usage

```
qaGating(x, threshold = 100)
```

Arguments

| | |
|-----------|--|
| x | flowSet or flowFrame to be checked |
| threshold | flowFrames with fewer events than this threshold will be identified. |

Value

A vector containing the flowFrames with fewer events than the threshold.

Examples

```
plate1<-read.flowSet(path = system.file("extdata", "ss_example", package =
"flowTime"), alter.names = TRUE)
qaGating(plate1)
```

| | |
|---------------|--|
| read.plateSet | <i>Read FCS files from set of plates</i> |
|---------------|--|

Description

Reads all folders within the specified path containing the specified pattern in the folder names. Each folder contains a set a plate of FCS files. These folders typically make up a whole experiment. Plates are numbered according to the standard lexicographical ordering of your operating system.

Usage

```
read.plateSet(path = getwd(), pattern = "", ...)
```

Arguments

| | |
|---------|---|
| path | The path to search for folders containing FCS files |
| pattern | The regex pattern used to identify the folders of FCS files to be read |
| ... | Additional arguments passed to read.flowSet. Note that ‘alter.names’ is forced to be TRUE in this implementation. |

Value

A single flowSet containing all FCS files within the identified folders. The index of each folder in the list according to lexicographical ordering (1,2,...) is prepended to the sampleNames.

Examples

```
# Read in both of the example data sets as a single flowSet
plate1<-read.plateSet(path = system.file("extdata", package = "flowTime"),
pattern = "")
```

`saveGates`*Save a yeast gate set*

Description

Save a yeast gate set

Usage

```
saveGates(  
  yeastGate = NULL,  
  dipsingletGate = NULL,  
  dipdoubletGate = NULL,  
  hapsingletGate = NULL,  
  hapdoubletGate = NULL,  
  path = getwd(),  
  fileName = "defaultGates.RData"  
)
```

Arguments

`yeastGate` a gate object defining the population of yeast cells
`dipsingletGate` a gate object defining the population of diploid singlet cells
`dipdoubletGate` a gate object defining the population of diploid doublet cells
`hapsingletGate` a gate object defining the population of haploid singlet cells
`hapdoubletGate` a gate object defining the population of haploid doublet cells
`path` path to the folder in which you would like to save the gates
`fileName` name of the .Rdata file you would like to save these gates within

Value

a .RData file in the "extdata" folder of the package containing the specified gates

Examples

```
loadGates(system.file("extdata/SORPGates.RData", package = "flowTime"))  
#not run:  
#saveGates()
```

| | |
|-------------|---|
| steadyState | <i>Analysis of steady state fluorescence flow cytometry</i> |
|-------------|---|

Description

Generates a data frame which can be used to visualize and analyze steady state flow cytometry data. Steady state in this case means that

Usage

```
steadyState(flowset, gated = FALSE, ploidy = NA, only = NA)
```

Arguments

| | |
|---------|--|
| flowset | your flowSet to be analyzed |
| gated | boolean is the data already gated? |
| ploidy | character gate to subset your flowset based on the ploidy of you strains |
| only | character which population of events to analyze, 'yeast', 'singlets', or 'doublets'? |

Value

a data frame containing all of the selected subset of events from the original flowSet

Examples

```
dat <- read.flowSet(path = system.file("extdata", "ss_example",
package = "flowTime"), alter.names = TRUE)
annotation <- read.csv(system.file("extdata", "ss_example.csv",
package = "flowTime"))
dat <- annotateFlowSet(dat, annotation, mergeBy = "name")
loadGates(gatesFile = 'SORPGates')
steadyState(dat, gated = FALSE, ploidy = "diploid", only = "singlets")
```

| | |
|---------------|--|
| summarizeFlow | <i>Generate summary statistics for a flowSet</i> |
|---------------|--|

Description

Gates a sample to all yeast, then singlet, then doublets. Also calculates singlet to doublet ratio. Returns a list of data frames, e.g. output\$singlets, output\$doublets, etc.

Usage

```
summarizeFlow(
  flowset,
  channel = NA,
  gated = FALSE,
  ploidy = FALSE,
  only = FALSE
)
```

Arguments

| | |
|---------|--|
| flowset | the flowSet to be summarized |
| channel | character vector which data channel(s) should be summarized? If excluded (or NA) all channels will be summarized (default) |
| gated | boolean is the data already appropriately gated? |
| ploidy | character does the flowSet contain haploid or diploid cells? |
| only | character summarize only "singlet", "doublet", or all "yeast" cells, FALSE will return all |

Value

data frame containing the specified summary statistics of the specified cell populations for each frame

Examples

```
plate1 <- read.flowSet(path = system.file("extdata", "ss_example",
package = "flowTime"), alter.names = TRUE)
summarizeFlow(plate1, channel = "FL1.A", gated = TRUE,
ploidy = "diploid", only = "yeast")
```

tidyFlow

Generate a tidy dataset from time-course flow cytometry data

Description

Generates a tibble containing all parameters and phenoData from a flowSet which can be used to visualize and analyze timecourse flow cytometry data.

Usage

```
tidyFlow(flowset, gated = FALSE, ploidy = NA, only = NA)
```

Arguments

| | |
|---------|--|
| flowset | your flowSet to be analyzed |
| gated | boolean is the data already gated? |
| ploidy | character gate to subset your flowset based on the ploidy of you strains |
| only | character which population of events to analyze, 'yeast', 'singlets', or 'doublets'? |

Value

a data frame containing all of the selected subset of events from the original flowSet for all parameters including experiment time, etime, the time after the initial reading at which each event was collected.

Examples

```
plate1<-read.flowSet(path=system.file("extdata", "tc_example",  
package = "flowTime"), alter.names = TRUE)  
annotation <- read.csv(system.file("extdata", "tc_example.csv",  
package = "flowTime"))  
plate1 <- annotateFlowSet(plate1, annotation)  
tidy_dat <- tidyFlow(plate1, gated = TRUE)  
head(tidy_dat)
```

yeastGate

A gate for the set of all yeast cells

Description

Typically set in FSC.A by SSC.A space to excluded any debris

Usage

```
data(yeastGate)
```

Format

formal class polygonGate

Index

* datasets

- dipdoubletGate, [5](#)
- dipsingletGate, [6](#)
- hapdoubletGate, [7](#)
- hapsingletGate, [8](#)
- yeastGate, [15](#)

addbs, [2](#)

addnorm, [3](#)

annotateFlowSet, [4](#)

createAnnotation, [5](#)

dipdoubletGate, [5](#)

dipsingletGate, [6](#)

flsummary, [6](#)

getTime, [7](#)

hapdoubletGate, [7](#)

hapsingletGate, [8](#)

loadGates, [8](#)

meanMedianSD, [9](#)

ploidy, [9](#)

polyGate, [10](#)

qaGating, [10](#)

read.plateSet, [11](#)

regex, [11](#)

saveGates, [12](#)

steadyState, [13](#)

summarizeFlow, [13](#)

tidyFlow, [14](#)

yeastGate, [15](#)