

Package ‘CytoGLMM’

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Type Package

Title Conditional Differential Analysis for Flow and Mass Cytometry Experiments

Version 1.18.0

Description The CytoGLMM R package implements two multiple regression strategies: A bootstrapped generalized linear model (GLM) and a generalized linear mixed model (GLMM). Most current data analysis tools compare expressions across many computationally discovered cell types. CytoGLMM focuses on just one cell type. Our narrower field of application allows us to define a more specific statistical model with easier to control statistical guarantees. As a result, CytoGLMM finds differential proteins in flow and mass cytometry data while reducing biases arising from marker correlations and safeguarding against false discoveries induced by patient heterogeneity.

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URL <https://christofseiler.github.io/CytoGLMM>,
<https://github.com/ChristofSeiler/CytoGLMM>

BugReports <https://github.com/ChristofSeiler/CytoGLMM/issues>

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Imports stats, methods, BiocParallel, RColorBrewer, cowplot,
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mbest, pheatmap, stringr, strucchange, tibble, ggrepel, MASS,
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Contents

cytoflexmix	2
cytoglm	4
cytoglmm	5
cytogroup	6
cytostab	7
cyto_check	8
generate_data	9
glmm_moment	9
is_unpaired	10
plot.cytoflexmix	10
plot.cytoglm	11
plot.cytoglmm	12
plot.cyttogroup	13
plot_coeff	13
plot_heatmap	14
plot_lda	15
plot_mds	16
plot_model_selection	17
plot_prcomp	18
print.cytoglm	18
print.cytoglmm	19
remove_samples	20
summary.cytoglm	20
summary.cytoglmm	21
Index	22

cytoflexmix	<i>Logistic mixture regression</i>
-------------	------------------------------------

Description

Logistic mixture regression

Usage

```
cytoflexmix(  
  df_samples_subset,  
  protein_names,  
  condition,  
  group = "donor",  
  cell_n_min = Inf,  
  cell_n_subsample = 0,
```

```

    ks = seq_len(10),
    num_cores = 1
  )

```

Arguments

<code>df_samples_subset</code>	Data frame or tibble with proteins counts, cell condition, and group information
<code>protein_names</code>	A vector of column names of protein to use in the analysis
<code>condition</code>	The column name of the condition variable
<code>group</code>	The column name of the group variable
<code>cell_n_min</code>	Remove samples that are below this cell counts threshold
<code>cell_n_subsample</code>	Subsample samples to have this maximum cell count
<code>ks</code>	A vector of cluster sizes
<code>num_cores</code>	Number of computing cores

Value

A list of class `cytoglm` containing

<code>flexmixfits</code>	list of <code>flexmix</code> objects
<code>df_samples_subset</code>	possibly subsampled <code>df_samples_subset</code> table
<code>protein_names</code>	input protein names
<code>condition</code>	input condition variable
<code>group</code>	input group names
<code>cell_n_min</code>	input <code>cell_n_min</code>
<code>cell_n_subsample</code>	input <code>cell_n_subsample</code>
<code>ks</code>	input <code>ks</code>
<code>num_cores</code>	input <code>num_cores</code>

Examples

```

set.seed(23)
df <- generate_data()
protein_names <- names(df)[3:12]
df <- dplyr::mutate_at(df, protein_names, function(x) asinh(x/5))
mix_fit <- CytoGLMM::cytoflexmix(df,
                                protein_names = protein_names,
                                condition = "condition",
                                group = "donor",
                                ks = 2)

mix_fit

```

cytoglm

*Fit GLM with bootstrap resampling***Description**

Fit GLM with bootstrap resampling

Usage

```
cytoglm(
  df_samples_subset,
  protein_names,
  condition,
  group = "donor",
  covariate_names = NULL,
  cell_n_min = Inf,
  cell_n_subsample = 0,
  num_boot = 100,
  num_cores = 1
)
```

Arguments

<code>df_samples_subset</code>	Data frame or tibble with proteins counts, cell condition, and group information
<code>protein_names</code>	A vector of column names of protein to use in the analysis
<code>condition</code>	The column name of the condition variable
<code>group</code>	The column name of the group variable
<code>covariate_names</code>	The column names of covariates
<code>cell_n_min</code>	Remove samples that are below this cell counts threshold
<code>cell_n_subsample</code>	Subsample samples to have this maximum cell count
<code>num_boot</code>	Number of bootstrap samples
<code>num_cores</code>	Number of computing cores

ValueA list of class `cytoglm` containing

<code>tb_coef</code>	coefficient table
<code>df_samples_subset</code>	possibly subsampled <code>df_samples_subset</code> table
<code>protein_names</code>	input protein names
<code>condition</code>	input condition variable
<code>group</code>	input group names
<code>covariate_names</code>	input covariates

```

cell_n_min      input cell_n_min
cell_n_subsample      input cell_n_subsample

unpaired        true if unpaired samples were provided as input
num_boot        input num_boot
num_cores       input num_cores
formula_str     formula use in the regression model

```

Examples

```

set.seed(23)
df <- generate_data()
protein_names <- names(df)[3:12]
df <- dplyr::mutate_at(df, protein_names, function(x) asinh(x/5))
glm_fit <- CytoGLMM::cytoglm(df,
                             protein_names = protein_names,
                             condition = "condition",
                             group = "donor",
                             num_boot = 10) # in practice >=1000

glm_fit

```

cytoglmm

Fit GLMM with method of moments

Description

Fit GLMM with method of moments

Usage

```

cytoglmm(
  df_samples_subset,
  protein_names,
  condition,
  group = "donor",
  covariate_names = NULL,
  cell_n_min = Inf,
  cell_n_subsample = 0,
  num_cores = 1
)

```

Arguments

```

df_samples_subset      Data frame or tibble with proteins counts, cell condition, and group information
protein_names          A vector of column names of protein to use in the analysis
condition              The column name of the condition variable
group                  The column name of the group variable
covariate_names        The column names of covariates

```

cell_n_min Remove samples that are below this cell counts threshold
cell_n_subsample Subsample samples to have this maximum cell count
num_cores Number of computing cores

Value

A list of class `cytoglm` containing

glmmfit `mbest` object
df_samples_subset possibly subsampled `df_samples_subset` table
protein_names input protein names
condition input condition variable
group input group names
covariate_names input covariates
cell_n_min input cell_n_min
cell_n_subsample input cell_n_subsample
num_cores input num_cores

Examples

```
set.seed(23)
df <- generate_data()
protein_names <- names(df)[3:12]
df <- dplyr::mutate_at(df, protein_names, function(x) asinh(x/5))
glmm_fit <- CytoGLMM::cytoglm(df,
                               protein_names = protein_names,
                               condition = "condition",
                               group = "donor")

glmm_fit
```

cytogroup	<i>Group-specific fixed effects model</i>
-----------	---

Description

Group-specific fixed effects model

Usage

```
cytogroup(
  df_samples_subset,
  protein_names,
  condition,
  group = "donor",
  cell_n_min = Inf,
  cell_n_subsample = 0
)
```

Arguments

<code>df_samples_subset</code>	Data frame or tibble with proteins counts, cell condition, and group information
<code>protein_names</code>	A vector of column names of protein to use in the analysis
<code>condition</code>	The column name of the condition variable
<code>group</code>	The column name of the group variable
<code>cell_n_min</code>	Remove samples that are below this cell counts threshold
<code>cell_n_subsample</code>	Subsample samples to have this maximum cell count

Value

A list of class `cytoglm` containing

<code>groupfit</code>	<code>glm</code> object
<code>df_samples_subset</code>	possibly subsampled <code>df_samples_subset</code> table
<code>protein_names</code>	input protein names
<code>condition</code>	input condition variable
<code>group</code>	input group names
<code>cell_n_min</code>	input <code>cell_n_min</code>
<code>cell_n_subsample</code>	input <code>cell_n_subsample</code>

Examples

```
set.seed(23)
df <- generate_data()
protein_names <- names(df)[3:12]
df <- dplyr::mutate_at(df, protein_names, function(x) asinh(x/5))
group_fit <- CytoGLMM::cytogroup(df,
                                protein_names = protein_names,
                                condition = "condition",
                                group = "donor")

group_fit
```

cytostab

Evaluate parameter stability with respect to gating scheme

Description

Evaluate parameter stability with respect to gating scheme

Usage

```
cytostab(
  df_samples_subset,
  protein_names,
  condition,
  group = "donor",
  cell_n_min = Inf,
  cell_n_subsample = 0
)
```

Arguments

<code>df_samples_subset</code>	Data frame or tibble with proteins counts, cell condition, and group information
<code>protein_names</code>	A vector of column names of protein to use in the analysis
<code>condition</code>	The column name of the condition variable
<code>group</code>	The column name of the group variable
<code>cell_n_min</code>	Remove samples that are below this cell counts threshold
<code>cell_n_subsample</code>	Subsample samples to have this maximum cell count

Value

A data frame

Examples

```
set.seed(23)
df <- generate_data()
protein_names <- names(df)[3:12]
df <- dplyr::mutate_at(df, protein_names, function(x) asinh(x/5))
stab <- CytoGLMM::cytostab(df,
                           protein_names = protein_names,
                           condition = "condition",
                           group = "donor")

stab
```

cyto_check

Check if input to cytoxxx function have errors

Description

Check if input to cytoxxx function have errors

Usage

```
cyto_check(cell_n_subsample, cell_n_min, protein_names)
```

Arguments

cell_n_subsample Subsample samples to have this maximum cell count

cell_n_min A vector of column names of protein to use in the analysis

protein_names A vector of column names of protein to use in the analysis

Value

NULL.

generate_data	<i>Generate dataset for vignettes and simulation studies</i>
---------------	--

Description

Generate dataset for vignettes and simulation studies

Usage

```
generate_data()
```

Value

`tibble` data frame

Examples

```
set.seed(23)
df <- generate_data()
str(df)
df
```

glmm_moment	<i>Generalized linear mixed model with maximum likelihood</i>
-------------	---

Description

Generalized linear mixed model with maximum likelihood

Usage

```
glmm_moment(
  df_samples,
  protein_names,
  response,
  group = "donor",
  covariate_names = NULL,
  num_cores = 1
)
```

Arguments

df_samples	Data frame or tibble with proteins counts, cell condition, and group information
protein_names	A vector of column names of protein to use in the analysis
response	The column name of the condition variable
group	The column name of the group variable
covariate_names	The column names of covariates
num_cores	Number of computing cores

Value

`mbest` object

is_unpaired	<i>Check if samples match or paired on condition</i>
-------------	--

Description

Check if samples match or paired on condition

Usage

```
is_unpaired(df_samples_subset, condition, group)
```

Arguments

df_samples_subset	Data frame or tibble with proteins counts, cell condition, and group information
condition	The column name of the condition variable
group	The column name of the group variable

Value

A boolean

plot.cytoflexmix	<i>Plot all components of mixture regression</i>
------------------	--

Description

Plot all components of mixture regression

Usage

```
## S3 method for class 'cytoflexmix'
plot(x, k = NULL, separate = FALSE, ...)
```

Arguments

x	A cytoflexmix class
k	Number of clusters
separate	create two separate ggplot2 objects
...	Other parameters

Value

[ggplot2](#) object

Examples

```
set.seed(23)
df <- generate_data()
protein_names <- names(df)[3:12]
df <- dplyr::mutate_at(df, protein_names, function(x) asinh(x/5))
mix_fit <- CytoGLMM::cytoflexmix(df,
                                protein_names = protein_names,
                                condition = "condition",
                                group = "donor",
                                ks = 2)

plot(mix_fit)
```

plot.cytoglm	<i>Plot bootstraped coefficients</i>
--------------	--------------------------------------

Description

Plot bootstraped coefficients

Usage

```
## S3 method for class 'cytoglm'
plot(x, order = FALSE, separate = FALSE, ...)
```

Arguments

x	A cytoglm class
order	Order the markers according to the mangintute of the coefficients
separate	create two separate ggplot2 objects
...	Other parameters

Value

[ggplot2](#) object

```
set.seed(23)
df <- generate_data()
protein_names <- names(df)[3:12]
df <- dplyr::mutate_at(df, protein_names, function(x) asinh(x/5))
glm_fit <- CytoGLMM::cytoglm(df,
                              protein_names = protein_names,
                              condition = "condition",
                              group = "donor",
                              num_boot = 10) # in practice >=1000
plot(glm_fit)
```

plot.cytoglmm	<i>Plot fixed coefficients of random effects model</i>
---------------	--

Plot fixed coefficients of random effects model

```
## S3 method for class 'cytoglmm'
plot(x, order = FALSE, separate = FALSE, ...)
```

x	A cytoglmm class
order	Order the markers according to the mangintute of the coefficients
separate	create two separate <code>ggplot2</code> objects
...	Other parameters

ggplot2 object

[illegible]

plot.cytogroup	<i>Plot fixed coefficients of group-specific fixed effects model</i>
----------------	--

Description

Plot fixed coefficients of group-specific fixed effects model

Usage

```
## S3 method for class 'cytgroup'
plot(x, order = FALSE, separate = FALSE, ...)
```

Arguments

x	A cytoglmm class
order	Order the markers according to the magnitude of the coefficients
separate	create two separate ggplot2 objects
...	Other parameters

Value

[ggplot2](#) object

Examples

```
set.seed(23)
df <- generate_data()
protein_names <- names(df)[3:12]
df <- dplyr::mutate_at(df, protein_names, function(x) asinh(x/5))
group_fit <- CytoGLMM::cytgroup(df,
                                protein_names = protein_names,
                                condition = "condition",
                                group = "donor")

plot(group_fit)
```

plot_coeff	<i>Helper function to plot regression coefficient</i>
------------	---

Description

Helper function to plot regression coefficient

Usage

```
plot_coeff(
  tb,
  title_str,
  title_str_right,
  xlab_str,
  redline = 0,
  order = FALSE,
  separate = FALSE
)
```

Arguments

tb	A data frame
title_str	Title string for summary plot
title_str_right	Title for bootstrap sample plot
xlab_str	Label on x-axis
redline	Point on x-axis to draw the red line
order	Order the markers according to the magnitude of the coefficients
separate	Plot both summary and bootstrap samples

Value

[ggplot2](#) object or list of two objects if separate is true

plot_heatmap	<i>Heatmap of median marker expression</i>
--------------	--

Description

Heatmap of median marker expression

Usage

```
plot_heatmap(
  df_samples,
  sample_info_names,
  protein_names,
  arrange_by_1,
  arrange_by_2 = "",
  cluster_cols = FALSE,
  fun = median
)
```

Arguments

df_samples	Data frame or tibble with proteins counts, cell condition, and group information
sample_info_names	Column names that contain information about the cell, e.g. donor, condition, file name, or cell type
protein_names	A vector of column names of protein to use in the analysis
arrange_by_1	Column name
arrange_by_2	Column name
cluster_cols	Apply hierarchical cluster to columns
fun	Summary statistics of marker expression

Value

`pheatmap` object

Examples

```
set.seed(23)
df <- generate_data()
protein_names <- names(df)[3:12]
df <- dplyr::mutate_at(df, protein_names, function(x) asinh(x/5))
CytoGLMM::plot_heatmap(df,
  protein_names = protein_names,
  sample_info_names = c("donor", "condition"),
  arrange_by_1 = "condition")
```

plot_lda

LDA on marker expression

Description

LDA on marker expression

Usage

```
plot_lda(
  df_samples,
  protein_names,
  group,
  cor_scaling_factor = 1,
  arrow_color = "black",
  marker_color = "black",
  marker_size = 5
)
```

Arguments

df_samples	Data frame or tibble with proteins counts, cell condition, and group information
protein_names	A vector of column names of protein to use in the analysis
group	The column name of the group variable
cor_scaling_factor	Scaling factor of circle of correlations
arrow_color	Color of correlation circle
marker_color	Colors of marker names
marker_size	Size of markerr names

Value

`ggplot2` object

Examples

```
set.seed(23)
df <- generate_data()
protein_names <- names(df)[3:12]
df <- dplyr::mutate_at(df, protein_names, function(x) asinh(x/5))
df$condition <- rep(c("A", "B", "C", "D"), each = length(df$condition)/4)
CytoGLMM::plot_lda(df,
                    protein_names = protein_names,
                    group = "condition",
                    cor_scaling_factor = 2)
```

plot_mds	<i>MDS on median marker expression</i>
----------	--

Description

MDS on median marker expression

Usage

```
plot_mds(
  df_samples,
  protein_names,
  sample_info_names,
  color,
  sample_label = ""
)
```

Arguments

df_samples	Data frame or tibble with proteins counts, cell condition, and group information
protein_names	A vector of column names of protein to use in the analysis
sample_info_names	Column names that contain information about the cell, e.g. donor, condition, file name, or cell type
color	Column name
sample_label	Column name

Value

cowplot object

Examples

```
set.seed(23)
df <- generate_data()
protein_names <- names(df)[3:12]
df <- dplyr::mutate_at(df, protein_names, function(x) asinh(x/5))
CytoGLMM::plot_mds(df,
  protein_names = protein_names,
  sample_info_names = c("donor", "condition"),
  color = "condition")
```

plot_model_selection *Plot model selection to choose number optimal number of clusters*

Description

Plot model selection to choose number optimal number of clusters

Usage

```
plot_model_selection(fit, k = NULL)
```

Arguments

fit	A cytoflexmix class
k	Number of clusters

Value

cowplot object

Examples

```
set.seed(23)
df <- generate_data()
protein_names <- names(df)[3:12]
df <- dplyr::mutate_at(df, protein_names, function(x) asinh(x/5))
mix_fit <- CytoGLMM::cytoflexmix(df,
  protein_names = protein_names,
  condition = "condition",
  group = "donor",
  ks = 1:2)

plot_model_selection(mix_fit)
```

plot_prcomp	<i>Plot PCA of subsampled data using ggplot</i>
-------------	---

Description

Plot PCA of subsampled data using ggplot

Usage

```
plot_prcomp(
  df_samples,
  protein_names,
  color_var = "treatment",
  subsample_size = 10000,
  repel = TRUE
)
```

Arguments

df_samples	Data frame or tibble with proteins counts, cell condition, and group information
protein_names	A vector of column names of protein to use in the analysis
color_var	A column name
subsample_size	Subsample per color_var variable
repel	Repel labels

Value

cowplot object

Examples

```
set.seed(23)
df <- generate_data()
protein_names <- names(df)[3:12]
df <- dplyr::mutate_at(df, protein_names, function(x) asinh(x/5))
CytoGLMM::plot_prcomp(df,
  protein_names = protein_names,
  color_var = "condition")
```

print.cytoglm	<i>Extact and print bootstrap GLM fit</i>
---------------	---

Description

Extact and print bootstrap GLM fit

Usage

```
## S3 method for class 'cytoglm'
print(x, ...)
```

Arguments

x	A cytoglm class
...	Other parameters

Value

NULL.

Examples

```
set.seed(23)
df <- generate_data()
protein_names <- names(df)[3:12]
df <- dplyr::mutate_at(df, protein_names, function(x) asinh(x/5))
glm_fit <- CytoGLMM::cytoglm(df,
                              protein_names = protein_names,
                              condition = "condition",
                              group = "donor",
                              num_boot = 10) # in practice >=1000
print(glm_fit)
```

```
print.cytoglmm
```

Extact and print GLMM fit

Description

Extract and print GLMM fit

Usage

```
## S3 method for class 'cytoglmm'
print(x, ...)
```

Arguments

x	A cytoglmm class
...	Other parameters

Value

NULL.

Examples

[illegible]

remove_samples	<i>Remove samples based on low cell counts</i>
----------------	--

Description

Remove samples based on low cell counts

Usage

```
remove_samples(df_samples_subset, condition, group, unpaired, cell_n_min)
```

Arguments

df_samples_subset	Data frame or tibble with proteins counts, cell condition, and group information
condition	The column name of the condition variable
group	The column name of the group variable
unpaired	true if unpaired samples were provided as input
cell_n_min	Remove samples that are below this cell counts threshold

Value

NULL.

summary.cytoglm	<i>Extact and calculate p-values of bootstrap GLM fit</i>
-----------------	---

Description

Extact and calculate p-values of bootstrap GLM fit

Usage

```
## S3 method for class 'cytoglm'
summary(object, method = "BH", ...)
```

Arguments

object	A cytoglm class
method	Multiple comparison adjustment method
...	Other parameters

Value

[tibble](#) data frame

Index

cowplot, [17](#), [18](#)
cyto_check, [8](#)
cytoflexmix, [2](#)
cytoglm, [4](#)
cytoglmm, [5](#)
cytogroup, [6](#)
cytostab, [7](#)

flexmix, [3](#)

generate_data, [9](#)
ggplot2, [11–14](#), [16](#)
glm, [7](#)
glmm_moment, [9](#)

is_unpaired, [10](#)

mbest, [6](#), [10](#)

pheatmap, [15](#)
plot.cytoflexmix, [10](#)
plot.cytoglm, [11](#)
plot.cytoglmm, [12](#)
plot.cytogroup, [13](#)
plot_coeff, [13](#)
plot_heatmap, [14](#)
plot_lda, [15](#)
plot_mds, [16](#)
plot_model_selection, [17](#)
plot_prcomp, [18](#)
print.cytoglm, [18](#)
print.cytoglmm, [19](#)

remove_samples, [20](#)

summary.cytoglm, [20](#)
summary.cytoglmm, [21](#)

tibble, [9](#), [20](#), [21](#)