Package 'GrowthCurveME'

October 23, 2024

Title Mixed-Effects Modeling for Cellular Growth Data

Version 0.0.1

Description This is an R package that provides user-friendly
wrappers to the saemix package for performing linear and non-linear
mixed-effects regression modeling for in-vitro growth-assay data to
account for clustering or longitudinal analysis via repeated
measurements. The package allows users to fit a variety of growth
models, including linear, exponential, logistic, and Gompertz
functions. For non-linear models, starting values are automatically
calculated. The package includes functions for summarizing models,
visualizing data and results, calculating doubling time and other key
statistics, and generating model diagnostic plots and residual summary
statistics. It also provides functions for generating
publication-ready summary tables for reports. Additionally, users can
fit linear and non-linear least-squares regression models if
clustering is not applicable.

License GPL (>= 3)

Depends R (>= 3.6.0)

Imports dplyr (>= 1.1.4),
flextable (>= 0.9.6),
ggplot2 (>= 3.5.1),
knitr (>= 1.46),
magrittr (>= 2.0.3),
minpack.lm (>= 1.2-4),
moments (>= 0.14.1),
nlraa (>= 1.9.7),
patchwork (>= 1.2.0),
rlang (>= 1.1.3),
saemix (>= 3.3),
stringr (>= 1.5.1),
tibble (>= 3.2.1),
tidyr (>= 1.3.1),
viridis (>= 0.6.5)

Suggests rmarkdown (>= 2.27),
testthat (>= 3.2.1.1)

Encoding UTF-8

LazyData true

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RoxygenNote 7.3.2

Config/testthat/edition 3

Contents

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exponential_mixed_model

Fit an exponential mixed-effects regression model

Description

'exponential_mixed_model()' is a function utilized with the `growth_curve_model_fit` function for fitting a mono-exponential mixed-effects regression model to growth data utilizing the saemix package. Starting values are derived from an initial least-squares model using the `nlsLM` function.

Usage

```
exponential_mixed_model(
  data_frame,
  model_type = "mixed",
  fixed_rate = TRUE,
  num_chains = 1
)
```

Arguments

data_frame   A data frame object that at minimum contains three variables:

- cluster - a character type variable used to specify how observations are nested or grouped by a particular cluster. Note if using a least-squares model, please fill in all values of cluster with a single dummy character string, do NOT leave blank.
- time - a numeric type variable used for measuring time such as minutes, hours, or days

- growth_metric - a numeric type variable used for measuring growth over time such as cell count or confluency

model_type   A character string specifying the type of regression model to be used. If "mixed" a mixed-effects regression model will be used with fixed and random effects to account for clustering. Defaults to "mixed".

fixed_rate   A logical value specifying whether the rate constant of the function should be treated as a fixed effect (TRUE) or random effect (FALSE). Defaults to TRUE

num_chains   A numeric value specifying the number of chains to run in parallel in the MCMC algorithm of saemix. Defaults to 1.

Value

Returns an exponential model object of class 'saemix' when a mixed-effects model is specified or a model object of class 'nls' if a least-squares model is specified.

See Also

growth_curve_model_fit

Examples

```
# Load example data (exponential data from GrowthCurveME package)
data(exp_mixed_data)
# Fit an exponential mixed-effects growth model
exp_mixed_model <- growth_curve_model_fit(
  data_frame = exp_mixed_data,
  function_type = "exponential"
)
# Fit an exponential mixed-effected model using exponential_mixed_model()
exp_mixed_model <- exponential_mixed_model(data_frame = exp_mixed_data)
```

---

exp_mixed_data   *Sample exponential growth dataset*

Description

A dataset containing the minimum required variables needed to input data into the GrowthModelME package functions

Usage

```
exp_mixed_data
```

Format

A data frame with 240 rows and 3 variables:

cluster A character type variable used to specify the clustering of values by a particular metric. Note when selecting a least-squares model instead of a mixed-effects model, do not leave this variable NA, fill in this values for this variable with 1 repative dummy variable for the package to run properly

time A numeric type variable for any measurement in time such as minutes, hours, or days

growth_metric A numeric type variable for measuring growth such as confluency or cell count

Source

Created through simulation to serve as an example

Examples

```
data(exp_mixed_data)
```

---

gompertz_mixed_model   *Fit a Gompertz mixed-effects regression model*

Description

'gompertz_mixed_model()' is a function utilized with the growth_curve_model_fit function for fitting a Gompertz mixed-effects regression model to growth data utilizing the saemix package. Starting values are derived from an initial least-squares model using the nlsLM function.

Usage

```
gompertz_mixed_model(
  data_frame,
  model_type = "mixed",
  fixed_rate = TRUE,
  num_chains = 1
)
```

Arguments

data_frame	A data frame object that at minimum contains three variables:
	• cluster - a character type variable used to specify how observations are nested or grouped by a particular cluster. Note if using a least-squares model, please fill in all values of cluster with a single dummy character string, do NOT leave blank.
	• time - a numeric type variable used for measuring time such as minutes, hours, or days
	• growth_metric - a numeric type variable used for measuring growth over time such as cell count or confluency
model_type	A character string specifying the type of regression model to be used. If "mixed" a mixed-effects regression model will be used with fixed and random effects to account for clustering. Defaults to "mixed".
fixed_rate	A logical value specifying whether the rate constant of the function should be treated as a fixed effect (TRUE) or random effect (FALSE). Defaults to TRUE
num_chains	A numeric value specifying the number of chains to run in parallel in the MCMC algorithm of saemix. Defaults to 1.

Value

Returns a Gompertz model object of class 'saemix' when a mixed-effects model is specified or a model object of class 'nls' if a least-squares model is specified.

See Also

[growth_curve_model_fit](#)

Examples

```
# Load example data (Gompertz data from GrowthCurveME package)
data(gomp_mixed_data)
# Fit a Gompertz mixed-effects growth model
gomp_mixed_model <- growth_curve_model_fit(
  data_frame = gomp_mixed_data,
  function_type = "gompertz"
)
# Fit a Gompertz mixed-effected model using gompertz_mixed_model()
gomp_mixed_model <- gompertz_mixed_model(data_frame = gomp_mixed_data)
```

---

gomp_mixed_data   *Sample Gompertz growth dataset*

Description

A dataset containing the minimum required variables needed to input data into the GrowthModelME package functions

Usage

```
gomp_mixed_data
```

Format

A data frame with 975 rows and 3 variables:

cluster A character type variable used to specify the clustering of values by a particular metric. Note when selecting a least-squares model instead of a mixed-effects model, do not leave this variable NA, fill in this values for this variable with 1 repative dummy variable for the package to run properly

time A numeric type variable for any measurement in time such as minutes, hours, or days

growth_metric A numeric type variable for measuring growth such as confluency or cell count

Source

Created through simulation to serve as an example

Examples

```
data(log_mixed_data)
```

---

growth_boostrap_ci   *Create bootstrap estimates and 95% confidence intervals for mixed-effects and/or least-squares models for each time-point*

Description

This function leverages the `saemix.bootstrap` function for mixed-effects models and the `predict_nls` function for least-squares models to compute bootstrapped 95% confidence intervals for each time-point for graphical purposes. Estimates of the fixed-effects values are calculated based on the median (50th percentile) of the simulated bootstrap data, with the 95% confidence interval constructed from the 2.5th and 97.5th percentiles.

Usage

```
growth_boostrap_ci(
  data_frame,
  growth_model_object,
  growth_model_summary_list,
  boot_n_sim = 200,
  mix_boot_method = "case"
)
```

Arguments

data_frame   A data frame object that at minimum contains three variables:

- cluster - a character type variable used to specify how observations are nested or grouped by a particular cluster. Note if using a least-squares model, please fill in all values of cluster with a single dummy character string, do NOT leave blank.
- time - a numeric type variable used for measuring time such as minutes, hours, or days
- growth_metric - a numeric type variable used for measuring growth over time such as cell count or confluency

growth_model_object

A saemix or nls type model object that is created using `growth_curve_model_fit` when return_summary = FALSE

growth_model_summary_list

A list object created by the `growth_curve_model_fit` function when return_summary = TRUE.

boot_n_sim   A numeric value specifying the number of bootstrap simulations to be performed. See `saemix.bootstrap` for mixed-effects models and `predict_nls` for least-squares models. Defaults to 200.

mix_boot_method

For mixed-effects models, a character string specifying the bootstrap algorithm to use. Options include "case", "residual", "parametric" or "conditional". Defaults to "case". See `saemix.bootstrap` for more details.

Value

An appended version of growth_model_summary_list with a fourth data frame titled "boot_sim"

See Also

[growth_curve_model_fit](#)

Examples

```
# Fit an mixed-effects growth model to the data, return summary
# and bootstrap estimates (boot_n_sim set to 6 for speed)
exp_mixed_model_summary <- growth_curve_model_fit(
  data_frame = exp_mixed_data,
  function_type = "exponential",
  bootstrap_time = TRUE,
  boot_n_sim = 6
)
```

---

growth_curve_model_fit

Fit a growth function using mixed-effects regression modeling

---

Description

'growth_curve_model_fit()' fits a mixed-effects model to a data frame based on a user-defined function to account for clustering.

Usage

```
growth_curve_model_fit(
  data_frame,
  function_type = "exponential",
  model_type = "mixed",
  fixed_rate = TRUE,
  num_chains = 1,
  time_unit = "hours",
  return_summary = TRUE,
  bootstrap_time = FALSE,
  boot_n_sim = 200,
  mix_boot_method = "case"
)
```

Arguments

data_frame   A data frame object that at minimum contains three variables:

- cluster - a character type variable used to specify how observations are nested or grouped by a particular cluster. Note if using a least-squares model, please fill in all values of cluster with a single dummy character string, do NOT leave blank.
- time - a numeric type variable used for measuring time such as minutes, hours, or days
- growth_metric - a numeric type variable used for measuring growth over time such as cell count or confluency

function_type   A character string specifying the function for modeling the shape of the growth. Options include "exponential", "linear", "logistic", or "gompertz".

model_type	A character string specifying the type of regression model to be used. If "mixed" a mixed-effects regression model will be used with fixed and random effects to account for clustering. Defaults to "mixed".
fixed_rate	A logical value specifying whether the rate constant of the function should be treated as a fixed effect (TRUE) or random effect (FALSE). Defaults to TRUE
num_chains	A numeric value specifying the number of chains to run in parallel in the MCMC algorithm of saemix. Defaults to 1.
time_unit	A character string specifying the units in which time is measured in. Defaults to "hours"
return_summary	A logical value specifying whether to return the growth_model_summary_list when TRUE (list object containing summarized data) or the object model object when FALSE. Defaults to TRUE.
bootstrap_time	Logical value indicating whether to append a data frame with bootstrap estimates and 95% confidence intervals for each time point. Defaults to FALSE. See [growth_boostrap_ci](#) for more details.
boot_n_sim	A numeric value specifying the number of bootstrap simulations to be performed. Defaults to 200. See [growth_boostrap_ci](#) for more details.
mix_boot_method	
	For mixed-effects models ONLY, a character string specifying the bootstrap algorithm to use. Options include "case", "residual", "parametric" or "conditional". Defaults to "case". See [growth_boostrap_ci](#) for more details.

Value

A list object with the following data frames within the list:

- model_summary_wide - a data frame with 1 row containing key model estimates, doubling-time, and model metrics depending on the model_type and function_type specified

- model_summary_long - a data frame that is a long dataset version of 'model_summary_wide' that can be used to generate a table of the model results (see function [growth_model_summary_table](#))

- model_residual_data - a data frame containing the original data frame values as well as predicted values, residuals, and theoretical quantiles of the residuals depending on the model_type selected (see functions [growth_model_residual_plots](#) and [growth_vs_time_plot](#)

- simulated_data - A data frame containing the bootstrap estimates and 95% confidence intervals for each time point.ONLY GENERATED WHEN bootstrap_time = TRUE

Note when return_summary is FALSE, will return a model object of class 'saemix' when a mixed-effects model is specified or a model object of class 'nls' if a least-squares model is specified.

Examples

```
# Load example data (exponential data)
data(exp_mixed_data)
# Fit an mixed-effects growth model to the data and return summary
exp_mixed_model_summary <- growth_curve_model_fit(
data_frame = exp_mixed_data,
function_type = "exponential")
# Create flextable object from the summary list object for documentation
exp_model_table <- growth_model_summary_table(
growth_model_summary_list = exp_mixed_model_summary)
exp_model_table
# Create growth vs time plot of data with fitted values (plot_type = 2),
```

```
# adjust aesthetics and parameters as desired
exp_growth_plot <- growth_vs_time_plot(
growth_model_summary_list = exp_mixed_model_summary,
plot_type = 2)
print(exp_growth_plot)
# Check residuals and model assumptions
residual_diag_plot <- growth_model_residual_plots(
growth_model_summary_list = exp_mixed_model_summary)
print(residual_diag_plot)
```

---

growth_model_residual_plots

Create residual diagnostic plots for growth model

Description

'growth_model_residual_plots()' is function that generates residual diagnostic plots and summary statistics for a growth model summary list object produced by growth_curve_model_fit.

Usage

```
growth_model_residual_plots(
  growth_model_summary_list,
  residual_type = "cluster",
  weighted = TRUE
)
```

Arguments

growth_model_summary_list
>   A list object created by the growth_curve_model_fit function.

residual_type   A character string specifying the type of residuals to be displayed in the plot. Options include "population" for the fixed-effects residuals for mixed-effects and least-squares models and "cluster" for fixed and random-effects residuals for mixed-effects regression models. Defaults to "cluster".

weighted   A logical value, when TRUE displays weighted residuals for mixed-effects models or Standardized residuals for least-squares models, when FALSE displays the raw residuals for mixed-effects and least-squares models. Defaults to "TRUE".

Value

Returns a ggplot2 collage of model diagnostic plots with the following plots displayed:

- Residual vs Fitted Values - a model diagnostic plot for assessing the distribution of standardized residuals vs the model fitted values, useful in detecting improper function specification, homogeneity of variance, and outlier detection.

- Q-Q Plot - a model diagnostic plot (quantile-quantile) plot for comparing standardized residuals vs their theoretical quantiles, useful in assessing normality assumptions and outlier detection.

- Residual Density Plot - a model diagnostic showing the distribution of standardized residuals (histogram) with a normal distribution curve overlaid based on the residuals mean and standard deviation, useful in assessing normality assumptions and skewness.

- Residual Summary Statistics - a list of descriptive statistics of the standardized residuals including: mean, median, minimum, maximum, skewness, and kurtosis.

See Also

growth_curve_model_fit

Examples

```
# Load example data (exponential data)
data(exp_mixed_data)
# Fit an mixed-effects growth model to the data and produce summary list
exp_mixed_model_summary <- growth_curve_model_fit(
data_frame = exp_mixed_data,
function_type = "exponential")
# Check residuals and model assumptions
residual_diag_plot <- growth_model_residual_plots(
  growth_model_summary_list = exp_mixed_model_summary)
print(residual_diag_plot)
```

---

growth_model_summary_table

Create a printable table of the summarized growth model result reporting

---

Description

'growth_model_summary_table()' creates a flextable object that can be used for documentation or Rmarkdown reports from the list object created by growth_curve_model_fit. The 'model_summary_long' data frame from the list object is used to generate the table.

Usage

```
growth_model_summary_table(
  growth_model_summary_list,
  font_name = "Albany AMT",
  font_size_header = 14,
  font_size_body = 12,
  use_knit_print = FALSE
)
```

Arguments

growth_model_summary_list

A list object created by the growth_curve_model_fit function.

font_name   A character string specifying the name of the font to use when rendering the table. Defaults to "Albany AMT". See font.

font_size_header

A numeric value specifying the size of the font for the header of the table. Defaults to 14. See fontsize

font_size_body A numeric value specifying the size of the font for the header of the table. Defaults to 12. See fontsize

use_knit_print A logical value to specify whether the flextable should be printer using the [knit_print](#) function instead of the flextable object being returned. Defaults to FALSE.

Value

A flextable object of the 'model_summary_long' data frame

See Also

[growth_curve_model_fit](#)

Examples

```
# Load example data (exponential data)
data(exp_mixed_data)
# Fit an mixed-effects growth model to the data
exp_mixed_model_summary <- growth_curve_model_fit(
data_frame = exp_mixed_data,
function_type = "exponential")
# Create flextable object of the growth model results
exp_model_table <- growth_model_summary_table(
growth_model_summary_list = exp_mixed_model_summary)
# Print the table in the view pane
exp_model_table
```

---

growth_vs_time_plot   *Generate growth vs time plots*

Description

'growth_vs_time_plot()' is a function that can be used to generate different plots from a list object created by the [growth_curve_model_fit](#) function. Please refer to the documentation for the 'plot_type' parameter for the different plot options.

Usage

```
growth_vs_time_plot(
  growth_model_summary_list,
  plot_type = 2,
  growth_metric_name = "growth_metric",
  time_name = "time",
  cluster_name = "cluster",
  plot_title = "Growth vs Time",
  x_aix_breaks = ggplot2::waiver(),
  x_limits = c(NA, NA),
  n_x_axis_breaks = NULL,
  y_aix_breaks = ggplot2::waiver(),
  y_limits = c(NA, NA),
  n_y_axis_breaks = NULL,
  x_axis_text_size = 8,
  y_axis_text_size = 12,
```

```
    x_axis_title_size = 14,
    y_axis_title_size = 14,
    plot_title_size = 20,
    geom_point_size = 2,
    geom_line_width = 0.5,
    ci_plot_annoate_value = "double_time",
    annotate_value_text_size = 6
)
```

Arguments

growth_model_summary_list

> A list object created by the [growth_curve_model_fit](#) function.

plot_type   A numeric value used to specify the plot type to graph. Values include 1, 2, 3, 4
                 with descriptions of each below (defaults to 2):

   - 1 - A scatterplot of the growth_metric vs time data where each point is
     colored by cluster if applicable.
   - 2 - A scatterplot of the growth_metric vs time data where each point is col-
     ored by cluster if applicable and the model predicted values are overlayed
     as line. When a mixed-effect model summary list is in-putted, the pre-
     dicted values will be the ind_fit_value which accounts for both fixed and
     random effects. When a least-squares model summary list is in-putted the
     predicted values will be the fitted values accounting for fixed effects only
     (pop_fit_value).
   - 3 - A scatterplot version of plot_type = 2 where each cluster is separated
     into their own plot forming a matrix of growth_metric vs time plots by
     cluster.
   - 4 - A plot of bootstrapped estimates as a smooth line, with corresponding
     bootstrapped 95% confidence intervals as a shaded region. NOTE: plot can
     only be generated if bootstrap_time was set to TRUE in [growth_curve_model_fit](#)
     when growth_model_summary_list list object was generated.

growth_metric_name

> A character string for specifying the name of the growth metric (y-axis title) to
> be displayed on the plot. Defaults to "growth_metric".

time_name   A character string for specifying the name of the time variable (x-axis title) to
                 be displayed on the plot. Defaults to "time".

cluster_name   A character string for specifying the name of the cluster variable (legend title)
                 to be displayed on the plot. Defaults to "cluster".

plot_title   A character string for specifying the title to be displayed over the plot. Defaults
                 to "Growth vs Time".

x_aix_breaks   A numeric vector specifying manual numeric breaks. Defaults to ggplot2::waiver().
                 See [scale_x_continuous](#).

x_limits   A numeric vector of length two providing limits for the x-axis. Use NA to refer
                 to the existing minimum or maximum. Defaults to c(NA, NA). See [scale_x_continuous](#).

n_x_axis_breaks

> An integer specifying the number of major breaks for the x-axis. Defaults to
> NULL. See [scale_x_continuous](#).

y_aix_breaks   A numeric vector specifying manual numeric breaks. Defaults to ggplot2::waiver().
                 See [scale_y_continuous](#).

y_limits   A numeric vector of length two providing limits for the y-axis. Use NA to refer
                  to the existing minimum or maximum. Defaults to c(NA, NA). See [scale_y_continuous](#).

n_y_axis_breaks
                  An integer specifying the number of major breaks for the x-axis. Defaults to
                  NULL. See [scale_y_continuous](#).

x_axis_text_size
                  A numeric value specifying the size of the x-axis text. Defaults to 8. See
                  [element_text](#).

y_axis_text_size
                  A numeric value specifying the size of the y-axis text. Defaults to 12. See
                  [element_text](#).

x_axis_title_size
                  A numeric value specifying the size of the x-axis title. Defaults to 14. See
                  [element_text](#).

y_axis_title_size
                  A numeric value specifying the size of the y-axis title. Defaults to 14. See
                  [element_text](#).

plot_title_size
                  A numeric value specifying the size of the plot title. Defaults to 20. See
                  [element_text](#).

geom_point_size
                  A numeric value specifying the size of the points on the graph. Defaults to 2.
                  See [geom_point](#).

geom_line_width
                  A numeric value specifying the width of the line (applicable only for plot_type
                  = 2, 3, or 4). Defaults to 0.5.

ci_plot_annoate_value
                  A character string specifying whether to add the doubling time or rate estimates
                  from the model to plot 4. Options include "double_time" for the doubling time
                  with 95% CI, "rate" for the rate estimate with 95% CI, or "none" for no annota-
                  tion. Defaults to "double_time"

annotate_value_text_size
                  A numeric value specifying the size of the annotation text. Defaults to 6. See
                  [geom_text](#). See [geom_line](#).

Value

Returns a ggplot2 plot

See Also

[growth_curve_model_fit](#)

Examples

```
# Load example data (exponential data)
data(exp_mixed_data)
# Fit an mixed-effects growth model to the data
exp_mixed_model_summary <- growth_curve_model_fit(
  data_frame = exp_mixed_data,
  function_type = "exponential"
)
```

```
# Create growth vs time plot of data with fitted values (plot_type = 2)
exp_growth_plot <- growth_vs_time_plot(
  growth_model_summary_list = exp_mixed_model_summary,
  plot_type = 2
)
print(exp_growth_plot)
```

---

linear_mixed_model   *Fit a linear mixed-effects regression model*

Description

'linear_mixed_model()' is a function utilized with the [growth_curve_model_fit](#) function for fitting a linear mixed-effects regression model to growth data utilizing the saemix package

Usage

```
linear_mixed_model(
  data_frame,
  model_type = "mixed",
  fixed_rate = TRUE,
  num_chains = 1
)
```

Arguments

data_frame   A data frame object that at minimum contains three variables:

- cluster - a character type variable used to specify how observations are nested or grouped by a particular cluster. Note if using a least-squares model, please fill in all values of cluster with a single dummy character string, do NOT leave blank.
- time - a numeric type variable used for measuring time such as minutes, hours, or days
- growth_metric - a numeric type variable used for measuring growth over time such as cell count or confluency

model_type   A character string specifying the type of regression model to be used. If "mixed" a mixed-effects regression model will be used with fixed and random effects to account for clustering. Defaults to "mixed".

fixed_rate   A logical value specifying whether the rate constant of the function should be treated as a fixed effect (TRUE) or random effect (FALSE). Defaults to TRUE

num_chains   A numeric value specifying the number of chains to run in parallel in the MCMC algorithm of saemix. Defaults to 1.

Value

Returns a linear model object of class 'saemix' when a mixed-effects model is specified or a model object of class 'nls' if a least-squares model is specified.

See Also

[growth_curve_model_fit](#)

Examples

```
# Load example data (linear data from GrowthCurveME package)
data(lin_mixed_data)
# Fit a linear mixed-effects growth model
lin_mixed_model <- growth_curve_model_fit(
data_frame = lin_mixed_data,
function_type = "linear")
# Fit an linear mixed-effects model using linear_mixed_model()
lin_mixed_model <- linear_mixed_model(data_frame = lin_mixed_data)
```

---

lin_mixed_data   *Sample linear growth dataset*

Description

A dataset containing the minimum required variables needed to input data into the GrowthModelME package functions

Usage

```
lin_mixed_data
```

Format

A data frame with 110 rows and 3 variables:

cluster A character type variable used to specify the clustering of values by a particular metric. Note when selecting a least-squares model instead of a mixed-effects model, do not leave this variable NA, fill in this values for this variable with 1 repetitive dummy variable for the package to run properly

time A numeric type variable for any measurement in time such as minutes, hours, or days

growth_metric A numeric type variable for measuring growth such as confluency or cell count

Source

Created through simulation to serve as an example

Examples

```
data(log_mixed_data)
```

logistic_mixed_model   *Fit a logistic mixed-effects regression model*

Description

'logistic_mixed_model()' is a function utilized with the `growth_curve_model_fit` function for fitting a logistic mixed-effects regression model to growth data utilizing the saemix package. Starting values are derived from an initial least-squares model using the `nlsLM` function.

Usage

```
logistic_mixed_model(
  data_frame,
  model_type = "mixed",
  fixed_rate = TRUE,
  num_chains = 1
)
```

Arguments

data_frame	A data frame object that at minimum contains three variables:

- cluster - a character type variable used to specify how observations are nested or grouped by a particular cluster. Note if using a least-squares model, please fill in all values of cluster with a single dummy character string, do NOT leave blank.
- time - a numeric type variable used for measuring time such as minutes, hours, or days
- growth_metric - a numeric type variable used for measuring growth over time such as cell count or confluency

model_type	A character string specifying the type of regression model to be used. If "mixed" a mixed-effects regression model will be used with fixed and random effects to account for clustering. Defaults to "mixed".
fixed_rate	A logical value specifying whether the rate constant of the function should be treated as a fixed effect (TRUE) or random effect (FALSE). Defaults to TRUE
num_chains	A numeric value specifying the number of chains to run in parallel in the MCMC algorithm of saemix. Defaults to 1.

Value

Returns a logistic model object of class 'saemix' when a mixed-effects model is specified or a model object of class 'nls' if a least-squares model is specified.

See Also

`growth_curve_model_fit`

Examples

```
# Load example data (logistic data from GrowthCurveME package)
data(log_mixed_data)
# Fit a logistic mixed-effects growth model to the data
log_mixed_model <- growth_curve_model_fit(data_frame = log_mixed_data,
function_type = "logistic")
# Fit a logistic mixed-effected model using logistic_mixed_model()
log_mixed_model <- logistic_mixed_model(data_frame = log_mixed_data)
```

---

log_mixed_data *Sample logistic growth dataset*

Description

A dataset containing the minimum required variables needed to input data into the GrowthModelME package functions

Usage

```
log_mixed_data
```

Format

A data frame with 320 rows and 3 variables:

cluster A character type variable used to specify the clustering of values by a particular metric. Note when selecting a least-squares model instead of a mixed-effects model, do not leave this variable NA, fill in this values for this variable with 1 repative dummy variable for the package to run properly

time A numeric type variable for any measurement in time such as minutes, hours, or days

growth_metric A numeric type variable for measuring growth such as confluency or cell count

Source

Created through simulation to serve as an example

Examples

```
data(log_mixed_data)
```

---

summarize_growth_model

Summarize growth model object and data

Description

'summarize_growth_model()' is a function used to create a list object of data frames based on a user's input data and outputed growth model object from growth_curve_model_fit. The list object (referred to in this package as 'growth_model_summary_list') can be used to extract model predicted values, residuals, and can be in-putted into supporting functions from GrowthCurveME to generate plots and perform model diagnostics.

Usage

```
summarize_growth_model(
  data_frame,
  growth_model_object,
  model_type = "mixed",
  function_type = "exponential",
  fixed_rate = TRUE,
  time_unit = "hours"
)
```

Arguments

data_frame   A data frame object that at minimum contains three variables:

- cluster - a character type variable used to specify how observations are nested or grouped by a particular cluster. Note if using a least-squares model, please fill in all values of cluster with a single dummy character string, do NOT leave blank.
- time - a numeric type variable used for measuring time such as minutes, hours, or days
- growth_metric - a numeric type variable used for measuring growth over time such as cell count or confluency

growth_model_object

The model object that is created using the growth_curve_model_fit()

model_type   A character string specifying the model_type that was fit using the growth_curve_model_fit function. Options include either "mixed" or "least-squares. Defaults to "mixed".

function_type   A character string specifying the function for modeling the shape of the growth. Options include "exponential", "linear", "logistic", or "gompertz".

fixed_rate   A logical value specifying whether the rate constant of the function should be treated as a fixed effect (TRUE) or random effect (FALSE). Defaults to TRUE

time_unit   A character string specifying the units in which time is measured in. Defaults to "hours"

Value

A list object with the following data frames within the list:

- model_summary_wide - a data frame with 1 row containing key model estimates, doubling-time, and model metrics depending on the model_type and function_type specified

- model_summary_long - a data frame that is a long dataset version of 'model_summary_wide' that can be used to generate a table of the model results (see function growth_model_summary_table)

- model_residual_data - a data frame containing the original data frame values as well as predicted values, residuals, and theoretical quantiles of the residuals depending on the model_type selected (see functions growth_model_residual_plots and growth_vs_time_plot

See Also

growth_curve_model_fit

Examples

```
# Load example data (exponential data)
data(exp_mixed_data)
# Fit an mixed-effects growth model to the data
exp_mixed_model <- growth_curve_model_fit(
data_frame = exp_mixed_data,
function_type = "exponential",
return_summary = FALSE)
# Summarize the data by creating a summary list object
exp_mixed_model_summary <- summarize_growth_model(
data_frame = exp_mixed_data,
growth_model_object = exp_mixed_model,
model_type = "mixed",
function_type = "exponential",
time_unit = "hours")
# Extracting a data frame from the list object
model_summary_wide <- exp_mixed_model_summary[["model_summary_wide"]]
```

---

summarize_growth_model_ls

Summarize least-squares growth model object and data

Description

'summarize_growth_model_mixed()' is a function used within the summarize_growth_model function to create a list object of data frames based on a user's input data frame and outputed least-squares growth model object from growth_curve_model_fit. The list object (referred to in this package as 'growth_model_summary_list') can be used to extract model predicted values, residuals, and can be in-putted into supporting functions from GrowthCurveME to generate plots and perform model diagnostics.

Usage

```
summarize_growth_model_ls(
  data_frame,
  ls_model,
  function_type = "exponential",
  time_unit = "hours"
)
```

Arguments

`data_frame`	A data frame object that at minimum contains three variables:

     • cluster - a character type variable used to specify how observations are nested or grouped by a particular cluster. Note if using a least-squares model, please fill in all values of cluster with a single dummy character string, do NOT leave blank.

     • time - a numeric type variable used for measuring time such as minutes, hours, or days

     • growth_metric - a numeric type variable used for measuring growth over time such as cell count or confluency

`ls_model`	The least-squares model object that is created using the 'growth_curve_model_fit()'
`function_type`	A character string specifying the function for modeling the shape of the growth. Options include "exponential", "linear", "logistic", or "gompertz".
`time_unit`	A character string specifying the units in which time is measured in. Defaults to "hours"

Value

A list object with the following data frames within the list:

- model_summary_wide - a data frame with 1 row containing key model estimates, doubling-time, and model metrics depending on the model_type and function_type specified

- model_summary_long - a data frame that is a long dataset version of 'model_summary_wide' that can be used to generate a table of the model results (see function growth_model_summary_table)

- model_residual_data - a data frame containing the original data frame values as well as predicted values, residuals, and theoretical quantiles of the residuals depending on the model_type selected (see functions growth_model_residual_plots and growth_vs_time_plot

See Also

growth_curve_model_fit summarize_growth_model

Examples

```
# Load example data (exponential data)
data(exp_mixed_data)
# Fit an mixed-effects growth model to the data
exp_ls_model <- growth_curve_model_fit(
data_frame = exp_mixed_data,
function_type = "exponential",
model_type = "least-squares",
return_summary = FALSE)
# Summarize the data by creating a summary list object
exp_ls_model_summary <- summarize_growth_model_ls(
data_frame = exp_mixed_data,
ls_model = exp_ls_model,
function_type = "exponential",
time_unit = "hours")
```

summarize_growth_model_mixed

Summarize mixed-effects growth model object and data

Description

'summarize_growth_model_mixed()' is a function used within the summarize_growth_model function to create a list object of data frames based on a user's input data frame and outputed mixed-effects growth model object from growth_curve_model_fit. The list object (referred to in this package as 'growth_model_summary_list') can be used to extract model predicted values, residuals, and can be in-putted into supporting functions from GrowthCurveME to generate plots and perform model diagnostics.

Usage

```
summarize_growth_model_mixed(
  data_frame,
  mixed_growth_model,
  function_type = "exponential",
  fixed_rate = TRUE,
  time_unit = "hours"
)
```

Arguments

data_frame   A data frame object that at minimum contains three variables:

- cluster - a character type variable used to specify how observations are nested or grouped by a particular cluster. Note if using a least-squares model, please fill in all values of cluster with a single dummy character string, do NOT leave blank.
- time - a numeric type variable used for measuring time such as minutes, hours, or days
- growth_metric - a numeric type variable used for measuring growth over time such as cell count or confluency

mixed_growth_model
                    The mixed-effects model object that is created using the 'growth_curve_model_fit()'

function_type   A character string specifying the function for modeling the shape of the growth. Options include "exponential", "linear", "logistic", or "gompertz".

fixed_rate   A logical value specifying whether the rate constant of the function should be treated as a fixed effect (TRUE) or random effect (FALSE). Defaults to TRUE

time_unit   A character string specifying the units in which time is measured in. Defaults to "hours"

Value

A list object with the following data frames within the list:

- model_summary_wide - a data frame with 1 row containing key model estimates, doubling-time, and model metrics depending on the model_type and function_type specified

- model_summary_long - a data frame that is a long dataset version of 'model_summary_wide' that can be used to generate a table of the model results (see function growth_model_summary_table)

- model_residual_data - a data frame containing the original data frame values as well as predicted values, residuals, and theoretical quantiles of the residuals depending on the model_type selected (see functions growth_model_residual_plots and growth_vs_time_plot

See Also

growth_curve_model_fit summarize_growth_model

Examples

```
# Load example data (exponential data)
data(exp_mixed_data)
# Fit an mixed-effects growth model to the data
exp_mixed_model <- growth_curve_model_fit(
data_frame = exp_mixed_data,
function_type = "exponential",
return_summary = FALSE)
# Summarize the data by creating a summary list object
exp_mixed_model_summary <- summarize_growth_model_mixed(
data_frame = exp_mixed_data,
mixed_growth_model = exp_mixed_model,
fixed_rate = TRUE,
function_type = "exponential",
time_unit = "hours")
model_summary_wide <- exp_mixed_model_summary[["model_summary_wide"]]
```