

Package ‘swash’

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Type Package

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Depends R (>= 3.5.0), lubridate, sf, spdep, zoo, strucchange

Description The Swash-Backwash Model for the Single Epidemic Wave was developed by Cliff and Haggett (2006) <[doi:10.1007/s10109-006-0027-8](https://doi.org/10.1007/s10109-006-0027-8)> to model the velocity of spread of infectious diseases across space. This package enables the calculation of the Swash-Backwash Model for user-supplied panel data on regional infections. The package provides additional functions for bootstrap confidence intervals, country comparison, visualization of results, and data management. Furthermore, it contains several functions for analysis and visualization of (spatial) infection data.

License GPL (>= 2)

Imports methods

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swash-package	<i>Implementation of the Swash-Backwash Model for the Single Epidemic Wave and additional functions in R</i>
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Description

Swash-Backwash Model for the single epidemic wave (Cliff and Haggett 2006) with additional functions for bootstrap confidence intervals and data management; other functions for spatio-temporal analysis and modeling of infectious diseases

Details

The Swash-Backwash Model (SBM) for the Single Epidemic Wave is the spatial equivalent of the classic epidemiological SIR (Susceptible-Infected-Recovered) model. It was developed by Cliff and Haggett (2006) to model the velocity of spread of infectious diseases across space. Current applications can be found, for example, in Smallman-Raynor et al. (2022a,b). This package enables the calculation of the Swash-Backwash Model for user-supplied panel data on regional infections. The core of this is the `swash()` function, which calculates the model and creates a model object of the `sbm` class defined in this package. This class can be used to visualize results (`summary()`, `plot()`) and calculate bootstrap confidence intervals for the model estimates (`confint(sbm)`); the latter returns an object of class `sbm_ci` as defined in this package. Two `sbm_ci` objects for different countries may be compared with `compare_countries()`, which allows the estimation of mean differences of a user-specified model parameter (e.g., spatial reproduction number R_{OA}) between two countries. This makes it possible to check whether the spatial spread velocity of a communicable disease is significantly different in one country than in another country; the result is an object of class `countries`.

The package also contains other functions for spatio-temporal analysis and modeling of infectious diseases, such as fitting logistic growth models and exponential growth models for the initial phase of a spread, all of which can be used both on `sbm` objects (`growth(sbm)`, `growth_initial(sbm)`) and stand-alone (`logistic_growth()`, `exponential_growth()`). These function return objects of class `loggrowth` and `expgrowth`, respectively, both defined in this package. Other functions include spatial statistics (`nbstat()` for neighborhood statistics), breakpoints analysis for time series models (`plot_breakpoints()`), and fit metrics (`metrics()`, `binary_metrics()`, `binary_metrics_glm()`). The package includes example data from the SARS-CoV-2/COVID-19 pandemic.

Author(s)

Thomas Wieland

References

Chowell G, Simonsen L, Viboud C, Yang K (2014) Is West Africa Approaching a Catastrophic Phase or is the 2014 Ebola Epidemic Slowing Down? Different Models Yield Different Answers for Liberia. *PLoS currents* 6. doi:[10.1371/currents.outbreaks.b4690859d91684da963dc40e00f3da81](https://doi.org/10.1371/currents.outbreaks.b4690859d91684da963dc40e00f3da81)

Chowell G, Viboud C, Hyman JM, Simonsen L (2015) The Western Africa ebola virus disease epidemic exhibits both global exponential and local polynomial growth rates. *PLOS Currents Outbreaks*, *ecurrents.outbreaks.8b55f4bad99ac5c5db3663e916803261*. doi:[10.1371/currents.outbreaks.8b55f4bad99ac5c5db3663e916803261](https://doi.org/10.1371/currents.outbreaks.8b55f4bad99ac5c5db3663e916803261)

Cliff AD, Haggett P (2006) A swash-backwash model of the single epidemic wave. *Journal of Geographical Systems* 8(3), 227-252. doi:[10.1007/s1010900600278](https://doi.org/10.1007/s1010900600278)

Li, MY (2018) An Introduction to Mathematical Modeling of Infectious Diseases. doi:[10.1007/9783319721224](https://doi.org/10.1007/9783319721224)

Nishiura H, Chowell G (2009) The effective reproduction number as a prelude to statistical estimation of time-dependent epidemic trends. In Chowell G, Hyman JM, Bettencourt LMA (eds.) Mathematical and statistical estimation approaches in epidemiology, 103–121. doi:[10.1007/9789048123131_5](https://doi.org/10.1007/9789048123131_5)

Pell B, Kuang Y, Viboud C, Chowell G (2018) Using phenomenological models for forecasting the 2015 ebola challenge. *Epidemics* 22, 62–70. doi:[10.1016/j.epidem.2016.11.002](https://doi.org/10.1016/j.epidem.2016.11.002)

Smallman-Raynor MR, Cliff AD, Stickler PJ (2022a) Meningococcal Meningitis and Coal Mining in Provincial England: Geographical Perspectives on a Major Epidemic, 1929–33. *Geographical Analysis* 54, 197–216. doi:10.1111/gean.12272

Smallman-Raynor MR, Cliff AD, The COVID-19 Genomics UK (COG-UK) Consortium (2022b) Spatial growth rate of emerging SARS-CoV-2 lineages in England, September 2020–December 2021. *Epidemiology and Infection* 150, e145. doi:10.1017/S0950268822001285.

Viboud C, Bjørnstad ON, Smith DL, Simonsen L, Miller MA, Grenfell BT (2006) Synchrony, Waves, and Spatial Hierarchies in the Spread of Influenza. *Science* 312, 447–451. doi:10.1126/science.1125237

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Wieland T (2020) A phenomenological approach to assessing the effectiveness of COVID-19 related nonpharmaceutical interventions in Germany. *Safety Science* 131, 104924. doi:10.1016/j.ssci.2020.104924

Wieland T (2022) Spatial patterns of excess mortality in the first year of the COVID-19 pandemic in Germany. *European Journal of Geography* 13(4), 18–33. doi:10.48088/ejg.t.wie.13.4.018.033

Wieland T (2025) Assessing the effectiveness of non-pharmaceutical interventions in the SARS-CoV-2 pandemic: results of a natural experiment regarding Baden-Württemberg (Germany) and Switzerland in the second infection wave. *Journal of Public Health* 33(11), 2497–2511. doi:10.1007/s1038902402218x

Examples

```

data(COVID19Cases_geoRegion)
# Get SWISS COVID19 cases at NUTS 3 level

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[!COVID19Cases_geoRegion$geoRegion %in% c("CH", "CHFL"),]
# Exclude CH = Switzerland total and CHFL = Switzerland and Liechtenstein total

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[COVID19Cases_geoRegion$datum <= "2020-05-31",]
# Extract first COVID-19 wave

CH_covidwave1 <-
  swash (
    data = COVID19Cases_geoRegion,
    col_cases = "entries",
    col_date = "datum",
    col_region = "geoRegion"
  )
# Swash-Backwash Model for Swiss COVID19 cases
# Spatial aggregate: NUTS 3 (cantons)

summary(CH_covidwave1)
# Summary of Swash-Backwash Model

plot(CH_covidwave1)
# Plot of Swash-Backwash Model edges and total epidemic curve

```

as_balanced	<i>Correction of Non-balanced Panel Dataset with Regional Infection Data</i>
-------------	--

Description

This function corrects non-balanced input panel data by replacing missing entries with a user-given constant (e.g., 0).

Usage

```
as_balanced(  
  data,  
  col_cases,  
  col_date,  
  col_region,  
  fill_missing = 0  
)
```

Arguments

data	data.frame with regional infection data
col_cases	Column containing the cases (numeric)
col_date	Column containing the time points (e.g., days)
col_region	Column containing the unique identifier of the regions (e.g., name, NUTS 3 code)
fill_missing	Constant to fill missing values (default and recommended: 0)

Details

The Swash-Backwash Model for the Single Epidemic Wave does not necessarily require balanced panel data in order for the calculations to be carried out. However, for a correct estimation it is implicitly assumed that the input data is balanced. The function corrects non-balanced panel data. It is executed automatically within the `swash()` function (when using the function `is_balanced()`), but can also be used separately.

Value

data	Corrected input dataset (data.frame)
------	--------------------------------------

Author(s)

Thomas Wieland

See Also

[is_balanced](#)

Examples

```

data(COVID19Cases_geoRegion)
# Get SWISS COVID19 cases at NUTS 3 level

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[!COVID19Cases_geoRegion$geoRegion %in% c("CH", "CHFL"), ]
# Exclude CH = Switzerland total and CHFL = Switzerland and Liechtenstein total

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[COVID19Cases_geoRegion$datum <= "2020-05-31", ]
# Extract first COVID-19 wave

COVID19Cases_geoRegion_balanced <-
  is_balanced(
    data = COVID19Cases_geoRegion,
    col_cases = "entries",
    col_date = "datum",
    col_region = "geoRegion"
  )
# Test whether "COVID19Cases_geoRegion" is balanced panel data

COVID19Cases_geoRegion_balanced$data_balanced
# Balanced? TRUE or FALSE

if (COVID19Cases_geoRegion_balanced$data_balanced == FALSE) {
  COVID19Cases_geoRegion <-
    as_balanced(
      COVID19Cases_geoRegion,
      col_cases = "entries",
      col_date = "datum",
      col_region = "geoRegion"
    )
}
# Correction of dataset "COVID19Cases_geoRegion"
# not necessary as parameter balance of is_balanced is set TRUE by default

```

binary_metrics	<i>Fit metrics of observed and expected binary variables</i>
----------------	--

Description

Calculation of fit metrics for binary variables (Sensitivity, specificity, accuracy)

Usage

```

binary_metrics(
  observed,
  expected,
  no_information_rate = "negative"
)

```

Arguments

observed	Numeric vector: Y observed
expected	Numeric vector: Y expected
no_information_rate	bool argument which indicates whether the no-information rate is calculated based on negatives or positives

Details

The function computes model performance metrics for binary outcomes. Observed and expected data must be stated by the user. The function returns sensitivity, specificity, accuracy, and no-information rate.

Value

list with two entries:

fit_metrics:	list with fit metrics (sens, spec, ...)
observed_expected:	data.frame with observed, expected and hit (1/0)

Author(s)

Thomas Wieland

References

Altman DG, Bland JM (1994) Diagnostic tests. 1: Sensitivity and specificity. *British Medical Journal* 308, 1552. [doi:10.1136/bmj.308.6943.1552](https://doi.org/10.1136/bmj.308.6943.1552).

Boehmke B, Greenwell B (2020) Hands-On Machine Learning with R (1 ed.). Taylor & Francis, New York, NY.

See Also

[metrics](#), [binary_metrics_glm](#)

Examples

```
obs <- c(1,1,0,0,0,0,1,0,1)
exp <- c(0,1,0,0,0,0,1,0,0)

binary_metrics(
  obs,
  exp
)
```

`binary_metrics_glm` *Fit metrics for binary logit model*

Description

Calculation of fit metrics for binary variables (Sensitivity, specificity, accuracy) out of binary logit models (glm object)

Usage

```
binary_metrics_glm(
  logit_model,
  threshold = 0.5
)
```

Arguments

<code>logit_model</code>	<code>glm</code> object with binary logit model
<code>threshold</code>	Threshold for distinction of probability with respect to TRUE or FALSE

Details

The function computes model performance metrics for binary outcomes. A binary logit model (glm) must be stated by the user. The function returns sensitivity, specificity, accuracy, and no-information rate.

Value

list with two entries:

<code>fit_metrics:</code>	list with fit metrics (sens, spec, ...)
<code>observed_expected:</code>	data.frame with observed, expected and hit (1/0)

Author(s)

Thomas Wieland

References

Altman DG, Bland JM (1994) Diagnostic tests. 1: Sensitivity and specificity. *British Medical Journal* 308, 1552. [doi:10.1136/bmj.308.6943.1552](https://doi.org/10.1136/bmj.308.6943.1552).

Boehmke B, Greenwell B (2020) Hands-On Machine Learning with R (1 ed.). Taylor & Francis, New York, NY.

See Also

[metrics](#), [binary_metrics](#)

Examples

```

dep <- c(1,1,0,0,0,0,1,0,1, 1)
x <- c(2,3,1,1,0,1,3,2,1,3)

testmodel <-
  glm(
    dep~x,
    family=binomial()
  )

summary(testmodel)

binary_metrics_glm(testmodel)

```

C19dNUTSdata

Regional cumulative COVID-19 deaths

Description

Cumulative COVID-19 deaths absolute and per 100,000 pop at NUTS3 level for 31 EU/EFTA countries

Usage

```
data("C19dNUTSdata")
```

Format

A data frame with 1,143 observations (each one represents a spatial NUTS unit).

NUTS_ID NUTS ID of the spatial unit

CNTR_CODE Country code (= NUTS 0 ID) of the given spatial unit

NUTS_Level NUTS level of the given spatial unit (0 = national, 1, 2, 3)

NUTS2_ID NUTS 2 ID of the spatial unit

NUTS1_ID NUTS 1 ID of the spatial unit

NUTS_Name Latin name of the spatial unit

C19deaths Cumulative COVID-19 deaths [persons]

pop2020 Population in 2020 [persons]

C19deaths_per100000 Cumulative COVID-19 deaths [per 100,000]

annotation Annotation)

Details

Note: This data was originally released in the author's package C19dNUTS in 2022 (<https://cran.r-project.org/package=C19dNUTS>). Some of the URLs referred to here were moved or deleted.

The dataset contains cumulative COVID-19 deaths at the regional level (mostly NUTS 3, N=1,143) for 31 EU/EFTA countries (AT, BE, BG, CH, CY, CZ, DE, DK, EE, EL, ES, FI, FR, HR, HU, IE, IS, IT, LT, LU, LV, MT, NL, NO, PL, PT, RO, SE, SI, SK, UK). The C19deaths variable contains the absolute number of COVID-19 related deaths, and the variable C19deaths_per100000 equals the death numbers relative to the population (per 100,000).

Unless otherwise noted, data includes all reported COVID-19 related deaths since the beginning of the COVID-19 pandemic through June 2022. Please refer to the source section below for the exact date on which each raw dataset was retrieved. The spatial level is the current NUTS 2021 classification of the European Union (see '<https://ec.europa.eu/eurostat/web/nuts/background>'), with one slight modification (see "Technical details" below). The variable NUTS_Level documents the spatial level for which the numbers apply (mostly NUTS_Level = 3 for NUTS3).

Technical details:

This dataset contains cumulative numbers and no time series, as many countries only publish cumulative data on COVID-19 deaths. In cases where countries only publish COVID-19 deaths in the form of daily data, the numbers were summed up over the entire period under consideration at the respective spatial level.

The definition of a COVID-19 death may vary between countries. The respective definition can usually be found on the website of the national health authority. In some countries, data is reported based on different definitions. For example, Lithuania uses three different definitions, namely a) based on the main cause of death in the death certificate, b) based on a mention in the death certificate and c) died within 28 days of a positive SARS-CoV-2 test (https://open-data-sets-1s-osp-sdg.hub.arcgis.com/datasets/ba35de03e111430f88a86f7d1f351de6_0/about). In England, for example, a distinction is made between the deceased who tested positive and those who died from COVID-19 based on the death certificate (<https://coronavirus.data.gov.uk/details/deaths>). In these cases, the definition used has always been the equivalent of the total number of COVID-19 deaths as reported by the national figures from Johns Hopkins University (<https://coronavirus.jhu.edu/data/cumulative-cases>).

In some cases, countries publish regional COVID-19 data directly at NUTS3 level (e.g., Germany) or NUTS2 level (e.g., Italy). In most cases, the regional level had to be linked manually using the name of the region (e.g., Bulgaria, Norway, Switzerland). Some countries even publish the relevant data on a smaller scale, i.e. below NUTS3 (e.g., Austria, Netherlands, Poland, England). In these cases, where a reference table (subnational spatial unit <-> NUTS3) was available, the lower level was linked to the NUTS3 level (e.g., England). If no reference table but geodata (shapefiles) for the lower spatial level was available (e.g., Austria, Netherlands, Poland), the lower level was linked to the NUTS3 level via a spatial join (Polygon centroids; in cases where the centroid was outside the polygon, it was placed inside the polygon manually). In these cases, the numbers were then summed up at NUTS3 level.

The spatial reference used here is the current EU NUTS Shapefile (<https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/nuts>; accessed 2022-06-23). The dataset can be linked directly to this shapefile, where the unique id field to which the link can be made is the column NUTS_ID. However, there is one exception: To ensure data compatibility, the UK NUTS3 regions UKM61 and UKM63 were aggregated into one region (UKM61).

The data reflects 1,309,326 COVID-19 related deaths in the 31 countries in the investigated time period. The variable C19deaths_per100000 is non-normally distributed (Shapiro-Wilk test: $W = 0.92284$, $p < 0.01$). The natural log of C19deaths_per100000 is spatially autocorrelated (Moran's I with queen contiguous spatial weighting: $I = 0.65228$, $p < 0.01$).

Data limitations:

It can be assumed that there are differences between countries and possibly also over time in the definition of a COVID-19 death (see "Technical details" above). Please check the definition on the website of the respective national health authority.

Data on COVID-19 deaths are incomplete for the following EU/EFTA countries: Bulgaria, France, Poland. In Bulgaria, regional COVID-19 deaths were only published for the years 2020 and 2021 (36,142 COVID-19 related deaths in total), i.e. the cases for 2022 are missing. France only publishes the COVID-19 patients which died in a hospital at the regional level, which equals 120,630 COVID-19 related deaths over the period under consideration (as of 2022-06-30). The total number of COVID-19 related deaths in France for the same time is equal to 149,533, which means that there is a lack of 28,903 COVID-19 fatalities (19.3 %, e.g., people which died in nursing homes). Polish deaths are missing COVID-19 deaths from the first pandemic wave. Therefore only the COVID-19 fatalities from the date 2020-11-24 are included, which equals 102,449 deaths. In the previous period, 13,780 COVID-19 deaths were reported, which are not included in the data set, i.e. 11.9% of the deaths are missing.

Of the 31 EU/EFTA countries included, regional data are only available for 24 countries. The following countries have not published sub-national data for COVID-19 deaths: Cyprus, Finland, Iceland, Hungary, Estonia, Latvia, Malta. The values for Finland, Hungary, Estonia and Latvia refer to the national level (NUTS 0), which is indicated by the variable NUTS_Level = 0. In the cases of Cyprus, Malta and Iceland (which are rather small countries), the NUTS 0 level also corresponds to the NUTS 2 level, which is why they are marked here in the dataset with NUTS_Level = 2. It is comparatively difficult to compare the data with Belgium because COVID-19 death figures are only published there at NUTS 1 level (3 regions; NUTS_Level = 1).

Some countries report separately persons who died of/with COVID-19 who live outside the country or cannot be assigned to a region (e.g., Greece, Norway). These cases are shown separately in the dataset, but cannot be related to population numbers and cannot be linked to the NUTS shapefile.

Norway does not provide COVID-19 data for the NUTS3 regions NO0B1 and NO0B2.

In the UK, each country (England, Wales, Scotland, and Northern Ireland) is independently responsible for publishing COVID-19 data. Therefore the data are not all available at the same spatial aggregation level (e.g. England: NUTS 3, Wales: NUTS 2).

Source

Raw data of COVID-19 deaths:

Note: Some of the URLs have been moved or deleted.

AT: https://covid19-dashboard.ages.at/data/CovidFaelle_Timeline_GKZ.csv (accessed 2022-06-23)

BE: https://epistat.sciensano.be/Data/COVID19BE_MORT.csv (accessed 2022-06-21)

BG: https://www.nsi.bg/sites/default/files/files/data/table/COVID_2020_2021_EN.xls (accessed 2022-06-29)

CH: <https://www.covid19.admin.ch/api/data/20220621-t6j901v4/downloads/sources-csv.zip> (accessed 2022-06-21)

CY: <https://covid19.who.int/region/euro/country/cy> (accessed 2022-06-30)

CZ: <https://onemocneni-aktualne.mzcr.cz/api/v2/covid-19/umrti.csv> (accessed 2022-06-24)

DE: https://npgeo-corona-npgeo-de.hub.arcgis.com/datasets/917fc37a709542548cc3be077a786c17_0/about (accessed 2022-06-23)

DK: <https://files.ssi.dk/covid19/overvagning/dashboard/overvaagningsdata-dashboard-covid19-28062022> (accessed 2022-06-29), folder: "Regionalt_DB", file: "07_antal_doede_pr_dag_pr_region"

EE: <https://www.terviseamet.ee/en/coronavirus/coronavirus-dataset> (accessed 2022-07-11)

EL: <https://github.com/Sandbird/covid19-Greece> (accessed 2022-07-02), file "regions"

ES: https://cnecovid.isciii.es/covid19/resources/casos_hosp_uci_def_sexo_edad_provres.csv (accesssed 2022-06-28)

FI: <https://covid19.who.int/region/euro/country/fi> (accessed 2022-07-01)

FR: <https://www.data.gouv.fr/fr/datasets/synthese-des-indicateurs-de-suivi-de-lepidemie-covid-19/> (accessed 2022-07-01), file "table-indicateurs-open-data-dep-2022-06-30-19h00"

HR: <https://www.koronavirus.hr/zupanije/139> (accessed 2022-06-28)

HU: <https://covid19.who.int/region/euro/country/hu> (accessed 2022-07-02)

IE: <https://epi-covid-19-hpscireland.hub.arcgis.com/> (accessed 2022-06-29)

IS: <https://www.covid.is/data> (accessed 2022-06-27)

IT: <https://github.com/pcm-dpc/COVID-19/tree/master/dati-regioni> (accessed 2022-06-24), file "dpc-covid19-ita-regioni-latest_raw"

LV: <https://covid19.gov.lv/en/node/16387> (accessed 2022-07-27)

LT: https://open-data-ls-osp-sdg.hub.arcgis.com/datasets/ba35de03e111430f88a86f7d1f351de6_0/explore (accessed 2022-06-27)

LU: <https://covid19.public.lu/fr/graph.html> (accessed 2022-06-27)

MT: <https://covid19.who.int/table> (accessed 2022-07-01)

NL: https://data.rivm.nl/covid-19/COVID-19_aantallen_gemeente_per_dag.csv (accessed 2022-06-27)

NO: <https://www.fhi.no/contentassets/8a971e7b0a3c4a06bdbf381ab52e6157/vedlegg/2022/ukerapport-uke-20-16.05—22.05.22.pdf> (accessed 2022-07-07)

PL: <https://www.gov.pl/web/koronawirus/wykaz-zarazen-koronawirusem-sars-cov-2> (accessed 2022-06-23)

PT: <https://github.com/dssg-pt/covid19pt-data/blob/master/data.csv> (accessed 2022-06-29)

RO: <https://covid19.geo-spatial.org/?map=decese> (accessed 2022-07-01)

SE: <https://experience.arcgis.com/experience/19fc7e3f61ec4e86af178fe2275029c5> (accessed 2022-06-23)

SI: https://www.nizj.si/sites/www.nizj.si/files/uploaded/tedenski_prikaz_umrli20220627.xlsx (accessed 2022-06-28)

SK: <https://github.com/Institut-Zdravotnych-Analyz/covid19-data> (accessed 2022-06-28), folder "Deaths", file "OpenData_Slovakia_Covid_Deaths_AgeGroup_District"

UK - England: <https://coronavirus.data.gov.uk/details/deaths> (accessed 2022-06-24), file "lta_2022_06_23_cumDeaths60Da

UK - Northern Ireland: https://www.nisra.gov.uk/system/files/statistics/Weekly_Deaths%20-%20w%20e%2017th%20June%202022.XLSX (accessed 2022-07-01)

UK - Scotland: <https://www.nrscotland.gov.uk/files/statistics/covid19/covid-deaths-22-data-week-25.xlsx> (data for 2021-2022) and <https://www.nrscotland.gov.uk/files/statistics/covid19/covid-deaths-20-data-final.xlsx> (data for 2022) (accessed 2022-07-01)

UK - Wales: <https://public.tableau.com/app/profile/public.health.wales.health.protection/viz/COVID-19Rapidmortalitydata/Summary> (accessed 2022-07-04)

Population data:

https://ec.europa.eu/eurostat/databrowser/view/DEMO_R_PJANGRP3/default/table?lang=en&category=reg.reg_dem.reg_dempoar (accessed 2022-06-22)

Examples

```
data(C19dNUTSdata)

# Summary:
summary(C19dNUTSdata)

# Check for normal distribution:
hist(C19dNUTSdata$C19deaths_per100000)
shapiro.test(C19dNUTSdata$C19deaths_per100000)

# no. of regions for each country:
table(C19dNUTSdata$CNTR_CODE)
# only for countries with data on at least NUTS 2 level:
table(C19dNUTSdata[C19dNUTSdata$NUTS_Level > 1,]$CNTR_CODE)
```

compare_countries

Two-country Comparison of Swash-Backwash Model Parameters

Description

This function enables bootstrap estimates for the mean difference of Swash-Backwash Model parameters of two countries to be compared.

Usage

```
compare_countries(
  sbm1,
  sbm2,
  country_names = c("Country 1", "Country 2"),
  indicator = "R_0A",
  iterations = 20,
  samples_ratio = 0.8,
  alpha = 0.05,
  replace = TRUE
)
```

Arguments

sbm1	A <code>sbm</code> object for country 1
sbm2	A <code>sbm</code> object for country 2
country_names	list with user-given country names (two entries)
indicator	character, indicator to be analyzed ("S_A", "I_A", "R_A", "t_LE", "t_LE", or "R_OA" (default and recommended: "R_OA"))
iterations	Number of iterations for resampling (default: 100)
samples_ratio	Proportion of regions included in each sample (default: 0.8)
alpha	Significance level α for the confidence intervals (default: 0.05)
replace	Resampling with replacement (TRUE or FALSE, default: TRUE = bootstrap resampling)

Details

The combination of the Swash-Backwash Model and bootstrap resampling allows the estimation of mean differences of a user-specified model parameter (e.g., spatial reproduction number R_{OA}) between two countries. This makes it possible to check whether the spatial spread velocity of a communicable disease is significantly different in one country than in another country. Since the initial data in the Swash-Backwash Model should be balanced, *entity-based bootstrap sampling* is carried out in the `compare_countries()` function. This means that not, for example, 80% of all observations are included in each sample at a sample ratio equal to $p = 0.8$, but rather all observations for 80% of the regions. For both countries, B bootstrap samples (default: 100) are drawn for which the Swash-Backwash Model is calculated. Based on the distribution of indicators, confidence intervals are calculated at the user-specified significance level α . The `compare_countries()` function calculates the differences of the user's desired indicator between the two samples, D , and also calculates α confidence intervals for this.

Value

object of class `countries`, see [countries-class](#)

Author(s)

Thomas Wieland

References

Cliff AD, Haggett P (2006) A swash-backwash model of the single epidemic wave. *Journal of Geographical Systems* 8(3), 227-252. [doi:10.1007/s1010900600278](https://doi.org/10.1007/s1010900600278)

Efron B, Tibshirani RJ (1993) An Introduction to the Bootstrap.

Ramachandran KM, Tsokos CP (2021) Mathematical Statistics with Applications in R (Third Edition). Ch. 13.3.1 (Bootstrap confidence intervals). [doi:10.1016/B9780128178157.000130](https://doi.org/10.1016/B9780128178157.000130)

Smallman-Raynor MR, Cliff AD, Stickler PJ (2022) Meningococcal Meningitis and Coal Mining in Provincial England: Geographical Perspectives on a Major Epidemic, 1929-33. *Geographical Analysis* 54, 197-216. [doi:10.1111/gean.12272](https://doi.org/10.1111/gean.12272)

Smallman-Raynor MR, Cliff AD, The COVID-19 Genomics UK (COG-UK) Consortium (2022) Spatial growth rate of emerging SARS-CoV-2 lineages in England, September 2020–December 2021. *Epidemiology and Infection* 150, e145. doi:10.1017/S0950268822001285.

See Also

[swash](#), [countries-class](#)

Examples

```
data(COVID19Cases_geoRegion)
# Get Swiss COVID19 cases at NUTS 3 level

data(Oesterreich_Faelle)
# Get Austrian COVID19 cases at NUTS 3 level
# (first wave, same final date as in Swiss data: 2020-05-31)

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[!COVID19Cases_geoRegion$geoRegion %in% c("CH", "CHFL"),]
# Exclude CH = Switzerland total and CHFL = Switzerland and Liechtenstein total

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[COVID19Cases_geoRegion$datum <= "2020-05-31",]
# Extract first COVID-19 wave

CH_covidwave1 <-
  swash (
    data = COVID19Cases_geoRegion,
    col_cases = "entries",
    col_date = "datum",
    col_region = "geoRegion"
  )
# Swash-Backwash Model for Swiss COVID19 cases
# Spatial aggregate: NUTS 3 (cantons)

AT_covidwave1 <-
  swash (
    data = Oesterreich_Faelle,
    col_cases = "Faelle",
    col_date = "Datum",
    col_region = "NUTS3"
  )
# Swash-Backwash Model for Austrian COVID19 cases
# Spatial aggregate: NUTS 3

AT_vs_CH <-
  compare_countries(
    CH_covidwave1,
    AT_covidwave1,
    country_names = c("Switzerland", "Austria"))
# Country comparison Switzerland vs. Austria
# default config: 20 iterations, alpha = 0.05, sample ratio = 80%,
```

```
# indicator: R_0A

summary(AT_vs_CH)
# Summary of country comparison

plot(AT_vs_CH)
# Plot of country comparison
```

confint-methods *Methods for Function confint*

Description

Methods for function `confint`

Methods

```
signature(object = "sbm", iterations = 100, samples_ratio = 0.8, alpha = 0.05, replace = TRUE)
```

Creates bootstrap confidence intervals for `sbm` objects. The argument `iterations` indicates the number of bootstrap samples which are drawn. Since the initial data in the Swash-Backwash Model should be balanced, *entity-based bootstrap sampling* is carried out. This means that not, for example, 80% of all observations are included in each sample at a sample ratio equal to $p = 0.8$ (`samples_ratio = 0.8`), but rather all observations for 80% of the regions. The significance level for the confidence intervals α is set by the argument `alpha` (default: 0.05, which corresponds to a 95% confidence level).

Author(s)

Thomas Wieland

References

Cliff AD, Haggett P (2006) A swash-backwash model of the single epidemic wave. *Journal of Geographical Systems* 8(3), 227-252. [doi:10.1007/s1010900600278](https://doi.org/10.1007/s1010900600278)

Efron B, Tibshirani RJ (1993) An Introduction to the Bootstrap.

Ramachandran KM, Tsokos CP (2021) Mathematical Statistics with Applications in R (Third Edition). Ch. 13.3.1 (Bootstrap confidence intervals). [doi:10.1016/B9780128178157.000130](https://doi.org/10.1016/B9780128178157.000130)

Smallman-Raynor MR, Cliff AD, Stickler PJ (2022) Meningococcal Meningitis and Coal Mining in Provincial England: Geographical Perspectives on a Major Epidemic, 1929-33. *Geographical Analysis* 54, 197-216. [doi:10.1111/gean.12272](https://doi.org/10.1111/gean.12272)

Smallman-Raynor MR, Cliff AD, The COVID-19 Genomics UK (COG-UK) Consortium (2022) Spatial growth rate of emerging SARS-CoV-2 lineages in England, September 2020–December 2021. *Epidemiology and Infection* 150, e145. [doi:10.1017/S0950268822001285](https://doi.org/10.1017/S0950268822001285).

See Also

[sbm_ci-class](#)

countries-class	<i>Class "countries"</i>
-----------------	--------------------------

Description

The class "countries" contains the results of a two-country comparison analysis using the Swash-Backwash Model, including two "sbm_ci" classes for each country. Use `summary(countries)` and `plot(countries)` for results summary and plotting, respectively.

Objects from the Class

Objects can be created by calls of the form `new("countries", ...)`. Objects can be created by the function `compare_countries(sbm1, sbm2)`.

Slots

`sbm_ci1`: Object of class "sbm_ci" Results of "confint(sbm1)" for country 1
`sbm_ci2`: Object of class "sbm_ci" Results of "confint(sbm1)" for country 2
`D`: Object of class "numeric" Results: Difference D between the samples with respect to the chosen indicator
`D_ci`: Object of class "numeric" Results: α confidence intervals of D
`config`: Object of class "list" Configuration details for bootstrap sampling
`country_names`: Object of class "character" User-stated country names
`indicator`: Object of class "character" User-stated indicator to be tested

Methods

`plot` `signature(x = "countries")`: Plots the results of a two-country comparison with the Swash-Backwash Model
`show` `signature(object = "countries")`: Prints an countries object; use `summary(sbm_ci)` for results
`summary` `signature(object = "countries")`: Prints a summary of a countries object (results of the two-country comparison)

Author(s)

Thomas Wieland

Examples

```
showClass("countries")
```

COVID19Cases_geoRegion

*Switzerland Daily COVID-19 cases by region***Description**

A dataset containing COVID-19 cases by region (NUTS 3 = cantons) and time periods (days) for Switzerland (Source: Federal Office of Public Health FOPH).

Usage

```
data(COVID19Cases_geoRegion)
```

Format

A data.frame with multiple columns:

geoRegion (character) Region for which the data was collected.
datum (Date) Date of record.
entries (integer) Number of reported cases on this date.
sumTotal (integer) Cumulative case numbers.
timeframe_14d (logical) Indicates whether the time period covers the last 14 days.
timeframe_all (logical) Indicates whether the time period covers all previous data.
offset_last7d (integer) Offset of the last 7 days.
sumTotal_last7d (integer) Cumulative case numbers of the last 7 days.
offset_last14d (integer) Offset of the last 14 days.
sumTotal_last14d (integer) Cumulative case numbers of the last 14 days.
offset_last28d (integer) Offset of the last 28 days.
sumTotal_last28d (integer) Cumulative case numbers of the last 28 days.
sum7d (numeric) Sum of the last 7 days.
sum14d (numeric) Sum of the last 14 days.
mean7d (numeric) Average of the last 7 days.
mean14d (numeric) Average of the last 14 days.
entries_diff_last_age (integer) Difference from the last age group.
pop (integer) Population of the region.
inz_entries (numeric) Incidence of the entries.
inzsumTotal (numeric) Incidence of cumulative cases.
inzmean7d (numeric) Incidence of the 7-day average.
inzmean14d (numeric) Incidence of the 14-day average.
inzsumTotal_last7d (numeric) Incidence of cumulative cases in the last 7 days.

inzsumTotal_last14d (numeric) Incidence of cumulative cases in the last 14 days.
inzsumTotal_last28d (numeric) Incidence of cumulative cases in the last 28 days.
inzsum7d (numeric) Incidence of the last 7 days.
inzsum14d (numeric) Incidence of the last 14 days.
sumdelta7d (numeric) Difference in sums of the last 7 days.
inzdelta7d (numeric) Difference in incidence of the last 7 days.
type (character) Type of recorded data (e.g., COVID-19 cases).
type_variant (character) Variant of the data type.
version (character) Version of the data collection.
datum_unit (character) Unit of date specification (e.g., day).
entries_letzter_stand (integer) Last known count of entries.
entries_neu_gemeldet (integer) Newly reported entries.
entries_diff_last (integer) Difference in last entries.

Details

The data is included as it was published in by the Swiss Federal Office of Public Health (Bundesamt fuer Gesundheit, BAG). Note that the reporting date equals the date of SARS-CoV-2 testing.

Source

Federal Office of Public Health FOPH (2023) COVID-19 Dashboard Source Data. <https://www.covid19.admin.ch/api/data/documentation> (retrieved 2023-06-28)

Examples

```

data(COVID19Cases_geoRegion)
# Get SWISS COVID19 cases at NUTS 3 level

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[!COVID19Cases_geoRegion$geoRegion %in% c("CH", "CHFL"),]
# Exclude CH = Switzerland total and CHFL = Switzerland and Liechtenstein total

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[COVID19Cases_geoRegion$datum <= "2020-05-31",]
# Extract first COVID-19 wave

COVID19Cases_geoRegion_balanced <-
  is_balanced(
    data = COVID19Cases_geoRegion,
    col_cases = "entries",
    col_date = "datum",
    col_region = "geoRegion"
  )
# Test whether "COVID19Cases_geoRegion" is balanced panel data

COVID19Cases_geoRegion_balanced$data_balanced
# Balanced? TRUE or FALSE
  
```

did_fatalities_splm_coef*Results from a Difference-in-Differences Model*

Description

Example data frame with results from a difference-in-differences model

Usage

```
data(did_fatalities_splm_coef)
```

Format

A `data.frame` with multiple columns:

Var Coefficient name

Estimate Coef. estimate

Std_Error_Bonferroni Coef. standard error

t_value_Bonferroni Coef. t value

Pr_t_Bonferroni Coef. p value

CI_lower_Bonferroni Coef. lower confidence interval

CI_upper_Bonferroni Coef. upper confidence interval

Details

Data frame with results from a difference-in-differences model (SPLM model), example data

Source

Wieland T (2025) Assessing the effectiveness of non-pharmaceutical interventions in the SARS-CoV-2 pandemic: results of a natural experiment regarding Baden-Württemberg (Germany) and Switzerland in the second infection wave. *Journal of Public Health* 33(11), 2497-2511. doi:10.1007/s1038902402218x

Examples

```
data(did_fatalities_splm_coef)
```

expgrowth-class	<i>Class "expgrowth"</i>
-----------------	--------------------------

Description

The class "expgrowth" contains the results of the `exponential_growth()` function. Use `summary(expgrowth)` for results summary.

Objects from the Class

Objects can be created by the function `exponential_growth`.

Slots

`exp_gr`: Object of class `numeric` Exponential growth rate
`y_0`: Object of class `numeric` Baseline
`R0`: Object of class `numeric` Basic reproduction number, derived from exponential growth model
`doubling`: Object of class `numeric` Doubling rate, derived from exponential growth model
`model_data`: Object of class `lm` OLS model
`config`: Object of class `list` Model fit configurations

Methods

`summary` `signature(object = "expgrowth")`: Prints a summary of `expgrowth` objects
`print` `signature(x = "expgrowth")`: Prints an `expgrowth` object; use `summary(expgrowth)` for results

Author(s)

Thomas Wieland

References

Bonifazi G et al. (2021) A simplified estimate of the effective reproduction number R_t using its relation with the doubling time and application to Italian COVID-19 data. *The European Physical Journal Plus* 136, 386. [doi:10.1140/epjp/s13360021013396](https://doi.org/10.1140/epjp/s13360021013396)

Chowell G, Viboud C, Hyman JM, Simonsen L (2015) The Western Africa ebola virus disease epidemic exhibits both global exponential and local polynomial growth rates. *PLOS Currents Outbreaks*, *ecurrents.outbreaks.8b55f4bad99ac5c5db3663e916803261*. [doi:10.1371/currents.outbreaks.8b55f4bad99ac5c5db3663e916803261](https://doi.org/10.1371/currents.outbreaks.8b55f4bad99ac5c5db3663e916803261)

Pell B, Kuang Y, Viboud C, Chowell G (2018) Using phenomenological models for forecasting the 2015 ebola challenge. *Epidemics* 22, 62–70. [doi:10.1016/j.epidem.2016.11.002](https://doi.org/10.1016/j.epidem.2016.11.002)

Wieland T (2020) A phenomenological approach to assessing the effectiveness of COVID-19 related nonpharmaceutical interventions in Germany. *Safety Science* 131, 104924. [doi:10.1016/j.ssci.2020.104924](https://doi.org/10.1016/j.ssci.2020.104924)

Examples

```
showClass("expgrowth")
```

exponential_growth	<i>Exponential Growth Model for Epidemic Data</i>
--------------------	---

Description

Estimation of exponential growth models from daily infections data

Usage

```
exponential_growth(
  y,
  t,
  GI = 4
)
```

Arguments

y	numeric vector with cumulative infections data over time
t	vector of class numeric or Date with time points or dates
GI	Generation interval for computing R_0

Details

This function allows the estimation of an exponential growth model. The user must specify the dependent variable (daily infections) and the time variable (time counter or date values). The estimation is performed using a linearized model as an OLS estimator. The results are the exponential growth rate r , basic reproduction number R_0 , and the doubling rate.

Value

object of class [expgrowth-class](#)

Author(s)

Thomas Wieland

References

Bonifazi G et al. (2021) A simplified estimate of the effective reproduction number R_t using its relation with the doubling time and application to Italian COVID-19 data. *The European Physical Journal Plus* 136, 386. [doi:10.1140/epjp/s13360021013396](https://doi.org/10.1140/epjp/s13360021013396)

Chowell G, Viboud C, Hyman JM, Simonsen L (2015) The Western Africa ebola virus disease epidemic exhibits both global exponential and local polynomial growth rates. *PLOS Currents Outbreaks*, *ecurrents.outbreaks.8b55f4bad99ac5c5db3663e916803261*. [doi:10.1371/currents.outbreaks.8b55f4bad99ac5c5db3663e916803261](https://doi.org/10.1371/currents.outbreaks.8b55f4bad99ac5c5db3663e916803261)

Pell B, Kuang Y, Viboud C, Chowell G (2018) Using phenomenological models for forecasting the 2015 ebola challenge. *Epidemics* 22, 62–70. doi:10.1016/j.epidem.2016.11.002

Wieland T (2020) A phenomenological approach to assessing the effectiveness of COVID-19 related nonpharmaceutical interventions in Germany. *Safety Science* 131, 104924. doi:10.1016/j.ssci.2020.104924

See Also

[growth_initial](#), [logistic_growth](#)

Examples

```
data(COVID19Cases_geoRegion)
# Get SWISS COVID19 cases at NUTS 3 level

COVID19Cases_ZH <-
  COVID19Cases_geoRegion[
    (COVID19Cases_geoRegion$geoRegion == "ZH")
    & (COVID19Cases_geoRegion$sumTotal > 0)
  ,
  ]
# COVID cases for Zurich

expgrowth_BS <- exponential_growth (
  y = COVID19Cases_ZH$sumTotal[1:28],
  t = COVID19Cases_ZH$datum[1:28]
)
# Exponential growth model for the first 4 weeks

summary(expgrowth_BS)
# Summary of exponential growth model

expgrowth_BS@doubling
# Doubling rate
```

growth

Logistic Growth Models for Regional Infections

Description

Estimates N logistic growth models for N regions.

Usage

```
growth(
  object,
  S_iterations = 10,
  S_start_est_method = "bisect",
  seq_by = 10,
  nls = TRUE
)
```

Arguments

object	object of class sbm
S_iterations	Number of iterations for saturation value search
S_start_est_method	Method for saturation value search, either "bisect" or "trial_and_error"
seq_by	No of segments for the "trial_and_error" estimation of the saturation value
nls	Nonlinear estimation? TRUE or FALSE

Details

The function estimates logistic growth models for regional infections based on a sbm object. See [logistic_growth](#) for further details.

Value

list with two entries:

results:	Object of class "data.frame" Results of the logistic growth models (coefficients and derivates)
logistic_growth_models:	Object of class "list" List with N entries for N growth models resp. loggrowth objects

Author(s)

Thomas Wieland

References

Chowell G, Simonsen L, Viboud C, Yang K (2014) Is West Africa Approaching a Catastrophic Phase or is the 2014 Ebola Epidemic Slowing Down? Different Models Yield Different Answers for Liberia. *PLoS currents* 6. [doi:10.1371/currents.outbreaks.b4690859d91684da963dc40e00f3da81](https://doi.org/10.1371/currents.outbreaks.b4690859d91684da963dc40e00f3da81)

Pell B, Kuang Y, Viboud C, Chowell G (2018) Using phenomenological models for forecasting the 2015 ebola challenge. *Epidemics* 22, 62–70. [doi:10.1016/j.epidem.2016.11.002](https://doi.org/10.1016/j.epidem.2016.11.002)

Wieland T (2020) Flatten the Curve! Modeling SARS-CoV-2/COVID-19 Growth in Germany at the County Level. *REGION* 7(2), 43–83. [doi:10.18335/region.v7i2.324](https://doi.org/10.18335/region.v7i2.324)

See Also

[logistic_growth](#), [exponential_growth](#)

Examples

```
data(COVID19Cases_geoRegion)
# Get SWISS COVID19 cases at NUTS 3 level

COVID19Cases_geoRegion <-
COVID19Cases_geoRegion[!COVID19Cases_geoRegion$geoRegion %in% c("CH", "CHFL"),]
```

```

# Exclude CH = Switzerland total and CHFL = Switzerland and Liechtenstein total

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[COVID19Cases_geoRegion$datum <= "2020-05-31", ]
# Extract first COVID-19 wave

CH_covidwave1 <-
  swash (
    data = COVID19Cases_geoRegion,
    col_cases = "entries",
    col_date = "datum",
    col_region = "geoRegion"
  )
# Swash-Backwash Model for Swiss COVID19 cases
# Spatial aggregate: NUTS 3 (cantons)

CH_covidwave1_growth <- growth(CH_covidwave1)
CH_covidwave1_growth
# Logistic growth models for sbm object CH_covidwave1

```

growth-methods	<i>Methods for Function growth</i>
----------------	------------------------------------

Description

Methods for function growth

Methods

`signature(object = "sbm", S_iterations = 10, S_start_est_method = "bisect", seq_by = 10, nls = TRUE)`
 Estimation of N logistic growth models for N regions. Both OLS and NLS estimation are estimated by default (set `nls = FALSE` to skip NLS estimation). Parameters `S_iterations`, `S_start_est_method`, and `seq_by` are used to control the saturation value estimation (see [logistic_growth](#)).

Author(s)

Thomas Wieland

growth_initial	<i>Exponential Growth Models for Regional Infections</i>
----------------	--

Description

Estimates N exponential growth models for a given time period in N regions.

Usage

```
growth_initial(
  object,
  time_units = 10,
  GI = 4
)
```

Arguments

object	object of class <code>sbm</code>
time_units	numeric value for the analysis time (time units from start)
GI	Generation interval for computing R_0

Details

The function estimates exponential growth models for regional infections based on a `sbm` object. Such models are design for the analysis of the *initial* phase of an epidemic spread. The user must state how much time units (from start) are included. See [exponential_growth](#) for further details of the estimation.

Value

list with two entries:

results:	Object of class "data.frame" Results of the exponential growth models (growth rate, basic reproduction number, doubling rate) for each region
exponential_growth_models:	Object of class "list" List with N entries for N exponential models

Author(s)

Thomas Wieland

References

Bonifazi G et al. (2021) A simplified estimate of the effective reproduction number R_t using its relation with the doubling time and application to Italian COVID-19 data. *The European Physical Journal Plus* 136, 386. [doi:10.1140/epjp/s13360021013396](https://doi.org/10.1140/epjp/s13360021013396)

Chowell G, Viboud C, Hyman JM, Simonsen L (2015) The Western Africa ebola virus disease epidemic exhibits both global exponential and local polynomial growth rates. *PLOS Currents Outbreaks*, *ecurrents.outbreaks.8b55f4bad99ac5c5db3663e916803261*. [doi:10.1371/currents.outbreaks.8b55f4bad99ac5c5db3663e916803261](https://doi.org/10.1371/currents.outbreaks.8b55f4bad99ac5c5db3663e916803261)

Pell B, Kuang Y, Viboud C, Chowell G (2018) Using phenomenological models for forecasting the 2015 ebola challenge. *Epidemics* 22, 62–70. [doi:10.1016/j.epidem.2016.11.002](https://doi.org/10.1016/j.epidem.2016.11.002)

Wieland T (2020) A phenomenological approach to assessing the effectiveness of COVID-19 related nonpharmaceutical interventions in Germany. *Safety Science* 131, 104924. [doi:10.1016/j.ssci.2020.104924](https://doi.org/10.1016/j.ssci.2020.104924)

Examples

```

data(COVID19Cases_geoRegion)
# Get SWISS COVID19 cases at NUTS 3 level

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[!COVID19Cases_geoRegion$geoRegion %in% c("CH", "CHFL"),]
# Exclude CH = Switzerland total and CHFL = Switzerland and Liechtenstein total

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[COVID19Cases_geoRegion$datum <= "2020-05-31",]
# Extract first COVID-19 wave

CH_covidwave1 <-
  swash (
    data = COVID19Cases_geoRegion,
    col_cases = "entries",
    col_date = "datum",
    col_region = "geoRegion"
  )
# Swash-Backwash Model for Swiss COVID19 cases
# Spatial aggregate: NUTS 3 (cantons)

CH_covidwave1_initialgrowth_3weeks <-
  growth_initial(
    CH_covidwave1,
    time_units = 21
  )
CH_covidwave1_initialgrowth_3weeks$results
# Exponential models for sbm object CH_covidwave1
# initial growth in the first 3 weeks

```

growth_initial-methods

Methods for Function growth_initial

Description

Methods for function `growth_initial`

Methods

`signature(object = "sbm", time_units = 10, GI = 4)` Estimation of N exponential growth models for the initial phase of an epidemic spread for N regions. Set argument `GI` for the calculation of the basic reproduction number(see [exponential_growth](#)).

Author(s)

Thomas Wieland

hist_ci*Creating Histograms with Confidence Intervals*

Description

Plot of a histogram of a given vector x and the related confidence intervals (lower, upper).

Usage

```
hist_ci(
  x,
  alpha = 0.05,
  col_bars = "grey",
  col_ci = "red",
  ...
)
```

Arguments

x	A numeric vector
alpha	Significance level α for $1-\alpha*100$ confidence intervals
col_bars	Color of bars in histogram
col_ci	Color of lines for confidence interval
...	Additional arguments passed to <code>barplot()</code>

Details

Helper function for `plot(sbm_ci)`, but may be used separately.

Value

Histogram plot, no returned value

Author(s)

Thomas Wieland

Examples

```
numeric_vector <- c(1,9,5,6,3,10,20,6,9,14,3,5,8,6,11)
# any numeric vector

hist_ci(numeric_vector)
```

Infections

Infections

Description

Daily SARS-CoV-2 infection in Germany spring 2020

Usage

```
data(Infections)
```

Format

A data.frame with multiple columns:

infectedtest_CW2 Calendar week 2020 of conducted test
infection_date Estimated date of infection
infections_daily Daily infections
infections_daily_lwr Daily infections lower confidence interval
infections_daily_upr Daily infections upper confidence interval
infections_cum Cumulative infections
infections_cum_lwr Cumulative infections lower confidence interval
infections_cum_upr Cumulative infections upper confidence interval
R4 Estimated effective reproduction number R_t with generation interval = 4
R4_lwr Estimated effective reproduction number R_t with generation interval = 4 lower confidence interval
R4_upr Estimated effective reproduction number R_t with generation interval = 4 upper confidence interval
R7 Estimated effective reproduction number R_t with generation interval = 7
R7_lwr Estimated effective reproduction number R_t with generation interval = 7 lower confidence interval
R7_upr Estimated effective reproduction number R_t with generation interval = 7 upper confidence interval
onsets_of_symptoms Daily onsets of symptoms
onsets_of_symptoms_lwr Daily onsets of symptoms lower confidence interval
onsets_of_symptoms_upr Daily onsets of symptoms upper confidence interval
reported_cases Daily reported cases
day Time counter (day)
ln_inf_cum Nat. log. of cumulative infections
ln_inf_daily Nat. log. of daily infections
ln_R4 Nat. log. of estimated effective reproduction number R_t with generation interval = 4

ln_R7 Nat. log. of estimated effective reproduction number R_t with generation interval = 7
infection_date_CW Calendar week of infection data (numeric)
infection_date_CW2 Calendar week of infection data (categorical)
infectedtest_CW Calendar week of conducted test
conducted_tests No. of conducted tests
negative_tests No. of negative tests
positive_tests No. of positive tests
positive_tests_share Share of positive tests (average per day)
conducted_tests_index No. of conducted tests (average per day), index (CW 14 = 100)
conducted_tests_dailyaverage No. of conducted tests, average per day
positive_tests_dailyaverage Positive tests, average per day
infections_daily_testweighted Daily infections weighted by test volume
ln_inf_daily_tw Nat. log. of daily infections weighted by test volume

Details

Example data with daily SARS-CoV-2 infections in Germany. See Wieland (2020) for data sources and method of backdating infections.

Source

Wieland T (2020) A phenomenological approach to assessing the effectiveness of COVID-19 related nonpharmaceutical interventions in Germany. *Safety Science* 131, 104924. [doi:10.1016/j.ssci.2020.104924](https://doi.org/10.1016/j.ssci.2020.104924)

Examples

```
data(Inflections)
```

<code>is_balanced</code>	<i>Test whether Panel Dataset with Regional Infection Data is Balanced</i>
--------------------------	--

Description

The function tests whether the input panel data with regional infections is balanced.

Usage

```
is_balanced(
  data,
  col_cases,
  col_date,
  col_region,
  as_balanced = TRUE,
  fill_missing = 0
)
```

Arguments

data	data.frame with regional infection data
col_cases	Column containing the cases (numeric)
col_date	Column containing the time points (e.g., days)
col_region	Column containing the unique identifier of the regions (e.g., name, NUTS 3 code)
as_balanced	Boolean argument which indicates whether non-balanced panel data shall be balanced (default: TRUE)
fill_missing	Constant to fill missing values (default and recommended: 0)

Details

The Swash-Backwash Model for the Single Epidemic Wave does not necessarily require balanced panel data in order for the calculations to be carried out. However, for a correct estimation it is implicitly assumed that the input data is balanced. The function tests whether the panel data is balanced. It is executed automatically within the swash() function (using automatic correction with as_balanced = TRUE), but can also be used separately.

Value

List with two entries:

data_balanced	Result of test (TRUE or FALSE)
data	Input dataset (data.frame)

Author(s)

Thomas Wieland

See Also

[as_balanced](#)

Examples

```
data(COVID19Cases_geoRegion)
# Get SWISS COVID19 cases at NUTS 3 level

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[!COVID19Cases_geoRegion$geoRegion %in% c("CH", "CHFL"),]
# Exclude CH = Switzerland total and CHFL = Switzerland and Liechtenstein total

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[COVID19Cases_geoRegion$datum <= "2020-05-31",]
# Extract first COVID-19 wave

COVID19Cases_geoRegion_balanced <-
  is_balanced(
    data = COVID19Cases_geoRegion,
```

```

col_cases = "entries",
col_date = "datum",
col_region = "geoRegion"
)
# Test whether "COVID19Cases_geoRegion" is balanced panel data

COVID19Cases_geoRegion_balanced$data_balanced
# Balanced? TRUE or FALSE

if (COVID19Cases_geoRegion_balanced$data_balanced == FALSE) {
  COVID19Cases_geoRegion <-
    as_balanced(
      COVID19Cases_geoRegion,
      col_cases = "entries",
      col_date = "datum",
      col_region = "geoRegion"
    )
}
# Correction of dataset "COVID19Cases_geoRegion"
# not necessary as parameter balance of is_balanced is set TRUE by default

```

loggrowth-class *Class "loggrowth"*

Description

The class "loggrowth" contains the results of the `logistic_growth()` function. Use `summary(loggrowth)` and `plot(loggrowth)` for results summary and plotting, respectively.

Objects from the Class

Objects can be created by the function `logistic_growth`.

Slots

LinModel: Object of class `list` Results of the OLS helper model

GrowthModel_OLS: Object of class `list` Results of the OLS fit (predicted, parameters, first derivative)

GrowthModel_NLS: Object of class `list` Results of the NLS fit (predicted, parameters, first derivative)

t: Object of class `numeric` Input time points data

y: Object of class `numeric` Input infections data

config: Object of class `list` Model fit configurations

Methods

plot `signature(x = "loggrowth")`: Plots the results of the logistic growth model (observed, predicted, first derivative)

summary `signature(object = "loggrowth")`: Prints a summary of `loggrowth` objects

print `signature(x = "loggrowth")`: Prints an `loggrowth` object; use `summary(loggrowth)` for results

Author(s)

Thomas Wieland

References

Chowell G, Simonsen L, Viboud C, Yang K (2014) Is West Africa Approaching a Catastrophic Phase or is the 2014 Ebola Epidemic Slowing Down? Different Models Yield Different Answers for Liberia. *PLoS currents* 6. doi:10.1371/currents.outbreaks.b4690859d91684da963dc40e00f3da81

Pell B, Kuang Y, Viboud C, Chowell G (2018) Using phenomenological models for forecasting the 2015 ebola challenge. *Epidemics* 22, 62–70. doi:10.1016/j.epidem.2016.11.002

Wieland T (2020) Flatten the Curve! Modeling SARS-CoV-2/COVID-19 Growth in Germany at the County Level. *REGION* 7(2), 43–83. doi:10.18335/region.v7i2.324

Examples

```
showClass("loggrowth")
```

logistic_growth	<i>Logistic Growth Model for Epidemic Data</i>
-----------------	--

Description

Estimation of logistic growth models from cumulative infections data, linearized OLS and/or NLS

Usage

```
logistic_growth(
  y,
  t,
  S = NULL,
  S_start = NULL,
  S_end = NULL,
  S_iterations = 10,
  S_start_est_method = "bisect",
  seq_by = 10,
  nls = TRUE
)
```

Arguments

y	numeric vector with cumulative infections data over time
t	vector of class numeric or Date with time points or dates
S	Saturation value for the model
S_start	Start value of the saturation value for estimation
S_end	End value of the saturation value for estimation
S_iterations	Number of iterations for saturation value search
S_start_est_method	Method for saturation value search, either "bisect" or "trial_and_error"
seq_by	No of segments for the "trial_and_error" estimation of the saturation value
nls	Nonlinear estimation? TRUE or FALSE

Details

This function allows the estimation of a logistic growth model. The user must specify the dependent variable (cumulative infections) and the time variable (time counter or date values). The estimation is performed using a linearized model as an OLS estimator and as an NLS estimator. For the former, the saturation value can either be specified by the user or found using a search algorithm. The parameters from the OLS fit are used as starting values for the NLS estimation.

Value

object of class [loggrowth-class](#)

Author(s)

Thomas Wieland

References

Chowell G, Simonsen L, Viboud C, Yang K (2014) Is West Africa Approaching a Catastrophic Phase or is the 2014 Ebola Epidemic Slowing Down? Different Models Yield Different Answers for Liberia. *PLoS currents* 6. [doi:10.1371/currents.outbreaks.b4690859d91684da963dc40e00f3da81](https://doi.org/10.1371/currents.outbreaks.b4690859d91684da963dc40e00f3da81)

Pell B, Kuang Y, Viboud C, Chowell G (2018) Using phenomenological models for forecasting the 2015 ebola challenge. *Epidemics* 22, 62–70. [doi:10.1016/j.epidem.2016.11.002](https://doi.org/10.1016/j.epidem.2016.11.002)

Wieland T (2020) Flatten the Curve! Modeling SARS-CoV-2/COVID-19 Growth in Germany at the County Level. *REGION* 7(2), 43–83. [doi:10.18335/region.v7i2.324](https://doi.org/10.18335/region.v7i2.324)

See Also

[loggrowth-class](#), [growth](#), [exponential_growth](#)

Examples

```

data(COVID19Cases_geoRegion)
# Get SWISS COVID19 cases at NUTS 3 level

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[!COVID19Cases_geoRegion$geoRegion %in% c("CH", "CHFL"),]
# Exclude CH = Switzerland total and CHFL = Switzerland and Liechtenstein total

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[COVID19Cases_geoRegion$datum <= "2020-05-31",]
# Extract first COVID-19 wave

COVID19Cases_BS <-
  COVID19Cases_geoRegion[(COVID19Cases_geoRegion$geoRegion == "ZH")
    & (COVID19Cases_geoRegion$sumTotal > 0),]
# COVID cases for Zurich

loggrowth_BS <- logistic_growth (
  y = as.numeric(COVID19Cases_BS$sumTotal),
  t = COVID19Cases_BS$datum,
  S = 5557,
  S_start = NULL,
  S_end = NULL,
  S_iterations = 10,
  S_start_est_method = "bisect",
  seq_by = 10,
  nls = TRUE
)
# Logistic growth model with stated saturation value

summary(loggrowth_BS)
# Summary of logistic growth model

plot(loggrowth_BS)
# Plot of logistic growth model

```

metrics

Fit metrics of observed and expected numeric variables

Description

Calculation of fit metrics for observed and expected numeric variables (e.g. R^2 , $RMSE$, MAE , $MAPE$).

Usage

```
metrics(
  observed,
  expected,
```

```

plot = TRUE,
plot.main = "Observed vs. expected",
xlab = "Observed",
ylab = "Expected",
point.col = "blue",
point.pch = 19,
line.col = "red",
plot_residuals.main = "Residuals",
legend.cex = 0.7
)

```

Arguments

observed	Numeric vector of observed values.
expected	Numeric vector of expected or predicted values.
plot	Logical. If TRUE, diagnostic plots for observed vs. expected values and relative residual distributions are created.
plot.main	Character string. Title of the observed vs. expected plot.
xlab	Character string. Label of the x-axis.
ylab	Character string. Label of the y-axis.
point.col	Color of points in the observed vs. expected plot.
point.pch	Plotting character used for points.
line.col	Color of the identity line ($y = x$).
plot_residuals.main	Character string. Title of the residuals bar plot.
legend.cex	Numeric. Character expansion factor for legends.

Details

The function computes several goodness-of-fit metrics comparing observed and expected numeric values. In addition to classical error measures such as mean squared error (MSE), root mean squared error (RMSE), mean absolute error (MAE), and mean absolute percentage error (MAPE), the coefficient of determination (R^2) is calculated.

If `plot = TRUE`, the function produces:

- a scatter plot of observed versus expected values including the identity line,
- a bar plot of relative residual frequencies.

Value

A list with two elements:

fit_metrics	A list containing the computed fit metrics: SQR, SAR, SQT, R2, MSE, RMSE, MAE, and MAPE.
observed_expected	A data.frame containing observed values, expected values, residuals, and derived residual measures.

Author(s)

Thomas Wieland

References

Boehmke B, Greenwell B (2020). *Hands-On Machine Learning with R* (1st ed.). Taylor & Francis, New York, NY.

See Also

[metrics](#)

Examples

```
obs <- c(10, 12, 15, 18, 20)
exp <- c(11, 13, 14, 17, 21)

metrics(
  observed = obs,
  expected = exp
)
```

nbmatrix

Construct Neighbourhood Matrix from Polygons

Description

Building a neighbourhood matrix based on regions (polygons) with contiguous boundaries and resulting a data frame

Usage

```
nbmatrix(
  polygon_sf,
  ID_col,
  row.names = NULL
)
```

Arguments

<code>polygon_sf</code>	<code>sf</code> object with polygons
<code>ID_col</code>	Column of <code>polygon_sf</code> with unique ID of each polygon
<code>row.names</code>	<code>row.names</code> for the <code>sf</code> object

Details

The function is based on `spdep::poly2nb`, which creates neighbours lists. The input is a `sf` object (spatial data frame) and the results are 1) a `nb` list (`poly2nb` result) and 2) a `data.frame`.

Value

list with two entries:

nb: Object of class "sb" Neighbours list; see the `spdep:poly2nb` documentation
 nbmat: Object of class "data.frame" Dataset neighbouring regions

Author(s)

Thomas Wieland

References

Wieland T (2020) Flatten the Curve! Modeling SARS-CoV-2/COVID-19 Growth in Germany at the County Level. *REGION* 7(2), 43–83. [doi:10.18335/region.v7i2.324](https://doi.org/10.18335/region.v7i2.324)

Wieland T (2022) Spatial patterns of excess mortality in the first year of the COVID-19 pandemic in Germany. *European Journal of Geography* 13(4), 18-33. [doi:10.48088/ejg.t.wie.13.4.018.033](https://doi.org/10.48088/ejg.t.wie.13.4.018.033)

See Also

[nbstat](#)

Examples

```
data(RKI_Corona_counties)
# German counties (Source: Robert Koch Institute)

Corona_nbmat <-
  nbmatrix (
    RKI_Corona_counties,
    ID_col="AGS"
  )
# Creating neighborhood matrix
```

nbstat

Calculate Neighbourhood Statistics from Polygons

Description

Calculating descriptive neighbourhood statistics based on regions (polygons) with contiguous boundaries and resulting a data frame

Usage

```
nbstat(
  polygon_sf,
  ID_col,
  link_data,
  data_ID_col,
  data_col,
  func = "sum",
  row.names = NULL
)
```

Arguments

polygon_sf	sf object with polygons
ID_col	Column of polygon_sf with unique ID of each polygon
link_data	data.frame to merge with
data_ID_col	Column with unique ID of each polygon in data.frame
data_col	Column with regarded numeric values in data.frame
func	Descriptive statistic (FUN) to be computed for data_col of the neighbouring regions
row.names	row.names for the sf object

Details

The function is based on `spdep::poly2nb`, which creates neighbours lists. The input is a `sf` object (spatial data frame) and the results are 1) a `nb` list (`poly2nb` result) and 2) a `data.frame`.

Value

list with three entries:

nbmat:	Object of class "data.frame" Dataset neighbouring regions
nbmat_data:	Object of class "data.frame" Dataset neighbouring regions and linked data
nbmat_data_aggregate:	Object of class "data.frame" Dataset with statistic by region

Author(s)

Thomas Wieland

References

Wieland T (2020) Flatten the Curve! Modeling SARS-CoV-2/COVID-19 Growth in Germany at the County Level. *REGION* 7(2), 43–83. [doi:10.18335/region.v7i2.324](https://doi.org/10.18335/region.v7i2.324)

Wieland T (2022) Spatial patterns of excess mortality in the first year of the COVID-19 pandemic in Germany. *European Journal of Geography* 13(4), 18-33. [doi:10.48088/ejg.t.wie.13.4.018.033](https://doi.org/10.48088/ejg.t.wie.13.4.018.033)

See Also

[nbmatrix](#)

Examples

```
data(RKI_Corona_counties)
# German counties (Source: Robert Koch Institute)

Corona_nbstat <-
  nbstat (
    RKI_Corona_counties,
    ID_col="AGS",
    link_data = RKI_Corona_counties,
    data_ID_col = "AGS",
    data_col = "EWZ",
    func = "sum"
  )
Corona_nbstat$nbmat_data_aggregate
# Sum of population (EWZ) of neighbouring counties
```

Oesterreich_Faelle *Austria Daily COVID-19 cases by region 2020-02-26 to 2020-05-31*

Description

A dataset containing COVID-19 cases by region (NUTS 3) and time periods (days) for Austria (Source: BMSGPK).

Usage

```
data(Oesterreich_Faelle)
```

Format

A data.frame with multiple columns:

NUTS3 (character) Region for which the data was collected.

Datum (Date) Date of record.

Faelle (integer) Number of reported cases on this date.

Details

The original data was originally published by BMSGPK at a smaller spatial scale level (political districts, "Politische Bezirke"). The data was linked to a corresponding shapefile from Statistik Austria (2022), joined to the NUTS3 level via a spatial join, and summed over the Austrian NUTS3 regions. The spatial join is based on polygon centroids of the political districts level; in cases where the centroid was outside the polygon, it was placed inside the polygon manually.

Source

BMSPGK, Oesterreichisches COVID-19 Open Data Informationsportal (2022) COVID-19: Zeitliche Darstellung von Daten zu Covid19-Faelen je Bezirk. <https://www.data.gv.at/katalog/dataset/4b71eb3d-7d55-4967-b80d-91a3f220b60c> (retrieved 2022-06-23)

Statistik Austria (2022) Politische Bezirke. <https://www.data.gv.at/katalog/dataset/stat-gliederung-osterreichs-in-politische-bezirke131e2> (retrieved 2022-06-27)

Wieland T (2022) C19dNUTS: Dataset of Regional COVID-19 Deaths per 100,000 Pop (NUTS). R package v1.0.1. doi:10.32614/CRAN.package.C19dNUTS

Examples

```
data(Oesterreich_Faelle)
# Get Austrian COVID19 cases at NUTS 3 level
# (first wave, same final date as in Swiss data: 2020-05-31)

AT_covidwave1 <-
  swash (
    data = Oesterreich_Faelle,
    col_cases = "Faelle",
    col_date = "Datum",
    col_region = "NUTS3"
  )
# Swash-Backwash Model for Austrian COVID19 cases
# Spatial aggregate: NUTS 3

summary(AT_covidwave1)
# Summary of model results
```

Description

Methods for function `plot` for different S4 classes: `sbm`, `sbm_ci`, and `loggrowth`.

Methods

`signature(x = "sbm") plot.sbm(x, y, ...)`: Plots the results of the Swash-Backwash Model. This generates two plots:

- Edges over time.
- Total infections per time unit.

Arguments:

- `x`: An object of class `sbm` representing the results of the Swash-Backwash Model.
- `y`: Optional argument for additional customization, such as plot style or axis labels.
- `...`: Additional graphical parameters that can be passed to control plot appearance.

Details: This method is used to visualize the output of the Swash-Backwash Model, providing insight into the dynamics of the modeled epidemic.

`signature(x = "sbm_ci") plot.sbm_ci(x, y, ...)`: Plots the results of bootstrap confidence intervals for the Swash-Backwash Model. This generates a single figure with six subplots:

- S_A (susceptible population),
- I_A (infected population),
- R_A (recovered population),
- t_{FE} (final epidemic time),
- t_{LE} (last epidemic time),
- R_{0A} (basic reproduction number).

Arguments:

- `x`: An object of class `sbm_ci` containing the bootstrap confidence intervals for the Swash-Backwash Model.
- `y`: Optional argument for additional customization, such as plot style or axis labels.
- `...`: Additional graphical parameters for fine-tuning the plots.

Details: This method is used to visualize the bootstrap confidence intervals for various parameters of the Swash-Backwash Model.

`signature(x = "countries") plot.sbm(x, y = NULL, col_bars = "grey", col_ci = "red")`: Plots the results of the between-countries analysis via Swash-Backwash Model. This generates four plots:

- Indicator for country 1
- Indicator for country 2
- Boxplots of the distribution of the indicator in country 1 and 2
- Distribution of the difference between the indicators of country 1 and 2

Arguments:

- `x`: An object of class `countries` representing the results of the Swash-Backwash Model country analysis.
- `y`: Not relevant
- `col_bars`: Color of bars
- `col_ci`: Color of confidence intervals

Details: This method is used to visualize the output of the Swash-Backwash Model, providing insight into the dynamics of the modeled epidemic.

`signature(x = "loggrowth") plot.loggrowth(x, y, ...)`: Plots the results of the logistic growth model, including:

- Observed values,
- Predicted values,
- First derivative (growth rate).

Arguments:

- `x`: An object of class `loggrowth` containing the data for the logistic growth model.
- `y`: Optional argument for additional customization of the plot (e.g., color, labels).
- `...`: Additional arguments for graphical parameters.

Details: This method is useful for visualizing the observed and predicted growth patterns in an epidemic or similar phenomena modeled by logistic growth.

Author(s)

Thomas Wieland

plot_breakpoints *Calculating and plotting breakpoints in time series*

Description

The function calculates breakpoints for time series and provides plots of the analysis results

Usage

```
plot_breakpoints(  
  dataset,  
  formula,  
  alpha = 0.05,  
  line.col = "chocolate",  
  ci.col = c(  
    rgb(0, 0, 255, maxColorValue = 255, alpha = 0.5),  
    rgb(0, 255, 0, maxColorValue = 255, alpha = 0.5),  
    rgb(255, 0, 0, maxColorValue = 255, alpha = 0.5)  
,  
  legend.show = TRUE,  
  legend.pos = c(  
    "topright",  
    "topright",  
    "topright",  
    "topright"  
  ),  
  xlab = "Time",  
  ylab = "Y",  
  ylim = NULL,  
  plot.main = c(  
    "Breakpoints",  
    "Segment model fits",  
    "BIC and Residual Sum of Squares",  
    "Model without breaks (one segment)"  
,  
  output.full = TRUE,  
  separate_plots = FALSE,  
  ...  
)
```

Arguments

dataset data.frame object with (infections) time series

formula	formula object for linear regression formula
alpha	Significance level α for $1-\alpha*100$ confidence intervals
line.col	Line color in time series plot
ci.col	Colors for confidence intervals in 3 plots
legend.show	bool: Show legend?
legend.pos	Position of legend
xlab	Label of x axis
ylab	Label of y axis
ylim	Limits of y axis
plot.main	Titles for 4 plots
output.full	bool: All 4 plots or just one (breakpoints)?
separate_plots	bool: All 4 plots in one or separate?
...	Further arguments passed to breakpoints()

Details

The function uses the `breakpoints()` function from the `strucchange` package (Zeileis et al. 2003) to estimate breaks in time series given by the user. These breakpoints are visualized, confidence intervals and model diagnostics are calculated, and for M breakpoints, $M + 1$ models are estimated and returned.

Value

`data.frame` with one row for each model segment with coefficients, R^2 , etc.

Author(s)

Thomas Wieland

References

Wieland T (2020) A phenomenological approach to assessing the effectiveness of COVID-19 related nonpharmaceutical interventions in Germany. *Safety Science* 131, 104924. [doi:10.1016/j.ssci.2020.104924](https://doi.org/10.1016/j.ssci.2020.104924)

Zeileis A, Kleiber C, Krämer W, Hornik K (2003) Testing and dating of structural changes in practice. *Computational Statistics & Data Analysis* 44(1-2) 109–123. [doi:10.1016/S01679473\(03\)00030-6](https://doi.org/10.1016/S01679473(03)00030-6)

See Also

[logistic_growth](#), [exponential_growth](#)

Examples

```
data(Inflections)
# Confirmed SARS-CoV-2 cases in Germany

plot.breakpoints(
  Inflections,
  log(infections_daily) ~ day,
  output.full = TRUE
)
# Breakpoints for time series
```

plot_coef_ci

Plot Point Estimates With Confidence Intervals

Description

Plotting point estimates with confidence intervals from regression results

Usage

```
plot_coef_ci(
  point_estimates,
  confint_lower,
  confint_upper,
  coef_names,
  p = NULL,
  estimate_colors = NULL,
  confint_colors = NULL,
  auto_color = FALSE,
  alpha = 0.05,
  set_estimate_colors = c("red", "grey", "green"),
  set_confint_colors = c("#ffcccb", "lightgray", "#CCFFCC"),
  skipvars = NULL,
  plot.xlab = "Independent variables",
  plot.main = "Point estimates with CI",
  axis.at = seq(-30, 40, by = 5),
  pch = 15,
  cex = 2,
  lwd = 5,
  y.cex = 0.8
)
```

Arguments

point_estimates	numeric vector containing point estimates
confint_lower	numeric vector containing lower confidence intervals

```

confint_upper numeric vector containing upper confidence intervals
coef_names character vector containing coefficient names
p numeric vector containing  $p$  values of the coefficients (optional)
estimate_colors
  vector containing colors for the point estimates (optional)
confint_colors vector containing colors for the confidence intervals (optional)
auto_color bool value which indicates whether the colors are found automatically based on
  coef and CI values
alpha Significance level  $\alpha$  for  $1-\alpha*100$  confidence intervals
set_estimate_colors
  Colors for point estimates (significant negative, not significant, significant positive)
set_confint_colors
  Colors for confidence intervals (significant negative, not significant, significant positive)
skipvars List with coefficients to be dropped
plot.xlab Label of x axis
plot.main Plot title
axis.at Position of y axis
pch Point type
cex Point size
lwd Line width (confidence intervals)
y.cex Font size of y axis

```

Details

The function checks whether the input vectors have the same length. If `auto_color` is TRUE, the colors from `set_estimate_colors` and `set_confint_colors` are used, and the significance level is determined based on the coefficient and confidence interval values (all three below 0 = significant negative, all three above 0 = significant positive).

Value

Coefficients plot, no returned value

Author(s)

Thomas Wieland

References

Wieland T (2025) Assessing the effectiveness of non-pharmaceutical interventions in the SARS-CoV-2 pandemic: results of a natural experiment regarding Baden-Württemberg (Germany) and Switzerland in the second infection wave. *Journal of Public Health* 33(11), 2497-2511. doi:10.1007/s1038902402218x

Examples

```
data(did_fatalities_splm_coef)
# Results of a difference-in-differences model

plot_coef_ci(
  point_estimates = did_fatalities_splm_coef$Estimate,
  confint_lower = did_fatalities_splm_coef$CI_lower_Bonferroni,
  confint_upper = did_fatalities_splm_coef$CI_upper_Bonferroni,
  coef_names = did_fatalities_splm_coef$Var,
  skipvars = c(
    "Alpha_share",
    "lambda",
    "rho",
    "log(D_Infections_daily_7dsum_per100000_lag2weeks)",
    "vacc_cum_per100000_lag2weeks"
  ),
  lwd = 13,
  pch = 19,
  auto_color = TRUE
)
# Plot with point estimates and confidence intervals
```

plot_regions

Plots of Regional Infections Over Time

Description

Plots regional infection curves in N plots for N regions.

Usage

```
plot_regions(
  object,
  col = "red",
  lty = "solid",
  scale = FALSE,
  normalize_by_col = NULL,
  normalize_factor = 1,
  plot_rollingmean = FALSE,
  rollingmean_col = "blue",
  rollingmean_lty = "solid",
  rollingmean_k = 7,
  rollingmean_align = "center",
  rollingmean_fill = NA,
  growth_col = "orange",
  growth_lty = "solid",
  growth_per_time_unit = 1
)
```

Arguments

object	object of class sbm
col	Color of line plot
lty	Type of line plot
scale	Set y axis of the plots uniformly based on the maximum value across all regions? (boolean, default: FALSE)
normalize_by_col	Normalize infection numbers by stating a column in the input data frame (e.g., regional population)
normalize_factor	Multiply density/incidence with a factor (say, 100,000 inhabitants)
plot_rollmean	Plot rolling mean?
rollmean_col	Color of rolling mean line
rollmean_lty	Type of rolling mean line
rollmean_k	integer width of the rolling window (see <code>zoo::rollmean</code>)
rollmean_align	specifying whether the index of the result should be left- or right-aligned or centered (default) compared to the rolling window of observations (see <code>zoo::rollmean</code>)
rollmean_fill	filling values at the left/within/to the right of the data range (see <code>zoo::rollmean</code>)
growth_col	Color of growth line
growth_lty	Line type of growth line
growth_per_time_unit	Time unit for growth rates

Details

Plots regional infection curves in N plots for N regions, with the number of columns equals 4 and the number of rows is calculated based the size of N .

Value

Plot only, no returned value

Author(s)

Thomas Wieland

Examples

```
data(COVID19Cases_geoRegion)
# Get SWISS COVID19 cases at NUTS 3 level

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[!COVID19Cases_geoRegion$geoRegion %in% c("CH", "CHFL"),]
# Exclude CH = Switzerland total and CHFL = Switzerland and Liechtenstein total
```

```
COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[COVID19Cases_geoRegion$datum <= "2020-05-31", ]
  # Extract first COVID-19 wave

CH_covidwave1 <-
  swash (
    data = COVID19Cases_geoRegion,
    col_cases = "entries",
    col_date = "datum",
    col_region = "geoRegion"
  )
  # Swash-Backwash Model for Swiss COVID19 cases
  # Spatial aggregate: NUTS 3 (cantons)

  plot_regions(CH_covidwave1)
  # Plot of regional infections
```

plot_regions-methods *Methods for Function plot_regions*

Description

Methods for function `plot_regions`

Methods

```
signature( object = "sbm", col = "red", lty = "solid", scale = FALSE, normalize_by_col = NULL, normalize_fa
  Plots regional infection curves in  $N$  plots for  $N$  regions, with the number of columns equals 4
  and the number of rows is calculated based the size of  $N$ . Set the color by the argument col.
  If scale is TRUE, the y axis of the plots is set uniformly based on the maximum value across
  all regions. If the input data contains a column to normalize the infection numbers (such as
  regional population), the user may use this data to normalize the infection numbers by setting
  normalize_by_col. If this density value should be multiplied by a factor (e.g. regional infec-
  tions per 100,000 inhabitants), this can be set with the argument normalize_by_col (default:
  1).
```

Author(s)

Thomas Wieland

print-methods	<i>Methods for Function print</i>
---------------	-----------------------------------

Description

Methods for function print

Methods

```
signature(x = "sbm") Prints an sbm object; use summary(sbm) for results
signature(x = "sbm_ci") Prints an sbm_ci object; use summary(sbm_ci) for results
signature(x = "loggrowth") Prints an loggrowth object; use summary(loggrowth) for results
signature(x = "expgrowth") Prints an expgrowth object; use summary(expgrowth) for results
```

quantile_ci	<i>Computing Quantiles for a given Numeric Vector</i>
-------------	---

Description

Computes quantiles for a given vector x and the related confidence intervals (lower, upper).

Usage

```
quantile_ci(
  x,
  alpha = 0.05
)
```

Arguments

x	A numeric vector
alpha	Significance level α for $1-\alpha*100$ confidence intervals

Details

Helper function for `plot(sbm_ci)`, but may be used separately.

Value

A numeric vector with lower and upper quantile

Author(s)

Thomas Wieland

Examples

```
numeric_vector <- c(1,9,5,6,3,10,20,6,9,14,3,5,8,6,11)
# any numeric vector

quantile_ci(numeric_vector)
```

RKI_Corona_counties *German Counties with COVID-19 Cases*

Description

A dataset containing German counties (NUTS 3) with COVID-19 cases (Source: Robert Koch Institute).

Usage

```
data(RKI_Corona_counties)
```

Format

A data.frame with multiple columns:

OBJECTID unknown/not necessary
ADE (unknown/not necessary)
GF unknown/not necessary
BSG unknown/not necessary
RS (character) County code 1
AGS (character) County code 2
SDV_RS (character) County code 3
GEN (character) County name
BEZ (character) County type
IBZ unknown/not necessary
BEM unknown/not necessary
NBD unknown/not necessary
SN_L unknown/not necessary
SN_R unknown/not necessary
SN_K unknown/not necessary
SN_V1 unknown/not necessary
SN_V2 unknown/not necessary
SN_G unknown/not necessary
FK_S3 unknown/not necessary
NUTS (character) NUTS 3 code

RS_0 unknown/not necessary
AGS_0 unknown/not necessary
WSK unknown/not necessary
EWZ (numeric) Population
KFL (numeric) Area in sq. km
DEBKID unknown/not necessary
Shape_Are unknown/not necessary
Shape_Len unknown/not necessary
death_rate
cases (numeric) COVID-19 cases
deaths (numeric) COVID-19 associated deaths
cases_per_ (numeric) COVID-19 cases per 100,000 inhabitants
cases_pe_1 unknown/not necessary
BL (character) Federal state
BL_ID (integer) Federal state ID
county (character) County name
last_updat Date of last update
geometry Geometry

Details

The data is included as it was published in by the Robert Koch Institute (Robert Koch-Institut, RKI) but extended by the geometry column (Original data: shapefile).

Source

RKI (2020) RKI Corona Landkreise. Robert Koch-Institut (RKI), dl-de/by-2-0. Attribution: Robert Koch-Institut, Bundesamt für Kartographie und Geodäsie. <https://npgeo-corona-npgeo-de.hub.arcgis.com/datasets/917fc37a7095> (retrieved 2020-03-30)

Examples

```

data(RKI_Corona_counties)
# German counties (Source: Robert Koch Institute)

Corona_nbstat <-
  nbstat (
    RKI_Corona_counties,
    ID_col="AGS",
    link_data = RKI_Corona_counties,
    data_ID_col = "AGS",
    data_col = "EWZ",
    func = "sum"
  )
Corona_nbstat$nbmat_data_aggregate
# Sum of population (EWZ) of neighbouring counties
  
```

R_t*Effective Reproduction Number for Epidemic Data*

Description

Calculation of the effective reproduction number for infection/surveillance data

Usage

```
R_t(  
  infections,  
  GP = 4,  
  correction = FALSE  
)
```

Arguments

infections	numeric vector with infection data
GP	Generation period, in days
correction	Correction of values equal to zero? (Recommended)

Details

The function calculates the effective reproduction number, R_t , of an infections time series.

Value

list with two entries:

R_t:	Object of class "numeric" R_t values
infections_data:	Object of class "data.frame" Dataset with infections data and R_t

Author(s)

Thomas Wieland

References

Bonifazi G et al. (2021) A simplified estimate of the effective reproduction number R_t using its relation with the doubling time and application to Italian COVID-19 data. *The European Physical Journal Plus* 136, 386. [doi:10.1140/epjp/s13360021013396](https://doi.org/10.1140/epjp/s13360021013396)

Wieland T (2020) A phenomenological approach to assessing the effectiveness of COVID-19 related nonpharmaceutical interventions in Germany. *Safety Science* 131, 104924. [doi:10.1016/j.ssci.2020.104924](https://doi.org/10.1016/j.ssci.2020.104924)

See Also

[logistic_growth](#)

Examples

```
data(COVID19Cases_geoRegion)
# Get SWISS COVID19 cases at NUTS 3 level

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[!COVID19Cases_geoRegion$geoRegion %in% c("CH", "CHFL"),]
# Exclude CH = Switzerland total and CHFL = Switzerland and Liechtenstein total

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[COVID19Cases_geoRegion$datum <= "2020-05-31",]
# Extract first COVID-19 wave

COVID19Cases_BS <-
  COVID19Cases_geoRegion[(COVID19Cases_geoRegion$geoRegion == "ZH")
    & (COVID19Cases_geoRegion$sumTotal > 0),]
# COVID cases for Zurich

Rt_BS <- R_t(infections = COVID19Cases_BS$entries)
# Effective reproduction number

Rt_BS
```

sbm-class

Class "sbm"

Description

The class "sbm" contains the results of the Swash-Backwash Model and the related input data as well as additional information. Use `summary(sbm)` and `plot(sbm)` for results summary and plotting, respectively.

Objects from the Class

Objects can be created by the function `swash`.

Slots

R_0A: Object of class "numeric" Model result: spatial reproduction number R_{0A}
integrals: Object of class "numeric" Model result: integrals S_A , I_A , and R_A
velocity: Object of class "numeric" Model result: velocity measures t_{FE} and t_{LE}
occ_regions: Object of class "data.frame" Model result: Occurrence at regional level
SIR_regions: Object of class "data.frame" Model result: Susceptible, infected and recovered regions over time

```

cases_by_date: Object of class "data.frame" Total cases by date
cases_by_region: Object of class "data.frame" Cumulative cases by region
input_data: Object of class "data.frame" Input data
data_statistics: Object of class "numeric" Diagnostics of input data
col_names: Object of class "character" Original column names in input data

```

Methods

```

confint signature(object = "sbm"): Creates bootstrap confidence intervals for sbm objects.
plot signature(x = "sbm"): Plots the results of the Swash-Backwash Model; two plots: edges
    over time, total infections per time unit
print signature(x = "sbm"): Prints an sbm object; use summary(sbm) for results
show signature(object = "sbm"): Prints an sbm object; use summary(sbm) for results
summary signature(object = "sbm"): Prints a summary of sbm objects (results of the Swash-
    Backwash Model)
growth signature(object = "sbm"): Estimates logistic growth models from sbm objects
growth_initial signature(object = "sbm"): Estimates exponential growth models from sbm ob-
    jects for a given time period

```

Author(s)

Thomas Wieland

References

Cliff AD, Haggett P (2006) A swash-backwash model of the single epidemic wave. *Journal of Geographical Systems* 8(3), 227-252. [doi:10.1007/s1010900600278](https://doi.org/10.1007/s1010900600278)

Smallman-Raynor MR, Cliff AD, Stickler PJ (2022) Meningococcal Meningitis and Coal Mining in Provincial England: Geographical Perspectives on a Major Epidemic, 1929–33. *Geographical Analysis* 54, 197–216. [doi:10.1111/gean.12272](https://doi.org/10.1111/gean.12272)

Smallman-Raynor MR, Cliff AD, The COVID-19 Genomics UK (COG-UK) Consortium (2022) Spatial growth rate of emerging SARS-CoV-2 lineages in England, September 2020–December 2021. *Epidemiology and Infection* 150, e145. [doi:10.1017/S0950268822001285](https://doi.org/10.1017/S0950268822001285).

Wieland T (2020) Flatten the Curve! Modeling SARS-CoV-2/COVID-19 Growth in Germany at the County Level. *REGION* 7(2), 43–83. [doi:10.18335/region.v7i2.324](https://doi.org/10.18335/region.v7i2.324)

Examples

```
showClass("sbm")
```

sbm_ci-class	<i>Class "sbm_ci"</i>
--------------	-----------------------

Description

The class "sbm_ci" contains the results of the Swash-Backwash Model, confidence intervals for the model estimates, and the related input data as well as additional information. Use `summary(sbm_ci)` and `plot(sbm_ci)` for results summary and plotting, respectively.

Objects from the Class

Objects can be created by the function `confint(sbm)`.

Slots

`R_0A`: Object of class "numeric" Model result: spatial reproduction number R_{0A}
`integrals`: Object of class "numeric" Model result: integrals S_A , I_A , and R_A
`velocity`: Object of class "numeric" Model result: velocity measures t_{FE} and t_{LE}
`occ_regions`: Object of class "data.frame" Model result: Occurrence at regional level
`cases_by_date`: Object of class "data.frame" Total cases by date
`cases_by_region`: Object of class "data.frame" Cumulative cases by region
`input_data`: Object of class "data.frame" Input data
`data_statistics`: Object of class "numeric" Diagnostics of input data
`col_names`: Object of class "character" Column names in input data
`integrals_ci`: Object of class "list" Confidence intervals for integrals S_A , I_A , and R_A
`velocity_ci`: Object of class "list" Confidence intervals for velocity measures t_{FE} and t_{LE}
`R_0A_ci`: Object of class "numeric" Confidence intervals for spatial reproduction number R_{0A}
`iterations`: Object of class "data.frame" Results of bootstrap sampling iterations
`ci`: Object of class "numeric" Lower and upper confidence intervals based on user input
`config`: Object of class "list" Configuration details for bootstrap sampling

Methods

`plot` signature(`x = "sbm_ci"`): Plots the results of bootstrap confidence intervals for the Swash-Backwash Model; one figure with six plots: S_A , I_A , R_A , t_{FE} , t_{LE} , and R_{0A}
`print` signature(`x = "sbm_ci"`): Prints an `sbm_ci` object; use `summary(sbm_ci)` for results
`show` signature(`object = "sbm_ci"`): Prints an `sbm_ci` object; use `summary(sbm_ci)` for results
`summary` signature(`object = "sbm_ci"`): Prints a summary of `sbm_ci` objects (bootstrap confidence intervals for Swash-Backwash Model estimates)

Author(s)

Thomas Wieland

References

Cliff AD, Haggett P (2006) A swash-backwash model of the single epidemic wave. *Journal of Geographical Systems* 8(3), 227-252. doi:10.1007/s1010900600278

Efron B, Tibshirani RJ (1993) An Introduction to the Bootstrap.

Ramachandran KM, Tsokos CP (2021) Mathematical Statistics with Applications in R (Third Edition). Ch. 13.3.1 (Bootstrap confidence intervals). doi:10.1016/B9780128178157.000130

Smallman-Raynor MR, Cliff AD, Stickler PJ (2022) Meningococcal Meningitis and Coal Mining in Provincial England: Geographical Perspectives on a Major Epidemic, 1929–33. *Geographical Analysis* 54, 197–216. doi:10.1111/gean.12272

Smallman-Raynor MR, Cliff AD, The COVID-19 Genomics UK (COG-UK) Consortium (2022) Spatial growth rate of emerging SARS-CoV-2 lineages in England, September 2020–December 2021. *Epidemiology and Infection* 150, e145. doi:10.1017/S0950268822001285.

Examples

```
showClass("sbm_ci")
```

show-methods *Methods for Function show*

Description

Methods for function show

Methods

```
signature(object = "sbm") Prints an sbm object; use summary(sbm) for results  
signature(object = "sbm_ci") Prints an sbm_ci object; use summary(sbm_ci) for results  
signature(object = "loggrowth") Prints an loggrowth object; use summary(loggrowth) for  
results  
signature(object = "expgrowth") Prints an expgrowth object; use summary(expgrowth) for  
results
```

summary-methods	<i>Methods for Function summary</i>
-----------------	-------------------------------------

Description

Methods for function `summary`

Methods

```
signature(object = "sbm") Prints a summary of sbm objects (results of the Swash-Backwash
Model)
signature(object = "sbm_ci") Prints a summary of sbm_ci objects (bootstrap confidence inter-
vals for Swash-Backwash Model estimates)
signature(object = "countries") Prints a summary of a countries object built with the func-
tion compare_countries
signature(object = "loggrowth") Prints a summary of a loggrowth object built with the func-
tion logistic_growth
signature(object = "expgrowth") Prints a summary of a expgrowth object built with the func-
tion exponential_growth
```

swash	<i>Swash-Backwash Model for the Single Epidemic Wave</i>
-------	--

Description

Analysis of regional infection/surveillance data using the Swash-Backwash Model for the single epidemic wave by Cliff and Haggett (2006)

Usage

```
swash(
  data,
  col_cases,
  col_date,
  col_region
)
```

Arguments

<code>data</code>	<code>data.frame</code> with regional infection data
<code>col_cases</code>	Column containing the cases (numeric)
<code>col_date</code>	Column containing the time points (e.g., days)
<code>col_region</code>	Column containing the unique identifier of the regions (e.g., name, NUTS 3 code)

Details

The function performs the analysis of the input panel data using the Swash-Backwash Model. The output is an object of class "sbm". The results can be viewed using `summary(sbm)`. The user must state panel data with daily infections.

Value

object of class [sbm-class](#)

Author(s)

Thomas Wieland

References

Cliff AD, Haggett P (2006) A swash-backwash model of the single epidemic wave. *Journal of Geographical Systems* 8(3), 227-252. [doi:10.1007/s1010900600278](https://doi.org/10.1007/s1010900600278)

Smallman-Raynor MR, Cliff AD, Stickler PJ (2022) Meningococcal Meningitis and Coal Mining in Provincial England: Geographical Perspectives on a Major Epidemic, 1929–33. *Geographical Analysis* 54, 197–216. [doi:10.1111/gean.12272](https://doi.org/10.1111/gean.12272)

Smallman-Raynor MR, Cliff AD, The COVID-19 Genomics UK (COG-UK) Consortium (2022) Spatial growth rate of emerging SARS-CoV-2 lineages in England, September 2020–December 2021. *Epidemiology and Infection* 150, e145. [doi:10.1017/S0950268822001285](https://doi.org/10.1017/S0950268822001285).

See Also

[sbm-class](#)

Examples

```
data(COVID19Cases_geoRegion)
# Get SWISS COVID19 cases at NUTS 3 level

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[!COVID19Cases_geoRegion$geoRegion %in% c("CH", "CHFL"),]
# Exclude CH = Switzerland total and CHFL = Switzerland and Liechtenstein total

COVID19Cases_geoRegion <-
  COVID19Cases_geoRegion[COVID19Cases_geoRegion$datum <= "2020-05-31",]
# Extract first COVID-19 wave

CH_covidwave1 <-
  swash (
    data = COVID19Cases_geoRegion,
    col_cases = "entries",
    col_date = "datum",
    col_region = "geoRegion"
  )
# Swash-Backwash Model for Swiss COVID19 cases
# Spatial aggregate: NUTS 3 (cantons)
```

```
summary(CH_covidwave1)
# Summary of Swash-Backwash Model

plot(CH_covidwave1)
# Plot of Swash-Backwash Model edges and total epidemic curve
```

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