Package 'EVI'

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Title Epidemic Volatility Index as an Early-Warning Tool

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Description Implementation of the epidemic volatility index (EVI), as
discussed by Kostoulas et. al. (2021). EVI is a new, conceptually simple, early warning tool for oncoming epidemic waves.
EVI is based on the volatility of newly reported cases per unit of time,
ideally per day, and issues an early warning when the volatility change rate exceeds a threshold.

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`deviant` *This function produces the Epidemic Volatility Index based output data*

Description

This is the main function of the `EVI-package` that you should use to analyze a time series of observed cases per unit of time (ideally per day).

Usage

```
deviant(new_cases, cum = FALSE, r_a = 7, r = 0.2, lag_max = 30)
```

Arguments

`new_cases`	the time series of the newly observed cases per unit of time (ideally per day).
`cum`	TRUE or FALSE; TRUE if the time series is recorded as the cumulative number of the reported cases and FALSE (the default) if newly reported cases per unit of time are recorded.
`r_a`	The window size for the moving average that will be analyzed. If set to 1 the actual observations are analyzed. However, due to the variability of the reported cases between working days and weekends it is recommended that the 7-day moving average is analyzed (i.e. r_a = 7), which is the default for this argument. Users could prefer a longer interval of 14 days or one month (i.e., r_a=14 or 30, respectively).
`r`	Definition for the minimum difference in the mean number of cases, one week before and after each time point that, if present, should be detected. This is the case definition and the default is 0.2 (with 0 <= r <= 1). A value of r=0.2 means that we have a case when the mean number of the newly observed cases in the next 7 days is at least 20% higher than the mean number of the newly observed cases in the past 7 days.

`lag_max` Integer. Restriction of the maximum window size for the rolling window size. The default is set to one month (lag_max=30) to prevent excess volatility of past epidemic waves from affecting the most recent volatility estimates and the ability of EVI to warn for upcoming waves that may be smaller and of lower volatility than previous ones.

Details

For each time point the stored variables are:

Value

- Dates: the date for each time point (with origin 01-01-1970).
- Days: the serial number for each time point.
- EVI: the estimated EVI for each time point.
- Cases: the rolling average of the newly observed cases for each time point. A 7-day rolling average is calculated by default (i.e., r_a=7). The user has the option to change this by modifying r_a.
- Index: takes values 1 or 0 for the issuance of an early warning or not, respectively.
- ppv: the positive predictive value for each time point.
- npv: the negative predictive value for each time point.
- lag_all: the selected rolling window size for EVI calculation for each time point.
- c_all: the selected cut-off for issuing an early warning for each time point.
- se_all: the sensitivity (Se) of EVI up to this time point.
- sp_all: the specificity (Sp) of EVI up to this time point.

References

Kostoulas, P., Meletis, E., Pateras, K. et al. The epidemic volatility index, a novel early warning tool for identifying new waves in an epidemic. Sci Rep 11, 23775 (2021). doi: 10.1038/s41598021-026223

Examples

```
## Not run:
   # Epidemic Volatility Index (EVI) Explained:
  vignette('EVI', package='EVI')

  # For information on how to cite EVI:
  citation('EVI')

## End(Not run)
```

`deviant_update` *Deviant Updater function*

Description

This function is used after first running the deviant function. Once the `deviant()` function has been used to analyze the already observed time series, the deviant_update() function is used to obtain the EVI output and issue early warnings for the new cases that are recorded.

Usage

```
deviant_update(new_cases, cum = FALSE, r_a = 7, r = 0.2, lag_max = 30)
```

Arguments

`new_cases`	the time series of the newly observed cases per unit of time (ideally per day).
`cum`	TRUE if the time series is recorded as the cumulative number of the reported cases and FALSE (the default) if newly reported cases per unit of time are recorded.
`r_a`	The window size for the moving average that will be analyzed. If set to 1 the actual observations are analyzed. However, due to the variability of the reported cases between working days and weekends it is recommended that the 7-day moving average is analyzed (i.e. r_a = 7), which is the default for this argument. Users could prefer a longer interval of 14 days or one month (i.e., r_a=14 or 30, respectively).
`r`	Definition for the minimum difference in the mean number of cases, one week before and after each time point that, if present, should be detected. This is the case definition and the default is 0.2 (with 0 <= r <= 1). A value of r=0.2 means that we have a case when the mean number of the newly observed cases in the next 7 days is at least 20% higher than the mean number of the newly observed cases in the past 7 days.
`lag_max`	Integer. Restriction of the maximum window size for the rolling window size. The default is set to one month (lag_max=30) to prevent excess volatility of past epidemic waves from affecting the most recent volatility estimates and the ability of EVI to warn for upcoming waves that may be smaller and of lower volatility than previous ones.

Value

After running the deviant_update() function the output of the deviant function (EVI_output) is also updated with a new row of data for each newly observed time point.

References

Kostoulas, P., Meletis, E., Pateras, K. et al. The epidemic volatility index, a novel early warning tool for identifying new waves in an epidemic. Sci Rep 11, 23775 (2021). doi: 10.1038/s41598021-026223

Examples

```
        ## Not run:
           # Epidemic Volatility Index (EVI) Explained:
          vignette('EVI', package='EVI')

          # For information on how to cite EVI:
          citation('EVI')

## End(Not run)
```

---

evi *Calculation of the Epidemic Volatility Index*

Description

Calculates the relative change in the standard deviation between two consecutive rolling windows.

Usage

```
evi(rollsd)
```

Arguments

`rollsd`	numeric vector - returned and stored as roll from the rollsd() function.

Value

Returns a vector of the relative changes in the standard deviation between two consecutive rolling windows for a time series.

References

Kostoulas, P., Meletis, E., Pateras, K. et al. The epidemic volatility index, a novel early warning tool for identifying new waves in an epidemic. Sci Rep 11, 23775 (2021). doi: 10.1038/s41598021-026223

Examples

```
data("Italy")
cases = mova(cases = Italy$Cases)
roll = rollsd(cases = cases)
ev = evi(rollsd = roll)
```

`evi.graphs` *Epidemic Volatility Index Graphs*

Description

This function produces plots of the time series data with the EVI predictions.

Usage

```
evi.graphs(EVI_output, graph = c("EVI"), ln = TRUE, type = "p")
```

Arguments

`EVI_output`	output of the `deviant()` function
`graph`	Type of graph to be plotted. Options: "EVI", "PPV", "NPV". "EVI" (the default) is giving a plot of the confirmed cases, with red dots corresponding to time points that an early warning was issued and grey dots corresponding to time points without an early warning indication. "PPV" is giving a plot of the confirmed cases with colored dots corresponding to time points with an early warning. Color intensity is increasing with higher PPV. "NPV" is giving a plot of the confirmed cases with colored dots corresponding to time points without an early warning. Color intensity is increasing with higher NPV.
`ln`	TRUE or FALSE; If TRUE (the default) the output of the graph will be presented on the logarithmic scale. IF FALSE the output data will be presented on the original scale.
`type`	By default, points are plotted on EVI graphs. In cases where, changes are very sudden or data sparsely available, type="l" introduces lines on top of points for the "EVI" type of graph.

Value

Three types of plots are generated: (i) A plot of the confirmed cases with red dots corresponding to time points that an early warning was issued and grey dots corresponding to time points without an early warning indication. (ii) A plot of the confirmed cases with colored dots corresponding to time points with an early warning. Color intensity is increasing with higher positive predictive value (PPV). (iii) A plot of the confirmed cases with colored dots corresponding to time points without an early warning. Color intensity is increasing with higher negative predictive value (NPV).

An EVI_output is required as input, derived from the `deviant()` function.

References

Kostoulas, P., Meletis, E., Pateras, K. et al. The epidemic volatility index, a novel early warning tool for identifying new waves in an epidemic. Sci Rep 11, 23775 (2021). doi: 10.1038/s41598021-026223

Examples

```
        ## Not run:
           # Epidemic Volatility Index (EVI) Explained:
          vignette('EVI', package='EVI')

          # For information on how to cite EVI:
          citation('EVI')

## End(Not run)
```

`evifcut` *Sensitivity-Specificity estimation for each cut-off value and rolling window size*

Description

This function calculates the sensitivity and the specificity for each cut-off value and rolling window size.

Usage

```
evifcut(evi, cases, cut, r)
```

Arguments

`evi`	numeric vector - object (obtained from the evi function and stored as ev) that corresponds to the relative change in the standard deviation.
`cases`	numeric vector with the number of new cases per unit of time (i.e., daily).
`cut`	threshold value (0 <= c <= 0.5) for issuing an early warning. If evi >= c, an early warning is issued and otherwise is not.
`r`	Definition for the minimum difference in the mean number of cases, one week before and after each time point that, if present, should be detected. This is the case definition and the default is 0.2 (with 0 <= r <= 1). A value of r=0.2 means that we have a case when the mean number of the newly observed cases in the next 7 days is at least 20% higher than the mean number of the newly observed cases in the past 7 days.

Value

Returns a list of the estimated Sensitivity, Specificity, apparent and true prevalence for each cut-off value and rolling window size

References

Kostoulas, P., Meletis, E., Pateras, K. et al. The epidemic volatility index, a novel early warning tool for identifying new waves in an epidemic. Sci Rep 11, 23775 (2021). doi: 10.1038/s41598021-026223

Examples

```
data("Italy")
cases = mova(cases = Italy$Cases)
roll = rollsd(cases = cases)
ev = evi(rollsd = roll)
evifcut(evi = ev, cases = cases, cut = 0.01, r = 0.2)
```

`indic` *Issue of an Early Warning*

Description

This function produces the early warning signal (Index).

Usage

```
indic(evi, cut, cases)
```

Arguments

`evi`	numeric vector - object (obtained from the evi function and stored as ev) that corresponds to the relative change in the standard deviation.
`cut`	threshold value (0 <= c <= 0.5) for issuing an early warning. If evi >= c an early warning is issued and otherwise is not.
`cases`	numeric vector with the number of new cases per unit of time (i.e., daily).

Value

A vector of 0s and 1s is produced, where a 1 (Index = 1) is recorded when an early warning is issued and a 0 (Index = 0) when an early warning is not issued.

References

Kostoulas, P., Meletis, E., Pateras, K. et al. The epidemic volatility index, a novel early warning tool for identifying new waves in an epidemic. Sci Rep 11, 23775 (2021). doi: 10.1038/s41598021-026223

Examples

```
data("Italy")
cases = mova(cases = Italy$Cases, r_a = 7)
roll = rollsd(cases = cases, lag_t = 7)
ev = evi(rollsd = roll)
ind=indic(evi = ev, cut = 0.01, cases = cases)
```

Italy *Cases of the first 149 days of the COVID-19 pandemic in Italy.*

Description

A data frame containing the number of cases for the first 149 days of the COVID-19 pandemic in Italy.

Usage

```
data(Italy)
```

Format

A data frame with 149 rows and 3 variables:

Date ID of date encoded with origin="01-01-1970".

Cases Number of newly observed cases per day.

Cum_Cases Cumulative number of newly observed cases per day.

Source

COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University. https://github.com/CSSEGISandData/COVID-19

References

Dong E, Du H, Gardner L. An interactive web-based dashboard to track COVID-19 in real time. Lancet Inf Dis. 20(5):533-534. doi: 10.1016/S14733099(20)301201

medvol *Standard deviation*

Description

This function calculates the standard deviation of a vector.

Usage

```
medvol(x)
```

Arguments

x	numeric vector

Value

Returns the standard deviation of a vector.

References

Kostoulas, P., Meletis, E., Pateras, K. et al. The epidemic volatility index, a novel early warning tool for identifying new waves in an epidemic. Sci Rep 11, 23775 (2021). doi: 10.1038/s41598021-026223

Examples

```
x = c(2,2,1,4,9,10,23,10,9,10,14,12,10)
medvol(x)
```

---

mova *Moving Average*

Description

This function calculates the moving average of a time series.

Usage

```
mova(cases, r_a = 7)
```

Arguments

cases	the time series of the newly observed cases per unit of time (ideally per day).
r_a	The window size for the moving average that will be analyzed. If set to 1 the actual observations are analyzed. However, due to the variability of the reported cases between working days and weekends it is recommended that the 7-day moving average is analyzed (i.e. r_a = 7), which is the default for this argument. Users could prefer a longer interval of 14 days or one month (i.e., r_a=14 or 30, respectively).

Value

Returns as a vector the moving average for a time series.

References

Kostoulas, P., Meletis, E., Pateras, K. et al. The epidemic volatility index, a novel early warning tool for identifying new waves in an epidemic. Sci Rep 11, 23775 (2021). doi: 10.1038/s41598021-026223

Examples

```
data("Italy")
mova(cases = Italy$Cases, r_a = 7)
mova(cases = Italy$Cases, r_a = 14)
```

`rollsd` *Rolling standard deviation*

Description

This function computes the rolling standard deviation for a time series.

Usage

```
rollsd(cases, lag_t = 7)
```

Arguments

`cases`	the time series of the newly observed cases per unit of time (ideally per day).
`lag_t`	integer - the size of the rolling window for which the rolling standard deviation is calculated (minimum/default value = 7, maximum recommended value = 30).

Value

Returns a vector with the estimated rolling standard deviation for a time series.

References

Kostoulas, P., Meletis, E., Pateras, K. et al. The epidemic volatility index, a novel early warning tool for identifying new waves in an epidemic. Sci Rep 11, 23775 (2021). doi: 10.1038/s41598021-026223

Examples

```
data("Italy")
cases = mova(cases=Italy$Cases, r_a = 7)
roll = rollsd(cases=cases,lag_t = 7)
```

`status` *True status definition*

Description

This function defines the true status based on the case definition.

Usage

```
status(cases, r)
```

Arguments

`cases`	the time series of the newly observed cases per unit of time (ideally per day).
`r`	Definition for the minimum difference in the mean number of cases, one week before and after each time point that, if present, should be detected. This is the case definition and the default is 0.2 (with 0 <= r <= 1). A value of r=0.2 means that we have a case when the mean number of the newly observed cases in the next 7 days is at least 20% higher than the mean number of the newly observed cases in the past 7 days.

Value

A vector of 0s and 1s is produced. Status = 1 is when the expected rise in the number of cases occurs and Status = 0 when the expected rise in the number of cases does not occur.

References

Kostoulas, P., Meletis, E., Pateras, K. et al. The epidemic volatility index, a novel early warning tool for identifying new waves in an epidemic. Sci Rep 11, 23775 (2021). doi: 10.1038/s41598021-026223

Examples

```
data("Italy")
cases = mova(cases=Italy$Cases)
status = status(cases=cases, r=0.2)
```

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