Package: hydropeak (via r-universe)

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Type Package

Title Detect and Characterize Sub-Daily Flow Fluctuations

Version 0.1.2

Description An important environmental impact on running water ecosystems is caused by hydropeaking - the discontinuous release of turbine water because of peaks of energy demand. An event-based algorithm is implemented to detect flow fluctuations referring to increase events (IC) and decrease events (DC). For each event, a set of parameters related to the fluctuation intensity is calculated. The framework is introduced in Greimel et al. (2016) ``A method to detect and characterize sub-daily flow fluctuations'' <doi:10.1002/hyp.10773> and can be used to identify different fluctuation types according to the potential source: e.g., sub-daily flow fluctuations caused by hydropeaking, rainfall, or snow and glacier melt. This is a companion to the package 'hydroroute', which is used to detect and follow hydropower plant-specific hydropeaking waves at the sub-catchment scale and to describe how hydropeaking flow parameters change along the longitudinal flow path as proposed and validated in Greimel et al. (2022).

License GPL-2

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Contents

`all_metrics` *Event Based Fluctuation Flow Parameters*

Description

Given an event with equal flow trend, all metrics implemented in the package **hydropeak** are computed and combined to a data frame. It includes also an identifier of the gauging station provided by the user and the starting time of the event.

Usage

```
all_metrics(x, id, event_type)
```

Arguments

`x`	Data frame (time series) from an event with equal flow trend. The data frame must contain a date-time column (`Time`) and a flow rate column (`Q`) and must be in a compatible format (see `flow()`).
`id`	Character string which refers to the identifier of the gauging station (in Austria: HZBCODE).

event_type — Numeric value which indicates the event type. By using get_events(), this is internally computed. If metrics for a single event have to be computed individually, the event type has to be provided as an argument or can be computed with event_type().

Value

A data frame including all computed metrics, IDs of gauging stations, event type (see event_type() for an overview of possible event types), and starting time of an event x. Included metrics are amp(), mafr(), mefr(), dur(), ratio().

Examples

```
data(Q)
# decreasing event:
Q4 <- flow(Q[3:4, ])
all_metrics(Q4, id = Q$ID[1], event_type = 4)
all_metrics(Q4, id = Q$ID[1], event_type = event_type(Q4))

# increasing event:
Q2 <- flow(Q[486:487, ])
all_metrics(Q2, id = Q$ID[1], event_type = 2)
all_metrics(Q2, id = Q$ID[1], event_type = event_type(Q2))

# constant event (at beginning or after NA event):
Q0 <- flow(Q[1:3, ])
all_metrics(Q0, id = Q$ID[1], event_type = 0)
all_metrics(Q0, id = Q$ID[1], event_type = event_type(Q0))
```

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amp *AMP - Amplitude (Metric 1)*

Description

The amplitude (AMP, unit: m^3/s) of an event is defined as the difference between the flow maximum (Q_{max}) and the flow minimum (Q_{min}). Given an event with equal flow trend, the amplitude is computed and returned.

Usage

```
amp(x)
```

Arguments

x — Data frame (time series) from an event with equal flow trend. The data frame must contain a date-time column (Time) and a flow rate column (Q) and must be in a compatible format (see flow()).

Value

Returns a positive numeric value which is the difference of `max(x$Q)` and `min(x$Q)` of an event. If a data frame containing `NA` flow rates (`Q`) is given, `NA` is returned.

Examples

```
data(Q)
Q <- flow(Q[3:4, ])
amp(Q)
```

`dur` *DUR - Duration (Metric 4)*

Description

The duration of an event is specified as the number of consecutive time steps with equal flow trend.

Usage

```
dur(x)
```

Arguments

`x`	Data frame (time series) from an event with equal flow trend. The data frame must contain a date-time column (`Time`) and a flow rate column (`Q`) and must be in a compatible format. (see `flow()`).

Value

Returns an integer value which is the number of consecutive time steps.

Examples

```
data(Q)
Q <- flow(Q[3:4, ])
dur(Q)
```

`Events` *Events*

Description

A complementary dataset to the flow fluctuation dataset Q. It contains the events and metrics such as computed by `get_events()`.

Usage

```
Events
```

Format

A data frame with 165 rows and 8 variables:

ID Character string which refers to the identifier of the gauging station (in Austria: HZBCODE)

EVENT_TYPE Event types are defined as follows:

- 0: Constant event after NA event or constant event as first event in time series
- 1: Constant event after DC
- 2: Increasing event (IC)
- 3: Constant event after IC
- 4: Decreasing event (DC)
- 5: NA event

Time Date-time of event starting point

AMP Amplitude (`amp()`)

MAFR Maximum flow fluctuation rate (`mafr()`)

MEFR Mean flow fluctuation rate (`mefr()`)

DUR Duration (`dur()`)

RATIO Flow ratio (`ratio()`)

`event_type` *Event Type*

Description

Given a data frame (time series) of equal flow (Q) trend, it is determined whether the flow is increasing or decreasing, constant or if missing values occur. It returns a numeric value which indicates the event type. As the event type is already determined when the change points are computed, this function is mainly used for demonstration purpose or if metrics should be computed individually.

Usage

```
event_type(x)
```

Arguments

x	Data frame (time series) from an event with equal flow trend. Data frame must contain a date-time column (Time) and a flow rate column (Q) and must be in a compatible format. (see flow()).

Value

Returns an numeric value which indicates the event type. Event types are defined as follows:

- 0: Constant event after NA event or constant event as first event in time series
- 1: Constant event after DC
- 2: Increasing event (IC)
- 3: Constant event after IC
- 4: Decreasing event (DC)
- 5: NA event

Examples

```
data(Q)
# decreasing event
Q4 <- flow(Q[3:4, ])
event_type(Q4)

# increasing event
Q2 <- flow(Q[486:487, ])
event_type(Q2)
```

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flow *'flow' S3 Class for Flow Rate Time Series*

Description

The function flow() creates a flow rate time series object which is formatted to be compatible with the functions in the **hydropeak** package.

Usage

```
flow(
  x,
  format = "%d.%m.%Y %H:%M",
  tz = "Etc/GMT-1",
  cols = c(1, 2, 3),
  steplength = 15,
  full = TRUE
)

validate_flow(x)
```

Arguments

x	Data frame which contains at least a column with an ID of the gauging station, a column with date-time values in character representation and a column with flow rates
format	Character string giving the date-time format of the date-time column in the input data frame (default: dd.mm.YYYY HH:MM)
tz	Character string specifying the time zone to be used for the conversion (default: Etc/GMT-1).
cols	Integer vector specifying column indices in the input data frame which contain gauging station ID, date-time and flow rate to be renamed. The default indices are 1 (ID), 2 (date-time) and 3 (flow rate, Q).
steplength	Numeric value which specifies the distance between (equispaced) time steps in minutes. (default: 15, which refers to 15 minutes). Non-equispaced time steps are not supported and missing time steps are imputed if argument full is set to TRUE (default), Q values are assumed to be NA.
full	A logical. If TRUE (default) imputes missing time step values so the time series is complete. Imputed Q values are set to NA. It should only be set to FALSE, if it is known, that the time series is complete.

Value

Returns a flow object which inherits from data frame (time series). It contains at least a gauging station ID column (ID) converted to character values, a date-time column (Time) converted to class "POSIXlt" (see base::strptime()) and a flow rate column (Q), which is converted to numeric values. The flow() object ensures that input flow fluctuation time series data can be processed with the functions in the **hydropeak** package. Therefore, it is mandatory to provide the correct indices (see argument cols) and the correct date-time format (see argument format) of the input data frame.

Examples

```
data(Q)
Q <- flow(Q)
```

`get_events` *Flow Fluctuation Events and Metrics*

Description

Given a data frame (time series) of stage measurements, all increase (IC) and decrease (DC) events are determined and all metrics implemented in the package **hydropeak** (see `all_metrics()`) are computed and combined to a data frame. Optionally, NA events and constant events can be included. NA events occur due to missing stage measurement values. The beginning of NA events refers to the last measurement with a non-missing Q value. Constant events are events where the Q values stay constant over time. An event is uniquely identifiable through the combination of the event starting time (`Time`) and the gauging station identifier (`ID`).

Usage

```
get_events(x, mc.cores = 2L, omit.constant = TRUE, omit.na = TRUE, ...)
```

Arguments

`x`	Data frame (time series) of stage measurements which contains at least a column with ID of the gauging station (default: column index 1) column with date-time values (default: columns index 2) in character representation and a column with flow rates (default: column index 3). If the column indices differ from `c(1, 2, 3)`, they have to be specified as `...` argument in the format `c(i, j, k)`.
`mc.cores`	Number of cores to use with `parallel::mclapply()`. On Windows, this will be set to 1.
`omit.constant`	A logical. If `FALSE` (default) it does not return events with constant measurements. Otherwise these events are included.
`omit.na`	A logical. If `FALSE` (default) it does not return missing value events. Otherwise these events are included.
`...`	Arguments to be passed to `flow()` to specify the date-time format in the input data (default: `dd.mm.YYYY HH:MM`), the time zone used for the conversion (default: `Etc/GMT-1`) and the column indices in the input data, which contain date-time values and flow rate values. The default indices are 1 (ID), 2 (date-time) and 3 (flow rate, Q), i.e. `cols = c(1, 2, 3)`.

Value

A data frame which contains for every event in a given time series all metrics (`all_metrics()`), gauging station ID, event type, and starting time of an event. Included metrics are `amp()`, `mafr()`, `mefr()`, `dur()`, `ratio()`. These metrics are only computed for increasing (IC) and decreasing (DC) events. For all other events the values are set to 0 except for flow ratio that is set to 1. Event types are defined as follows:

- 0: Constant event after NA event or constant event as first event in time series
- 1: Constant event after DC

- 2: Increasing event (IC)
- 3: Constant event after IC
- 4: Decreasing event (DC)
- 5: NA event

Examples

```
# Data with multiple events and different stations
data(Q)
get_events(Q)

# including constant events
get_events(Q, omit.constant = FALSE)
```

`get_events_dir` *Flow Fluctuation Events and Metrics from Input Directory*

Description

Given a directory path it calls `get_events_file()` for each file in the directory, recursively. The resulting events are split into separate files for each gauging station ID (`ID`) and `Event_Type` and are written to the given output directory.

Usage

```
get_events_dir(
  Q_dir,
  inputsep = ";",
  inputdec = ".",
  outdir = file.path(tempdir(), "Events"),
  mc.cores = 2L,
  ...
)
```

Arguments

`Q_dir`	A character string containing the path name where the input data are located.
`inputsep`	Field separator character string for input data.
`inputdec`	Character string for decimal points in input data.
`outdir`	A character string naming a directory where the output file(s) should be written to.
`mc.cores`	Number of cores to use with `parallel::mclapply()`. On Windows, this will be set to 1.
`...`	Arguments to be passed to `get_events_file()` and further to `get_events()` and `flow()`.

Value

No return value, called for side effects.

Examples

```
Q_dir <- "./inst/extdata"
get_events_dir(Q_dir, inputsep = ",", inputdec = ".")
```

`get_events_file` *Flow Fluctuation Events and Metrics from Input File*

Description

Given a file path it reads a data frame (time series) of stage measurements and calls `get_events()`. The resulting events can be optionally written to a single file or to separate files for each gauging station ID (`ID`) and `Event_Type`. Files which produce errors return `NULL`.

Usage

```
get_events_file(
  Q_file,
  inputsep = ";",
  inputdec = ".",
  save = FALSE,
  split = TRUE,
  outdir = file.path(tempdir(), "Events"),
  mc.cores = 2L,
  return = TRUE,
  ...
)
```

Arguments

`Q_file`	A character string containing the name of the file which the data are to be read from with `utils::read.csv()`.
`inputsep`	Field separator character string for input data.
`inputdec`	Character string for decimal points in input data.
`save`	A logical. If `FALSE` (default) events (results from `get_events()`) are not written to file(s), otherwise events are written to `outdir`.
`split`	A logical. If `TRUE` (default) output files are separated by their gauging station ID (`ID`) and by `Event_Type`, otherwise all events are written to a single file.
`outdir`	A character string naming a directory where the output file(s) should be written to.
`mc.cores`	Number of cores to use with `parallel::mclapply()`. On Windows, this will be set to 1.

return	A logical. If TRUE (default) it returns the resulting data frame or list of data frames. Otherwise it returns NULL.
...	Arguments to be passed to get_events() and further to flow().

Value

A data frame which contains for every increase or decrease event in a given time series all metrics (all_metrics()), gauging station ID, event type, and starting time of an event. Included metrics are amp(), mafr(), mefr(), dur(), ratio(). The returned data frame is not split. Returns NULL, if argument return is set to FALSE.

Examples

```
Q_file <- system.file("extdata", "Q.csv", package = "hydropeak")
# save to tempdir()
events <- get_events_file(Q_file, inputsep = ",", inputdec = ".",
save = TRUE, split = TRUE, return = TRUE)
```

---

mafr *MAFR - Maximum Flow Fluctuation Rate (Metric 2)*

Description

The maximum flow fluctuation rate (MAFR, unit: m^3/s) represents the highest absolute flow change of two consecutive time steps within an event. Given an event with equal flow trend, the maximum flow fluctuation rate is computed and returned.

Usage

```
mafr(x)
```

Arguments

x	Data frame (time series) from an event with equal flow trend. The data frame must contain a date-time column (Time) and a flow rate column (Q) and must be in a compatible format (see flow()).

Value

Returns a numeric value which is the maximum (absolute) flow fluctuation rate. If a data frame containing NA flow rates (Q) is given, NA is returned.

Examples

```
data(Q)
Q <- flow(Q[3:4, ])
mafr(Q)
```

mefr *MEFR - Mean Flow Fluctuation Rate (Metric 3)*

Description

The mean flow fluctuation rate (MEFR, unit: m^3/s^2) is calculated by the event amplitude divided by the number of time steps (duration) within an event. Given an event with equal flow trend, amplitude and duration are computed. From these metrics the mean flow fluctuation rate is calculated and returned.

Usage

```
mefr(x)
```

Arguments

x	Data frame (time series) from an event with equal flow trend. The data frame must contain a date-time column (Time) and a flow rate column (Q) and must be in a compatible format. (see flow()).

Value

Returns a numeric value which is the mean flow fluctuation rate computed by the event amplitude amp() divided by the number of time steps dur(). If a data frame containing NA flow rates (Q) is given, NA is returned.

Examples

```
data(Q)
Q <- flow(Q[3:4, ])
mefr(Q)
```

Q *Flow Fluctuations Q*

Description

A dataset containing sub-daily flow fluctuations of five consecutive days from two different gauging stations. One time step is 15 minutes.

Usage

```
Q
```

Format

A data frame with 960 rows and 3 variables:

ID Character string which refers to the identifier of the gauging station (in Austria: HZBCODE)

Time Character string with date-time information of stage measurements which needs to be converted to a compatible format (see `flow()`)

Q Flow, stage measurements in m^3/s

`ratio` *RATIO - Flow Ratio (Metric 5)*

Description

The metric flow ratio (RATIO) is defined as the flow maximum divided by the flow minimum, $\frac{Q_{max}}{Q_{min}}$. Given an event with equal flow trend, the flow ratio is computed and returned.

Usage

```
ratio(x, event_type)
```

Arguments

`x`	Data frame (time series) from an event with equal flow trend. The data frame must contain a date-time column (`Time`) and a flow rate column (`Q`) and must be in a compatible format. (see `flow()`).
`event_type`	Numeric value which specifies the event type. See `get_events()` for an overview of the event types.

Value

Returns a numeric value which is the flow ratio computed by `max(x$Q)` divided by `min(x$Q)`. If a data frame containing `NA` flow rates (`Q`) is given, `NA` is returned.

Examples

```
data(Q)
Q <- flow(Q[3:4, ])
ratio(Q, event_type(Q))
```

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