

Package ‘imageData’

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Title Aids in Processing and Plotting Data from a Lemna-Tec
Scanalyzer

Author Chris Brien <Chris.Brien@unisa.edu.au>.

Maintainer Chris Brien <Chris.Brien@unisa.edu.au>

Depends R (>= 3.5.0)

Imports dae, ggplot2, stats, XLConnect, Hmisc, GGally, RColorBrewer,
reshape, grid

Suggests testthat

Description Extracts traits from imaging data produced using a Lemna-Tec Scanalyzer
(see <<http://www.lemnatec.com/products/hardware-solutions/scanalyzer-3d>> for more
information). Growth rates between successive imagings are obtained and those for
a nominated set of intervals can also be calculated. Profile or longitudinal plots
of the traits and growth rates can be produced. These allow one to check for
anomalous data and to explore growth patterns in the data.

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URL <http://chris.brien.name>

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anom	<i>Tests if any values in a vector are anomalous in being outside specified limits</i>
------	--

Description

Test whether any values in x are less than the value of lower, if it is not NULL, or are greater than the value of upper, if it is not NULL, or both.

Usage

```
anom(x, lower=NULL, upper=NULL, na.rm = TRUE)
```

Arguments

- x A [vector](#) containing the values to be tested.
- lower A [numeric](#) such that values in x below it are considered to be anomalous.
- upper A [numeric](#) such that values in x above it are considered to be anomalous.
- na.rm A [logical](#) indicating whether NA values should be stripped before the testing proceeds.

Value

A [logical](#) indicating whether any values have been found to be outside the limits specified by lower or upper or both.

Author(s)

Chris Brien

Examples

```
data(exampleData)
anom.val <- anom(longi.dat$Area.smooth.AGR, lower=2.5)
```

anomPlot	<i>Identifies anomalous individuals and produces longitudinal plots without them and with just them</i>
----------	---

Description

Uses [intervalValueCalculate](#) and the function [anom](#) to identify anomalous individuals. The user can elect to print the anomalous individuals, a longitudinal profile plot without the anomalous individuals and/or a longitudinal profile plot with only the anomalous individuals. The plots are produced using ggplot. The plot can be faceted so that a grid of plots is produced.

Usage

```
anomPlot(data, x="xDays+24.16666667", response="Area.smooth.RGR",
          individuals="Snapshot.ID.Tag",
          breaks=seq(12, 36, by=2), vertical.line=NULL,
          groupsFactor=NULL, lower=NULL, upper=NULL,
          start.time=NULL, end.time=NULL, times.factor = "Days",
          suffix.interval=NULL,
          columns.retained=c("Snapshot.ID.Tag", "Smarthouse", "Lane",
                             "Position", "Treatment.1", "Genotype.ID"),
          whichPrint=c("anomalous", "innerPlot", "outerPlot"), na.rm=TRUE, ...)
```

Arguments

data	A data.frame containing the data to be tested and plotted.
x	A character giving the variable to be plotted on the x-axis.
response	A character specifying the response variable that is to be tested and plotted on the y-axis.
individuals	A character giving the name(s) of the factor(s) that define the subsets of the data for which each subset corresponds to the response value for an individual.
breaks	A numeric vector giving the breaks to be plotted on the x-axis scale.
vertical.line	A numeric giving position on the x-axis at which a vertical line is to be drawn. If NULL, no line is drawn.
groupsFactor	A factor giving the name of a factor that defines groups of individuals between which the test for anomalous individuals can be varied by setting values for one or more of lower, upper, start.time and end.time to be NULL, a single value or a set of values whose number equals the number of levels of groupsFactor. If NULL or only a dingle value is supplied, the test is the same for all individuals.
lower	A numeric such that values in response below it are considered to be anomalous. If NULL, there is no testing for values below the lower bound.
upper	A numeric such that values in response above it are considered to be anomalous. If NULL, there is no testing for values above the upper bound.

start.time	A numeric giving the start of the time interval, in terms of a level of times.factor, during which testing for anomalous values is to occur. If NULL, the interval will start with the first observation.
end.time	A numeric giving the end of the time interval, in terms of a level of times.factor, during which testing for anomalous values is to occur. If NULL, the interval will end with the last observation.
times.factor	A character giving the name of the column in data containing the factor for times at which the data was collected. Its levels should be numeric values stored as characters.
suffix.interval	A character giving the suffix to be appended to response to form the name of the column containing the calculated values. If it is NULL then nothing will be appended.
columns.retained	A character giving the names of the columns in data that are to be retained in the data.frame of anomalous individuals.
whichPrint	A character indicating what is to be printed. If anomalous is included, the columns.retained are printed for the anomalous individuals.
na.rm	A logical indicating whether NA values should be stripped before the testing proceeds.
...	allows for arguments to be passed to longiPlot .

Value

A [list](#) with three components:

1. data, a data frame resulting from the [merge](#) of data and the [logical](#) identifying whether or not an individual is anomalous;
2. innerPlot, an object of class ggplot storing the longitudinal plot of the individuals that are not anomalous;
3. outerPlot, an object of class ggplot storing the longitudinal plot of only the individuals that are anomalous.

The name of the column indicating anomalous individuals will be result of concatenating the response, [anom](#) and, if it is not NULL, suffix.interval, each separated by a full stop. The ggplot objects can be plotted using print and can be modified by adding ggplot functions before printing. If there are no observations to plot, NULL will be returned for the plot.

Author(s)

Chris Brien

See Also

[anom](#), [intervalValueCalculate](#), [ggplot](#).

Examples

```
data(exampleData)
anomalous <- anomPlot(longi.dat, response="Area.smooth.AGR",
                      lower=2.5, start.time=40,
                      x = "xDays+35.42857143", vertical.line=29,
```

```
breaks=seq(28, 42, by=2),  
whichPrint=c("innerPlot"),  
y.title="Area.smooth.AGR")
```

calcLagged	<i>Replaces the values in a vector with the result of applying an operation to it and a lagged value</i>
------------	--

Description

Replaces the values in `x` with the result of applying an operation to it and the value that is `lag` positions either before it or after it in `x`, depending on whether `lag` is positive or negative. For positive `lag` the first `lag` values will be NA, while for negative `lag` the last `lag` values will be NA. When operation is NULL, the values are moved `lag` positions down the vector.

Usage

```
calcLagged(x, operation = NULL, lag = 1)
```

Arguments

<code>x</code>	A vector containing the values on which the calculations are to be made.
<code>operation</code>	A character giving the operation to be performed on pairs of values in <code>x</code> . If operation is NULL then the values are moved <code>lag</code> positions down the vector.
<code>lag</code>	A integer specifying, for the second value in the pair to be operated on, the number positions it is ahead of or behind the current value.

Value

A [vector](#) containing the result of applying operation to values in `x`. For positive `lag` the first `lag` values will be NA, while for negative `lag` the last `lag` values will be NA.

Author(s)

Chris Brien

See Also

[Ops](#)

Examples

```
data(exampleData)  
longi.dat$Days.diffs <- calcLagged(longi.dat$xDays, operation = "-")
```

calcTimes	<i>Calculates for a set of times, the time intervals after an origin time and the position of each with in that time</i>
-----------	--

Description

For the column specified in imageTimes, having converted it to POSIXct if not already converted, calculates for each value the number of intervalUnits between the time and the startTime. Then the number of timePositions within the intervals is calculated for the values in imageTimes. The function difftimes is used in doing the calculations, but the results are converted to numeric. For example intervals could correspond to the number of Days after Planting and the timePositions to the hour within each day.

Usage

```
calcTimes(data, imageTimes = NULL, timeFormat = "%Y-%m-%d %H:%M",
          intervals = "Time.after.Planting..d.", startTime = NULL,
          intervalUnit = "days", timePositions = NULL)
```

Arguments

data	A data.frame containing any columns specified by imageTimes, intervals and timePositions.
imageTimes	A character giving the name of the column that contains the time that each cart was imaged. Note that in importing data into R, spaces and nonalphanumeric characters in names are converted to full stops. If imageTimes is NULL then no calculations are done.
timeFormat	A character giving the POSIXct format of characters containing times, in particular imageTimes and startTime. Note that if fractions of seconds are required options(digits.secs) must be used to set the number of decimal places and timeFormat must use %OS for seconds in timeFormat.
intervals	A character giving the name of the column in data containing, as a numeric or a factor , the calculated times after startTime to be plotted on the x-axis. It is given as the number of intervalUnits between the two times. If startTime is NULL then intervals is not calculated.
startTime	A character giving the time, in the POSIXct format specified by timeFormat, to be subtracted from imageTimes to calculate intervals. For example, it might be the day of planting or treatment. If startTime is NULL then intervals is not calculated.
intervalUnit	A character giving the name of the unit in which the values of the intervals should be expressed. It must be one of "secs", "mins", "hours" or "days".
timePositions	A character giving the name of the column in data containing, as a numeric , the value of the time position within an interval (for example, the time of imaging during the day expressed in hours plus a fraction of an hour). If timePositions is NULL then it is not calculated.

Value

A data.frame, being the unchanged data data.frame when imageTimes is NULL or containing either intervals and/or timePositions depending on which is not NULL.

Author(s)

Chris Brien

See Also[as.POSIXct](#), [imagetimesPlot](#).**Examples**

```
data(exampleData)
raw.dat <- calcTimes(data = raw.dat,
                     imageTimes = "Snapshot.Time.Stamp", timePositions = "Hour")
```

corrPlot

*Calculates and plots correlation matrices for a set of responses***Description**

Having calculated the correlations a heat map indicating the magnitude of the correlations is produced using ggplot. In this heat map, the darker the red in a cell then the closer the correlation is to -1, while the deeper the blue in the cell, then the closer the correlation is to 1. Also produced is a matrix plot of all pairwise combinations of the variables. The matrix plot contains a scatter diagram for each pair, as well as the value of the correlation coefficient. The argument `pairs.sets` can be used to restrict the pairs in the matrix plot to those combinations within each set.

Usage

```
corrPlot(responses, data, which.plots = c("heatmap", "matrixplot"),
         title = NULL, labels = NULL, labelSize = 4,
         show.sig = FALSE, pairs.sets = NULL, ...)
```

Arguments

<code>responses</code>	A character giving the names of the columns in data containing the variables to be correlated.
<code>data</code>	A data.frame containing the columns of variables to be correlated.
<code>which.plots</code>	A character specifying the plots of the correlations to be produced.
<code>title</code>	Title for the plots.
<code>labels</code>	A character specifying the labels to be used in the plots. If <code>labels</code> is <code>NULL</code> , <code>responses</code> is used for the labels.
<code>labelSize</code>	A numeric giving the size of the labels in the matrixplot.
<code>show.sig</code>	A logical indicating whether or not to give asterisks indicating significance on the plot.
<code>pairs.sets</code>	A list each of whose components is a numeric giving the position of the variable names in <code>responses</code> that are to be included in the set. All pairs of variables in this <code>pairs.set</code> will be included in a matrix plot.
<code>...</code>	allows passing of arguments to other functions

Value

NULL.

Author(s)

Chris Brien

See Also

[ggplot.](#)

Examples

```
## Not run:
data(exampleData)
responses <- c("Area", "Area.SV", "Area.TV", "Image.Biomass", "Max.Height", "Centre.Mass",
              "Density", "Compactness.TV", "Compactness.SV")
corrPlot(responses, longi.dat, pairs.sets=list(c(1:4), c(5:7)))

## End(Not run)
```

cumulate

Calculates the cumulative sum, ignoring the first element if exclude.1st is TRUE

Description

Uses cumsum to calculate the cumulative sum, ignoring the first element if exclude.1st is TRUE.

Usage

```
cumulate(x, exclude.1st = FALSE)
```

Arguments

`x` A [vector](#) containing the values to be cumulated.

`exclude.1st` A [logical](#) indicating whether or not the first value of the cumulative sum is to be NA.

Value

A [vector](#) containing the cumulative sum.

Author(s)

Chris Brien

See Also

[cumsum](#)

Examples

```
data(exampleData)
Area.cum <- cumulate(longi.dat$Area)
```

designFactors

Adds the factors and covariates for a blocked, split-plot design

Description

Add the following factors and covariates to a data frame containing imaging data from the Plant Accelerator: Zones, xZones, SHZones, ZLane, ZMainplots, Subplots and xMainPosn. It checks that the numbers of levels of the factors are consistent with the observed numbers of carts and observations.

Usage

```
designFactors(data, insertName = NULL, designfactorMethod = "LanePosition",
             nzones = 6, nlanesperzone = 4, nmainplotsperlane = 11, nsubplotspermain = 2)
```

Arguments

data	A data.frame to which are to be added the design factors and covariates and which must contain the following columns: Smarthouse, Snapshot.ID.Tag, XDays, xPosn and, if designfactorMethod = "LanePosition", Lane and Position.
insertName	A character giving the name of the column in the data.frame after which the new factors and covariates are to be inserted. If NULL, they are added after the last column.
designfactorMethod	A character giving the method to use to obtain the columns for the design factors Zones, ZLane, Mainplots and Subplots. For LanePosition, it is assumed that (i) Lane can be divided into Zones and ZLane, each with nzones and nlanesperzone levels, respectively, and (ii) Position can be divided into Mainplots and Subplots, each with nmainplotsperlane and nmainplotsperlane levels, respectively. The factor SHZones is formed by combining Smarthouse and Zones and ZMainplots is formed by combining ZLane and Mainplots. For StandardOrder, the factors Zones, ZLane, Mainplots, Subplots are generated in standard order, with the levels of Subplots changing for every observation and the levels of subsequent changing only after all combinations of the levels of the factors to its right have been cycled through.
nzones	A numeric giving the number of zones in a smarthouse.
nlanesperzone	A numeric giving the number of lanes in each zone.
nmainplotsperlane	A numeric giving the number of mainplots in each lane.
nsubplotspermain	A numeric giving the number of subplots in a main plot.

Details

The factors Zones, ZLane, ZMainplots and Subplots are derived for each Smarthouse based on the values of nzones, nlanesperzone, nmainplotsperlane, nsubplotspermain, Zones being the blocks in the split-plot design. Thus, the number of carts in each Smarthouse must be the product of these values and the number of observations must be the product of the numbers of smarthouse, carts and imagings for each cart. If this is not the case, it may be able to be achieved by including in data rows for extra observations that have values for the Snapshot.ID.Tag, Smarthouse, Lane, Position and Time.after.Planting..d. and the remaining columns for these rows have missing values (NA) Then SHZones is formed by combining Smarthouse and Zones and the covariates xZones and xMainPosn calculated. The covariate xZones is calculated from Zones and xMainPosn is formed from the mean of xPosn for each main plot.

Value

A `data.frame` including the columns:

1. Smarthouse: factor with levels for the Smarthouse
2. Zones: factor dividing the Lanes into groups, usually of 4 lanes
3. xZones: numeric corresponding to Zones, centred by subtracting the mean of the unique positions
4. SHZones: factor for the combinations of Smarthouse and Zones
5. ZLane: factor for the lanes within a Zone
6. ZMainplots: factor for the main plots within a Zone
7. Subplots: factor for the subplots
8. xMainPosn: numeric for the main-plot positions within a Lane, centred by subtracting the mean of the unique positions

Author(s)

Chris Brien

Examples

```
data(exampleData)
longi.dat <- designFactors(longi.prime.dat, insertName = "xDays",
                           nzones = 1, nlanesperzone = 1, nmainplotsperlane = 10,
                           designfactorMethod="StandardOrder")
```

exampleData

A small data set to use in function examples

Description

Imaging data for 20 of the plants from an experiment in a Smarthouse in the Plant Accelerator. It is used as a small example in the documentation for `imageData`.

Usage

```
data(exampleData)
```

Format

Four data.frames: raw.dat (280 rows by 33 columns), longi.prime.dat (280 rows by 45 columns), longi.dat (280 rows by 63 columns), cart.dat (20 rows by 14 columns).

fitSpline	<i>Produce the fits from a natural cubic smoothing spline applied to a response in a data.frame</i>
-----------	---

Description

Uses smooth.spline to fit a spline to all the values of response stored in data.

The amount of smoothing can be controlled by df. If df = NULL, the amount of smoothing is controlled by the default arguments and those you supply for smooth.spline. The method of Huang (2001) for correcting the fitted spline for estimation bias at the end-points will be applied if correctBoundaries is TRUE.

The derivatives of the fitted spline can also be obtained, and the Relative Growth Rate (RGR) computed using them, provided correctBoundaries is FALSE. Otherwise, growth rates can be obtained by difference using [splitContGRdiff](#).

By default, smooth.spline will issue an error if there are not at least four distinct x-values. On the other hand, fitSplines issues a warning and sets all smoothed values and derivatives to NA. The handling of missing values in the observations is controlled via na.x.action and na.y.action.

Usage

```
fitSpline(data, response, x, df=NULL, smoothing.scale = "identity",
          correctBoundaries = FALSE,
          deriv=NULL, suffices.deriv=NULL, RGR=NULL, AGR=NULL,
          na.x.action="exclude", na.y.action = "exclude", ...)
```

Arguments

data	A data.frame containing the column to be smoothed.
response	A character giving the name of the column in data that is to be smoothed.
x	A character giving the name of the column in data that contains the values of the predictor variable.
df	A numeric specifying the desired equivalent number of degrees of freedom of the smooth (trace of the smoother matrix). Lower values result in more smoothing. If df = NULL, the amount of smoothing is controlled by the default arguments for and those that you supply to smooth.spline.
smoothing.scale	A character giving the scale on which smoothing is to be performed. The two possibilities are "identity", for directly smoothing the observed response, and "logarithmic", for scaling the log-transformed response.
correctBoundaries	A logical indicating whether the fitted spline values are to have the method of Huang (2001) applied to them to correct for estimation bias at the end-points. Note that deriv must be NULL for correctBoundaries to be set to TRUE.
deriv	A numeric specifying one or more orders of derivatives that are required.

suffices.deriv	A character giving the characters to be appended to the names of the derivatives.
RGR	A character giving the character to be appended to the smoothed response to create the RGR name, but only when <code>smoothing.scale</code> is <code>identity</code> . When <code>smoothing.scale</code> is <code>identity</code> : (i) if RGR is not NULL <code>deriv</code> must include 1 so that the first derivative is available for calculating the RGR; (ii) if RGR is NULL, the RGR is not calculated from the AGR. When <code>smoothing.scale</code> is <code>logarithmic</code> , the RGR is the backtransformed first derivative and so, to obtain it, merely include 1 in <code>deriv</code> and any suffix for it in <code>suffices.deriv</code> .
AGR	A character giving the character to be appended to the smoothed response to create the AGR name, but only when <code>smoothing.scale</code> is <code>logarithmic</code> . When <code>smoothing.scale</code> is <code>logarithmic</code> : (i) if AGR is not NULL, <code>deriv</code> must include 1 so that the first derivative is available for calculating the AGR; (ii) If AGR is NULL, the AGR is not calculated from the RGR. When <code>smoothing.scale</code> is <code>identity</code> , the AGR is the first derivative and so, to obtain it, merely include 1 in <code>deriv</code> and any suffix for it in <code>suffices.deriv</code> .
na.x.action	A character string that specifies the action to be taken when values of <code>x</code> are NA. The possible values are <code>fail</code> , <code>exclude</code> or <code>omit</code> . For <code>exclude</code> and <code>omit</code> , predictions and derivatives will only be obtained for nonmissing values of <code>x</code> . The difference between these two codes is that for <code>exclude</code> the returned <code>data.frame</code> will have as many rows as data, the missing values have been incorporated.
na.y.action	A character string that specifies the action to be taken when values of <code>y</code> , or the response, are NA. The possible values are <code>fail</code> , <code>exclude</code> , <code>omit</code> , <code>allx</code> , <code>trimx</code> , <code>ltrimx</code> or <code>rtrimx</code> . For all options, except <code>fail</code> , missing values in <code>y</code> will be removed before smoothing. For <code>exclude</code> and <code>omit</code> , predictions and derivatives will be obtained only for nonmissing values of <code>x</code> that do not have missing <code>y</code> values. Again, the difference between these two is that, only for <code>exclude</code> will the missing values will be incorporated into the returned <code>data.frame</code> . For <code>allx</code> , predictions and derivatives will be obtained for all nonmissing <code>x</code> . For <code>trimx</code> , they will be obtained for all nonmissing <code>x</code> between the first and last nonmissing <code>y</code> values that have been ordered for <code>x</code> ; for <code>ltrimx</code> and <code>utrimx</code> either the lower or upper missing <code>y</code> values, respectively, are trimmed.
...	allows for arguments to be passed to <code>smooth.spline</code> .

Value

A `data.frame` containing `x` and the fitted smooth. The names of the columns will be the value of `x` and the value of response with `.smooth` appended. The number of rows in the `data.frame` will be equal to the number of pairs that have neither a missing `x` or response and it will have the same order of codes as data. If `deriv` is not NULL, columns containing the values of the derivative(s) will be added to the `data.frame`; the name each of these columns will be the value of response with `.smooth.dvf` appended, where `f` is the order of the derivative, or the value of response with `.smooth.` and the corresponding element of `suffices.deriv` appended. If RGR is not NULL, the RGR is calculated as the ratio of value of the first derivative of the fitted spline and the fitted value for the spline.

Author(s)

Chris Brien

References

Huang, C. (2001). Boundary corrected cubic smoothing splines. *Journal of Statistical Computation and Simulation*, **70**, 107-121.

See Also

[splitSplines](#), [smooth.spline](#), [predict.smooth.spline](#), [splitContGRdiff](#)

Examples

```
data(exampleData)
fit <- fitSpline(longi.dat, response="Area", , x="xDays", df = 4,
                 deriv=c(1,2), suffices.deriv=c("AGRdv","Acc"))
```

getDates	<i>Forms a subset of responses in data that contains their values for the nominated times</i>
----------	---

Description

Forms a subset of responses in data that contains their values for the nominated times.

Usage

```
getDates(responses, times.factor = "Days", data, which.times,
         suffix = NULL, include.times.factor = FALSE,
         include.individuals = FALSE, individuals = "Snapshot.ID.Tag")
```

Arguments

responses	A character giving the names of the columns in data whose values are to be subsetting.
times.factor	A character giving the name of the column in data containing the factor for times at which the data was collected. Its levels will be used to identify the subset and should be numeric values stored as characters.
data	A data.frame containing the column from which the growth rates are to be calculated.
which.times	A vector giving the times that are to be selected.
suffix	A character giving the suffix to be appended to responses to form the names of the columns containing the subset.
include.times.factor	A logical indicating whether or not to include the times.factor in the result, the name in the result having the suffix with a separating full appended.
include.individuals	A logical indicating whether or not to include the individuals column in the result.
individuals	A character giving the name of the column in data containing an identifier for each individual.

Value

A `data.frame` containing the subset of responses ordered by as many of the initial columns as are required to uniquely identify each row (see `order` for more information). The names of the columns for responses and `times.factor` in the subset are the concatenation of their names in `data` and `suffix` separated by a full stop.

Author(s)

Chris Brien

Examples

```
data(exampleData)
AreaLast <- getDates("Area.smooth", data = longi.dat,
                     which.times = c(42), suffix = "last")
```

GrowthRates

Calculates growth rates (AGR, PGR, RGRdiff) between pairs of values in a vector

Description

Calculates either the Absolute Growth Rate (AGR), Proportionate Growth Rate (PGR) or Relative Growth Rate (RGR) between pairs of time points, the second of which is lag positions before the first in `x`.

Usage

```
AGRdiff(x, time.diffs, lag=1)
PGR(x, time.diffs, lag=1)
RGRdiff(x, time.diffs, lag=1)
```

Arguments

<code>x</code>	A <code>numeric</code> from which the growth rates are to be calculated.
<code>time.diffs</code>	a numeric giving the time differences between successive values in <code>x</code> .
<code>lag</code>	A integer specifying, for the second value in the pair to be operated on, the number positions it is ahead of the current value.

Details

The AGRdiff is calculated as the difference between a pair of values divided by the `time.diffs`. The PGR is calculated as the ratio of a value to a second value which is lag values ahead of the first in `x` and the ratio raised to the power of the reciprocal of `time.diffs`. The RGRdiff is calculated as the log of the PGR and so is equal to the difference between the logarithms of a pair of values divided by the `time.diffs`. The differences and ratios are obtained using `calcLagged` with `lag = 1`.

Value

A `numeric` containing the growth rates which is the same length as `x` and in which the first lag values NA.

Author(s)

Chris Brien

See Also[intervalGRAverage](#), [intervalGRdiff](#), [splitContGRdiff](#), [splitSplines](#), [calcLagged](#)**Examples**

```
data(exampleData)
longi.dat$Area.AGR <- with(longi.dat, AGRdiff(Area, time.diffs = Days.diffs))
```

imageData-pkg

*Aids in Processing and Plotting Data from a Lemna-Tec Scanalyzer***Description**

Extracts traits from imaging data produced using a Lemna-Tec Scanalyzer (see <http://www.lemnatec.com/products/hardware/solutions/scanalyzer-3d> for more information). Growth rates between successive imagings are obtained and those for a nominated set of intervals can also be calculated. Profile or longitudinal plots of the traits and growth rates can be produced. These allow one to check for anomalous data and to explore growth patterns in the data.

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For an overview of the use of these functions and an example see below.

(i) Data

[RiceRaw.dat](#)
germplasm panel.

Data for an experiment to investigate a rice

(ii) Data frame manipulation

[designFactors](#)

Adds the factors and covariates for a blocked, split-plot design.

[getDates](#)

Forms a subset of 'responses' in 'data' that contains their values for the nominated times.

[importExcel](#)

Imports an Excel imaging file and allows some renaming of variables.

[longitudinalPrime](#)

Selects a set variables to be retained in a data frame of longitudinal data.

[twoLevelOpcreate](#)

Creates a data.frame formed by applying, for each response, a binary operation to the values of two different treatments.

(iii) Plots

<code>anomPlot</code>	Identifies anomalous individuals and produces longitudinal plots without them and with just them.
<code>corrPlot</code>	Calculates and plots correlation matrices for a set of responses.
<code>imagentimesPlot</code>	Plots the time within an interval versus the interval. For example, the hour of the day carts are imaged against the days after planting (or some other number of days after an event).
<code>longiPlot</code>	Plots longitudinal data from a Lemna Tec Scanalyzer.
<code>probeDF</code>	Compares, for a set of specified values of df, a response and the smooths of it, possibly along with growth rates calculated from the smooths.

(iv) Calculations value-by-value

<code>GrowthRates</code>	Calculates growth rates (AGR, PGR, RGRdiff) between pairs of values in a vector.
<code>WUI</code>	Calculates the Water Use Index (WUI).
<code>anom</code>	Tests if any values in a vector are anomalous in being outside specified limits.
<code>calcTimes</code>	Calculates for a set of times, the time intervals after an origin time and the position of each with in that time.
<code>calcLagged</code>	Replaces the values in a vector with the result of applying an operation to it and a lagged value.
<code>cumulate</code>	Calculates the cumulative sum, ignoring the first element if <code>exclude.1st</code> is TRUE.

(v) Calculations over multiple values

<code>fitSpline</code>	Produce the fits from a natural cubic smoothing spline applied to a response in a 'data.frame'.
<code>intervalGRaverage</code>	Calculates the growth rates for a specified time interval by taking weighted averages of growth rates for times within the interval.
<code>intervalGRdiff</code>	Calculates the growth rates for a specified time interval.
<code>intervalValueCalculate</code>	Calculates a single value that is a function of an individual's values for a response over a specified time interval.
<code>intervalWUI</code>	Calculates water use indices (WUI) over a specified time interval to a data.frame.

(vi) Calculations in each split of a 'data.frame'

<code>splitContGRdiff</code>	Adds the growth rates calculated continuously over time for subsets of a response to a 'data.frame'.
<code>splitSplines</code>	Adds the fits after fitting a natural cubic smoothing spline to subsets of a response to a 'data.frame'.

<code>splitValueCalculate</code>	Calculates a single value that is a function of an individual's values for a response.
(vii) Principal variates analysis (PV A)	
<code>intervalPVA</code>	Selects a subset of variables observed within a specified time interval using PVA.
<code>PVA</code>	Selects a subset of variables using PVA.
<code>rcontrib</code>	Computes a measure of how correlated each variable in a set is with the other variable, conditional on a nominated subset of them.

Overview

This package can be used to carry out a full seven-step process to produce phenotypic traits from measurements made in a high-throughput phenotyping facility, such as one based on a Lemna-Tec Scanalyzer 3D system and described by Al-Tamimi et al. (2016). Otherwise, individual functions can be used to carry out parts of the process.

The basic data consists of imaging data obtained from a set of pots or carts over time. The carts are arranged in a grid of Lanes \times Positions. There should be a unique identifier for each cart, which by default is `Snapshot.ID.Tag`, and variable giving the Days after Planting for each measurement, by default `Time.after.Planting.d..` In some cases, it is expected that there will be a column labelled `Snapshot.Time.Stamp`, which reflects the time of the imaging from which a particular data value was obtained.

The full seven-step process is as follows:

1. Use `importExcel` to import the raw data from the Excel file. This step should also involve any editing of the data needed to take account of mishaps during the data collection and the need to remove faulty data (produces `raw.dat`). Generally, data can be removed by replacing only values for responses with missing values (NA) for carts whose data is to be removed, leaving the identifying information intact.
2. Use `longitudinalPrime` to select a subset of the imaging variables produced by the Lemna Tec Scanalyzer and, if the design is a blocked, split-plot design, use `designFactors` to add co-variates and factors that might be used in the analysis (produces the data frame `longi.prime.dat`).
3. Add derived traits that result in a value for each observation: use `splitContGRdiff` to obtain continuous growth rates i.e. a growth rate for each time of observation, except the first; `WUI` to produce continuous Water Use Efficiency Indices (WUE) and `cumulate` to produce cumulative responses. (Produces the data frame `longi.dat`.)
4. Use `splitSplines` to fit splines to smooth the longitudinal trends in the primary traits and calculate continuous growth rates from the smoothed response (added to the data frame `longi.dat`). There are two options for calculating continuous smoothed growth rates: (i) by differencing — use `splitContGRdiff`; (ii) from the first derivatives of the splines — in `splitSplines` include 1 in the `deriv` argument, include "AGR" in `suffices.deriv` and set the RGR to say "RGR". Optionally, use `probeDF` to compare the smooths for a number of values of `df` and, if necessary, re-run `splitSplines` with a revised value of `df`.
5. Perform an exploratory examination of the unsmoothed data by using `longiPlot` to produce longitudinal plots of unsmoothed imaging traits and continuous growth rates. Also, use `longiPlot` to plot the smoothed imaging traits and continuous growth rates and `anomPlot` to check for anomalies in the data.

6. Produce cart data: traits for which there is a single value for each Snapshot.ID.Tag or cart. (produces the data frame cart.dat)
 - (a) Set up a cart data.frame with the factors and covariates for a single observation from all carts. This can be done by subsetting longi.dat so that there is one entry for each cart.
 - (b) Use [getDates](#) to add traits at specific times to the cart data.frame, often the first and last day of imaging for each Snapshot.ID.Tag. The times need to be selected so that there is one and only one observation for each cart. Also form traits, such as growth rates over the whole imaging period, based on these values
 - (c) Based on the longitudinal plots, decide on the intervals for which growth rates and WUEs are to be calculated. The growth rates for intervals are calculated from the continuous growth rates, using [intervalGRdiff](#), if the continuous growth rates were calculated by differencing, or [intervalGRAverage](#), if they were calculated from first derivatives. To calculate WUEs for intervals, use [intervalWUI](#). The interval growth rates and WUEs are added to the cart data.frame.
7. (Optional) There is also the possibility that, for experiments investigating salinity, the Shoot Ion Independent Tolerance (SIIT) index can be calculated using [twoLevel0pcreate](#).

Author(s)

Chris Brien <Chris.Brien@unisa.edu.au>.

Maintainer: Chris Brien <Chris.Brien@unisa.edu.au>

References

Al-Tamimi, N, Brien, C.J., Oakey, H., Berger, B., Saade, S., Ho, Y. S., Schmockel, S. M., Tester, M. and Negrao, S. (2016) New salinity tolerance loci revealed in rice using high-throughput non-invasive phenotyping. *Nature Communications*, **7**, 13342.

See Also

[dae](#)

Examples

```
## Not run:
### This example can be run because the data.frame RiceRaw.dat is available with the package
## Step 1: Import the raw data
data(RiceRaw.dat)

## Step 2: Select imaging variables and add covariates and factors (produces longi.dat)
longi.dat <- longitudinalPrime(data=RiceRaw.dat, smarthouse.lev=c("NE", "NW"))

longi.dat <- designFactors(longi.dat, insertName = "xDays",
                           designfactorMethod="StandardOrder")

### Particular edits to longi.dat
longi.dat <- within(longi.dat,
  {
    Days.after.Salting <- as.numfac(Days) - 29
  })
longi.dat <- with(longi.dat, longi.dat[order(Snapshot.ID.Tag, Days), ])

## Step 3: Form derived traits that result in a value for each observation
#### Set responses
```

```

responses.image <- c("Area")
responses.smooth <- paste(responses.image, "smooth", sep=".")

### Form growth rates for each observation of a subset of responses by differencing
longi.dat <- splitContGRdiff(longi.dat, responses.image,
                             INDICES="Snapshot.ID.Tag",
                             which.rates = c("AGR","RGR"))

### Form Area.WUE
longi.dat <- within(longi.dat,
                    {
                      Area.WUE <- WUI(Area.AGR*Days.diffs, Water.Loss)
                    })

### Add cumulative responses
longi.dat <- within(longi.dat,
                    {
                      Water.Loss.Cum <- unlist(by(Water.Loss, Snapshot.ID.Tag,
                                                  cumulate, exclude.1st=TRUE))
                      WUE.cum <- Area / Water.Loss.Cum
                    })

### Step 4: Fit splines to smooth the longitudinal trends in the primary traits and
### calculate their growth rates
#'
### Smooth responses
#+
for (response in c(responses.image, "Water.Loss"))
  longi.dat <- splitSplines(longi.dat, response, x="xDays", INDICES = "Snapshot.ID.Tag",
                           df = 4, na.rm=TRUE)
longi.dat <- with(longi.dat, longi.dat[order(Snapshot.ID.Tag, xDays), ])

### Loop over smoothed responses, forming growth rates by differences
#+
responses.GR <- paste(responses.smooth, "AGR", sep=".")
longi.dat <- splitContGRdiff(longi.dat, responses.smooth,
                             INDICES="Snapshot.ID.Tag",
                             which.rates = c("AGR","RGR"))

### Finalize longi.dat
longi.dat <- with(longi.dat, longi.dat[order(Snapshot.ID.Tag, xDays), ])

### Step 5: Do exploratory plots on unsmoothed and smoothed longitudinal data
responses.longi <- c("Area","Area.AGR","Area.RGR", "Area.WUE")
responses.smooth.plot <- c("Area.smooth","Area.smooth.AGR","Area.smooth.RGR")
titles <- c("Total area (1000 pixels)",
           "Total area AGR (1000 pixels per day)", "Total area RGR (per day)",
           "Total area WUE (1000 pixels per mL)")
titles.smooth<-titles
nresp <- length(responses.longi)
limits <- list(c(0,1000), c(-50,125), c(-0.05,0.40), c(0,30))

### Plot unsmoothed profiles for all longitudinal responses
#+ "01-ProfilesAll"
klimit <- 0
for (k in 1:nresp)
{

```

```

    klimit <- klimit + 1
    longiPlot(data = longi.dat, response = responses.longi[k],
              y.title = titles[k], x="xDays+35.42857143",
              ggplotFuncs = list(geom_vline(xintercept=29, linetype="longdash", size=1),
                                scale_x_continuous(breaks=seq(28, 42, by=2)),
                                scale_y_continuous(limits=limits[[klimit]])))
  }

#' ### Plot smoothed profiles for all longitudinal responses - GRs by difference
#+ "01-SmoothedProfilesAll"
nresp.smooth <- length(responses.smooth.plot)
limits <- list(c(0,1000), c(0,100), c(0.0,0.40))
for (k in 1:nresp.smooth)
{
  longiPlot(data = longi.dat, response = responses.smooth.plot[k],
            y.title = titles.smooth[k], x="xDays+35.42857143",
            ggplotFuncs = list(geom_vline(xintercept=29, linetype="longdash", size=1),
                              scale_x_continuous(breaks=seq(28, 42, by=2)),
                              scale_y_continuous(limits=limits[[klimit]])))

  print(plt)
}

##### AGR anomalies - plot without anomalous plants followed by plot of anomalous plants
#+ "01-0254-AGRanomalies"
anom.ID <- vector(mode = "character", length = 0L)
response <- "Area.smooth.AGR"
cols.output <- c("Snapshot.ID.Tag", "Smarthouse", "Lane", "Position",
                 "Treatment.1", "Genotype.ID", "Days")
anomalous <- anomPlot(longi.dat, response=response, lower=2.5, start.time=40,
                      x = "xDays+35.42857143", vertical.line=29, breaks=seq(28, 42, by=2),
                      whichPrint=c("innerPlot"), y.title=response)
subs <- subset(anomalous$data, Area.smooth.AGR.anom & Days==42)
if (nrow(subs) == 0)
{ cat("\n#### No anomalous data here\n\n")
} else
{
  subs <- subs[order(subs["Smarthouse"],subs["Treatment.1"], subs[response]),]
  print(subs[c(cols.output, response)])
  anom.ID <- unique(c(anom.ID, subs$Snapshot.ID.Tag))
  outerPlot <- anomalous$outerPlot + geom_text(data=subs,
                                                aes_string(x = "xDays+35.42857143",
                                                            y = response,
                                                            label="Snapshot.ID.Tag"),
                                                size=3, hjust=0.7, vjust=0.5)

  print(outerPlot)
}

### Step 6: Form single-value plant responses in Snapshot.ID.Tag order.
#'
### 6a) Set up a data frame with factors only
#+
cart.dat <- longi.dat[longi.dat$Days == 31,
                     c("Smarthouse", "Lane", "Position", "Snapshot.ID.Tag",
                       "xPosn", "xMainPosn",

```

```

      "Zones", "xZones", "SHZones", "ZLane", "ZMainplots", "Subplots",
      "Genotype.ID", "Treatment.1")
cart.dat <- cart.dat[do.call(order, cart.dat), ]

#### 6b) Get responses based on first and last date.
#
#### Observation for first and last date
cart.dat <- cbind(cart.dat, getDates(responses.image, data = longi.dat,
                                   which.times = c(31), suffix = "first"))
cart.dat <- cbind(cart.dat, getDates(responses.image, data = longi.dat,
                                   which.times = c(42), suffix = "last"))
cart.dat <- cbind(cart.dat, getDates(c("WUE.cum"),
                                   data = longi.dat,
                                   which.times = c(42), suffix = "last"))
responses.smooth <- paste(responses.image, "smooth", sep=".")
cart.dat <- cbind(cart.dat, getDates(responses.smooth, data = longi.dat,
                                   which.times = c(31), suffix = "first"))
cart.dat <- cbind(cart.dat, getDates(responses.smooth, data = longi.dat,
                                   which.times = c(42), suffix = "last"))

#### Growth rates over whole period.
#+
tottime <- 42 - 31
cart.dat <- within(cart.dat,
  {
    Area.AGR <- (Area.last - Area.first)/tottime
    Area.RGR <- log(Area.last / Area.first)/tottime
  })

#### Calculate water index over whole period
cart.dat <- merge(cart.dat,
  intervalWUI("Area", water.use = "Water.Loss",
    start.times = c(31),
    end.times = c(42),
    suffix = NULL,
    data = longi.dat, include.total.water = TRUE),
  by = c("Snapshot.ID.Tag"))
names(cart.dat)[match(c("Area.WUI", "Water.Loss.Total"), names(cart.dat))] <-
  c("Area.Overall.WUE", "Water.Loss.Overall")
cart.dat$Water.Loss.rate.Overall <- cart.dat$Water.Loss.Overall / (42 - 31)

#### 6c) Add growth rates and water indices for intervals
#### Set up intervals
#+
start.days <- list(31,35,31,38)
end.days <- list(35,38,38,42)
suffices <- list("31to35", "35to38", "31to38", "38to42")

#### Rates for specific intervals from the smoothed data by differencing
#+
for (r in responses.smooth)
{ for (k in 1:length(suffices))
  {
    cart.dat <- merge(cart.dat,
      intervalGRdiff(r,
        which.rates = c("AGR", "RGR"),
        start.times = start.days[k][1]),

```

```

        end.times = end.days[k][[1]],
        suffix.interval = suffices[k][[1]],
        data = longi.dat),
    by = "Snapshot.ID.Tag")
  }
}

##### Water indices for specific intervals from the unsmoothed and smoothed data
#+
for (k in 1:length(suffices))
{
  cart.dat <- merge(cart.dat,
    intervalWUI("Area", water.use = "Water.Loss",
      start.times = start.days[k][[1]],
      end.times = end.days[k][[1]],
      suffix = suffices[k][[1]],
      data = longi.dat, include.total.water = TRUE),
    by = "Snapshot.ID.Tag")
  names(cart.dat)[match(paste("Area.WUI", suffices[k][[1]], sep="."),
    names(cart.dat))] <- paste("Area.WUE", suffices[k][[1]], sep=".")
  cart.dat[paste("Water.Loss.rate", suffices[k][[1]], sep=".")] <-
    cart.dat[[paste("Water.Loss.Total", suffices[k][[1]], sep=".")]] /
      (end.days[k][[1]] - start.days[k][[1]])
}

cart.dat <- with(cart.dat, cart.dat[order(Snapshot.ID.Tag), ])

### Step 7: Form continuous and interval SIITs
#'
### 7a) Calculate continuous
#+
cols.retained <- c("Snapshot.ID.Tag", "Smarthouse", "Lane", "Position",
  "Days", "Snapshot.Time.Stamp", "Hour", "xDays",
  "Zones", "xZones", "SHZones", "ZLane", "ZMainplots",
  "xMainPosn", "Genotype.ID")
responses.GR <- c("Area.smooth.AGR", "Area.smooth.AGR", "Area.smooth.RGR")
suffices.results <- c("diff", "SIIT", "SIIT")
responses.SIIT <- unlist(Map(paste, responses.GR, suffices.results, sep="."))

longi.SIIT.dat <-
  twoLevelOpcreate(responses.GR, longi.dat, suffices.treatment=c("C", "S"),
    operations = c("-", "/", "/"), suffices.results = suffices.results,
    columns.retained = cols.retained,
    by = c("Smarthouse", "Zones", "ZMainplots", "Days"))
longi.SIIT.dat <- with(longi.SIIT.dat,
  longi.SIIT.dat[order(Smarthouse, Zones, ZMainplots, Days), ])

### Plot SIIT profiles
#'
#+ "03-SIITProfiles"
k <- 2
nresp <- length(responses.SIIT)
limits <- with(longi.SIIT.dat, list(c(min(Area.smooth.AGR.diff, na.rm=TRUE),
  max(Area.smooth.AGR.diff, na.rm=TRUE)),
  c(0, 3),
  c(0, 1.5)))

#Plots

```

```

for (k in 1:nresp)
{
  longiPlot(data = longi.SIIT.dat, x="xDays+35.42857143",
            response = responses.SIIT[k],
            y.title=responses.SIIT[k],
            facet.x="Smarthouse", facet.y=".",
            ggplotFuncs = list(geom_vline(xintercept=29, linetype="longdash", size=1),
                              scale_x_continuous(breaks=seq(28, 42, by=2)),
                              scale_y_continuous(limits=limits[[klimit]])))
}

### 7b) Calculate interval SIITs and check for large values for SIIT for Days 31to35
#+ "01-SIITIntClean"
suffices <- list("31to35","35to38","31to38","38to42")
response <- "Area.smooth.RGR.31to35"
SIIT <- paste(response, "SIIT", sep=".")
responses.SIITinterval <- as.vector(outer("Area.smooth.RGR", suffices, paste, sep="."))

cart.SIIT.dat <- twoLevelOpcreate(responses.SIITinterval, cart.dat,
                                suffices.treatment=c("C","S"),
                                suffices.results="SIIT",
                                columns.suffixed="Snapshot.ID.Tag")

tmp<-na.omit(cart.SIIT.dat)
print(summary(tmp[SIIT]))
big.SIIT <- with(tmp, tmp[tmp[SIIT] > 1.15, c("Snapshot.ID.Tag.C","Genotype.ID",
                                             paste(response,"C",sep="."),
                                             paste(response,"S",sep="."), SIIT)])

big.SIIT <- big.SIIT[order(big.SIIT[SIIT]),]
print(big.SIIT)
plt <- ggplot(tmp, aes_string(SIIT)) +
  geom_histogram(aes(y = ..density..), binwidth=0.05) +
  geom_vline(xintercept=1.15, linetype="longdash", size=1) +
  theme_bw() + facet_grid(Smarthouse ~.)

print(plt)
plt <- ggplot(tmp, aes_string(x="Smarthouse", y=SIIT)) +
  geom_boxplot() + theme_bw()

print(plt)
remove(tmp)

## End(Not run)

```

imagetimesPlot

Plots the position of a time within an interval against the interval for each cart

Description

Uses ggplot to produce a plot of the time position within an interval against the interval. For example, one might plot the hour of the day carts are imaged against the days after planting (or some other number of days after an event). A line is produced for each value of groupVariable and the colour is varied according to the value of the colourVariable. Each Smarthouse is plotted separately. It aids in checking whether delays occurred in imaging the plants.

Usage

```
imagetimesPlot(data, intervals = "Time.after.Planting.d.", timePositions = "Hour",
  groupVariable = "Snapshot.ID.Tag", colourVariable = "Lane",
  ggplotFuns = NULL)
```

Arguments

<code>data</code>	A data.frame containing any columns specified by <code>intervals</code> , <code>timePositions</code> , <code>groupVariable</code> and <code>colourVariable</code> .
<code>intervals</code>	A character giving the name of the column in <code>data</code> containing, as a numeric or a factor , the calculated times to be plotted on the x-axis. For example, it could be the days after planting or treatment.
<code>timePositions</code>	A character giving the name of the column in <code>data</code> containing, as a numeric , the value of the time position within an interval (for example, the time of imaging during the day expressed in hours plus a fraction of an hour).
<code>groupVariable</code>	A character giving the name of the column in <code>data</code> containing the variable to be used to group the plotting.
<code>colourVariable</code>	A character giving the name of the column in <code>data</code> containing the variable to be used to colour the plotting.
<code>ggplotFuns</code>	A list , each element of which contains the results of evaluating a ggplot function. It is created by calling the list function with a ggplot function call for each element.

Value

An object of class "ggplot", which can be plotted using `print`.

Author(s)

Chris Brien

See Also

[ggplot](#), [calcTimes](#).

Examples

```
data(exampleData)
library(ggplot2)
longi.dat <- calcTimes(longi.dat, imageTimes = "Snapshot.Time.Stamp",
  timePositions = "Hour")
imagetimesPlot(data = longi.dat, intervals = "Days", timePositions = "Hour",
  ggplotFuns=list(scale_colour_gradient(low="grey20", high="black"),
    geom_line(aes(group=Snapshot.ID.Tag, colour=Lane))))
```

importExcel	<i>Imports an Excel imaging file and allows some renaming of variables</i>
-------------	--

Description

Uses XLConnect to import a sheet of imaging data produced by the Lemna Tec Scanalyzer. Basically, the data consists of imaging data obtained from a set of pots or carts over time. There should be a column, which by default is called `Snapshot.ID.Tag`, containing a unique identifier for each cart and a column, which by default is labelled `Snapshot.Time.Stamp`, containing the time of imaging for each observation in a row of the sheet. Also, if `startTime` is not `NULL`, `calcTimes` is called to calculate, or recalculate if already present, `timeAfterStart` from `imageTimes` by subtracting a supplied `startTime`.

Using `cameraType`, `keepCameraType`, `labsCamerasViews` and `prefix2suffix`, some flexibility is provided for renaming the columns with imaging data. For example, if the column names are prefixed with `'RGB_SV1'`, `'RGB_SV2'` or `'RGB_TV'`, the `'RGB_'` can be removed and the `'SV1'`, `'SV2'` or `'TV'` become suffices.

Usage

```
importExcel(file, sheet="raw data", sep = ",",
            cartId = "Snapshot.ID.Tag",
            imageTimes = "Snapshot.Time.Stamp",
            timeAfterStart = "Time.after.Planting..d.",
            cameraType = "RGB", keepCameraType = FALSE,
            labsCamerasViews = NULL, prefix2suffix = TRUE,
            startTime = NULL,
            timeFormat = "%Y-%m-%d %H:%M",
            imagetimesPlot = TRUE, ...)
```

Arguments

<code>file</code>	A character giving the path and name of the file containing the data.
<code>sheet</code>	A character giving the name of the sheet containing the data, that must include columns whose names are as specified by <code>cartId</code> , which uniquely indexes the carts in the experiment, and <code>imageTimes</code> , which reflects the time of the imaging from which a particular data value was obtained. It is also assumed that a column whose name is specified by <code>timeAfterStart</code> is in the sheet or that it will be calculated from <code>imageTimes</code> using the value of <code>startTime</code> supplied in the function call.
<code>sep</code>	A character giving the separator used in a csv file.
<code>cartId</code>	A character giving the name of the column that contains the unique Id for each cart. Note that in importing data into R, spaces and nonalphanumeric characters in names are converted to full stops.
<code>imageTimes</code>	A character giving the name of the column that contains the time that each cart was imaged. Note that in importing data into R, spaces and nonalphanumeric characters in names are converted to full stops.
<code>timeAfterStart</code>	A character giving the name of the column that contains or is to contain the difference between <code>imageTimes</code> and <code>startTime</code> . The function <code>calcTimes</code> is called to calculate the differences. For example, it might contain the number of

	days after planting. Note that in importing data into R, spaces and nonalphanumeric characters in names are converted to full stops.
cameraType	A character string nominating the abbreviation used for the cameraType. A warning will be given if no variable names include this cameraType.
keepCameraType	A logical specifying whether to retain the cameraType in the variables names. It will be the start of the prefix or suffix and separated from the remainder of the prefix or suffix by an underscore (_).
labsCamerasViews	A named character whose elements are new labels for the camera-view combinations and the name of each element is the old label for the camera-view combination in the data being imported. If labsCamerasViews is NULL, all column names beginning with cameraType are classed as imaging variables and the unique prefixes amongst them determined. If no imaging variables are found then no changes are made. Note that if you want to include a recognisable cameraType in a camera-view label, it should be at the start of the label in labsCamerasViews and separated from the rest of the label by an underscore (_).
prefix2suffix	A logical specifying whether the variables names with prefixed camera-view labels are to have those prefixes transferred to become suffixes. The prefix is assumed to be all the characters up to the first full stop (.) in the variable name and must contain cameraType to be moved. It is generally assumed that the characters up to the first underscore (_) are the camera type and this is removed if keepCameraType is FALSE. If there is no underscore (_), the whole prefix is moved. If labsCamerasViews is NULL, all column names beginning with cameraType are classed as imaging variables and the unique prefixes amongst them determined. If no imaging variables are found then no changes are made.
startTime	A character giving the time of planting, in the POSIXct format timeFormat, to be subtracted from imageTimes in recalculating timeAfterStart. If startTime is NULL then timeAfterStart is not recalculated.
timeFormat	A character giving the POSIXct format of characters containing times, in particular imageTimes and startTime.
imagetimesPlot	A logical indicating whether a plot of the imaging times against the recalculated Time.After.Planting...d.. It aids in checking Time.After.Planting...d. and what occurred in imaging the plants.
...	allows for arguments to be passed to imagetimesPlot . However, if intervals is passed an error will occur; use timeAfterStart instead.

Value

A [data.frame](#) containing the data.

Note

XLConnect uses Java and can take a lot of memory. You may have to increase the amount of RAM allocated to the Java heap. For example, `options(java.parameters = "-Xmx10g")` allocates 10 gigabytes of RAM, which has been needed on occasion to read Excel imaging files. Java itself must also be configured to allocate at least this amount of memory.

Also, note that XLConnect cannot import cells with some Excel functions. For example, it cannot import cells that use ROUNDOWN in a formula. The problem can be avoided by converting the formulae into values.

Author(s)

Chris Brien

See Also[as.POSIXct](#), [calcTimes](#), [imagetimesPlot](#)**Examples**

```
## Not run:
raw.0169.dat <- importExcel(file = "0169 analysis_20140603.xlsx",
                           startTime = "2013-05-23 8:00 AM")

camview.labels <- c("SF0", "SL0", "SU0", "TV0")
names(camview.labels) <- c("RGB_Side_Far_0", "RGB_Side_Lower_0",
                          "RGB_Side_Upper_0", "RGB_TV_0")
raw.19.dat <- suppressWarnings(importExcel(file = "../data/raw19datarow.csv",
                                           cartId = "Snapshot.ID.Tags",
                                           startTime = "06/10/2017 0:00 AM",
                                           timeFormat = "%d/%m/%Y %H:M",
                                           labsCamerasViews = camview.labels,
                                           imagetimesPlot = FALSE))

## End(Not run)
```

intervalGRAverage	<i>Calculates the growth rates for a specified time interval by taking weighted averages of growth rates for times within the interval</i>
-------------------	--

Description

Using previously calculated growth rates over time, calculates the Absolute Growth Rates for a specified interval using the weighted averages of AGRs for each time point in the interval (AGR) and the Relative Growth Rates for a specified interval using the weighted geometric means of RGRs for each time point in the interval (RGR).

Usage

```
intervalGRAverage(responses, individuals = "Snapshot.ID.Tag",
                  which.rates = c("AGR", "RGR"), suffices.rates=c("AGR", "RGR"),
                  start.time, end.time, times.factor = "Days", suffix.interval,
                  data, sep=".", na.rm=TRUE)
```

Arguments

responses	A character giving the names of the responses for which there are columns in data that contain the growth rates that are to be averaged. The names of the growth rates should have either AGR or RGR appended to the responses names.
individuals	A character giving the name(s) of the factor(s) that define the subsets of the data for which each subset corresponds to the responses for an individual.
which.rates	A character giving the growth rates that are to be averaged to obtain growth rates for an interval. It should be a combination "AGR" and "RGR".


```

df = 4, deriv=1, suffices.deriv="AGRdv", RGR="RGRdv")
Area.smooth.GR <- intervalGRAverage("Area.smooth", which.rates = c("AGR","RGR"),
                                     suffices.rates = c("AGRdv","RGRdv"),
                                     start.time = 31, end.time = 35,
                                     suffix.interval = "31to35",
                                     data = longi.dat)

```

intervalGRdiff	<i>Calculates the growth rates for a specified time interval</i>
----------------	--

Description

Using the values of the responses, calculates the specified combination of the Absolute Growth Rates using differences (AGR), the Proportionate Growth Rates (PGR) and Relative Growth Rates using log differences (RGR) between two nominated time points.

Usage

```

intervalGRdiff(responses, individuals = "Snapshot.ID.Tag",
               which.rates = c("AGR","PGR","RGR"), suffices.rates=NULL,
               times.factor = "Days", start.times, end.times, suffix.interval,
               data)

```

Arguments

responses	A character giving the names of the columns in data from which the growth rates are to be calculated.
individuals	A character giving the name(s) of the factor(s) that define the subsets of the data for which each subset corresponds to the responses for an individual.
which.rates	A character giving the growth rates that are to be calculated. It should be a combination "AGR", "PGR" and "RGR".
suffices.rates	A character giving the characters to be appended to the names of the responses in constructing the names of the columns containing the calculated growth rates. The order of the suffices in suffices.rates should correspond to the order of the elements of which.rates.
times.factor	A character giving the name of the column in data containing the factor for times at which the data was collected. Its levels will be used in calculating growth rates and should be numeric values stored as characters.
start.times	A numeric giving the times, in terms of levels of times.factor, that will give a single value for each Snapshot.ID.Tag and that will be taken as the observation at the start of the interval for which the growth rate is to be calculated.
end.times	A numeric giving the times, in terms of levels of times.factor, that will give a single value for each Snapshot.ID.Tag and that will be taken as the observation at the end of the interval for which the growth rate is to be calculated.
suffix.interval	A character giving the suffix to be appended to response to form the names of the columns containing the calculated the growth rates.
data	A data.frame containing the column from which the growth rates are to be calculated.

Details

The AGR is calculated as the difference between the values of response at the `end.times` and `start.times` divided by the difference between `end.times` and `start.times`. The PGR is calculated as the ratio of response at the `end.times` to that at `start.times` and the ratio raised to the power of the reciprocal of the difference between `end.times` and `start.times`. The RGR is calculated as the log of the PGR and so is equal to the difference between the logarithms of response at the `end.times` and `start.times` divided by the difference between `end.times` and `start.times`.

Value

A [data.frame](#) with the growth rates. The name of each column is the concatenation of (i) one of responses, (ii) one of AGR, PGR or RGR, or the appropriate element of `suffices.rates`, and (iii) `suffix.interval`, the three components being separated by full stops.

Author(s)

Chris Brien

See Also

[intervalGRaverage](#), [intervalWUI](#), [getDates](#), [GrowthRates](#), [splitSplines](#), [splitContGRdiff](#)

Examples

```
data(exampleData)
Area.smooth.GR <- intervalGRdiff("Area.smooth", which.rates = c("AGR", "RGR"),
                                start.times = 31, end.times = 35,
                                suffix.interval = "31to35",
                                data = longi.dat)
```

intervalPVA	<i>Selects a subset of variables observed within a specified time interval using Principal Variable Analysis (PVA)</i>
-------------	--

Description

Principal Variable Analysis (PVA) (Cummings, 2007) selects a subset from a set of the variables such that the variables in the subset are as uncorrelated as possible, in an effort to ensure that all aspects of the variation in the data are covered. Here, all observations in a specified time interval are used for calculation the correlations on which the selection is based.

Usage

```
intervalPVA(responses, data, times.factor = "Days", start.time, end.time,
            nvarselect = NULL, p.variance = 1, include = NULL,
            plot = TRUE, ...)
```

Arguments

responses	A character giving the names of the columns in data from which the variables are to be selected.
data	A data.frame containing the columns of variables from which the selection is to be made.
times.factor	A character giving the name of the column in data containing the factor for times at which the data was collected. Its levels will be used to identify the subset and should be numeric values stored as characters.
start.time	A numeric giving the time, in terms of a level of times.factor, at which the time interval begins; observations at this time and up to and including end.time will be included.
end.time	A numeric giving the time, in terms of levels of times.factor, at the end of the interval; observations after this time will not be included.
nvarselect	A numeric specifying the number of variables to be selected, which includes those listed in include. If nvarselect = 1, as many variables are selected as is need to satisfy p.variance.
p.variance	A numeric specifying the minimum proportion of the variance that the selected variables must account for,
include	A character giving the names of the columns in data for the variables whose selection is mandatory.
plot	A logical indicating whether a plot of the cumulative proportion of the variance explained is to be produced.
...	allows passing of arguments to other functions.

Details

The variable that is most correlated with the other variables is selected first for inclusion. The partial correlation for each of the remaining variables, given the first selected variable, is calculated and the most correlated of these variables is selects for inclusion next. Then the partial correlations are adjust for the second included variables. This process is repeated until the specified criteria have been satisfied. The possibilities are to:

1. the default (nvarselect = NULL and p.variance = 1) select all variables in increasing order of amount of information they provide;
2. select exactly nvarselect variables;
3. select just enough variables, up to a maximum of nvarselect variables, to explain at least $p.variance \times 100$ per cent of the total variance.

Value

A [data.frame](#) giving the results of the variable selection. It will contain the columns Variable, Selected, h.partial, Added.Propn and Cumulative.Propn.

Author(s)

Chris Brien

References

Cumming, J. A. and D. A. Wood (2007) Dimension reduction via principal variables. *Computational Statistics and Data Analysis*, **52**, 550–565.

See Also

[PVA](#), [rcontrib](#)

Examples

```
data(exampleData)
responses <- c("Area", "Area.SV", "Area.TV", "Image.Biomass", "Max.Height", "Centre.Mass",
              "Density", "Compactness.TV", "Compactness.SV")
results <- intervalPVA(responses, longi.dat,
                      start.time = "31", end.time = "31",
                      p.variance=0.9, plot = FALSE)
```

intervalValueCalculate

Calculates a single value that is a function of an individual's values for a response over a specified time interval

Description

Splits the values of a response into subsets corresponding individuals and applies a function that calculates a single value from each individual's observations during a specified time interval. It includes the ability to calculate the observation that corresponds to the calculated value of the function.

Usage

```
intervalValueCalculate(response, weights=NULL, individuals = "Snapshot.ID.Tag",
                      FUN = "max", which.obs = FALSE, which.levels = NULL,
                      start.time=NULL, end.time=NULL, times.factor = "Days",
                      suffix.interval=NULL, data, sep=".", na.rm=TRUE, ...)
```

Arguments

response	A character giving the name of the column in data from which the values of FUN are to be calculated.
weights	A character giving the name of the column in data containing the weights to be supplied as w to FUN.
individuals	A character giving the name(s) of the factor(s) that define the subsets of the data for which each subset corresponds to the response value for an individual.
FUN	A character giving the name of the function that calculates the value for each subset.
which.obs	A logical indicating whether or not to determine the observation corresponding to the value of the function, instead of the value of the function itself.
which.levels	A character giving the name of the factor whose levels are to be identified as the level of the observation whose value matches the value of the function.
start.time	A numeric giving the times, in terms of levels of times.factor, that will give a single value for each Snapshot.ID.Tag and that will be taken as the observation at the start of the interval for which the growth rate is to be calculated. If start.time is NULL, the interval will start with the first observation.

intervalWUI	<i>Calculates water use indices (WUI) over a specified time interval to a data.frame</i>
-------------	--

Description

Calculates the Water Use Index (WUI) between two time points for a set of responses.

Usage

```
intervalWUI(responses, water.use = "Water.Use",
             individuals = "Snapshot.ID.Tag", times.factor = "Days",
             start.times, end.times, suffix.interval = NULL,
             data, include.total.water = FALSE, na.rm = FALSE)
```

Arguments

responses	A character giving the names of the columns in data from which the growth rates are to be calculated.
water.use	A character giving the names of the column in data which contains the water use values.
individuals	A character giving the name(s) of the factor(s) that define the subsets of the data for which each subset corresponds to the responses for an individual.
times.factor	A character giving the name of the column in data containing the factor for times at which the data was collected. Its levels will be used in identifying the intervals and should be numeric values stored as characters.
start.times	A numeric giving the times, in terms of levels of times.factor, that will give a single value for each Snapshot.ID.Tag and that will be taken as the observation at the start of the interval for which the growth rate is to be calculated.
end.times	A numeric giving the times, in terms of levels of times.factor, that will give a single value for each Snapshot.ID.Tag and that will be taken as the observation at the end of the interval for which the growth rate is to be calculated.
suffix.interval	A character giving the suffix to be appended to response to form the names of the columns containing the calculated the growth rates.
data	A data.frame containing the column from which the growth rates are to be calculated.
include.total.water	A logical indicating whether or not to include a column in the results for the total of water.use for the interval for each individual.
na.rm	A logical indicating whether NA values should be stripped before the calculation proceeds.

Details

The WUI is calculated as the difference between the values of a response at the end.times and start.times divided by the sum of the water use after start.times until end.times. Thus, the water use up to start.times is not included.

Value

A `data.frame` containing the WUIs, the name of each column being the concatenation of one of responses, WUI and, if not NULL, `suffix.interval`, the three components being separated by a full stop. If the total water is to be included, the name of the column will be the concatenation of `water.use`, `Total` and the suffix, each separated by a full stop('.').

Author(s)

Chris Brien

See Also

[intervalGRaverage](#), [intervalGRdiff](#), [splitValueCalculate](#), [getDates](#), [GrowthRates](#)

Examples

```
data(exampleData)
Area.smooth.WUI <- intervalWUI("Area", water.use = "Water.Loss",
                               start.times = 31, end.times = 35,
                               suffix = "31to35",
                               data = longi.dat, include.total.water = TRUE)
```

longiPlot

Plots longitudinal data from a Lemna Tec Scanalyzer

Description

Produce profile or longitudinal plots of the data from a Lemna Tec Scanalyzer using `ggplot`. A line is drawn for the data for each `Snapshot.ID.Tag` and the plot can be faceted so that a grid of plots is produced.

Usage

```
longiPlot(data, x = "xDays+44.5", response = "Area", individuals="Snapshot.ID.Tag",
          x.title = "Days", y.title = "Area (1000 pixels)", title = NULL,
          facet.x = "Treatment.1", facet.y = "Smarthouse", labeller = NULL,
          colour = "black", colour.column=NULL, colour.values=NULL,
          alpha = 0.1, ggplotFuncs = NULL, printPlot = TRUE)
```

Arguments

<code>data</code>	A <code>data.frame</code> containing the data to be plotted.
<code>x</code>	A <code>character</code> giving the variable to be plotted on the x-axis.
<code>response</code>	A character specifying the response variable that is to be plotted on the y-axis.
<code>individuals</code>	A <code>character</code> giving the name(s) of the <code>factor</code> (s) that define the subsets of the data for which each subset corresponds to the response values for an individual.
<code>x.title</code>	Title for the x-axis.
<code>y.title</code>	Title for the y-axis.
<code>title</code>	Title for the plot.

facet.x	A data.frame giving the variable to be used to form subsets to be plotted in separate columns of plots. Use "." if a split into columns is not wanted.
facet.y	A data.frame giving the variable to be used to form subsets to be plotted in separate rows of plots. Use "." if a split into columns is not wanted.
labeller	A ggplot function for labelling the facets of a plot produced using the ggplot function. For more information see ggplot .
colour	A character specifying a single colour to use in drawing the lines for the profiles. If colouring according to the values of a variable is required then use <code>colour.column</code> .
colour.column	A character giving the name of a column in data over whose values the colours of the lines are to be varied. The colours can be specified using <code>colour.values</code> .
colour.values	A character vector specifying the values of the colours to use in drawing the lines for the profiles. If this is a named vector, then the values will be matched based on the names. If unnamed, values will be matched in order (usually alphabetical) with the limits of the scale.
alpha	A numeric specifying the degrees of transparency to be used in plotting. It is a ratio in which the denominator specifies the number of points (or line) that must be overplotted to give a solid cover.
ggplotFuncs	A list , each element of which contains the results of evaluating a ggplot function. It is created by calling the list function with a ggplot function call for each element.
printPlot	A logical indicating whether or not to print the plot.

Value

An object of class "[ggplot](#)", which can be plotted using `print`.

Author(s)

Chris Brien

See Also

[ggplot](#), [labeller](#).

Examples

```
data(exampleData)
longiPlot(data = longi.dat, response = "Area.smooth")

plt <- longiPlot(data = longi.dat, response = "Area.smooth", x.title = "DAP",
  y.title = "Area.smooth", x="xDays+35.42857143", printPlot=FALSE)
plt <- plt + ggplot2::geom_vline(xintercept=29, linetype="longdash", size=1) +
  ggplot2::scale_x_continuous(breaks=seq(28, 42, by=2)) +
  ggplot2::scale_y_continuous(limits=c(0,750))
print(plt)

longiPlot(data = longi.dat, response = "Area.smooth", x.title = "DAP",
  y.title = "Area.smooth", x="xDays+35.42857143",
  ggplotFuncs = list(ggplot2::geom_vline(xintercept=29, linetype="longdash",
    size=1),
```

```
ggplot2::scale_x_continuous(breaks=seq(28, 42, by=2)),
ggplot2::scale_y_continuous(limits=c(0,750)))
```

longitudinalPrime	<i>Selects a set variables to be retained in a data frame of longitudinal data</i>
-------------------	--

Description

Forms the prime traits by selecting a subset of the traits in a data.frame of imaging data produced by the Lemna Tec Scanalyzer. The imaging traits to be retained are specified using the `traits` and `labsCamerasViews` arguments. Some imaging traits are divided by 10000 to convert them from pixels to kilopixels. Also added are factors and explanatory variates that might be of use in an analysis.

Usage

```
longitudinalPrime(data, cartId = "Snapshot.ID.Tag",
  imageTimes = "Snapshot.Time.Stamp",
  timeAfterStart = "Time.after.Planting..d.",
  idcolumns = c("Genotype.ID", "Treatment.1"),
  traits = list(all = c("Area",
    "Boundary.Points.To.Area.Ratio",
    "Caliper.Length", "Compactness",
    "Convex.Hull.Area"),
  side = c("Center.Of.Mass.Y",
    "Max.Dist.Above.Horizon.Line")),
  labsCamerasViews = list(all = c("SV1", "SV2", "TV"),
    side = c("SV1", "SV2")),
  smarthouse.lev = NULL,
  calcWaterLoss = TRUE, pixelsPERcm)
```

Arguments

data A [data.frame](#) containing the columns specified by `cartId`, `imageTimes`, `timeAfterStart`, `idcolumns`, `traits` and `cameras` along with the following columns: `Smarthouse`, `Lane`, `Position`, `Weight.Before`, `Weight.After`, `Water.Amount`, `Projected.Shoot.Area..pixels`.

The defaults for the arguments to `longitudinalPrime` requires a [data.frame](#) containing the following columns, although not necessarily in the order given here:

`Smarthouse`, `Lane`, `Position`, `Weight.Before`, `Weight.After`, `Water.Amount`, `Projected.Shoot.Area..pixels.`, `Area.SV1`, `Area.SV2`, `Area.TV`, `Boundary.Points.To.Area.Ratio.SV1`, `Boundary.Points.To.Area.Ratio.SV2`, `Boundary.Points.To.Area.Ratio.TV`, `Caliper.Length.SV1`, `Caliper.Length.SV2`, `Caliper.Length.TV`, `Compactness.SV1`, `Compactness.SV2`, `Compactness.TV`, `Convex.Hull.Area.SV1`, `Convex.Hull.Area.SV2`, `Convex.Hull.Area.TV`, `Center.Of.Mass.Y.SV1`, `Center.Of.Mass.Y.SV2`, `Max.Dist.Above.Horizon.Line.SV1`, `Max.Dist.Above.Horizon.Line.SV2`.

cartId	A character giving the name of the column that contains the unique Id for each cart.
imageTimes	A character giving the name of the column that contains the time that each cart was imaged.
timeAfterStart	A character giving the name of the column that contains the time after some nominated starting time e.g. the number of days after planting.
idcolumns	A character vector giving the names of the columns that identify differences between the plants or carts e.g. Genotype.ID, Treatment.1, Treatment.2.
traits	A character or a list whose components are characters . Each character gives the names of the columns for imaging traits whose values are required for each of the camera-view combinations given in the corresponding list component of labsCamerasViews. If labsCamerasViews or a component of labsCamerasViews is NULL, then the contents of traits or the corresponding component of traits are merely treated as the names of columns to be retained.
labsCamerasViews	A character or a list whose components are characters . Each character gives the labels of the camera-view combinations for which is required values of each of the imaging traits in the corresponding character of traits. It is assumed that the camera-view labels are appended to the trait names and separated from the trait names by a full stop (.). If labsCamerasViews or a component of labsCamerasViews is NULL, then the contents of the traits or the corresponding component of traits are merely treated as the names of columns to be retained.
smarthouse.lev	A character vector giving the levels to use for the Smarthouse factor. If NULL then the unique values in Smarthouse will be used.
calcWaterLoss	A logical indicating whether to calculate the Water.Loss. If it is FALSE, Water.Before, Water.After and Water.Amount will not be in the returned data.frame . They can be copied across by listing them in a component of traits and set the corresponding component of cameras to NULL.
pixelsPERcm	A numeric giving the number of pixels per cm for the images. <i>No longer used.</i>

Details

The columns are copied from data, except for those columns in the list under **Value** that have '(calculated)' appended.

Value

A [data.frame](#) containing the columns specified by cartId, imageTimes, timeAfterStart, idcolumns, traits and cameras. The defaults will result in the following columns:

1. Smarthouse: factor with levels for the Smarthouse
2. Lane: factor for lane number in a smarthouse
3. Position: factor for east/west position in a lane
4. Days: factor for the number of Days After Planting (DAP)
5. cartId: unique code for each cart
6. imageTimes: time at which an image was taken in POSIXct format
7. Reps: factor indexing the replicates for each combination of the factors in idcolumns (calculated)

8. xPosn: numeric for the Positions within a Lane (calculated)
9. Hour: hour of the day, to 2 decimal places, at which the image was taken (calculated)
10. xDays: numeric for the DAP that is centred by subtracting the mean of the unique days (calculated)
11. idcolumns: the columns listed in idcolumns that have been converted to factors
12. Weight.Before: weight of the pot before watering (only if calcWaterLoss is TRUE)
13. Weight.After: weight of the pot after watering (only if calcWaterLoss is TRUE)
14. Water.Amount: the weight of the water added (= Water.After - Water.Before) (calculated)
15. Water.Loss: the difference between Weight.Before for the current imaging and the Weight.After for the previous imaging (calculated unless calcWaterLoss is FALSE)
16. Area: the Projected.Shoot.Area..pixels. divided by 1000 (calculated)
17. Area.SV1: the Projected.Shoot.Area from Side View 1 divided by 1000 (calculated)
18. Area.SV2: the Projected.Shoot.Area from Side View 2 divided by 1000 (calculated)
19. Area.TV: the Projected.Shoot.Area from Top View divided by 1000 (calculated)
20. Boundary.To.Area.Ratio.SV1
21. Boundary.To.Area.Ratio.SV2
22. Boundary.To.Area.Ratio.TV
23. Caliper.Length.SV1
24. Caliper.Length.SV2
25. Caliper.Length.TV
26. Compactness.SV1 from Side View 1
27. Compactness.SV2 from Side View 2
28. Compactness.TV: from Top View
29. Convex.Hull.Area.SV1: area of Side View 1 Convex Hull divided by 1000 (calculated)
30. Convex.Hull.Area.SV2: area of Side View 2 Convex Hull divided by 1000 (calculated)
31. Convex.Hull.TV: Convex.Hull.Area.TV divided by 1000 (calculated)
32. Center.Of.Mass.Y.SV1: Centre of Mass from Side View 1
33. Center.Of.Mass.Y.SV2: Centre of Mass from Side View 2
34. Max.Dist.Above.Horizon.Line.SV1: the Max.Dist.Above.Horizon.Line.SV1 converted to cm using pixelsPERcm (calculated)
35. Max.Dist.Above.Horizon.Line.SV2: the Max.Dist.Above.Horizon.Line.SV2 converted to cm using pixelsPERcm (calculated)

Author(s)

Chris Brien

Examples

```
data(exampleData)
longiPrime.dat <- longitudinalPrime(data=raw.dat, smarthouse.lev=1)

longiPrime.dat <- longitudinalPrime(data=raw.dat, smarthouse.lev=1,
                                   traits = list(a = "Area", c = "Compactness"),
                                   labsCamerasViews = list(all = c("SV1", "SV2", "TV"),
```

```

t = "TV"))

longiPrime.dat <- longitudinalPrime(data=raw.dat, smarthouse.lev=1,
                                   traits = c("Area.SV1", "Area.SV2", "Area.TV",
                                              "Compactness.TV"),
                                   labsCamerasViews = NULL)

longiPrime.dat <- longitudinalPrime(data=raw.dat, smarthouse.lev=1,
                                   calcWaterLoss = FALSE,
                                   traits = list(img = c("Area", "Compactness"),
                                                H2O = c("Weight.Before", "Weight.After",
                                                       "Water.Amount")),
                                   labsCamerasViews = list(all = c("SV1", "SV2", "TV"),
                                                           H2O = NULL))

```

probeDF	<i>Compares, for a set of specified values of df, a response and the smooths of it, possibly along with growth rates calculated from the smooths</i>
---------	--

Description

Takes a response and, for each individual, uses [splitSplines](#) to smooth its values for each individual using the degrees of freedom values in df. Provided get.rates is TRUE, both the Absolute Growth Rates (AGR) and the Relative Growth Rates (RGR) are calculated for each smooth, either using differences or first derivatives. A combination of the unsmoothed and smoothed values, as well as the AGR and RGR, can be plotted for each value in df. Note that the arguments that modify the plots apply to all plots that are produced. The handling of missing values is controlled via na.x.action and na.y.action

Usage

```

probeDF(data, response = "Area", xname="xDays", individuals="Snapshot.ID.Tag",
        na.x.action="exclude", na.y.action = "exclude",
        df, smoothing.scale = "identity", correctBoundaries = FALSE,
        get.rates = TRUE, rates.method="differences",
        times.factor = "Days", x = NULL, x.title = NULL,
        facet.x = "Treatment.1", facet.y = "Smarthouse", labeller = NULL,
        which.traits = c("response", "AGR", "RGR"),
        which.plots = "smoothedonly",
        deviations.boxplots = "none",
        ggplotFuncs = NULL,
        ...)

```

Arguments

data	A data.frame containing the data.
response	A character specifying the response variable to be supplied to smooth.spline and that is to be plotted on the y-axis.
xname	A character giving the name of the numeric that contains the values of the predictor variable to be supplied to smooth.spline .

individuals	A character giving the name(s) of the factor (s) that define the subsets of the data for which each subset corresponds to the response values for an individual.
na.x.action	A character string that specifies the action to be taken when values of x are NA. The possible values are fail, exclude or omit. For exclude and omit, predictions and derivatives will only be obtained for nonmissing values of x. The difference between these two codes is that the returned data.frame will have as many rows as data, the missing values have been incorporated.
na.y.action	A character string that specifies the action to be taken when values of y, or the response, are NA. The possible values are fail, exclude, omit, allx, trimx, ltrimx or rtrimx. For all options, except fail, missing values in y will be removed before smoothing. For exclude and omit, predictions and derivatives will be obtained only for nonmissing values of x that do not have missing y values. Again, the difference between these two is that, only for exclude will the missing values will be incorporated into the returned data.frame. For allx, predictions and derivatives will be obtained for all nonmissing x. For trimx, they will be obtained for all nonmissing x between the first and last nonmissing y values that have been ordered for x; for ltrimx and utrimx either the lower or upper missing y values, respectively, are trimmed.
df	A numeric specifying the set of degrees of freedom to be probed.
smoothing.scale	A character giving the scale on which smoothing is to be performed. The two possibilities are "identity", for directly smoothing the observed response, and "logarithmic", for scaling the log-transformed response.
correctBoundaries	A logical indicating whether the fitted spline values are to have the method of Huang (2001) applied to them to correct for estimation bias at the end-points. Note that if rates.method is set to "derivatives" then it is not possible to have correctBoundaries set to TRUE.
get.rates	A logical specifying whether or not the growth rates (AGR and RGR) are to be computed and stored.
rates.method	A character specifying the method to use in calculating the growth rates. The two possibilities are "differences" and "derivates".
times.factor	A character giving the name of the column in data containing the factor for times at which the data was collected. Its levels will be used in calculating growth rates and should be numeric values stored as characters.
x	A character giving the variable to be plotted on the x-axis. If x is NULL then xname is used.
x.title	Title for the x-axis. If NULL then set to times.factor.
facet.x	A data.frame giving the variable to be used to form subsets to be plotted in separate columns of plots. Use "." if a split into columns is not wanted.
facet.y	A data.frame giving the variable to be used to form subsets to be plotted in separate rows of plots. Use "." if a split into columns is not wanted.
labeller	A ggplot function for labelling the facets of a plot produced using the ggplot function. For more information see ggplot .
which.traits	A character giving the traits that are to be produced. One of more of response, AGR and RGR. If all, all three traits are produced. The unsmoothed growth rates are not calculated if only smoothed plots are requested.

<code>which.plots</code>	A character giving the plots that are to be produced. If none, no plots are produced. If <code>smoothedonly</code> , plots of the smoothed traits are plotted. If <code>bothseparately</code> , plots of the unsmoothed trait followed by the smoothed trait are produced for each trait. If <code>compare</code> , a combined plot of the unsmoothed trait and the smoothed trait is produced for each value of <code>df</code> .
<code>deviations.boxplots</code>	A character specifying whether boxplots of the absolute and/or relative deviations of the values of a trait from their smoothed values are to be produced. If none, no plots are produced. The argument <code>which.traits</code> controls the traits for which boxplots are produced.
<code>ggplotFuncs</code>	A list , each element of which contains the results of evaluating a ggplot function. It is created by calling the list function with a ggplot function call for each element. Note that these functions are applied to all three plots produced.
<code>...</code>	allows passing of arguments to longiPlot .

Value

A [data.frame](#) containing `individuals`, `times.factor`, `facet.x`, `facet.y`, `xname`, `response`, and, for each `df`, the smoothed response, the AGR and the RGR. It is returned invisibly. The names of the new data are constructed by joining elements separated by full stops (`.`). In all cases, the last element is the value of `df`. For the smoothed response, the other elements are `response` and `"smooth"`; for AGR and RGR, the other elements are the name of the smoothed response and either `"AGR"` or `"RGR"`.

Author(s)

Chris Brien

See Also

[splitSplines](#), [splitContGRdiff](#), [smooth.spline](#), [ggplot](#).

Examples

```
data(exampleData)
vline <- list(ggplot2::geom_vline(xintercept=20, linetype="longdash", size=1),
             ggplot2::scale_x_continuous(breaks=seq(12, 36, by=2)))
probeDF(data = longi.dat, response = "Area", df = c(4,7), x="xDays+24.16666667",
        ggplotFuncs=vline)
```

PVA

Selects a subset of variables using Principal Variable Analysis (PVA)

Description

Principal Variable Analysis (PVA) (Cummings, 2007) selects a subset from a set of the variables such that the variables in the subset are as uncorrelated as possible, in an effort to ensure that all aspects of the variation in the data are covered.

Usage

```
PVA(responses, data, nvarselect = NULL, p.variance = 1, include = NULL,
    plot = TRUE, ...)
```

Arguments

responses	A character giving the names of the columns in data from which the variables are to be selected.
data	A data.frame containing the columns of variables from which the selection is to be made.
nvarselect	A numeric specifying the number of variables to be selected, which includes those listed in include. If nvarselect = 1, as many variables are selected as is need to satisfy p.variance.
p.variance	A numeric specifying the minimum proportion of the variance that the selected variables must account for,
include	A character giving the names of the columns in data for the variables whose selection is mandatory.
plot	A logical indicating whether a plot of the cumulative proportion of the variance explained is to be produced.
...	allows passing of arguments to other functions

Details

The variable that is most correlated with the other variables is selected first for inclusion. The partial correlation for each of the remaining variables, given the first selected variable, is calculated and the most correlated of these variables is selects for inclusion next. Then the partial correlations are adjust for the second included variables. This process is repeated until the specified criteria have been satisfied. The possibilities are:

1. the default (nvarselect = NULL and p.variance = 1), which selects all variables in increasing order of amount of information they provide;
2. to select exactly nvarselect variables;
3. to select just enough variables, up to a maximum of nvarselect variables, to explain at least p.variance*100 per cent of the total variance.

Value

A [data.frame](#) giving the results of the variable selection. It will contain the columns Variable, Selected, h.partial, Added.Propn and Cumulative.Propn.

Author(s)

Chris Brien

References

Cumming, J. A. and D. A. Wood (2007) Dimension reduction via principal variables. *Computational Statistics and Data Analysis*, **52**, 550–565.

See Also

[intervalPVA](#), [rcontrib](#)

Examples

```
data(exampleData)
responses <- c("Area", "Area.SV", "Area.TV", "Image.Biomass", "Max.Height", "Centre.Mass",
              "Density", "Compactness.TV", "Compactness.SV")
results <- PVA(responses, longi.dat, p.variance=0.9, plot = FALSE)
```

rcontrib

Computes a measure of how correlated each variable in a set is with the other variable, conditional on a nominated subset of them

Description

A measure of how correlated a variable is with those in a set is given by the square root of the sum of squares of the correlation coefficients between the variables and the other variables in the set (Cummings, 2007). Here, the partial correlation between the subset of the variables listed in response that are not listed in include is calculated from the partial correlation matrix for the subset, adjusting for those variables in include. This is useful for manually deciding which of the variables not in include should next be added to it.

Usage

```
rcontrib(responses, data, include = NULL)
```

Arguments

responses	A character giving the names of the columns in data from which the correlation measure is to be calculated.
data	A data.frame containing the columns of variables from which the correlation measure is to be calculated.
include	A character giving the names of the columns in data for the variables for which other variables are to be adjusted.

Value

A [numeric](#) giving the correlation measures.

Author(s)

Chris Brien

References

Cumming, J. A. and D. A. Wood (2007) Dimension reduction via principal variables. *Computational Statistics and Data Analysis*, **52**, 550–565.

See Also

[PVA](#), [intervalPVA](#)

Examples

```
data(exampleData)
responses <- c("Area", "Area.SV", "Area.TV", "Image.Biomass", "Max.Height", "Centre.Mass",
              "Density", "Compactness.TV", "Compactness.SV")
h <- rcontrib(responses, longi.dat, include = "Area")
```

RiceRaw.dat	<i>Data for an experiment to investigate a rice germplasm panel</i>
-------------	---

Description

The data is from an experiment in a Smarthouse in the Plant Accelerator. It is described in Al-Tamimi et al. (2016). It is used in [imageData-pkg](#) as an executable example to illustrate the use of `imageData`.

Usage

```
data(RiceRaw.dat)
```

Format

A data.frame containing 14784 observations on 33 variables.

Source

It will be made available on Dryad

References

Al-Tamimi, N, Brien, C.J., Oakey, H., Berger, B., Saade, S., Ho, Y. S., Schmockel, S. M., Tester, M. and Negrao, S. (2016) New salinity tolerance loci revealed in rice using high-throughput non-invasive phenotyping. *Nature Communications*, **7**, 13342.

<code>splitContGRdiff</code>	<i>Adds the growth rates calculated continuously over time for subsets of a response to a data.frame</i>
------------------------------	--

Description

Uses [AGRdiff](#), [PGR](#) and [RGRdiff](#) to calculate growth rates continuously over time for a subset of the values of response and stores the results in data. The subsets are those values with the same levels combinations of the factors listed in INDICES.

Usage

```
splitContGRdiff(data, responses, INDICES,
                which.rates = c("AGR", "PGR", "RGR"), suffices.rates=NULL,
                times.factor = "Days")
```

Arguments

data	A data.frame containing the columns for which growth rates are to be calculated.
responses	A character giving the names of the columns in data for which growth rates are to be calculated.
INDICES	A character giving the name(s) of the factor (s) that define the subsets of response for which growth rates are to be calculated continuously. If the columns corresponding to INDICES are not factor (s) then they will be coerced to factor (s). The subsets are formed using by .
which.rates	A character giving the growth rates that are to be calculated. It should be a combination "AGR", "PGR" and "RGR".
times.factor	A character giving the name of the column in data containing the factor for times at which the data was collected. Its levels will be used in calculating growth rates and should be numeric values stored as characters.
suffices.rates	A character giving the characters to be appended to the names of the responses to provide the names of the columns containing the calculated growth rates. The order of the suffices in suffices.rates should correspond to the order of the elements of which.rates. If NULL, the values of which.rates are used.

Value

A [data.frame](#) containing data to which has been added a column for the differences between the times.factor, if it is not already in data, and columns with growth rates. The name of the column for times.factor differences will be the times.factor with ".diff" appended and, for each of the growth-rate columns will be the value of response with one of ".AGR", ".PGR" or "RGR" or the corresponding value from suffices.GR appended.

Author(s)

Chris Brien

See Also

[fitSpline](#), [splitSplines](#)

Examples

```
data(exampleData)
longi.dat <- splitContGRdiff(longi.dat, response="Area.smooth",
                             INDICES = "Snapshot.ID.Tag", which.rates=c("AGR", "RGR"))
```

splitSplines	<i>Adds the fits after fitting a natural cubic smoothing spline to subsets of a response to a data.frame</i>
--------------	--

Description

Uses `fitSpline` to fit a spline to a subset of the values of response and stores the fitted values in data. The subsets are those values with the same levels combinations of the factors listed in INDICES and the degrees of smoothing is controlled by df. The derivatives of the fitted spline can also be obtained, as can the Relative Growth Rates (RGR).

By default, `smooth.spline` will issue an error if there are not at least four distinct x-values. On the other hand, `fitSpline` issues a warning and sets all smoothed values and derivatives to NA. The handling of missing values in the observations is controlled via `na.x.action` and `na.y.action`.

Usage

```
splitSplines(data, response, x, INDICES, df = NULL, smoothing.scale = "identity",
             correctBoundaries = FALSE,
             deriv = NULL, suffices.deriv=NULL, RGR=NULL, AGR=NULL, sep=".",
             na.x.action="exclude", na.y.action = "exclude", ...)
```

Arguments

data	A data.frame containing the column to be smoothed.
response	A character giving the name of the column in data that is to be smoothed.
x	A character giving the name of the column in data that contains the values of the predictor variable.
INDICES	A character giving the name(s) of the factor (s) that define the subsets of response that are to be smoothed separately. If the columns corresponding to INDICES are not factor (s) then they will be coerced to factor (s). The subsets are formed using split .
df	A numeric specifying the desired equivalent number of degrees of freedom of the smooth (trace of the smoother matrix). Lower values result in more smoothing. If df = NULL, ordinary leave-one-out cross-validation is used to determine the amount of smooth.
smoothing.scale	A character giving the scale on which smoothing is to be performed. The two possibilities are "identity", for directly smoothing the observed response, and "logarithmic", for scaling the log-transformed response.
correctBoundaries	A logical indicating whether the fitted spline values are to have the method of Huang (2001) applied to them to correct for estimation bias at the end-points. Note that deriv must be NULL for correctBoundaries to be set to TRUE.
deriv	A numeric specifying one or more orders of derivatives that are required.
suffices.deriv	A character giving the characters to be appended to the names of the derivatives.
RGR	A character giving the character to be appended to the smoothed response to create the RGR name, but only when smoothing.scale is identity. When smoothing.scale is identity: (i) if RGR is not NULL deriv must include 1 so that the first derivative is available for calculating the RGR; (ii) if RGR is NULL, the RGR is not calculated from the AGR. When smoothing.scale is logarithmic, the RGR is the backtransformed first derivative and so, to obtain it, merely include 1 in deriv and any suffix for it in suffices.deriv.

AGR	A character giving the character to be appended to the smoothed response to create the AGR name, but only when <code>smoothing.scale</code> is logarithmic. When <code>smoothing.scale</code> is logarithmic: (i) if AGR is not NULL, <code>deriv</code> must include 1 so that the first derivative is available for calculating the AGR; (ii) If AGR is NULL, the AGR is not calculated from the RGR. When <code>smoothing.scale</code> is identity, the AGR is the first derivative and so, to obtain it, merely include 1 in <code>deriv</code> and any suffix for it in <code>suffices.deriv</code> .
sep	A character giving the separator to use when the levels of INDICES are combined. This is needed to avoid using a character that occurs in a factor to delimit levels when the levels of INDICES are combined to identify subsets.
na.x.action	A character string that specifies the action to be taken when values of x are NA. The possible values are fail, exclude or omit. For exclude and omit, predictions and derivatives will only be obtained for nonmissing values of x. The difference between these two codes is that the returned <code>data.frame</code> will have as many rows as data, the missing values have been incorporated.
na.y.action	A character string that specifies the action to be taken when values of y, or the response, are NA. The possible values are fail, exclude, omit, allx, trimx, ltrimx or rtrimx. For all options, except fail, missing values in y will be removed before smoothing. For exclude and omit, predictions and derivatives will be obtained only for nonmissing values of x that do not have missing y values. Again, the difference between these two is that, only for exclude will the missing values will be incorporated into the returned <code>data.frame</code> . For allx, predictions and derivatives will be obtained for all nonmissing x. For trimx, they will be obtained for all nonmissing x between the first and last nonmissing y values that have been ordered for x; for ltrimx and rtrimx either the lower or upper missing y values, respectively, are trimmed.
...	allows for arguments to be passed to <code>smooth.spline</code> .

Value

A [data.frame](#) containing data to which has been added a column with the fitted smooth, the name of the column being response with `.smooth` appended to it. If `deriv` is not NULL, columns containing the values of the derivative(s) will be added to data; the name each of these columns will be the value of response with `.smooth.dvf` appended, where f is the order of the derivative, or the value of response with `.smooth.` and the corresponding element of `suffices.deriv` appended. If RGR is not NULL, the RGR is calculated as the ratio of value of the first derivative of the fitted spline and the fitted value for the spline. Any pre-existing smoothed and derivative columns in data will be replaced. The ordering of the `data.frame` for the x values will be preserved as far as is possible; the main difficulty is with the handling of missing values by the function merge. Thus, if missing values in x are retained, they will occur at the bottom of each subset of INDICES and the order will be problematic when there are missing values in y and `na.y.action` is set to omit.

Author(s)

Chris Brien

References

Huang, C. (2001). Boundary corrected cubic smoothing splines. *Journal of Statistical Computation and Simulation*, **70**, 107-121.

See Also

[fitSpline](#), [smooth.spline](#), [predict.smooth.spline](#), [splitContGRdiff](#), [split](#)

Examples

```
data(exampleData)
longi.dat <- splitSplines(longi.dat, response="Area", x="xDays",
  INDICES = "Snapshot.ID.Tag",
  df = 4, deriv=1, suffices.deriv="AGRdv", RGR="RGRdv")
```

splitValueCalculate	<i>Calculates a single value that is a function of an individual's values for a response</i>
---------------------	--

Description

Splits the values of a response into subsets corresponding individuals and applies a function that calculates a single value to each individual's observations. It includes the ability to calculate the observation that corresponds to the calculated value of the function.

Usage

```
splitValueCalculate(response, weights=NULL, individuals = "Snapshot.ID.Tag",
  FUN = "max", which.obs = FALSE, which.levels = NULL,
  data, na.rm=TRUE, sep=".", ...)
```

Arguments

response	A character giving the name of the column in data from which the values of FUN are to be calculated.
weights	A character giving the name of the column in data containing the weights to be supplied as w to FUN.
individuals	A character giving the name(s) of the factor(s) that define the subsets of the data for which each subset corresponds to the response value for an individual.
FUN	A character giving the name of the function that calculates the value for each subset.
which.obs	A logical indicating whether or not to determine the observation corresponding to the value of the function, instead of the value of the function itself.
which.levels	A character giving the name of the factor whose levels are to be identified as the level of the observation whose value matches the value of the function.
data	A data.frame containing the column from which the function is to be calculated.
na.rm	A logical indicating whether NA values should be stripped before the calculation proceeds.
sep	A character giving the separator to use when the levels of individuals are combined. This is needed to avoid using a character that occurs in a factor to delimit levels when the levels of individuals are combined to identify subsets.
...	allows for arguments to be passed to FUN.

Value

A [data.frame](#), with the same number of rows as there are individuals, containing the values of the function for the individuals.

Author(s)

Chris Brien

See Also

[splitContGRdiff](#), [splitSplines](#)

Examples

```
data(exampleData)
Area.smooth.max <- splitValueCalculate("Area.smooth", data = longi.dat)
```

twoLevelOpcreate	<i>Creates a data.frame formed by applying, for each response, a binary operation to the paired values of two different treatments</i>
------------------	--

Description

Takes pairs of values for a set of responses indexed by a two-level `treatment.factor` and calculates, for each of pair, the result of applying a binary operation to their values for the two levels of the `treatment.factor`. The level of the `treatment.factor` designated the control will be on the right of the binary operator and the value for the other level will be on the left.

Usage

```
twoLevelOpcreate(responses, data, treatment.factor = "Treatment.1",
  suffices.treatment = c("Cont", "Salt"), control = 1,
  columns.suffixes = NULL,
  operations = "/", suffices.results="OST",
  columns.retained = c("Snapshot.ID.Tag", "Smarthouse", "Lane",
    "Zones", "xZones", "SHZones", "ZLane",
    "ZMainplots", "xMainPosn", "Genotype.ID"),
  by = c("Smarthouse", "Zones", "ZMainplots"))
```

Arguments

<code>responses</code>	A character giving the names of the columns in data that contain the responses to which the binary operations are to be applied.
<code>data</code>	A data.frame containing the columns specified by <code>treatment.factor</code> , <code>columns.retained</code> and responses.
<code>treatment.factor</code>	A factor with two levels corresponding to what is to be designated the control and treated observations .

suffices.treatment	A character giving the characters to be appended to the names of the responses and columns.suffixed in constructing the names of the columns containing the responses and columns.suffixed for each level of the treatment.factor. The order of the suffices in suffices.treatment should correspond to the order of the levels of treatment.factor.
control	A numeric , equal to either 1 or 2, that specifies the level of treatment.factor that is the control treatment. The value for the control level will be on the right of the binary operator.
columns.suffixed	A character giving the names of the columns.retained in data that are to be have the values for each treatment retained and whose names are to be suffixed using suffices.treatment. Generally, this is done when columns.retained has different values for different levels of the treatment.factor.
operations	A character giving the binary operations to perform on the values for the two different levels of the treatment.factor. It should be either of length one, in which case the same operation will be performed for all columns specified in response.GR, or equal in length to response.GR so its elements correspond to those of response.GR.
suffices.results	A character giving the characters to be appended to the names of the responses in constructing the names of the columns containing the results of applying the operations. The order of the suffices in suffices.results should correspond to the order of the operators in operations.
columns.retained	A character giving the names of the columns in data that are to be retained in the data.frame being created. These are usually factors that index the results of applying the operations and that might be used subsequently.
by	A character giving the names of the columns in data whose combinations will be unique for the observation for each treatment. It is used by merge when combining the values of the two treatments in separate columns in the data.frame to be returned.

Value

A **data.frame** containing the following columns and the values of the :

1. those from data nominated in columns.retained;
2. those containing the treated values of the columns whose names are specified in responses; the treated values are those having the other level of treatment.factor to that specified by control;
3. those containing the control values of the columns whose names are specified in responses; the control values are those having the level of treatment.factor specified by control;
4. those containing the values calculated using the binary operations; the names of these columns will be constructed from responses by appending suffices.results to them.

Author(s)

Chris Brien

Examples

```
data(exampleData)
responses <- c("Area.smooth.AGR", "Area.smooth.RGR")
cols.retained <- c("Snapshot.ID.Tag", "Smarthouse", "Lane", "Position",
                  "Days", "Snapshot.Time.Stamp", "Hour", "xDays",
                  "Zones", "xZones", "SHZones", "ZLane", "ZMainplots",
                  "xMainPosn", "Genotype.ID")

longi.SIIT.dat <-
  twoLevel0pcreate(responses, longi.dat, suffices.treatment=c("C", "S"),
                  operations = c("-", "/"),
                  suffices.results = c("diff", "SIIT"),
                  columns.retained = cols.retained,
                  by = c("Smarthouse", "Zones", "ZMainplots", "Days"))

longi.SIIT.dat <- with(longi.SIIT.dat,
                      longi.SIIT.dat[order(Smarthouse, Zones, ZMainplots, Days), ])
```

WUI

Calculates the Water Use Index (WUI)

Description

Calculates the Water Use Index, returning NA if the water use is zero.

Usage

```
WUI(response, water)
```

Arguments

response	A numeric giving the value of the response achieved.
water	A numeric giving the amount of water used.

Value

A [numeric](#) containing the water divided by the response, unless water is zero in which case NA is returned.

Author(s)

Chris Brien

Examples

```
data(exampleData)
Area.WUE <- with(longi.dat, WUI(Area.AGR, Water.Loss))
```

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