

Package ‘IntervalQuestionStat’

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Title Tools to Deal with Interval-Valued Responses in Questionnaires

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Description S4 classes, methods and functions to deal with interval-valued responses in questionnaires. They allow for computing any arithmetic and statistical operations with interval-valued data, preparing plots, transforming interval-valued responses into Likert-type and visual analogue scales responses, analysing respondents answers reliability and simulating interval-valued responses in a questionnaire.

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IntervalQuestionStat-package

Tools to Deal with Interval-Valued Responses in Questionnaires

Description

IntervalQuestionStat is an open source package for R. It provides S4 classes and methods to deal with interval-valued responses in questionnaires. It also includes some basic functions for doing the statistical analysis of this type of data.

Details

In Social and Educational Sciences and many other disciplines, interval-valued scales arise as an alternative to traditional Likert-type or visual analogue scales in some questionnaires measuring people's behaviour (attitudes, opinions, perceptions, feelings, etc.). This type of data cannot be numerically measured because they concern intrinsically imprecise valued attributes. Likert-type and visual analogue scales force to choose a single point response linked to a statement or question, so individual differences are almost systematically overlooked. To overcome the limitations of these traditional scales in capturing uncertainty of respondent answers, interval-valued scales allow respondents to select a range or interval of real data and not being constrained to a single point.

The package aims to provide the following functionality:

1. Calculation of basic operations with interval-valued data (see [arithmetic](#) and [distance](#)).
2. Calculation of some central tendency and variation measures (see [mean](#), [var](#) and [cov](#)).

3. Visualization of interval-valued data (see [plot](#)).
4. Transformation of interval-valued responses into Likert-type or visual analogue responses (see [ivd2likert](#) and [ivd2vas](#)).
5. Statistical analysis of reliability of questionnaire's responses (see [cronbach](#)).
6. Simulation of interval-valued responses in questionnaires (see [simulIVS](#)).

For a complete list of classes and methods call `help(package="IntervalQuestionStat")`.

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- Moore, R.E.; Kearfott, R.B.; Cloud, M.J. (2009). *Introduction to Interval Analysis*. Society for Industrial and Applied Mathematics, USA.

`apply`*Apply functions over IntervalMatrix margins*

Description

This function returns the numeric vector or the list of interval-valued data obtained by applying a function to margins of an interval-valued data matrix.

Usage

```
## S4 method for signature 'IntervalMatrix'  
apply(X, MARGIN, FUN)
```

Arguments

X	a matrix of interval-valued data.
MARGIN	a numeric value giving the direction which the function will be applied over. <ul style="list-style-type: none">• 1: the function will be applied by rows.• 2: the function will be applied by columns.
FUN	the function to be applied.

Value

Returns the numeric vector or the list of interval-valued data obtained by applying the selected function to margins of an interval-valued data matrix.

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

See Also

Other IntervalMatrix-method: [IntervalMatrix-class](#), [IntervalMatrix](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [show\(\)](#)

Examples

```
data <- matrix(c(0, 2, 0, 4, 1, 3, 3, 9), 2, 4, byrow = TRUE)  
m <- IntervalMatrix(data)  
apply(m, 1, mean)  
apply(m, 2, mean)  
apply(m, 1, var)  
apply(m, 2, var)
```

arithmetic *Interval arithmetic operations*

Description

Applies arithmetic operations using interval-based calculations.

Usage

```
## S4 method for signature 'numeric,IntervalData'
e1 + e2

## S4 method for signature 'IntervalData,numeric'
e1 + e2

## S4 method for signature 'IntervalData,IntervalData'
e1 + e2

## S4 method for signature 'numeric,IntervalData'
e1 - e2

## S4 method for signature 'IntervalData,numeric'
e1 - e2

## S4 method for signature 'IntervalData,IntervalData'
e1 - e2

## S4 method for signature 'IntervalData,ANY'
e1 - e2 # -e1

## S4 method for signature 'numeric,IntervalData'
e1 * e2

## S4 method for signature 'IntervalData,numeric'
e1 * e2
```

Arguments

e1 an interval-valued data or single numeric value.
e2 an interval-valued data or single numeric value.

Details

Implementation of Minkowski's sum and product by a scalar operators: +, -, *. Using mid/spr-characterisation, these operations can be settled for two interval-valued data A and B and a real number γ as follows:

$$A + B = [(\text{mid } A + \text{mid } B) \mp (\text{spr } A + \text{spr } B)]$$

and

$$\gamma \cdot A = \begin{cases} [\gamma \cdot \text{mid } A \mp \gamma \cdot \text{spr } A] & \text{if } \gamma \geq 0, \\ [\gamma \cdot \text{mid } A \pm \gamma \cdot \text{spr } A] & \text{if } \gamma < 0. \end{cases}$$

Value

Returns an interval-valued data of the class [IntervalData](#).

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

References

- Minkowski, H. (1903). Volumen und oberfläche. *Mathematische Annalen*, 57:447-495.
- Moore, R.E.; Kearfott, R.B.; Cloud, M.J. (2009). *Introduction to Interval Analysis*. Society for Industrial and Applied Mathematics, USA.

See Also

Other IntervalData-method: [IntervalData-class](#), [IntervalData](#), [as.IntervalData\(\)](#), [distance\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [plot\(\)](#), [show\(\)](#)

Examples

```
i1 <- IntervalData(0, 1)
i2 <- IntervalData(2, 3)
-i1
i1 + 1
1 + i1
i1 - 1
1 - i1
i1 + i2
i1 - i2
2*i1
i1*2
-2*i1
i1*(-2)

## Note that i1-i1 is not {0}
i1-i1
```

as.IntervalData *Convert an object to IntervalData class*

Description

This function coerce a real number to an object of IntervalData class.

Usage

```
## S4 method for signature 'numeric'  
as.IntervalData(object)
```

Arguments

object a single real number.

Value

Returns an object of class [IntervalData](#).

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

See Also

Other IntervalData-method: [IntervalData-class](#), [IntervalData](#), [arithmetic](#), [distance\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [plot\(\)](#), [show\(\)](#)

Other conversion: [as.IntervalList\(\)](#)

Examples

```
as.IntervalData(1)
```

as.IntervalList *Convert an object to IntervalList class*

Description

This function coerce an object of IntervalData to an object of IntervalList class.

Usage

```
## S4 method for signature 'IntervalData'  
as.IntervalList(object)
```

Arguments

object an interval-valued data.

Value

Returns an object of class [IntervallList](#).

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

See Also

Other IntervallList-method: [IntervallList-class](#), [IntervallList](#), [cov\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [mean\(\)](#), [plot\(\)](#), [sum\(\)](#), [var\(\)](#)

Other conversion: [as.IntervalData\(\)](#)

Examples

```
as.IntervallList(IntervalData(0, 1))
```

c

Combine interval-valued data into an interval-valued data list

Description

This function combines its arguments into a object of class [IntervallList](#).

Usage

```
## S4 method for signature 'IntervalData'  
c(x, ...)  
## S4 method for signature 'IntervallList'  
c(x, ...)
```

Arguments

x an [IntervalData](#) or [IntervallList](#) object.
... additional arguments.

Value

An interval-valued data list with the combination of given elements

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

Examples

```
## Combine 'IntervalData' objects
i1 <- IntervalData(0, 1)
i2 <- IntervalData(0, 2)
list1 <- c(i1, i2)
list1

## Combine 'IntervallList' objects
list2 <- c(list1, list1)
list2

## Combine both 'IntervalData' and 'IntervallList' objects
list3 <- c(i1, list1)
list3
list4 <- c(list1, i1)
list4
```

cov

*Calculate the covariance of two samples of n interval-valued data***Description**

This function calculates the covariance of two samples of n interval-valued data.

Usage

```
## S4 method for signature 'IntervallList,IntervallList'
cov(x, y, theta = 1)
```

Arguments

x a list of interval-valued data.
y a list of interval-valued data with the same length as **x**.
theta a single positive numeric value. By default, theta=1.

Details

Let \mathcal{X} and \mathcal{Y} be two interval-valued random sets and let $((x_1, y_1), (x_2, y_2), \dots, (x_n, y_n))$ be a sample of n independent observations drawn from $(\mathcal{X}, \mathcal{Y})$. Then, the sample covariance is defined as follows,

$$s_{\mathcal{X}\mathcal{Y}} = s_{\text{mid } \mathcal{X} \text{ mid } \mathcal{Y}} + \theta \cdot s_{\text{spr } \mathcal{X} \text{ spr } \mathcal{Y}},$$

where $\theta > 0$ and

$$s_{\text{mid } \mathcal{X} \text{ mid } \mathcal{Y}} = \frac{1}{n} \sum_{i=1}^n (\text{mid } x_i - \text{mid } \bar{x})(\text{mid } y_i - \text{mid } \bar{y}),$$

with \bar{x} and \bar{y} being the sample Aumann means of the given random samples.

Value

Returns the calculated covariance of two samples of n interval-valued data, i.e., a real number.

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

See Also

Other IntervalList-method: [Intervallist-class](#), [Intervallist](#), [as.Intervallist\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [mean\(\)](#), [plot\(\)](#), [sum\(\)](#), [var\(\)](#)

Examples

```
list <- Intervallist(c(1, 3), c(2, 5))
cov(list, list)
var(list)
cov(list, list, 1/3)
var(list, 1/3)
```

```
list1 <- IntervalList(c(0, 3, 2, 5, 6), c(4, 5, 4, 8, 7))
list2 <- IntervalList(c(3, 0, 3, 1, 4), c(7, 4, 6, 2, 6))
cov(list1, list2)
cov(list1, list2, 1/3)
```

cronbach

Estimate Cronbach's α coefficient

Description

Calculates Cronbach's α coefficient as an estimate of reliability for Likert-type, visual analogue and interval-valued data scales responses.

Usage

```
cronbach(data, ivd = TRUE, type = 1, theta = 1)
```

Arguments

data	a matrix or dataframe.
ivd	a logical value indicating if an interval-valued scale is used (default) or not.
type	a number specifying the order and the characterisation that is being used. Only four options are allowed: <ul style="list-style-type: none"> • 1: inf/sup-characterisation is used variable by variable (default). • 2: mid/spr-characterisation is used variable by variable. • 3: all infimums are followed by all supremums in the same variable order. • 4: all mid-points are followed by all spreads in the same variable order.
theta	a single positive numeric value. By default, theta=1.

Details

For Likert-type and visual analogue scale responses the Cronbach's α coefficient computed by `cronbach()` is defined as follows,

$$\alpha = \frac{k}{k-1} \left(1 - \frac{\sum_{j=1}^k s_{X_j}^2}{s_{X_{total}}^2} \right),$$

where $k > 1$ is the number of items, $s_{X_j}^2$ is the sample variance of the j -th item and $s_{X_{total}}^2$ is the sample variance of the sum of all the involved items, that is,

$$X_{total} = X_1 + X_2 + \dots + X_k.$$

Analogously, for interval-valued scale responses the Cronbach's α coefficient computed by this function is defined as follows,

$$\alpha = \frac{k}{k-1} \left(1 - \frac{\sum_{j=1}^k s_{\mathcal{X}_j}^2}{s_{\mathcal{X}_{total}}^2} \right),$$

where $k > 1$ is the number of items, $s_{\mathcal{X}_j}^2$ is the sample Frechet variance of the j -th item and $s_{\mathcal{X}_{total}}^2$ is the sample Frechet variance of the sum of all the involved items, that is,

$$\mathcal{X}_{total} = \mathcal{X}_1 + \mathcal{X}_2 + \dots + \mathcal{X}_k.$$

Value

Returns the calculated Cronbach's α coefficient for the given dataset.

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

References

Cronbach L.J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, 16, 297-334.

Examples

```
## Calculate Cronbach's alpha coefficient for interval-valued responses
data1 <- matrix(c(1, 1.5, 3.8, 4, 2.6, 3, 6, 7), 2, 4, byrow = TRUE)
cronbach(data1)

## Calculate Cronbach's alpha coefficient for Likert-type responses
data2 <- ivd2likert(IntervalMatrix(data1))
cronbach(data2, ivd = FALSE)

## Calculate Cronbach's alpha coefficient for visual analogue responses
data3 <- ivd2vas(IntervalMatrix(data1))
cronbach(data3, ivd = FALSE)
```

```
## Real-life example
## Load the data
data(lackinfo, package = "IntervalQuestionStat")

## Calculate Cronbach's alpha coefficient for interval-valued responses
cronbach(lackinfo[, 4:13])

## Convert to Likert-type responses and calculate Cronbach's alpha coefficient
cronbach(ivd2likert(IntervalMatrix(lackinfo[, 4:13])), ivd = FALSE)

## Convert to visual analogue responses and calculate Cronbach's alpha coefficient
cronbach(ivd2vas(IntervalMatrix(lackinfo[, 4:13])), ivd = FALSE)
```

distance

Calculate the θ -distance between two interval-valued data

Description

The θ -distance for two given interval-valued data A and B was defined by Gil et al. (2002) as follows,

$$d_{\theta}(A, B) = \sqrt{(\text{mid } A - \text{mid } B)^2 + \theta \cdot (\text{spr } A - \text{spr } B)^2},$$

where θ is a positive real number.

Usage

```
## S4 method for signature 'IntervalData,IntervalData'
distance(e1, e2, theta = 1)
```

Arguments

e1 an interval-valued data.
e2 an interval-valued data.
theta a single positive numeric value. By default theta=1.

Value

Returns the calculated θ -distance, i.e. a single numeric value.

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

References

Gil, M.A.; Lubiano, M.A.; Montenegro, M.; Lopez, M.T. (2002). Least squares fitting of an affine function and strength of association for interval-valued data. *Metrika* 56:97-111.

See Also

Other IntervalData-method: [IntervalData-class](#), [IntervalData](#), [arithmetic](#), [as.IntervalData\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [plot\(\)](#), [show\(\)](#)

Examples

```
i1 <- IntervalData(0, 1)
i2 <- IntervalData(3, 7)
distance(i1, i2)
distance(i1, i2, 1/3)
```

IntervalData	<i>Create an IntervalData object</i>
--------------	--------------------------------------

Description

For convenience, objects of class `IntervalData` may be created with this function.

Usage

```
IntervalData(a1, a2, type = 1)
```

Arguments

<code>a1</code>	a number specifying the infimum or the mid-point of the interval.
<code>a2</code>	a number specifying the supremum or the spread of the interval.
<code>type</code>	a number specifying the characterisation that is being used. Only two options are allowed: <ul style="list-style-type: none">• 1: inf/sup-characterisation is used (default).• 2: mid/spr-characterisation is used.

Value

Object of class `IntervalData`.

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

See Also

Other IntervalData-method: [IntervalData-class](#), [arithmetic](#), [as.IntervalData\(\)](#), [distance\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [plot\(\)](#), [show\(\)](#)

Examples

```
IntervalData(0, 2)
IntervalData(1, 1, 2)
```

IntervalData-class *S4 class representing an interval-valued data*

Description

Each nonempty compact real interval K can be characterised in terms of either its infimum and supremum or its mid-point and spread as follows,

$$K = [\inf K, \sup K] = [\text{mid } K \mp \text{spr } K],$$

where $\inf K \leq \sup K$ and $\text{spr } K \geq 0$.

Slots

mid: Single numeric value specifying the mid-point of the interval.

spr: Single numeric value specifying the spread of the interval.

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

See Also

Other IntervalData-method: [IntervalData](#), [arithmetic](#), [as.IntervalData\(\)](#), [distance\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [plot\(\)](#), [show\(\)](#)

Examples

```
showClass("IntervalData")
showMethods(classes = "IntervalData")
```

IntervalList *Create an IntervalList object*

Description

For convenience, objects of class IntervalList may be created with this function.

Usage

```
IntervalList(x, y = NULL, type = 1)
```

Arguments

- x a numeric vector, matrix or data frame.
- y NULL (default) or a numeric vector with compatible dimensions to x.
- type a number specifying the order and the characterisation that is being used. Only two options are allowed:
- 1: inf/sup-characterisation is used (default).
 - 2: mid/spr-characterisation is used.

Value

Object of class [IntervallList](#).

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

See Also

Other IntervalList-method: [IntervallList-class](#), [as.IntervallList\(\)](#), [cov\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [mean\(\)](#), [plot\(\)](#), [sum\(\)](#), [var\(\)](#)

Examples

```
IntervallList(c(0, 2, 5), c(1, 6, 10))
IntervallList(c(0.5, 4, 7.5), c(0.5, 2, 2.5), 2)
IntervallList(matrix(c(0, 2, 5, 1, 6, 10), 3, 2))
IntervallList(matrix(c(0.5, 4, 7.5, 0.5, 2, 2.5), 3, 2), type = 2)
```

IntervalList-class *S4 class representing a list of interval-valued data*

Description

S4 class representing a list of interval-valued data

Slots

.Data: The data part, which is an object of class 'list'.

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

See Also

Other IntervalList-method: [IntervallList](#), [as.IntervallList\(\)](#), [cov\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [mean\(\)](#), [plot\(\)](#), [sum\(\)](#), [var\(\)](#)

Examples

```
showClass("Intervallist")
showMethods(classes = "Intervallist")
```

IntervalMatrix	<i>Create an IntervalMatrix object</i>
----------------	--

Description

For convenience, objects of class `IntervalMatrix` may be created with this function.

Usage

```
IntervalMatrix(data, type = 1)
```

Arguments

<code>data</code>	a matrix or data frame containing the interval-valued data information.
<code>type</code>	a number specifying the characterisation that is being used. Only four options are allowed: <ul style="list-style-type: none"> • 1: inf/sup-characterisation is used variable by variable (default). • 2: mid/spr-characterisation is used variable by variable. • 3: all infimums are followed by all supremums in the same variable order. • 4: all mid-points are followed by all spreads in the same variable order.

Value

Object of class `IntervalMatrix`.

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

See Also

Other `IntervalMatrix`-method: [IntervalMatrix-class](#), [apply\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [show\(\)](#)

Examples

```
data <- matrix(c(0, 2, 0, 4, 1, 3, 3, 9), 2, 4, byrow = TRUE)
IntervalMatrix(data)
data <- matrix(c(1, 1, 2, 2, 2, 1, 6, 3), 2, 4, byrow = TRUE)
IntervalMatrix(data, 2)
data <- matrix(c(0, 0, 2, 4, 1, 3, 3, 9), 2, 4, byrow = TRUE)
IntervalMatrix(data, 3)
data <- matrix(c(1, 2, 1, 2, 2, 6, 1, 3), 2, 4, byrow = TRUE)
IntervalMatrix(data, 4)
```

IntervalMatrix-class *S4 class representing a matrix of interval-valued data*

Description

S4 class representing a matrix of interval-valued data

Slots

.Data: The data part, which is an object of class 'matrix'.

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

See Also

Other IntervalMatrix-method: [IntervalMatrix](#), [apply\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [show\(\)](#)

Examples

```
showClass("IntervalMatrix")
showMethods(classes = "IntervalMatrix")
```

ivd2likert *Convert interval-valued data responses into Likert-type responses*

Description

Associate each interval-valued data in a questionnaire to a Likert-type response following the minimum θ -distance criterion.

Usage

```
## S4 method for signature 'IntervalData'
ivd2likert(x, k = 7, minimum = 1, maximum = 7, theta = 1)

## S4 method for signature 'IntervalList'
ivd2likert(x, k = 7, minimum = 1, maximum = 7, theta = 1)

## S4 method for signature 'IntervalMatrix'
ivd2likert(x, k = 7, minimum = 1, maximum = 7, theta = 1)
```

Arguments

x	an interval-valued data or a list or matrix of interval-valued data.
k	a single positive integer value indicating the number of different Likert-type responses to be considered. By default, k=7.
minimum	a single real number indicating the lower bound of the interval-valued scale used. By default, minimum=1.
maximum	a single real number indicating the upper bound of the interval-valued scale used. By default, maximum=7.
theta	a single positive numeric value. By default, theta=1.

Details

If a k -point Likert-type scale with reference interval $[l, u]$ is considered, then the minimum distance criterion consists in associating each interval-valued scale response with the real number in the set defined by $\{L_1, L_2, \dots, L_k\}$, where

$$L_i = l + (i - 1) \frac{u - l}{k - 1}, \quad i = 1, 2, \dots, k,$$

with the smallest θ -distance to the given data. That is, each interval-valued data A is associated with the real number $L(A)$ such that

$$L(A) = \arg \min_{L \in \{L_1, L_2, \dots, L_k\}} d_\theta(A, \{L\}).$$

If ties are produced, they are broken at random.

Value

Returns the nearest Likert-type responses for the given interval-valued data following the minimum θ -distance criterion.

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

See Also

Other IntervalData-method: [IntervalData-class](#), [IntervalData](#), [arithmetic](#), [as.IntervalData\(\)](#), [distance\(\)](#), [ivd2vas\(\)](#), [plot\(\)](#), [show\(\)](#)

Other IntervalList-method: [IntervalList-class](#), [IntervalList](#), [as.IntervalList\(\)](#), [cov\(\)](#), [ivd2vas\(\)](#), [mean\(\)](#), [plot\(\)](#), [sum\(\)](#), [var\(\)](#)

Other IntervalMatrix-method: [IntervalMatrix-class](#), [IntervalMatrix](#), [apply\(\)](#), [ivd2vas\(\)](#), [show\(\)](#)

Examples

```
## Convert to Likert-type response an interval-valued response
ivd2likert(IntervalData(3, 3.2), 11, 0, 10)

## Convert to Likert-type responses a list of interval-valued responses
ivd2likert(IntervalList(c(3, 8.7), c(3.2, 9)), 11, 0, 10)

## Convert to Likert-type response a matrix or dataframe of interval-valued responses
ivd2likert(IntervalMatrix(matrix(c(1, 1.5, 3.8, 4, 2.6, 3, 6, 7), 2, 4, byrow = TRUE)))
```

ivd2vas

Convert interval-valued data responses to visual-analogue responses

Description

Reduce each interval-valued data information to its mid-point so it can be considered as a response from a visual analogue scale. That is, given an interval-valued data A this method returns its mid-point $\text{mid } A$.

Usage

```
## S4 method for signature 'IntervalData'
ivd2vas(x)

## S4 method for signature 'IntervalList'
ivd2vas(x)

## S4 method for signature 'IntervalMatrix'
ivd2vas(x)
```

Arguments

x an interval-valued data or a list or matrix of interval-valued data.

Value

Returns the mid-points of the given interval-valued data to be considered as visual analogue scale responses in a questionnaire.

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

See Also

Other IntervalData-method: [IntervalData-class](#), [IntervalData](#), [arithmetic](#), [as.IntervalData\(\)](#), [distance\(\)](#), [ivd2likert\(\)](#), [plot\(\)](#), [show\(\)](#)

Other IntervalList-method: [IntervalList-class](#), [IntervalList](#), [as.IntervalList\(\)](#), [cov\(\)](#), [ivd2likert\(\)](#), [mean\(\)](#), [plot\(\)](#), [sum\(\)](#), [var\(\)](#)

Other IntervalMatrix-method: [IntervalMatrix-class](#), [IntervalMatrix](#), [apply\(\)](#), [ivd2likert\(\)](#), [show\(\)](#)

Examples

```
## Convert to visual analogue response an interval-valued response
ivd2vas(IntervalData(3, 3.2))

## Convert to visual analogue responses a list of interval-valued responses
ivd2vas(IntervalList(c(3, 8.7), c(3.2, 9)))

## Convert to likert-type response a matrix or dataframe of interval-valued responses
ivd2vas(IntervalMatrix(matrix(c(1, 1.5, 3.8, 4, 2.6, 3, 6, 7), 2, 4, byrow = TRUE)))
```

lackinfo

Lack of information questionnaire dataset

Description

A dataset containing some biographical data and the responses to 5 items measuring the perception of lack of information in a questionnaire.

Usage

```
lackinfo
```

Format

A data frame with 50 observations of the following 13 variables:

- id: identification number.
- sex: sex of the respondent (male or female).
- age: respondent's age (in years).
- inf1: infimum of respondent's interval-valued answer to item 1.
- sup1: supremum of respondent's interval-valued answer to item 1.
- inf2: infimum of respondent's interval-valued answer to item 2.
- sup2: supremum of respondent's interval-valued answer to item 2.
- inf3: infimum of respondent's interval-valued answer to item 3.
- sup3: supremum of respondent's interval-valued answer to item 3.

- inf4: infimum of respondent's interval-valued answer to item 4.
- sup4: supremum of respondent's interval-valued answer to item 4.
- inf5: infimum of respondent's interval-valued answer to item 5.
- sup5: supremum of respondent's interval-valued answer to item 5.

Details

An educational innovation project was carried out for improving teaching-learning processes at the University of Oviedo (Spain) for the 2020/2021 academic year. A total of 50 students have been requested to answer an online questionnaire about some biographical data (sex and age) and their perception of lack of information by selecting the interval that best represents their level of agreement to the statements proposed in a interval-valued scale bounded between 1 and 7, where 1 represents the option 'strongly disagree' and 7 represents the option 'strongly agree'.

These are the 5 items used to measure the perception of lack of information:

- I1: I receive too little information from my classmates.
- I2: It is difficult to receive relevant information from my classmates.
- I3: It is difficult to receive relevant information from the teacher.
- I4: The amount of information I receive from my classmates is very low.
- I5: The amount of information I receive from the teacher is very low.

Examples

```
data(lackinfo, package = "IntervalQuestionStat")
head(lackinfo)
summary(lackinfo)
```

mean

Calculate the sample Aumann mean of n interval-valued data

Description

This function calculates the sample Aumann mean of n interval-valued data.

Usage

```
## S4 method for signature 'IntervalList'
mean(x)
```

Arguments

x a list of interval-valued data.

Value

Returns the calculated sample Aumann mean of n interval-valued data, i.e., other interval-valued data.

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

References

Aumann, R.J. (1965). Integrals of set-valued functions. *Journal of Mathematical Analysis and Applications*, 12(1):1-12.

See Also

Other IntervalList-method: [IntervalList-class](#), [IntervalList](#), [as.IntervalList\(\)](#), [cov\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [plot\(\)](#), [sum\(\)](#), [var\(\)](#)

Examples

```
mean(IntervalList(c(1, 3), c(2, 5)))
```

plot

Plot an interval-valued data or a list of interval-valued data

Description

S4 methods for function plot. As in the generic plot S3 ‘graphics’ method, these methods plot interval-valued data contained in IntervalData and IntervalList objects.

Usage

```
## S4 method for signature 'IntervalData,missing'
plot(x, y, layout = c("vertical", "horizontal"), bounds = FALSE, mid = FALSE, ...)
## S4 method for signature 'IntervalData,IntervalData'
plot(x, y, bounds = FALSE, ...)
## S4 method for signature 'IntervalList,missing'
plot(x, y, layout = c("vertical", "horizontal"), bounds = FALSE, mid = FALSE, ...)
## S4 method for signature 'IntervalList,IntervalList'
plot(x, y, bounds = FALSE, ...)
```

Arguments

x	an object of type IntervalData or IntervalList representing the values of an interval-value variable.
y	an object of type IntervalData or IntervalList representing the values of a second interval-value variable, to be displayed along y (vertical) coordinates.
layout	the axes along which the interval-valued variables be displayed. Alternatives are "vertical" (default) and "horizontal".
bounds	a logical value indicating if interval bounds should be plotted or not (default).
mid	a logical value indicating if the interval mid-points should be plotted or not (default).
...	graphical arguments to be passed to methods.

Value

This function does not return any value. It only plots interval-valued data.

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

See Also

Other IntervalData-method: [IntervalData-class](#), [IntervalData](#), [arithmetic](#), [as.IntervalData\(\)](#), [distance\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [show\(\)](#)

Other IntervalList-method: [IntervalList-class](#), [IntervalList](#), [as.IntervalList\(\)](#), [cov\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [mean\(\)](#), [sum\(\)](#), [var\(\)](#)

Examples

```
i1 <- IntervalData(0, 1)
i2 <- IntervalData(2, 3)
plot(i1)
plot(i1, bounds = TRUE, mid = TRUE)
plot(i1, i2)
plot(i1, i2, bounds = TRUE)

list1 <- IntervalList(c(0, 3, 2, 5, 6), c(4, 5, 4, 8, 7))
list2 <- IntervalList(c(3, 0, 3, 1, 4), c(7, 4, 6, 2, 6))
plot(list1)
plot(list1, layout = "horizontal")
plot(list1, bounds = TRUE, mid = TRUE)
plot(list1, list2)
plot(list1, list2, bounds = TRUE)

## Extra arguments
plot(list1, list2, bounds = TRUE, main = "My interval-valued data plot", col = "blue", lwd = 2)
```

show

Print basic information of interval-valued data

Description

Print inf/sup and mid/spr characterisations of a given interval-valued data.

Usage

```
## S4 method for signature 'IntervalData'
show(object)

## S4 method for signature 'IntervalMatrix'
show(object)
```

Arguments

object an object of class `IntervalData` or `IntervalMatrix`.

Value

The object's inf/sup and mid/spr characterisations.

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

See Also

Other `IntervalData`-method: [IntervalData-class](#), [IntervalData](#), [arithmetic](#), [as.IntervalData\(\)](#), [distance\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [plot\(\)](#)

Other `IntervalMatrix`-method: [IntervalMatrix-class](#), [IntervalMatrix](#), [apply\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#)

Examples

```
## Show an interval-valued data
i <- IntervalData(0, 1)
show(i)

## Show an interval-valued data list
list <- IntervallList(c(0, 3, 2, 5, 6), c(4, 5, 4, 8, 7))
show(list)

## Show an interval-valued data matrix
m <- IntervalMatrix(matrix(c(0, 2, 0, 4, 1, 3, 3, 9), 2, 4, byrow = TRUE))
show(m)
```

simulIVS

Simulation of interval-valued responses to a questionnaire

Description

This function generates n interval-valued responses to each of k items of a questionnaire. These interval-valued responses are simulated mimicking the human behavior, considering for it a finite mixture of three different procedures adapting the ideas of De la Rosa de Saa et al. (2015) and Lubiano et al. (2021).

Usage

```

simulIVS(
  n,
  k,
  w1 = 0.05,
  w2 = 0.35,
  w3 = 0.6,
  p = 2,
  q = 2,
  minimum = 1,
  maximum = 7
)

```

Arguments

<code>n</code>	a positive integer indicating the number of observations in the questionnaire.
<code>k</code>	a single positive integer indicating the number of items in the questionnaire.
<code>w1</code>	a single numeric value in $[0, 1]$ indicating the proportion of observations that are generated in the first procedure. By default, <code>w1=0.05</code> .
<code>w2</code>	a single numeric value in $[0, 1]$ indicating the proportion of observations that are generated in the second procedure. By default, <code>w2=0.35</code> .
<code>w3</code>	a single numeric value in $[0, 1]$ indicating the proportion of observations that are generated in the third procedure. By default, <code>w3=0.60</code> .
<code>p</code>	a single positive numeric value indicating the first parameter of a beta distribution. By default, <code>p=2</code> .
<code>q</code>	a positive numeric value indicating the second parameter of the beta distribution. By default, <code>q=2</code> .
<code>minimum</code>	a single numeric value indicating the lower bound of the interval-valued scale used in the questionnaire. By default, <code>minimum=1</code> .
<code>maximum</code>	a single numeric value indicating the upper bound of the interval-valued scale used in the questionnaire. By default, <code>maximum=7</code> .

Value

This function returns n interval-valued responses to each of k items in a questionnaire contained in a matrix of dimensions $n \times 2k$ with values in the interval $[\text{minimum}, \text{maximum}]$. All interval-valued data's infimums appear in the first k columns of the matrix and then appear its corresponding supremums.

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>,
with contributions from Asun Lubiano <lubiano@uniovi.es>

References

- De la Rosa de Saa, S.; Gil, M.A.; Gonzalez-Rodriguez, G.; Lopez, M.T.; Lubiano M.A. (2015). Fuzzy rating scale-based questionnaires and their statistical analysis, *IEEE Transactions on Fuzzy Systems*, 23(1):111-126.
- Lubiano, M.A.; Garcia-Izquierdo, A.L.; Gil, M.A. (2021). Fuzzy rating scales: Does internal consistency of a measurement scale benefit from coping with imprecision and individual differences in psychological rating? *Information Sciences*, 550:91-108.

Examples

```
data <- simulIVS(100, 5)
head(data)
```

sum

Calculate the sum of n interval-valued data

Description

This function calculates the sum of n interval-valued data.

Usage

```
## S4 method for signature 'IntervalList'
sum(x)
```

Arguments

x a list of interval-valued data.

Value

Returns the calculated sum of n interval-valued data, i.e., other interval-valued data.

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

References

Hankin, R.K.S. (2010). A step-by-step guide to writing a simple package that uses S4 methods: a "hello world" example. Technical Report. Auckland University of Technology.

See Also

Other IntervalList-method: [IntervalList-class](#), [IntervalList](#), [as.IntervalList\(\)](#), [cov\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [mean\(\)](#), [plot\(\)](#), [var\(\)](#)

Examples

```
sum(IntervallList(c(1, 3), c(2, 5)))
```

var

Calculate the sample Frechet variance of n interval-valued data

Description

This function calculates the sample Frechet variance of n interval-valued data.

Usage

```
## S4 method for signature 'IntervallList'
var(x, theta = 1)
```

Arguments

`x` a list of interval-valued data.
`theta` a single positive numeric value. By default, theta=1.

Details

Let \mathcal{X} be an interval-valued random set and let (x_1, x_2, \dots, x_n) be a sample of n independent observations drawn from \mathcal{X} . Then, the sample Frechet variance is defined as follows,

$$s_{\mathcal{X}}^2 = \frac{1}{n} \sum_{i=1}^n d_{\theta}^2(x_i, \bar{x})$$

where $\theta > 0$ and \bar{x} denotes the sample Aumann mean of (x_1, x_2, \dots, x_n) .

Value

Returns the calculated sample Frechet variance of n interval-valued data, i.e., a real number.

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

References

Frechet, M. (1948). Les elements aleatoires de nature quelconque dans un espace distance. Annales de l'institut Henri Poincare, 10(4):215-310.

See Also

Other IntervallList-method: [IntervallList-class](#), [IntervallList](#), [as.IntervallList\(\)](#), [cov\(\)](#), [ivd2likert\(\)](#), [ivd2vas\(\)](#), [mean\(\)](#), [plot\(\)](#), [sum\(\)](#)

Examples

```
var(IntervallList(c(1, 3), c(2, 5)))
var(IntervallList(c(1, 3), c(2, 5)), 1/3)
```

[*Extract parts of an interval-valued object*]

Description

Extract parts of interval-valued lists or matrices.

Usage

```
## S4 method for signature 'IntervallList'
x[i]
## S4 method for signature 'IntervalMatrix'
x[i, j]
```

Arguments

x	interval-valued object from which to extract elements.
i	indices specifying interval-valued list's elements or interval-valued matrix's rows to extract.
j	indices specifying interval-valued matrix's columns to extract.

Value

Selected parts of an interval-valued object

Author(s)

Jose Garcia Garcia <garciagarjose@uniovi.es>

Examples

```
list <- IntervallList(c(1,3,5), c(2, 4, 6))
list[1]
list[c(1, 3)]

m <- IntervalMatrix(matrix(c(1, 2, 6, 7, 3, 4, 5, 6, 2, 3, 4, 5), 2, 6, byrow = TRUE))
m[1,1]
m[1,]
m[, 1]
m[, c(1,3)]
```

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