Package ‘FuzzyAHP’

March 9, 2017

Type Package
Title (Fuzzy) AHP Calculation
Version 0.9.0
Date 2017-03-06
URL http://github.com/JanCaha/FuzzyAHP/
Description Calculation of AHP (Analytic Hierarchy Process -
with classic and fuzzy weights based on Saaty's pairwise
comparison method for determination of weights.
Encoding UTF-8
Depends R (>= 3.0.0), methods, MASS
Suggests knitr
License LGPL (>= 3)
LazyData TRUE
VignetteBuilder knitr
RoxygenNote 5.0.1
Collate 'class-FuzzyData.R' 'class-PairwiseComparisonMatrix.R'
'class-FuzzyPairwiseComparisonMatrix.R' 'class-FuzzyWeights.R'
'class-Weights.R' 'function-bindFuzzyData.R'
'function-buildFuzzyPairwiseComparisonMatrix.R'
'function-buildPairwiseComparisonMatrix.R'
'function-calculateAHP.R' 'function-calculateFuzzyAHP.R'
'function-calculateWeights.R' 'function-compare.R'
'function-consistencyIndex.R' 'function-consistencyRatio.R'
'function-defuzzify.R' 'function-getFuzzyNumbers.R'
'function-getFuzzyScale.R' 'function-insertInto.R'
'function-internal-optimization.R'
'function-internal-weights.R' 'function-print.R'
'function-strictConsistency.R' 'function-textRepresentation.R'
'function-weakConsistency.R' 'package-FuzzyAHP.R'
NeedsCompilation no
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Repository CRAN

Date/Publication 2017-03-09 14:09:50

R topics documented:

FuzzyAHP-package ........................................... 3
bindColums .................................................. 3
buildFuzzyPairwiseComparisonMatrix ....................... 4
buildPairwiseComparisonMatrix ............................ 5
calculateAHP ............................................... 5
calculateWeights ......................................... 6
calculateWeights_old_methods ............................ 7
calculate_weighting_vector ................................ 8
compareFuzzyNumbers ..................................... 9
compareResults ............................................. 10
consistencyIndex ......................................... 10
consistencyRatio ......................................... 11
defuzzify .................................................. 12
fuzzyData .................................................. 13
FuzzyData-class ........................................... 13
fuzzyPairwiseComparisonMatrix ............................ 14
FuzzyPairwiseComparisonMatrix-class ....................... 15
fuzzyPairwiseComparisonMatrix1 ........................... 15
FuzzyWeights-class ........................................ 16
getFuzzyNumber ........................................... 16
getFuzzyScale ............................................. 17
insertInto .................................................. 18
pairwiseComparisonMatrix ................................ 19
PairwiseComparisonMatrix-class .......................... 20
strictConsistency ......................................... 20
textRepresentation ....................................... 21
weakConsistency .......................................... 21
Weights-class ............................................. 22

Index 23
Description

**FuzzyAHP** is an open source (LGPL 3) package for R. The package is only suitable for AHP that uses categorical rating of criteria for alternatives instead of pairwise comparison of alternatives according to each criteria. This adaptation of AHP is common in situations when the number of alternatives is high and the pairwise comparison is thus inadequate or impossible to construct. The weights for criteria are, however, still determined from the pairwise comparison matrix. This approach towards AHP is common in Geosciences as well as other fields.

The determination of criteria weights is done according to process described by Krejčí, Pavlačka, and Talašová (2016), which yields significantly narrower fuzzy numbers than previously used approaches.

Details

Please see vignettes for more details about the package and examples of use.

Complete list of classes and methods call `help(package="FuzzyAHP")`.

Author(s)

Jan Caha <cahik@atlas.cz>, with contributions from Aneta Drážná

References


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**bindColumns**

*Function that binds two FuzzyData together into one FuzzyData*

Description

This methods construct object `FuzzyData` based on two `FuzzyData`. The functions merges the sources into single output. This method should be used in situations when both weights and input data are fuzzy.
Usage
bind_columns(data1, data2)

## S4 method for signature 'FuzzyData,FuzzyData'
bind_columns(data1, data2)

Arguments

- data1: An object of \texttt{FuzzyData}.
- data2: An object of \texttt{FuzzyData}.

Value

An object of class \texttt{FuzzyData}

---

\texttt{buildFuzzyPairwiseComparisonMatrix}

\textit{Function that builds Fuzzy Pairwise Comparison Matrix based on list of Pairwise Comparison Matrices or Fuzzy Pairwise Comparison Matrices}

---

Description

This function builds Fuzzy Pairwise Comparison Matrix based on list of Pairwise Comparison Matrices or Fuzzy Pairwise Comparison Matrices. The resulting Fuzzy Pairwise Comparison Matrix is calculated as minimum, geometric mean and maximum of each cell of all Pairwise Comparison Matrices in \texttt{listOfMatrices}. In case of Fuzzy Pairwise Comparison Matrices the resulting Fuzzy Pairwise Comparison Matrix is calculated as geometric mean of minimum, modal and maximum values.

Usage

buildFuzzyPairwiseComparisonMatrix(listOfMatrices)

## S4 method for signature 'list'
buildFuzzyPairwiseComparisonMatrix(listOfMatrices)

Arguments

- listOfMatrices: An object of \texttt{list}.

Value

An object of class \texttt{FuzzyPairwiseComparisonMatrix}
buildPairwiseComparisonMatrix

Function that builds Pairwise Comparison Matrix based on list of Pairwise Comparison Matrices

Description

This function builds Pairwise Comparison Matrix based on list of Pairwise Comparison Matrices the resulting Pairwise Comparison Matrix is calculated as geometric mean of all Pairwise Comparison Matrices in listofMatrices.

Usage

buildPairwiseComparisonMatrix(listOfMatrices, agg = "geometric")

## S4 method for signature 'list,character'
buildPairwiseComparisonMatrix(listOfMatrices, agg = "geometric")

Arguments

- **listOfMatrices**: An object of list.
- **agg**: A character specifying aggregation used to build Pairwise comparison matrix. Values "geometric" and "arithmetic" means are implemented, with "geometric" being default value.

Value

An object of class `PairwiseComparisonMatrix`

---

calculateAHP

Function to calculate result of AHP

Description

This function calculates output of AHP based on Weights or FuzzyWeights on data represented either by `matrix` or `FuzzyData`.
Usage

```r
calculateAHP(weights, data)
```

```r
## S4 method for signature 'Weights, matrix'
calculateAHP(weights, data)
```

```r
## S4 method for signature 'FuzzyWeights, matrix'
calculateAHP(weights, data)
```

```r
## S4 method for signature 'FuzzyWeights, FuzzyData'
calculateAHP(weights, data)
```

```r
## S4 method for signature 'PairwiseComparisonMatrix, matrix'
calculateAHP(weights, data)
```

```r
## S4 method for signature 'FuzzyPairwiseComparisonMatrix, matrix'
calculateAHP(weights, data)
```

```r
## S4 method for signature 'FuzzyPairwiseComparisonMatrix, FuzzyData'
calculateAHP(weights, data)
```

Arguments

- `weights`: object of class `Weights` or `FuzzyWeights`. Alternatively objects of classes `PairwiseComparisonMatrix` or `FuzzyPairwiseComparisonMatrix` can be passed to directly calculate weights from these classes.

- `data`: matrix or `FuzzyData` with number of columns equal to number of rows in `weights`.

Value

Either a matrix (if `Weights` and matrix were used as inputs) or `FuzzyData` (if `FuzzyWeights` were used).

---

**calculateWeights**  
*Function to calculate fuzzy weights based on comparison matrix*

Description

This functions calculates `Weights` or `FuzzyWeights` based on input pairwise comparison matrix.

Usage

```r
calculateWeights(comparisonMatrix)
```

```r
## S4 method for signature 'PairwiseComparisonMatrix'
calculateWeights(comparisonMatrix)
```
## calculateWeights_old_methods

Function to calculate fuzzy weights based on comparison matrix using older approaches.

### Arguments

- `comparisonMatrix`:
  - Object of either `PairwiseComparisonMatrix` or `FuzzyPairwiseComparisonMatrix`.

### References


### See Also

- `PairwiseComparisonMatrix-class`

## Description

This functions calculates fuzzy weights based on input fuzzy pairwise comparison matrix.

### Usage

```r
calculateWeights_old_methods(comparisonMatrix, type = "Chang")
```

## Arguments

- `comparisonMatrix`:
  - Object of `FuzzyPairwiseComparisonMatrix`.

- `type`:
  - A "character" representing type of method used for weights or fuzzy weights determination. Currently implemented methods are "Chang", "Wang" and "Tesfamariam". The default value is "Chang".
**calculate_weighting_vector**

**Value**

FuzzyWeights. If fuzzy weighting vector is to be obtained please see calculate_weighting_vector function.

**References**


**See Also**

calculate_weighting_vector

---

**calculate_weighting_vector**

*Function to calculate fuzzy weighting vector*

**Description**

This function calculates fuzzy weighting vector from FuzzyWeights. The calculation was first described by Chang (1996).

**Usage**

```r
calculate_weighting_vector(fuzzyWeights)
```

```r
## S4 method for signature 'FuzzyWeights'
calculate_weighting_vector(fuzzyWeights)
```

**Arguments**

- `fuzzyWeights` object of FuzzyWeights

**Value**

weighting vector for defined FuzzyWeights.
**compareFuzzyNumbers**

**Function to mutually compare fuzzy data**

**Description**

This function compares fuzzy data `FuzzyData` to identify the optimal (best) cases. The `FuzzyData` can only contain one fuzzy number, otherwise the comparison is not possible. The calculation of type “possibilityTheory” can be time consuming as it is based on comparing each fuzzy number to a maximal fuzzy number obtained from the set of fuzzy numbers.

**Usage**

```r
compareFuzzyNumbers(fuzzyData, type, progressBar = FALSE)
```

```r
## S4 method for signature 'FuzzyData,character'
compareFuzzyNumbers(fuzzyData, type,
    progressBar = FALSE)
```

**Arguments**

- `fuzzyData` A `FuzzyData`
- `type` A “character” representing type of comparison. Currently implemented methods are “Chen” and "possibilityTheory".
- `progressBar` logical value indicating if textual progress bar should be printed (default value FALSE)

**Value**

A "matrix" of numeric value in case of "Chen" method or a "matrix" with two values in case of "possibilityTheory".

**References**

### compareResults

**Function to rank results**

**Description**

This function ranks data from the highest value to the lowest. Essentially it does `(nrow(data) + 1) - rank(data, na.last = FALSE)`. 

**Usage**

```r
compareResults(data)

## S4 method for signature 'matrix'
compareResults(data)
```

**Arguments**

- `data`: A matrix with one column. Usually an output of function `calculateAHP`.

**Value**

A "matrix" of numeric value that indicates ranking of each row, with the highest value ranked as 1.

### consistencyIndex

**Function to determine Consistency Index**

**Description**

This method calculates Consistency index for `PairwiseComparisonMatrix`.

**Usage**

```r
consistencyIndex(comparisonMatrix)

## S4 method for signature 'PairwiseComparisonMatrix'
consistencyIndex(comparisonMatrix)

## S4 method for signature 'FuzzyPairwiseComparisonMatrix'
consistencyIndex(comparisonMatrix)
```

**Arguments**

- `comparisonMatrix`: A `PairwiseComparisonMatrix`

**Value**

A numeric value of Consistency index.
**consistencyRatio**

*Function to determine Consistency Ratio*

---

**Description**

This method calculates Consistency Ratio for `PairwiseComparisonMatrix`. The consistency ratio can only be provided for `PairwiseComparisonMatrix` with less than 10 rows. For bigger matrices the value is not known.

**Usage**

```r
consistencyRatio(comparisonMatrix, print.report = TRUE)
```

```r
## S4 method for signature 'PairwiseComparisonMatrix'
consistencyRatio(comparisonMatrix,
    print.report = TRUE)
```

```r
## S4 method for signature 'FuzzyPairwiseComparisonMatrix'
consistencyRatio(comparisonMatrix,
    print.report = TRUE)
```

**Arguments**

- `comparisonMatrix`  
  A `PairwiseComparisonMatrix`

- `print.report`  
  Optional boolean parameter stating if short report should be printed along with determination of Consistency Ratio. Default value is `TRUE`.

**Details**

Generally pairwise comparison matrixes are considered to be consistent if the value of Consistency Ratio is smaller than 0.1. For matrices comparing more then 10 elements then Consistency Ratio is unsuitable, because the values of random index, that is necessary to obtain Consistency Ratio, are only known for matrixes with size smaller than $10 \times 10$.

**Value**

A numeric value of Consistency Ratio, for `PairwiseComparisonMatrix` with more than 10 an error is raised.
defuzzify  

Function to defuzzify fuzzy data

Description

This function defuzzifies FuzzyData into single value. The FuzzyData can only contain one fuzzy number, otherwise the defuzzification is not possible.

Usage

```r
defuzzify(fuzzyData, type = "mean")
```

```r
## S4 method for signature 'FuzzyData'
defuzzify(fuzzyData, type = "mean")
```

Arguments

- **fuzzyData**  
  A FuzzyData
- **type**  
  A "character" representing type of defuzzification. Currently implemented methods are "Yager", "modalValue", "modalValueDominancy", "mean". The default value is "mean".

Details

The triangular fuzzy numbers \( \tilde{A} \) represented as triplet \([a1, a2, a3] \) are defuzzified using these methods: "Yager":

\[
def(\tilde{A}) = \frac{(a2 - a1)(a1 + 2/3(a2 - a1) + (a3 - a2)(a2 + 1/3(a3 - a2)))}{(a2 - a1) + (a3 - a2)}
\]

"modalvalue":

\[
def(\tilde{A}) = a2
\]

"modalValueDominancy":

\[
def(\tilde{A}) = (a1 + 4 \times a2 + a3)/6
\]

"mean":

\[
def(\tilde{A}) = (a1 + a2 + a3)/3
\]

Value

A numeric value of defuzzified value, based on defuzzification method.
fuzzyData  

Function that creates FuzzyData

Description
This method constructs object FuzzyData based on provided matrix. The matrix needs to have rows represent individual fuzzy numbers and three columns that represent minimal, modal and maximal value of fuzzy number.

Usage
fuzzyData(data, single.value = TRUE)

## S4 method for signature 'matrix'
fuzzyData(data, single.value = TRUE)

Arguments
data A matrix with 3 columns.
single.value An optional boolean parameter (default value TRUE) specifying if the data to be turn into fuzzy data is single vector of fuzzy numbers (then it needs to have 3 columns) or if the whole matrix needs to be turn into fuzzy values.

Value
An object of class FuzzyData

See Also
FuzzyData

FuzzyData-class

Class "FuzzyData"

Description
An S4 class to represent fuzzy data.

Slots
fnMin A numeric vector of minimal values of fuzzy data.
fnModal A numeric vector of modal values of fuzzy data.
fnMax A numeric vector of maximal values of fuzzy data.
fuzzyPairwiseComparisonMatrix

Function that creates Fuzzy Pairwise Comparisons Matrix

Description
This method constructs an object FuzzyPairwiseComparisonMatrix based on provided PairwiseComparisonMatrix and an optional fuzzy scale.

Usage
fuzzyPairwiseComparisonMatrix(pairwiseComparisonMatrix, fuzzyScale, comparsionNotInScale, width)

## S4 method for signature 'PairwiseComparisonMatrix'
fuzzyPairwiseComparisonMatrix(pairwiseComparisonMatrix, fuzzyScale = getFuzzyScale(type = "full"), comparsionNotInScale = FALSE, width = 1)

## S4 method for signature 'matrix'
fuzzyPairwiseComparisonMatrix(pairwiseComparisonMatrix)

Arguments
pairwiseComparisonMatrix
PairwiseComparisonMatrix or matrix.
fuzzyScale
A numeric vector that defines fuzzy scale. Default scale is described in details.
comparsionNotInScale
A boolean variable. If TRUE the intensities not found in fuzzyScale are calculated with use of width parameter. Default value FALSE.
width
A numeric parameter, specifying the width of calculated fuzzy intensity. If comparsionNotInScale is FALSE then the parameter is not considered. Default value 1.

Details
Parameter fuzzyScale is expected as a vector containing \(n^3\) values that represent triangular fuzzy numbers used as fuzzy intensity of importance (only the values equal or higher than 1, inverse values are calculated automatically). The values need to be ordered by fuzzy values. Default value of this parameter is `as.double(c(1/2,1,2,1,2,3,2,3,4,3,4,5,4,5,6,5,6,7,6,7,8,7,8,9,8,9,9,9))`. Another possibility is `as.double(c(1/3,1,3,1,3,5,3,5,7,5,7,9,7,9,9,9))`.

If param pairwiseComparisonMatrix is matrix then it needs to be of character type. Each element in the matrix must be specified as triplet "x;y;z", where x<=y<=z. From this matrix a pairwise comparison is constructed from y values and x and z function as lower and upper limits of y respectively. In this case the optional parameter fuzzyScale is not taken into account at all.
Value

Object of class FuzzyPairwiseComparisonMatrix

Description

An S4 class to represent a fuzzy pairwise comparison matrix.

Slots

fnMin A matrix of minimal values of fuzzy preferences.
fnModal A matrix of modal values of fuzzy preferences.
fnMax A matrix of maximal values of fuzzy preferences.
variableNames Names of variables in the pairwise comparison matrix obtained either as colnames or rownames.

fuzzyPairwiseComparisonMatrix1

Function that creates Fuzzy Pairwise Comparisons Matrix

Description

This method constructs object FuzzyPairwiseComparisonMatrix based on provided PairwiseComparisonMatrix and two matrices that form lower and upper significant values of the PairwiseComparisonMatrix that form middle significant value.

Usage

fuzzyPairwiseComparisonMatrix1(lowerValues, pairwiseComparisonMatrix, upperValues)

## S4 method for signature 'matrix,PairwiseComparisonMatrix,matrix'

fuzzyPairwiseComparisonMatrix1(lowerValues, pairwiseComparisonMatrix, upperValues)

Arguments

lowerValues A matrix of "double" that consists of lower significant values.
pairwiseComparisonMatrix PairwiseComparisonMatrix that consists of middle significant values.
upperValues A matrix of "double" that consists of upper significant values.
Details

This function allows user to specify fuzzy pairwise comparison matrix that is not based on fuzzy scale but rely more on user’s specification. The middle significant values have to be defined by PairwiseComparisonMatrix to ensure some elementary properties. The significant values provided to this function have to be correctly ordered and fuzzy numbers have to be reciprocal otherwise the function fails.

Value

Object of class FuzzyPairwiseComparisonMatrix

FuzzyWeights-class

Class "FuzzyWeights"

Description

An S4 class to represent fuzzy weights for fuzzy AHP calculation.

Slots

fnMin Object of class numeric containing minimal values of fuzzy weights.
fnModal Object of class numeric containing modal values of fuzzy weights.
fnMax Object of class numeric containing maximal values of fuzzy weights.

getFuzzyNumber

Function to extract specific fuzzy numbers

Description

This methods helps with extracting fuzzy numbers from FuzzyData and FuzzyWeights.

Usage

getFuzzyNumber(object, index)

## S4 method for signature 'FuzzyData,integer'
getFuzzyNumber(object, index)

## S4 method for signature 'FuzzyWeights,integer'
getFuzzyNumber(object, index)

Arguments

object An object of class FuzzyData or FuzzyWeights
index An object of class integer that represents one or more indices to extract the data from
getFuzzyScale

Value
A matrix where rows are fuzzy numbers and columns are important values.

Description
This method creates fuzzy scale that are used while fuzzifying Piecewise comparison matrix.

Full scale is:

\[
\begin{array}{ccc}
1/2 & 1 & 2 \\
1 & 2 & 3 \\
2 & 3 & 4 \\
3 & 4 & 5 \\
4 & 5 & 6 \\
5 & 6 & 7 \\
6 & 7 & 8 \\
7 & 8 & 9 \\
8 & 9 & 9 \\
\end{array}
\]

Basic scale is:

\[
\begin{array}{ccc}
1/3 & 1 & 3 \\
1 & 3 & 5 \\
3 & 5 & 7 \\
5 & 7 & 9 \\
7 & 9 & 9 \\
\end{array}
\]

Usage
getFuzzyScale(type)

## S4 method for signature 'character'
getFuzzyScale(type)

Arguments

type
An object of class character. Two values are possible "full" and "basic".

Value
A matrix representing the fuzzy scale.
insertInto

*Function that inserts FuzzyData on specific column number in another FuzzyData*

**Description**

This method constructs object `FuzzyData` based on two `FuzzyData` and index. The functions merge the sources into single output. It inserts `data2` onto specific position (defined by `index`) in `data1`.

**Usage**

```r
insertInto(data1, data2, index)
```

`## S4 method for signature 'FuzzyData,FuzzyData'
insertInto(data1, data2, index)`

**Arguments**

- **data1**: An object of `FuzzyData` - data to insert into.
- **data2**: An object of `FuzzyData` - data that should be inserted.
- **index**: An integer specifying the column position on which `data2` should be inserted.

**Value**

An object of class `FuzzyData`

**Examples**

```r
values = c(1,2,3,4,5,6,7,8,9)
values = matrix(values, nrow = 3, ncol = 3, byrow = TRUE)
fData = fuzzyData(values, single.value = FALSE)

v = c(15,16,17)
v = matrix(v, nrow = 3, ncol = 1, byrow = TRUE)
fd = fuzzyData(v, single.value = FALSE)

fData = insertInto(fData, fd, 2)
```
pairwiseComparisonMatrix

Function that creates Pairwise Comparisons Matrix

Description

This method constructs object `PairwiseComparisonMatrix` based on provided matrix. The matrix needs to be square and reciprocal with the intensity of importance (comparisons). Since the version 0.6.9 the comparisons can be represented as either characters (e.g. "1", "9", "1/9") or numeric (e.g. 1, 9, 1/9).

Usage

```r
pairwiseComparisonMatrix(matrix)
```

## S4 method for signature 'matrix'

```r
pairwiseComparisonMatrix(matrix)
```

Arguments

- `matrix` A reciprocal square matrix with ones on the main diagonal.

Value

An object of class `PairwiseComparisonMatrix`

See Also

- `PairwiseComparisonMatrix`

Examples

```r
comparisonMatrixValues = c("1","9","5","1/9","1","1/3","1/5","3","1")
comparisonMatrix = matrix(comparisonMatrixValues, nrow = 3, ncol = 3, byrow = TRUE)
matrix = pairwiseComparisonMatrix(comparisonMatrix)

comparisonMatrixValues = c(1,9,5,1/9,1/3,1/5,3,1)
comparisonMatrix = matrix(comparisonMatrixValues, nrow = 3, ncol = 3, byrow = TRUE)
matrix = pairwiseComparisonMatrix(comparisonMatrix)
```
PairwiseComparisonMatrix-class

Class "PairwiseComparisonMatrix"

Description

An S4 class to represent a pairwise comparison matrix.

Slots

valuesChar  A pairwise comparison matrix based on Saaty's method as characters.
values  A pairwise comparison matrix based on Saaty's method as numeric.
variableNames  Names of variables in the pairwise comparison matrix obtained either as colnames or rownames.

strictConsistency  Function to assess strict consistency of Comparison Matrix

Description

Check if 

\[ a_{ik} = a_{ij} \times a_{jk} \]

applies for all \( i, j, k = 1, 2, \ldots, n \), where \( n \) is size of \( a \).

Usage

strictConsistency(PairwiseComparisonMatrix, print.report = TRUE)

## S4 method for signature 'FuzzyPairwiseComparisonMatrix'
strictConsistency(PairwiseComparisonMatrix, print.report = TRUE)

## S4 method for signature 'PairwiseComparisonMatrix'
strictConsistency(PairwiseComparisonMatrix, print.report = TRUE)

Arguments

PairwiseComparisonMatrix
  A FuzzyPairwiseComparisonMatrix or PairwiseComparisonMatrix.

print.report  Optional boolean parameter stating if short report should be printed along with determination of Weak Consistency. Default value is TRUE.
Value

Boolean value indicating if Comparison Matrix passed the weak consistency test and a warning message listing the problematic triplets if the matrix is not consistent.

<table>
<thead>
<tr>
<th>textRepresentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function to create text representation of (Fuzzy) Pairwise comparison matrix</td>
</tr>
</tbody>
</table>

Description

This method creates text representation of Pairwise comparison matrices.

Usage

textRepresentation(x, whole = TRUE)

## S4 method for signature 'FuzzyPairwiseComparisonMatrix'
textRepresentation(x, whole = TRUE)

## S4 method for signature 'PairwiseComparisonMatrix'
textRepresentation(x, whole = TRUE)

Arguments

- `x`: An object of class `FuzzyPairwiseComparisonMatrix` or `PairwiseComparisonMatrix`
- `whole`: A boolean object specifying if the whole matrix should be created or only its upper half should be filled.

Value

A dataframe of character type.

<table>
<thead>
<tr>
<th>weakConsistency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function to assess Weak Consistency of Comparison Matrix</td>
</tr>
</tbody>
</table>

Description

Check if for $a_{ij} > 1, a_{jk} > 1$ applies that

$$a_{ik} >= \max(a_{ij}, a_{jk})$$

for all $i, j, k = 1, 2, \ldots, n$, where $n$ is size of $a$. 
Usage

weakConsistency(PairwiseComparisonMatrix, print.report = TRUE)

## S4 method for signature 'FuzzyPairwiseComparisonMatrix'
weakConsistency(PairwiseComparisonMatrix,
    print.report = TRUE)

## S4 method for signature 'PairwiseComparisonMatrix'
weakConsistency(PairwiseComparisonMatrix,
    print.report = TRUE)

Arguments

PairwiseComparisonMatrix
  
  A FuzzyPairwiseComparisonMatrix or PairwiseComparisonMatrix.

print.report
  
  Optional boolean parameter stating if short report should be printed along with
determination of Weak Consistency. Default value is TRUE.

Value

Boolean value indicating if Comparison Matrix passed the weak consistency test and a warning
message listing the problematic triplets if the matrix is not consisten.

Weights-class Class "Weights"

Description

An S4 class representing weights for AHP calculation. Each value in numeric vector represents
one weight.

Slots

weights Object of class numeric containing weights.
Index

bindColumns, 3
buildFuzzyPairwiseComparisonMatrix, 4
buildFuzzyPairwiseComparisonMatrix, list-method (buildFuzzyPairwiseComparisonMatrix), 4
buildPairwiseComparisonMatrix, 5
buildPairwiseComparisonMatrix, list, character-method (buildPairwiseComparisonMatrix), 5
calculate_weighting_vector, 8, 8
calculate_weighting_vector, (calculate_weighting_vector), 8
calculate_weighting_vector, FuzzyWeights-method (calculate_weighting_vector), 8
calculateAHP, 5
calculateAHP, FuzzyPairwiseComparisonMatrix, FuzzyData-method (calculateAHP), 5
calculateAHP, FuzzyPairwiseComparisonMatrix, matrix-method (calculateAHP), 5
calculateAHP, FuzzyWeights, FuzzyData-method (calculateAHP), 5
calculateAHP, FuzzyWeights, matrix-method (calculateAHP), 5
calculateAHP, PairwiseComparisonMatrix, matrix-method (calculateAHP), 5
calculateAHP, Weights, matrix-method (calculateAHP), 5
calculateWeights, 6
calculateWeights, FuzzyPairwiseComparisonMatrix-method (calculateWeights), 6
calculateWeights, PairwiseComparisonMatrix-method (calculateWeights), 6
calculateWeights_old_methods, 7
calculateWeights_old_methods, (calculateWeights_old_methods), 7
calculateWeights_old_methods, FuzzyPairwiseComparisonMatrix-method (calculateWeights_old_methods), 14

calculate_weights, 8
character, 5
character-method
compareFuzzyNumbers, 9
compareFuzzyNumbers, FuzzyData, character-method
compareResults, 10
compareResults, FuzzyData, character-method
compareResults, matrix-method
compareResults, method
consistencyIndex, 10
consistencyIndex, FuzzyPairwiseComparisonMatrix-method (consistencyIndex), 10
consistencyIndex, PairwiseComparisonMatrix-method (consistencyIndex), 10
consistencyRatio, 11
consistencyRatio, FuzzyPairwiseComparisonMatrix-method (consistencyRatio), 11
consistencyRatio, PairwiseComparisonMatrix-method (consistencyRatio), 11
defuzzify, 12
defuzzify, FuzzyData, character-method (defuzzify), 12
defuzzify, FuzzyData-method (defuzzify), 12
FuzzyAHP-package, 3
FuzzyData, 3–6, 9, 12, 13, 16, 18
FuzzyData, 13
FuzzyData, matrix-method (FuzzyData), 13
FuzzyData-class, 13
FuzzyPairwiseComparisonMatrix, 4, 6, 7, 14–16, 20–22
FuzzyPairwiseComparisonMatrix-method
fuzzyPairwiseComparisonMatrix, matrix-method (fuzzyPairwiseComparisonMatrix), 14
fuzzyPairwiseComparisonMatrix, PairwiseComparisonMatrix-method (fuzzyPairwiseComparisonMatrix), 14
fuzzyPairwiseComparisonMatrix, PairwiseComparisonMatrix, fuzzyPairwiseComparisonMatrix-method (fuzzyPairwiseComparisonMatrix), 14
fuzzyPairwiseComparisonMatrix, PairwiseComparisonMatrix, fuzzyPairwiseComparisonMatrix-class (fuzzyPairwiseComparisonMatrix), 14
fuzzyPairwiseComparisonMatrix, PairwiseComparisonMatrix-Matrix-method (fuzzyPairwiseComparisonMatrix), 14
FuzzyPairwiseComparisonMatrix-class, 15
FuzzyPairwiseComparisonMatrix-method, (calculateWeights_old_methods), 7
fuzzyPairwiseComparisonMatrix1, 15
fuzzyPairwiseComparisonMatrix1, matrix, PairwiseComparisonMatrix-method (fuzzyPairwiseComparisonMatrix1), 15
FuzzyWeights, 5–8, 16
FuzzyWeights-class, 16
FuzzyWeights-method (calculate_weighting_vector), 8
getFuzzyNumber, 16
getFuzzyNumber, FuzzyData, integer-method (getFuzzyNumber), 16
getFuzzyNumber, FuzzyWeights, integer-method (getFuzzyNumber), 16
getFuzzyScale, 17
getFuzzyScale, character-method (getFuzzyScale), 17
insertInto, 18
insertInto, FuzzyData, FuzzyData, integer-method (insertInto), 18
insertInto, FuzzyData, FuzzyData-method (insertInto), 18
list, 4, 5
PairwiseComparisonMatrix, 5–7, 10, 11, 14–16, 19–22
pairwiseComparisonMatrix, 19
PairwiseComparisonMatrix, logical-method (textRepresentation), 21
pairwiseComparisonMatrix, matrix-method (pairwiseComparisonMatrix), 19
PairwiseComparisonMatrix-class, 7, 20
strictConsistency, 20
strictConsistency, FuzzyPairwiseComparisonMatrix-method (strictConsistency), 20
strictConsistency, PairwiseComparisonMatrix-method (strictConsistency), 20
textRepresentation, 21
textRepresentation, FuzzyPairwiseComparisonMatrix, logical-method (textRepresentation), 21
textRepresentation, FuzzyPairwiseComparisonMatrix-method (textRepresentation), 21
textRepresentation, PairwiseComparisonMatrix-method (textRepresentation), 21
weakConsistency, 21
weakConsistency, FuzzyPairwiseComparisonMatrix-method (weakConsistency), 21
weakConsistency, PairwiseComparisonMatrix-method (weakConsistency), 21
Weights, 5, 6
Weights-class, 22