Package ‘FuzzyAHP’

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**bindColumns**

**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")`.

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**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**

`bindColumns(data1, data2)`

```r
## S4 method for signature 'FuzzyData,FuzzyData'
bindColumns(data1, data2)
```
Arguments

data1 An object of `FuzzyData`.
data2 An object of `FuzzyData`.

Value

An object of class `FuzzyData`.

buildFuzzyPairwiseComparisonMatrix

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

Description

This function builds Fuzzy Pairwise Comparison Matrix based on list of 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 `listOfMatrices`.

Usage

buildFuzzyPairwiseComparisonMatrix(listOfMatrices)

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

Arguments

listOfMatrices An object of `list`.

Value

An object of class `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`. 
**calculateAHP**  

*Usage*

```r
buildPairwiseComparisonMatrix(listOfMatrices)
```

## S4 method for signature 'list'

buildPairwiseComparisonMatrix(listOfMatrices)

*Arguments*

- `listOfMatrices` An object of `list`.

*Value*

An object of class `PairwiseComparisonMatrix`

---

**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)
```

## S4 method for signature 'Weights,matrix'

calculateAHP(weights, data)

## S4 method for signature 'FuzzyWeights,matrix'

calculateAHP(weights, data)

## S4 method for signature 'FuzzyWeights,FuzzyData'

calculateAHP(weights, data)

## S4 method for signature 'PairwiseComparisonMatrix,matrix'

calculateAHP(weights, data)

## S4 method for signature 'FuzzyPairwiseComparisonMatrix,matrix'

calculateAHP(weights, data)

## S4 method for signature 'FuzzyPairwiseComparisonMatrix,FuzzyData'

calculateAHP(weights, data)
calculateWeights

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).

Description

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

Usage

calculateWeights(comparisonMatrix)

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

## S4 method for signature 'FuzzyPairwiseComparisonMatrix'
calculateWeights(comparisonMatrix)

Arguments

comparisonMatrix object of either PairwiseComparisonMatrix or FuzzyPairwiseComparisonMatrix

References


See Also

PairwiseComparisonMatrix-class
calculateWeights_old_methods

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

Description
This function calculates FuzzyWeights based on input fuzzy pairwise comparison matrix.

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

## S4 method for signature 'FuzzyPairwiseComparisonMatrix'
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".

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

### Arguments
- `fuzzyWeights`: object of `FuzzyWeights`

### Value
Weighting vector for defined `FuzzyWeights`.

### References

---

**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
closeFuzzyNumbers(fuzzyData, type, progressBar = FALSE)
## S4 method for signature 'FuzzyData,character'
closeFuzzyNumbers(fuzzyData, type, progressBar = FALSE)
```
**compareResults**

**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".

**Description**

This function ranks data from the highest value to the lowest. Essentially it does (nrow(data)+1) - rank(data, na.last = "keep", ties.method = "max").

**Usage**

```r
compareResults(data)
```

### S4 method for signature 'matrix'
```r
class(compareResults) <- "compareResults"
cache(compareResults) <- FALSE
```

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

\texttt{comparisonMatrix} \\
A \texttt{PairwiseComparisonMatrix} \\

\texttt{print.report} \\
Optional boolean parameter stating if short report should be printed along with determination of Consistency Ratio. Default value is \texttt{TRUE}.

Details

Generally pairwise comparison matrixes are considered to be consistent if the value of Consistency Ration is smaller than 0.1. For matrices comparing more than 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 \texttt{PairwiseComparisonMatrix} with more than 10 an error is raised.

defuzzify Function to defuzzify fuzzy data

Description

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

Usage

\texttt{defuzzify(fuzzyData, type = "mean")}

## S4 method for signature 'FuzzyData'
\texttt{defuzzify(fuzzyData, type = "mean")}

Arguments

\texttt{fuzzyData} \\
A \texttt{FuzzyData} \\

\texttt{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 $\hat{A}$ represented as triplet $[a_1, a_2, a_3]$ are defuzzified using these methods: "Yager":

\[
def(\hat{A}) = \frac{(a_2 - a_1)(a_1 + 2/3(a_2 - a_1)) + (a_3 - a_2)(a_2 + 1/3(a_3 - a_2))}{(a_2 - a_1) + (a_3 - a_2)}
\]
"modalvalue":
\[ \text{def}(\tilde{A}) = a_2 \]

"modalValueDominancy":
\[ \text{def}(\tilde{A}) = (a_1 + 4 \times a_2 + a_3)/6 \]

"mean":
\[ \text{def}(\tilde{A}) = (a_1 + a_2 + a_3)/3 \]

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

---

**fuzzyData**

*Function that creates FuzzyData*

**Description**
This method constructs an 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 turned into fuzzy data is a single vector of fuzzy numbers (then it needs to have 3 columns) or if the whole matrix needs to be turned into fuzzy values.

**Value**
An object of class **FuzzyData**

**See Also**
- FuzzyData
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 methods construct 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. Default value getFuzzyScale(type="full").
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)). Another possibility is eg. as.double(c(1/3,1,3,1,3,5,3,5,7,5,7,9,7,9,9))

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
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 users 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

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

Function to create Fuzzy Scale

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 an object FuzzyData based on two FuzzyData and index. The function merges the sources into a single output. It inserts data2 onto a specific position (defined by index) in data1.

Usage

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

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 an object `PairwiseComparisonMatrix` based on the provided matrix. The matrix needs to be square and reciprocal with the intensity of importance (comparisons). Since 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.
**textRepresentation**

*Function to create text representation of (Fuzzy) Pairwise comparison matrix*

**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.

**weakConsistency**

*Function to assess Weak Consistency of Comparison Matrix*

**Description**

Check if for \( a_{ij} > 1, a_{jk} > 1 \) applies that

\[
a_{ik} \geq \max(a_{ij}, a_{jk})
\]

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)
Weights-class

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.

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.
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