Package ‘FuzzyAHP’

May 21, 2018

Type Package

Title (Fuzzy) AHP Calculation

Version 0.9.1

Date 2018-05-21

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, testthat

License LGPL (>= 3)

LazyData TRUE

VignetteBuilder knitr

RoxygenNote 6.0.1

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-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  2018-05-21 13:26:34 UTC

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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, Pavláčka, 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)**

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**References**


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### bindColumns

*Function that binds two FuzzyData together into one FuzzyData*

**Description**

This method constructs 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**

```r
bindColumns(data1, data2)
```

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

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

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.

Arguments

- listofMatrices: An object of list.

Value

An object of class FuzzyPairwiseComparisonMatrix.
**calculateAHP**

Usage

```r
buildPairwiseComparisonMatrix(listOfMatrices)
```

```r
## 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)
```

```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)
```
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 functions 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")
```

```r
## 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)
```

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

```r
## S4 method for signature 'FuzzyData,character'
compareFuzzyNumbers(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".

---

**compareResults**  
*Function to rank results*

**Description**

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

**Usage**

```r
compareResults(data)
```

```r
## 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)
```

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

```r
## 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)
```
defuzzify

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
Ration 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

defuzzify(fuzzyData, type = "mean")

## 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 $[a_1, a_2, a_3]$ are defuzzified using these
methods: "Yager":

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

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

"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.

---

Function that creates FuzzyData

Description

This method constructs an object of class `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

```r
fuzzyData(data, single.value = TRUE)
```

## S4 method for signature 'matrix'

```r
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`
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, comparisonNotInScale, width)

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

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

Arguments

pairwiseComparisonMatrix  
A PairwiseComparisonMatrix or matrix.

fuzzyScale  
A numeric vector that defines fuzzy scale. Default scale is described in details.

comparisonNotInScale  
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 comparisonNotInScale 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

FuzzyPairwiseComparisonMatrix-class

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 methods construct object FuzzyPairwiseComparisonMatrix based on provided PairwiseComparisonMatrix and two matrices that form lower an 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

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 method 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:

<table>
<thead>
<tr>
<th></th>
<th>1/2</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>
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)

```r
## 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 methods construct object FuzzyData based on two FuzzyData and index. The functions merges the sources into single output. It inserts data2 onto specific position (defined by index) in data1.

Usage

insertInto(data1, data2, index)

```r
## 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.
pairwiseComparisonMatrix

Function that creates Pairwise Comparisons Matrix

Description

This method constructs an 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
tp pairwiseComparisonMatrix(matrix)
```

Arguments

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

Value

An object of class `PairwiseComparisonMatrix`

See Also

`PairwiseComparisonMatrix`
Examples

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, 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 consisten.

---

**textRepresentation**

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

**Description**

This method creates text representation of Pairwise comparison matrices.

**Usage**

```r
textRepresentation(x, whole = TRUE)
```

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

```r
## 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)

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.
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