Package ‘MCDA’

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Title Functions to Support the Multicriteria Decision Aiding Process

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Description Functions which can be useful to support the analyst in the Multicriteria Decision Aiding (MCDA) process involving multiple, conflicting criteria.

Imports Rglpk, glpkAPI, methods

Suggests Rgraphviz

License CeCILL-2

Encoding UTF-8

URL https://github.com/paterijk/MCDA

NeedsCompilation no

Repository CRAN

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R topics documented:

`additiveValueFunctionElicitation`
Elicitation of a general additive value function.

Description

Elicits a general additive value function from a ranking of alternatives.

Usage

```
additiveValueFunctionElicitation(performanceTable,
                                  criteriaMinMax, epsilon,
                                  alternativesRanks = NULL,
                                  alternativesPreferences = NULL,
                                  alternativesIndifferences = NULL,
                                  alternativesIDs = NULL,
                                  criteriaIDs = NULL)
```

Arguments

`performanceTable`
: Matrix or data frame containing the performance table. Each row corresponds to an alternative, and each column to a criterion. Rows (resp. columns) must be named according to the IDs of the alternatives (resp. criteria).

`criteriaMinMax`
: Vector containing the preference direction on each of the criteria. "min" (resp. "max") indicates that the criterion has to be minimized (maximized). The elements are named according to the IDs of the criteria.

`epsilon`
: Numeric value containing the minimal difference in value between two consecutive alternatives in the final ranking.

`alternativesRanks`
: Optional vector containing the ranks of the alternatives. The elements are named according to the IDs of the alternatives. If not present, then at least one of alternativesPreferences or alternativesIndifferences should be given.

`alternativesPreferences`
: Optional matrix containing the preference constraints on the alternatives. Each line of the matrix corresponds to a constraint of the type alternative a is strictly preferred to alternative b. If not present, then either alternativesRanks or alternativesIndifferences should be given.

`alternativesIndifferences`
: Optional matrix containing the indifference constraints on the alternatives. Each line of the matrix corresponds to a constraint of the type alternative a is indifferent to alternative b. If not present, then either alternativesRanks or alternativesPreferences should be given.

`alternativesIDs`
: Vector containing IDs of alternatives, according to which the datashould be filtered.

`criteriaIDs`
: Vector containing IDs of criteria, according to which the data should be filtered.

Value

The function returns a list structured as follows :

`optimum`
: The value of the objective function.

`valueFunctions`
: A list containing the value functions which have been determined. Each value function is defined by a matrix of breakpoints, where the first row corresponds to the abscissa (row labelled "x") and where the second row corresponds to the ordinate (row labelled "y").

`overallValues`
: A vector containing the overall values of the input alternatives.

`ranks`
: A vector containing the ranks of the alternatives obtained via the elicited value functions. Ties method = "min".

`Kendall`
: Kendall's tau between the input ranking and the one obtained via the elicited value functions.

`errors`
: The errors (sigma) which have to be added to the overall values of the alternatives in order to respect the input ranking.

References

Based on the UTA algorithm (E. Jacquet-Lagreze, J. Siskos, Assessing a set of additive utility functions for multicriteria decision-making, the UTA method, European Journal of Operational Research, Volume 10, Issue 2, 151–164, June 1982) except that the breakpoints of the value functions are the actual performances of the alternatives on the criteria.

Examples

```
# ----------------------------------------
# ranking some cars (from original article on UTA by Siskos and Lagreze, 1982)

# the separation threshold

epsilon <-0.01
```

```
# the performance table

performanceTable <- rbind(
c(173, 11.4, 10.01, 10, 7.88, 49500),
c(176, 12.3, 10.48, 11, 7.96, 46700),
c(142, 8.2, 7.30, 5, 5.65, 32100),
c(148, 10.5, 9.61, 7, 6.15, 39150),
c(178, 14.5, 11.05, 13, 8.06, 64700),
c(180, 13.6, 10.40, 13, 8.47, 75700),
c(182, 12.7, 12.26, 11, 7.81, 68593),
c(145, 14.3, 12.95, 11, 8.38, 55000),
c(161, 8.6, 8.42, 7, 5.11, 35200),
c(117, 7.2, 6.75, 3, 5.81, 24800)
)

rownames(performanceTable) <- c(
  "Peugeot 505 GR",
  "Opel Record 2000 LS",
  "Citroen Visa Super E",
  "VW Golf 1300 GLS",
  "Citroen CX 2400 Pallas",
  "Mercedes 230",
  "BMW 520",
  "Volvo 244 DL",
  "Peugeot 104 ZS",
  "Citroen Dyane")

colnames(performanceTable) <- c(
  "MaximalSpeed",
  "ConsumptionTown",
  "Consumption120kmh",
  "HP",
  "Space",
  "Price")

# ranks of the alternatives

alternativesRanks <- c(1,2,3,4,5,6,7,8,9,10)

names(alternativesRanks) <- row.names(performanceTable)

# criteria to minimize or maximize

criteriaMinMax <- c("max","min","min","max","max","min")

names(criteriaMinMax) <- colnames(performanceTable)

x<-additiveValueFunctionElicitation(performanceTable,
                                      criteriaMinMax, epsilon,
                                      alternativesRanks = alternativesRanks)
```

AHP *Analytic Hierarchy Process (AHP) method*

Description

AHP is a multi-criteria decision analysis method which was originally developed by Thomas L. Saaty in 1970s.

Usage

```
AHP(criteriaWeightsPairwiseComparisons, alternativesPairwiseComparisonsList)
```

Arguments

`criteriaWeightsPairwiseComparisons`
: Matrix or data frame containing the pairwise comparison matrix for the criteria weights. Lines and columns are named according to the IDs of the criteria.

`alternativesPairwiseComparisonsList`
: A list containing a matrix or data frame of pairwise comparisons (comparing alternatives) for each criterion. The elements of the list are named according to the IDs of the criteria. In each matrix, the lines and the columns are named according to the IDs of the alternatives.

Value

The function returns a vector containing the AHP score for each alternative.

References

The Analytic Hierarchy Process: Planning, Priority Setting (1980), ISBN 0-07-054371-2, McGraw-Hill

Examples

```
style <- t(matrix(c(1,0.25,4,1/6,4,1,4,0.25,0.25,0.25,1,0.2,6,4,5,1),
                  nrow=4,ncol=4))

colnames(style) = c("Corsa","Clio","Fiesta","Sandero")
rownames(style) = c("Corsa","Clio","Fiesta","Sandero")

reliability <- t(matrix(c(1,2,5,1,0.5,1,3,2,0.2,1/3,1,0.25,1,0.5,4,1),
                        nrow=4,ncol=4))

colnames(reliability) = c("Corsa","Clio","Fiesta","Sandero")
rownames(reliability) = c("Corsa","Clio","Fiesta","Sandero")

fuel <- t(matrix(c(1,2,4,1,0.5,1,3,2,0.25,1/3,1,0.2,1,0.5,5,1),nrow=4,ncol=4))

colnames(fuel) = c("Corsa","Clio","Fiesta","Sandero")
```

```
rownames(fuel) = c("Corsa","Clio","Fiesta","Sandero")

alternativesPairwiseComparisonsList <- list(style=style,
                                            reliability=reliability,
                                            fuel=fuel)

criteriaWeightsPairwiseComparisons <- t(matrix(c(1,0.5,3,2,1,4,1/3,0.25,1),
                                               nrow=3,ncol=3))
colnames(criteriaWeightsPairwiseComparisons) = c("style","reliability","fuel")
rownames(criteriaWeightsPairwiseComparisons) = c("style","reliability","fuel")

overall1 <- AHP(criteriaWeightsPairwiseComparisons,
                alternativesPairwiseComparisonsList)
```

---

applyPiecewiseLinearValueFunctionsOnPerformanceTable
Applies value functions on a performance table.

Description

Transforms a performance table via given piecewise linear value functions.

Usage

```
applyPiecewiseLinearValueFunctionsOnPerformanceTable(valueFunctions,
                                            performanceTable,
                                            alternativesIDs = NULL,
                                            criteriaIDs = NULL)
```

Arguments

`valueFunctions`	A list containing, for each criterion, the piecewise linear value functions defined by the coordinates of the break points. Each value function is defined by a matrix of breakpoints, where the first row corresponds to the abscissa (row labelled "x") and where the second row corresponds to the ordinate (row labelled "y").
`performanceTable`	Matrix or data frame containing the performance table. Each row corresponds to an alternative, and each column to a criterion. Rows (resp. columns) must be named according to the IDs of the alternatives (resp. criteria).
`alternativesIDs`	Vector containing IDs of alternatives, according to which the datashould be filtered.
`criteriaIDs`	Vector containing IDs of criteria, according to which the data should be filtered.

Value

The function returns a performance table which has been transformed through the given value functions.

Examples

```
# the value functions

v<-list(
  Price = array(c(30, 0, 16, 0, 2, 0.0875),
    dim=c(2,3), dimnames = list(c("x", "y"), NULL)),
  Time = array(c(40, 0, 30, 0, 20, 0.025, 10, 0.9),
    dim = c(2, 4), dimnames = list(c("x", "y"), NULL)),
  Comfort = array(c(0, 0, 1, 0, 2, 0.0125, 3, 0.0125),
    dim = c(2, 4), dimnames = list(c("x", "y"), NULL)))

# the performance table

performanceTable <- rbind(
     c(3,10,1),
c(4,20,2),
c(2,20,0),
c(6,40,0),
c(30,30,3))

rownames(performanceTable) <- c("RER","METRO1","METRO2","BUS","TAXI")

colnames(performanceTable) <- c("Price","Time","Comfort")

# the transformed performance table

applyPiecewiseLinearValueFunctionsOnPerformanceTable(v,performanceTable)
```

`assignAlternativesToCategoriesByThresholds`
Assign alternatives to categories according to thresholds.

Description

Assign alternatives to categories according to thresholds representing the lower bounds of the categories.

Usage

```
assignAlternativesToCategoriesByThresholds(alternativesScores,
             categoriesLowerBounds,
             alternativesIDs = NULL,
             categoriesIDs = NULL)
```

Arguments

`alternativesScores`
Vector representing the overall scores of the alternatives. The elements are named according to the IDs of the alternatives.

categoriesLowerBounds
: Vector containing the lower bounds of the categories. An alternative is assigned to a category if it's score is higher or equal to the lower bound of the category, and strictly lower to the lower bound of the category above.

alternativesIDs
: Vector containing IDs of alternatives, according to which the datashould be filtered.

categoriesIDs
: Vector containing IDs of categories, according to which the data should be filtered.

Value

The function returns a vector containing the assignments of the alternatives to the categories.

Examples

```
# the separation threshold

epsilon <-0.05

# the performance table

performanceTable <- rbind(
  c(3,10,1),
  c(4,20,2),
  c(2,20,0),
  c(6,40,0),
  c(30,30,3))

rownames(performanceTable) <- c("RER","METRO1","METRO2","BUS","TAXI")

colnames(performanceTable) <- c("Price","Time","Comfort")

# ranks of the alternatives

alternativesAssignments <- c("good","medium","medium","bad","bad")

names(alternativesAssignments) <- row.names(performanceTable)

# criteria to minimize or maximize

criteriaMinMax <- c("min","min","max")

names(criteriaMinMax) <- colnames(performanceTable)

# number of break points for each criterion

criteriaNumberOfBreakPoints <- c(3,4,4)

names(criteriaNumberOfBreakPoints) <- colnames(performanceTable)

# ranks of the categories
```

```
categoriesRanks <- c(1,2,3)

names(categoriesRanks) <- c("good","medium","bad")

x<-UTADIS(performanceTable, criteriaMinMax, criteriaNumberOfBreakPoints,
            alternativesAssignments, categoriesRanks,0.1)

npt <- applyPiecewiseLinearValueFunctionsOnPerformanceTable(x$valueFunctions,
                                                             performanceTable)

scores <- weightedSum(npt, c(1,1,1))

# add a lower bound for the "bad" category

lbs <- c(x$categoriesLBs,0)

names(lbs) <- c(names(x$categoriesLBs),"bad")

assignments<-assignAlternativesToCategoriesByThresholds(scores,lbs)
```

LPDMRSort *MRSort that takes into account large performance differences.*

Description

MRSort is a simplified ElectreTRI method that uses the pessimistic assignment rule, without indifference or preference thresholds attached to criteria. LPDMRSort considers both a binary discordance and a binary concordance conditions including several interactions between them.

Usage

```
LPDMRSort(performanceTable, categoriesLowerProfiles, criteriaWeights,
          criteriaMinMax, majorityThreshold, criteriaVetos = NULL,
          criteriaDictators = NULL, majorityRule = "",
          alternativesIDs = NULL, criteriaIDs = NULL,
          categoriesIDs = NULL)
```

Arguments

`performanceTable`
: Matrix or data frame containing the performance table. Each row corresponds to an alternative, and each column to a criterion. Rows (resp. columns) must be named according to the IDs of the alternatives (resp. criteria).

`categoriesLowerProfiles`
: Matrix containing, in each row, the lower profiles of the categories. The columns are named according to the criteria, and the rows are named according to the

categories. The index of the row in the matrix corresponds to the rank of the category.

`criteriaWeights`
: Vector containing the weights of the criteria. The elements are named according to the IDs of the criteria.

`criteriaMinMax`
: Vector containing the preference direction on each of the criteria. "min" (resp. "max") indicates that the criterion has to be minimized (maximized). The elements are named according to the IDs of the criteria.

`majorityThreshold`
: The cut threshold for the concordance condition. Should be at least half of the sum of the weights.

`criteriaVetos`
: Matrix containing in each row a vector defining the veto values for the lower profile of the category. NA values mean that no veto is defined. A veto threshold for criterion i and category k represents the performance below which an alternative is forbidden to outrank the lower profile of category k, and thus is forbidden to be assigned to the category k. The rows are named according to the categories, whereas the columns are named according to the criteria.

`criteriaDictators`
: Matrix containing in each row a vector defining the dictator values for the lower profile of the category. NA values mean that no veto is defined. A dictator threshold for criterion i and category k represents the performance above which an alternative is guaranteed to outrank the lower profile of category k, and thus may no be assigned below category k. The rows are named according to the categories, whereas the columns are named according to the criteria.

`majorityRule`
: String denoting how the vetoes and dictators are combined in order to form the assignment rule. The values to choose from are "", "V", "D", "v", "d", "dV", "Dv", "dv". "" corresponds to using only the majority rule without vetoes or dictators, "V" considers only the vetoes, "D" only the dictators, "v" is like "V" only that a dictator may invalidate a veto, "d" is like "D" only that a veto may invalidate a dictator, "dV" is like "V" only that if there is no veto we may then consider the dictator, "Dv" is like "D" only that when there is no dictator we may consider the vetoes, while finally "dv" is identical to using both dictator and vetoes only that when both are active they invalidate each other, so the majority rule is considered in that case.

`alternativesIDs`
: Vector containing IDs of alternatives, according to which the datashould be filtered.

`criteriaIDs`
: Vector containing IDs of criteria, according to which the data should be filtered.

`categoriesIDs`
: Vector containing IDs of categories, according to which the data should be filtered.

Value

The function returns a vector containing the assignments of the alternatives to the categories.

References

Bouyssou, D. and Marchant, T. An axiomatic approach to noncompensatory sorting methods in MCDM, II: more than two categories. European Journal of Operational Research, 178(1): 246–276, 2007.

Meyer, P. and Olteanu, A-L. Integrating large positive and negative performance differences in majority-rule sorting models. European Journal of Operational Research, submitted, 2015.

Examples

```
# the performance table

performanceTable <- rbind(c(10,10,9), c(10,9,10), c(9,10,10), c(9,9,10),
                          c(9,10,9), c(10,9,9), c(10,10,7), c(10,7,10),
                          c(7,10,10), c(9,9,17), c(9,17,9), c(17,9,9),
                          c(7,10,17), c(10,17,7), c(17,7,10), c(7,17,10),
                          c(17,10,7), c(10,7,17), c(7,9,17), c(9,17,7),
                          c(17,7,9), c(7,17,9), c(17,9,7), c(9,7,17))

profilesPerformances <- rbind(c(10,10,10),c(0,0,0))

vetoPerformances <- rbind(c(7,7,7),c(0,0,0))

dictatorPerformances <- rbind(c(17,17,17),c(0,0,0))

rownames(performanceTable) <- c("a1", "a2", "a3", "a4", "a5", "a6", "a7",
                                "a8", "a9", "a10", "a11", "a12",  "a13",
                                "a14", "a15", "a16", "a17", "a18", "a19",
                                "a20", "a21", "a22", "a23", "a24")

rownames(profilesPerformances) <- c("P","F")

rownames(vetoPerformances) <- c("P","F")

rownames(dictatorPerformances) <- c("P","F")

colnames(performanceTable) <- c("c1","c2","c3")

colnames(profilesPerformances) <- c("c1","c2","c3")

colnames(vetoPerformances) <- c("c1","c2","c3")

colnames(dictatorPerformances) <- c("c1","c2","c3")

lambda <- 0.5

weights <- c(1/3,1/3,1/3)

names(weights) <- c("c1","c2","c3")

categoriesRanks <-c(1,2)
```

```
names(categoriesRanks) <- c("P","F")

criteriaMinMax <- c("max","max","max")

names(criteriaMinMax) <- colnames(performanceTable)

assignments <-rbind(c("P","P","P","F","F","F","F","F","F","F","F","F",
                     "F","F","F","F","F","F","F","F","F","F","F","F"),
                    c("P","P","P","F","F","F","P","P","P","P","P","P",
                     "P","P","P","P","P","P","P","P","P","P","P","P"),
                    c("P","P","P","F","F","F","F","F","F","F","F","F",
                     "P","P","P","P","P","P","F","F","F","F","F","F"),
                    c("P","P","P","F","F","F","P","P","P","P","P","P",
                     "P","P","P","P","P","P","F","F","F","F","F","F"),
                    c("P","P","P","F","F","F","F","F","F","P","P","P",
                     "F","F","F","F","F","F","F","F","F","F","F","F"),
                    c("P","P","P","F","F","F","F","F","F","P","P","P",
                     "P","P","P","P","P","P","P","P","P","P","P","P"),
                    c("P","P","P","F","F","F","F","F","F","P","P","P",
                     "P","P","P","P","P","P","F","F","F","F","F","F"))

colnames(assignments) <- rownames(performanceTable)

majorityRules <- c("V","D","v","d","dV","Dv","dv")

for(i in 1:7)
{
  ElectreAssignments<-LPDMRSort(performanceTable, profilesPerformances,
                               weights, criteriaMinMax, lambda,
                               criteriaVetos=vetoPerformances,
                               criteriaDictators=dictatorPerformances,
                               majorityRule = majorityRules[i])

  print(all(ElectreAssignments == assignments[i,]))
}
```

`LPDMRSortIdentifyIncompatibleAssignments`

Identifies all sets of assignment examples which are incompatible with the MRSort sorting method extended to handle large performance differences.

Description

MRSort is a simplified ElectreTRI method that uses the pessimistic assignment rule, without indifference or preference thresholds attached to criteria. LPDMRSort considers both a binary discordance and a binary concordance conditions including several interactions between them. This function outputs all (or a fixed number of) sets of incompatible assignment examples ranging in size from the minimal size and up to a given threshold. The retrieved sets are also not contained in each other.

Usage

```
LPDMRSortIdentifyIncompatibleAssignments(performanceTable,
                                          assignments,
                                          categoriesRanks,
                                          criteriaMinMax,
                                          majorityRule = "",
                                          incompatibleSetsLimit = 100,
                                          largerIncompatibleSetsMargin = 0,
                                          alternativesIDs = NULL,
                                          criteriaIDs = NULL)
```

Arguments

`performanceTable`
: Matrix or data frame containing the performance table. Each row corresponds to an alternative, and each column to a criterion. Rows (resp. columns) must be named according to the IDs of the alternatives (resp. criteria).

`assignments`
: Vector containing the assignments (IDs of the categories) of the alternatives to the categories. The elements are named according to the alternatives.

`categoriesRanks`
: Vector containing the ranks of the categories. The elements are named according to the IDs of the categories.

`criteriaMinMax`
: Vector containing the preference direction on each of the criteria. "min" (resp. "max") indicates that the criterion has to be minimized (maximized). The elements are named according to the IDs of the criteria.

`majorityRule`
: String denoting how the vetoes and dictators are combined in order to form the assignment rule. The values to choose from are "", "V", "D", "v", "d", "dV", "Dv", "dv". "" corresponds to using only the majority rule without vetoes or dictators, "V" considers only the vetoes, "D" only the dictators, "v" is like "V" only that a dictator may invalidate a veto, "d" is like "D" only that a veto may invalidate a dictator, "dV" is like "V" only that if there is no veto we may then consider the dictator, "Dv" is like "D" only that when there is no dictator we may consider the vetoes, while finally "dv" is identical to using both dictator and vetoes only that when both are active they invalidate each other, so the majority rule is considered in that case.

`incompatibleSetsLimit`
: Pozitive integer denoting the upper limit of the number of sets to be retrieved.

`largerIncompatibleSetsMargin`
: Pozitive integer denoting whether sets larger than the minimal size should be retrieved, and by what margin. For example, if this is 0 then only sets of the minimal size will be retrieved, if this is 1 then sets also larger by 1 element will be retrieved.

`alternativesIDs`
: Vector containing IDs of alternatives, according to which the datashould be filtered.

`criteriaIDs`
: Vector containing IDs of criteria, according to which the data should be filtered.

Value

The function returns NULL if there is a problem, or a list containing the incompatible sets of alternatives as vectors.

References

Bouyssou, D. and Marchant, T. An axiomatic approach to noncompen-satory sorting methods in MCDM, II: more than two categories. European Journal of Operational Research, 178(1): 246–276, 2007.

Meyer, P. and Olteanu, A-L. Integrating large positive and negative performance differences in majority-rule sorting models. European Journal of Operational Research, submitted , 2015.

Examples

```
# the performance table

performanceTable <- rbind(c(10,10,9), c(10,9,10), c(9,10,10), c(9,9,10),
                          c(9,10,9), c(10,9,9), c(10,10,7), c(10,7,10),
                          c(7,10,10), c(9,9,17), c(9,17,9), c(17,9,9),
                          c(7,10,17), c(10,17,7), c(17,7,10), c(7,17,10),
                          c(17,10,7), c(10,7,17), c(7,9,17), c(9,17,7),
                          c(17,7,9), c(7,17,9), c(17,9,7), c(9,7,17),
                          c(7,7,7))

rownames(performanceTable) <- c("a1", "a2", "a3", "a4", "a5", "a6", "a7",
                                "a8", "a9", "a10", "a11", "a12", "a13",
                                "a14", "a15", "a16", "a17", "a18", "a19",
                                "a20", "a21", "a22", "a23", "a24", "a25")

colnames(performanceTable) <- c("c1","c2","c3")

assignments <-rbind(c("P","P","P","F","F","F","F","F","F","F","F","F",
                    "F","F","F","F","F","F","F","F","F","F","F","F","P"),
                    c("P","P","P","F","F","F","P","P","P","P","P","P",
                    "P","P","P","P","P","P","P","P","P","P","P","P","P"),
                    c("P","P","P","F","F","F","F","F","F","F","F","F",
                    "P","P","P","P","P","P","F","F","F","F","F","F","P"),
                    c("P","P","P","F","F","F","P","P","P","P","P","P",
                    "P","P","P","P","P","P","F","F","F","F","F","F","P"),
                    c("P","P","P","F","F","F","F","F","F","P","P","P",
                    "F","F","F","F","F","F","F","F","F","F","F","F","P"),
                    c("P","P","P","F","F","F","F","F","F","P","P","P",
                    "P","P","P","P","P","P","P","P","P","P","P","P","P"),
                    c("P","P","P","F","F","F","F","F","F","P","P","P",
                    "P","P","P","P","P","P","F","F","F","F","F","F","P"))

colnames(assignments) <- rownames(performanceTable)

categoriesRanks <-c(1,2)

names(categoriesRanks) <- c("P","F")
```

```
criteriaMinMax <- c("max","max","max")

names(criteriaMinMax) <- colnames(performanceTable)

majorityRules <- c("V","D","v","d","dV","Dv","dv")

for(i in 1:1)# change to 7 in order to perform all tests
{
  incompatibleAssignmentsSets<-LPDMRSortIdentifyIncompatibleAssignments(
                                 performanceTable, assignments[i,],
                                 categoriesRanks, criteriaMinMax,
                                 majorityRule = majorityRules[i])

  filteredAlternativesIDs <- setdiff(rownames(performanceTable),
                                     incompatibleAssignmentsSets[[1]])

  x<-LPDMRSortInferenceExact(performanceTable, assignments[i,],
                             categoriesRanks, criteriaMinMax,
                             majorityRule = majorityRules[i],
                             readableWeights = TRUE,
                             readableProfiles = TRUE,
                             minmaxLPD =  TRUE,
                             alternativesIDs = filteredAlternativesIDs)

  ElectreAssignments<-LPDMRSort(performanceTable, x$profilesPerformances,
                                x$weights, criteriaMinMax, x$lambda,
                                criteriaVetos=x$vetoPerformances,
                                criteriaDictators=x$dictatorPerformances,
                                majorityRule = majorityRules[i],
                                alternativesIDs = filteredAlternativesIDs)

  print(all(ElectreAssignments == assignments[i,filteredAlternativesIDs]))
}
```

`LPDMRSortInferenceExact` *Identification of profiles, weights, majority threshold and veto and dictator thresholds for the MRSort sorting approach extended to handle large performance differences.*

Description

MRSort is a simplified ElectreTRI method that uses the pessimistic assignment rule, without indifference or preference thresholds attached to criteria. LPDMRSort considers both a binary discordance and a binary concordance conditions including several interactions between them. The identification of the profiles, weights, majority threshold and veto and dictator thresholds are done by taking into account assignment examples.

Usage

```
LPDMRSortInferenceExact(performanceTable, assignments,
            categoriesRanks, criteriaMinMax,
            majorityRule = "", readableWeights = FALSE,
            readableProfiles = FALSE, minmaxLPD = FALSE,
            alternativesIDs = NULL, criteriaIDs = NULL)
```

Arguments

`performanceTable`
: Matrix or data frame containing the performance table. Each row corresponds to an alternative, and each column to a criterion. Rows (resp. columns) must be named according to the IDs of the alternatives (resp. criteria).

`assignments`
: Vector containing the assignments (IDs of the categories) of the alternatives to the categories. The elements are named according to the alternatives.

`categoriesRanks`
: Vector containing the ranks of the categories. The elements are named according to the IDs of the categories.

`criteriaMinMax`
: Vector containing the preference direction on each of the criteria. "min" (resp. "max") indicates that the criterion has to be minimized (maximized). The elements are named according to the IDs of the criteria.

`majorityRule`
: String denoting how the vetoes and dictators are combined in order to form the assignment rule. The values to choose from are "", "V", "D", "v", "d", "dV", "Dv", "dv". "" corresponds to using only the majority rule without vetoes or dictators, "V" considers only the vetoes, "D" only the dictators, "v" is like "V" only that a dictator may invalidate a veto, "d" is like "D" only that a veto may invalidate a dictator, "dV" is like "V" only that if there is no veto we may then consider the dictator, "Dv" is like "D" only that when there is no dictator we may consider the vetoes, while finally "dv" is identical to using both dictator and vetoes only that when both are active they invalidate each other, so the majority rule is considered in that case.

`readableWeights`
: Boolean parameter indicating whether the weights are to be spaced more evenly or not.

`readableProfiles`
: Boolean parameter indicating whether the profiles are to be spaced more evenly or not.

`minmaxLPD`
: Boolean parameter indicating whether the veto thresholds are to be minimized (or maximized if lower criteria values are preferred) while the dictator thresholds are to be maximized (or minimized if lower criteria values are preferred).

`alternativesIDs`
: Vector containing IDs of alternatives, according to which the data should be filtered.

`criteriaIDs`
: Vector containing IDs of criteria, according to which the data should be filtered.

Value

The function returns NULL if there is a problem, or a list structured as follows :

`lambda` The majority threshold.

`weights` A vector containing the weights of the criteria. The elements are named according to the criteria IDs.

`profilesPerformances` A matrix containing the lower profiles of the categories. The columns are named according to the criteria, whereas the rows are named according to the categories. The lower profile of the lower category can be considered as a dummy profile.

`vetoPerformances` A matrix containing the veto profiles of the categories. The columns are named according to the criteria, whereas the rows are named according to the categories. The veto profile of the lower category can be considered as a dummy profile.

References

Bouyssou, D. and Marchant, T. An axiomatic approach to noncompen- satory sorting methods in MCDM, II: more than two categories. European Journal of Operational Research, 178(1): 246–276, 2007.

Meyer, P. and Olteanu, A-L. Integrating large positive and negative performance differences in majority-rule sorting models. European Journal of Operational Research, submitted, 2015.

Examples

```
# the performance table

performanceTable <- rbind(c(10,10,9), c(10,9,10), c(9,10,10), c(9,9,10),
                          c(9,10,9), c(10,9,9), c(10,10,7), c(10,7,10),
                          c(7,10,10), c(9,9,17), c(9,17,9), c(17,9,9),
                          c(7,10,17), c(10,17,7), c(17,7,10), c(7,17,10),
                          c(17,10,7), c(10,7,17), c(7,9,17), c(9,17,7),
                          c(17,7,9), c(7,17,9), c(17,9,7), c(9,7,17))

rownames(performanceTable) <- c("a1", "a2", "a3", "a4", "a5", "a6", "a7",
                                "a8", "a9", "a10", "a11", "a12", "a13",
                                "a14", "a15", "a16", "a17", "a18", "a19",
                                "a20", "a21", "a22", "a23", "a24")

colnames(performanceTable) <- c("c1","c2","c3")

categoriesRanks <-c(1,2)

names(categoriesRanks) <- c("P","F")

criteriaMinMax <- c("max","max","max")

names(criteriaMinMax) <- colnames(performanceTable)
```

```
assignments <-rbind(c("P","P","P","F","F","F","F","F","F","F","F","F",
                    "F","F","F","F","F","F","F","F","F","F","F","F"),
                    c("P","P","P","F","F","F","P","P","P","P","P","P",
                    "P","P","P","P","P","P","P","P","P","P","P","P"),
                    c("P","P","P","F","F","F","F","F","F","F","F","F",
                    "P","P","P","P","P","P","F","F","F","F","F","F"),
                    c("P","P","P","F","F","F","P","P","P","P","P","P",
                    "P","P","P","P","P","P","F","F","F","F","F","F"),
                    c("P","P","P","F","F","F","F","F","F","P","P","P",
                    "F","F","F","F","F","F","F","F","F","F","F","F"),
                    c("P","P","P","F","F","F","F","F","F","P","P","P",
                    "P","P","P","P","P","P","P","P","P","P","P","P"),
                    c("P","P","P","F","F","F","F","F","F","P","P","P",
                    "P","P","P","P","P","P","F","F","F","F","F","F"))

colnames(assignments) <- rownames(performanceTable)

majorityRules <- c("V","D","v","d","dV","Dv","dv")

for(i in 1:1)# change to 7 in order to perform all tests
{
  x<-LPDMRSortInferenceExact(performanceTable, assignments[i,],
                             categoriesRanks, criteriaMinMax,
                             majorityRule = majorityRules[i],
                             readableWeights = TRUE,
                             readableProfiles = TRUE,
                             minmaxLPD = TRUE)

  ElectreAssignments<-LPDMRSort(performanceTable, x$profilesPerformances,
                                x$weights, criteriaMinMax, x$lambda,
                                criteriaVetos=x$vetoPerformances,
                                criteriaDictators=x$dictatorPerformances,
                                majorityRule = majorityRules[i])

  print(x)

  print(all(ElectreAssignments == assignments[i,]))
}
```

MARE *Multi-Attribute Range Evaluations (MARE)*

Description

MARE is a multi-criteria decision analysis method which was originally developed by Hodgett et al. in 2014.

Usage

```
MARE(performanceTableMin,
      performanceTable,
      performanceTableMax,
      criteriaWeights,
      criteriaMinMax,
      alternativesIDs = NULL,
      criteriaIDs = NULL)
```

Arguments

`performanceTableMin`
: Matrix or data frame containing the minimum performance table. Each column corresponds to an alternative, and each row to a criterion. Columns (resp. rows) must be named according to the IDs of the alternatives (resp. criteria).

`performanceTable`
: Matrix or data frame containing the most likely performance table. Each column corresponds to an alternative, and each row to a criterion. Columns (resp. rows) must be named according to the IDs of the alternatives (resp. criteria).

`performanceTableMax`
: Matrix or data frame containing the maximum performance table. Each column corresponds to an alternative, and each row to a criterion. Columns (resp. rows) must be named according to the IDs of the alternatives (resp. criteria).

`criteriaWeights`
: Vector containing the weights of the criteria. The elements are named according to the IDs of the criteria.

`criteriaMinMax`
: Vector containing the preference direction on each of the criteria. "min" (resp. "max") indicates that the criterion has to be minimized (maximized). The elements are named according to the IDs of the criteria.

`alternativesIDs`
: Vector containing IDs of alternatives, according to which the data should be filtered.

`criteriaIDs`
: Vector containing IDs of criteria, according to which the data should be filtered.

Value

The function returns an element of type mare which contains the MARE scores for each alternative.

References

Richard E. Hodgett, Elaine B. Martin, Gary Montague, Mark Talford (2014). Handling uncertain decisions in whole process design. Production Planning & Control, Volume 25, Issue 12, 1028-1038.

Examples

```
performanceTableMin <- t(matrix(c(78,87,79,19,8,68,74,8,90,89,74.5,9,20,81,30),
                   nrow=3,ncol=5, byrow=TRUE))
```

```
performanceTable <- t(matrix(c(80,87,86,19,8,70,74,10,90,89,75,9,33,82,30),
                              nrow=3,ncol=5, byrow=TRUE))
performanceTableMax <- t(matrix(c(81,87,95,19,8,72,74,15,90,89,75.5,9,36,84,30),
                                 nrow=3,ncol=5, byrow=TRUE))

row.names(performanceTable) <- c("Yield","Toxicity","Cost","Separation","Odour")
colnames(performanceTable) <- c("Route One","Route Two","Route Three")
row.names(performanceTableMin) <- row.names(performanceTable)
colnames(performanceTableMin) <- colnames(performanceTable)
row.names(performanceTableMax) <- row.names(performanceTable)
colnames(performanceTableMax) <- colnames(performanceTable)

weights <- c(0.339,0.077,0.434,0.127,0.023)
names(weights) <- row.names(performanceTable)

criteriaMinMax <- c("max", "max", "max", "max", "max")
names(criteriaMinMax) <- row.names(performanceTable)

overall1 <- MARE(performanceTableMin,
                   performanceTable,
                   performanceTableMax,
                   weights,
                   criteriaMinMax)

overall2 <- MARE(performanceTableMin,
                    performanceTable,
                    performanceTableMax,
                    weights,
                    criteriaMinMax,
                    alternativesIDs = c("Route Two","Route Three"),
                    criteriaIDs = c("Yield","Toxicity","Cost","Separation"))
```

MRSort *Electre TRI-like sorting method axiomatized by Bouyssou and Marchant.*

Description

This simplification of the Electre TRI method uses the pessimistic assignment rule, without indifference or preference thresholds attached to criteria. Only a binary discordance condition is considered, i.e. a veto forbids an outranking in any possible concordance situation, or not.

Usage

```
MRSort(performanceTable, categoriesLowerProfiles,
             criteriaWeights, criteriaMinMax, majorityThreshold,
             criteriaVetos = NULL, alternativesIDs = NULL,
             criteriaIDs = NULL, categoriesIDs = NULL)
```

Arguments

`performanceTable`
: Matrix or data frame containing the performance table. Each row corresponds to an alternative, and each column to a criterion. Rows (resp. columns) must be named according to the IDs of the alternatives (resp. criteria).

`categoriesLowerProfiles`
: Matrix containing, in each row, the lower profiles of the categories. The columns are named according to the criteria, and the rows are named according to the categories. The index of the row in the matrix corresponds to the rank of the category.

`criteriaWeights`
: Vector containing the weights of the criteria. The elements are named according to the IDs of the criteria.

`criteriaMinMax`
: Vector containing the preference direction on each of the criteria. "min" (resp. "max") indicates that the criterion has to be minimized (maximized). The elements are named according to the IDs of the criteria.

`majorityThreshold`
: The cut threshold for the concordance condition. Should be at least half of the sum of the weights.

`criteriaVetos`
: Matrix containing in each row a vector defining the veto values for the lower profile of the category. NA values mean that no veto is defined. A veto threshold for criterion i and category k represents the performance below which an alternative is forbidden to outrank the lower profile of category k, and thus is forbidden to be assigned to the category k. The rows are named according to the categories, whereas the columns are named according to the criteria.

`alternativesIDs`
: Vector containing IDs of alternatives, according to which the datashould be filtered.

`criteriaIDs`
: Vector containing IDs of criteria, according to which the data should be filtered.

`categoriesIDs`
: Vector containing IDs of categories, according to which the data should be filtered.

Value

The function returns a vector containing the assignments of the alternatives to the categories.

References

Bouyssou, D. and Marchant, T. An axiomatic approach to noncompen- satory sorting methods in MCDM, II: more than two categories. European Journal of Operational Research, 178(1): 246–276, 2007.

Examples

```
# the performance table

performanceTable <- rbind(
```

```
  c(1,10,1),
  c(4,20,2),
  c(2,20,0),
  c(6,40,0),
  c(30,30,3))

rownames(performanceTable) <- c("RER","METRO1","METRO2","BUS","TAXI")

colnames(performanceTable) <- c("Price","Time","Comfort")

# lower profiles of the categories
# (best category in the first position of the list)

categoriesLowerProfiles <- rbind(c(3, 11, 3),c(7, 25, 2),c(NA,NA,NA))

colnames(categoriesLowerProfiles) <- colnames(performanceTable)

rownames(categoriesLowerProfiles)<-c("Good","Medium","Bad")

# criteria to minimize or maximize

criteriaMinMax <- c("min","min","max")

names(criteriaMinMax) <- colnames(performanceTable)

# vetos

criteriaVetos <- rbind(c(10, NA, NA),c(NA, NA, 1),c(NA,NA,NA))

colnames(criteriaVetos) <- colnames(performanceTable)
rownames(criteriaVetos) <- c("Good","Medium","Bad")

# weights

criteriaWeights <- c(1,3,2)

names(criteriaWeights) <- colnames(performanceTable)


# MRSort

assignments<-MRSort(performanceTable, categoriesLowerProfiles,
                          criteriaWeights, criteriaMinMax, 3,
                          criteriaVetos = criteriaVetos)

print(assignments)

# un peu de filtrage

assignments<-MRSort(performanceTable, categoriesLowerProfiles,
                          criteriaWeights, criteriaMinMax, 2,
                          categoriesIDs = c("Medium","Bad"),
                          criteriaIDs = c("Price","Time"),
```

```
                          alternativesIDs = c("RER", "BUS"))

print(assignments)
```

MRSortIdentifyIncompatibleAssignments

Identifies all sets of assignment examples which are incompatible with the MRSort method.

Description

This MRSort method, which is a simplification of the Electre TRI method, uses the pessimistic assignment rule, without indifference or preference thresholds attached to criteria. Only a binary discordance condition is considered, i.e. a veto forbids an outranking in any possible concordance situation, or not. This function outputs for all (or a fixed number of) sets of incompatible assignment examples ranging in size from the minimal size and up to a given threshold. The retrieved sets are also not contained in each other.

Usage

```
MRSortIdentifyIncompatibleAssignments(performanceTable,
                                      assignments,
                                      categoriesRanks,
                                      criteriaMinMax, veto = FALSE,
                                      incompatibleSetsLimit = 100,
                                      largerIncompatibleSetsMargin = 0,
                                      alternativesIDs = NULL,
                                      criteriaIDs = NULL)
```

Arguments

`performanceTable`
: Matrix or data frame containing the performance table. Each row corresponds to an alternative, and each column to a criterion. Rows (resp. columns) must be named according to the IDs of the alternatives (resp. criteria).

`assignments`
: Vector containing the assignments (IDs of the categories) of the alternatives to the categories. The elements are named according to the alternatives.

`categoriesRanks`
: Vector containing the ranks of the categories. The elements are named according to the IDs of the categories.

`criteriaMinMax`
: Vector containing the preference direction on each of the criteria. "min" (resp. "max") indicates that the criterion has to be minimized (maximized). The elements are named according to the IDs of the criteria.

`veto`
: Boolean parameter indicating whether veto profiles are being used by the model or not.

`incompatibleSetsLimit`
: Pozitive integer denoting the upper limit of the number of sets to be retrieved.

`largerIncompatibleSetsMargin`
: Pozitive integer denoting whether sets larger than the minimal size should be retrieved, and by what margin. For example, if this is 0 then only sets of the minimal size will be retrieved, if this is 1 then sets also larger by 1 element will be retrieved.

`alternativesIDs`
: Vector containing IDs of alternatives, according to which the datashould be filtered.

`criteriaIDs`
: Vector containing IDs of criteria, according to which the data should be filtered.

Value

The function returns NULL if there is a problem, or a list containing the incompatible sets of alternatives as vectors.

References

Bouyssou, D. and Marchant, T. An axiomatic approach to noncompen- satory sorting methods in MCDM, II: more than two categories. European Journal of Operational Research, 178(1): 246–276, 2007.

Examples

```
performanceTable <- rbind(c(10,10,9), c(10,9,10), c(9,10,10), c(9,9,10),
                          c(9,10,9), c(10,9,9), c(10,10,7), c(10,7,10),
                          c(7,10,10), c(9,9,17), c(9,17,9), c(17,9,9),
                          c(7,10,17), c(10,17,7), c(17,7,10), c(7,17,10),
                          c(17,10,7), c(10,7,17), c(7,9,17), c(9,17,7),
                          c(17,7,9), c(7,17,9), c(17,9,7), c(9,7,17))

rownames(performanceTable) <- c("a1", "a2", "a3", "a4", "a5", "a6", "a7",
                                "a8", "a9", "a10", "a11", "a12", "a13",
                                "a14", "a15", "a16", "a17", "a18", "a19",
                                "a20", "a21", "a22", "a23", "a24")

colnames(performanceTable) <- c("c1","c2","c3")

assignments <-c("P", "P", "P", "F", "F", "F", "F", "F", "F", "P", "F",
                "F", "F", "F", "F", "F", "F", "F", "F", "F", "F", "F",
                "F", "F")

names(assignments) <- rownames(performanceTable)

categoriesRanks <-c(1,2)

names(categoriesRanks) <- c("P","F")

criteriaMinMax <- c("max","max","max")
```

```
names(criteriaMinMax) <- colnames(performanceTable)

incompatibleAssignmentsSets<-MRSortIdentifyIncompatibleAssignments(
                               performanceTable, assignments,
                               categoriesRanks, criteriaMinMax,
                               veto = TRUE,
                               alternativesIDs = c("a1","a2","a3","a4",
                               "a5","a6","a7","a8","a9","a10"))

print(incompatibleAssignmentsSets)

filteredAlternativesIDs <- setdiff(c("a1","a2","a3","a4","a5","a6","a7","a8","a9"),
                                   incompatibleAssignmentsSets[[1]])

print(filteredAlternativesIDs)

x<-MRSortInferenceExact(performanceTable, assignments, categoriesRanks,
                        criteriaMinMax, veto = TRUE,
                        readableWeights = TRUE, readableProfiles = TRUE,
                        alternativesIDs = filteredAlternativesIDs)

ElectreAssignments<-MRSort(performanceTable, x$profilesPerformances, x$weights,
                           criteriaMinMax, x$lambda,
                           criteriaVetos=x$vetoPerformances,
                           alternativesIDs = filteredAlternativesIDs)
```

`MRSortInferenceApprox` *Identification of profiles, weights, majority threshold and veto thresholds for MRSort using a metaheuristic approach.*

Description

MRSort is a simplification of the Electre TRI method that uses the pessimistic assignment rule, without indifference or preference thresholds attached to criteria. Only a binary discordance condition is considered, i.e. a veto forbids an outranking in any possible concordance situation, or not. The identification of the profiles, weights, majority threshold and veto thresholds are done by taking into account assignment examples.

Usage

```
MRSortInferenceApprox(performanceTable, assignments,
             categoriesRanks, criteriaMinMax, alg_total_time = 90,
             alg_repeats = 3, alg_repeat_time = 30,
             alg_repeat_iterations = 30, mh_max_temp_step = 0.2,
             mh_min_temp_step = 0.02, mh_temp_step_increase = 1.25,
             mh_temp_step_decrease = 0.8, veto = FALSE,
             alternativesIDs = NULL, criteriaIDs = NULL)
```

Arguments

performanceTable
: Matrix or data frame containing the performance table. Each row corresponds to an alternative, and each column to a criterion. Rows (resp. columns) must be named according to the IDs of the alternatives (resp. criteria).

assignments
: Vector containing the assignments (IDs of the categories) of the alternatives to the categories. The elements are named according to the alternatives.

categoriesRanks
: Vector containing the ranks of the categories. The elements are named according to the IDs of the categories.

criteriaMinMax
: Vector containing the preference direction on each of the criteria. "min" (resp. "max") indicates that the criterion has to be minimized (maximized). The elements are named according to the IDs of the criteria.

alg_total_time
: A strictly pozitive integer value denoting the total allowed time in seconds of all algorithm executions.

alg_repeats
: A strictly pozitive integer value denoting the number of times the algorithm is executed.

alg_repeat_time
: A strictly pozitive integer value denoting the total allowed time in seconds for each algorithm execution.

alg_repeat_iterations
: A strictly pozitive integer value denoting the maximum number of iterations that the algorithm will execute. Each algorithm execution is stopped when either this limit is reached or when the amount of time given by alg_repeat_time passes.

mh_max_temp_step
: A value between 0 and 1 used for determining the rate at which the temperature of the simulated annealing algorithm decreases. This parameter is the highest allowed value of this decrease. Larger values make the simulated annealing algorithm perform fewer steps.

mh_min_temp_step
: A value between 0 and 1 used for determining the rate at which the temperature of the simulated annealing algorithm decreases. This parameter is the lowest allowed value of this decrease. Smaller values make the simulated annealing algorithm perform more steps.

mh_temp_step_increase
: A value stricly above 1 used for determining the rate at which the temperature step increases following improvements in the overall fitness of the solution. Larger values lead to a quicker reduction of the simulated annealing algorithm steps when improvements are made to the solution.

mh_temp_step_decrease
: A value between 0 and 1 used for determining the rate at which the temperature step decreases following non-improvements in the overall fitness of the solution. Smaller values lead to a quicker increase in the simulated annealing algorithm steps when the fitness of the solution does not increase from iteration to iteration.

veto
: Boolean parameter indicating whether veto profiles are to be used or not.

alternativesIDs
: Vector containing IDs of alternatives, according to which the datashould be filtered.

criteriaIDs
: Vector containing IDs of criteria, according to which the data should be filtered.

Value

The function returns NULL if there is a problem, or a list structured as follows :

lambda
: The majority threshold.

gamma
: Separation threshold used in the linear programs.

weights
: A vector containing the weights of the criteria. The elements are named according to the criteria IDs.

profilesPerformances
: A matrix containing the lower profiles of the categories. The columns are named according to the criteria, whereas the rows are named according to the categories. The lower profile of the lower category can be considered as a dummy profile.

References

Bouyssou, D. and Marchant, T. An axiomatic approach to noncompen- satory sorting methods in MCDM, II: more than two categories. European Journal of Operational Research, 178(1): 246–276, 2007.

Olteanu, A-L. and Meyer, P. Inferring the parameters of a majority rule sorting model with vetoes on large datasets. DA2PL 2014 : From Multicriteria Decision Aid to Preference Learning, 20-21 november 2014, Paris, France, 2014, pp. 87-94.

Examples

```
performanceTable <- rbind(c(10,10,9), c(10,9,10), c(9,10,10), c(9,9,10),
                          c(9,10,9), c(10,9,9), c(10,10,7), c(10,7,10),
                          c(7,10,10), c(9,9,17), c(9,17,9), c(17,9,9),
                          c(7,10,17), c(10,17,7), c(17,7,10), c(7,17,10),
                          c(17,10,7), c(10,7,17), c(7,9,17), c(9,17,7),
                          c(17,7,9), c(7,17,9), c(17,9,7), c(9,7,17))

rownames(performanceTable) <- c("a1", "a2", "a3", "a4", "a5", "a6", "a7",
                                "a8", "a9", "a10", "a11", "a12", "a13",
                                "a14", "a15", "a16", "a17", "a18", "a19",
                                "a20", "a21", "a22", "a23", "a24")

colnames(performanceTable) <- c("c1","c2","c3")

assignments <-c("P", "P", "P", "F", "F", "F", "F", "F", "F", "F", "F",
                "F", "F", "F", "F", "F", "F", "F", "F", "F", "F", "F",
                "F", "F")

names(assignments) <- rownames(performanceTable)
```

```
categoriesRanks <-c(1,2)

names(categoriesRanks) <- c("P","F")

criteriaMinMax <- c("max","max","max")

names(criteriaMinMax) <- colnames(performanceTable)

set.seed(1)

x<-MRSortInferenceApprox(performanceTable, assignments, categoriesRanks,
                         criteriaMinMax, 180, 3, 30, 30, 0.2, 0.02, 1.25, 0.8,
                         veto = TRUE,
                         alternativesIDs = c("a1","a2","a3","a4","a5","a6","a7"))

print(x)

ElectreAssignments<-MRSort(performanceTable, x$profilesPerformances,
                        x$weights, criteriaMinMax, x$lambda,
                        criteriaVetos=x$vetoPerformances,
                        alternativesIDs = c("a1","a2","a3","a4","a5","a6","a7"))
```

MRSortInferenceExact *Identification of profiles, weights and majority threshold for the MR-Sort sorting method using an exact approach.*

Description

The MRSort method, a simplification of the Electre TRI method, uses the pessimistic assignment rule, without indifference or preference thresholds attached to criteria. Only a binary discordance condition is considered, i.e. a veto forbids an outranking in any possible concordance situation, or not. The identification of the profiles, weights and majority threshold are done by taking into account assignment examples.

Usage

```
MRSortInferenceExact(performanceTable, assignments,
             categoriesRanks, criteriaMinMax,
             veto = FALSE, readableWeights = FALSE,
             readableProfiles = FALSE,
             alternativesIDs = NULL, criteriaIDs = NULL)
```

Arguments

performanceTable
: Matrix or data frame containing the performance table. Each row corresponds to an alternative, and each column to a criterion. Rows (resp. columns) must be named according to the IDs of the alternatives (resp. criteria).

`assignments` Vector containing the assignments (IDs of the categories) of the alternatives to the categories. The elements are named according to the alternatives.

`categoriesRanks` Vector containing the ranks of the categories. The elements are named according to the IDs of the categories.

`criteriaMinMax` Vector containing the preference direction on each of the criteria. "min" (resp. "max") indicates that the criterion has to be minimized (maximized). The elements are named according to the IDs of the criteria.

`veto` Boolean parameter indicating whether veto profiles are being used or not.

`readableWeights` Boolean parameter indicating whether the weights are to be spaced more evenly or not.

`readableProfiles` Boolean parameter indicating whether the profiles are to be spaced more evenly or not.

`alternativesIDs` Vector containing IDs of alternatives, according to which the data should be filtered.

`criteriaIDs` Vector containing IDs of criteria, according to which the data should be filtered.

Value

The function returns NULL if there is a problem, or a list structured as follows :

`lambda` The majority threshold.

`weights` A vector containing the weights of the criteria. The elements are named according to the criteria IDs.

`profilesPerformances` A matrix containing the lower profiles of the categories. The columns are named according to the criteria, whereas the rows are named according to the categories. The lower profile of the lower category can be considered as a dummy profile.

`vetoPerformances` A matrix containing the veto profiles of the categories. The columns are named according to the criteria, whereas the rows are named according to the categories. The veto profile of the lower category can be considered as a dummy profile.

References

Bouyssou, D. and Marchant, T. An axiomatic approach to noncompen- satory sorting methods in MCDM, II: more than two categories. European Journal of Operational Research, 178(1): 246–276, 2007.

Examples

```
performanceTable <- rbind(c(10,10,9), c(10,9,10), c(9,10,10), c(9,9,10),
                          c(9,10,9), c(10,9,9), c(10,10,7), c(10,7,10),
                          c(7,10,10), c(9,9,17), c(9,17,9), c(17,9,9),
                          c(7,10,17), c(10,17,7), c(17,7,10), c(7,17,10),
                          c(17,10,7), c(10,7,17), c(7,9,17), c(9,17,7),
                          c(17,7,9), c(7,17,9), c(17,9,7), c(9,7,17))

rownames(performanceTable) <- c("a1", "a2", "a3", "a4", "a5", "a6", "a7",
                                "a8", "a9", "a10", "a11", "a12", "a13",
                                "a14", "a15", "a16", "a17", "a18", "a19",
                                "a20", "a21", "a22", "a23", "a24")

colnames(performanceTable) <- c("c1","c2","c3")

assignments <-c("P", "P", "P", "F", "F", "F", "F", "F", "F", "F", "F", "F",
                "F", "F", "F", "F", "F", "F", "F", "F", "F", "F", "F", "F")

names(assignments) <- rownames(performanceTable)

categoriesRanks <-c(1,2)

names(categoriesRanks) <- c("P","F")

criteriaMinMax <- c("max","max","max")

names(criteriaMinMax) <- colnames(performanceTable)

x<-MRSortInferenceExact(performanceTable, assignments, categoriesRanks,
                         criteriaMinMax, veto = TRUE, readableWeights = TRUE,
                         readableProfiles = TRUE,
                         alternativesIDs = c("a1","a2","a3","a4","a5","a6","a7"))

ElectreAssignments<-MRSort(performanceTable, x$profilesPerformances,
                           x$weights, criteriaMinMax, x$lambda,
                           criteriaVetos=x$vetoPerformances,
                           alternativesIDs = c("a1","a2","a3","a4","a5","a6","a7"))
```

---

normalizePerformanceTable *Function to normalize (or rescale) the columns (or criteria) of a performance table.*

Description

Standardizes the range of the criteria according to a few methods : percentage of max, scale between 0 and 1, scale to 0 mean and 1 standard deviation, scale to euclidian unit length.

Usage

```
normalizePerformanceTable(performanceTable,
                              normalizationTypes,
                              alternativesIDs = NULL,
                              criteriaIDs = NULL)
```

Arguments

`performanceTable`
: A matrix containing the performance table to be plotted. The columns are labelled according to the criteria IDs, and the rows according to the alternatives IDs.

`normalizationTypes`
: Vector indicating the type of normalization that should be applied to each of the criteria. Possible values : "percentageOfMax", "rescaling" (minimum becomes 0, maximum becomes 1), "standardization" (rescale to a mean of 0 and a standard deviation of 1), "scaleToUnitLength" (scale the criteria values such that the column has euclidian length 1). Any other value (like "none") will result in no data transformation. The elements are named according to the IDs of the criteria.

`alternativesIDs`
: Vector containing IDs of alternatives, according to which the data should be filtered.

`criteriaIDs`
: Vector containing IDs of criteria, according to which the data should be filtered.

Examples

```
library(MCDA)

performanceTable <- matrix(runif(5*9), ncol=5)

row.names(performanceTable) <- c("x1","x2","x3","x4","x5","x6","x7","x8","x9")

colnames(performanceTable) <- c("g1","g2","g3","g4", "g5")

normalizationTypes <- c("percentageOfMax","rescaling",
                        "standardization","scaleToUnitLength", "none")

names(normalizationTypes) <- c("g1","g2","g3","g4","g5")

normalizedPerformanceTable <- normalizePerformanceTable(performanceTable,
                                                         normalizationTypes)
```

plotAlternativesValuesPreorder

Function to plot a preorder of alternatives, based on some score or ranking.

Description

Plots a preorder of alternatives as a graph, representing the ranking of the alternatives, w.r.t. some scores or ranks. A decreasing order or increasing order can be specified, w.r.t. to these scores or ranks.

Usage

```
plotAlternativesValuesPreorder(alternativesValues,
                                decreasing = TRUE,
                                alternativesIDs = NULL)
```

Arguments

`alternativesValues`
: A vector containing some values related to alternatives, as scores or ranks. The elements of the vector are named according to the IDs of the alternatives.

`decreasing`
: A boolean to indicate if the alternatives are to be sorted increasingly (FALSE) or decreasingly (TRUE) w.r.t. the alternativesValues.

`alternativesIDs`
: Vector containing IDs of alternatives, according to which the data should be filtered.

Examples

```
library(MCDA)

alternativesValues <- c(10,1,8,3,8,3,4,4,8,5)

names(alternativesValues) <- c("x10","x1","x9","x2","x8",
                               "x3","x7","x4","x6","x5")

plotAlternativesValuesPreorder(alternativesValues,
                               decreasing=TRUE,
                               alternativesIDs=c("x10","x3","x7",
                                                 "x4","x6","x5"))
```

plotMARE *Plot Multi-Attribute Range Evaluations (MARE)*

Description

Plots the output of function MARE()

Usage

```
plotMARE(x)
```

Arguments

x	Output from function MARE()

Examples

```
performanceTableMin <- t(matrix(c(78,87,79,19,8,68,74,8,90,89,74.5,9,20,81,30),
                                  nrow=3,ncol=5, byrow=TRUE))
performanceTable <- t(matrix(c(80,87,86,19,8,70,74,10,90,89,75,9,33,82,30),
                                nrow=3,ncol=5, byrow=TRUE))
performanceTableMax <- t(matrix(c(81,87,95,19,8,72,74,15,90,89,75.5,9,36,84,30),
                                   nrow=3,ncol=5, byrow=TRUE))

row.names(performanceTable) <- c("Yield","Toxicity","Cost","Separation","Odour")
colnames(performanceTable) <- c("Route One","Route Two","Route Three")
row.names(performanceTableMin) <- row.names(performanceTable)
colnames(performanceTableMin) <- colnames(performanceTable)
row.names(performanceTableMax) <- row.names(performanceTable)
colnames(performanceTableMax) <- colnames(performanceTable)

weights <- c(0.339,0.077,0.434,0.127,0.023)
names(weights) <- row.names(performanceTable)

criteriaMinMax <- c("max", "max", "max", "max", "max")
names(criteriaMinMax) <- row.names(performanceTable)

overall1 <- MARE(performanceTableMin, performanceTable, performanceTableMax,
                           weights, criteriaMinMax)
plotMARE(overall1)

overall2 <- MARE(performanceTableMin,
                    performanceTable,
                    performanceTableMax,
                    weights,
                    criteriaMinMax,
                    alternativesIDs = c("Route Two","Route Three"),
                    criteriaIDs = c("Yield","Toxicity","Cost","Separation"))
plotMARE(overall2)
```

---

plotMRSortSortingProblem

Plot the categories and assignments of an Electre TRI-like sorting problem (via separation profiles).

Description

The profiles shown are the separation profiles between the classes. They are stored as the lower profiles of the categories.

Usage

```
plotMRSortSortingProblem(performanceTable, categoriesLowerProfiles,
                          assignments, criteriaMinMax,
                          criteriaUBs, criteriaLBs,
                          alternativesIDs = NULL, criteriaIDs = NULL)
```

Arguments

`performanceTable`
: Matrix or data frame containing the performance table. Each row corresponds to an alternative, and each column to a criterion. Rows (resp. columns) must be named according to the IDs of the alternatives (resp. criteria).

`categoriesLowerProfiles`
: Matrix containing, in each row, the lower profiles of the categories (the separation profiles in fact). The columns are named according to the criteria, and the rows are named according to the categories. The index of the row in the matrix corresponds to the rank of the category.

`assignments`
: Vector containing the assignments (IDs of the categories) of the alternatives to the categories. The elements are named according to the alternatives.

`criteriaMinMax`
: Vector containing the preference direction on each of the criteria. "min" (resp. "max") indicates that the criterion has to be minimized (maximized). The elements are named according to the IDs of the criteria.

`criteriaLBs`
: Vector containing the lower bounds of the criteria to be considered for the plotting. The elements are named according to the IDs of the criteria.

`criteriaUBs`
: Vector containing the upper bounds of the criteria to be considered for the plotting. The elements are named according to the IDs of the criteria.

`alternativesIDs`
: Vector containing IDs of alternatives, according to which the datashould be filtered.

`criteriaIDs`
: Vector containing IDs of criteria, according to which the data should be filtered.

Examples

```
# the performance table

performanceTable <- rbind(
  c(1,10,1),
  c(4,20,2),
  c(2,20,0),
  c(6,40,0),
  c(30,30,3))

rownames(performanceTable) <- c("RER","METRO1","METRO2","BUS","TAXI")

colnames(performanceTable) <- c("Price","Time","Comfort")

# lower profiles of the categories
# (best category in the first position of the list)

categoriesLowerProfiles <- rbind(c(3, 11, 3),c(7, 25, 2),c(30,30,0))

colnames(categoriesLowerProfiles) <- colnames(performanceTable)

rownames(categoriesLowerProfiles)<-c("Good","Medium","Bad")

# criteria to minimize or maximize

criteriaMinMax <- c("min","min","max")

names(criteriaMinMax) <- colnames(performanceTable)

# lower bounds of the criteria for the determination of value functions

criteriaLBs=c(0,5,0)

names(criteriaLBs) <- colnames(performanceTable)

# upper bounds of the criteria for the determination of value functions

criteriaUBs=c(50,50,4)

names(criteriaUBs) <- colnames(performanceTable)

# weights

criteriaWeights <- c(1,3,2)

names(criteriaWeights) <- colnames(performanceTable)

assignments <- assignments<-MRSort(performanceTable,
                                          categoriesLowerProfiles,
                                          criteriaWeights,
                                          criteriaMinMax, 3)
```

```
names(assignments) <- rownames(performanceTable)

plotMRSortSortingProblem(performanceTable, categoriesLowerProfiles,
                              assignments, criteriaMinMax,
                              criteriaUBs, criteriaLBs)
```

---

plotPiecewiseLinearValueFunctions
Function to plot piecewise linear value functions.

Description

Plots piecewise linear value function.

Usage

```
plotPiecewiseLinearValueFunctions(valueFunctions,
                                      criteriaIDs = NULL)
```

Arguments

valueFunctions	A list containing, for each criterion, the piecewise linear value functions defined by the coordinates of the break points. Each value function is defined by a matrix of breakpoints, where the first row corresponds to the abscissa (row labelled "x") and where the second row corresponds to the ordinate (row labelled "y").
criteriaIDs	Vector containing IDs of criteria, according to which the data should be filtered.

Examples

```
v<-list(
  Price = array(c(30, 0, 16, 0, 2, 0.0875),
    dim=c(2,3), dimnames = list(c("x", "y"), NULL)),
  Time = array(c(40, 0, 30, 0, 20, 0.025, 10, 0.9),
    dim = c(2, 4), dimnames = list(c("x", "y"), NULL)),
  Comfort = array(c(0, 0, 1, 0, 2, 0.0125, 3, 0.0125),
    dim = c(2, 4), dimnames = list(c("x", "y"), NULL)))

# plot the value functions

plotPiecewiseLinearValueFunctions(v)
```

`plotRadarPerformanceTable`
Function to plot radar plots of alternatives of a performance table.

Description

Plots radar plots of alternatives contained in a performance table, either in one radar plot, or on multiple radar plots. For a given alternative, the plot shows how far above/below average (the thick black line) each of the criteria performances values are (average taken w.r.t. to the filtered performance table).

Usage

```
plotRadarPerformanceTable(performanceTable,
                                criteriaMinMax=NULL,
                                alternativesIDs = NULL,
                                criteriaIDs = NULL,
                                overlay=FALSE)
```

Arguments

`performanceTable`
A matrix containing the performance table to be plotted. The columns are labelled according to the criteria IDs, and the rows according to the alternatives IDs.

`criteriaMinMax` Vector indicating whether criteria should be minimized or maximized. If it is given, a "higher" value in the radar plot corresponds to a more preferred value according to the decision maker. "min" (resp. "max") indicates that the criterion has to be minimized (maximized). The elements are named according to the IDs of the criteria.

`alternativesIDs`
Vector containing IDs of alternatives, according to which the data should be filtered.

`criteriaIDs` Vector containing IDs of criteria, according to which the data should be filtered.

`overlay` Boolean value indicating if the plots should be overlayed on one plot (TRUE), or not (FALSE)

Examples

```
library(MCDA)

performanceTable <- matrix(runif(6*9), ncol=6)

row.names(performanceTable) <- c("x1","x2","x3","x4","x5","x6","x7","x8","x9")

colnames(performanceTable) <- c("g1","g2","g3","g4","g5","g6")
```

```
criteriaMinMax <- c("min","max","min","max","min","max")

names(criteriaMinMax) <- c("g1","g2","g3","g4","g5","g6")

# plotRadarPerformanceTable(performanceTable, criteriaMinMax, overlay=TRUE)

plotRadarPerformanceTable(performanceTable, criteriaMinMax,
                          alternativesIDs = c("x1","x2","x3","x4"),
                          criteriaIDs = c("g1","g3","g4","g5","g6"),
                          overlay=FALSE)

# plotRadarPerformanceTable(performanceTable, criteriaMinMax,
#                           alternativesIDs = c("x1","x2"),
#                           criteriaIDs = c("g1","g3","g4","g5","g6"),
#                           overlay=FALSE)
```

`TOPSIS` *Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method*

Description

TOPSIS is a multi-criteria decision analysis method which was originally developed by Hwang and Yoon in 1981.

Usage

```
TOPSIS(performanceTable,
          criteriaWeights,
          criteriaMinMax,
          positiveIdealSolutions = NULL,
          negativeIdealSolutions = NULL,
          alternativesIDs = NULL,
          criteriaIDs = NULL)
```

Arguments

`performanceTable`
: Matrix or data frame containing the performance table. Each row corresponds to an alternative, and each column to a criterion. Rows (resp. columns) must be named according to the IDs of the alternatives (resp. criteria).

`criteriaWeights`
: Vector containing the weights of the criteria. The elements are named according to the IDs of the criteria.

`criteriaMinMax`
: Vector containing the preference direction on each of the criteria. "min" (resp. "max") indicates that the criterion has to be minimized (maximized). The elements are named according to the IDs of the criteria.

`positiveIdealSolutions`
: Vector containing the positive ideal solutions for each criteria. The elements are named according to the IDs of the criteria.

`negativeIdealSolutions`
: Vector containing the negative ideal solutions for each criteria. The elements are named according to the IDs of the criteria.

`alternativesIDs`
: Vector containing IDs of alternatives, according to which the data should be filtered.

`criteriaIDs`
: Vector containing IDs of criteria, according to which the data should be filtered.

Value

The function returns a vector containing the TOPSIS score for each alternative.

References

Hwang, C.L.; Yoon, K. (1981). Multiple Attribute Decision Making: Methods and Applications. New York: Springer-Verlag. http://hodgett.co.uk/topsis-in-excel/

Examples

```
performanceTable <- matrix(c(5490,51.4,8.5,285,6500,70.6,7,
                              288,6489,54.3,7.5,290),
                              nrow=3,
                              ncol=4,
                              byrow=TRUE)

row.names(performanceTable) <- c("Corsa","Clio","Fiesta")

colnames(performanceTable) <- c("Purchase Price","Economy",
                                   "Aesthetics","Boot Capacity")

weights <- c(0.35,0.25,0.25,0.15)

criteriaMinMax <- c("min", "max", "max", "max")

positiveIdealSolutions <- c(0.179573776, 0.171636015, 0.159499658, 0.087302767)
negativeIdealSolutions <- c(0.212610118, 0.124958799, 0.131352659, 0.085797547)

names(weights) <- colnames(performanceTable)
names(criteriaMinMax) <- colnames(performanceTable)
names(positiveIdealSolutions) <- colnames(performanceTable)
names(negativeIdealSolutions) <- colnames(performanceTable)

overall1 <- TOPSIS(performanceTable, weights, criteriaMinMax)

overall2 <- TOPSIS(performanceTable,
                       weights,
                       criteriaMinMax,
                       positiveIdealSolutions,
```

```
                          negativeIdealSolutions)

overall3 <- TOPSIS(performanceTable,
                      weights,
                      criteriaMinMax,
                      alternativesIDs = c("Corsa","Clio"),
                      criteriaIDs = c("Purchase Price","Economy","Aesthetics"))

overall4 <- TOPSIS(performanceTable,
                    weights,
                    criteriaMinMax,
                    positiveIdealSolutions,
                    negativeIdealSolutions,
                    alternativesIDs = c("Corsa","Clio"),
                    criteriaIDs = c("Purchase Price","Economy","Aesthetics"))
```

UTA *UTA method to elicit value functions.*

Description

Elicits value functions from a ranking of alternatives, according to the UTA method.

Usage

```
UTA(performanceTable, criteriaMinMax,
    criteriaNumberOfBreakPoints, epsilon,
    alternativesRanks = NULL,
    alternativesPreferences = NULL,
    alternativesIndifferences = NULL,
    criteriaLBs=NULL, criteriaUBs=NULL,
    alternativesIDs = NULL, criteriaIDs = NULL,
    kPostOptimality = NULL)
```

Arguments

`performanceTable`
: Matrix or data frame containing the performance table. Each row corresponds to an alternative, and each column to a criterion. Rows (resp. columns) must be named according to the IDs of the alternatives (resp. criteria).

`criteriaMinMax`
: Vector containing the preference direction on each of the criteria. "min" (resp. "max") indicates that the criterion has to be minimized (maximized). The elements are named according to the IDs of the criteria.

`criteriaNumberOfBreakPoints`
: Vector containing the number of breakpoints of the piecewise linear value functions to be determined. Minimum 2. The elements are named according to the IDs of the criteria.

`epsilon` Numeric value containing the minimal difference in value between two consecutive alternatives in the final ranking.

`alternativesRanks` Optional vector containing the ranks of the alternatives. The elements are named according to the IDs of the alternatives. If not present, then at least one of alternativesPreferences or alternativesIndifferences should be given.

`alternativesPreferences` Optional matrix containing the preference constraints on the alternatives. Each line of the matrix corresponds to a constraint of the type alternative a is strictly preferred to alternative b. If not present, then either alternativesRanks or alternativesIndifferences should be given.

`alternativesIndifferences` Optional matrix containing the indifference constraints on the alternatives. Each line of the matrix corresponds to a constraint of the type alternative a is indifferent to alternative b. If not present, then either alternativesRanks or alternativesPreferences should be given.

`criteriaLBs` Vector containing the lower bounds of the criteria to be considered for the elicitation of the value functions. If not specified, the lower bounds present in the performance table are taken.

`criteriaUBs` Vector containing the upper bounds of the criteria to be considered for the elicitation of the value functions. If not specified, the upper bounds present in the performance table are taken.

`alternativesIDs` Vector containing IDs of alternatives, according to which the datashould be filtered.

`criteriaIDs` Vector containing IDs of criteria, according to which the data should be filtered.

`kPostOptimality` A small positive threshold used during the postoptimality analysis (see article on UTA by Siskos and Lagreze in EJOR, 1982). If not specified, no postoptimality analysis is performed.

Value

The function returns a list structured as follows :

`optimum` The value of the objective function.

`valueFunctions` A list containing the value functions which have been determined. Each value function is defined by a matrix of breakpoints, where the first row corresponds to the abscissa (row labelled "x") and where the second row corresponds to the ordinate (row labelled "y").

`overallValues` A vector of the overall values of the input alternatives.

`ranks` A vector of the ranks of the alternatives obtained via the elicited value functions. Ties method = "min".

`Kendall` Kendall's tau between the input ranking and the one obtained via the elicited value functions. NULL if no input ranking is given but alternativesPreferences or alternativesIndifferences.

`errors` A vector of the errors (sigma) which have to be added to the overall values of the alternatives in order to respect the input ranking.

`minimumWeightsPO` In case a post-optimality analysis is performed, the minimal weight of each criterion, else NULL.

`maximumWeightsPO` In case a post-optimality analysis is performed, the maximal weight of each criterion, else NULL.

`averageValueFunctionsPO` In case a post-optimality analysis is performed, average value functions respecting the input ranking, else NULL.

References

E. Jacquet-Lagreze, J. Siskos, Assessing a set of additive utility functions for multicriteria decision-making, the UTA method, European Journal of Operational Research, Volume 10, Issue 2, 151–164, June 1982.

Examples

```
# the separation threshold

epsilon <-0.05

# the performance table

performanceTable <- rbind(
   c(3,10,1),
c(4,20,2),
c(2,20,0),
c(6,40,0),
c(30,30,3))

rownames(performanceTable) <- c("RER","METRO1","METRO2","BUS","TAXI")

colnames(performanceTable) <- c("Price","Time","Comfort")

# ranks of the alternatives

alternativesRanks <- c(1,2,2,3,4)

names(alternativesRanks) <- row.names(performanceTable)

# criteria to minimize or maximize

criteriaMinMax <- c("min","min","max")

names(criteriaMinMax) <- colnames(performanceTable)

# number of break points for each criterion
```

```
criteriaNumberOfBreakPoints <- c(3,4,4)

names(criteriaNumberOfBreakPoints) <- colnames(performanceTable)

x<-UTA(performanceTable, criteriaMinMax,
        criteriaNumberOfBreakPoints, epsilon,
        alternativesRanks = alternativesRanks)

# plot the value functions obtained

plotPiecewiseLinearValueFunctions(x$valueFunctions)

# apply the value functions on the original performance table

transformedPerformanceTable <- applyPiecewiseLinearValueFunctionsOnPerformanceTable(
  x$valueFunctions,
  performanceTable)

# calculate the overall score of each alternative

weightedSum(transformedPerformanceTable,c(1,1,1))

# ----------------------------------------
# ranking some cars (from original article on UTA by Siskos and Lagreze, 1982)

# the separation threshold

epsilon <-0.01

# the performance table

performanceTable <- rbind(
c(173, 11.4, 10.01, 10, 7.88, 49500),
c(176, 12.3, 10.48, 11, 7.96, 46700),
c(142, 8.2, 7.30, 5, 5.65, 32100),
c(148, 10.5, 9.61, 7, 6.15, 39150),
c(178, 14.5, 11.05, 13, 8.06, 64700),
c(180, 13.6, 10.40, 13, 8.47, 75700),
c(182, 12.7, 12.26, 11, 7.81, 68593),
c(145, 14.3, 12.95, 11, 8.38, 55000),
c(161, 8.6, 8.42, 7, 5.11, 35200),
c(117, 7.2, 6.75, 3, 5.81, 24800)
)

rownames(performanceTable) <- c(
  "Peugeot 505 GR",
  "Opel Record 2000 LS",
  "Citroen Visa Super E",
  "VW Golf 1300 GLS",
  "Citroen CX 2400 Pallas",
  "Mercedes 230",
  "BMW 520",
  "Volvo 244 DL",
```

```
  "Peugeot 104 ZS",
  "Citroen Dyane")

colnames(performanceTable) <- c(
  "MaximalSpeed",
  "ConsumptionTown",
  "Consumption120kmh",
  "HP",
  "Space",
  "Price")

# ranks of the alternatives

alternativesRanks <- c(1,2,3,4,5,6,7,8,9,10)

names(alternativesRanks) <- row.names(performanceTable)

# criteria to minimize or maximize

criteriaMinMax <- c("max","min","min","max","max","min")

names(criteriaMinMax) <- colnames(performanceTable)

# number of break points for each criterion

criteriaNumberOfBreakPoints <- c(5,4,4,5,4,5)

names(criteriaNumberOfBreakPoints) <- colnames(performanceTable)

# lower bounds of the criteria for the determination of value functions

criteriaLBs=c(110,7,6,3,5,20000)

names(criteriaLBs) <- colnames(performanceTable)

# upper bounds of the criteria for the determination of value functions

criteriaUBs=c(190,15,13,13,9,80000)

names(criteriaUBs) <- colnames(performanceTable)

x<-UTA(performanceTable, criteriaMinMax,
        criteriaNumberOfBreakPoints, epsilon,
        alternativesRanks = alternativesRanks,
        criteriaLBs = criteriaLBs, criteriaUBs = criteriaUBs)


# plot the value functions obtained

plotPiecewiseLinearValueFunctions(x$valueFunctions)

# apply the value functions on the original performance table
```

```
transformedPerformanceTable <- applyPiecewiseLinearValueFunctionsOnPerformanceTable(
      x$valueFunctions,
      performanceTable)

# calculate the overall score of each alternative

weights<-c(1,1,1,1,1,1)

names(weights)<-colnames(performanceTable)

weightedSum(transformedPerformanceTable,c(1,1,1,1,1,1))

# the same analysis with less extreme value functions
# from the post-optimality analysis

x<-UTA(performanceTable, criteriaMinMax,
        criteriaNumberOfBreakPoints, epsilon,
        alternativesRanks = alternativesRanks,
        criteriaLBs = criteriaLBs,
        criteriaUBs = criteriaUBs,
        kPostOptimality = 0.01)

# plot the value functions obtained

plotPiecewiseLinearValueFunctions(x$averageValueFunctionsPO)

# apply the value functions on the original performance table

transformedPerformanceTable <- applyPiecewiseLinearValueFunctionsOnPerformanceTable(
      x$averageValueFunctionsPO,
      performanceTable)

# calculate the overall score of each alternative

weights<-c(1,1,1,1,1,1)

names(weights)<-colnames(performanceTable)

weightedSum(transformedPerformanceTable,c(1,1,1,1,1,1))


# ----------------------------------------
# Let us consider only 2 criteria : Price and MaximalSpeed. What happens ?

# x<-UTA(performanceTable, criteriaMinMax,
#         criteriaNumberOfBreakPoints, epsilon,
#         alternativesRanks = alternativesRanks,
#         criteriaLBs = criteriaLBs, criteriaUBs = criteriaUBs,
#         criteriaIDs = c("MaximalSpeed","Price"))


# plot the value functions obtained
```

```
# plotPiecewiseLinearValueFunctions(x$valueFunctions,
#                                   criteriaIDs = c("MaximalSpeed","Price"))

# apply the value functions on the original performance table

# transformedPerformanceTable <- applyPiecewiseLinearValueFunctionsOnPerformanceTable(
#   x$valueFunctions,
#   performanceTable,
#   criteriaIDs = c("MaximalSpeed","Price")
#   )

# calculate the overall score of each alternative

# weights<-c(1,1,1,1,1,1)

# names(weights)<-colnames(performanceTable)

# weightedSum(transformedPerformanceTable,
#          weights, criteriaIDs = c("MaximalSpeed","Price"))

# ----------------------------------------
# An example without alternativesRanks, but with alternativesPreferences
# and alternativesIndifferences

alternativesPreferences <- rbind(c("Peugeot 505 GR","Opel Record 2000 LS"),
                                 c("Opel Record 2000 LS","Citroen Visa Super E"))

alternativesIndifferences <- rbind(c("Peugeot 104 ZS","Citroen Dyane"))

x<-UTA(performanceTable, criteriaMinMax,
        criteriaNumberOfBreakPoints, epsilon = 0.1,
        alternativesPreferences = alternativesPreferences,
        alternativesIndifferences = alternativesIndifferences,
        criteriaLBs = criteriaLBs, criteriaUBs = criteriaUBs
        )
```

UTADIS — *UTADIS method to elicit value functions in view of sorting alternatives in ordered categories*

Description

Elicits value functions from assignment examples, according to the UTADIS method.

Usage

```
UTADIS(performanceTable, criteriaMinMax,
    criteriaNumberOfBreakPoints,
    alternativesAssignments, categoriesRanks, epsilon,
```

```
criteriaLBs=NULL, criteriaUBs=NULL,
alternativesIDs = NULL, criteriaIDs = NULL,
categoriesIDs = NULL)
```

Arguments

`performanceTable`
: Matrix or data frame containing the performance table. Each row corresponds to an alternative, and each column to a criterion. Rows (resp. columns) must be named according to the IDs of the alternatives (resp. criteria).

`criteriaMinMax`
: Vector containing the preference direction on each of the criteria. "min" (resp. "max") indicates that the criterion has to be minimized (maximized). The elements are named according to the IDs of the criteria.

`criteriaNumberOfBreakPoints`
: Vector containing the number of breakpoints of the piecewise linear value functions to be determined. Minimum 2. The elements are named according to the IDs of the criteria.

`alternativesAssignments`
: Vector containing the assignments of the alternatives to categories. Minimum 2 categories. The elements of the vector are named according to the IDs of the alternatives.

`categoriesRanks`
: Vector containing the ranks of the categories. Minimum 2 categories. The elements of the vector are named according to the IDs of the categories.

`epsilon`
: Numeric value containing the minimal difference in value between the upper bound of a category and an alternative of that category.

`criteriaLBs`
: Vector containing the lower bounds of the criteria to be considered for the elicitation of the value functions. If not specified, the lower bounds present in the performance table are taken.

`criteriaUBs`
: Vector containing the upper bounds of the criteria to be considered for the elicitation of the value functions. If not specified, the upper bounds present in the performance table are taken.

`alternativesIDs`
: Vector containing IDs of alternatives, according to which the datashould be filtered.

`criteriaIDs`
: Vector containing IDs of criteria, according to which the data should be filtered.

`categoriesIDs`
: Vector containing IDs of categories, according to which the data should be filtered.

Value

The function returns a list structured as follows :

`optimum`
: The value of the objective function.

`valueFunctions`
: A list containing the value functions which have been determined. Each value function is defined by a matrix of breakpoints, where the first row corresponds to the abscissa (row labelled "x") and where the second row corresponds to the ordinate (row labelled "y").

overallValues — A vector of the overall values of the input alternatives.

categoriesLBs — A vector containing the lower bounds of the considered categories.

errors — A list containing the errors (sigmaPlus and sigmaMinus) which have to be substracted and added to the overall values of the alternatives in order to respect the input ranking.

References

J.M. Devaud, G. Groussaud, and E. Jacquet-Lagrèze, UTADIS : Une méthode de construction de fonctions d'utilité additives rendant compte de jugements globaux, European Working Group on Multicriteria Decision Aid, Bochum, 1980.

Examples

```
# the separation threshold

epsilon <-0.05

# the performance table

performanceTable <- rbind(
  c(3,10,1),
  c(4,20,2),
  c(2,20,0),
  c(6,40,0),
  c(30,30,3))

rownames(performanceTable) <- c("RER","METRO1","METRO2","BUS","TAXI")

colnames(performanceTable) <- c("Price","Time","Comfort")

# ranks of the alternatives

alternativesAssignments <- c("good","medium","medium","bad","bad")

names(alternativesAssignments) <- row.names(performanceTable)

# criteria to minimize or maximize

criteriaMinMax <- c("min","min","max")

names(criteriaMinMax) <- colnames(performanceTable)

# number of break points for each criterion

criteriaNumberOfBreakPoints <- c(3,4,4)

names(criteriaNumberOfBreakPoints) <- colnames(performanceTable)

# ranks of the categories

categoriesRanks <- c(1,2,3)
```

```
names(categoriesRanks) <- c("good","medium","bad")

x<-UTADIS(performanceTable, criteriaMinMax, criteriaNumberOfBreakPoints,
           alternativesAssignments, categoriesRanks,0.1)

# filtering out category "good" and assigment examples "RER" and "TAXI"

y<-UTADIS(performanceTable, criteriaMinMax, criteriaNumberOfBreakPoints,
           alternativesAssignments, categoriesRanks,0.1,
           categoriesIDs=c("medium","bad"),
           alternativesIDs=c("METRO1","METRO2","BUS"))

# working furthermore on only 2 criteria : "Comfort" and "Time"

z<-UTADIS(performanceTable, criteriaMinMax, criteriaNumberOfBreakPoints,
            alternativesAssignments, categoriesRanks,0.1,
            criteriaIDs=c("Comfort","Time"))
```

UTASTAR *UTASTAR method to elicit value functions.*

Description

Elicits value functions from a ranking of alternatives, according to the UTASTAR method.

Usage

```
UTASTAR(performanceTable, criteriaMinMax,
    criteriaNumberOfBreakPoints, epsilon,
    alternativesRanks = NULL,
    alternativesPreferences = NULL,
    alternativesIndifferences = NULL,
    criteriaLBs=NULL, criteriaUBs=NULL,
    alternativesIDs = NULL, criteriaIDs = NULL,
    kPostOptimality = NULL)
```

Arguments

`performanceTable`
: Matrix or data frame containing the performance table. Each row corresponds to an alternative, and each column to a criterion. Rows (resp. columns) must be named according to the IDs of the alternatives (resp. criteria).

`criteriaMinMax`
: Vector containing the preference direction on each of the criteria. "min" (resp. "max") indicates that the criterion has to be minimized (maximized). The elements are named according to the IDs of the criteria.

criteriaNumberOfBreakPoints
: Vector containing the number of breakpoints of the piecewise linear value functions to be determined. Minimum 2. The elements are named according to the IDs of the criteria.

epsilon
: Numeric value containing the minimal difference in value between two consecutive alternatives in the final ranking.

alternativesRanks
: Optional vector containing the ranks of the alternatives. The elements are named according to the IDs of the alternatives. If not present, then at least one of alternativesPreferences or alternativesIndifferences should be given.

alternativesPreferences
: Optional matrix containing the preference constraints on the alternatives. Each line of the matrix corresponds to a constraint of the type alternative a is strictly preferred to alternative b. If not present, then either alternativesRanks or alternativesIndifferences should be given.

alternativesIndifferences
: Optional matrix containing the indifference constraints on the alternatives. Each line of the matrix corresponds to a constraint of the type alternative a is indifferent to alternative b. If not present, then either alternativesRanks or alternativesPreferences should be given.

criteriaLBs
: Vector containing the lower bounds of the criteria to be considered for the elicitation of the value functions. If not specified, the lower bounds present in the performance table are taken.

criteriaUBs
: Vector containing the upper bounds of the criteria to be considered for the elicitation of the value functions. If not specified, the upper bounds present in the performance table are taken.

alternativesIDs
: Vector containing IDs of alternatives, according to which the datashould be filtered.

criteriaIDs
: Vector containing IDs of criteria, according to which the data should be filtered.

kPostOptimality
: A small positive threshold used during the postoptimality analysis (see article on UTA by Siskos and Lagreze in EJOR, 1982). If not specified, no postoptimality analysis is performed.

Value

The function returns a list structured as follows :

optimum
: The value of the objective function.

valueFunctions
: A list containing the value functions which have been determined. Each value function is defined by a matrix of breakpoints, where the first row corresponds to the abscissa (row labelled "x") and where the second row corresponds to the ordinate (row labelled "y").

overallValues
: A vector of the overall values of the input alternatives.

ranks
: A vector of the ranks of the alternatives obtained via the elicited value functions. Ties method = "min".

`Kendall` Kendall's tau between the input ranking and the one obtained via the elicited value functions.

`errors` A list containing the errors (sigmaPlus and sigmaMinus) which have to be substracted and added to the overall values of the alternatives in order to respect the input ranking.

`minimumWeightsPO` In case a post-optimality analysis is performed, the minimal weight of each criterion, else NULL.

`maximumWeightsPO` In case a post-optimality analysis is performed, the maximal weight of each criterion, else NULL.

`averageValueFunctionsPO` In case a post-optimality analysis is performed, average value functions respecting the input ranking, else NULL.

References

Siskos, Y. and D. Yannacopoulos, UTASTAR: An ordinal regression method for building additive value functions, Investigacao Operacional , 5 (1), 39–53, 1985.

Examples

```
# the separation threshold

epsilon <-0.05

# the performance table

performanceTable <- rbind(
   c(3,10,1),
c(4,20,2),
c(2,20,0),
c(6,40,0),
c(30,30,3))

rownames(performanceTable) <- c("RER","METRO1","METRO2","BUS","TAXI")

colnames(performanceTable) <- c("Price","Time","Comfort")

# ranks of the alternatives

alternativesRanks <- c(1,2,2,3,4)

names(alternativesRanks) <- row.names(performanceTable)

# criteria to minimize or maximize

criteriaMinMax <- c("min","min","max")

names(criteriaMinMax) <- colnames(performanceTable)
```

```
# number of break points for each criterion

criteriaNumberOfBreakPoints <- c(3,4,4)

names(criteriaNumberOfBreakPoints) <- colnames(performanceTable)

x<-UTASTAR(performanceTable, criteriaMinMax,
        criteriaNumberOfBreakPoints, epsilon,
        alternativesRanks = alternativesRanks)

# plot the value functions obtained

plotPiecewiseLinearValueFunctions(x$valueFunctions)

# apply the value functions on the original performance table

transformedPerformanceTable <- applyPiecewiseLinearValueFunctionsOnPerformanceTable(
  x$valueFunctions,
  performanceTable)

# calculate the overall score of each alternative

weightedSum(transformedPerformanceTable,c(1,1,1))

# ----------------------------------------
# ranking some cars (from original article on UTA by Siskos and Lagreze, 1982)

# the separation threshold

epsilon <-0.01

# the performance table

performanceTable <- rbind(
c(173, 11.4, 10.01, 10, 7.88, 49500),
c(176, 12.3, 10.48, 11, 7.96, 46700),
c(142, 8.2, 7.30, 5, 5.65, 32100),
c(148, 10.5, 9.61, 7, 6.15, 39150),
c(178, 14.5, 11.05, 13, 8.06, 64700),
c(180, 13.6, 10.40, 13, 8.47, 75700),
c(182, 12.7, 12.26, 11, 7.81, 68593),
c(145, 14.3, 12.95, 11, 8.38, 55000),
c(161, 8.6, 8.42, 7, 5.11, 35200),
c(117, 7.2, 6.75, 3, 5.81, 24800)
)

rownames(performanceTable) <- c(
  "Peugeot 505 GR",
  "Opel Record 2000 LS",
  "Citroen Visa Super E",
  "VW Golf 1300 GLS",
  "Citroen CX 2400 Pallas",
  "Mercedes 230",
```

```
  "BMW 520",
  "Volvo 244 DL",
  "Peugeot 104 ZS",
  "Citroen Dyane")

colnames(performanceTable) <- c(
  "MaximalSpeed",
  "ConsumptionTown",
  "Consumption120kmh",
  "HP",
  "Space",
  "Price")

# ranks of the alternatives

alternativesRanks <- c(1,2,3,4,5,6,7,8,9,10)

names(alternativesRanks) <- row.names(performanceTable)

# criteria to minimize or maximize

criteriaMinMax <- c("max","min","min","max","max","min")

names(criteriaMinMax) <- colnames(performanceTable)

# number of break points for each criterion

criteriaNumberOfBreakPoints <- c(5,4,4,5,4,5)

names(criteriaNumberOfBreakPoints) <- colnames(performanceTable)

# lower bounds of the criteria for the determination of value functions

criteriaLBs=c(110,7,6,3,5,20000)

names(criteriaLBs) <- colnames(performanceTable)

# upper bounds of the criteria for the determination of value functions

criteriaUBs=c(190,15,13,13,9,80000)

names(criteriaUBs) <- colnames(performanceTable)

x<-UTASTAR(performanceTable, criteriaMinMax,
        criteriaNumberOfBreakPoints, epsilon,
        alternativesRanks = alternativesRanks,
        criteriaLBs = criteriaLBs, criteriaUBs = criteriaUBs)


# plot the value functions obtained

plotPiecewiseLinearValueFunctions(x$valueFunctions)
```

```
# apply the value functions on the original performance table

transformedPerformanceTable <- applyPiecewiseLinearValueFunctionsOnPerformanceTable(
      x$valueFunctions,
      performanceTable)

# calculate the overall score of each alternative

weights<-c(1,1,1,1,1,1)

names(weights)<-colnames(performanceTable)

weightedSum(transformedPerformanceTable,c(1,1,1,1,1,1))

# the same analysis with less extreme value functions
# from the post-optimality analysis

x<-UTASTAR(performanceTable, criteriaMinMax,
        criteriaNumberOfBreakPoints, epsilon,
        alternativesRanks = alternativesRanks,
        criteriaLBs = criteriaLBs,
        criteriaUBs = criteriaUBs,
        kPostOptimality = 0.01)

# plot the value functions obtained

plotPiecewiseLinearValueFunctions(x$averageValueFunctionsPO)

# apply the value functions on the original performance table

transformedPerformanceTable <- applyPiecewiseLinearValueFunctionsOnPerformanceTable(
      x$averageValueFunctionsPO,
      performanceTable)

# calculate the overall score of each alternative

weights<-c(1,1,1,1,1,1)

names(weights)<-colnames(performanceTable)

weightedSum(transformedPerformanceTable,c(1,1,1,1,1,1))


# ----------------------------------------
# Let us consider only 2 criteria : Price and MaximalSpeed. What happens ?

x<-UTASTAR(performanceTable, criteriaMinMax,
        criteriaNumberOfBreakPoints, epsilon,
        alternativesRanks = alternativesRanks,
        criteriaLBs = criteriaLBs, criteriaUBs = criteriaUBs,
        criteriaIDs = c("MaximalSpeed","Price"))
```

```
# plot the value functions obtained

plotPiecewiseLinearValueFunctions(x$valueFunctions,
                                  criteriaIDs = c("MaximalSpeed","Price"))

# apply the value functions on the original performance table

transformedPerformanceTable <- applyPiecewiseLinearValueFunctionsOnPerformanceTable(
  x$valueFunctions,
  performanceTable,
  criteriaIDs = c("MaximalSpeed","Price")
  )

# calculate the overall score of each alternative

weights<-c(1,1,1,1,1,1)

names(weights)<-colnames(performanceTable)

weightedSum(transformedPerformanceTable,
          weights, criteriaIDs = c("MaximalSpeed","Price"))


# ----------------------------------------
# An example without alternativesRanks, but with alternativesPreferences
# and alternativesIndifferences

alternativesPreferences <- rbind(c("Peugeot 505 GR","Opel Record 2000 LS"),
                                c("Opel Record 2000 LS","Citroen Visa Super E"))

alternativesIndifferences <- rbind(c("Peugeot 104 ZS","Citroen Dyane"))

x<-UTASTAR(performanceTable, criteriaMinMax,
        criteriaNumberOfBreakPoints, epsilon = 0.1,
        alternativesPreferences = alternativesPreferences,
        alternativesIndifferences = alternativesIndifferences,
        criteriaLBs = criteriaLBs, criteriaUBs = criteriaUBs
        )
```

`weightedSum` *Weighted sum of evaluations of alternatives.*

Description

Computes the weighted sum of the evaluations of alternatives, stored in a performance table, with respect to a vector of criteria weights.

Usage

```
weightedSum(performanceTable, criteriaWeights,
      alternativesIDs = NULL, criteriaIDs = NULL)
```

Arguments

`performanceTable`
: Matrix or data frame containing the performance table. Each row corresponds to an alternative, and each column to a criterion. Rows (resp. columns) must be named according to the IDs of the alternatives (resp. criteria).

`criteriaWeights`
: Vector containing the weights of the criteria. The elements are named according to the IDs of the criteria.

`alternativesIDs`
: Vector containing IDs of alternatives, according to which the performance table should be filtered.

`criteriaIDs`
: Vector containing IDs of criteria, according to which the performance table should be filtered.

Value

The function returns a vector containing the weighted sum of the alternatives with respect to the criteria weights.

Examples

```
performanceTable <- matrix(runif(3*4), ncol=3)

row.names(performanceTable) <- c("x1","x2","x3","x4")

colnames(performanceTable) <- c("g1","g2","g3")

weights <- c(1,2,3)

names(weights) <- c("g1","g2","g3")

overall1 <- weightedSum(performanceTable, weights)

overall2 <- weightedSum(performanceTable, weights,
      alternativesIDs <- c("x2","x3"), criteriaIDs <- c("g2","g3"))
```

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