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Title Decision Models with Multi Attribute Utility Theory

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Description Provides functions for the creation, evaluation and test of decision models based in Multi Attribute Utility Theory (MAUT). Can process and evaluate local risk aversion utilities for a set of indexes, compute utilities and weights for the whole decision tree defining the decision model and simulate weights employing Dirichlet distributions under addition constraints in weights. Also includes other rating analysis methods as for example the Colley, Offensive - Defensive ratings and the ranking aggregation with Borda count.

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URL https://github.com/pedroguarderas/mau

Depends R (>= 3.0)

Imports data.table, gtools, stringr, igraph, RColorBrewer, ggplot2, Rdpack, markdown

RoxygenNote 7.2.3

Suggests knitr, rmarkdown, testthat (>= 3.1.0)

VignetteBuilder knitr

RdMacros Rdpack

Config/testthat/edition 3

Repository https://pedroguarderas.r-universe.dev

RemoteUrl https://github.com/pedroguarderas/mau

RemoteRef HEAD

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Contents

`mau-package` *mau*

Description

Provides functions for the creation, evaluation and test of decision models based in Multi Attribute Utility Theory (MAUT).

Details

MAUT models are defined employing a decision tree where similarity relations between different index utilities are defined, this helps to group utilities following a criteria of similarity. Each final node has an utility and weight associated, the utility of any internal node in the decision tree is computed by adding the weighted sum of eaf of its final nodes. In a model with n indexes, a criteria is composed by $C \subset \{1, \ldots, n\}$, the respective utility is given by:

$$\sum_{i \in C}^{n} w_i u_i(x_i)$$

Currently, each utility is defined like a piecewise risk aversion utility, those functions are of the following form:

$$ax + b$$

or

$$ae^{cx} + b$$

The current capabilities of **mau** are:

1. Read a list of risk aversion utilities defined in a standardized format.
2. Evaluate utilities of a table of indexes.
3. Load decision trees defined in column standard format.
4. Compute criteria utilities and weights for any internal node of the decision tree.
5. Simulate weights employing Dirichlet distributions under addition constraints in weights.

Author(s)

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References

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Barron FH, Barrett BE (1996). “Decision Quality Using Ranked Attribute Weights.” *Manage. Sci.*, **42**(11), 1515–1523. ISSN 0025-1909, doi:10.1287/mnsc.42.11.1515.

Bodily SE (1992). “Introduction: The Practice of Decision and Risk Analysis.” *Interfaces*, **22**(6), 1-4. doi:10.1287/inte.22.6.1.

See Also

Useful links:

- `https://github.com/pedroguarderas/mau`

Examples

```
library( mau )
vignette( topic = 'Running_MAUT', package = 'mau' )
```

bar_plot *Bar plot of utilities*

Description

Create ggplot2 bar plots of the utilities at any level of the decision model

Usage

```
bar_plot(model, deep, colors, title, xlab, ylab)
```

Arguments

model	data.table obtained with compute_model
deep	the deep to navigate the model object a select the utilities
colors	a list of colors for the bars
title	title for the bar plot
xlab	label for horizontal axis
ylab	label for vertical axis

Value

ggplot2 object.

Author(s)

Pedro Guarderas <pedro.felipe.guarderas@gmail.com>

Examples

```
library( mau )
vignette( topic = 'Running_MAUT', package = 'mau' )
```

borda_count *Borda count*

Description

Rank aggregation with the Borda count method

Usage

```
borda_count(R, v = NULL)
```

Arguments

`R`	matrix with rankings
`v`	vector of votes for each ranking

Value

Vector with aggregated ranking

Author(s)

Pedro Guarderas <`pedro.felipe.guarderas@gmail.com`>

Examples

```
m <- 10
n <- 5
R <- matrix( runif( m * n ), m, n )
v <- sample( 50:100, n )
r <- borda_count( R, v )
```

`colley_rating` *Colley method*

Description

Rank computation using the Cooley method with ties if required

Usage

```
colley_rating(n, w, l, t = NULL)
```

Arguments

`n`	symmetric matrix of number of times each player faced another, zero diagonal
`w`	accumulated vector of wins for each player
`l`	accumulated vector of losses for each player
`t`	symmetric matrix of ties, with zero diagonal

Value

Vector with ratings

Author(s)

Pedro Guarderas <`pedro.felipe.guarderas@gmail.com`>

Examples

```
d <- 10
n <- matrix( sample( x = 0:5, size = d * d, replace = TRUE ), d, d )
n <- n + t( n )
diag( n ) <- 0
g <- rowSums( n )
# Number of win matches for each team
w <- sapply( 1:d, FUN = function( i ) sample( x = 1:g[i], size = 1, replace = TRUE ) )
# Number of lost matches for ech team
l <- rowSums( n ) - w
r <- colley_rating( n, w, l )
```

compute_model *Evaluation of decision tree nodes*

Description

Evaluation of decision tree nodes. All the MAUT model is computed at every level the utilities are computed considering the given weights.

Usage

```
compute_model(tree, utilities, weights)
```

Arguments

`tree`	initial tree structure with utilities in its leafs.
`utilities`	data.table with ordered columns containing the values of utilities.
`weights`	weights for the decision model.

Details

The whole decision model can be computed a any level and represented in a table format.

Value

data.table structure containing the utilities of the model for every level the decision tree.

Author(s)

Pedro Guarderas, Andrés Lopez <`pedro.felipe.guarderas@gmail.com`>

See Also

`stand_string`, `read_utilities`, `eval_utilities`, `read_tree`, `make_decision_tree`, `sim_const_weights`.

Examples

```
vignette( topic = 'Running_MAUT', package = 'mau' )
```

`deep_compute` *Compute the deep position of every node*

Description

For the computation of the complete decision model is necessary to establish the deep position of every node.

Usage

```
deep_compute(tree)
```

Arguments

`tree`	igraph object representing the tree

Value

igraph object updated

Author(s)

Pedro Guarderas, Andrés Lopez

See Also

`read_tree`

`divide_weights` *Divide weights of internal nodes*

Description

After the addition of weights for internal nodes the final weights have to be computed dividing by the total weight of each parent.

Usage

```
divide_weights(tree)
```

Arguments

`tree`	igraph object representing the tree

Value

igraph object updated

Author(s)

Pedro Guarderas, Andrés Lopez

See Also

`read_tree`

`eval_utilities` *Evaluate utilities*

Description

Evaluation of utilities for a data.table of indexes, the utilities functions are computed over every index represented by each column of the input table.

Usage

```
eval_utilities(index, columns, functions)
```

Arguments

`index`	data.table of indexes.
`columns`	columns with indexes where the utilities will be computed.
`functions`	vector of characters with name of functions.

Details

Every index has associated an utility function, inside `mau` is possible to employ any functions, the only special requirement is that the utility has to be normalized, this means that the utility is bounded between 0 and 1.

Also is possible to consider utilities with constant risk aversion CRA, in the sense of Arrow, for such case there is only two types of functions $u(x) = ax + b$ or $u(x) = ae^{bx} + c$, to determine these functions, it is only necessary to specify the parameters a, b and c. For a decision model only elaborated with CRA utilities, `mau` could read a text file where every utility is piecewise defined.

The format for the text file containing the definition of utility functions is given by is:

[Header]

[Function name]
[min1 max1 a1 b1 c1]
[min2 max2 a2 b2 c2]
[min3 max3 a3 b3 c3]
...
[Function name]
[min1 max1 a1 b1 c1]
[min2 max2 a2 b2 c2]
[min3 max3 a3 b3 c3]

...

If the coefficient c is non zero the function is interpreted as an exponential type.

Value

data.table with utilities evaluated for every index.

Author(s)

Pedro Guarderas, <pedro.felipe.guarderas@gmail.com>, Andrés Lopez.

See Also

read_utilities, stand_string

Examples

```
library( mau )
vignette( topic = 'Running_MAUT', package = 'mau' )
```

index_weights *Compute leaves weights*

Description

The computation of weights could be determined in an inverse processes given the internal weights.

Usage

```
index_weights(tree)
```

Arguments

tree	igraph object representing the tree

Value

igraph object updated

Author(s)

Pedro Guarderas, Andrés Lopez

See Also

read_tree

make_decision_tree *Evaluate utilities*

Description

Create decision tree for MAUT models exporting to an igraph object.

Usage

```
make_decision_tree(tree.data)
```

Arguments

`tree.data`	data.table with decision tree information.

Details

With the tree information loaded by the `read_tree` the decision tree could be represented like an igraph object.

Value

igraph object containing the graph of the decision tree.

Author(s)

Pedro Guarderas, Andrés Lopez <pedro.felipe.guarderas@gmail.com>

See Also

`read_tree`

Examples

```
library( data.table )
library( igraph )
file <- system.file("extdata", "tree.csv", package = "mau" )
tree.data <- read_tree( file, skip = 0, nrows = 8 )
tree <- make_decision_tree( tree.data )
plot( tree )
```

`od_rating` *Offensive - Defensive rating method*

Description

Computes rating using the offensive-defensive method

Usage

```
od_rating(A, iter = 1000, rer = 1e-12)
```

Arguments

`A`	matrix with scores
`iter`	number of iterations
`rer`	relative error to stop computation

Value

list with rating, offensive score, defensive score and number of iterations.

Author(s)

Pedro Guarderas <pedro.felipe.guarderas@gmail.com>

Examples

```
A <- matrix( c( 0, 7, 21, 7, 0,
52, 0, 34, 25, 27,
24, 16, 0, 7, 3,
38, 17, 5, 0, 14,
45, 7, 30, 52, 0 ), nrow = 5, ncol = 5 )
r <- od_rating( A )
```

`plot_sim_weight` *Plot decision MAUT model with weights simulations*

Description

Spider plot for the decision model considering the weights simulated with a Dirichlet distributions, every simulation is represented with lines, a box plot is included to account the behavior of every global utility.

Usage

```
plot_sim_weight(
  S,
  title = "Simulations",
  xlab = "ID",
  ylab = "Utility",
  lines.cols = "blue",
  box.col = "gold",
  box.outlier.col = "darkred",
  utility.col = "darkgreen",
  utility.point.col = "darkgreen",
  text.col = "black"
)
```

Arguments

`S`	first element of the simulation list produced by the function `sim_weights`, `sim_const_weights`.
`title`	text for the title plot.
`xlab`	text for x-axis label.
`ylab`	text for y-axis label.
`lines.cols`	the spectrum of colors for the simulation is selected randomly from a base color.
`box.col`	color for the boxes.
`box.outlier.col`	color for the outlier points representing the extreme observations in the boxplot.
`utility.col`	the main utility value is also plotted with this specific color.
`utility.point.col`	the line of main utilities is plotted with points represented with this color.
`text.col`	color for the text values plotted for each utility.

Value

ggplot object with the plot of simulations.

Author(s)

Pedro Guarderas

See Also

`sim_const_weights` `sim_weights`

`read_tree` *Evaluate utilities*

Description

Read a csv file where the decision tree is defined.

Usage

```
read_tree(file, skip, nrows)
```

Arguments

`file`	input csv file containing the tree.
`skip`	starting row for read.
`nrows`	number of rows to read.

Value

data.table with utilities.

Author(s)

Pedro Guarderas, Andrés Lopez

See Also

`read_utilities`, `make_decision_tree`

Examples

```
library( data.table )
library( igraph )
file <- system.file("extdata", "tree.csv", package = "mau" )
sheetIndex <- 1
tree.data <- read_tree( file, skip = 0, nrows = 8 )
```

read_utilities *Read utilities*

Description

Builds utility functions from definition standard.

Usage

```
read_utilities(file, script, lines, skip = 2, encoding = "utf-8")
```

Arguments

`file`	standardize file with definitions.
`script`	output script where the utility functions are defined automatically.
`lines`	number lines to read in `file`.
`skip`	to read the `file` it had to `skip` a given number of lines.
`encoding`	file encoding.

Details

The basic MAUT models are built with functions of constant absolute risk aversion, this functions could be defined with simple parameters, only is necessary a function name and the domain of definition of every function and more important is necessary no more than three coefficients for the function definition.

Value

Returns data table with definition of utility functions by range.

Author(s)

Pedro Guarderas, Andrés Lopez

See Also

`stand_string`

Examples

```
library( data.table )
file <- system.file("extdata", "utilities.txt", package = "mau" )
script <- 'utilities.R'
lines <- 17
skip <- 2
encoding <- 'utf-8'
functions <- read_utilities( file, script, lines, skip, encoding )
```

`sim_const_weights` *Simulation of constrained weights*

Description

Simulation of weights employing the Dirichlet distribution. The concentration parameters for the Dirichlet distribution are tentative weights, additionally constraints over partial sums of weights are introduced by a list ordered structure.

Usage

```
sim_const_weights(n, utilities, alpha, constraints)
```

Arguments

`n`	number of simulations
`utilities`	utility dataframe, first column is the identifier
`alpha`	concentration parameter for the Dirichlet distribution
`constraints`	list of sum constraints

Details

Employing the properties of the Dirichlet distribution, weights could be simulated with a given concentration, additionally this simulation can be carry out by subsets of weights only to meet specific constraints.

Value

List with data.frames {simulation, weights} with total utilities and simulated weights

Author(s)

Pedro Guarderas `<pedro.felipe.guarderas@gmail.com>`

See Also

`eval_utilities`

Examples

```
library( data.table )
N <- 10
utilities <- data.table( id = 1:N,
                         u1 = runif( N, 0, 1 ),
                         u2 = runif( N, 0, 1 ),
                         u3 = runif( N, 0, 1 ),
                         u4 = runif( N, 0, 1 ) )
n <- 100
```

```
alpha <- c( 0.2, 0.5, 0.1, 0.2 )
constraints <- list( list( c(1,2), 0.7 ),
                     list( c(3,4), 0.3 ) )
S <- sim_const_weights( n, utilities, alpha, constraints )
plot.S <- plot_sim_weight( S$simulation, title = 'Simulations',
                           xlab = 'ID', ylab = 'Utility' )
plot( plot.S )
```

sim_weights *Simulation of weights*

Description

Simulation of weights employing the Dirichlet distribution. The concentration parameters for the Dirichlet distribution are tentative weights.

Usage

```
sim_weights(n, utilities, alpha)
```

Arguments

`n`	number of simulations
`utilities`	utility dataframe, first column is the identifier
`alpha`	concentration parameter for the Dirichlet distribution

Details

Taking advantage of the Dirichlet distribution properties, the weights could be simulated with a concentration around given weights.

Value

List with data.frames {simulation, weights} with total utilities and simulated weights

Author(s)

Pedro Guarderas <`pedro.felipe.guarderas@gmail.com`>

See Also

`eval_utilities`

Examples

```
library( data.table )
N <- 10
utilities <- data.table( id = 1:N,
                       u1 = runif( N, 0, 1 ),
                       u2 = runif( N, 0, 1 ),
                       u3 = runif( N, 0, 1 ),
                       u4 = runif( N, 0, 1 ) )
n <- 100
alpha <- c( 0.2, 0.5, 0.1, 0.2 )
S <- sim_weights( n, utilities, alpha )
```

---

spider_plot *Spider plot*

Description

Generates an spider plot for a decision model

Usage

```
spider_plot(
  data,
  data.label,
  data.fill,
  data.color,
  data.linetype,
  data.alpha,
  data.size,
  data.label.color,
  data.label.size,
  group,
  criteria,
  valor,
  title,
  title.font,
  title.color,
  title.size,
  label.font,
  label.size,
  label.color,
  label.angle,
  label.position,
  theta,
  grid,
  grid.color,
  grid.radius.color,
  grid.linetype,
  grid.size,
  grid.radius.linetype,
  grid.radius.size,
  axis,
  axis.label,
  axis.color,
  axis.size,
  axis.linetype,
  axis.angle,
  axis.label.color,
  axis.label.size,
  axis.label.displace,
  axis.label.angle,
  legend.position,
  legend.size,
  legend.text.color,
  plot.margin
)
```

Arguments

`data`	data.table with the utilities of a decision model
`data.label`	data label
`data.fill`	data fill color
`data.color`	data color
`data.linetype`	line type for data
`data.alpha`	alpha scale for data
`data.size`	line size for data
`data.label.color`	label color for data
`data.label.size`	label size for data
`group`	name for the column of groups
`criteria`	column name for criteria
`valor`	column name for utilities
`title`	plot title
`title.font`	font type for title
`title.color`	plot title color
`title.size`	plot title size
`label.font`	font type for labels
`label.size`	labels size
`label.color`	labels color

`label.angle`	labels angle
`label.position`	labels position
`theta`	plot rotation angle
`grid`	grid for plot
`grid.color`	grid color
`grid.radius.color`	grid radius color
`grid.linetype`	grid line type
`grid.size`	grid line size
`grid.radius.linetype`	grid radius line type
`grid.radius.size`	grid radius line size
`axis`	axis
`axis.label`	axis label
`axis.color`	axis color
`axis.size`	axis size
`axis.linetype`	axis line type
`axis.angle`	axis angle
`axis.label.color`	axis label color
`axis.label.size`	axis label size
`axis.label.displace`	axis label displacement
`axis.label.angle`	axis label angel
`legend.position`	label position
`legend.size`	legend size
`legend.text.color`	legend text color
`plot.margin`	plot margin

Value

ggplot2 object with the spider plot

Author(s)

Pedro Guarderas, Andrés Lopez <`pedro.felipe.guarderas@gmail.com`>

Examples

```
# Preparing data
library( data.table )
library( ggplot2 )
library( mau )
n <- 27
m <- 4
cols <- sample( colors()[ grepl('(purple|blue|olive)', colors() ) ], m, replace = TRUE )

axis <- seq( 0.1, 1, 0.1 )
dat <- data.table( grp = paste( 'A', sort( rep( 1:m, n ) ), sep = '' ),
                   val = qlnorm( runif( m * n ) * plnorm( 1, 3, 4 ), 3, 4 ) )

dat <- dat[ order( grp, val ) ]
dat[ , cri := factor( rep( paste( 'c', n:1, sep = '' ), m ),
              levels = paste( 'c', n:1, sep = '' ), ordered = TRUE ) ]
dat <- as.data.frame( dat )

parameters <- list( data = dat,
                    data.label = paste( 'A', 1:m,  ' class', sep = '' ),
                    data.fill = cols,
                    data.color = cols,
                    data.linetype = rep( 'solid', m ),
                    data.alpha = rep( 0.05, m ),
                    data.size = rep( 0.7, m ),
                    data.label.color = 'black',
                    data.label.size = 15,

                    group = as.name( 'grp' ),
                    criteria = as.name( 'cri' ),
                    valor = as.name( 'val' ),

                    # Spider plot parameters
                    title = 'Spider',
                    title.font = 'New Times Roman',
                    title.color = 'red3',
                    title.size = 20,

                    label.font = 'New Times Roman',
                    label.size = rep( 3, n ),
                    label.color = rep( 'steelblue4', n ),
                    label.angle = rep( 0, n ),
                    label.position = rep( 1.05, n ),

                    theta = pi/3,

                    grid = seq( 0.1, 1, 0.1 ),
                    grid.color = 'grey75',
                    grid.radius.color = 'grey75',
                    grid.linetype = 'dashed',
                    grid.size = 0.5,
                    grid.radius.linetype = 'solid',
                    grid.radius.size = 0.5,

                    axis = axis, # Same as grid
                    axis.label = paste( 100 * axis, '%', sep = '' ),
                    axis.color = 'black',
                    axis.size = 0.7,
                    axis.linetype = 'solid',
                    axis.angle = 0.4*pi,
                    axis.label.color = 'darkgreen',
                    axis.label.size = 3,
                    axis.label.displace = -0.07,
                    axis.label.angle = 0,

                    legend.position = c(0.9, 0.9),
                    legend.size = 0.5,
                    legend.text.color = 'black',

                    plot.margin = unit( c( 1.0, 1.0, 1.0, 1.0 ),"cm") )


p <- do.call( spider_plot, parameters )

plot(p)
```

`stand_string` *Standardize strings*

Description

Function to correct and standardize names, designed to eliminate special characters, spaces and other characters.

Usage

```
stand_string(x, chr = NULL, rep = NULL)
```

Arguments

`x`	text to be formatted
`chr`	character vector of replace characters
`rep`	character vector of replacement characters

Value

Returns data table with definition of utility functions by range

Author(s)

Julio Andrade, Pedro Guarderas, Andrés Lopez <`pedro.felipe.guarderas@gmail.com`>

Examples

```
x <- c( "H?\u00da\u00e0n with C@1_ad1",
        "M\u00a1a/\u00ac\u00b0r&\u00eca *_the#-rot",
        "ju%LI\u00d6 a P\u00e9rs",
        "(S)tev\n\u00e9n\t los cat%$" )
y <- sapply( x, FUN = stand_string )
names( y ) <- NULL
```

`sum_weights` *Sum weights for internal nodes*

Description

The weights of the internal nodes has to be computed first is necessary to add each weights of the leaves.

Usage

```
sum_weights(tree)
```

Arguments

`tree`	igraph object representing the tree

Value

igraph object updated

Author(s)

Pedro Guarderas, Andrés Lopez

See Also

`read_tree`

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