

JMcDM: A Julia package for multiple-criteria decision making tools

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Abstract

Ca. 100 words

Keywords: keyword 1, keyword 2, keyword 3

Required Metadata

Current code version

Ancillary data table required for subversion of the codebase. Kindly replace examples in right column with the correct information about your current code, and leave the left column as it is.

Nr.	Code metadata description	Please fill in this column
C1	Current code version	v0.1.5
C2	Permanent link to code/repository used for this code version	https://github.com/jbytecode/JMcDM
C3	Code Ocean compute capsule	
C4	Legal Code License	MIT
C5	Code versioning system used	git
C6	Software code languages, tools, and services used	Julia
C7	Compilation requirements, operating environments & dependencies	Julia 1.4
C8	If available Link to developer documentation/manual	https://jbytecode.github.io/JMcDM/docs/build
C9	Support email for questions	mhsatman@istanbul.edu.tr

Table 1: Code metadata (mandatory)

1. Motivation and significance

The one-dimensional array a is in ascending order if and only if $a_i \leq a_{i+1}$ where $i = 1, 2, \dots, n - 1$, and n is the length of array. In other terms, the process of ordering numbers requires the logical \leq operator to be perfectly defined. Since the operator \leq is not defined for any set of points in higher dimensions, \mathbb{R}^p for $p \geq 2$, there is not a unique ordering of points.

In multi-dimensional case, the binary domination operator \succ applied on points a and b , $a \succ b$, is true iff each item in a is not worse than the

correspoing item in b and at least one item is better than the corresponding item in b ?. On the other hand, the more relaxed operator \succeq returns true if each item in a is as good as the corresponding item in b ?. Several outranking methods in MCDA (Multiple-Criteria Decision Analysis) define a unique ranking mechanism to select the best alternative among others.

Suppose a decision process has n alternatives and m criteria which are either to be maximized or minimized. Each single criterion has a weight $0 \leq w_i \leq 1$ where $\sum_i^m w_i = 1$. f_i is either maximum or minimum. $g_j(.)$ is evolution function and it is taken as $g_j(x) = x$ in many methods. A multiple criteria decision problem can be represented using the decision table

Criteria	C_1	C_2	\dots	C_m
Weights	w_1	w_2	\dots	w_m
Functions	f_1	f_2	\dots	f_m
A_1	$g_1(A_1)$	$g_2(A_1)$	\dots	$g_m(S_A)$
A_2	$g_1(A_2)$	$g_2(A_2)$	\dots	$g_m(A_2)$
\vdots	\vdots	\vdots	\ddots	\vdots
A_n	$g_1(A_n)$	$g_2(A_n)$	\dots	$g_m(A_n)$

Table 2: Sample decision matrix

without loss of generality. When A_1, A_2, \dots, A_n are alternatives and C_1, C_2, \dots, C_m are different situations of a single criterion then the decision problem is said to be single criterion decision problem. If A_i and C_j are strategies of two game players then $g_j(A_i)$ is the gain of the row player when she selects the strategy i and the column player selects the strategy C_j .

Multiple-criteria decision-making (MCDM) tools provide several algo-

25 rithms for ordering or selecting alternatives and/or determining the weights
 26 when there is uncertainty. Although some algorithms are suitable for hand
 27 calculations, a computer software is often required. *PyTOPS* is a Python
 28 tool for TOPSIS ?. *Super Decisions* is a software package which is mainly
 29 focused on AHP (Analytic Hierarchy Process) and ANP (Analytic Network
 30 Process) ?. *Visual Promethee* implements Promethee method on Windows
 31 platforms ?. *M-BACBETH* is an other commercial software product that
 32 implements MACBETH with a easy to use GUI. ?. [\[List more software here](#)
 33 [if exist.\]](#)

34 *JMcDM* is designed to provide a developer-friendly library for solving
 35 multiple-criteria decision problems in Julia ?. Since Julia is a dynamic lan-
 36 guage, it is also useful for researchers that familiar with REPL environments.
 37 The package includes multi-criteria decision methods as well as a game solver
 38 for zero-sum games and methods for single criterion methods.

39 **2. Software description**

40 *2.1. Software Architecture*

41 *JMcDM* provides a framework for performing multi-criteria decision anal-
 42 ysis as well as it includes utility functions for development of new methods.
 43 Each single MCDM method returns an object in subtype of `MCDMResult`
 44 which is defined as

```

    45 abstract type MCDMResult end
  
```

46 and it is used to derive new return types. For instance, the `topsis()` function
 47 always returns a `TopsisResult` object which is defined as

```

48 struct TopsisResult <: MCDMResult
49     decisionMatrix::DataFrame
50     weights::Array{Float64,1}
51     normalizedDecisionMatrix::DataFrame
52     normalizedWeightedDecisionMatrix::DataFrame
53     bestIndex::Int64
54     scores::Array{Float64,1}
55 end

```

and holds many outputs in a single `struct`. Function definitions are also similar but they may differ depending on the requirements of algorithms. For instance the function `topsis` is defined as

```

59 function topsis(
60     decisionMat::DataFrame,
61     weights::Array{Float64,1},
62     fns::Array{Function,1})::TopsisResult

```

where `decisionMat` is the decision matrix, `weights` are weights of criteria, and `fns` is an array of functions (either `minimum` or `maximum`) that determine the optimization directions.

The package is registered in Julia package repository and it is available for downloading and installing using Julia's package manager.

```

68 julia> using Pkg
69 julia> Pkg.add("JMCDM")

```

and

71 `julia> \]`

72 `(@v1.5) pkg> add JMCDM`

73 present two distinct ways of install the package.

74 *2.2. Software Functionalities*

75 The package implements methods for TOPSIS (Technique for Order Pref-
76 erence by Similarity to Ideal Solutions)?, ELECTRE (Elemination and Choice
77 Translating Reality)?, PROMETHEE (Preference Ranking Organization METHod
78 for Enrichment of Evaluations)?, DEMATEL (The Decision Making Trial
79 and Evaluation Laboratory)?, MOORA (Multi-Objective Optimization By
80 Ratio Analysis)?, VIKOR (VlseKriterijumska Optimizcija I Kaompromisno
81 Resenje in Serbian)?, AHP (Analytic Hierarchy Process)?, GRA (Grey Re-
82 lational Analysis)?, NDS (Non-dominated Sorting)?, SAW (Simple Additive
83 Weighting)?, ARAS (Additive Ratio Assessment)?, WPM (Weighted Prod-
84 uct Model)?, WASPAS (Weighted Aggregated Sum Product ASsessment)?,
85 EDAS (Evaluation based on Distance from Average Solution)?, MARCOS
86 (Measurement Alternatives and Ranking according to COmpromise Solu-
87 tion)?, MABAC (Multi-Attributive Border Approximation area Compari-
88 son)?, MAIRCA (Multi Attributive Ideal-Real Comparative Analysis)?, CO-
89 PRAS (COMplex PROportional ASsessment)?, COCOSO (Combined Com-
90 promise Solution)?, and CRITIC (CRiteria Importance Through Intercrite-
91 ria Correlation)? for multiple-criteria tools. The package also performs DEA
92 for Data Envelopement Analysis? and includes a method for zero-sum game
93 solver.

94 *2.3. Sample code snippets analysis*

95 Suppose a decision problem is given in Table 3.

Criteria	Age	Size	Price	Distance	Population
Weights	0.35	0.15	0.25	0.20	0.05
Functions	min	max	min	min	max
A_1	6	140	150000	950	1500
A_1	4	90	100000	1500	2000
A_1	12	140	75000	550	1100

Table 3: Decision matrix

96 In this sample problem, a decision maker is subject to select an apartment
 97 by considering age of the building, size (in m^2 s), price (in \$), distance to city
 98 centre, and nearby population. The data can be entered as a two-dimensional
 99 array (matrix) or as a DataFrame object:

```

100 julia> using JMCDM, DataFrames
101 julia> df = DataFrame(
102   :age      => [6.0, 4, 12],
103   :size     => [140.0, 90, 140],
104   :price    => [150000.0, 100000, 75000],
105   :distance => [950.0, 1500, 550],
106   :population => [1500.0, 2000, 1100]);
107
108 julia> w = [0.35, 0.15, 0.25, 0.20, 0.05];
109 julia> fns = [minimum, maximum, minimum, minimum, maximum];

```

```

110 julia> result = topsis(df, w, fns);
111 julia> result.scores
112 3-element Array{Float64,1}:
113 0.5854753145549456
114 0.6517997936899308
115 0.41850223305822903
116
117 julia> result.bestIndex
118 2

```

119 The same analysis can be performed using `saw()` for the method of Simple
120 Additive Weighting

```

121 julia> result = saw(df, w, fns);
122 julia> result.bestIndex
123 2

```

124 as well as using `wpm` for the method of Weighted Product Method

```

125 julia> result = wpm(df, w, fns);
126 julia> result.bestIndex
127 2

```

128 For any method, `?methodname` shows the documentation as in the same
129 way in other Julia packages.

130 **3. Illustrative Examples**

131 Provide at least one illustrative example to demonstrate the major func-
132 tions.


```
julia> result1
```

3x7 DataFrame							
Row	topsis	electre	cocoso	moora	vikor	wpm	waspas
	String	String	String	String	String	String	String
1			✓	✓	✓		
2	✓	✓				✓	✓
3		✓					

Figure 1: Image A

```
julia> result2
```

3x7 DataFrame							
Row	grey	aras	saw	edas	marcos	mabac	mairca
	String	String	String	String	String	String	String
1							
2		✓	✓	✓	✓		
3	✓					✓	✓

Figure 2: Image A

```
133 julia> methods1 = [:topsis, :electre, :vikor, :moora, :cocoso, :wpm, :waspas]
134 julia> result1 = summary(df, w, fns, methods1);

135 julia> methods2 = [:aras, :saw, :edas, :marcos, :mabac, :mairca, :grey];
136 julia> result2 = summary(df, w, fns, methods2);
```

137 4. Impact

138 **This is the main section of the article and the reviewers weight**
139 **the description here appropriately** Indicate in what way new research

140 questions can be pursued as a result of the software (if any). Indicate in
141 what way, and to what extent, the pursuit of existing research questions is
142 improved (if so). Indicate in what way the software has changed the daily
143 practice of its users (if so). Indicate how widespread the use of the software
144 is within and outside the intended user group. Indicate in what way the
145 software is used in commercial settings and/or how it led to the creation of
146 spin-off companies (if so).

147 *JMcDM* provides a moderate number of MCDA tools and utility func-
148 tions for developing new methods as well as performing decision analysis
149 using a single function call for each method. A researcher can easily perform
150 sequential analysis by changing the problem parameters and can compare
151 results of many tools. Existing software packages are mainly focused on pro-
152 viding a small subset of methods. *JMcDM* is an all-in-one solution and has
153 potential for increasing user productivity. Seeing the different results pro-
154 duced by the methods together also helps to discover which parameters the
155 research is more sensitive to and the reasons for them.

156 **5. Conclusions**

157 Set out the conclusion of this original software publication.

158 **6. Conflict of Interest**

159 We wish to confirm that there are no known conflicts of interest associated
160 with this publication and there has been no significant financial support for
161 this work that could have influenced its outcome.

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165 Journal.

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192 **Current executable software version**

193 Ancillary data table required for sub version of the executable software:
194 (x.1, x.2 etc.) kindly replace examples in right column with the correct
195 information about your executables, and leave the left column as it is.

Nr.	(Executable) software meta-data description	Please fill in this column
S1	Current software version	For example 1.1, 2.4 etc.
S2	Permanent link to executables of this version	For example: <i>https</i> : <i>//github.com/combogenomics/DuctApe/releases/tag/DuctApe-0.16.4</i>
S3	Legal Software License	List one of the approved licenses
S4	Computing platforms/Operating Systems	For example Android, BSD, iOS, Linux, OS X, Microsoft Windows, Unix-like , IBM z/OS, distributed/web based etc.
S5	Installation requirements & dependencies	
S6	If available, link to user manual - if formally published include a reference to the publication in the reference list	For example: <i>http</i> : <i>//mozart.github.io/documentation/</i>
S7	Support email for questions	

Table 4: Software metadata (optional)