AHP Editor v0.1

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Introduction

This text was originally written as part of new edition of text book: Modelling of Decision Processes. Since the new edition is not finished – this fragment is being published separately as introductory material to the AHP Editor and "ahp" package for R.

AHP (Analytic Hierarchy Process) is the method developed by professor Saaty [1] in late seventies of last century. It quickly gained popularity a during the years has been used to solve various types of decision problems including safety and security related decision making, i.e.. Preference evaluation of infrastructure security [2, 3], information security [4] and others.

During that time various support tools and programs has been developed to ease creation of decision hierarchies and weight coefficient computation. From those better known for example SuperDecisions [5]. Prof .Saaty did participate in development process of SuperDecisions.

To model larger decision problems it is more often than not useful to use more general computational product as for example R, which allow to use many different methods (including AHP) as well as to incorporate manipulation with the results into more complex workflow. This documents focuses on such options.

1 R Language and package "ahp"

R language [6] is open source computational environment originally intended for statistical computations. At present time the R is extensively used to solve significantly broader portfolio of problems including high performance computing on super computers.

Support for AHP method discussed in this document is provided by package “ahp” [7]. This package implements several functions for computation of the weight coefficients and scoring of the solution alternatives and the visualization of the results.

Simple example of the usage is demonstrated bellow:

```
library(ahp)
cars <- Load("c:/path/cars.ahp")
Calculate(cars)
library(data.tree)
print(cars, filterFun = isNotLeaf)
Analyze(cars)
AnalyzeTable(cars)
```

In example the decision hierarchy is being loaded from external file (cars.ahp). Weight computation is provided by function Calculate. Using print command, it is possible to print hierarchy itself on the screen.

Finally functions Analyze and AnalyzeTable visualize results of the analysis into tabular form. Difference is in formatting – Analyze doesn’t use it (clean text output) while AnalyzeText produces formatted table with extensive use of colors to signal significance of the results. See table 2 for output of this function.

From the usage point of view most problematic seems to be steps leading to definition of the input file. Package authors do not provide other than basic tools allowing to create the file “by hand” in text editor. The resulting YAML (YAML Ain’t Markup Language) file is than imported into R for further processing.

Unfortunatelly the creation by hand is being prone to errors of various kind, which makes the process slow and painful.

Structurally the file looks like this:

```
Version: 2.0

Alternatives: &alternatives
  Alternative name 1:
    Property 1: property value
    Property 2: property value
    …
  Alternative name 2:
    …
Goal:
  preferences:
    pairwise:
      - [item1, item2, weight]
      - …
  children:
    criteria hierarchy …
```

Even for simple decision problems the input file tends to be long (relatively speaking). For example - the car choice problem, demonstrated in this document, uses hierarchy formed by 10 nodes. In this case we are deciding between 6 alternatives. The file in YAML format describing this problem is around 250 lines long.

R during import tends to stop on first error it encounters, which makes the file debugging process very long and tedious.

To speed up this process small tool has been developed AHP Editor. It allows to design decision criteria hierarchy and also provides a form to specify pairwise comparison of the ctriteria/alternatives.

2 AHP Editor v0.1

You can download the editor free of charge from:

https://fbiweb.vsb.cz/~sen76/data/uploads/programy/AHPEditor%20v0.1.7z

At present time it is possible to run the editor in Windows operating system supporting .Net Framework. The editor has been programmed in C# programming language and is being distributed including source code under MIT license.

The Editor itself at present time supports only basic capabilities of "ahp" package. It allows to define alternatives including its properties and to define criteria hierarchy with pairwise comparison. It does not support definition of functions to derive weight coefficients. It is also capable to evaluate preferences of single evaluator.

GUI (graphical user interface) of the editor is based on two forms for definition of the alternatives (fig. 2), specification of the goal/criteria hierarchy and pairwise comparison (fig. 3).

General visualization of the decision situation is available on figure 1.

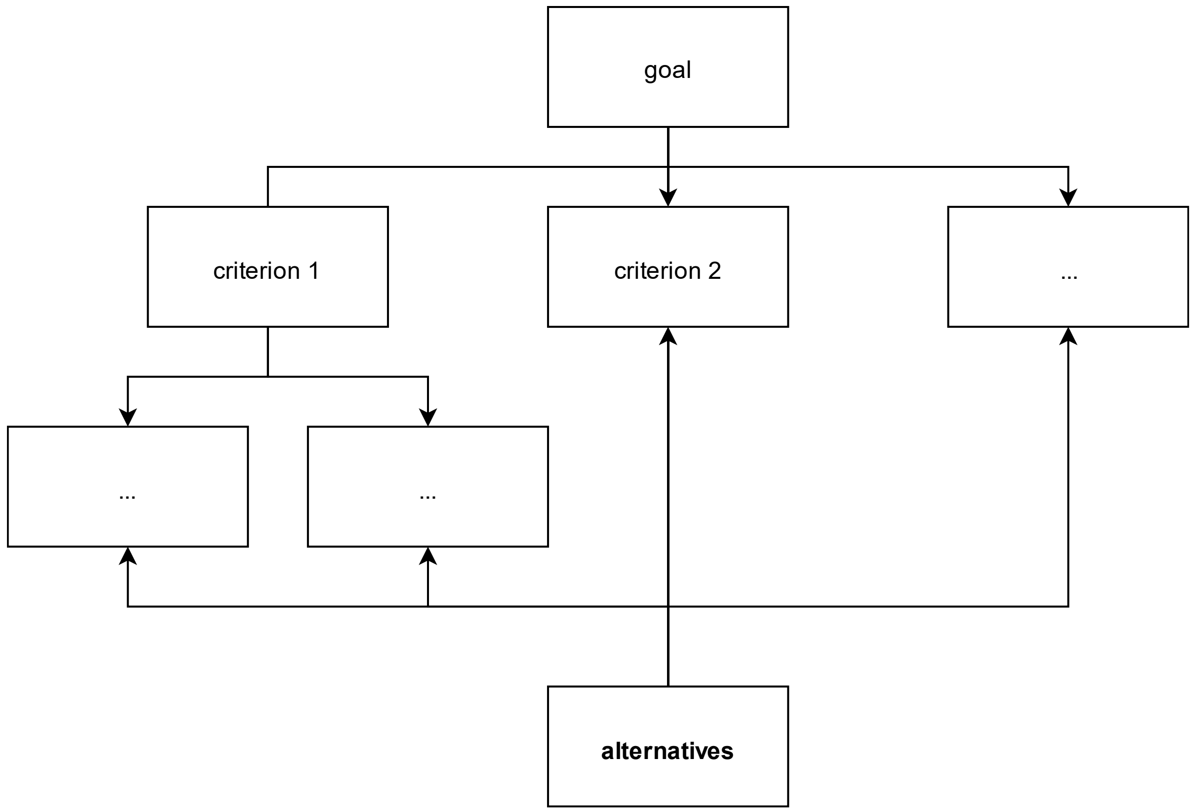

Fig. 1: Structure of decision problem as hierarchy

Alternatives on fig. 1 are characterized by its properties. In leaf nodes of the goal hierarchy preferences are measured for the alternatives themselves as opposed to non-leaf nodes, for which the children nodes are compared.

AHP method is generally usable also to derive weight coefficients without necessarily using the alternatives, but implementation of the method in package “ahp”, at present time, does not support this option.

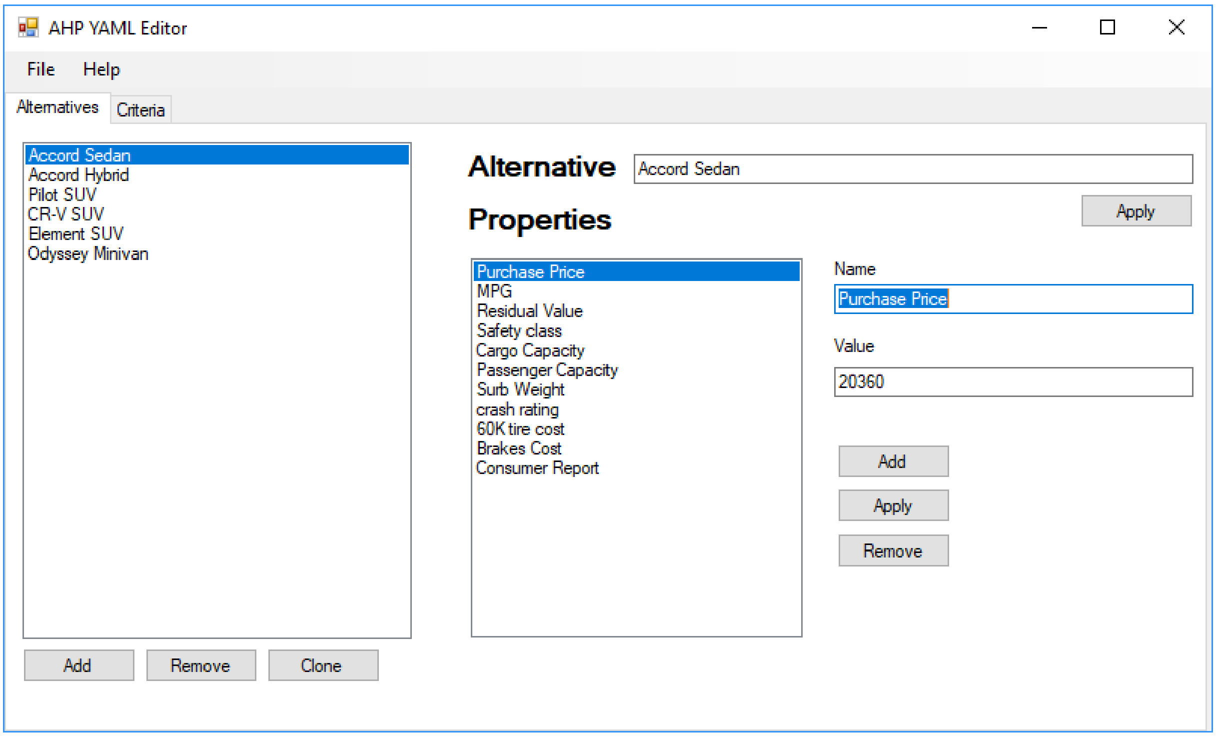

Fig. 2: Alternatives definition

Alternatives are defined by *Adding* alternative to the decision problem. It is recommend to rename the alternative so it identifies it (as opposed to general name as Alternative 1 etc.). It is necessary to click *Apply* button to apply changes to the alternative definition.

Each variant is characterized by properties. Value of the properties determine utility of the alternative when compared with other alternatives. To make the comparison possible, structure of the properties must be same for all alternatives. Also value of all properties and all alternatives.

The value itself does not need to be numeric only. Thou it is possible to process numeric values by functions to derive weights for the hierarchy. The function definition at present time is not supported by Editor, so the exported file, needs to be manually adjusted to use them.

When using numeric values, please note, that that Editor works with the property values as with text – so the export function might export decimals with inappropriate decimal symbol as R requires "." as decimal symbol while for example in Czech the "," is used as decimal symbol. Editor will not perform automatic transformation – either fill in values using "." or perform manual adjustment of the exported file at later time.

Properties can be *add*ed, removed. Change of the property name or value must be applied to the property by clicking on *Apply* button.

Considering consistency requirements on property structure, **we recommend starting with definition of first alternative in its entirety (with all required properties). Such alternative can be cloned** thus ensuring that the required structure of the properties will remain the same.

After cloning, it is naturally necessary to change alternative names and property.

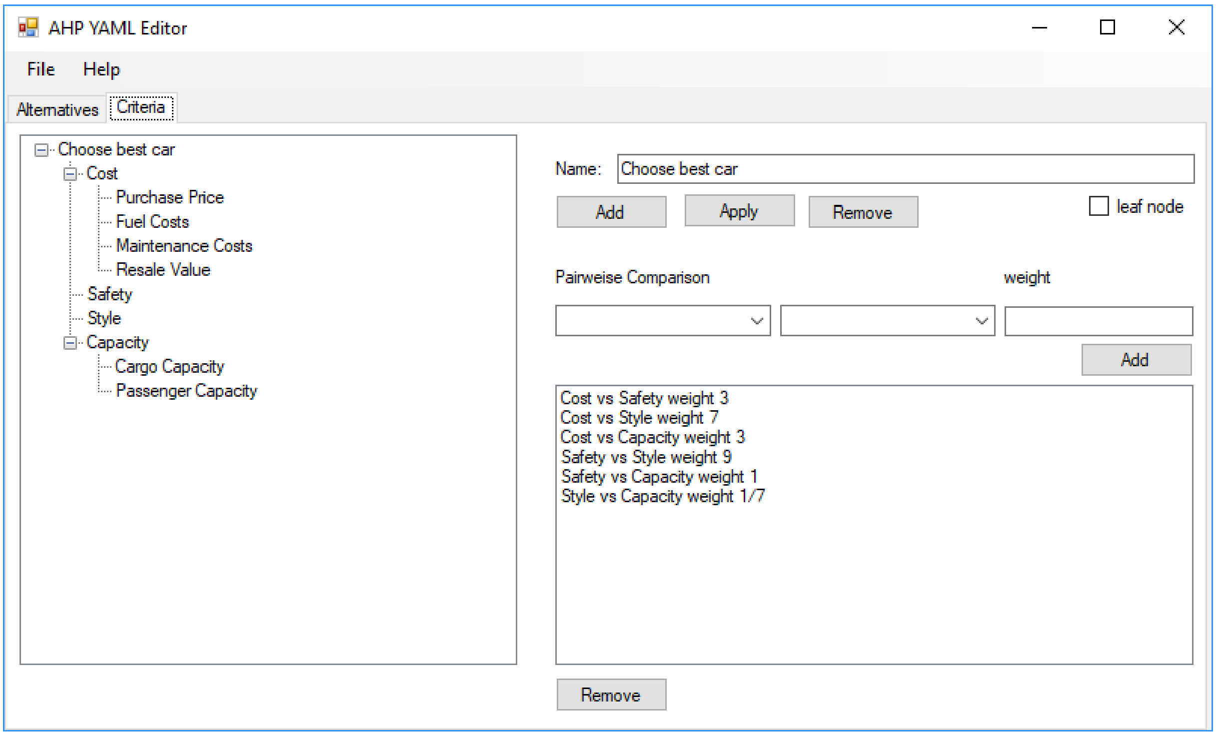

Fig. 3. Criteria definition and pairwise comparison

Clicking button *Add* (close to Name) will add new node to the criteria hierarchy just under the selected node. *Apply* then changes name and or identification of the leaf node. *Remove* will remove selected node from the hierarchy including all of its children nodes and associated pairwise comparison.

Removing root node will thus remove whole hierarchy.

The leaf node check box is used to define whether or not should the Editor consider the node as leaf. From structural point of view, it is possible to identify leaf nodes automatically (as the do not have children), but the AHP method works slightly differently as leaf nodes connect alternatives. See fig. 1 to illustrate this approach.

If the editor is being used to define the hierarchy only, setting leaf nodes is not necessary. Please note, that the resulting file will not be directly processable by the functions of “ahp” package.

Pairwise comparison for non-leaf nodes will be performed on children nodes. For leaf nodes alternatives are compared. For example for the node *choose best car* (see fig. 3) will compare these nodes:

- costs
- safety
- style

- capacity

Pair to compare is defined by choosing the pair in the combo boxes and setting up the preference (weight). The weight is in interval 1 – 9, where 1 represents situation where both criteria are equal utility wise and 9 represents dominance of first criterion over the second criterion. In case of the second criterion dominance over the first – weight is set as 1/X, i.e. 1/9.

Pairwise comparison forms, from point of view of data structures, matrix with symmetrical parts, which can be derived from each other – see table 1 for example.

Tab. 1: Preference table for choosing best car

	Costs	**Safety**	**Style**	**Capacity**
Costs	1	3	7	3
Safety	1/3	1	9	1
Style	1/7	1/9	1	1/7
Capacity	1/3	1	7	1

Considering this – only highlighted parts of table 1 must defined in the Editor. Other information will be derived from it automatically.

At present time it is possible to only add and remove the pairs (so no edits … sorry :-).

For leaf nodes, the Editor will fill alternatives in the combo boxes.

Editor supports two file format – JSON are editable in the Editor (File -> Save/Open), while YAML files (*.ahp) can be only exported (File -> Export) from the Editor. YAML files are usable by “ahp” package in R.

Example – choosing the car

The example specifies the decision problem as follow: we need to choose best car for the family, considering the budget of 25 000 USD. The example itself has been originally formulated by prof. Saaty for AHP method usage demonstration and since then it has been published in multiple variants and sources.

The example, we are using has been derived form variant described on Wikipedia [8].

Editable JSON file (cars.json) and exported YAML file (cars.ahp) are available from:

https://fbiweb.vsb.cz/~sen76/data/uploads/programy/cars.7z

After the import “ahp” package detects following hierarchy (using print function):

```
                         levelName
1  Root
2   ¦--Cost
```

```
 ¦   ¦--Purchase Price
 ¦   ¦--Fuel Costs
 ¦   ¦--Maintenance Costs
 ¦   °--Resale Value
 ¦--Safety
 ¦--Style
 °--Capacity
     ¦--Cargo Capacity
     °--Passenger Capacity
```

AnalyzeTable then generates table 2 with derived weights of the nodes. The alternatives presumed utility may be compared as whole – see root row or various nodes or parts of the hierarchy.

Result wise car *Accord Sedan* has been established as best value, followed by Odyssey Minivan and Accord Hybrid.

Accord Sedan thou did not "win" in all criteria – from safety and capacity point of view Odyssey Minivan was evaluated as best.

Tab. 2: Hierarchy AHP and alternatives comparison

	Weight	Accord Sedan	Odyssey Minivan	Accord Hybrid	CR-V SUV	Element SUV	Pilot SUV	Inconsistency
Root	100.0%	22.0%	21.2%	18.3%	15.8%	13.3%	9.3%	7.5%
Cost	51.0%	12.8%	4.7%	9.1%	11.3%	11.2%	1.9%	1.5%
Purchase Price	24.9%	6.1%	2.4%	0.6%	6.1%	9.1%	0.6%	8.0%
Fuel Costs	12.8%	2.9%	1.1%	6.2%	1.3%	0.9%	0.4%	3.1%
Resale Value	8.2%	1.8%	0.9%	0.8%	3.4%	0.9%	0.5%	0.5%
Maintenance Costs	5.1%	1.9%	0.3%	1.5%	0.5%	0.4%	0.5%	4.0%
Safety	23.4%	5.1%	10.2%	5.1%	0.8%	0.5%	1.8%	8.0%
Capacity	21.5%	2.8%	6.0%	2.8%	3.1%	1.4%	5.5%	0.0%
Passenger Capacity	17.9%	2.4%	4.9%	2.4%	2.4%	0.8%	4.9%	0.0%
Cargo Capacity	3.6%	0.3%	1.1%	0.3%	0.6%	0.6%	0.6%	0.2%
Style	4.1%	1.5%	0.3%	1.5%	0.6%	0.1%	0.2%	! 10.1%

In the inconsistency column the consistency of the preferences is being evaluated. For example consider criteria A, B, C – if A > B, B > C and C > A the consistency of such preferences will obviously not great.

Inconsistency works with consistency index as being computed by AHP method. The values are evaluated against random choice. The values under 10 % are usually considered as accurate enough for most purposes.

Style in tab. 2 has inconsistency value 10,1 % - the exclamation mark signals possible problems with consistency. Whether or not the accuracy is sufficient must decide the evaluator.

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