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Development of a computational tool in the Python language for the application of the AHP-Gaussian method

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Abstract

A known barrier to the adoption of mathematical methods in decision-making in everyday problems is the lack of basic knowledge of the applicable methods, as well as of adequate tools for resolution, without the requirement of deepening in specific disciplines. In this context, this work proposes an interactive tool developed in the Python language that enables the resolution of decision-making problems using the AHP-Gaussian method, from an online environment of free access. A hypothetical problem is solved with the tool, demonstrating its operation and the results obtained. The solution to a problem from the literature was also reproduced, demonstrating its applicability to real and complex problems. The tool proved to be a viable alternative to enable the access of people with little computational and mathematical instruction to a promising method that has been achieving good results in applications of the most different areas of knowledge.

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Keywords: Analytic Hierarchy Process; decision making; multicriteria.

1. Introduction

Decision-making is a science, and it also includes other natural, social, and thought sciences. Decisions can involve society and its relations, politics, organizations and businesses, the economy, and even everyday situations in the lives of individuals [1, 2]. Decision-making is an act known since the dawn of humanity and has inevitably developed from then on, [3] point out.

According to the work of [4], the increasing computational capacity for data processing has further strengthened the paradigm of decision-making with methods. Also, according to the author, the organizational context was responsible for fostering innovation in this science, since intuitive or just-based decisions no longer serve organizations that demanded more and more rationality and precision [5].

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In this scenario, the only way to support the problematic resolution of this complexity in a reasonable time is using multi-criteria models [6], enabling the implementation of mathematical models for decision-making in complex problems that have been used in several recent problems, such as [7–16].

2. Theoretical Background

For the development of the solution object of the present work, it was necessary to apply knowledge about the AHP-Gaussian method, as well as some development tools [17]. This section contextualizes a little of the origin of the method and describes the tools highlighting the suitability of the solution expected with this work.

As presented by Almeida et al. [18], the decision-making process in an OP problem can be encapsulated in a set of logically ordered steps. The steps described are:

1. Perception of a problematic situation: from the identification of a divergence between what is expected and what is perceived, whether for an individual, a set of individuals, or even in an organization.
2. Understanding of the problem: perfect understanding of the problem as well as the possibilities of boundary conditions.
3. Determination of the objective: the result of the previous steps, brings inputs for the formalization of a target object for solution.
4. Determination of the measure of effectiveness: also called in the literature the measure of operational effectiveness (MEO), the authors describe that this should be a measure that can answer the impact of each measure for the achievement of the objective function.
5. Construction of the model: from the previous steps a model is built.
6. Obtaining a database that will serve as input for the model: to work with models, especially mathematical models, there must be data properly treated and with a guarantee of consistency. So, if there is no structured database for this, you need to create a structure for the framework.
7. Optimization of the model solution: in this step, it is experienced what are the conditions that lead to the maximum return of the model.
8. Implementation (or not) of the model: at the end of the iteration, the decision maker chooses whether or not to deploy the model. The decision maker here is an agent who sometimes has more knowledge about the problem than the one involved in the modeling, and this non-transfer can happen due to several factors.

Last but not least, the authors point out that these steps should be applied in an iterative cycle. The main idea of the model is that at the end of the eight steps in a first iteration, new perspectives of the problem can be perceived that would not yet be considered in the first modeling, which in itself creates a new perception of the problem, feeding a new cycle and resulting in a new model, which can even have similar behavior to the previous one and repeat the iteration [19].

Also, according to Costa et al. [20], it should be understood that a model produced by the framework is volatile and conditioned to an application context. That way, if a solution was needed years after an iteration, or for a perceived problem elsewhere, a new round would be needed at every stage of the cycle [21] .

2.1 Multicriteria Analysis

Multicriteria Decision Aid (AMD) or simply Multicriteria Analysis, can be defined as a group of methods of operational research, which propose to assist decision-making in problems whereby nature it is necessary to choose within a set with more than one alternative, observing for this, a set of two or more criteria [22–25]. Thus, a multicriteria analysis method can be considered when the definition of the objective sought by the decision-maker for comparison between the set of alternatives is already known, state Santos et al. [26].

Costa et al. [27] also reinforce that multicriteria decision support tools are not necessarily substitutes for a decision-maker, since their main purpose is only to present the most favorable alternative to the function defined in the model.

2.2 AHP-Gaussian

Proposed by Tenório et al. [28], the AHP-Gaussian method is a derivation of AHP, as an alternative method for solving multicriteria decision-making problems.

The main innovation of the AHP-Gaussian method about the traditional AHP method is the non-use of the peer-to-peer weighting of criteria, supported by the Saaty Fundamental Scale. For the weighting of criteria, this new method uses the coefficient of variation – named in the Gaussian factor work, which is an index calculated based on the data from the decision matrix of the problem, reflecting the behavior of these data. Thus, the greatest benefit presented in this method is the reduction in the cognitive cost of applying the model, since the stage of judgment of the relationship between criteria originally proposed is exponentially demanding as the number of criteria increases. As a consequence of the reduction in effort mentioned, the method makes it possible to solve problems with an unlimited number of criteria without an increase in proportional complexity.

For a better understand of the axiomatic structure, we recommend the reading of [29].

2.3 Python

According to Drumond et al. [30] and Nassim et al. [31], Python language is already sometimes considered the first option both in the market and in the scientific environment, mainly because it is a dynamic language, and easy to learn. Still, according to the authors, the emergence of the notebook format made the adoption of the language even more flexible, allowing great results to be achieved without the requirement of a high level of instruction in programming by the user [32].

The choice of this language was given by the opportunity to create a tool in a popular language, expanding access to the AHP-Gaussian method, and providing a simple and fast means of testing the algorithm.

The notebook emerged as a way to structure scripts, bringing as main features the possibility of dividing the code into blocks that can be executed independently, and the addition of text snippets in blocks dedicated exclusively to documentation, according to Santos and Gomes [33].

There are many ways and tools to interpret notebooks, but as highlighted by Maêda et al. [34], the Jupyter environment ended up becoming the most popular form due to the fast feedback on executions and changes – due to the modular format of code structuring, and the high level of user interaction with all computing, since this happens within a graphical environment. Another advantage of the interaction layer of this tool is the possibility of using custom controls created using the programming language of the notebook [35].

At the time of this work, many platforms provide free services for running Python notebooks, with great computing possibilities, but serious limitations regarding the possibilities of using code for custom controls.

Through a literature review, the Jupyterhub[3] project was discovered, used by Drumond et al. [36] and Tenório et al. [37] to host notebooks for free in the environment, which provided access to execution and even editing of the code, without any impact on the original matrix, enabling interaction in classes, tutorials, and workshops. This is possible because the platform creates a new instance of the notebook by encapsulating it inside a Docker container for each user access, such that each person has an independent interaction environment [38].

3. Proposed methodology and development of a computational tool

To demonstrate the use of the proposed tool, creating a practical application, a hypothetical problem was defined to be solved. For this purpose, the tool assists in deciding to choose a car purchase option, from a list of three alternatives, based on four pre-defined criteria. The input data for the described problem is described in Table 1.

Table 1 - Input dataset for tool

	Price (R$)	Trunk (L)	Warranty (Years)	Delivery Time (Days)
Model 1	80000	660	3	30
Model 2	95000	800	5	1
Model 3	90000	720	5	45

When accessing the address of the tool, a Jupyter screen with no exit is initially presented. To start the program, just click on the 'play' icon. As the scope of the defined problem suggests, the number of alternatives and the number of criteria are met, three and four respectively. Then the "Generate Base" button is triggered. This action induces the appearance of a grid in the spreadsheet style, through which it is possible to interact, entering the input data of the problem. This is the second possible state for the program.

Then, as the program instruction suggests, the "Calculate" button is triggered. In the results, in addition to providing intermediate data of the calculation, the list of alternatives with a ranking is delivered, with the best alternative painted in green and the worst alternative in red.

At any time, you can use the "Clear All" button, which clears all inputs and calculations, returning to present on the screen the first state of the program.

4. Application of the AHP-Gaussian method and the Python algorithm to a real problem

The problem of the previous session was solved with the proposal to demonstrate how the program works. To validate the tool, they applied the problem addressed in the work of Maêda et al. [39].

The work proposed alternatives support decision-making in the school of aircraft models to be acquired by the Brazilian Air Force. The objective was precisely to apply models that optimized the purchase considering a set of aircraft alternatives, for which a subset of criteria to be observed: a characteristic multicriteria decision problem. The AHP-Gaussian method was used in two different scenarios, each scenario composed of a set of criteria and alternatives.

In this section, the data used for decision-making in the work of Maêda et al. [40], are presented, which are then submitted to the tool developed in this work, to prove its applicability in real problems, with high social and economic impact such as that presented by the authors in the referenced work.

The data used to input the analysis of scenario 1 are presented in Table 2, and for analysis of scenario 2 are presented in Table 3.

Table 2 - Input dataset for scenario 1 resolution

	Price	Vel. Cross.	Payload	Vol. Tot. Load	Auton. Max.	Auton. Trans.	Requirement. Clue	Comp.	Enver.
AIRBUS A330-200F	241.7	871	70000	475	7400	10830	2500	58.8	60.3
BOEING B767-300F	220.3	850	54000	450	6056	10880	2652	54.94	47.57
BOEING B777-200F	352.3	891	103000	653	9065	18705	2987	63.7	64.8
Type of Criterion	Min	Max	Max	Max	Max	Max	Min	Min	Min

Table 3 - Input dataset for scenario 2 resolution

	Price	Cost Conv.	Vel. Cross.	Auto. Max.	Weight Máx. It takes off.	Width Cab.	Comp.	Enver.	Price
AIRBUS A330-200	82	15	870	13450	242000	5,26	58,82	60,3	82
AIRBUS A330-300	95	16	870	11750	242000	5,26	63,66	60,3	95
BOEING B767-300ER	36	14	850	11320	186880	4,7	54,9	47,6	36
BOEING B777-300ER	155	30	920	13649	351543	5,88	73,86	64,8	155
Type of Criterion	Min	Min	Max	Max	Max	Max	Min	Min	Min

The program outputs for the data of scenarios 1 and 2, which correspond exactly to those described by the authors, are represented in Figures 1 and 2, respectively.

Figure 1 - Application of AHP-Gaussian with data from Scenario 1

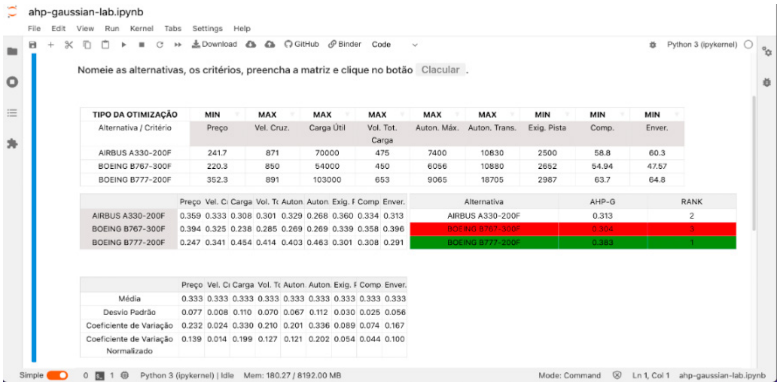
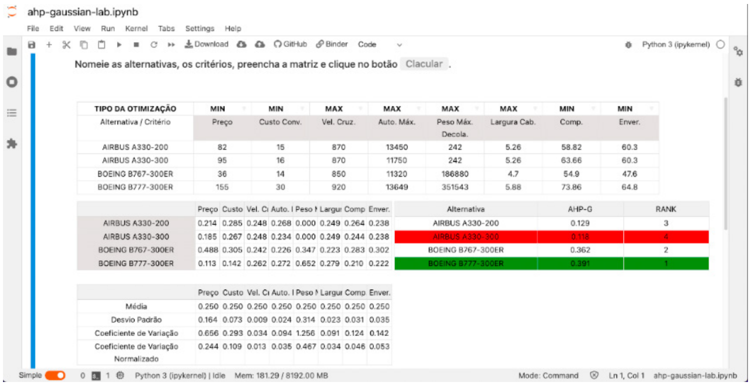


Figure 2 - Application of AHP-Gaussian with data from Scenario 2



From the result of the first iteration, the authors also experimented with the distillation of both scenarios, removing the alternative recommended by the method in each case. The processing of this experiment was also repeated in the present study, and the results again were the same as those presented by the authors, as can be seen in Figures 3 and 4, for scenario 1 distilled and scenario 2 distilled, respectively.

Figure 3. Application of AHP-Gaussian with data from scenario 1 distillate

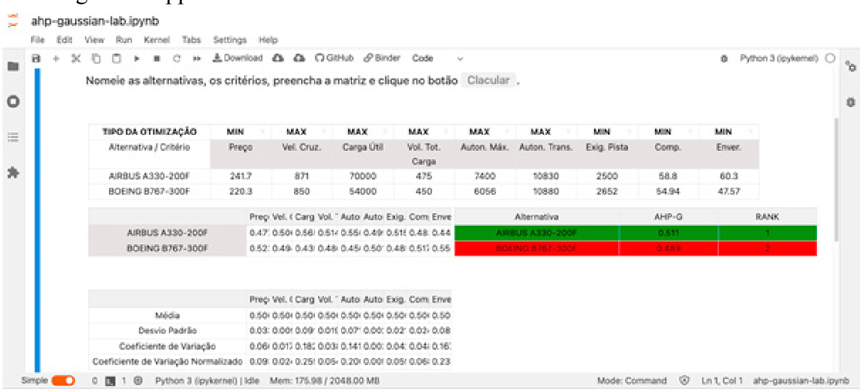
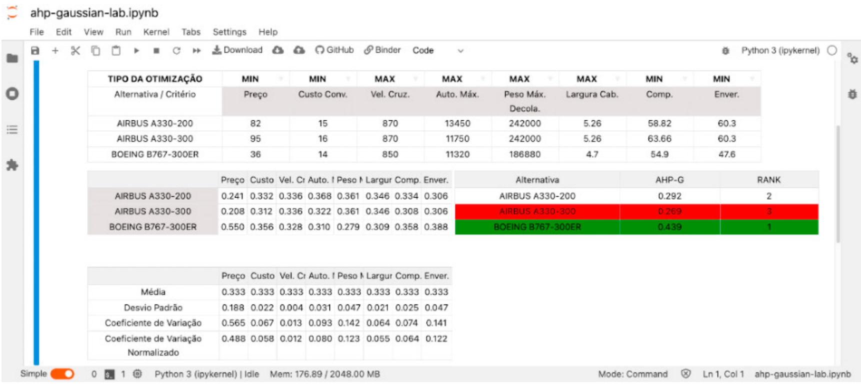


Figure 4. Application of AHP-Gaussian with data from scenario 2 distilled



TIPO DA OTIMIZAÇÃO	MIN	MIN	MAX	MAX	MAX	MAX	MIN	MIN
Alternativa / Critério	Preço	Custo Conv.	Vel. Cruz.	Auto. Máx.	Peso Máx. Decola.	Largura Cab.	Comp.	Enver.
AIRBUS A330-200	82	15	870	13450	242000	5.26	58.82	60.3
AIRBUS A330-300	95	16	870	11750	242000	5.26	63.66	60.3
BOEING B767-300ER	36	14	850	11320	186880	4.7	54.9	47.6

	Preço	Custo	Vel. Cr	Auto. I	Peso M	Largur	Comp.	Enver.
AIRBUS A330-200	0.241	0.332	0.336	0.368	0.361	0.346	0.334	0.306
AIRBUS A330-300	0.208	0.312	0.336	0.322	0.361	0.346	0.308	0.306
BOEING B767-300ER	0.550	0.356	0.328	0.310	0.279	0.309	0.358	0.388

Alternativa	AHP-G	RANK
AIRBUS A330-200	0.292	2
AIRBUS A330-300	0.269	3
BOEING B767-300ER	0.439	1

	Preço	Custo	Vel. Cr	Auto. I	Peso M	Largur	Comp.	Enver.
Média	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333
Desvio Padrão	0.188	0.022	0.004	0.031	0.047	0.021	0.025	0.047
Coeficiente de Variação	0.565	0.067	0.013	0.093	0.142	0.064	0.074	0.141
Coeficiente de Variação Normalizado	0.488	0.058	0.012	0.080	0.123	0.055	0.064	0.122

The implemented tool provides interactive graphical features, which remove the need for any understanding of programming on the part of the user. The application consists of a single screen, with three possible states. Its usability requires little interaction, and commands are triggered by buttons with suggestive titles. The output of the program is highlighted using a color scheme to highlight the most recommended option and the least recommended option.

The result of the demonstration problem applied showed that the best alternative among the three models would be model 2, even if it has a local preference in only one of the criteria. This is a characteristic of the AHP-Gaussian method, when the variance observed within the criterion in question (delivery time), because it proved to be significant, ended up weighting the criterion as being decisive for the choice about the other criteria.

The results of the submission of data from the real problem of choosing an aircraft model to the Brazilian Air Force, which was presented in Table 2 and Table 3, presented the same indicators as those found by Rocha et al. [41], showing the correct functioning of the program, as well as the feasibility of using the tool in applicable problems.

5. Final Considerations

The tool proposed in this work proved to be a simple-to-use option and serves as an alternative to the democratization of access and experimentation of a promising method for solving decision-making problems.

All of the tool's code is available in a public repository. The executable version of the tool can also be publicly accessed on the internet at: *https://mybinder.org/v2/gh/stsviniciusr/ahp-gaussian/main?labpath=ahp-gaussian-lab.ipynb*. In future works, the inclusion of documentation blocks in the tool proposed in this work can be considered, making it even richer. You might also consider encapsulating the code for a public package, which can be imported and used by third parties in notebooks or programs written in Python.

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