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Verbal Decision Analysis Applied on the Choice of Educational Tools Prototypes: A Study Case Aiming at Making Computer Engineering Education Broadly Accessible*

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Nowadays there is a growing demand for professionals with knowledge on software processes. With the aim of introducing these techniques to a considerable number of people, in an easy and accessible way, this paper presents ideas for educational tools that support its teaching. Currently, the only way people can have a good knowledge on the area is attending to formal courses, and our aim is to divulge the area via Computer Engineering Education techniques, such as educational tools or games that arouse people's interest for learning. This way, six prototypes are defined and Verbal Decision Analysis methods will be used to help selecting the prototype that fits the necessity of the users. The ORCLASS method will be applied using the ORCLASSWEB tool, with the aim of classifying the prototypes in two groups, acceptable and unacceptable designs. Then, the prototypes of the first group will be ordered using a tool based on the ZAPROS III-i method so that the most preferable interface will be selected. The research results show that the use of qualitative methods of decision support can benefit significantly on selecting the preferable interface for future development of real educational tools applications.

Keywords: verbal decision analysis; ORCLASS; ZAPROS III-i; educational tools prototypes

1. Introduction

The use of tools for stimulate the curiosity and motivate the learning is a current discussion theme, but few explored when related to Software Process. The learning of processes consists on the attendance to courses in which theoretical concepts are taught and exercised on some practical examples [1–3]. One way of improving this teaching and making it more interesting is to apply alternative methods, such as use case studies, execute project activities, games, simulators, tools, etc.

By means of several tools, students will be trained based on realistic experiences [3]. This approach allows them to acquire knowledge in simulation processes, which are not susceptible to risks of real projects. Therefore, the application of tools allows reducing the distance between theory and practice for the students and professionals who want to learn and practice the process [2].

In this paper, six prototypes of interface solutions for educational tools are presented, they were structured in requirements identified from a study of tools and games developed in another papers proposed [2, 3].

With the aim of selecting the best prototype among the ones presented, the interfaces will be described qualitatively, based on a set of multiple criteria. Then, multicriteria methods will be applied to determine the best prototype. Multi-Criteria Decision Analysis (MCDA) is an area that involves methods to support the process for decision making [22].

The Verbal Decision Analysis (VDA) [6] is a subarea of MCDA, in which the problems are represented by qualitative means (verbal) and there are no numeric measures to quantify the degree of the preferences of determined values. The problems that have qualitative nature and are difficult to be formalized are called unstructured problems [5].

According to [34], a potential way to improve the decision making process is to apply formal prescriptive design models and methods already developed in the literature. Thus, in this paper, we will use the ORCLASS and the ZAPROS III-*i* method, both belonging to the, VDA framework. The first method mentioned aims at classifying alternatives in different groups. After that, the second method will be applied in order to rank the alternatives selected based on the preferences of the decision maker.

2. Verbal decision analysis

It is known that the decision-making process is present throughout a person's life. Some decisions are simple, but others are not, and a considerable

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number of factors to be analyzed are involved. Due to the human nature, emotions and reasons become hard to separate, and the emotions influence on the decision making process specially if it is a personal decision or if the consequences of this decision affect the person who is in charge of making it.

These decision making processes can be easily solved when the problems are numerically described and analyzed. Unfortunately, not all the problems can be numerically evaluated.

Usually, multi-criteria decision support methods are based on well-structured mathematical models. Even if the description of the problems is initially defined in a qualitative way, they become later transformed into the required quantitative form, in accordance to the model established on the corresponding method [23].

According to [23] in the majority of multi-criteria problems, a set of alternatives exists, which can be evaluated against the same set of characteristics (called criteria or attributes). These multi-criteria (or multi-attribute) descriptions of alternatives will be used to define the necessary solution.

The Verbal Decision Analysis (VDA) framework is structured on the acknowledgement that most decision making problems can be qualitatively described. The Verbal Decision Analysis supports the decision making process by the verbal representation of problems. Some works developed based on the framework can be found in [7–13, 15–19, 24, 25, 31].

The methodologies of decision making support allow evaluating the alternatives considering the criteria set and the decision maker's preferences. As a multi-criteria decision support approach, the process doesn't have the aim of showing a solution for the decision maker, but to help on the decision making process [22].

According to [6], the most known methods of verbal decision analysis are: ZAPROS-III, ZAPROS-LM, PACOM and ORCLASS. The first three methods have the goal of establishing a rank of the alternatives based on an order of preference, while the ORCLASS one aims at the classification of alternatives.

3. ORCLASS method

3.1 Overview of the methodology

The ORCLASS methodology (Ordinal Classification) [6, 20] differs from the other verbal decision analysis methods (ZAPROS, PACOM) because it does not consist of ordering alternatives in a rank, but it aims at classifying the multi-criteria alternatives of a given set: one does not need to determine the complete preference order of the alternatives: the decision maker only needs these alternatives to be categorized into a decision group, among a few other groups of a set. Later, these groups can be rank-ordered so that the degrees of quality for each one can be obtained.

Table 1. Classification boards filled with the amount of cells that could be classified by transitivity depending on the decision maker's answer.

	B1	B2	B3
A1	I	1+17	2+8
A2	1+17	3+11	5+5
A3	2+8	5+5	8+2
		C1	
	B1	B2	B3
A1	1+17	3+11	5+5
A2	3+11	7+7	11+3
A3	5+5	11+3	17+1
		C2	
	B1	B2	B3
A1	2+8	5+5	8+2
A2	5+5	11+3	17+1
A3	8+2	17+1	II
		C3	

The method ORCLASS can compare only a small quantity of criteria and criteria values, because the methodology works combining them, and this might generate a high number of questions to the decision making.

The correct way to apply the methodology is to present combinations that will generate a great number of information with only one answer, based on transitivity. This way, it will be possible to minimize the number of combinations. Table 1 shows the classification boards and the number of cells that can be classified depending on the decision maker's answer to the question, for example: in the cell representing A2B2C1, we have 3+11, which means that if the decision maker classifies this cell as group I, 3 other cells can be classified by transitivity, and if the cell is classified as II, 11 other cells will be also classified. After the classified cells are updated, the values of the board need to be recalculated.

3.2 Method's structure

According to [20], Fig. 1 presents the structure to apply the VDA method ORCLASS.

In accordance with the scheme described in Fig. 1, the application of the method can be divided in three stages: Problem Formulation, Structuring of the Classification Rule and Analysis of the Information Obtained.

In the Problem's Formulation stage, the set of criteria and criteria values, and the groups to classify the alternatives are defined. The criteria

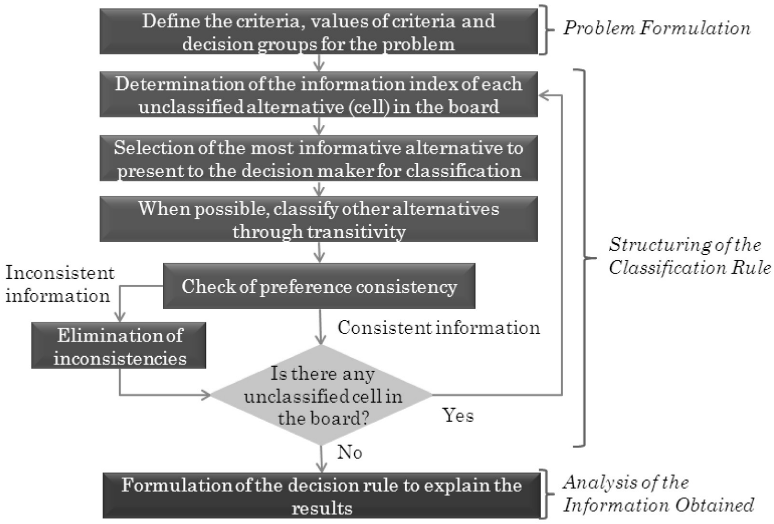

Fig. 1. Process applied to define the decision rule for classification in the ORCLASS method.

values must be sorted in descending order of preference (from most preferable to least).

The Structuring of the Classification Rule stage will be made based on the decision maker's preferences. For this process, classification matrices will be structured so that each cell is composed by a combination of values from each criterion defined to the problem, which represents a possible alternative to the problem. During the decision making process, as the elicitation of preferences is made, the classification board is being filled.

According to the structure on Fig. 1, the last stage of the methodology will be the Analysis of the Information Obtained, which is responsible for the division of the real alternatives in decision groups, based on the study of the classification board and the explanation of the decision rule.

The results of the decision rules are verbally formulated to be easily explained for the stakeholders.

3.3 A Tool for the ORCLASS method—The ORCLASSWEB tool

A tool was developed in order to facilitate the application of the method [24]. The ORCLASSWEB tool (available in http://runplanner.com.br/OrclassWeb/) was built in Java and it was proposed to automate the comparison process of alternatives and to provide the decision maker a concrete result for the problem, according to ORCLASS definition. The tool facilitates the decision making process using ORCLASS and performs it consistently, observing the method's rules and aiming to provide an accessible way to make the decision. ORCLASSWEB was developed divided in four stages: Criteria and criteria values Definition, Alternatives Definition, Preferences Elicitation, and Presentation of Results Obtained.

This tool was used on this paper to classify the prototypes in the classification groups determined on the model.

4. The ZAPROS III-i method

4.1 Overview

The ZAPROS III-*i* Method was structured based on the ZAPROS III one and it was validated and presented in [7, 9, 11, 20]. According to [33], among the advantages of the ZAPROS methodology, we can say that:

- It presents questions on the elicitation of preferences process understandable to the decision maker, based on criteria values. This procedure is psychologically valid (because it respects the limitations of the human information processing system) and represents the method's greatest feature;
- It presents considerable resistance to the decision maker's contradictory inputs, being capable of detecting and requesting for a solution to these problems;
- It specifies all the information of the qualitative comparison in a language that is understandable to the decision maker.

On the other hand, a disadvantage of the method is that the number of criteria and values of the criteria handled are limited, since they are responsible for the exponential growth of the problem's alternatives and of the information required on the process of preferences elicitation. Moreover, the scale of preferences is essentially qualitative, defined

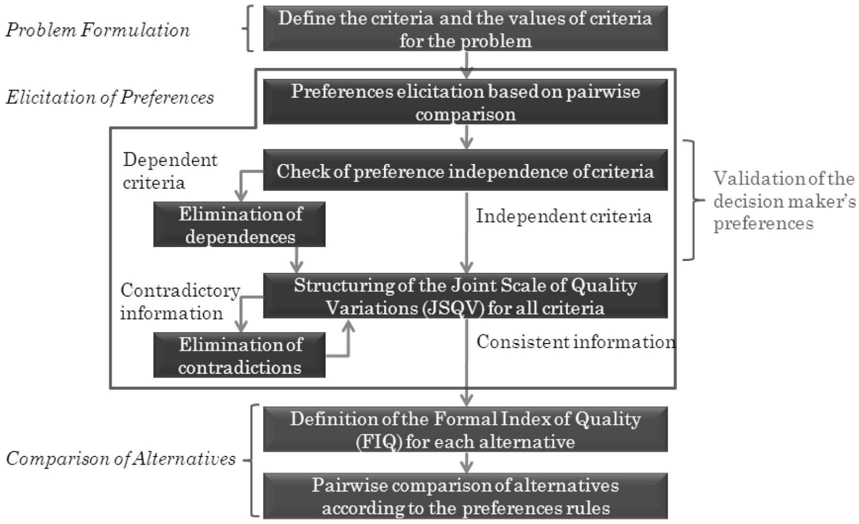

Fig. 2. Main steps to rank order a set of alternatives in the ZAPROS III-*i* method (6).

with verbal variables. This causes losses on the comparison capacity, because there are no exact values assigned to these symbols, and that leads to the absence of overall values—best or worst in any kind of situation, and cannot be recognized computationally. This way, there are a lot of incomparable alternatives, which can lead to an incomplete result. The ZAPROS III-*i* method presented improvements to the original methodology, especially regarding the incomparability issues, increasing the power of comparison of the methodology [20].

4.2 Structure

The ZAPROS III-*i* method is structured in three well-defined main steps (Fig. 2): Problem Formulation, Elicitation of Preferences and Comparison of Alternatives, and it aims at ranking multi-criteria alternatives in scenarios involving a rather small set of criteria and criteria values, and a great number of alternatives. The relevant criteria and their values to the decision making, and the scale of preferences based on the decision maker's preference are obtained in the first and second stages, respectively. In the last stage, the comparison between the alternatives based on the decision maker's preferences is performed.

A similar study was developed in [32] but using the PACOM (another method from the VDA framework to rank-order alternatives) instead of the ZAPROS one. The ZAPROS method differs from PACOM because it enables the structuring of a decision rule in the preferences elicitation process. As for the PACOM method, the preferences are elicited according to the criteria values presented on the alternatives. Thus, since it depends on the set of alternatives, whenever this set is changed, the preferences will probably have to be elicited again. This fact makes it unsuitable for simulation scenarios or for scenarios where the set of alternatives is not previously defined. Thus, the ZAPROS methodology was chosen to order the alternatives so that at the end of the process, a decision rule will be defined, and new prototypes for educational tools can be evaluated without the need of eliciting the preferences again. Another reason for using the ZAPROS methodology is that its application is supported by a decision support system—the Aranaú tool, which makes the decision processes more reliable and consistent.

4.3 A tool for the ZAPROS III-i method—The Aranaú tool

The manual application of the ZAPROS methodology can be tricky and time consuming. One has to make sure all the rules are correctly applied so that the decision rule is properly defined.

In order to facilitate the decision making process and perform it consistently, observing its complexity and aiming at making it accessible, a tool implemented in Java was first proposed in (9) and its final version is presented in (20). The tool applies the ZAPROS III-*i* method, including modifications that increased the method's comparison capacity. This tool was used on this paper to rank the prototypes classified as the acceptable group of the model.

5. Presentation of the prototypes

The prototypes represented by the Figs. 3, 4 and 5 were developed as examples of possible educational tools interfaces [8, 26]. The prototypes of interfaces

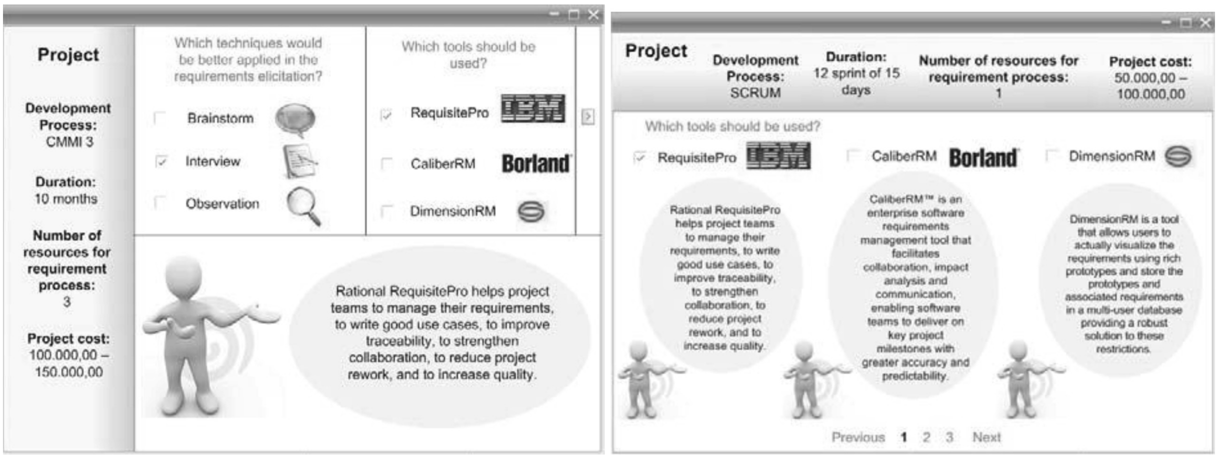

Fig. 3. Prototype 1, using buttons to navigate on the screens, and Prototype 2, with navigation similar to websites.

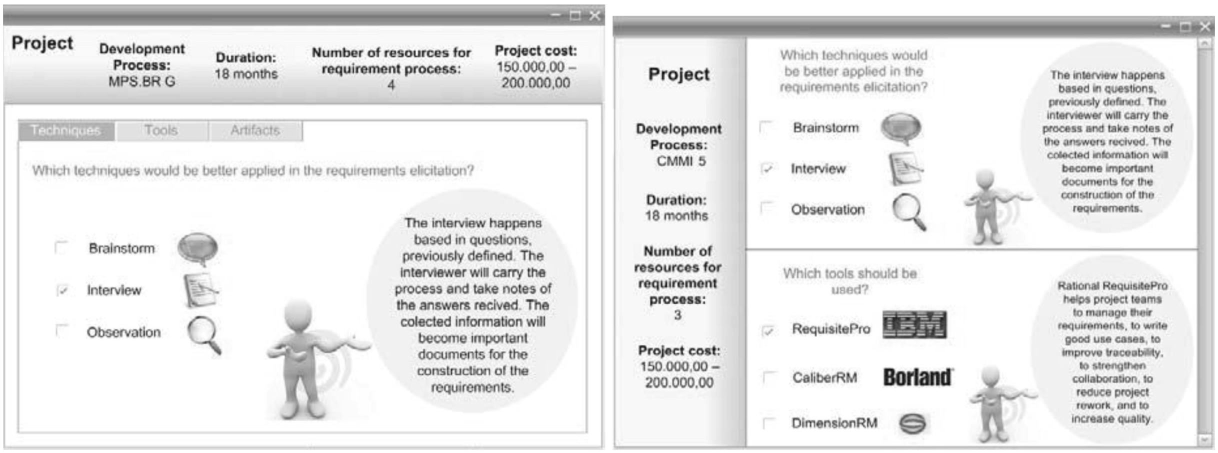

Fig. 4. Prototype 3, presenting the navigation based on tabs, and Prototype 4, with navigation similar to desktop applications.

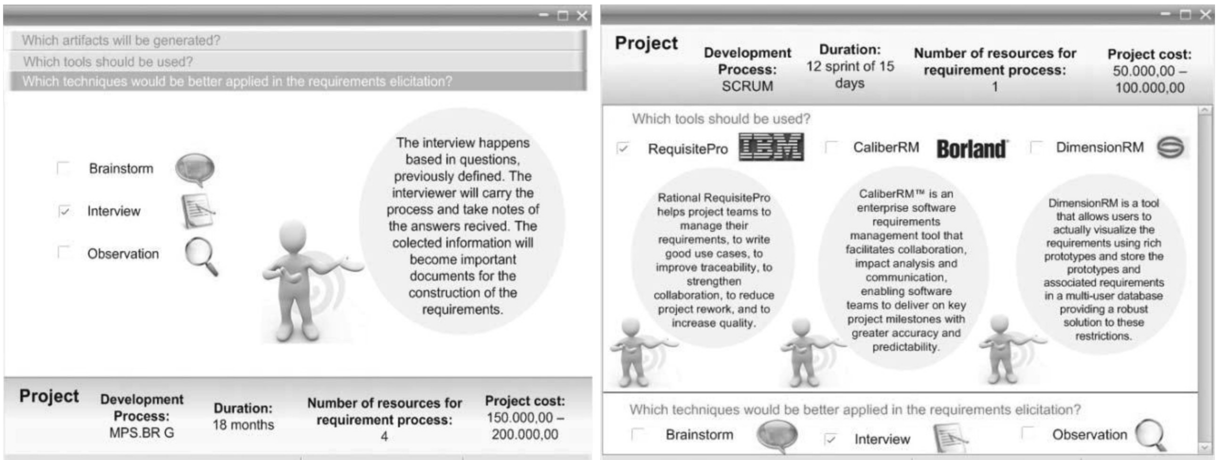

Fig. 5. Prototype 5, presenting the navigation via links, and Prototype 6, with navigation similar to desktop applications, using the scroll bar.

were created aiming to teach the software process "Analysis of Requirements", but the intention is that the application, when developed, can be so flexible that the users will be able to configure the educational tool to learn about any software process as they need.

It is important to clarify that the interfaces must be friendly, since this is an educational tool, thus it should be pleasant to use. Otherwise, the tool will not generate interest on the students.

The purpose of the tool is to select the best techniques and tools to be used in the analysis of requirements of a particular project. Each project has different characteristics, such as duration, cost and development process. As the educational tool will be flexible for teaching any software process, the questions, the options and the project characteristics can change according to the new configurations.

Observe that the main difference between the prototypes is the way of navigation through the tool, and the availability of the information presented.

The first prototype's navigation happens using the button for the application to present the next questions. The second prototype has a similar navigation to the pages of search from internet. The third prototype presents the navigation based on tabs and shows information for each answer selected.

The fourth interface's navigation is similar to desktop applications: using the scroll bar; and presents information based on the question. The fifth interface's navigation happens via links. Each question is presented in the prototype as links that, when selected, expands the related question and its options to be chosen. In the sixth interface, the questions are disposed one below the other, and the navigation is also similar to desktop applications: using the scroll bar.

Table 2. Criteria and associated values

Criteria	Values of Criteria
A. Information evidence	A1. The information are easily evident A2. The information are not so easily evident A3. The information are hard to find
B. Navigability	B1. Easy navigability B2. Medium navigability B3. Difficult navigability
C. Usability	C1. It was easy to use C2. The facility of use is reduced C3. It was hard to use

Table 3. Prototypes described as criteria values

Criteria:	Information evidence	Navigability	Usability
Prototype 1	A1	B2	C1
Prototype 2	A2	B2	C1
Prototype 3	A3	B3	C3
Prototype 4	A1	B1	C2
Prototype 5	A2	B3	C1
Prototype 6	A1	B1	C3

6. The multicriteria model for evaluating the educational tools prototypes

6.1 Criteria definition

As the first step of the Verbal Decision Analysis methodologies, the criteria were defined. After the study of other tools and games published, it was possible to describe a list of important requirements to be analyzed in the educational tool.

For each criterion, a set of values that represents the criteria are associated to each one. The criteria set and its respective values are described in the Table 2 [8, 26, 27]. These criteria will be used to describe the prototypes as the alternatives of the multicriteria problem, and they will be used in the classification and also in the rank-ordering of the alternatives.

6.2 Definition of groups

A set of decision groups must be defined for the ORCLASS method. The first group chosen involves the prototypes that can be future used to develop the real application; after the application of the methodology, the prototypes that will not be able to become a truly educational tool will classified in the second group.

6.3 Alternatives

Table 3 presents the prototypes defined as a combination of criterion values, in a way to generate the alternatives of the problem: through the analysis of each prototype's interface, it was possible to describe the screens as criterion values.

7. Computational results

In order to determine the best prototype among the defined ones, we will first classify them in two groups: one with acceptable interface models and one with the interfaces that should not be considered when creating the computational tool. For the classification task, the ORCLASSWEB tool will be used.

Then, the prototypes that are classified in the first group will be ordered from the most preferable one to the least, and the ordering task will be made using the Aranaú tool.

7.1 Classification of the prototypes—ORCLASSWEB application

The criteria, values of criteria and the alternatives for the problem were inserted in the ORCLASSWEB tool. Figure 6 shows the definition of alternatives and Fig. 7 presents the elicitation of preferences screen. For each blank cell in the classification board, the algorithm would ask the decision maker about his/her preferences, this way, the complete classification board was constructed.

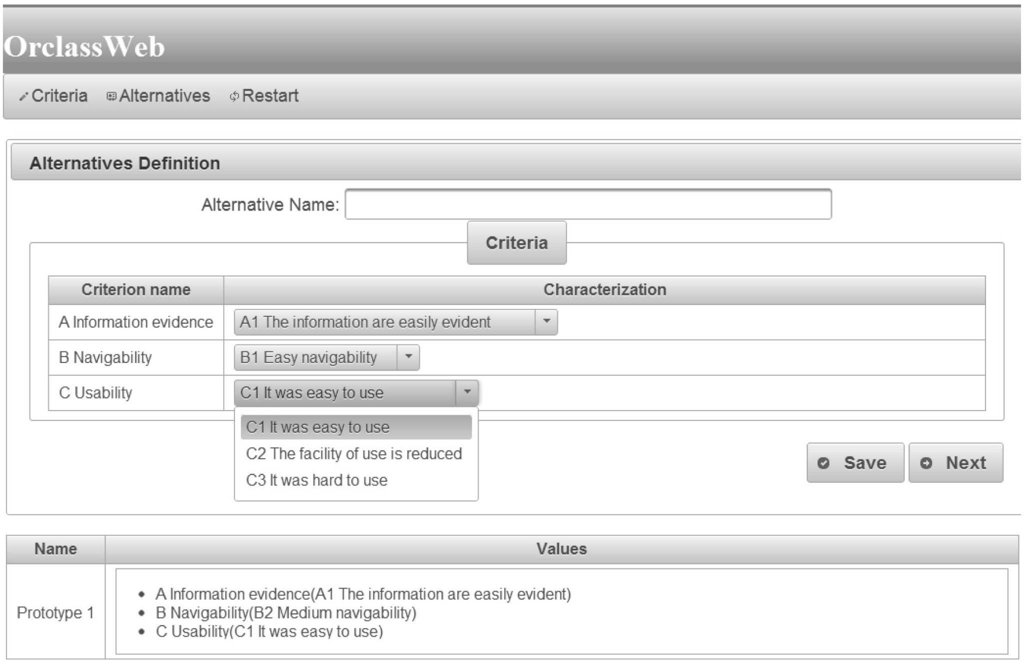

Fig. 6. Screen to define the alternatives of ORCLASSWEB tool.

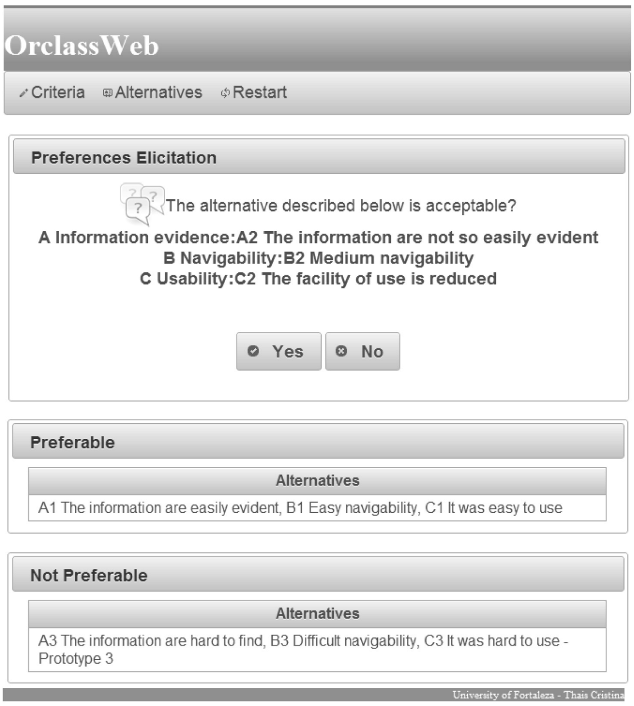

Fig. 7. Screen to elicit the preferences of ORCLASSWEB tool.

7.2 Division in groups

After the conclusion of the tools application, the result screen (Fig. 8) was analyzed in order to determine the classification of the real alternatives of the problem. Based on it, it was possible to see that Prototypes 3, 5 and 6 were classified as the second group. The first group is composed by the prototypes 1, 2 and 4, concluding that they are a possible interface for the future development of educational tools.

7.3 Decision rule for classifying alternatives

The decision rule [6] is an explanation of the results described in verbal way.

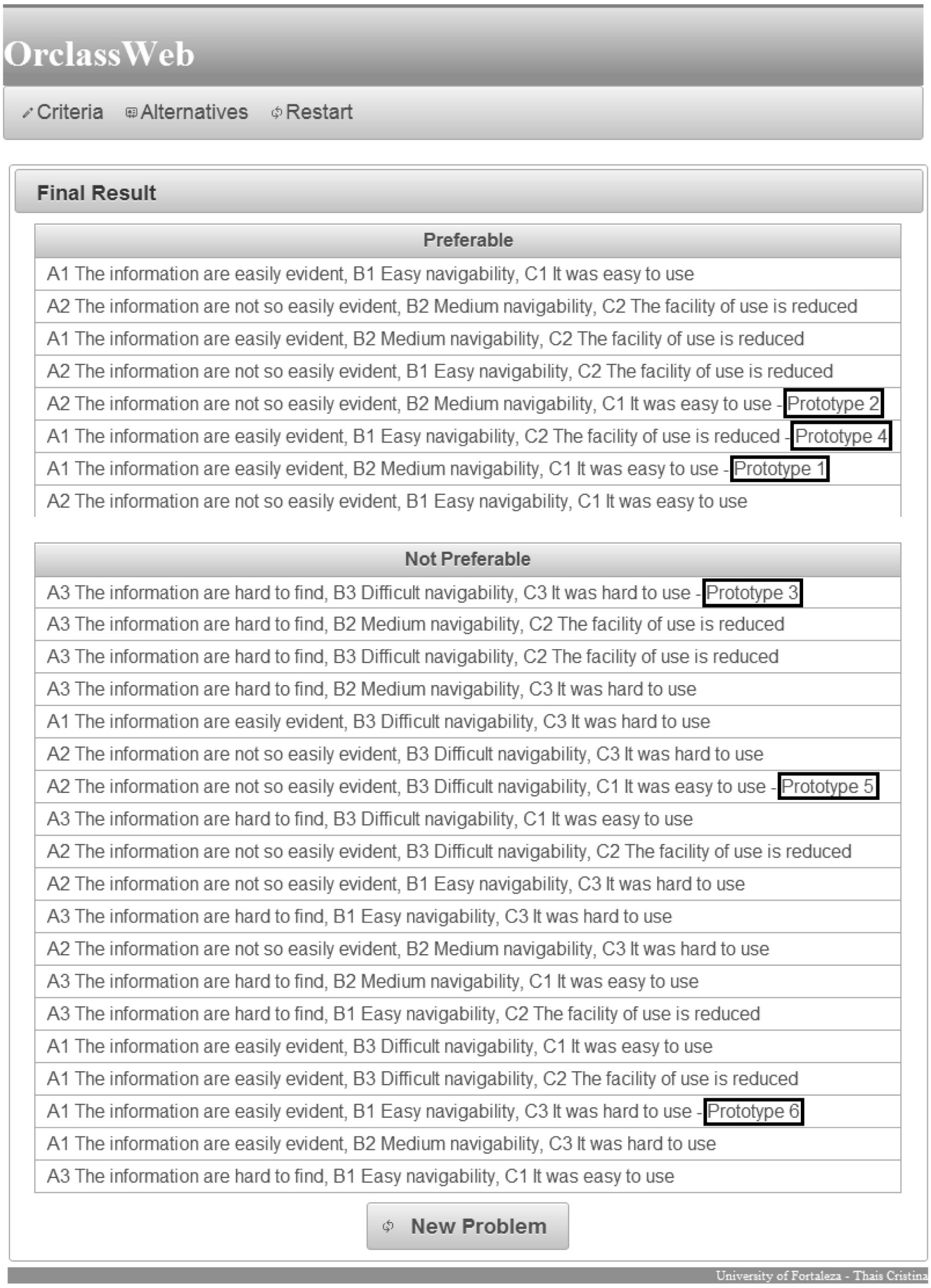

Fig. 8. Presentation of results—ORCLASSWEB tool.

Analyzing the answers obtained from the application of ORCLASS, it is possible to identify that any prototype composed by the criterion values A3 or B3 or C3 will not be accepted by the decision maker for constructing the aimed educational tool. Thus, the decision rules may be written as follows:

1. If the prototype has the availability of the information characteristic defined as hard to find, the prototype should not be accepted as a model for development;
2. If the prototype presents a difficult navigability through the screens, the prototype should not be accepted as a model for development;
3. If the prototype is hard to use, the prototype should not be accepted as a model for development.

7.4 Rank-ordering of the pre-selected prototypes—Aranaú tool application

The criteria, values of criteria and the alternatives of the problem were inserted in the Aranaú tool. Figure 9 shows the screens to visualize the defined

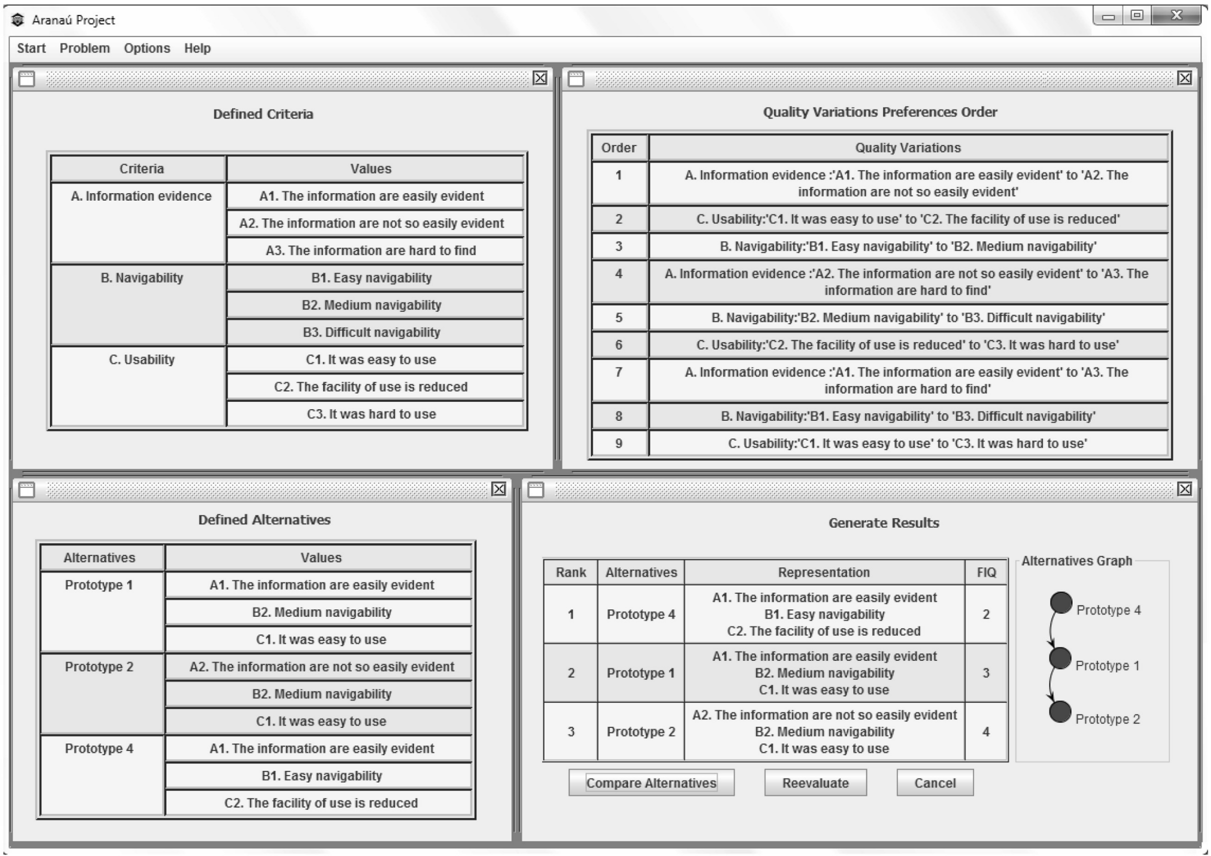

Fig. 9. Screens for presentation of defined criteria, preferences and alternatives, and results presentation of Aranaú tool.

criteria, preferences and alternatives of the problem, as well as the problem's result.

7.5 Rank of alternatives

Based on Fig. 9, it is possible to see that Prototype 4 has the best interface according to the decision maker for the construction of an educational tool, followed by Prototype 1, and then Prototype 2.

7.6 Decision rule for ordering alternatives

With the ZAPROS method application, it was possible to determine a decision rule for any other future alternative that one might need to evaluate, as long as the criteria set remains unchanged and this alternative can be described based on the criteria values. The comparison of the new alternative quality with the other alternatives in the set can be made based on the preferences presented in Fig. 9.

8. Conclusions

With the growing demand for professionals with software processes knowledge, there is a great need of introducing the techniques to a considerable number of people, in an easy and accessible way, in order to provide a brief overview of the area. The current learning consists of courses, usually formal ones, in which theoretical concepts are taught and practiced on some practical examples.

The use of tools for teaching is a current theme for discussion, but few explored when related to Software Process. The aim of using educational tools of Computer Engineering is to divulge the area to a great number of people, so that they feel motivated to enroll for formal courses and increase their knowledge on software processes.

This way, six prototypes of an educational game involving software process concepts were structured based on requirements identified from a study of tools and games previously developed. Among all the proposed prototypes, it was identified which would be the best one to be applied, attending a set of criteria.

In order to do so, Verbal Decision Analysis (VDA) techniques were applied on the task of selecting the prototype, determining which of them could be used to develop and disseminate a tool for Software Process education. This paper shows that the VDA methodologies can be applied in real problems of elicitation preferences and decision making, and also be combined to other methods of the framework, in a way to have a hybrid approach.

The prototypes were evaluated applying the ORCLASSWEB tool for classification: the prototypes were divided into two decision groups, being the first one composed by the interfaces that could be selected as prototypes for the development of educational tools, and the second composed by the interfaces that should not be selected as a prototype for the a real development. After that, the group containing the approved prototypes was rank-ordered based on the ZAPROS III-*i* method, using the Aranaú tool. This way, it was possible to determine that Prototype 4 was the most likely to generate a good tool for educational purposes.

Thus, this paper's main contribution is the presentation of a prototype that was evaluated and selected as being the most preferable one among other defined prototypes. This way, a tool to introduce the software development concepts can be created based on it and this tool can be used to diffuse the knowledge on the area.

Another important contribution was the hybrid approach that was used to select the best prototype of the defined set: the ORCLASS method was applied on the classification of these prototypes, and, after that, the ZAPROS III-*i* method was used to rank the ones that were classified as the prototypes that could be used to build a tool for the teaching of software processes. The study showed that the practices combined can add a great value to the decision process. Due to the limitations that the methods presented, this combination enables the decision making on complex scenarios, which would be a very difficult process if only the ZAPROS III-*i* method was applied.

As future works, educational tools for dissemination of Software Process knowledge would be developed based on the prototypes studied and created, with more attention to one selected from the decision analysis. It is also interesting to extend the prototypes of educational tools, in order to have a greater number of possible solutions for the tool.

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