Journal of Universal Computer Science, vol. 21, no. 11 (2015), 1470-1481
submitted: 10/5/14, accepted: 12/1/15, appeared: 1/11/15 © J.UCS

Analyzing the Multicriteria of the Interaction Design of an Educational Map Application for Digital TV from User Preferences

Daniel Almeida Chagas, Elizabeth Sucupira Furtado, Camila Loiola Brito Maia
Plácido Rogerio Pinheiro
(University of Fortaleza (UNIFOR)
Laboratório de Usabilidade e Qualidade de Uso do Software (Luqs)
Av. Washington Soares, 1321, Bl J Sl 30 – 60.811-905, Fortaleza, Brazil
daniel.helptech@gmail.com, elizabet@unifor.br, camila.maia@gmail.com
placido@unifor.br)

Abstract: The potential of digital TV demonstrates that it could be an excellent connection between map information suppliers and citizen, users of such information. The Brazilian digital television standard will be fully adopted in Brazil in 2016 and starts to be adopted in almost all Latin American Countries. It will reach many areas, being accessible to about 600000 people. Nevertheless, the Brazilian digital television standard and user population profile imposes restrictions on map access on TV or mobile screens, which leads to the challenge of this work. This article describes the analysis five criteria of three final prototypes of an educational application of maps for TV or mobile devices, based on ZAPROS III analysis. The results show the best interaction solutions suitable for DTV and mobile for maps.

Keywords: Geo-localization, maps, digital interactive television, interaction model, multi-criteria decision analysis
Categories: H.5.0, H.5.2, L.2.1, L.3.1, L.3.4, L.3.8

1 Introduction

The use of maps increased especially due to the popularization of mobile devices that are equipped with Global Positioning System (GPS) and Internet access. A Geographic Information System (GIS) is an application that provides georeferenced information along with functionalities for interaction with maps such as zoom, scroll, and various functionalities [Schimiguel, 2011]. Learning systems (GIS as ExpertCop [Furtado, 2007]) are characterized by using geographic features to represent, visually, explanations related to specific points, as soon as simulations of alternative routes. Explanations and simulations are learning strategies used in educational systems.

When applied to the Digital TV (DTV), there are still no GIS applications. The Brazilian DTV System (SBTVD) presents restrictions, primarily to embed images of maps in the GIS application. This embedded map application should be broadcasted along with the television video that will present a discourse related to the information on the map. The ability to embed maps in the GIS application depends on the size of the files that will be broadcasted. SBTVD has a practical limit of 6 megabytes per application, which creates restrictions on the number of layers of zoom on the map to be used, its legibility, the completeness of information plotted on the map, etc. These

problems could be reduced with the use of vector maps, as a vector image typically takes less space and does not lose quality when enlarged. But the SBTVD middleware lacks support for any kind of vector image.

The authors of this article studied alternatives of interaction design of a GIS application to the SBTVD standard, which was developed during the execution of a project that began in August 2011.

This project had as a client a Company responsible for monitoring urban traffic. This organization aimed to educate the target users (drivers and pedestrians) to the problems that cause disorders in the streets (like dirt, holes, works, etc.). The GIS application represents these problems that were treated under the light of a learning methodology used in development of an educative television video. The alternatives of the GIS application were built and implemented in NCL [Antonacci, 2000] and Lua [Ierusalimschy, 1996]. An important point in the design of the interaction solutions is that they were interchangeable to run between the DTV and (cellphones) mobile devices. In both modes, the screen resolution and the forms of interaction (remote control, built-in keyboard on the phone, the touchscreen phone) were analyzed to accelerate the search for information in a GIS application. This fact led authors of this paper to investigate the most preferred alternative by the target users. They decided to conduct usability test sessions to evaluate the users experience with each solution.

The analysis of alternative design solutions based on user experience is a problem unstructured, i.e., a complex problem, where most of the variables that surround it are qualitative. This type of problem should be solved by methods belonging to MultiCriteria Decision Aid (MCDA) [Simon, 1958]. The MCDA provides a decision process to a problem that has conflicting criteria and for which there are multiple Decision Makers (DM) with conflicting opinions too [Gomes, 2002].

To the problem of analysis of alternatives for maps for DTV, five criteria of evaluation were the key components of the problem. When working with more than one criterion, it is understood that a user may prefer the criterion X to criterion Y, and a user B may prefer a criterion Y to X. This analysis with multiple criteria and multiple DM becomes more complex the process of choosing a solution.

Within this context, the aim of this paper is to describe the process of analysis of the three alternatives of prototypes created for the GIS application for DTV. This process is based on ZAPROS III [Dimitriadi, 2005], a multi-criteria approach to Verbal Decision Analysis, which provides a ranking of the alternatives from the point of view of DM.

The results of this work led to identify the best alternatives, and then combining their good features to generate a fourth prototype. This article is an evolution of the work [Chagas, 2012], where the MCDA method used only focused on the analysis of pairs of criteria.

The structure of this article is as follows: Section 2 details the development of the educational content for this work; Section 3 details the alternatives of the GIS application for DTV; Section 4 is a brief theoretical background on the goals and processes derived from the analysis of verbal decision; Section 5 describes some experimental data; the analysis is performed in Section 6; in Section 7 we highlight some related work and summarize the results of experiments.

2 Preparation of Educational Content

The Company involved in the mentioned project is responsible for the traffic monitoring in a big City. This Company aimed to promote citizenship by providing a means to educate users via DTV and mobile devices. An educational video was developed to the following theme: explanation about public works in a specific neighborhood. The GIS application was the instrument to display and receive events - indications of road works or reports of traffic accidents. The video was defined by a content producer and a teacher, using the methodology of learning, called Fedathi Sequence (FS) [Borges Neto, 2003].

The FS is based on learning by problem solving. Its application is divided into the following phases: stance, maturation (or leaning), solution, and proof. First of all, the "stance", phase in which the content is structured with information about the project to improve the neighborhood mobility. The problem is presented to the viewer (the user of map application) in a way that relates the proposed situation and the subject that must be taught. The phase of "maturing or leaning" appears later on, and occurs when the characters raise questions. Here, the viewer must recognize the meaning of conjectures presented in the previous phase. Next, through the "solution", the viewer recognizes the situation using the map, while obtains feedback of the characters to the possible reflections made by the viewer concerning one of the problems. Finally, the "proof" phase is where the systematic solution is presented. The video presents a few concepts through reflection and comments by the characters, which raise the problems planned on the video. Details can be found in [Lisboa, 2013].

3 Interaction Design Solutions of a Map Application for DTV

Solutions were sought in HCI literature about the interaction design process of a map application and its assessment with the participation of the target users. Criteria of Nielsen [Nielsen, 1990] were found to guide the design of Web maps [Caminha, 2010], but nothing has been found for the design of maps for DTV. Three prototypes were developed in a process of incremental design.

The prototype A, seen in Figure 1 (a), was developed only in the NCL language. It uses the directional buttons to move the map, and the number to access the details of the occurrences. These details appear in the map, ball-shaped, and the map has two levels of zoom. The icons on the map are generic occurrences, followed by caption next to the map. The navigation instructions are highlighted in all screens.

The prototype B, seen in Figure 1 (b), uses the directional buttons and shortcuts to navigate and access the details on the map. The details of the occurrences appear in an animated window to the left. When accessing an occurrence, an animated window extends to the left of the map and the focus of the actions of the control goes to the left side of the screen. To return to the map, the user should simply press the 'right arrow' button on the remote control or on the phone. The map has two levels of zoom, one in the infographic format and the other one in the road format. The infographic format displays the names of the main districts of the city in their approximate geographic locations. The road format displays the streets, avenues and landmarks, similar to Google Maps so. On the other hand, to support the animation and the design

infographic on DTV, the prototype was also developed in Lua. The occurrences of maps have icons that are of great size, with colors and shapes. The navigation instructions appear in pop-up format when a user's action is detected.

The prototype C, seen in Figure 1 (c), was developed in NCL and Lua. It uses the directional buttons, and is composed of the shortcut buttons and a touchscreen of the phone to navigate and access the details on the map (but with different buttons of the prototype B). The details of the occurrences appear in a window to the left of the map, and when scrolling the list of occurrences, the occurrence map associated is also highlighted. The map has three levels of zoom, and the application starts with a median zoom, showing the central part of the city and its neighborhoods. The icons on the map of occurrence are small, gray, followed by explanatory text alongside. The navigation instructions are in part in the screen (like screen helps), driven by exclusive button (like shortcut).

(a) Prototype A – the map showing The entire city

(b) Prototype B– the infographic format in the first level of zoom

(c) Prototype C- the map showing part of the city (center)

Figure 1: The Three Prototypes

Before presenting the proposal for the analysis of these alternatives according to users' preferences, a brief theoretical background on the goals and processes derived from the Verbal Decision Analysis (VDA) will be presented.

4 Verbal Decision Analysis

The decision may be defined as a result of a process of choice, given an identified problem or when the decision maker faces an opportunity of creation, optimization or improvement in an environment. Moreover, decision making is a special activity of human behavior aimed at the conclusion of an objective that is presented in every activity of the human world. In the human world, emotions and reasons become hard to separate, and in personal decisions or when the consequences reach the decisors. The emotions often influence the decision making process [Machado, 2011] [Machado, 2012]. The conclusion of a decision making process is the selection or an ordination of an alternative from a group of alternatives that can be applied to solve the problem.

In order to solve the problem alternatives are options of solutions for the situation stated. Alternatives are defined and characterized on a set of criteria structured in its verbal and qualitatively nature. There is an enormous amount of practical problems for which are necessary to generate an ordinal scale of alternatives [Larichev, 1997]. VDA Framework is a set of methods (such as ZAPROS methods) defined to support the decision making process by the verbal representation of problems. The VDA framework is structured on the assurance that most decision making problems can be qualitatively described. It supports the decision making process by the verbal representation of problems [Larichev, 2001] [Mendes, 2010] [Tamanini, 2009].

4.1 Formal Statement of the Problem

The methodology follows the same problem formulation proposed in [Larichev, 1997]. Given:

1. K = 1, 2,..., N, representing a set of N criteria;
2. n_q represents the number of possible values on the scale of q-th criterion, ($q \in K$);
   For the ill-structured problems, as in this case, usually $n_q \leq 4$;
3. $X_q = \{x_{iq}\}$ represents a set of values to the q-th criterion, which is this criterion scale; $|X_q| = n_q$ ($q \in K$);
4. $Y = X_1 * X_2 * \ldots * X_n$ represents a set of vectors y_i (every possible alternative: hypothetical alternatives + real alternatives) such that:
   $y_i = (y_{i1}; y_{i2}; \ldots; y_{iQ})$, and $y_i \in Y$, $y_{iq} \in X_q$ and $Q = |Y|$, such that
   $|Y| = \prod_{q=1}^{Q} n_q$.
5. $A = \{a_i\} \in Y$, i=1,2,...,t. such that the set of t vectors represents the description of the real alternatives.

The ordering of multicriteria alternatives of the set A is defined on the basis of the decision maker's preferences (judgment) to build a reflection. The Method ZAPROS was created to be applied by pair comparison. It proposes the conception of comparing a pair of alternative with advantage of providing decision making, using simple and understandable dialogue. According to [Ustinovich, 2004], “one of the

most important features of ZAPROS methods is the use of psychologically grounded procedures for identifying the preferences. Furthermore, ZAPROS-III [Larichev, 2001] considers values known as Quality Variations (QV) and Formal Index of Quality (FIQ). The QV is a value "that represents the distances between the evaluations of two criteria" [Tamanini, 2010]. The FIQ, which main objective is to minimize the amount of pairs of alternatives to be compared, is used during the application aiming to rank the alternatives. According to [Tamanini, 2010], the application of the method can be in three stages: Problem Formulation, Elicitation of Users' Preferences, and Comparison of Alternatives, in which will be covered in the next two sections.

5 Alternatives Analysis from Users' Preferences

This section describes the two steps performed for the problem formulation and for the elicitation of users' preferences of the alternatives of map prototypes for DTV.

5.1 Problem Formulation

The Problem Formulation consists in the choice of criteria and possible values that will be part of the decision process, and of the alternatives to be analyzed. At this stage, five criteria were defined. Possible values for each criterion necessarily verbal (not calculated) were defined. Table 1 summarizes the five criteria and their possible values.

Criteria	Values
A Quantity of zoom regarding the perception of orientation in place	**A1**: Two levels of zoom, one being the infographic; **A2**: Three levels of zoom; **A3**: Two levels of zoom.
B Initial state of the map	**B1**: Map bounded by districts (Infographic); **B2**: Map showing part of the city (center); **B3**: Map showing the entire city.
C Iconization of occurrences	**C1**: Icons represented by allusive images for the occurrence, with colors; **C2**: Reduced icons represented by allusive images for the occurrence, plus explanatory text; **C3**: Generic icons represented by prominent caption and colors.
D Exhibition of details of events	**D1**: Details outside the map (left side) with focus on markers; **D2**: Details outside the map (left side); **D3**: Details inside the map.
E Metacommunication of navigation	**E1**: Popup info after delay time; **E2**: Help screen accessible via exclusive help button; **E3**: Information displayed on the screens (fixed) in highlighted color.

Table 1: Criteria and Values

5.2 Elicitation of The users' preferences during Usability Testing Sessions

The tested applications were broadcasted on a proprietary TV channel of the usability test lab, and they were received by commercial Digital TV equipment's (Sony Bravia KDL-22EX425 model and set-top box Visiontec VT7200). All prototypes had usability testing, simulating a living room of a house.

An individual test session was done with 15 participants, who used the three distinct applications in different order to minimize the influence of the same task in different prototypes. The profile of users was college students of both sexes, aged between 20 and 30 years, previous users of television and maps on the internet. The users were introduced on the use of maps in the DTV and the prototypes were presented to them to do specific tasks.

The tasks performed by the users were: i) Find the intersection between two specific streets in a specific neighborhood, and look and describe occurrences displayed on the scene; ii) Return to the home screen of the application and search for a specific avenue in another given neighborhood.

Questionnaires were applied during and after a test session to measure the task performance and get users' preferences in face to each criterion.

The users' preferences were elicited for two criteria, and then to the other criteria, two by two. In the proposed approach, this elicitation was performed by the application of post-test questionnaires with all users. In this post-test questionnaire, the answers of a user for the questions of preferences that match the criteria in pairs.

The changes of values for a criterion are called QV. For example, if a DM prefers changing from A1 to A2, QV is a_1; if a DM prefers changing from B1 to B2, QV is b_1; if a DM prefers changing from A2 to A3, QV is a_2. The JSQV (Joint Scale of Quality Variation) is the order of preference among QVs. For each DM, her order of preference for quality changes (JSQV) is calculated. In the end, the proposed approach generates a general JSQV, comparing the JSQV of all DM.

6 Results

The third phase of ZAPROS III method, called Comparison of Alternatives, consists in comparing the alternatives, resulting in a ranking of these alternatives. The alternatives of prototype, with their respective criterion values can be viewed in Table 2. The order of these alternatives is given by a 3-step algorithm, detailed in [Larichev, 2001].

In the first step, we conducted the analysis of performance. The performance of users for each evaluation criterion was measured by a scale from 0 to 3 (0 - the activity was not performed, 3 - the activity was performed with dexterity). The graphic performance score for each criterion is shown in Figure 2, in which we can see the average of users' performance on each criterion, per prototype, for all scenarios exercised. It is noticed that users had outperformed in the prototypes B and C. There was a better performance of the users in the criteria "Initial state of the map", "Metacommunication of navigation" and "Exhibition of details of events" in the prototype B, while in prototype C there was a better performance on criteria "Quantity of zoom regarding the perception of orientation in place" and "Iconization of occurrences". The prototype A had the worst performance of the users in all criteria.

Criteria	Alternative 1 (Prototype A)	Alternative 2 (Prototype B)	Alternative 3 (Prototype C)
A	**A3**: Two levels of zoom	**A1**: Two levels of zoom, one being the infographic	**A2**: three levels of zoom
B	**B3**: Map showing the entire city	**B1**: Map bounded by districts (infographic)	**B2**: Map showing part of the city (center)
C	**C3**: Generic icons represented by prominent caption and colors	**C1**: Icons represented by allusive images for the occurrence, with colors	**C2**: Reduced icons represented by allusive images for the occurrence, plus explanatory text
D	**D3**: Details inside the map	**D2**: Details outside of the map (left side)	**D1**: Details outside the map (left side) with focus on markers
E	**E3**: Information displayed on the screens (fixed) in highlighted color	**E1**: popup info after delay time	**E2**: Help screen accessible via exclusive help button

Table 2: Alternatives of Prototypes

The JSQV is the order of preference between the changes of criteria values, collected at post-test questionnaire. For each user we calculated her JSQV, i.e., her order of preference for quality changes. With all JSQVs calculated, we generated a general JSQV, comparing the JSQV of all decision-makers.

A weight was assigned for each variation of criterion value for each user, which corresponded to the position that this QV appears in JSQV of the user. These weights were summed for each QV, considering all users, generating a total amount that would be the weight of that QV. This amount is compared to the sum of the positions of other QVs, as a_2, a_3, b_1, b_2, b_3, and so on. In the end, the QVs will be sorted according to their weight value, in an increasing manner, thus forming the general JSQV.

The general JSQV after analysis of the post-test questionnaire for 15 users is as follows:

$$a_1 > b_1 > e_1 > c_1 > d_1 > e_2 > b_2 > d_2 > c_2 > a_2 > e_3 > b_3 > d_3 > c_3 > a_3$$

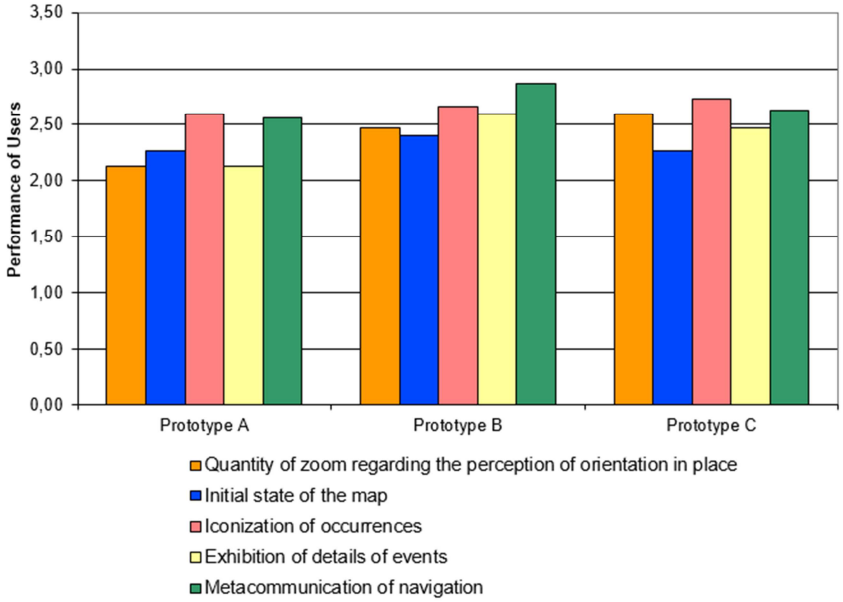

Figure 2: Performance of users in applications

Therefore, by general JSQV, it can be realized that a_1 is preferable to b_1, b_1 is preferable to e_1, and so on. So, it is preferable to change "two levels of zoom, one being the infographic" for "three levels of zoom" (a_1) to change the "map bounded by districts (infographic)" to "map showing part of the city (center)" (b_1).

With the complete JSQV, the next step is to make a ranking of alternatives of prototype, i.e., sort the prototypes according to users' preferences. The alternatives of prototype maps to DTV were then sorted according to the ZAPROS III methodology. The result can be seen in Table 3.

The algorithm assigns a score to the alternative prototype based on general JSQV, and then the ordering takes place in an increasing manner. The alternative which has a smaller number of points is the better alternative (rank 1). The alternative that has smaller points, with the exception of rank 1 will be the rank 2, and so on. Therefore, the winning alternative by ZAPROS III was the prototype B, with value 5.

Order	Alternative	Value
1	Prototype B	5
2	Prototype C	10
3	Prototype A	65

Table 3: Ranking of Alternatives of Prototype

The prototype B has the best value in 4 of 5 criteria (A1, B1, C1 and D1). Moreover, according to users' performance shown in Figure 2, the prototype B was the one that users performed better on most criteria (3 of 5 criteria).

The prototype C was second with 10, followed by prototype A with 65. Note that the score difference between the prototype B and the prototype C is much smaller than the score difference of the prototype B and the prototype A. The prototype C was also the second on performance of users, shown in Figure 2, followed by the prototype A.

Considering that the prototypes B and C had good results, a fourth prototype was implemented by taking the best features of these two prototypes. This fourth option was chosen to be shown to the customer.

7 Conclusion

In this work three prototypes that provide georeferenced information on DTV were developed in series, a sequence of the proposed improvements based on usability requirements. The analysis for the best solution and parts of them was taken.

According to the result of experiments, it is possible to observe that the prototype with rank 1 was the prototype B, whose criteria had the best values (better scenario) in 4 of the 5 criteria. Note also that users performed better on this prototype B in 3 of the 5 criteria. The preference of the users ended up relating to the performance of these users in usability testing. The prototype which they could interact with more tranquility and ease of use was the preferred.

The same happened to C prototype, which was second in both the analysis generated by ZAPROS-III methodology and the performance of users.

Finally, the prototype A ranked last in the analysis of ZAPROS-III and performance users. This prototype proved to be the most complicated for user interaction prototype, in which much of the scenarios was not performed by users, getting the value 0 (unable to perform) in most of the tests. This prototype has the worst values for the criteria, justifying the complexity of the interaction.

In the end, the best features of the prototypes B and C, the two best-ranked alternatives, were merged into a fourth prototype, which was delivered to the customer. The ZAPROS III methodology was used, in this case, not to choose one of the options prototype, but to identify the best options, and contribute to the implementation of a prototype with good acceptance by users.

Until this work, no developed prototypes still had text search function, which would imply the implementation and solutions entering text via the virtual keyboard to DTV.

A future work would be to use a hybrid methodology, applying the ZAPROS III methodology to sort solutions (the alternatives of prototype) and the ORCLASS method to classify these solutions [Pinheiro, 2014].

Acknowledgements

The first author is thankful to “Foundation for Support of Scientific and Technological Development Ceara State” (FUNCAP), the second author and fourth are thankful to National Counsel of Technological and Scientific Development

(CNPq) and the third author is thankful to "Coordination for the Improvement of Higher Level-or Education- Personnel" (CAPES) for the support received on this project.

References

[Antonacci, 2000] Antonacci, M.: NCL: Uma Linguagem Declarativa para Especificação de Documentos Hipermídia com Sincronização Temporal e Espacial (in portuguese), PhD Thesis, PUC-RJ, 2000.

[Borges Neto, 2003] Borges Neto, H., Santana, J. R.: Sequência Fedathi: uma proposta de mediação pedagógica na relação ensino/aprendizagem. Filosofia, Educação e realidade, EUFC, 2003.

[Caminha, 2010] Caminha, C., Furtado, V., Vasconcelos, E., Ayres, L.: Uma ferramenta de autoria para criação de mapas colaborativos para aplicações em egov 2.0. In Proc. Congress of the Brazilian Society of Computing, 2010.

[Chagas, 2012] Chagas, D. A., Furtado, E. S., Nobre, J.: AnáLise De Alternativas De Design De Mapas Para TV Digital Brasileira Baseada Em Multicritérios, In Proc. Brazilian Symposium on Human Factors in Computing Systems, Brazilian Computer Society, 325-334, 2012.

[Dimitriadi, 2005] Dimitriadi, G., Larichev, O.: Decision Support System and the ZAPROS-III Method for Ranking the Multiattribute Alternatives with Verbal Quality Estimates. Automation And Remote Control, v. 66, n. 8, 1322-1335, 2005.

[Furtado, 2007] Furtado, E., Furtado, V., Vasconcelos Filho, E.: A Conceptual Framework for the Design and Evaluation of Affective Usability in Educational Geosimulation Systems. INTERACT (1), 497-510, 2007.

[Gomes, 2002] Gomes, L. A., Gomes, C. S., & Almeida, A. T.: Tomada de Decisão Gerencial: Enfoque Multicritério. Atlas, 2002.

[Gomes, 2010] Gomes, L. F. A., Moshkovich, H., Torres, A.: Marketing decisions in small businesses: how verbal decision analysis can help. Int. J. Management and Decision Making, v. 11, n. 1, 19-36, 2010.

[Ierusalimschy, 1996] Ierusalimschy, R., Figueiredo, L., Celes Filho, W.: Lua: an extensible extension language. Software: Practice & Experience, v. 26, n. 6, 635-652, 1996.

[Larichev, 1997] Larichev, O. I., Moshkovich, H.M.: Verbal decision analysis for unstructured problems. The Netherlands: Kluwer Academic Publishers, 1997.

[Larichev, 2001] Larichev, O. I.: Method ZAPROS for Multicriteria Alternatives Ranking and the Problem of Incomparability, Informatica, v. 12, 89 - 100, 2001.

[Lisboa, 2013]. Lisboa, R., Furtado, E. S., Neto, H. Formação de telespectadores para TVD Interativa apoiada na Sequência Fedathi e Aplicada para o Desenvolvimento de Programas Jornalísticos, In Proc. Brazilian Symposium on Computing in Education, 2013.

[Machado, 2011] Machado, T. C. S., Menezes, A. C., Tamanini, I., Pinheiro, P. R.: A Hybrid Model in the Selection of Prototypes for educational Tools: An Applicability In Verbal Decision Analysis. In Proc. IEEE Symposium Series on Computational Intelligence in Multicriteria Decision-Making, Paris, 2011.

[Machado, 2012] Machado, T. C. S., Pinheiro, P. R., Tamanini, I.: Towards the Selection of Prototypes for Educational Tools: A Hybrid Model in the Verbal Decision Analysis. International Journal of Information Science, Scientific & Academic Publishing, v. 2, 23-32. DOI: 10.5923/j.ijis.20120203.04, 2012.

[Mendes, 2010] Mendes, M. S., Carvalho, A. L., Furtado, M. E. S., Pinheiro, P. R.: Towards for Analyzing Alternatives of Interaction Design Based on Verbal Decision Analysis of User Experience. International Journal of Interactive Mobile Technologies (iJIM), v. 4, 17-23, 2010.

[Nielsen, 1990] Nielsen, J.; Molich, R.: Heuristic evalution of user interfaces. In Proc. ACM Conference on Human Factors in Computing Systems, 249-256, 1990.

[Pinheiro, 2014] Pinheiro, P. R., Tamanini, I., Machado, T. C. S., Verbal Decision Analysis Applied on the Choice of Educational Tools Prototypes: A Study Case Aiming at Making Computer Engineering Education Broadly Accessible. International Journal of Engineering Education, v. 30, 585-595, 2014.

[Schimiguel, 2011] Schimiguel, J., Baranauskas, M. C., Medeiros, C.: Usabilidade de Aplicações SIG Web na Perspectiva do Usuário: um estudo de caso (in portuguese). GeoInfo, 262-268, 2005.

[Simon, 1958] Simon, H., & Newell, A.: Heuristic Problem Solving: The Next Advance In Operations Research. Operations Research , Harper and Row, 1958.

[Tamanini, 2009] Tamanini, I., Carvalho, A. L., Castro, A. K. A., Pinheiro, P. R.: A Novel Multicriteria Model Applied to Cashew Chestnut Industrialization Process. Advances in Soft Computing, v. 58, n. 1, 243- 252, 2009.

[Tamanini, 2010] Tamanini, I.: Improving the ZAPROS Method Considering the Incomparability Cases. Master Thesis, Graduate Program in Applied Informatics, University of Fortaleza, 2010.

[Ustinovich, 2004] Ustinovich, L., Kochin, D.: Verbal Decision Analysis Methods for Determining the Efficiency of Investments in Construction. Foundations of Civil and Environmental Engineering, 35-46, 2004.