Towards the Layered Evaluation of Interactive Adaptive Systems using ELECTRE TRI Method

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Abstract: The layered evaluation of interactive adaptive systems has to consider many evaluation methods. The best evaluation method to be used for individual layers depend on many parameters such as the evaluation criteria, the stage of the development cycle, and the characteristics of the layer under consideration. This paper presents a decision model for selecting the appropriate evaluation methods for individual layers of the interactive adaptive system. Our proposal is based on one multi-criteria method, namely ELECTRE TRI method. The proposed decision model is applied to determine the suitable evaluation methods for an adaptive hypermedia system.

1 INTRODUCTION

Nowadays Interactive Adaptive Systems (IAS) are omnipresent in many application domains such as education, tourism, and e-commerce (Brusilovsky et al., 1996; Goren-Bar et al., 2005; Goy et al., 2006). The evaluation of these systems is an important part of their development process. Several studies have reported the advantages of the layered evaluation approach for interactive adaptive systems (Brusilovsky et al., 2001; Weibelzahl, 2001; Paramythis et al., 2010). By applying this approach, each layer of adaptation is assessed individually where feasible (Paramythis et al., 2010). A layer of adaptation refers to a particular step in the adaptation process of IAS (Paramythis et al., 2010). In every layer, different evaluation methods can be applied. It is essential to choose the appropriate evaluation methods for individual layers in particular evaluation constraints (Paramythis et al., 2010). The literature has identified numerous evaluation methods for interactive adaptive systems (Gena, 2005; Gena and Weibelzahl, 2007; Velsen et al., 2008; Mulwa et al., 2011; Dhouib et al., 2016a). Some of them, like user-as-wizard (Masthoff, 2006), are specific for the IAS field. The diversity of the evaluation methods makes the choice of the best ones in particular settings a difficult task. For instance, evaluators need to understand the suitability of each evaluation method in a particular situation (Ferré and Bevan, 2011; Dhouib et al., 2016a). They also have to consider different criteria such as the availability of stakeholders, the system development phase, the characteristics of layers, etc. Using a particular Multi-Criteria Decision Analysis (MCDA) method in the choice of the suitable evaluation methods decision process is an important strategy to deal with the presence of numerous criteria.

In the interactive adaptive system literature, there are few research studies that address the question of the choice of evaluation methods for the individual layers. Paramythis *et al.* (Paramythis et al., 2010) for example, presented a framework that guides the layered evaluation of IAS. The proposed framework represents a revised version of the previous layered frameworks, mainly those of (Paramythis et al., 2001; Weibelzahl and Lauer, 2001; Brusilovsky et al, 2004). The authors propose the evaluation criteria related to every layer of adaptation and the methods to be applied for their evaluation. Another study was presented by (Dhouib et al., 2016b) in which Analytic Hierarchy Process was used for the selection of the best evaluation methods. In spite of the major progress in IAS research, we still lack a

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decision model that deal the problem of selection of suitable evaluation methods for individual layers with a sorting problematic. Then, this paper presents a novel decision model that assigns evaluation methods to each layer of adaptation. This kind of decision problem is known as a sorting problem under the MCDA approach (Roy, 1996). A large number of MCDA sorting methods are available in the literature. In this research, we adopt one MCDA method, namely the ELECTRE TRI method. This MCDA method is considered as one of the most commonly used MCDA methods for sorting alternatives into predefined categories. More details about the ELECTRE TRI method can be found in (Yu, 1992; Roy and Bouyssou, 1993).

The rest of this paper is structured as follows. First, we start by a description of the layered evaluation of interactive adaptive systems and the MCDA method adopted in this study (Section 2). Afterward, we present the decision model that guides IAS evaluators in the selection of appropriate evaluation methods for individual layers (Section 3). Following that, we illustrate our proposal with a case study related to an adaptive hypermedia system in order to validate it (Section 4). Finally, we present some conclusions and future work (Section 5).

2 STATE OF THE ART

2.1 The Layered Evaluation of Interactive Adaptive Systems

The main idea behind layered evaluation is to separate the adaptation process into its components (layers) and to assess them separately (Paramythis et al., 2001; Paramythis et al., 2010). In the literature, a number of layered evaluation approaches have been proposed (Karagiannidis and Sampson, 2000; Paramythis et al., 2001; Brusilovsky et al., 2004; Paramythis et al., 2010, Manouselis et al., 2014). These approaches differ essentially in the number of layers identified. Paramythis *et al.* (Paramythis et al., 2010) distinguished five layers for interactive adaptive systems, including (1) collection of input data in which data about the interaction context and the user interaction are collected, (2) interpretation of the collected data in which an interpretation of the previously collected input data is conducted, (3) modelling of the current state of the world in which knowledge about the interaction context is introduced in IAS' dynamic models, (4) deciding upon adaptation in which the appropriate adaptation is selected, and (5) applying adaptation which reflects the step of introduction of the adaptations in the user-system interaction. In every layer, different evaluation methods can be applied in order to identify in which layer the problem is.

2.2 Multi-criteria Decision Aid

2.2.1 Overview

Various MCDA methods have been developed to facilitate the decision-making process. MCDA methods consist of the three major concepts, including:

- The criteria which refer to the factors on which the decision is based. The identification of criteria is an essential step in the decision-making process.
- The alternatives which reflect the set of potential solutions for the decision-making problem.
- The preferences between two alternatives (a, b) that can have three types, including (1) preference aPb, which means that alternative a is preferred to b, (2) indifference aIb, which means that a is indifferent to b, and (3) incomparability aRb, which means that a is incomparable to b.

The next section presents the adopted MCDA method in the present research.

2.2.2 ELECTRE TRI

ELECTRE TRI is a sorting multi-criteria method. It assigns a set of alternatives to predefined ordered categories C (Yu, 1992; Mousseau and Slowinski, 1998). The assignment of alternatives into categories is done by means of a comparison of these alternatives with the profiles representing the frontiers between categories. ELECTRE TRI assigns alternatives to categories following two consecutive steps, including (1) construction of an outranking relation aSb_h, and (2) exploitation of the relation aSb_h.

The ELECTRE TRI method builds an index $\sigma(a, b_h)$ that represents the degree of credibility of the assertion aSb_h (where $\sigma(a, b_h) \in [0,1]$). In order to determine this index, the following items should be calculated:

- The partial concordance index $C_j(a,b_h)$

$$C_j(a, b_h) = \begin{cases} 0 \text{ if } g_j(b_h) - g_j(a) \geq p_j(b_h) \\ 1 \text{ if } g_j(b_h) - g_j(a) \leq q_j(b_h) \\ \frac{p_j(b_h)+g_j(a)-g_j(b_h)}{p_j(b_h)-q_j(b_h)} \text{Otherwise} \end{cases} \quad (1)$$

- The global concordance index

$$C(a, b_h)= \frac{\sum_{j\in f} w_j \, c_j\,(a,b_h)}{\sum_{j\in f} w_j} \quad (2)$$

- The discordance index

$$D_j\,(a, b_h)= \begin{cases} 0 \text{ if } g_j(b_h) - g_j(a) \leq p_j(b_h) \\ 1 \text{ if } g_j(b_h) - g_j(a) > v_j(b_h) \\ \frac{g_j(b_h)+g_j(a)- p_j(b_h)}{v_j(b_h)-p_j(b_h)} \text{otherwise} \end{cases} \quad (3)$$

- The credibility index $\sigma(a, b_h)$ of the outranking relation

$$\sigma(a, b_h) = c_j\,(a, b_h) \,.\, \prod_{j\in F} \frac{1- d_j\,(a,b_h)}{1- d_j\,(a,b_h)} \quad (4)$$

Where, $F^{-} = \{ j \in F : d_j\,(a, b_h) > c(a, b_h)\}$

The statement aSb_h is considered valid if $\sigma(a,b_h) \geq \lambda$, where $\lambda \in [0.5,1]$ (Mousseau et al., 2001).

Two assignment procedures can be evaluated using ELECTRE TRI:

- Pessimistic procedure: An alternative a is assigned to the highest category such that aSb_{h-1}.
- Optimistic procedure: An alternative a is assigned to the lowest category C_h such that $b_h > a$.

More details about the ELECTRE TRI method can be found in (Yu, 1992; Roy and Bouyssou, 1993; Mousseau et al., 2001).

The next section describes the decision-making problem and presents the decision process for the choice of appropriate evaluation methods for the layered evaluation.

3 THE PROPOSED DECISION MODEL

3.1 Problem Definition

A variety of MCDA methods has been proposed in order to solve the sorting decision problem. None of these MCDA methods is able to solve all types of decision-making situations (Guitouni and Martel, 1998). In order to identify the most appropriate one, an analysis of the different MCDA methods is conducted. In this analysis, we focus essentially on the characteristics of the decision problem.

As already presented, the layered evaluation consists in evaluating every layer of adaptation independently of the others. Different evaluation methods can be used for individual layers. Assigning the alternative evaluation methods to predefined layers corresponds to one of the problem statements proposed by Roy (Roy, 1968). The choice of appropriate evaluation methods in the case of the layered evaluation can be formulated as a sorting decision problem.

Given the presence of both quantitative and qualitative criteria with different types of scales, the ELECTRE TRI method seems to be an appropriate MCDA method for the given decision problem. In addition, ELECTRE TRI presents a powerful MCDA method that affects the different alternatives independently of each other. This has a significant importance in terms of saving computing time when a varied set of alternatives is presented.

3.2 Decision Process for the Choice of Appropriate Evaluation Methods for the Layered Evaluation

As already mentioned, the aim of this research is to identify the appropriate evaluation methods for the layered evaluation of interactive adaptive systems. To this end, we use a specific MCDA method, namely ELECTRE TRI. The different MCDA methods need a set of alternatives that corresponds to the possible solutions. In this study, the considered alternatives are the evaluation methods. In IAS literature, there is a variety of evaluation methods for individual layers. Examples of these evaluation methods include user-as-wizard (Masthoff, 2006), focus group (Krueger and Casey, 2009), heuristic evaluation (Magoulas et al., 2003).

Evaluation methods differ in terms of many criteria. In this study, six criteria, representing the situation where each evaluation method would be positioned, are considered. These criteria have a quantitative and qualitative nature and include:

- Layer's input data, which reflect the input data of the adaptive system's functionalities to be evaluated by a layer. The input data can be either shown to the participants or produced by them (Paramythis et al., 2010). The evaluation of this criterion is binary: we use 1 to represent the shown input data and 0 otherwise;
- Layer's output data, which refer to the data produced by the layers. Like the input data, they can be either shown or produced by the stakeholders (Paramythis et al., 2010). This

criterion has a binary evaluation, 1 represents the shown input data and 0 otherwise;

- System development phase, which reflects the moment in which a layer may be evaluated. Paramythis *et al.,* (Paramythis et al., 2010) distinguishes three evaluation phases, namely (1) the specification phase, which occurs when the general functionality of a layer has been produced, (2) the design phase, which occurs when the design of the IAS has been completed or partially completed, and (3) the implementation phase which occurs in the presence of a prototype of the system's functionality;
- Number of evaluators, which reflects the total number of evaluators involved in the IAS evaluation process. The evaluation of this criterion can yield a grade between 0 and N evaluators;
- Number of users, which refers to the total number of users involved in the layered evaluation process of the interactive adaptive systems. The assessment of this criterion can yield a grade between 0 and N users;
- Presence of real users, IAS evaluation can be applied in the presence of representative or real users. To make the use of this criterion in the decision model possible, the assessment made of this criterion is binary: we use 1 to represent the presence of real users and 0 otherwise.

It should be noted here that the mentioned criteria are not exhaustive and that other ones may be included. In the next step, a performance table is created. In which every evaluation method is classified according to the considered criteria. This classification is carried out through data collected from different previous research studies such as (Gena, 2005; Gena and Weibelzahl, 2007; Paramythis et al., 2010).

Then, a number of technical parameters for ELECTRE TRI have to be determined, namely the veto thresholds, the profile limits between categories, and the importance weights of criteria. When using ELECTRE TRI method, the evaluator has to give his/her preferences. It is important to note that the use of MCDA methods such as ELECTRE TRI method is based on the preference relation from the construction of a coherent family of criteria.

As already stated, two assignment procedures using ELECTRE TRI method are available, namely the optimistic and the pessimistic versions. In this step, an analysis of the usefulness of the results in each procedure is performed. The analyses conducted in this step consist in verifying if the different evaluation criteria that need to be assessed in each layer are covered by the proposed evaluation methods cover. In other words, a comparison is conducted between the evaluation factors to be assessed in the individual layers and the evaluation criteria covered. Every evaluation method allows assessing a number of evaluation factors in the individual layers of IAS, and depending on the context of use factors, a number of evaluation factors must be assessed in the layers. Examples of these evaluation criteria include transparency, predictability, timeliness, privacy and trust, appropriateness of adaptation, and unobtrusiveness.

In the final step, our proposal identifies the assignment procedure in which the evaluation factors that should be assessed in the individual layers are covered. Once the assignment procedure is identified, the final list of appropriate evaluation methods will be generated. Figure 1 shows the proposed decision model.

4 APPLICATION

This section investigates a case study in order to illustrate the feasibility of the proposed decision model. The research question addressed is "What are the best evaluation methods for individual layers of a specific adaptive hypermedia system?". In this study, the considered adaptive hypermedia system assists users in their information-seeking tasks by presenting information about the vehicles' times through a Web interface. The system adapts the interfaces in such a way as to present the relevant information about the user's destination (Dhouib et al., 2015).

4.1 Exploration by ELECTRE TRI Method

The first step corresponds to the identification of the problem's characteristics. This involves also the identification of alternative evaluation methods for interactive adaptive systems and the criteria that affect the choice of these methods. Table 1 illustrates the alternative evaluation methods considered in this study. Due to the specificities of the layered evaluation, the choice of alternative evaluation methods has to take into account the formative perspective (Paramythis et al., 2010).

As already stated, the application of the ELECTRE TRI method needs the consideration of a number of parameters such as the importance weights of criteria. The construction of these weights importance is carried out through an elicitation process with the decision maker. Table 2 illustrates the importance weights of the identified criteria.

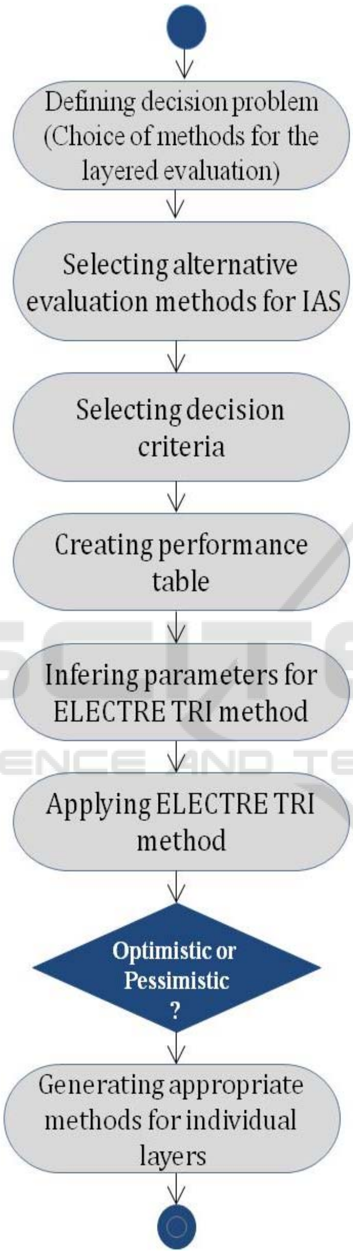

Figure 1: Decision process for choosing the appropriate evaluation methods for the layered evaluation of interactive adaptive systems (IAS).

The following step continues with an elicitation of the characteristics needed for the categories. In our context, the categories represent the layers of adaptation. The adaptation process of the considered

Table 1: The considered evaluation methods for interactive adaptive systems.

Number	Evaluation Methods
a1	Focus group
a2	User test
a3	Heuristic evaluation
a4	Cognitive walkthrough
a5	User-as-wizard
a6	Simulated-users
a7	Co-discovery
a8	Play with layer
a9	Logging use
a10	Thinking-aloud protocol
a11	Interviews
a12	Wizard of Oz
a13	Cross-validation
a14	Data mining
a15	Scenario-based design
a16	Coaching
a17	Contextual design
a18	Retrospective testing
a19	Prototypes
a20	Questionnaires

adaptive hypermedia system is centered on the five distinct layers of (Paramythis et al., 2010). The defined layers are collection of input data, interpretation of the collected data, modelling of the current state of the world, deciding upon adaptation, and applying adaptation. These layers have respectively the following priorities: very high, high, moderate, low, and very low. Four borders (b1, b2, b3 and b4), which constitute the limits of the different layers, are defined. Border b1, for example, determines the limit between the *collection of input data* and *interpretation of the collected data* layers, while b2 reflects the limit between *interpretation of*

Table 2: Considered decision criteria and relative weights.

Number	Decision Criteria	Weights
C1	System development phase	0.23
C2	Layer's input data	0.15
C3	Layer's output data	0.15
C4	Number of users	0.15
C5	Number of evaluators	0.20
C6	Presence of real users	0.12

the collected data and *modelling of the current state of the world* layers. We use the default value of ELECTRE TRI for the cut-off level λ, 0.76. This value gives an intermediate level of strictness to examination in order to help the assignment of alternatives into the categories.

In the following stage, the binary relations defined by aHb_i are identified, where *a* represents the alternatives evaluation method and b_i the limit profile between layers. Five steps are conducted, namely (1) determination of the partial concordance index, (2) identification of the global concordance index, (3) calculation of the discordance index, (4) determination of the credibility index, and (5) identification of the relations of preference from the determination of the cut-off level λ.

Table 3: Binary relations between alternatives and the reference limits profiles.

a_iSb1	a_iSb2	a_iSb3	a_iSb4
a1Ib1	a1Sb2	a1Sb3	a1Sb4
a2Ib1	a2Ib2	a2Ib3	a2Sb4
a3Sb1	a3Sb2	a3Sb3	a3Sb4
a4Ib1	a4Ib2	a4Ib3	a4Sb4
a5Ib1	a5Rb2	a5Sb3	a5Sb4
a6Sb1	a6Sb2	a6Sb3	a6Rb4
a7Ib1	a7Ib2	a7Rb3	a7Sb4
a8Sb1	a8Sb2	a8Sb3	a8Sb4
a9Ib1	a9Ib2	a9Ib3	a9Sb4
a10Ib1	a10Ib2	a10Ib3	a10Sb4
a11Ib1	a11Rb2	a11Ib3	a11Ib4
a12Ib1	a12Ib2	a12Ib3	a12Sb4
a13Sb1	a13Sb2	a13Rb3	a13Ib4
a14Sb1	a14Sb2	a14Rb3	a14Ib4
a15Ib1	a15Ib2	a15Sb3	a15Sb4
a16Ib1	a16Ib2	a16Ib3	a16Sb4
a17Ib1	a17Ib2	a17Ib3	a17Sb4
a18Ib1	a18Ib2	a18Ib3	a18Sb4
a19Ib1	a19Ib2	a19Ib3	a19Sb4
a20Ib1	a20Ib2	a20Ib3	a20Sb4

Table 3 presents the binary relations between alternatives and the reference actions in which the outranking relations (S), indifference (I), or incomparability (R) are defined.

4.2 Results and Discussion

The last stage of exploration of the ELECTRE TRI method consists in assigning the evaluation methods to the predefined layers. Two allocation procedures are supported by ELECTRE TRI method. The first allocation procedure begins with the pessimistic one. In this procedure, the comparison begins with the best reference action and proceeds to the action immediately below until the first profile b_i which is outranked by alternative a_i. After applying the ELECTRE TRI method, the appropriate evaluation methods are displayed according to the type of assignment (i.e., pessimistic or optimistic). Each evaluation method is compared to the reference profiles of the layers.

Table 4 shows the final result obtained through the optimistic and pessimistic versions of ELECTRE TRI method.

Finally, the evaluator has to compare the evaluation criteria to be assessed in each layer and the other ones covered in the proposed evaluation methods in each assignment procedure. Based on the information given about the context of use factors, the evaluation criteria to be covered in the adaptive system can be determined. It should be noted that the proposed results are dependent on the considered evaluation constraints. In this study, the pessimistic version of ELECTRE TRI is adopted. This version proposes the most suitable evaluation methods that cover the different evaluation criteria in each layer. Table 5 illustrates the appropriate evaluation methods for individual layers of the considered adaptive system. Considering the final results obtained, we can note that in each layer, different evaluation methods are proposed. These methods are divergent in their assignment in each layer of adaptation.

Table 4: Classification results by ELECTRE TRI.

Adaptation layers	Pessimistic procedure	Optimistic procedure
Collection of input data	a13, a14	a8, a15
Interpretation of the data	a15, a16, a8	a3, a6, a8, a9, a13
Modelling of the current state of the world	a1, a3, a6, a12, a19	a1, a5, a14, a16,
Deciding upon adaptation	a4, a2, a5, a9, a10, a17, a20	a4, a2, a11, a12, a20
Applying adaptation	a7, a11, a18	a7, a10, a17, a18, a19

Table 5: Final proposed evaluation methods.

Adaptation layers	Final proposed evaluation methods
Collection of input data	a13, a14
Interpretation of the data	a15, a16, a8
Modelling of the current state of the world	a1, a3, a6, a12, a19
Deciding upon adaptation	a4, a2, a5, a9, a10, a17, a20
Applying adaptation	a7, a11, a18

Every evaluation method is assigned to one layer according to which this method might be appropriate to assess the considered evaluation factors of the considered layer. It is important to examine carefully the evaluation methods generated and especially to infer the criteria that really represent the feedback from evaluator about the context of use factors. In this study, the ELECTRE TRI method is applied to the assignment problematic. It aims to allocate each alternative evaluation method to the appropriate layers. The different steps of adaptation are defined a priori by the evaluator. Five adaptation layers are identified in the adaptation process of the given adaptive system.

5 CONCLUSION AND FUTURE WORK

In this research paper, we are interested in proposing a decision model to guide the layered evaluation of interactive adaptive systems. The goal is to apply a multi-criteria decision sorting method in order to help evaluators in the choice of appropriate evaluation methods for individual layers. By doing so, it is possible to assign the best evaluation methods to the layers of adaptation for particular evaluation settings. To this end, one MCDA method is used, namely ELECTRE TRI. The proposed decision model is applied to determine the suitable evaluation methods for the individual layers of an adaptive hypermedia system.

It should be noted that the number of layers may change from an IAS to another and that not all layers can be evaluated in isolation in all contexts. In some cases, it may be necessary to evaluate the layers in combination (Paramythis et al., 2010). This depends essentially on some evaluation constraints and the nature of the IAS. The evaluation also has to consider the case of the whole adaptive systems in which there is no distinction between the different layers. Future directions of this research will then investigate how to handle the case of the whole adaptive system and the combination of layers. We also intend to include other criteria and to test our proposed model in real evaluation scenarios.

REFERENCES

Brusilovsky, P., Schwarz, E., Weber. G., 1996. Elm-art: an intelligent tutoring system on world wide web. In *Intelligent Tutoring Systems.* Lecture Notes in Computer Science, Springer Verlag, Berlin, 261–269.

Brusilovsky, P., Karagiannidis, C., Sampson, D. 2004. Layered evaluation of adaptive learning systems. *International Journal of Continuing Engineering Education and Lifelong Learning*, Burke, R. Hybrid recommender, 14, (4/5), 402-421.

Dhouib, A., Trablesi, A., Kolski, C. and Neji, M. 2015. A framework for supporting the choice of usability evaluation methods for interactive adaptive systems. *15th International Conference on Intelligent Systems Design and Applications*, December, Marrakesh, Maroc, 289-294.

Dhouib, A., Trabelsi, A., Kolski, C., Neji. M., 2016a. A classification and comparison of usability evaluation methods for interactive adaptive systems. *9th International Conference on Human System Interactions*, Portsmouth, UK, 246–251.

Dhouib A, Trablesi A, Kolski C, Neji M. 2016b. An approach for the selection of evaluation methods for interactive adaptive systems using analytic hierarchy process. *IEEE Tenth International Conference on Research Challenges in Information Science,* Grenoble, France, 1-10.

Ferré, X., and Bevan. N., 2011. Usability planner: a tool to support the process of selecting usability methods. In *Human-Computer Interaction–INTERACT* 2011, ed: Springer, 652-655.

Goren-Bar D, Graziola I., Rocchi C, Pianesi F, Stock O, Zancanaro M. 2005. Designing and redesigning an affective interface for an adaptive museum guide. In: *1st International Conference on Affective Computing and Intelligent Interaction,* Beijing, China. 3784: 939–946.

Goy, A., Ardissono, L., Petrone. G., 2006. Personalization in e-commerce applications. In *Brusilovsky, P., Kobsa, A., Nejdl,W. (eds.), The Adaptive Web: Methods and Strategies of Web Personalization*. Lecture Notes in Computer Science, Springer-Verlag, Berlin Heidelberg, New York vol. 4321.

Gena, C., Weibelzahl. S., 2007. Usability engineering for the adaptive web. In: Brusilovsky, P., Kobsa, A., Nejdl, W. (eds.). The Adaptive Web: Methods and *Strategies of Web Personalization,* Springer, Berlin, 720-762.

Guitouni, A., and Martel, J. M. 1998. Tentative guidelines to help choosing an appropriate MCDA method.

European Journal of Operational Research, 109:501–521.

Krueger, R., Casey, M. 2009. Focus Groups: A Practical Guide for Applied Research. *4th edn. Sage Publications,* Los Angeles.

Masthoff, J. 2006. The user as wizard: a method for early involvement in the design and evaluation of adaptive systems. In: *5thWorkshop on User-Centred Design and Evaluation of Adaptive Systems at AH'06*, Dublin, Ireland, 460–469.

Magoulas, G. D, Chen, S. Y, and Papanikolaou K. A. 2003. Integrating layered and heuristic evaluation for adaptive learning environments. In: *2nd Workshop on Empirical Evaluation of Adaptive Systems at UM2003*, Johnstown, PA, 5-14.

Manouselis, N., Karagiannidis, C., Sampson. D.G., 2014. Layered evaluation for data discovery and recommendation systems: an initial set of principles. *IEEE 14th International Conference on Advanced Learning Technologies (ICALT),* 518-519.

Mulwa, C., Lawless, S., Sharp, M., and Wade, V. 2011. The evaluation of adaptive and user-adaptive systems: a review. *International Journal of Knowledge and Web Intelligence,* IJKWI, 2, 2/3, 138-156.

Mousseau, V, Figueira, J & Naux, JP. 2001. Using assignment examples to infer weights for ELECTRE TRI method: Some experimental results. *European Journal of Operational Research*, 130(2): 263–275.

Paramythis, A., Weibelzahl, S., Masthoff. J., 2010. Layered evaluation of interactive adaptive systems: framework and formative methods. *User Modeling and User-Adapted Interaction*. 20, 383-453.

Roy, B., 1968. Classement et choix en présence de points de vue multiples (la méthode ELECTRE). *Revue Française d'Informatique et de Recherche Opérationnelle*, 8, 1968, 57–75.

Weibelzahl, S., 2001. Evaluation of adaptive systems. In: *8th International Conference on User Modeling*. LNCS, Springer, Berlin, 2109, 292-294.

Weibelzahl, S., Lauer, C. U. 2001. Framework for the evaluation of adaptive CBR-systems. In. *Vollrath, S. Schmitt, & U. Reimer (Eds.), Experience Management as Reuse of Knowledge. Proceedings of the 9th German Workshop on Case Based Reasoning*, GWCBR2001, 254-263.

Yu, W., 1992. ELECTRE TRI: aspects méthodologiques et manuel d'utilisation. *Document du LAMSADE n° 74 LAMSADE Université Paris-Dauphine.*

Van Velsen, L., Van der Geest, T., Klaassen, R., Steehouder, M. 2008. User-centered evaluation of adaptive and adaptable systems: a literature review. *The knowledge engineering review*, 23, 261-281.