

Evaluation framework based on fuzzy measured method in adaptive learning systems

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Abstract

Currently, e-learning systems are mainly web-based applications and tackle a wide range of users all over the world. Fitting learners' needs is considered as a key issue to guaranty the success of these systems. Many researches work on providing adaptive systems. Nevertheless, evaluation of the adaptivity is still in an exploratory phase. Adaptation methods are a basic factor to guaranty an effective adaptation. This issue is referred as meta-adaptation in numerous researches. In our research on the development of an evaluation framework of adaptive web-based learning systems, adaptation method assessment is a fundamental aspect. Currently, measures significantly lack to express the adaptive systems features and need to be explored. Consequently, we propose a three-fold approach. Firstly, specific adaptation measurement criteria are suggested. Secondly, experts and learners assess these criteria and both current learning situation and similar past experiences are considered. Finally, fuzzy group decision making theory is adopted to integrate different perceptions related to the adaptive system.

Keywords

e-learning, adaptive learning systems, evaluation

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Introduction

E-learning is a leader field for adaptive web based systems. The number of stakeholders is considerably growing all over the world. The IDC (International Data Corporation) forecasts an important increase in the e-learning market: \$21 billions in 2008. These users are different at many levels: Educational goals, social situation, language, skills, etc. To cope with their needs, several adaptive Web-based educational systems are currently available in the market. Nevertheless, many studies showed that adaptivity issue is non-sufficiently addressed in these systems (Graf & List, 2005; Brusilovsky, 2004; Gutl et al., 2004; Russell, 1999).

Optimizing adaptivity effectiveness necessitates essentially an objective evaluation which indicates the reasons of failures or successes. This idea is the key issue of layered evaluation approaches (Paramythis et al., 2001; Weibelzahl, 2003; Brusilovsky et al., 2004; Paramythis & Weibelzahl, 2005). The latter studies give an overview of adaptive system layers to be addressed in the evaluation process. However, specific measurement criteria which concretely describe adaptive systems features are significantly lacking and there are no evaluation frameworks for measuring the quality of adaptation. The main goal of our research is to provide a conceptual framework for adaptive learning systems evaluation. Adaptation method is an abstract layer which is considered in all adaptive systems. Consequently, it is essential to focus on this issue in the development of adaptive system evaluation framework.

In this paper, we aim to explore metrics related to the method layer in order to assess successes or limitations of methods in each learning context and to be able to choose the suitable method in the appropriate situation. The adaptation of adaptive methods to a specific context is referred in many researches as meta-adaptation (Brusilovsky, 2003; Revilla & Shipman, 2003; Hillman & Warren, 2004).

In our work, both experts and learners judgements are considered. Decisions related to the different measures are generally described by qualitative values. Fuzzy group decision making theory is adopted to evaluate the global degree of adaptation method performance.

Recent adaptive hypermedia systems are mainly based on AHAM (Adaptive Hypermedia Application Model) reference model (De Bra et al, 1999). Accordingly, in our research, we deal with adaptive systems that follow the principles presented in this model. In the following section, AHAM model is briefly introduced.

AHAM reference model

AHAM is a general reference model for adaptive hypermedia systems. It divides the adaptive application into three basic components: User Model, Domain Model and Adaptation Model.

Domain Model

Hypermedia systems are described generally by nodes and links. Adaptive Hypermedia systems, based on AHAM model, deal with concepts and concept relationships.

Concepts: AHAM introduces three types of concepts: fragments, pages and composite concepts. A fragment is an atomic information unit that cannot be modified by the adaptive hypermedia system. A page component is a set of fragments that are presented to the user at the same time. A composite component is a set of pages and/or other composite components. The hierarchy of these concepts is presented in Figure 1.

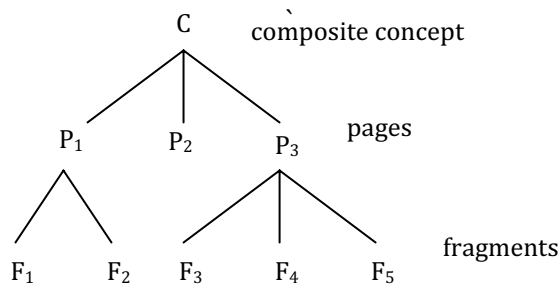


Figure 1. Concepts hierarchy

Concept relationships: Generally, in hypermedia systems, relationship between components is based on navigational link only. Nevertheless, in an adaptation context, semantic aspect is considered in concept relationship. Mainly, the following relationship types are considered in AHAM:

- Link : present the navigational link between components
- Prerequisite: designate order of reading between concepts
- Inhibitor: designate a non-desirable reading order.

AHAM allows others relationships' types to be added.

Adaptation Model

Adaptation model describes adaptive hypermedia systems at an abstract conceptual level. It uses information from domain model, user model and user interaction to update the user model and to perform adaptation. AHAM adopts language of rules to describe the adaptation strategies. The interpreter of these rules is called adaptation engine. It uses adaptation rules to generate HTML pages: It builds them by selecting and/or sorting fragments.

User Model

In order to fit users' needs, adaptive systems must store information about his or her preferences, knowledge, background, environment, etc. AHAM is based essentially on user knowledge about the application domain. Consequently, the user model is an overlay model of the domain model. For each concept in the domain model, attributes values about the concept are stored in the user model, such as: not known, learnt, well-known, read, ready to read, etc.

Adaptation methods evaluation approach

A system is called adaptive if it is able to change its own characteristics automatically according to user's needs (Oppermann, 1994). Different methods and techniques are applied in order to insure adaptivity. The method tackles adaptation in an abstract and conceptual level whereas techniques are an implementation of adaptation methods. Measures used in adaptive systems' evaluation are mainly borrowed from Human Computer Interaction (HCI) field and new approaches are strongly called for exploring new metrics to assess adaptivity (Gena & Weibelzahl, 2006). Accordingly, we aim to address in this paper these limitations and we focus essentially on adaptation methods in e-learning context.

Our approach is in three phases. Firstly, we explore measurement criteria associated to adaptation method. Secondly, different measures assessments are considered. Finally, a global evaluation result is generated which integrate the different perceptions related to the adaptive system.

Evaluation criteria exploration

One adaptation method can not be suitable to all contexts. For this reason, adaptation methods should be adapted to the changing context of adaptive learning systems and

learners. Current systems don't deal with meta-adaptation. Results of the proposed approach can contribute to integrate meta-adaptation in adaptive systems.

In AHAM, three basic models can be considered in each adaptive system: adaptation model, user model and domain model. Based on this principle, we assume that adaptation methods concern, in one hand, user modelling which deduces inferences from user interaction with the e-learning system. In the other hand, they are related to adaptive content and link generation. Consequently, adaptation methods can be divided into three main categories: user modelling methods, content or presentation methods and navigational or link methods.

The use of a single user model often results in rigid adaptation strategies (Revilla & Shipman, 2003). To cope with this difficulty, researchers have augmented this approach by employing multiple models (Revilla & Shipman, 2000). Different user modelling methods can be adopted to create the user model, to analyze the user interaction with adaptive system and to deduce new information about the user. They include:

- Overlay method
- Stereotype method
- Bayesian methods
- Modal logic
- Machine learning methods, such as features-based techniques, neural networks, and explicit user ratings.

Brusilovsky (2003) has revealed that users with different knowledge level of the subject may appreciate different adaptive navigation support technologies. The main adaptive navigation support methods are the following:

- Global guidance
- Local guidance
- Global orientation support
- Local orientation support
- Managing personalized views.

Presentation concerns the content presented to the adaptive system users. The following adaptive presentation methods can be adopted:

- Additional, prerequisite, and comparative explanations

- Explanation variants
- Sorting.

In order to evaluate adaptation methods, we introduce measurement criteria to assess adaptation methods performance. We propose three basic criteria as following:

Method appropriateness: The choice of the adaptation method affects adaptation quality and user satisfaction. Appropriateness criterion deals with which method is most appropriate, when and where? Many researches in software engineering tackle this problem. The situational approaches bring solutions that may be adapted to adaptive systems context. For instance local guidance method in link adaptation gives the user an idea of only the following step. But, global guidance gives the user an overview of all the following steps. Appropriateness study would help adaptive system designers to decide which method is most suitable, when and in which context.

Exactness of inferences: Adaptation methods update user model based on user interaction with the system. In the other hand, they generate adaptation (content and link) deduced from the current state of the user model. Nevertheless, inferences can be erroneous, since interpretation of human reaction is complex and not systematic. Number of learning concepts can be accessed by user and not learnt or only partially learnt. The user can see the web page without learning its concepts or understanding them. Although, the adaptation method can declare the concept as learnt and provide subsequent adaptation. Exactness of inferences evaluation criterion can be related either to user modelling methods or content and navigation methods which make inferences based on user model.

Learner acceptance: Adaptation should be perceived by learner as a natural process. Therefore, if the user feels to be spied on or forced to learn a given concept and to reach a particular link, then the adaptation method fails to fit the learner needs and it is not accepted. Care should be taken that these methods are not too obtrusive with respect to the interaction itself (Paramythis et al., 2001).

Evaluation criteria assessment

Criteria assessment is performed by learners and experts. In this research, we propose an adaptation method evaluation based on current measures and past evaluation experiences results. Measurement criteria related to adaptation methods are mainly qualitative and subjective. Decisions in this context are often expressed in natural language and evaluators are unable to assign exact numerical values to the different criteria. Assessment can be possibly performed by linguistic variables like:

“bad”, “poor”, “fair”, “good” and “excellent”. These values are imprecise and uncertain: They are commonly called fuzzy values. Integrating these different judgments in order to obtain a final evaluation is not evident. We propose to use fuzzy group decision making theory to obtain final assessment measures related to adaptation methods.

Global evaluation based on fuzzy group decision-making theory

In order to deal with fuzzy multi-criteria and multi-decisions evaluation problem, fuzzy group decision-making theory is adopted.

First, linguistic variable values are mapped into fuzzy numbers. In this paper, we use triangular fuzzy numbers (TFNs) which are a class of the fuzzy set representation (Dubois & Prade, 1978; Zadeh, 1975a, b, c). A triangular fuzzy number \tilde{N} is expressed by three real numbers (l,m,u): The parameters l, m, and u, respectively, indicate the lower, the mean, and the upper possible values. TFNs membership functions are the following:

$$\mu(x/\tilde{N}) = \begin{cases} 0 & x < l \\ (x - l) / (m - l) & l \leq x \leq m \\ (u - x) / (u - m) & m \leq x \leq u \\ 0 & x > u \end{cases}$$

Figure 2 illustrates the mapping of linguistic variables into the corresponding TFNs. In our work we adopt a five criteria assessment scale: “bad”, “poor”, “fair”, “good” and “excellent”. Conversion of these qualitative values into fuzzy numbers is showed in Table 1.

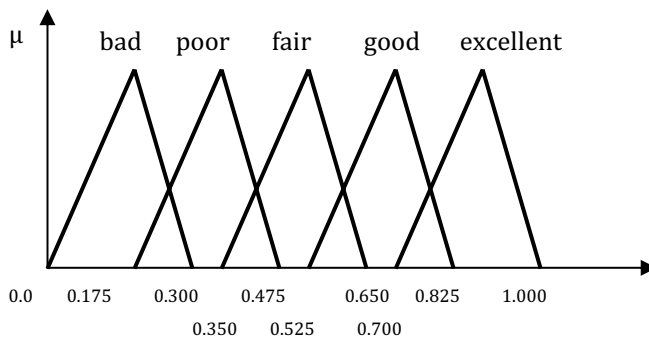


Figure 2. The mapping of linguistic variable into the corresponding TFN

Table 1. Linguistic variables conversion into TFN

Linguistic variables	TFN
Excellent	(0.700, 0.850, 1.000)
Good	(0.525, 0.675, 0.825)
Fair	(0.350, 0.500, 0.650)
Poor	(0.175, 0.325, 0.475)
Bad	(0.000, 0.150, 0.300)

In order to compute the fuzzy global evaluation result, first we integrate the different evaluators' fuzzy assessments for each criterion using geometric mean method suggested by (Buckley, 1985):

$$\tilde{N}_i = (\tilde{N}_i^1 \otimes \tilde{N}_i^2 \otimes \dots \otimes \tilde{N}_i^m)^{1/m}$$

\tilde{N}_i^j : Judgement of the evaluator j towards the criterion i;

\tilde{N}_i : The average fuzzy number of evaluators' judgments towards criterion i;

m: The total number of evaluators;

\otimes : Fuzzy number multiplication;

In our study we suppose that all criteria have the same weight. The global fuzzy evaluation result is obtained by using arithmetic mean as follow:

$$\tilde{N} = 1/n (\tilde{N}_1 \oplus \tilde{N}_2 \oplus \dots \oplus \tilde{N}_i)$$

n : The total number of criteria;

\oplus : Fuzzy number addition;

The last step is the defuzzification procedure. We adopt the center of area (COA) method to convert the global fuzzy evaluation result \tilde{N} , expressed by a triangular fuzzy number (l, m, u), to a non-fuzzy value E. The following equation is adopted:

$$E = [(u - l) + (m - l)] / 3 + l$$

Results of evaluations are stored in experience base in order to learn from the past and to use them in new evaluation situations. Global evaluation results of adaptation methods, can participate to improve awareness about the limits and strengths of these methods. Therefore, this research can contribute towards meta-adaptation support by understanding the applicability of current methods given user and context characteristics.

Conclusion

Adaptive learning systems are currently lacking evaluation frameworks for measuring concretely the quality and effectiveness of adaptation. As layered evaluation approaches advocate, evaluation practices should take into account components that are responsible for adaptive behaviour. Adaptation methods are strongly related to adaptive system components. Meta-adaptation, a new research issue, believes that one adaptation method can not be suitable for all contexts. In this paper, we propose a measurement centred evaluation approach focused on adaptation methods assessment.

The choice of adopted methods in user modelling, presentation and navigation steps are a key issue for adaptation performance. Evaluation of the method level is the first stage in the assessment of adaptive Web-based learning systems. In our research, we propose to explore specific measurement criteria to evaluate adaptation method. These criteria are assessed by both learners and experts and they are mainly expressed by qualitative statements. Global evaluation results are achieved by using fuzzy group decision making theory for the aggregation of different decisions. We propose to consider current learners and experts judgements related to measurement criteria and also similar past evaluations results in order to reinforce assessment decisions. This work can be used in order to support meta-adaptation. Knowledge base can be constructed, in future works, in order to store different adaptive learning situations with related adaptation method feedback. Adaptation process can be reinforced and guided to select suitable methods fitting varying contexts.

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