

# Measurement framework for aligning adaptation methods with business and usage factors in e-learning

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**Abstract**—E-learning is increasingly integrated in the society culture and in business world via e-university and e-training. Goals, needs, characteristics of learners are very different. Indeed, providing adaptive system is critical for the e-learning sustainability. Nevertheless, many recent studies have shown that, on one hand, adaptivity is concretely deficient in e-learning systems, on the other hand, specific measures are strongly lacking. In this paper, a measurement framework is proposed to assess adaptivity performance focusing on adaptation methods alignment with usage and business factors. The measurement generation process is described.

**Index Terms**—adaptation methods, alignment, e-learning, business factor, usage factor.

## I. INTRODUCTION

Adaptive Web-based education is a transversal domain which integrates e-learning, adaptivity, hypermedia and World Wide Web fields. It aims to guaranty the information society; that is, information for everyone and everywhere. Stakeholders in e-learning field are extremely different consequently they have various and changing needs. Indeed, providing adaptive systems is critical for the e-learning sustainability.

Statistics indicate that two thirds of developed adaptive Web-based hypermedia systems are being applied in the educational area [6]. Many recent researches have shown that current adaptive Web based learning systems are lacking adaptivity [14] [13] [8]. Moreover, it is of great concern that too much of the online education that has been offered so far has been transient, unsuccessful and far from sustainable [16].

As Brusilovsky states in [8], given the large set of existing techniques and systems, evaluation of adaptive systems and improving them is becoming more important than inventing new techniques with questionable benefits. Several evaluations are being conducted in adaptive e-learning field, theoretical and empirical ones. Results of these researches are quite subjective. In fact, there is much debate on how adaptive hypermedia applications should be evaluated since there is no standard or agreed measurement framework for assessing the value and the effectiveness of adaptation yielded by adaptive systems [15]. Furthermore, adaptive hypermedia systems are lacking specific adaptation metrics [12]. Many interested facets can be considered for measure within an adaptive Web-based learning system. Herein, we are mainly interested with meta-adaptation level.

As presented in [5] [6], various adaptation methods are available. One adaptation method cannot be suitable to all

situations [22] [21]. Accordingly, meta-adaptation is certainly a real necessity in adaptive hypermedia system. Indeed, adaptivity performance is strongly related to adaptation methods selection. In this work, a measurement framework is proposed. Adaptivity is considered according to both usage and business scales.

In the subsequent sections, firstly, adaptation methods are introduced. Secondly, measurement framework construction approach is described. Finally, specific adaptivity metrics are proposed.

## II. ADAPTATION LEVELS & METHODS

Adaptation systems aim to provide personalized services to the users. Systems that allow the user to change certain system parameters and adapt their behaviour accordingly are called adaptable. Systems that adapt to the users automatically based on the system's assumptions about user needs are called adaptive [19]. The whole spectrum of concept of adaptation in computer systems [20] is illustrated in Fig. 1.

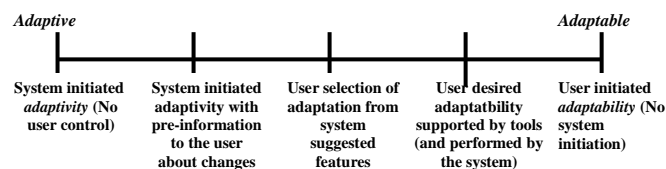


Fig 1. Spectrum of adaptation in computer

Meta-adaptation problem is related to timing strategies which are a sensible candidate for being adapted considering the user's individual and possibly changing acceptance border for interruptions by adaptations. The issue of which items should be automatically adapted by the system and which others that should be left to the user's control is quite challenging. Moreover, how items should be adapted leads us to consider the effectiveness of the adopted adaptation methods. The question can only be countered with respect to the particular user needs. Specific measures can bring guidance to the selection of adaptation methods which are suitable to the adaptive Web-based learning system business and usage context.

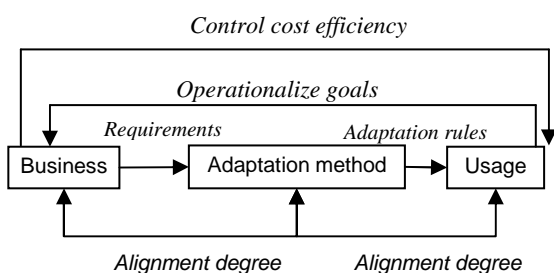
## III. MEASUREMENT FRAMEWORK CONSTRUCTION

According to Fenton [11], measurement is the process by which numbers or symbols are assigned to attributes of entities in the real world in such a way as to describe them according to clearly defined rules. Any measure is only as

good as its capability to reflect our intuitive understanding of the phenomenon that is being measured. Consequently, constructing a measurement framework to evaluate web-based learning system at a strategic level is closely associated to an understanding of the interaction flow: inter-relations, inputs, outputs, etc.

*A. Strategic level interaction flow*

More and more universities and companies are increasing their investment in e-learning solutions. However, e-learning efforts are not usually aligned to key organizational objectives [1]. Accordingly, dealing with business factor is a key issue for adaptive e-learning systems evaluation. On the other hand, adaptivity effectiveness could not be assessed without considering the system at a usage context. Hence, the usage facet is the second factor that we propose to consider herein. Fig. 2 illustrates the informational flow throughout adaptation method view, business view and usage view.



**Fig 2.** Informational flow throughout adaptation method, business and usage views

Adaptation method selection affects directly: the adaptivity degree provided to the learner, presented learning resources, as well as link navigation. The adaptation is effective by means of adaptation rules which applied at a usage stage. Feedback

gathered from the system use assesses the alignment degree of the system use with learner needs. At the business side, the system usage should be an operationalization of business goals. Cost control should be carried out to verify the sustainability of the e-learning process. Strategic level encapsulates planning and selection actions, consequently business requirements are basically collected at this stage. Adaptive e-learning system evaluation and improvement at a strategic level is traduced by assessing adaptation method alignment degree with both business and usage views.

In order to generate specific metrics for the alignment measurement, we propose to consider meta-model of each previously considered views. Meta-model mapping illustrated in [10] [24] [2] allows meta-model comparison. Metrics are elicited by studying the correspondence between these meta-models. In the following section this issue is detailed thoroughly.

*B. Meta-models mapping*

Firstly, as described in Fig. 3, we propose the Adaptation Method Meta-model (AMM). The latter describes, at the adaptive system side, adaptation method targets, application constraints and method characteristics. On the other hand, a basic business process meta-model is illustrated. The usage meta-model presented herein is based on adaptive meta-model proposed in [9] and [17]. The mapping is expressed by means of *correspond* link defined in [10]. It inter-relates similar notions that belong to different meta-models. Mapping between AMM meta-model and business process meta-model shows a correspondence link among cost and goal notions. Alignment between the two views should be considered in the measurement framework. Furthermore, alignment between learning concept and navigational link proposed at the method level and these ones adopted or assessed at the usage level should be tackled too.

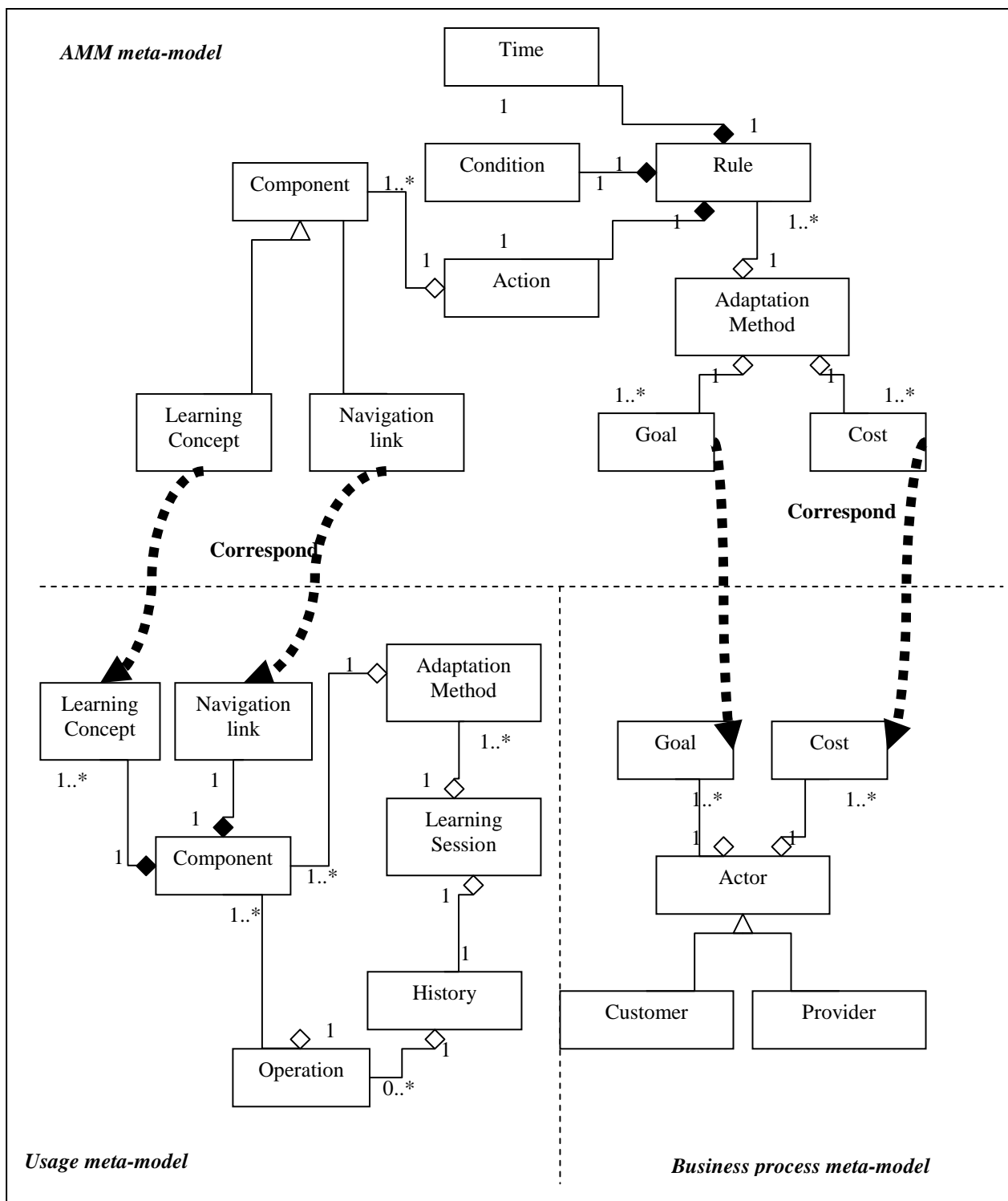


Fig 3. Meta-models mapping among adaptation method, usage and business

C. Measurement framework representation

Quality models are the first representations of measurement framework in software engineering area. These models aim at describing complex quality criteria by breaking them down into more manageable sub-criteria. Such models usually organize quality attributes in a tree with an abstract quality attributes at the top and more concrete ones on lower levels. The values determined by the measures are then aggregated towards the root of the tree to obtain values for higher level quality attributes. This concept

is described by Factor-Criteria-Metrics (FCM) model which was first introduced by McCall [18] and Boehm [3]. This approach is mentioned throughout the whole software engineering measurement literature. FCM models are usually constructed in a tree, where the upper branches hold high-level quality factors. The latter's are composed of lower-level criteria. These criteria are easier to understand than the factors themselves. Afterwards, metrics are proposed for them.

Fenton pointed out in [11] important questions that should be answered before carrying out a measurement process:

1. Why shall be measured?
2. What entities and attributes shall be quantified?
3. When shall the measurements be made?
4. How shall be measured, that is, with the help of which tools, collection and analyses techniques, and who shall perform it?

Basing on previously described principles the measurement framework for the evaluation of adaptive Web based educational system at strategic level is proposed.

#### IV. MEASUREMENT FRAMEWORK AT STRATEGIC LEVEL

As mentioned above we have defined two factors according to them adaptation methods are evaluated: Business and usage. Each factor has related criteria. The latter are associated to metrics which allow to measure alignment degree between adaptation method and the factor facet. As shown in Table. I, six metrics are proposed. Accordingly, why, what, how, when questions are answered for each considered criterion in the subsequent sections.

**Table I.** Metrics to evaluate adaptive method alignment to business and usage context

Factors	Criteria	Metrics
Business	Customer Goal	Customer satisfied goal rate
	Customer Cost efficiency	Customer-Return-On-Investment (C-ROI)
	Provider Cost efficiency	Provider Return-On-Investment (P-ROI)
Usage	Learner Acceptanc	Learner acceptance level
	Inference correctness	Mean Absolute Error (MAE)
	Appropriateness	Adaptation method appropriateness rate (AMAR)

##### A. Customer goal

*Why?* Customer goal is a critical criterion that should be pointed out in the evaluation process. In many cases e-learning market has failed to meet market expectations. Consequently, understanding customer goals and assessing at which extent adaptive Web-based educational system are adapted to them is very important.

*What's metric?* We propose to consider *satisfied customer goal rate* as a metric to assess at which extent adaptive Web-based learning system are aligned to the customer goals. A mean of alignment degree between customer goals and adaptation method goals is measured all over the

learning session. Non-alignment between the two sides' goals can be consequently detected.

*How?* Questionnaires and interviews can be used to collect customers' opinions about their goal satisfaction by the e-learning system.

*When?* This metric can be measured periodically as advocated in agile methods which are customer-centred approaches. Because established processes may be subject to alignment or improvement, the strategic view strongly relies on the comparison of software measures of different periods in time [4].

##### B. Customer cost efficiency

*Why?* A main issue that limits e-learning market growth is customer's uncertainty about investment costs recovering and measurable benefits achievement when adopting Web-based learning. Cost efficiency assessment can guide both customers and e-learning designers in strategic decision making.

*What's metric?* Mainly adopted metric to analyze cost efficiency is Return-On-Investment (C-ROI) [23]. In this context, we define Customer Return-On-Investment (C-ROI). This metric utilizes the percentage of the net benefits over overall costs. The net benefits are strongly related to goal satisfaction. It is crucial to convert goal satisfaction to monetary value in order to get an accurate and credible result.

*How?* Cost efficiency should be assessed with questionnaires, interviews and expert review. These techniques can be used simultaneously or separately.

*When?* This criterion should be estimated throughout both formative and summative evaluation approaches. For the former case, a predictive evaluation can be adopted during specification or design phases. For the latter, at the end of the learning session and periodically after that, benefit value could be assessed.

##### C. Provider cost efficiency

*Why?* Cost-efficiency of e-learning programs has been increasingly important since many several studies revealed that cost is the key obstruction for successful implementation of e-learning.

*What's metric?* Cost efficiency as mentioned above is analyzed by means of ROI metric which utilizes the percentage of the net benefits over overall costs. We propose to consider the overall cost as equals to adaptation method cost besides learning resources cost.

*How?* As described in the previous section data related to cost efficiency can be gathered by questionnaires, interviews and expert review.

*When?* As financial aspect is decisive at the provider side, this criterion should be periodically estimated in order to detect success or failure situation.

#### D. Learner acceptance

*Why?* Adaptation should be perceived by learner as a natural process. Therefore, if he/she feels to be spied on or constrained to learn a given concept or to reach a particular link, then the adaptation method is not accepted by learner.

*What's metric?* We propose to assess learner acceptance criterion by measuring Learner Acceptance Level (LAL) of proposed adaptations. The acceptance is related to learning provided concepts as well as navigational link. The answers were expected to be given on three-point scale: 1-Not accepted, 2-fairly accepted, 3-accepted.

*How?* Questionnaires, interviews, think aloud protocols are possible techniques to collect learner acceptance about proposed adaptations.

*When?* This criterion should be estimated at running conditions or at the end of the learning session.

#### E. Inference correctness

*Why?* The inference mechanism is the crucial part of many adaptive systems [26]. The adaptation behaviour is strongly related to learner properties that are deduced throughout inference mechanism. Consequently, measuring inference correctness assesses the validity of provided adaptation.

*What's metric?* We propose to use Mean Absolute Error (MAE) [25] metric which evaluate the distance between the system predictions and the user's opinion by means of rate vectors. In our context, system prediction and learner opinion about concept learning and navigational link are estimated. These predictions are generally expressed by the use of adjectives like known, not known, ready to learn, etc. MAE is calculated by the following formula:

$$MAE = \frac{\sum_{i=1}^n |u_i - r_i|}{n} \quad (1)$$

$n$  is the number of the learning concept and navigational link,  $u_i$  is the user's opinion about the learning concept  $i$  or the navigational link  $i$ , and  $r_i$  is the system inference about the learning concept or navigational link  $i$ .

*How?* Methods such as focus group, questionnaires, interviews, think aloud protocol, logging file and expert-based can be used.

*When?* This criterion is estimated at running conditions.

#### F. Appropriateness

*Why?* Several adaptation methods are available. Nevertheless, insuring adaptation method appropriateness is crucial; that means selecting the suitable method at the suitable timing with respect to the particular user needs.

*What's metric?* We propose *Adaptation Method Appropriateness Rate (AMAR)* metric. It is calculated by measuring the ratio of adopted recommendations among

overall proposed adaptations. Consequently the formula is as follow:

$$AMAR = \frac{\text{Number of adopted recommendations}}{\text{Number of total proposed adaptations}} \quad (2)$$

*How?* The data to be used by this metric are gathered by log files analysis. This technique shows the real learners' behaviour.

*When?* The appropriateness criterion should be assessed first at the specification stage in order to implement meta-adaptation. Afterwards, at running context the appropriateness should be measured in order to adopt the most suitable adaptation method at the right time.

## V. CONCLUSION

Current e-learning systems are lacking adaptivity. Although, this issue is essential for Web-based educational system sustainability, as various end users with different skills, characteristics and needs have an increasing interest for these systems. Evaluation of these systems and improving them necessitate a concrete measurement basis. At present, there is no standard or agreed evaluation framework for measuring the value and the effectiveness of adaptation yielded by adaptive systems. For this reason, we choose to tackle this problem by proposing a measurement framework for adaptive Web based educational systems evaluation.

Adaptivity is a quite complex task. Nevertheless, basic adaptation behaviours are affected by adaptation method selection and implementation at a strategic level. Adaptation is assessed by considering adaptation method alignment with both business and usage factors. The measurement framework construction is thoroughly described. Measurement allows a deep understanding of failure causes and brings guidance to designers to implement meta-adaptation. For the future, we aim to exploit the measurement framework for concrete evaluation and improvement tasks in adaptive- e-learning field.

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