

## TOWARDS ADAPTIVE USER INTERFACE QUANTIFICATION

H. HABIEB-MAMMAR AND A. SEFFAH  
*Human-Centered Software Engineering Group  
Concordia University, 1455 Maisonneuve West  
Montreal Quebec Canada H3G 1M8  
Telephone +1 514-848-2424  
mammar@cs.concordia.ca, seffah@cs.concordia.ca*

**Abstract.** In this paper we discuss our initial work in developing metrics for user interface adaptability. The particularity of the metrics that we suggest is that they are applicable on hyper document which respect the document model developed in the environment EDPHA. The extent to which the hyper document is adaptable will enable to compare it with other hyper documents and to enhance its content.

### 1. Introduction

Measuring the non-functional requirements (NFRs) in any software is one of the most difficult activities. One of the reasons is the difficulty in understanding them due to their inherent nature. Actually, the requirements of NFRs for any software are usually not easy to clarify, satisfy and to evaluate them in the final software. The use of metrics for all NFRs comes as a solution to these problems.

There are several NFRs such as performance, maintainability, reusability, security, and so on; adaptability is among the more important of the NFRs (Subramanian & Chung, 2000). The definition of adaptability given in (wordreference.com) is the following: “*adaptability is the ability to **change** or **be changed** to fit changed circumstances*”. In adaptable software system changes are tolerated in its environment without external intervention. For example, a dual-mode cell phone can find out by itself if any one of the two wireless standards it supports is available at its current location and if so it starts using that standard. A practical metric for this NFR will help software developers and their organizations.

It is known that good software is robust in the way that it can tolerate some deviations in the environment. For example, if user presses character keys while entering numeric data the software can be designed to ignore such incorrect key presses. While robustness to the software can be added at the

design or even the implementation stage, adaptability requirements cannot be added at such late stages. Adaptability differs from robustness in the scale of environment change. Adaptable software can tolerate much larger deviations in the environment than a robust one. Adaptability can be enforced only if it is considered at the architecture development stage.

Several measures for adaptability have been proposed, Fenton (Fenton, 1991) proposes a scale in terms of time spent in maintaining (the measure for maintainability, assuming adaptive maintenance), while Gilb (Gilb, 1988) proposes some measures for extendibility such as number of additions to an existing system.

In this paper we propose a different technique for measuring adaptability in a hypermedia presentation using the models developed in the environment EDPHA (Tarpin-Bernard & Habieb-Mammar, 2005). In this environment, author creates his/her hyper documents (web course, demo, exercises ...) using EDPHA author tool. At the end of the adaptation, the browser displays the adapted hyper document according to the user cognitive profile. We will measure adaptability in both sides i.e. before adaptation (Pre-adaptation metrics) and after adaptation (Post-adaptation metrics).

The word metric used in this paper indicates a scale of measurement. This paper represents the initial work we did to measure the NFR adaptability in hyper document presentation.

In section 2, we discuss the main issues of adaptive systems evaluation. In Section 3, we develop the ideas behind our metrics for hyper document presentation adaptability. In Section 4 we propose our two classes of adaptability metrics and conclude this paper.

## 2. Issues

There are many reasons why the empirical evaluation of adaptive systems has been so limited:

1. Adaptability is only one contributing factor to the usability of a system. So, if an adaptive system is evaluated as being 'effective' (or usable, satisfying, efficient, learnable), we cannot prove that it is the adaptation that made it effective. Similarly, if it turns out to be ineffective, it may not be the adaptation that is to blame. To overcome this problem, we can evaluate a system with adaptation to exactly the same system without adaptation (for instance Eklund and Brusilovsky, 1998). However, this needs to be done with care, as the non-adaptive system is often not designed optimally for the task (Höök, 1998).
2. Adaptation is often applied to multiple aspects of a system. When evaluating a system as a whole, this makes it difficult to decide what

exactly is responsible for its overall success or failure. For instance, Interbook (Eklund & Brusilovsky, 1998) provides both adaptive link annotation and direct guidance, and an experiment meant to test adaptive link annotation was spoiled by students mainly using direct guidance.

3. Adaptation itself can also be seen as consisting of multiple layers. Brusilovsky, Karagiannidis and Sampson (2001) distinguish between interaction assessment (getting a user model by interpreting user actions) and adaptation decision making (deciding the adaptation based on the model). Other authors have argued for even more layers (Paramythis, Totter & Stephanidis, 2001). They argue that evaluation should be conducted of each layer separately, so that it can be assessed which work and do not work.

We address here two difficulties related to adaptation evaluation:

#### DIFFICULTY IN DEFINING THE EFFECTIVENESS OF ADAPTATION

Various ways exist in which the effectiveness of an adaptive system could be defined. Most often, the focus seems to be on the end result: how much information have subjects absorbed after a certain amount of time, how well do subjects perform on a test of their abilities after a certain practice time. For example, it is hard to determine after how many practice trials the test should take place. When the number of practice trials is too large, a difference in strategy effectiveness may disappear because eventually all the students learn the correct responses, regardless of the strategy used. On the other hand, if the number of practice trials is too small, the effect of the strategies on the last phase of the learning process is neglected. Also, the effectiveness of a strategy may depend on the type of subjects. It may well be that one strategy is more effective for high-ability students, while another strategy is more effective for low-ability students (Habieb-Mammar & Tarpin-Bernard, 2004). Taking averages over subjects would hide this.

#### DIFFICULTY IN FINDING RESOURCES

The evaluation of an adaptive system requires a large number of subjects. Partly this is inherent to empirical evaluations: the power of a test (the likelihood of getting statistically significant results) increases with the number of subjects, we like to have at least eight subjects per condition.

### 3. QUANTIFYING AND MEASURING ADAPTABILITY ATTRIBUTES

In this paper we will focus on the presentation adaptability and define the metrics which enable to compare two or more hyper documents created using the hyper document model developed in EDPHA. This environment provides two models and two processes:

#### COGNITIVE USER MODEL

Relying on HAPPYneuron™ experience, an evaluation module composing of 7 exercises that enables to build a cognitive profile is built. The exercises are in French, highly interactive and require the user to perform complex tasks. This profile includes five sectors and focuses on differences between modalities (verbal, visual or musical). It involves 13 cognitive indicators visual/verbal/musical working memory, visual/verbal short-term memory, visual/verbal/musical long-term memory, form recognition, categorization, understanding, glossary and spatial exploration (Habieb-Mammar et al. 2002).

#### HYPER DOCUMENT MODEL

A classical model where the hyper-document is made of XML pages is used. Each **page** is divided into '**blocks**' that correspond to various concepts (e.g. title, definition, example, menu, etc.). Each **block** can be presented using different media **elements** to convey the same concept embedded in that **block** (e.g. a diagram vs. its textual description). Because of the specific properties of each type of media, some **elements** in a **block** can contain more details than others but the key concepts should be expressed in each of them.

In order to model not only hierarchical hyper-documents but also more graph-oriented hypermedia, **blocks** can be externalized (i.e. defined in another **page**) so that several **pages** can refer to them (Tarpin-Bernard & Habieb-Mammar, 2004).

Because the goal in EDPHA is only to study the effect of the presentation adaptation, items which model semantics are not include in the structure. The adaptation process selects the suitable elements that will maximize a set of criteria based on cognitive indicators and the characteristics of **elements**. The collection of these characteristics is designed as *signature*. Because perception and cognition are highly coupled, this signature describes 4 dimensions described below and it is a hybrid model that combines perceptual and cognitive characteristics:

The Visual component (V) describes the complexity of the visual information contained in the element (mainly in videos or images);

The Audio/Musical component (M) is related to the complexity of the audio information contained in the element (mainly in videos or sounds);

The Kinesthetic component (K) describes the interactivity of the element and the realness of the materials (abstract vs. concrete);

The Language component (L) qualifies the complexity of the verbal information contained in the element (in texts, diagrams, videos, sounds).

Each of the above four dimensions of the *signature* is represented by an indicator of the "level of complexity" that is an integer in the interval [0; 5]. Complex and composed elements have rich signatures. For instance, a diagram and its caption could have a "L3V2M0K0" signature, whereas a 10 seconds video could have a "L3V5M3K2" signature. Each element contains one or more of the media: text, image, sound or video (Habieb-Mammar and Tarpin-Bernard, 2004).

#### ADAPTIVE PRESENTATION PROCESS

In order to tailor the presentation to each user, dynamic generation of web pages is needed as opposed to having pre-stored static pages on disk. The sheer number of possible variants makes static pages impractical (Hook, 1998). In building an adapted version of a document, various techniques can be applied and the popular one is based on inference rules (Kobsa et al. 2001) and selection rules (De Bra et al., 2003). In the EDPHA environment, we use another approach that consists in optimizing numeric criteria.

The adaptation engine will analyze all the possible combinations of elements described in a page in order to estimate which one is the most compatible with the user profile. This is an automatic process but if necessary, the author can limit the possible combinations to be analyzed. There are two ways to proceed. First, the author can list the combinations s/he wants the engine to consider. The second way consists in listing the combinations s/he wants the engine not to consider. If the authors have 3 elements with the following signatures: L5V0M0K0 (text), L4V0M4K0 (recorded voice), L1V4M0K1 (diagram), s/he can force the system to choose between two bimodal combinations: (L5V0M0K0+L1V4M0K1) or (L4V0M4K0+L1V4M0K1).

#### FORMATTING PROCESS

The last process is in charge of formatting and displaying the final hyper document using a specific style sheet developed in EDPHA.

Spatial and temporal layouts are considered in order to enhance adaptability according to the display features (Habieb-Mammar and Tarpin-Bernard, 2004).

As stated earlier, we consider two types of measurements: (1) measurements for pre-adapted hyper document, (2) measurement for post-adapted hyper document. We will consider some measurable attributes that can quantitatively characterize adaptation.

#### 4. Metrics for pre-adapted hyper document

To measure adaptability in the pre-adapted hyper document, one condition has to be fulfilled i.e. creating this hyper document according to the model described above. Our goal is to measure and compare hyper documents which respect this model and evaluate the differences between them in term of number of alternatives and choices they provide. For example, a hyper document which includes many types (text, image, video ...) of the same item is qualified as rich pre-adapted whereas the one which contains only one or two types is a poor hyper document. Metrics are advantageous for the following reasons:

- Allow evaluating the degree of adaptability of hyper document.
- Allow comparison of adaptability of different hyper documents.
- And hence, allow modifying the hyper document to increase its adaptability.

In EDPHA, every hyper document respects the model defined above and contains the following contents (see Figure 1):

```

Page [title, style]
  {Block [name, group, position, include]
    {Element [name, sign-cogn, sign-mat, state]
      {Content [type="text": "sound" [duration, autostart]: "image"
        [width, high, link]: "video" [duration]]}...
    }
  }

```

Figure 1: Content of a hyper document.

With this structure the following definitions can be appreciated:

**Element Adaptability** of a block (EA): Let consider MAX determines the number of all possible ways to represent an element. EA = number of alternatives/MAX.

**Block Adaptability** (BA) = EA for all elements/Total number of elements.

**Page Adaptability** (PA) = BA for all blocks/Total number of blocks.

**Hyper document Adaptability** (HA) = PA of all pages/total number of pages

## 5. Metrics for post-adapted hyper document

The metrics used in the above section for pre-adaptation could be obviously applied after adaptation as well. However, we are not interested in if we were able to keep the numbers in the post-adapted document. Our goal was to analyze how much we were successful with adaptation i.e. whether we improved in terms of presentation and interaction or not.

Olsina et al. (1999) have defined a metric called 'Percentage of the presence of alternative text for non-text elements' which is a measure of the presence of alternative text for non-text elements (like images, graphic icons, audio/video files etc.)

There is more to be done to judge the effectiveness of the post- adapted hyper documents in terms of presentation and interactivity. The metrics presented here are very basic metrics; however, our intention is to show the research community that metrics approach could be applied to adapt hypertext documents as well. We need some strong metrics to evaluate the quality of adaptation.

## 6. Conclusion

This paper represents the initial work we did to measure adaptability in hyper document presentation. We proposed a new technique for measuring adaptability in hypermedia presentation in both sides i.e. before adaptation (Pre-adaptation metrics) i.e. when the hyped document is created and after adaptation (Post-adaptation metrics) i.e. when the adapted hyped document is displayed.

The main issues of adaptive systems evaluation are also discussed and ideas behind the adaptability metrics we suggested are developed. When applied to hyper document, the results help commenting and comparing them. These metrics also show that a long road is needed to provide quantification and evaluation of adaptable hyper document and interactive systems.

## References

- Brusilovsky, P., Karagiannidis, C., and Sampson, D.: 2001, The Benefits of Layered Evaluation of Adaptive Applications and Services. In: S. Weibelzahl, D. Chin, G. Weber (eds.): Proceedings of UM2001 Workshop on Empirical Evaluation of Adaptive Systems, Sonthofen, Germany. Pedagogical University of Freiburg, 1-8.
- De Bra, P., Stash, N., De Lange, B.: 2003, AHA! Adding Adaptive Behavior to Websites, in *Proceedings of the NLUUG Conference*, Ede, The Netherlands, pp. n-n+10.
- Eklund, J. and Brusilovsky, P.: 1998, The value of adaptivity in hypermedia learning environments: A short review of empirical evidence, in P. Brusilovsky and P. De Bra (eds.), *Proceedings of Second Adaptive Hypertext and Hypermedia Workshop at the Ninth ACM International Hypertext Conference Hypertext'98*, Pittsburgh, PA, June 20, 1998, Computing Science Reports, Report No. 98/12, Eindhoven University of Technology, Eindhoven, pp. 13-19.
- Fenton N.E.: 1991, *Software Metrics – A Rigorous Approach*, Chapman & Hall, London.
- Gilb T.: 1988, *Principles of Software Engineering Management*, Addison Wesley, England.
- Habieb-Mammar, H., Tarpin-Bernard, CUMAPH, F.: 2004, Cognitive User Modelling for Adaptive Presentation of Hyper-documents: An experimental study, in *AH2004 "Adaptive Hypermedia"*, Eindhoven University of Technology, the Netherlands, August 23 – 26 2004.
- Habieb-Mammar, H., Tarpin-Bernard, F., Prévôt, P.: 2002, Modélisation XML des interfaces adaptatives intégrant le profil cognitif de l'utilisateur, in *DVP'2002 Documents Virtuels Personnalises*, Brest, France 10 -11 July 2002.
- Höök, K.: 1997, Evaluating the utility and usability of an adaptive hypermedia system. In J. Moore, E. Edmonds and A. Puerta (eds.), *Proceedings of 1997 International Conference on Intelligent User Interfaces*, Orlando, Florida, January 7-9, 1997, ACM, pp. 179-186.
- Kobsa, A.: 2001, Generic user modeling systems, *User Modeling and User-Adapted Interaction*, available at: [www1.ics.uci.edu/~kobsa/papers/2001-UMUAI-kobsa.pdf](http://www1.ics.uci.edu/~kobsa/papers/2001-UMUAI-kobsa.pdf), Vol. 11, pp.49-63.
- Olsina, L. Godoy, D. Lafuente, G. and Rossi, G.: 1999, Specifying Quality Characteristics and Attributes for Websites. *ICSE 99 Web Engineering Workshop* [Internet]. Los Angeles, US. Available from: <http://citeseer.nj.nec.com/olsina16specifying.html>
- Paramythis, A., Totter, A., & Stephanidis, C.: 2001, A modular approach to the evaluation of Adaptive User Interfaces, in S. Weibelzahl, D. Chin & G. Weber (Eds.), *Proceedings of the Workshop on Empirical Evaluations of Adaptive Systems*, held in the context of the 8th International Conference on User Modeling (UM'2001), 13-17 July, Sonthofen, Germany Freiburg, Pedagogical University of Freiburg, pp. 9-24.
- Subramanian, N and Chung, L.: 2000, Architecture-Driven Embedded Systems Adaptation for Supporting Vocabulary Evolution, in *Proceedings of International Symposium on Principles of Software Evolution*, November, 2000, Kanazawa, Japan, pp 144-153.
- Tarpin-Bernard, F., Habieb-Mammar, H.: 2005, Modeling Elementary Cognitive Abilities for adaptive Hypermedia Presentation. In UMUAI (User Modeling and User-Adapted Interaction), *The Journal of Personalization Research*, Springer Netherlands Publisher, November 2005, ISSN: 0924-1868. 15 (5), pp. 459 – 495.