Empirical Evaluation of Learning Styles Adaptation Language

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Abstract. Typically, the behavior of adaptive systems is specified by a set of rules that are hidden somewhere in the system's implementation. These rules deal with instances of the domain model. The purpose of our approach was to specify the adaptive response of the system at a higher level (able to be applied and reused for different domains or adaptive applications) in an explicit form, that we call an *adaptation language*. Therefore our intention was to specify this response corresponding to some higher-level user traits (e.g., dealing with generic names instead of instances). To show the support for these higher-level traits we have chosen learning styles (LS) as an implementation field. We defined an XML-based adaptation language LAG-XLS for the AHA! (Adaptive Hypermedia Architecture) system. In this paper we will briefly present LAG-XLS and then focus on empirical evaluation of this novel methodology – thereby alleviating one of the problematic issues in adaptive hypermedia (AH) and AH authoring: the lack of empirical analysis.

1 Introduction

Initially, adaptive hypermedia systems (AHS) were mostly focused on the delivery of adaptive applications to end-users and less on the *authoring aspects* [2]. However, to allow a widespread use of AHS, the difficulty of the authoring process should be considered [2] and ways to make this process as "simple" and intuitive as possible should be found [5]. AH authoring is often considered to be a difficult, time-consuming and therefore expensive process [2]. In [9], to alleviate the so-called "authoring problem" we discussed limiting repetitive work by reuse of previously created materials and other components. These include the static parts of the authored courseware (e.g., domain model content) and the actual system dynamics (adaptive behavior). Most of existing standards (LOM, SCORM, etc.) address only static and not dynamic reuse [9]. Our research addresses the latter issue as well. In [9] we compared LAG-XLS ('LAG-excels'), a language (initially) developed for the AHA! system [7], with a more generic language for AH, LAG [3,5], as its theoretical basis. LAG-XLS focuses on adaptation to various LS, meaning here an individual's preferred way of learning. In [10] we discussed how our approach differs from other systems providing support for LS. In this paper we outline what type of strategies can be created in LAG-XLS, how they are applied and visualized in AHA! applications, and finally we present the evaluation results of our approach.

2 Adaptation to Learning Styles in AHA!

LAG-XLS: allows three types of adaptive behavior [9]: *selection of items* to present (e.g., media types); *ordering* information types (e.g., examples, theory, explanation); and creating *different navigation paths* (e.g., breadth-first vs. depth-first). Strategies are defined as XML files using a predefined DTD. XML was chosen as it is an extensible language and a W3C standard. LAG-XLS also allows for the creation of *meta-strategies,* tracing users' preferences for certain types of information or reading order.

Creating an AHA! adaptive application: consists of defining the domain/adaptation model (usually with the Graph Author tool, Figure 1), followed by writing application content, consisting of creating XHTML pages [7]. We extended the system by allowing for the possibility of applying *adaptive strategies,* as specified in LAG-XLS, to the domain model (see Figure 1). The authors can create their own strategies or reuse existing ones. The authors choose themselves which LS and from which LS model to apply and create corresponding strategies. We pre-defined *adaptation strategies* for the following LS [8,3]: Active versus Reflective (appear in Felder and Silverman, Honey and Mumford models), Verbalizer versus Imager (Visualizer) (Felder and Silverman, Riding model), Holist (Global) versus Analytic (Dunn and Dunn, Riding model), Field-Dependent versus Field-Independent (FDvsFI) (Witkin's dimension); strategies for inferring user preferences (*adaptation meta-strategies*) for textual or pictorial information (TextVersusImagePreference), and navigation in breadth-first or depth-first order (BFversusDFPreferences). In [10] we explained our choice for these LS. An author can also create variations of these predefined strategies. The requirements for doing this are to use elements as defined in the LAG-XLS DTD, and to ensure that the domain model concepts have the attributes required by the strategies [9]. Authors choose which strategies to apply to a particular application, and in which order (in case of application of several strategies, order can be important).

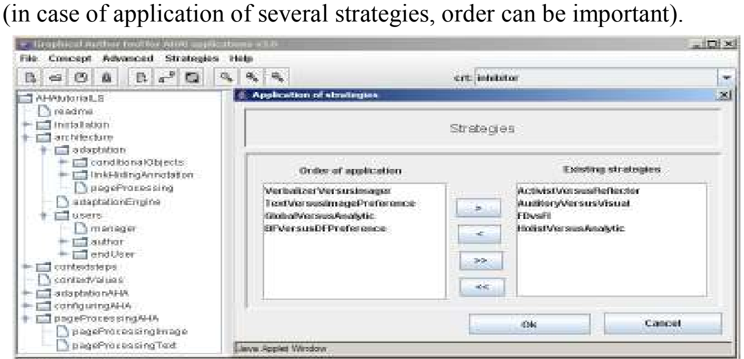

Fig. 1. Graph Author, strategies application: authors select strategies and application order

Visualization of strategies application in AHA!. Student experiments were performed with two applications: "AHAtutorialLS" a tutorial about AHA! using learning styles, and a smaller example called "WritingApplets". The learner can set his preferences (e.g., what his learning style is) via a registration form (if the learner knows what his LS is after filling a corresponding psychological questionnaire). Figure 2 shows the presentation of the "AHAtutorialLS" material to a user with a visual preference (*imager* style) and preference for getting an overview of all of the material at a high level before introducing the details (*global* style). Based on the visual preference, the topic about the "adaptation process in AHA!" is presented with an image. In the left frame, the user can see the table of contents. There, links to topics are annotated (*recommended topics*: blue with green bullets; *not recommended*: black with red bullets; *recommended & visited topics*: purple with white bullets) so that a user is first guided to concept pages at the same level in the hierarchy as the current concept, and afterwards to lower level concepts. In the example, after reading the "adaptation process in AHA!", the link to the same level topic "adaptation engine" is presented as desirable.

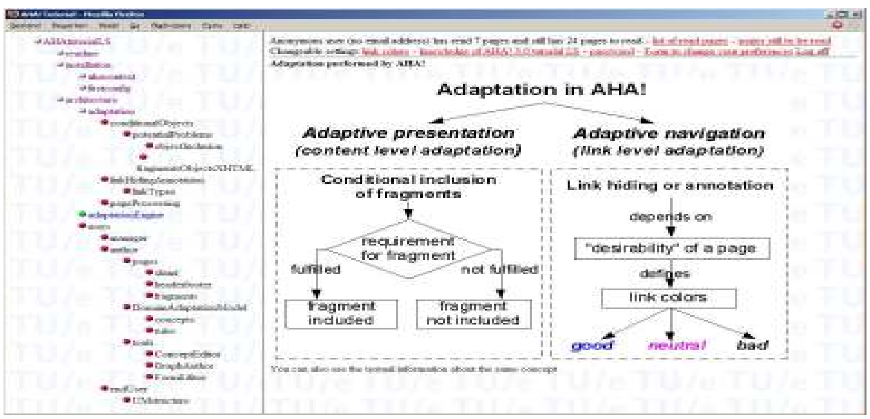

Fig. 2. Presentation of the application to the user with *imager* and *global* styles

Figure 3 shows the presentation of the same application to a user with a preference for textual material (*verbalizer* style) and for studying each topic in detail before going to the next (*analytic* style). To him, the "adaptation process in AHA!" topic is presented with text. The adaptive links annotation in the table of contents is also different. After reading about the current topic the user is guided towards more details on the same topic; therefore, the link to the page on "conditionalObjects" is annotated as desirable.

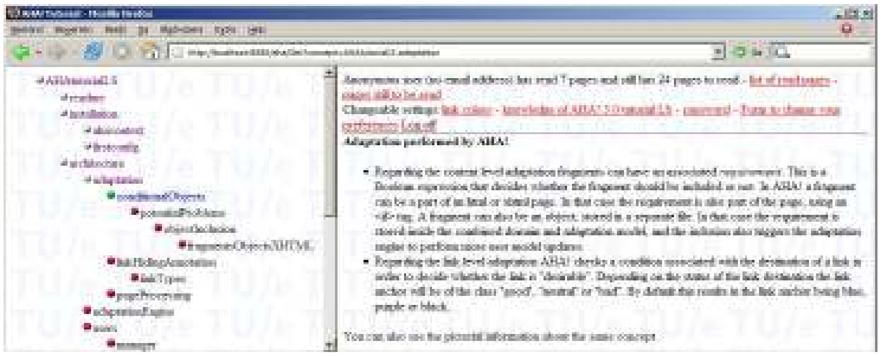

Fig. 3. Presentation of the application to the user with verbalizer and analytic style

If a learner does not choose any preference via the registration form (e.g., the learner does not know what his LS is) the system will present all links in the left frame as desirable. For topics that can be presented differently for users with visual or textual preference, a "default" representation is shown. The user can also let the system trace preferences. In the "AHAtutorialLS", the system can, after a number of browsing steps, identify preferences for text versus image and for navigation order. AHA! also allows users to change their user model settings via special forms. Therefore, if a user does not agree with the system's assumptions about his preferences he can inspect his user model and make changes in it.

In the "WritingApplets" example, a learner with the *active* learning style is shown with an activity first, then an example, explanation and theory. While for the learner with the *reflective* style this order is different – he is shown with an example first, then explanation and theory, and finally, he is asked to perform an activity.

3 Empirical Evaluation LAG-XLS

3.1 Evaluation Settings

To evaluate our approach, we tested the application of (meta-)instructional adaptation strategies created in LAG-XLS and applied to AHA! within an Adaptive Hypermedia course [1]. The course was given to a group of 34 students composed of 4th year undergraduate students studying Computer Science, combined with 1st year Masters students in Business Information Systems at the Eindhoven University of Technology.

3.2 The Experimental Assignment

The experimental steps of the LAG-XLS assignment were as follows.

1. The students had to perform the assignment in groups of 2-3 people in 4 weeks.

2. They had to install the AHA! system version that supports learning styles on their notebooks. The distribution contained two example applications (courses) – “AHAtutorialLS” and “WritingApplets” – and a number of strategies to apply:

- Two *instructional* strategies were used: VerbalizerVersusImager and GlobalVersusAnalytic; as well as two *monitoring* strategies: TextVersusImagePreference and BfvsDFpreference (breadth-first versus depth-first preference). They had to be applied to the “AHAtutorialLS” application. The instructional strategy ActivistVersusReflector had to be applied to the “WritingApplets” example.
- The students were able (and supposed) to work with the system as *authors* as well as *end users*. As *authors* they were required to use the Graph Author tool [7] – to see the concept structure of the courses and to select strategies to apply to a particular course. As *end users* they had to visualize the result of applying the strategies, while browsing through the course. They had to analyse how the same course is presented with different preference settings corresponding to different LS, as well as with the option of automatic preference tracing.

3. After the above steps were done, the students had to fill in a questionnaire, to examine their experience of working with the system.
4. The students were also asked to fill in the Felder-Solomon “Index of Learning Styles Questionnaire” (ILS) [8]. This psychological questionnaire maps a set of 44 questions over 4 dimensions representing learning preferences and styles. For the LAG-XLS language, dimensions of interest are represented by the values extracted for such LS as *active* versus *reflective*, *visual* versus *verbal*, *sequential* versus *global* (similar to analytic versus global/holist). The aim was to examine if the students’ preferred settings for working with the applications (as selected by them when using the LAG-XLS system) corresponded to the learning styles revealed by the ILS questionnaire. Moreover, these tests were aimed to check if the LAG-XLS AHA! system’s inferred preferences matched those of the ILS questionnaire.
5. Finally, after experimenting and analyzing the existing strategies, the students were asked to create their own strategies, or a variation of the existing strategies, in the LAG-XLS language, and to apply them in the provided applications.

3.3 Experimental quantitative results

The students stated their Learning Style preferences twice: whilst using LAG-XLS in AHA!, via pre-test questionnaires (Figure 5), and via the ILS questionnaire (Figure 6).

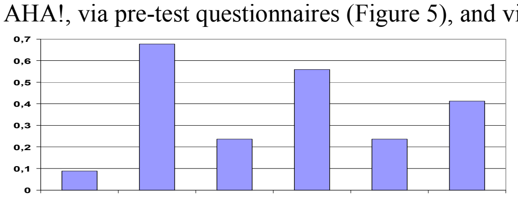

Fig. 5. Students’ average stated preferences (praxis - via LAG-XLS questionnaires)

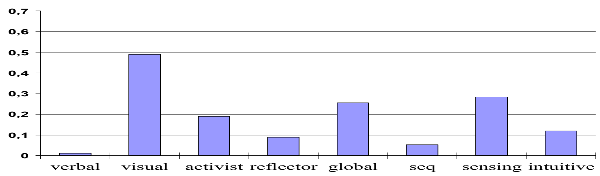

Fig. 6. ILS questionnaire results : average (theory - via ILS questionnaires)

Surprisingly, results show that 4th year students have still little understanding about their own knowledge processing abilities; they seem to posses little meta-knowledge on their preferences, as reflected in the differences between the two figures. Especially notable is the difference between stated ‘analytic’ (equivalent in this assignment with sequential) preference and the ILS questionnaire results, showing a ‘global’ tendency. Preferences also differ in the ‘active versus reflector’ group. In the ILS, the activist tendency is stronger, whereas in actual use, the ‘reflector’ tendency dominates. The students comments (following section) partially explain this gap between theory and praxis. One point in which both questionnaire results coincide is the students’ strong image preference. However, its intensity is, again, different in praxis and theory.
The students’ prior knowledge is shown in Figure 7. As most of them are computer science students, unsurprisingly, their XML knowledge was far greater than their prior knowledge on learning styles. The fact that most students had never heard of LS before may be another explanation for the fluctuating results on learning preferences.

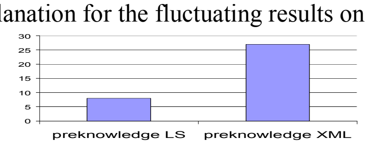

Fig. 7. Students’ pre-knowledge (expressed in number of students claiming that knowledge)

Figure 8 depicts the students’ general impression of their first encounter of learning LS in combination with adaptive hypermedia (AH). Students considered the implementation of *adaptive instructional strategies* and (*monitoring) meta-strategies* useful for adaptive educational systems (82%). Less strong, but still positive was their conviction about this experimental process being of a *pleasant* nature (67%). Most of the students having reservations also gave some justifications, as are shown and discussed in the next section. Figure 8 also shows a majority of students considering the work *easy*, although the percentage of students of that opinion is slightly lower (54%). This difference shows that, although students realized the necessity and importance of adaptive strategies in AH, and enjoyed the challenging programming work, they did not consider it trivial. Therefore reuse of ready-made, custom-designed strategies is necessary to be made available to AH authors, to reduce creation time and costs.

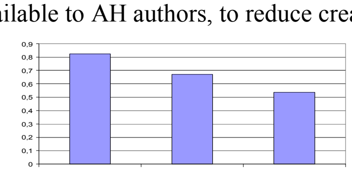

Fig. 8. Overall impression of instructional strategies and experiments (in percentage)

Figure 9 shows the average declared percentage of understanding and problems that students encountered. An ideal distribution should create a filled pentagon. A good distribution should at least have all the corners of the pentagon at values above 0.5, as is almost the case here. The students *understand the application strategies* – important as the core of the LAG-XLS language understanding - and are greatly *satisfied with the presentations*. They *understand the AHA! Graph author* very well. However creation of their own strategies was the most difficult problem (only 47% had no problems editing). When they figured out editing, their strategy changes worked well (75%).

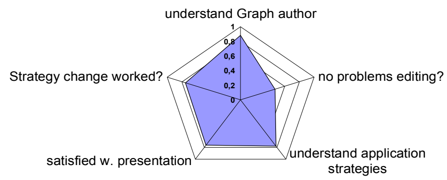

Fig. 9. Understanding the system and working with it (in percentage)

Figure 10 contains the comparison of selected preferences in LAG-XLS and the *strategies* that were applied, as well as the *meta-strategies* that deduced these preferences. All strategies and meta-strategies were considered by the majority (over 65%) of students appropriate. The 'winning' *strategy* is the "verbalizer vs. imager", which the students considered most accurate. Following are the "global vs. analytic" (73%) and "activist vs. reflector" strategy (67%). From the *meta-strategies*, the one liked best by students was the "text vs. image" meta-strategy. Actually, for the latter, most students noticed that it traced their behavior within *3 steps*. The "BF vs. DF" strategy was a more complex strategy, as, especially for a user with a breadth-first preference, it had to analyze a larger number of steps till the conclusion was made. The number of steps the students experienced was between 7 and 14, with an average of *13 steps*.

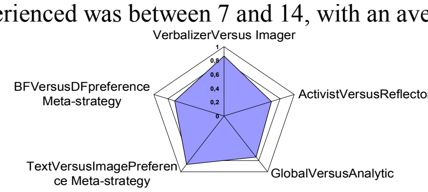

Fig. 10. Students comparison of questionnaire results versus praxis results whilst working with the system (praxis via questionnaires versus praxis deduced by system – in percentage)

3.4 Experimental Qualitative Results

The students were asked to also detail their own judgements and explain their understanding of the process of using the AHA! system together with the implementation of learning styles via the LAG-XLS language. Below are some sample comments.

1. When asked if they thought that application of different instructional/monitoring strategies for educational adaptive hypermedia is useful, students replied:

- "yes", because: "*I believe that the correct application of learning styles can be a good aid in studying. Presenting information in a user preferred form makes the user work and study more efficiently.*"; "*Since each person is unique, and does his/her best when anything is tailored to his/her unique needs. Perception skills vary from person to person, so if it is possible to give each person, the best possible method of learning suited to him/her, it is the best possible educational method.*"; "*Adapting a big amount of information to the best way the user perceives could lead to saved time and a better understanding of the studied problem.*"; "*When you know what kind of person you are (or the computer knows) it saves time, because you don't have to look for what you want, you automatically get it. And if you want more or other information on some subject then you normally would, you can just click on a link or something and still get it.*"; "*It is very easy to fool the system. The system doesn't check if the content is understood by the reader. Applying adaptive learning styles is a good thing, but I think that it isn't sufficient, because if I read an article I already know I don't read the article in depth, but an interesting article which I don't know, I will read it in depth.*"
- "no", because "*In theory the adaptive hypermedia could adjust to the preferred learning style of the student and ensure the most benefit from the learning experience. However, in practice, I believe the system has too many weak chains to be successful; it depends highly on competent authors, a wide availability of learning material in many different forms, and the ability of a computer program to (correctly) reason about a human behind the terminal.*" Here, the student correctly identifies the authoring problem: adaptive hypermedia is more time-consuming and costly than regular hypermedia - the price paid for adaptation [2].

2. In explaining why their own selection and meta-strategy for learning style detection in LAG-XLS were different from the results of the ILS questionnaire, students answered: "*I generally like to see the global picture first and then go into the details. However in the tutorial, this raises a problem for me. If I read the high level concepts first and then go into the details, I have forgotten what the high level contents were when reaching its details and then I have to read back into it. That is annoying, so I prefer to read depth-first. So actually I'm quite unsure what I prefer. Maybe I do prefer depth first. It's a bit hard to tell really.*"The described problem may be caused by the fact that the example application "AHAtutorialLS" was created by the authors of the system who might not have enough psychological knowledge about how to correctly structure the application in order to support the global and analytic LS. However the system provides the necessary functionality to present the application either in breadth-first or in depth-first order as recommended by the psychological research to support global and analytic LS correspondingly. *"My pictorial preference in the Tutorial was not representative of my general preferences (which were shown by the questionnaire). In this specific Tutorial application the pictures however were so good that these were preferred by me."* Other students also mention that LS preferences can vary in different domains.

3. When asked about another strategy that they would like to apply but doesn't work in LAG-XLS or that they would have liked to see implemented, but didn't know how to, students replied:

- *"developing entire new strategy is impossible without completely altering the entire Tutorial application ... We looked at the XML-files and of course we could make small alterations which change the number of steps after which a preference is derived, but we did not think that this was what you were looking for, since the general appearance of the system would be exactly the same, and the results are easily predicted."*
- *"GoodReadingVersusFastReading – a strategy that is able to track if a reader really does an effort to study/read the educational material presented. That way the system could 'warn' the user when he or she just seems to be clicking trough the material instead of actual 'learning' a matter".*
- *"DetailedVersusSummarised – a strategy that shows only the default content for the user who likes summaries, default content, images and links to those who likes details and a pair monitoring strategy for inferring a preference for summaries or detailed presentation".*

Thus most students were only able to create variations of the existing strategies by using different names for presentation items and by increasing/decreasing the number of steps required by the monitoring strategies to achieve a threshold. The students did not come up with any completely new strategies.

4. When asked to give some more suggestions for possible improvements of the current LAG-XLS implementation, students answered: to improve the AHA! installation; to have more help explaining the effect and application of strategies.

4 Discussion and Conclusion

From the evaluation results we can say that designing an application in such a way that different types of users get equivalent information appropriate to them is a useful endeavour. Students understood the process and liked being involved in it, in spite of the fact that it wasn't a simple endeavour. It is very reassuring that our students understood the basics of LS application, as they were computer science students, with little or no knowledge in this field prior to the course. As expected, they enjoyed modifying the adaptation code more than understanding psychological implications.

This was a small-scale exercise in *authoring the dynamics of adaptive hypermedia*, from the point of view of *tasks* involved (although the size of the group was average). However, this exercise has already given us insight into the further development of LAG-XLS, as it is the first time *authors* have been involved *only* in the *application* and *creation* of the *dynamic elements* of the adaptive multimedia delivery, the *adaptive strategy creation* (via adaptation language use). It is obvious from the results and comments that LAG-XLS allows a quick grasp on the adaptation process (for computer science students), as well as relatively easy handling and small modifications of existing adaptation strategies. However, some students were unable to create completely new strategies from scratch. The cause of this is yet to be determined: a possi-

ble explanation is the short time they had; another one, the fact that installation bugs detracted from the quick application of the potential of the language; finally, it might just be that they were aiming too high (see comment on what the teacher might want). This exercise shows also the challenges of the *end-user* side, the *learner*: theory and praxis don't always match in identification of LS. The end-user rarely has meta-knowledge of this type. Some of the students correctly identified this gap.
It is clear that the creation process of adaptive behaviour in itself requires a lot of psychological and/or pedagogical knowledge. As we are no psychologists, the main aim of our research is to allow the authors with experience in pedagogical psychology to design different types of strategies and apply these strategies to the applications. Moreover, the question about how to structure the application and organization of the materials to correctly suit different LS is left for the author of the application or psychologist. Therefore, from a future evaluation point of view, it would be interesting to test LAG-XLS with LS specialists, instead of computer scientists, focusing more on the *qualitative aspects* instead of the *technical aspects* of the language.

5 Acknowledgements

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References

1. Adaptive Hypermedia course at TU/e (2ID20) winter trimester 2004-2005, http://wwwis.win.tue.nl/~acristea/AH/
2. Brusilovsky, P., Developing adaptive educational hypermedia systems: from design models to authoring tools. "Authoring Tools for Advanced Technology Learning Environments", Eds. T. Murray, S. Blessing, S. Ainsworth, Kluwer (2003).
3. Coffield, F., Learning Styles and Pedagogy in post-16 learning: A systematic and critical review. Learning & Skills research centre. http://www.lsda.org.uk/files/pdf/1543.pdf
4. Cristea, A.I., and Calvi, L. The three Layers of Adaptation Granularity. UM'03. Springer.
5. Cristea, A.I., and Verschoor, M. The LAG Grammar for Authoring the Adaptive Web, ITCC'04 April, 2004, Las Vegas, US, IEEE (2004).
6. Cristea, A. Authoring of Adaptive Hypermedia; Adaptive Hypermedia and Learning Environments; "Advances in Web-based Education: Personalized Learning Environments". Eds.: Sherry Y. Chen & Dr. George D. Magoulas. IDEA Publishing group (2006).
7. De Bra, P., Stash, N., Smits, D., Creating Adaptive Web-Based Applications, Tutorial at the 10th International Conference on User Modeling, Edinburgh, Scotland (2005)
8. R. M. Felder & B. A. Soloman 2000. Learning styles and strategies. At URL: http://www.engr.ncsu.edu/learningstyles/ilsweb.html
9. Stash, N., Cristea, A., De Bra, P. Explicit Intelligence in Adaptive Hypermedia: Generic Adaptation Languages for Learning Preferences and Styles, Proceedings of the HT 2005 CIAH Workshop, Salzburg, (2005)
10. Stash, N., Cristea, A., De Bra, P. Authoring of Learning Styles in Adaptive Hypermedia: Problems and Solutions. In Proceedings of WWW'04, Alternate Education track. (New York, US 17-22 May 2004). ACM.