Adaptation Criteria for Preparing Learning Material for Adaptive Usage: Structured Content Analysis of Existing Systems

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Abstract. Using learning material in an adaptive way requires a preparation beforehand. In order to guide the process of creating learning material, criteria for adaptation and techniques for content preparation have to be known. The aim of this paper is to give first hints for such guidance. Therefore, adaptation criteria and provisions which can be used to realize such a preparation should be identified. For this purpose, adaptation criteria were derived by investigating 30 existing adaptive hypermedia systems. Based on these criteria first hints for preparation of learning material for adaptive use will be given.

Keywords: adaptation criteria, content preparation, structured content analysis.

1 Introduction

Learning is an individual process of gathering and understanding knowledge and learners have different preferences and requirements for learning. This diversity commonly requires a supply of learning material that fits to the learners' needs [1]. In traditional learning scenarios teachers should perform this task. In the case of e-learning, this task could be realized by adaptive hypermedia systems [2]. Thereby, a system is called *adaptable* if the user has the opportunity to change the system characteristics and it is called *adaptive* if the system is able to change its own characteristics automatically according to the users' needs [3]. Before using learning objects (LO) in an adaptable or adaptive way it is necessary to prepare them according to the adaptation purpose. The preparation is normally quite expensive [4], so that a preparation of the whole organizational knowledge base is not realizable. Furthermore, the extreme rise of organizational documents [5] which is additionally boosted by the trend of user-generated content, leads to an unmanageable set of resources which could be used for educational purposes. Therefore, organizations have to decide systematically which knowledge elements of their knowledge base should be prepared for an adaptive usage.

So far, this decision is normally made without a systematic deliberation. Typically, resources which can be reused frequently would be prepared. Surely, frequent reusability reduces the cost per usage (economies of scale) and seems to be a good indicator. But chances for development of a certain topic, importance of LO for specific situations or

A. Holzinger (Ed.): USAB 2008, LNCS 5298, pp. 411–418, 2008.

strategic thoughts are mostly not considered. In times of rapidly growing amounts of organizational contents, this intuitive approach cannot be realized successfully.

This paper focuses on structuring that decision problem by identifying adaptation criteria and giving first hints for the content preparation for an adaptive use. Section 2 describes the content preparation for adaptive hypermedia systems and a study to identify adaptation criteria is presented in section 3. Provisions for content preparation according to the identified adaptation criteria are presented in section 4. Finally, the paper closes with a conclusion and outlook.

2 Content Preparation for Adaptive Hypermedia Systems

The learner´s need for LOs that fit to her preferences and environmental circumstances can be seen as a need for adaptation. In order to fulfil this adaptation need, LOs have to be prepared. A well known distinction of adaptation between adaptation of presentation and adaption of navigation was proposed by Brusilovsky [2]. Adaptation of navigation can be realized by arranging a sequence of content fragments, e.g., LO, in order to adapt the navigation possibilities according to an adaptation need. The presentation can be adapted by presenting different pieces or versions of content to the learner [2]. Generally, versions of content with specific characteristics can be associated to rules or models used in adaptive hypermedia systems [2], [6]. Defining such rules is based on the assumption that different versions of knowledge, like LOs, are available.

Frequently, the realized adaptation is based on topics and thus, existing documents can be assigned to an adaptation need. By contrast, adaptation based on other criteria, like preferences or learning styles, requires different versions of contents for one topic. Adaptation rules are usually not defined for single resources rather than for characteristics of LOs. These characteristics are technically described by metadata [7]. The need for quality metadata in adaptation processes is ample discussed in literature, e.g. [8], [9], [10]. Thus, the most generic applicable step for using LOs adaptively is to describe them by meaningful metadata.

If knowledge is not available in different versions with characteristics useful for adaptation, contents have to be prepared. Thus, different LOs have to be created by modifying the characteristics of one available or created LO targeting one topic. Dimensions of adaptation and thus, the required characteristics of contents have to be known in order to create these different versions and to identify techniques to prepare contents. Identified opportunities for adaptation and related content preparation techniques represent action alternatives of the mentioned decision problem and can be seen as a first structuring approach. In order to investigate dimensions of adaptation and associated content preparation techniques, a study investigating 30 adaptive hypermedia systems was realized.

3 Study to Identify Adaptation Criteria

The main goal of this study is to identify criteria to which contents can be adapted. These general criteria should represent the starting point of an adaptation action and

instances of the criteria could be used to define adaptation rules. In the following, these criteria are called *adaptation criteria*. Because of the limited literature in the field of techniques to prepare content for adaptive use a survey of existing systems was conducted.

3.1 Study Design and Procedure

The first step of this study was to identify relevant adaptive hypermedia systems which can be analyzed. One initial classification of adaptive hypermedia systems was found in the very well cited article from Brusilovsky [2]. To structure the identified systems, the author decided to use these three categories: adaptive hypermedia systems in education, adaptive hypermedia systems for serving on-line information, and adaptive hypermedia related to information retrieval (IR) problems. Overall, 158 systems could be found consisting of 56 adaptive educational systems, 52 adaptive on-line information systems and 50 adaptive systems for IR. From the author's point of view, this collection represents a good trade-off between efforts and benefit for searching.

In the second step, a qualitative content analysis based on the approach described in [11] was realized. During the identification and classification of existing systems no detailed investigation of system functionalities has been conducted. The qualitative content analysis uses initial predefined categories derived from literature and forms the starting point for the study [11]. The openness is ensured by allowing a flexible adjustment which is realized by changing or deleting initial categories or creating new categories if necessary [11]. Thus, an existing theoretical foundation can be integrated without losing or not considering the specifics of researched data.

Brusilovsky describes some criteria in [2], to which information can be provided adaptively. These criteria were developed by analyzing existing systems known in 2001. These established criteria were used to inform the study. The criteria are: user interests, user knowledge, individual traits, platform, and location[2]. Brusilovsky describes these criteria in [2] without revealing analysis process and compares his results with those from a paper performed in 1996. This leads to the assumption that these criteria could have changed since 2001 and that they should be examined.

The process of content analysis was quite elaborative and thus, a detailed investigation of all 158 identified systems seemed as too laborious. 10 systems per category seemed as an appropriate sample to identify the criteria for adaptivity. Overall, 30 systems from the 158 identified systems were selected for a detailed investigation. The systems of each category were ordered alphabetically and the first and every 5th system were chosen. For every paper, at least one and at most two academic papers (conference-, journal-paper, technical report or Ph.D – Thesis), have to be identified for detailed investigation. Because of the limited space for this paper, a list of the 30 considered systems with citations can be found at http://www.uibk.ac.at/iwi/adaptation_criteria.html.

For 26 systems two academic papers each could be considered for the structured content analysis. For four systems only one scientific paper could be considered. Overall, 56 academic papers were considered for the detailed investigation of adaptive criteria.

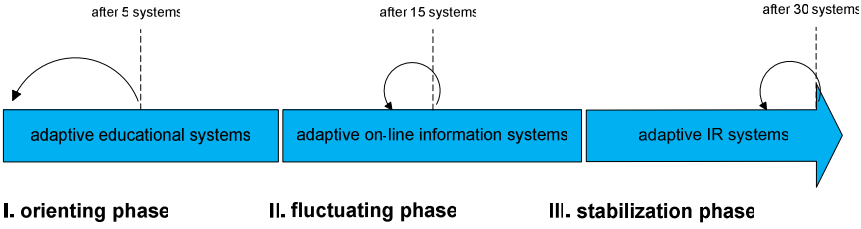

Fig. 1. Coding procedure performed in the study, based on [13]

For identifying the categories for adaptation, a qualitative content analysis approach was chosen. Thereby, the procedure based on the iterative approach proposed by Dey [12]. The phases of content analysis are independent from researched systems.

The content analysis starts with adaptive educational systems and an orienting phase using the initial criteria. New criteria, material can be adapted to, were defined if a description of an adaptation based on these criteria could be found in a scientific paper and these criteria does not fit perfectly to one predefined criteria. Thus, a criterion had to be mentioned in a paper which was used to provide information adaptively. The criteria were formulated in a first step and described more precisely over the time. After the investigation of five systems the first draft of criteria looked reasonable stable to a certain degree. Changes during the development of the first draft of codes demanded a rescan and recoding of the first five systems.

By coding the first five adaptive on-line information systems it turned out that some new criteria occur. To ensure the homogeneity within and between all 15 investigated systems, they were rescanned and recoded. Thereby, few changes in the first 10 adaptive educational systems were necessary. Most changes are related to the new defined criteria, especially relevant for on-line information systems. During analysis of the last 10 systems, no more specific codes for adaptive IR systems were found. Definitions for criteria turned out as suitable and good applicable in this phase. Only few criteria were merged or changed marginally. Overall, the criteria are stable and all identified characteristics could be represented by the final codes.

3.2 Results

The results of the structured content analysis are 13 adaptation criteria which are explained below. Beside the names of the adaptation criteria relative occurrence within the 30 adaptive hypermedia systems are depictured in brackets.

knowledge structure (73,3%): A list of terms or taxonomy of concepts, sub-concepts and their relations in a knowledge domain. The knowledge structure is used to differentiate one topic in several sub-topics and to use different characteristics of the sub-topics for adaptation.

user history (80%): A collection of data describing previous user interactions with a system. Usually, these data are log-data from systems the user has used and data which are useful for future adaptation provisions. Data from the user history are normally analyzed in order to derive values which can be represented by other criteria.

user request (27%): Additional interaction possibilities for user-initiated adaption. They are additional interaction possibilities which are provided to the user in order to change (1) a navigation path or (2) to consider requirements or values entered by the user. In the easiest way these opportunities are additional links and in more advanced cases input boxes are provided. In the context of adaptive hypermedia systems these user requests are used to adapt the systems information supply.

previous knowledge (47%): Knowledge of the user acquired in the past and relevant for using the system which has to be considered for information provision. This knowledge is required in order to gather the provided information successfully. Previous knowledge can be used to transfer information adaptively according different levels of previous knowledge.

content preferences (93%): Goals and interests for presented topics in a certain knowledge domain. Thereby, not the presentation style rather than the presented contents are affected and thus the choice of topics of presented contents is influenced. Different preferences, goals and interests can be used in order to select appropriate topics for the information requester adaptively.

presentation preferences (26,7%): Goals and interests for the style of content delivery. These preferences are used in order to present versions of the same content in different presentation styles, e.g., one figure in different colours or sizes. Thus, users feel more comfortable by consuming information which fit to their presentation preferences.

preferences for media types (7%): Goals and interests for the technical format of content delivery. Users have different preferences according content types, which can be a distinct to preferences of colour settings and usability aspects. Thus, different versions of the same content in the same presentation style can occur in different media types and thus transferred adaptively.

learning style (13%): Preference of a user for proceeding during learning. The suitability of these theories depends on learners and topics and they should increase learner's ability to absorb certain knowledge. Thus, depending on the learner and the topics, contents can be prepared according to different learning styles and pedagogy approaches and provided adaptively.

language (10%): Ability or preference of a user for the language used for content delivery. Information written in a different language can be a significant access barrier for learners. Thus, information should be provided adaptively considering the user's language skills.

device requirements (13,3%): Technical characteristics of the hardware and basic software relevant for accessing the system. Especially, different screen resolutions and colour settings have to be considered in order to ensure a correct presentation. Thus, versions which fit to the different hard- and software requirements have to be created and provided adaptively to ensure a smoothly information provision to the user.

bandwidth (10%): Data transfer rate available during a session with the system. Different quality of internet access influences speed and quality of information provision. The current bandwidth depends not only on the device in use and thus has to be investigated for every initiated session. Unsuitable large data volumes cause in very long

loading times or in the worst case the user cannot access the information. In order to ensure a comfortable information access data volume of transferred information should be adapted to the current bandwidth.

location (20%): Physical coordinates relevant for content delivery. The physical location could indicate a certain demand for contents which can be related to a location. By using GPS, IP or cell-based techniques this location is available and could be used for adaptation of information access.

user status (3%): User-related or environmental characteristics describing the users current circumstances. The current status of a user can influence his ability to access information and her preferences. Needs and preferences based on user's status, like stress or loud environment cannot be generalized and has to be entered by the user. Depending on different situational status of the user, information can be provided adaptively.

4 Content Preparation According to Adaptation Criteria

In order to create different versions of LOs according to the identified adaptation criteria, contents have to be prepared. In the following, provisions to prepare contents according to the identified criteria are proposed.

Knowledge structure, user history and user request act as a kind of top level criteria. They are mainly used to structure or to specify other criteria. Furthermore, required content preparation techniques can assign to one of the previous mentioned criteria. For that reason, no specific preparation technique could be identified rather than all other preparation techniques could be applied in principle. As mentioned before, creation of meaningful metadata is necessary for all adaptation criteria and thus, general relatable.

Preparing contents considering previous knowledge should prevent swamping learners with less knowledge and boring learners with high knowledge [14]. The preparation could be achieved by (1) adding information required to understand the offered learning material or (2) shortening information by facts, well-known by people with a certain knowledge level.

Content preferences can be considered by relating LOs to different topics. Thus, different versions, which can be related to different topics, should be created. Thereby, breaking one piece of content into various sub-units and the aggregation of several pieces of content to form larger units, called modularization, can be applied [15]. Contents considering presentation preferences can be created by changing font settings, colours or redesigning the layout of a LO.

Creating different versions of learning material according to learning styles or pedagogy approaches requires a didactical revision. These revision can be realized by adapting the navigation, e.g., modification of rules or creating different versions of learning material that conform with one learning style [16]. Considering different languages can be realized by translating LOs into different languages.

Adapting learning material to a location can be achieved by enriching contents by specifics of the location. That could be realized by adding local context to the learning material, in such way, that the local environment is linked to the learning material. Creating different versions of learning material according to the user's status can be

realized by situational preparation. Thus, specifics of a certain status can be considered and contents prepared according to the requirements of that status.

The preparation according device requirements and preferences for media types mainly concentrates on syntactical aspects. Because of the unknown syntax of resources, e.g., wrong formats and resources cannot be processed and have to be converted. Limitations of capacity, like screen resolutions, colour settings, or bandwidth, require transformation in order to readjust the size. That is primary necessary for multimedia contents, like pictures or videos. By converting resources into other formats or readjusting their sizes the appearance can be affected. Bad quality or deformations could appear, but the content itself, its meaning and sense, thus, semantics, is intentional not affected. The process of transferring content from one format or size into another is called transcoding [17]. Transcoding of resources can be realized automatically during build time [18] or during runtime [17].

5 Conclusions

Importance of personalized learning materials increases with the growing popularity of ubiquitous technologies in educational technology. In order to use learning material adaptively a preparation targeting the learners' adaptation needs is necessary. This preparation can be realized by varying the sequence of existing LOs or by preparing or creating specific versions. The need for a systematic procedure for adaptive content preparation increases by the growing demand for adaptive material. This paper introduces 13 adaptation criteria for preparing learning material adaptively and presents first hints of content preparation according these criteria. Both can be used to describe the action alternatives of content preparation. In order to guide the process of selection and preparation of contents for adaptive usage, these criteria can be seen as a first step for the development of such a procedure.

In further steps, these criteria will be sophisticated and together with other criteria a decision model will be developed. This decision model should answer the question: *Which organizational knowledge elements should be prepared for adaptive usage and which techniques should be applied?* In the next step, all authors of papers considered for the detailed investigation in section 3 should be asked within a survey. The main idea is to give developers the opportunity to correct values and to report about planned features and missing factors. Afterwards, all developers of the 158 identified systems should rate the identified criteria and their importance.

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