Flexible Learning and the Adaptive Delivery of Online Content

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Abstract

The vision for flexible learning is where a learner has "access to integrated learning materials, information banks, communication channels, and tools, so the learner, at his desktop, can call up the appropriate amount and type of learning material when it is necessary and useful for his work and performance" [Barker *et al,* 93]. There are various aspects of flexible learning, one of the most important among them being flexible delivery of content. Under this new paradigm of flexible learning, online learning systems have to deliver content in an adaptive manner so that the individual needs and preferences of the learners are accommodated. There are various dimensions to the problem of adaptive delivery of content. Our notion is not limited to the pedagogical dimension even though it is a very important component. We also consider other dimensions such as usability, infrastructural environment, and administrative requirements that are very important in real life delivery of online instruction.

A framework that accommodates these various dimensions of adaptive delivery of content is yet to be proposed. In this paper we report ongoing work on the design of such a framework. The framework enables the separation of content from delivery strategy. Instead of hard-coding any particular strategy or implementing any particular theory in the source code, the unique feature of externalization of the delivery strategies in XML notation enables the system to support an infinite variety of delivery strategies. Thus the same content may be delivered using different strategies based on student model or other conditions. This externalisation of delivery strategies allows users to quickly implement their strategies of choice and provide their learners with customised learning experiences. Parts of the framework discussed in this paper have been implemented in a commercial eLearning engine.

1. Introduction

"Flexible learning" is an outcome of a number of social and technological events that have occurred over the last decades. Increasingly, flexibility is considered important for personal, educational, and economic reasons. "Flexible learning is enabling learners to learn the way they want (frequency, timing, duration), how they want (mode of learning), and what they want (i.e., learners can define what constitutes learning to them)" [den Brande, 93]. There are a number of different aspects of flexible learning [Nikolova & Collis, 98]. In this paper our focus is on the very important issue that is related to online learning: *adaptive delivery of online content*. Thus flexibility is considered in terms of the adaptation of the delivery of instruction to the individual learner's needs and preferences.

In this paper we describe the design of a framework for adaptive delivery of online content. There are various dimensions to the problem of adaptive delivery of content. The one that has historically received most of the attention is the pedagogical one where the attempts have been to tailor the delivery of instruction to the *pedagogical* profile of the learner. Our notion is not limited to the pedagogical dimension even though it is an important component of our framework. We have found that while building real life software systems for online delivery of content other dimensions such as *usability*, the *ICT environment* of the learner, and *administrative requirements* of the business that is providing the online services play very important roles.

The rest of the paper is structured as follows. Section 2 discusses in some details the various dimensions of adaptive delivery of content. Section 3 describes some of the major approaches that have been used to implement adaptive delivery. Section 4 describes our own approach to this problem. Section 5 concludes the paper with a discussion of future work.

2. Dimensions of Adaptive Delivery

Adaptive delivery of content is a multi-dimensional phenomenon. In this section we shall look at the various dimensions.

2.1 Pedagogical Dimension

Work in learning theory has established that learners possess pre-determined learning preferences in terms of environmental, emotional, sociological, physical, and psychological conditions [Price *et al*, 91]. Varying preferences for each of these learning conditions combine to provide an individual **learning style** profile. For example, learners have been categorised based on the representation format they tend to think in: *visual*, *auditory*, or *kinaesthetic*. An adaptive delivery engine should deliver more visual content (perhaps flash animations) to learners with a visual leaning style, for learners with auditory learning style voice-over support should be provided while for kinaesthetic learners the engine should deliver hands on exercises that would engage the learner in some activities.

It has been found [Marton & Saljo, 84] that learning outcomes are significantly affected by the differences in **learning approach** of learners that is a composite of their motives and strategies to learn as well as their perception of tasks. While learners with a *deep approach* try to understand the intention of the learning material and search for relations in it, learners with a *surface approach* focus on memorising the material. It has been suggested [Scardamalia *et al*, 99] that a deeper approach to learning may be induced by strengthening the meta-cognitive aspects of learning, e.g., instead of just providing menus with tasks and topics, the software can be built in such a manner that focus learner attention on the different learning activities that can be applied to a task.

Another aspect that is very important form the pedagogical point of view is the issue of **learner control**. On one extreme we could have predetermined learning paths with very little flexibility provided to learners to filter content or sequence its delivery. On the other extreme we could have the learner in a sea of content and expect them to find their way through it. A middle ground is the *guided discovery* mode where the learner has control but some coaching is also provided.

One of the pedagogical aspects that have received considerable attention is the adaptation of the delivery of instruction based on the learner's prior knowledge. This is the so-called learner-modelling problem that we shall touch upon in section 3.1.

2.2 ICT Environmental Dimension

The ICT environment of the learner plays a very important role in online learning and by any stretch of the imagination the environments cannot be considered to be homogeneous. The variabilities are due to a number of factors: *deployment* (intranet vs. internet), *network access* (LAN vs. dial-up vs. 64K vs. T3), *operating system* (Windows vs. Linux), *CPU speeds* (legacy vs. P4), *browser* (Mozilla vs. Netscape vs. IE vs. Opera), *browser version* (legacy vs. ver. 6 and above), *plug-in availability*, *security characteristics* (access from within a firewall vs. from direct access), etc.

The need for adaptation based on the learners ICT environment is of utmost importance and various approaches have been adopted. For network access speed variabilities a common approach is to categorise online material as "network heavy" (e.g., video) or "network light" (e.g., flash) and ask the learners to access the materials suitable to their access capabilities. For browser idiosyncrasies (along with the presence or absence of plug-ins) automated approaches are used that involve client-side scripting techniques to identify the learners environment and use conditional logic to deliver content suitable for that environment.

2.3 Usability Dimension

Usability [Nielsen 98] is considered to be one of the key factors that determine the success or failure of IT systems more significantly than technology related reasons. The growing sophistication of demanding users require that usability considerations play an important role in the delivery of online content. The primary usability aspect is of course, the look and feel of the application. For example, one of the common requirements today is that of supporting the **personalisation** [Dean] of the interface that is used to access online content. Personalization (sometimes called customization) generally refers to making a Web site more responsive to the unique and individual needs of each user. For users, the desired result is relevant content appearing more prominently on the site, while less relevant content may be buried in menus.

Vernacular support is a very important usability requirement, although it may also be listed under the pedagogical dimension since the medium of instruction plays a major role in pedagogy. Attempts have been made to identify the locale of a user based on the IP address of his machine and deliver content in a language suitable for that locale.

Adaptation of delivery of online content based on usability issues is being increasingly supported. For example, today most sites and portals with a large user base support some form of personalisation; examples are MyYahoo, MyExcite, MyNetscape, etc. Support for users with special needs is also being provided but at a very slow pace.

2.4 Administrative Dimension

One of the major reasons for delivering content differently to different people is based on the business environment. In these cases administrative reasons rather than pedagogical ones drive how content is delivered to he learners. This is generally not considered to be “adaptive delivery” (perhaps “customised delivery” would be a more common term) but we will not constrain ourselves and adopt a generalist view.

Consider the scenario where registered (perhaps after payment) users at an educational portal are able to access all the content while unregistered visitors are only delivered content that is marked as “free”. Consider another scenario in which a university is offering a distance learning program where students who have submitted assignment no. 1 are delivered assignment no. 2 while those who are yet to submit are denied this delivery (perhaps they do not even get to see the hyperlink for assignment no. 2 on their screens). Consider another scenario where an NGO is offering an online course in treatment of malaria and the delivery of course content will vary based on whether the user is a health administrator or a field worker.

All of the above scenarios require adaptive delivery of online content where the adaptation is to be done based on certain conditions that may be considered administration related.

3. Implementation Approaches

Adaptive delivery of instruction has historically been one of the main drivers of educational technology; “The strongest argument for the use of computers in education is their potential to provide individualised instruction” [Ohlsson 93]. As a result of this history a number of initiatives may be found that have attempted to implement adaptive delivery in some form or the other. The multidimensional nature of this problem may be observed from the variety of approaches that have been used. In this section we shall briefly review some of the important approaches.

3.1 Intelligent Tutoring Systems

In 1984, Benjamin Bloom defined the "two-sigma problem," which states that students who receive one-on-one instruction perform two standard deviations better than students who receive traditional classroom instruction. Intelligent tutoring systems (ITS) or intelligent computer-aided instruction (ICAI) has been pursued for more than three decades by researchers in education, psychology, and artificial intelligence. ITS systems assess each learner's actions and develop a model of their knowledge, skills, and expertise. An overview of ITS may be found in at http://www.learningcircuits.org/feb2000/ong.html. An ITS consists of two major components. The *student model* stores information that is specific to each individual learner. At a minimum, such a model tracks how well a student is performing on the material being taught. Since the purpose of the student model is to provide data for the pedagogical module of the system, all of the information gathered should be able to be used by the tutor. The *pedagogical module* provides a model of the teaching process. It uses information from the student model to determine what aspects of the domain knowledge should be presented to the learner. This information, for example, may be new material, a review of previous topics, or feedback on the current topic. An ITS usually updates the learner model as a result of the learner’s responses and also notes which strategies are effective in helping the student, thus allowing adaptation to the learner’s needs as the tutoring progresses.

The following characteristics are to be noted with respect to the capability of ITS' in providing adaptive delivery of instruction:

- ITS' stress on the use of the information about what a learners knows (stored in the learner model) in adapting the delivery of instruction. Other elements of the pedagogical profile, e.g., learning style, learning approach, etc., the so called "global descriptors" [Ohlsson 93] are not utilized.
- Flexibility in term of learner control is not an integral part of the design of ITS' since they are built with bias towards more control of the system and less control of the learner.
- The teaching strategies are "hard-coded" in the pedagogical module and thus are not amenable to change. This lack of flexibility makes it harder to support adaptation in the teaching strategies that are used by the system.

3.2 Adaptive Hypermedia Systems

Adaptive hypermedia [Brusilovsky 94] technology based systems aim to support users by tailoring the system and augmenting the delivery of information. An effective adaptive hypermedia system will be capable of filtering out details that are outside a user's current field of interest or beyond their level of comprehension. In effect, adaptation controls the size of the hyperspace available to a user at a particular point in time. Control of information within a hypermedia system offers the prospects of addressing both the *lost in hyperspace* and the *information overload* problems.

Adaptation is a powerful way of augmenting the functionality of a hypermedia system. There are two main components of a hypermedia system that can be adapted; these are hypermedia links and information contained in the nodes. Adaptation of hypermedia links mainly affects navigation within a hypermedia system whereas adaptation of the nodes themselves affects the presentation of information. These two forms of adaptation are usually referred to as *navigational* and *presentational* [Smith 99].

3.2 Sequencing and Navigation in the SCORM-AICC Approach

The SCORM (Sharable Content Object Reference Model), which is a part of the Advanced Distributed Learning (ADL) Initiative (www.adlnet.org), is a set of interrelated technical specifications built upon the work of the AICC, IMS and IEEE to create one unified 'content model'. SCORM consists of three main sections: (a) an Extensible Markup Language (XML)-based specification for representing course structures (so courses can be moved from one eLearning engine to another); (b) a set of specifications relating to the run-time environment, including an API, content-to-engine data model, and a content launch specification; and (c) a specification for creating meta-data records for courses, content, and raw media elements.

The SCORM provides a means to sequence through the learning resources using prerequisites. The use of prerequisites is derived from the work done by the AICC. The content package allows for the Item structures to include a sub-element called *prerequisites*. This element provides a field that can be used to algorithmically represent the sequences of navigation through a content aggregation. This element mirrors certain tracked data elements in the Run-Time Environment Data Model. The data model provides a means for learning resources to report to an eLearning engine when a particular part of the learning resource is "complete" or "incomplete." The engine can then evaluate the statements in *prerequisites* to determine what learning resource the student should be delivered next. The *prerequisites* element defines what other parts of the content must have been completed before starting the *content aggregation* or *item*. This allows an engine to compute multiple paths through the learning content.

The SCORM defines (based on the AICC guidelines) operators of a prerequisite scripting language called "aicc_script"[Scorm1.2a]. These operators define the allowed representation of the logic to be computed by an eLearning engine, and define the way that the logic is to be encoded in the *prerequisite* elements located in the *organization* part of Content Packaging. The operators include AND (&), OR (|), NOT (~), EQUALS(=), NOT EQUALS (<>),etc., and includes facility for defining sets and defining precedence.

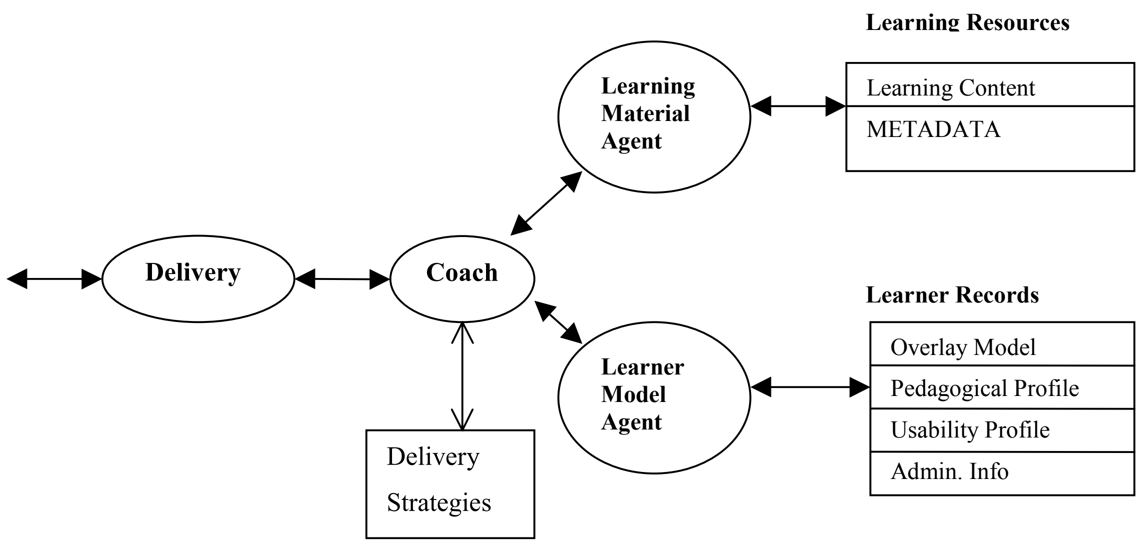
The limitations of the SCORM as far as adaptive delivery of content has been realised and a separate initiative has been started to suggest improvements to the model. The CLEO (Customised Learning Experience Online) [Rehak & Blackmon 01] is a collaborative project among vendors, academia, and the ADL initiative that aims to come up with a model that supports a rich and customised eLearning experience.

4. Our Approach

The objective of our research is to develop a framework that accommodates the different dimensions of adaptive delivery and that is amenable to implementation in conformance with leading edge eLearning standards such as SCORM. In this section we shall discuss our approach in some detail.

4.1 Architecture

The architecture we adopt is inspired by the LTSA (Learning Technology Standards Architecture) [LTSA 01] proposed by the IEEE. We have augmented the architecture with two processes (Learning Material Agent and Learner Model Agent) [Chen & Mizoguchi 99] and a data store (Delivery Strategies).



Information about the learner is managed by the Learner Model Agent. The Learner Records datastore holds the information about what a learner knows about a particular subject in the form of an *overlay model* [Smith] as well as the pedagogical and usability profile of a learner and other administration related info about the learner. Information about the online learning content is managed by the Learning Materials Agent. The Learning Resources datastore holds the learning materials and the meta-data about the materials in the SCORM standard. Adaptive delivery of content is performed by the Coach module that makes use of Delivery Strategies datastore (which holds different delivery strategies in XML notation) and information about the learner and the learning material to select the appropriate strategy to use for the given learner and content. The final delivery of the content to the learner is performed by the Delivery module.

4.2 Qualifiers and Strategies

Our approach to adaptive delivery is based upon three foundational concepts: *learner qualifiers (LQ)*, *content qualifiers (CQ)*, and *strategies*. Learner qualifiers are used to identify learners (a single learner or a group of learners) based on the four types of information stored about learners: (i) pedagogical profile (e.g., learning style, learning approach, etc.), (ii) usability profile (e.g., look and feel preferences of a learner), (iii) administrative information (e.g., units for which the learner is registered, whether the learner is a paying student or a 'free' one, etc.), and (iv) information already known by the learner for a particular subject (e.g., topics already mastered as determined by formative or summative evaluations).

Content qualifiers are used to identify or categorise the kind of content that is to be delivered. They are defined based on the metadata about the learning content that stored (discussed next in section 4.3).

Strategies are used to represent rules for delivering content and are defined as triples
<learner qualifier, content qualifier, action>
Various predefined actions are provided that enable different delivery mechanisms: (a) deliver material up to a certain depth of the learning material tree with different depths on the different branches, (b) deliver variant subtrees, (c) deliver the nodes of the tree with different orderings, etc.

Any strategy whose content qualifier contains references to specific learning material identifiers is considered to be a *local rule* or *tactic*. Tactics implement delivery strategies for a particular subject. Strategies which do not include such reference are considered as *generic rules* and implement delivery strategies that may be applied to a number of subject areas. Organisations are expected to gradually build up a body of tactics and generic delivery strategies through experimentation and fine tuning.

A number of strategies may be applicable in a particular context. This is handled by the simple mechanism of the capability of assigning priorities to strategies so that they may be applied in order from high to low priority. In the general case theorem proving techniques may have to be applied to reason about the applicability of strategies and resolve conflicts among them.

4.3 The role of metadata

The purpose of meta-data (data about data) is to provide a common nomenclature so that learning content can be self-describing. Learning content that is tagged with self-describing meta-data can be systematically searched for and retrieved for use and reuse. Meta-data for learning content has been under development within a number of international organizations over the past few years: IMS, IEEE LTSC, and ARIADNE, all of which were themselves inspired by the generic metadata work done under the Dublin Core initiative. The SCORM effort makes use of the work done by these various groups and provides a standard for eLearning metadata.

The SCORM identifies three types of learning content meta-data: raw media, content and course. There are nine categories of meta-data elements [Scorm 1.2b]:

- The *General* category groups the general information that describes the resource as a whole.
- The *Lifecycle* category groups the features related to the history and current state of this resource and those who have affected this resource during its evolution.
- The *Meta-metadata* category groups information about the meta-data record itself (rather than the resource that the record describes).
- The *Technical* category groups the technical requirements and characteristics of the resource.
- The *Educational* category groups the educational and pedagogic characteristics of the resource.
- The *Rights* category groups the intellectual property rights and conditions of use for the resource.
- The *Relation* category groups features that define the relationship between this resource and other targeted resources.
- The *Annotation* category provides comments on the educational use of the resource and information on when and by whom the comments were created.
- The *Classification* category describes where this resource falls within a particular classification system.

The presence of this rich metadata structure permits elaborate and precise definition of leaning content qualifiers. For example, the *educational* category may be used to define the content that is appropriate for a particular learning style. Similarly, the *technical* category may be used to define content that is appropriate for a particular ICT environment. The other categories may be used to define learning content suitable for particular administrative requirements.

4. 4 Representation of strategies

The notion of a strategy is very fundamental to the field of instruction design and has been variously called learning strategies, teaching strategies, and even transaction strategies [Merril *et al*, 90]. Varied approaches have been used for computational representation of strategies: [Carvalho *et al*, 99] mention the Teaching Strategy Definition Language, [Ranwez *et al*, 99] mention Pedagogical strategies as rules that are expressed in the pedagogical ontology, while [Jona 95] uses a data structure called a Pedagogical Knowledge Bundle to create a standard language for representing teaching strategies.

All of the above approaches employ a procedural language to express the strategies. The problem with a procedural approach is that it is difficult to separate the strategies from the software modules that implement other parts of the eLearning engine thus making it difficult for users who do not have the source code (and/or the programming skills in that language) to define new strategies or modify exiting ones.

In our approach we use a declarative method to express strategies. This is done by using the Extensible Markup Language (XML) to represent strategies. Keeping the strategies separate from the content and storing them in XML files that may be loaded by the Coach module permits the users to easily define strategies and experiment with them for effectiveness of the learning outcome. For each course, a separate strategy file is generated. Given below is a snippet from the strategy file for a course on data structures (currently only certain parts of the concepts defined above are implemented):

```
<Strategy>
    <Style>Free</Style>
    <Topic>
      <TopicName>Introduction To DataStructure</TopicName>
      <DisplayName>Introduction To DataStructure</DisplayName>
      <ToolTip>Overview of Arrays</ToolTip>
      <Labels>
        <Label>
          <LabelName>Array </LabelName>
          <DisplayName>Array </DisplayName>
          <HostedOn>server</HostedOn>
          <ToolTip>What is anArray?</ToolTip>
        </Label>
        <Label>
          <LabelName>Queue</LabelName>
          <DisplayName>Queue</DisplayName>
          <HostedOn>server</HostedOn>
          <ToolTip></ToolTip>
          <Image></Image>
        </Label>
……
```

4.6 Tool support

In order to enable users to easily define strategies and experiment with them it is essential that proper tool support be provided. As a part of our work we have developed a GUI based tool (implemented with Java Swing) that may be used to define strategies (currently only parts of the strategy may be generated by this tool).

5. Conclusion

The design of our framework has been done so as to support multiple dimensions of adaptive delivery. For all the dimensions, the basic mechanism is to dynamically determine a subtree of the course material tree and deliver it to the learner. The determination of what to deliver is based upon matching the characteristics of the learner against the learner qualifier defined in the strategy and matching the online content being delivered against the content qualifier defined in the strategy. The differences in the treatment of the dimensions are mainly reflected in the in the source of information being used to define the qualifiers. For the pedagogical dimension, the LQ is defined based on the pedagogical profile of the learner while the CQ is defined based on the educational category of the metadata; for the usability dimension the LQ is based on the usability profile while the CQ is based on the technical category.

The framework enables the separation of content from delivery strategy. The externalization of the delivery strategies in XML notation enables the system to support an infinite variety of delivery strategies. Thus the same content may be delivered using different strategies based on student model or other conditions. This externalisation of delivery strategies allows teachers and administrators to quickly implement their strategies of choice and provide their learners with customised learning experiences.

Our current research is concerned with providing pre-packaged bundles of delivery strategies (categorised by “vertical” subject areas) based on ontologies of instructional design to enable quick implementation of eLearning projects. Another area of research is concerned with providing scripting support in defining strategies; a predefined set of actions, however exhaustive, does not give the flexibility that might be provided by a scripting language; a major concern here is how to retain the declarative nature of our approach.

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