Multi-Model, Metadata Driven Approach to Adaptive Hypermedia Services for Personalized eLearning

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Abstract. One of the major obstacles in developing quality eLearning content is the substantial development costs involved and development time required [12]. Educational providers, such as those in the university sector and corporate learning, are under increasing pressure to enhance the pedagogical quality and technical richness of their course offerings while at the same time achieving improved return on investment. One means of enhancing the educational impact of eLearning courses, while still optimizing the return on investment, is to facilitate the personalization and repurposing of learning objects across multiple related courses. However, eLearning courses typically differ strongly in ethos, learning goals and pedagogical approach whilst learners, even within the same course, may have different personal learning goals, motivations, prior knowledge and learning style preferences. This paper proposes an innovative multi-model approach to the dynamic composition and delivery of personalized learning utilizing reusable learning objects. The paper describes an adaptive metadata driven engine that composes, at runtime, tailored educational experiences across a single content base. This paper presents the theoretical models, design and implementation of the adaptive hypermedia educational service. This service is currently being successfully used for the delivery of undergraduate degree courses in Trinity College, Dublin as well as being used as part of a major EU research trial.

1 Introduction

In the past Intelligent Tutoring Systems (ITS) traditionally have embedded experts' knowledge in the structure of its content and applied appropriate design models. However, such systems have continually been criticized for believing that this is sufficient for effective learning to occur [13]. In reality, these early systems constrained the learner and limited the opportunities for the learner to investigate topics the ITS deemed to be of little relevance.

Later ITSs used knowledge about the domain, the learner, and about teaching strategies to support flexible individualized learning and tutoring [4]. One of the goals of these ITSs was to adaptively deliver content. The majority of such ITSs merge the

content, narrative and learner modeling into a single engine, giving a system that adapts effectively yet is very difficult to repurpose.

Adaptive Hypermedia is a newer research domain [3]. Adaptive Hypermedia Systems (AHS) apply different forms of learner models to adapt the content and the links of hypermedia pages to the user [4]. While there tends to be a clearer separation of the learner model and content model in AHSs (as opposed to the integrated approach of ITSs) the narrative or pedagogical model in usually either embedded in the content or into the adaptive engine itself. This means that applying new or different pedagogical models, e.g. case based learning, simulations, etc., to the content model is more difficult and involves a re-authoring of the content model. This results in learning content that is difficult to reuse or an engine that is domain specific.

This paper proposes an approach that has a clear separation of content, learner and narrative models, and a generic adaptive engine that employs a multi-tiered AI model to achieve effective adaptation to the learner's requirements. The approach is to have very little semantics actually embedded in the adaptive engine itself. Therefore the pedagogic semantics that govern the narrative sequence of the learning experience are contained in a separate model. The adaptive engine reconciles the three models to compose, at runtime, the personalized course. Such dynamic construction of the learning experience is controlled by each learner via appropriate pedagogic instruments, e.g. indirect access to their learner model via an instrument. This approach enables multiple narrative models to be constructed to fulfill different learning goals, while these goals may be achieved from a common repository of content.

Section 2 presents the issues which impact on the development and representation of content within the Adaptive Hypermedia Service. Section 3 discusses the aspects of the learner which can be modeled to enable adaptation to the learner's preferences. Section 4 introduces the narrative model that facilitates the separation of content and structure and enables the course author to define how the service adapts to the learner's knowledge. Section 5 presents the Personalized Learning Service, an implementation of the multi-model, metadata driven approach to constructing Adaptive Hypermedia Services. Finally, section 6 discusses the conclusions drawn from this research.

2 Content Issues

The main goal of the multi-model approach is to separate the learning content from the adaptive linking logic or narrative. This separation improves the possibilities of reusing a piece of learning content as the learning object (LO) is no longer specific to a given implementation or narrative model. A second goal (with respect to content) of this approach is to allow course designers to easily discover learning content in the content repository by providing appropriate descriptive metadata.

Metadata may describe both technical and pedagogical aspects of the LO. This information is not only useful to a course designer in selecting appropriate learning content, but can be used by an adaptive engine to select appropriate content where

there may be many candidate LOs available to fulfill a learning or technical requirement.

2.1 Content Model for the Adaptive Service – The Content Model

The use of standards based metadata to represent the content model encourages the reuse of the learning objects outside of the adaptive hypermedia service. Content may also be imported into the services content repository from external repositories if that content has similar metadata associated with it. The content model utilized in the adaptive hypermedia service is based on IMS Learning Resource Metadata [9]. The IMS Metadata specification was chosen as the basis for the content model schema as it is based on the IEEE LOM specification and an XML binding is available.

Adaptivity is not, however, directly addressed by the IMS Metadata Specification and in order for the adaptive engine to choose between several candidate pieces of content (Section 2.3) it may be necessary for it to have further information about the learning objects. Within the EASEL [6] IST project (through which this research has been part funded) an extension to the IMS Metadata schema was developed. The extension consisted of the addition of a sub-section called Adaptivity to the Education section of the schema. This sub-section caters for user definable adaptivity types allowing the metadata creator to develop complex relationships and dependencies within the metadata description of the service [5].

From the perspective of a single reusable learning object, the adaptivity types might include competencies.taught, competencies.required and learningstyle. Included in each adaptivity type is the ability to reference, using a URI, an external resource that enables the metadata author to describe that type and any vocabularies or requirements associated with it.

2.2 Content Lifespan and Granularity

The separation of content from narrative eases the reuse of the learning objects and potentially increases their lifespan. For example, if many learning objects covering aspects of the Java programming language were developed three years ago then, if viewed as a complete course today, may be out of date with respect to the current version of the language. However, if viewed individually some of the learning objects (LO) may be reusable, e.g. those describing the control loops. If the narrative was embedded in the LOs then it may be more difficult to reuse them within another adaptive course.

The potential reuse of LOs is related to the granularity, or the scope, of the learning object. The smaller the granularity of the content the greater potential exists for the LOs reuse. One possible disadvantage of this approach is that if the fine grained LO, which the author terms pagelets, are poorly sequenced then they may appear to be inconsistent or incoherent. It is the function of the narrative author to ensure that the customized courses produced from the narrative contain pagelet

sequences that maintain learning concept coherency and have a logical flow (Section 4).

2.3 Candidate Content Groups

The mechanism employed by the narrative to refer to content is to use an indirection, whereby the narrative doesn't refer to individual pieces of content (LOs) directly, but to candidate content groups. Each candidate content group contains learning objects that fulfill the same content requirement. The LOs in a candidate content group may differ technically (e.g. bandwidth requirements), in instructional approach or on any other axes on which the adaptive service may be adaptive. The decision as to which LO to deliver can be made at runtime based on some information about the learner (Section 3). The requirement for different candidates can be determined by an educational instructional designer, although the task of generating the content for the candidates is generally a collaborative process between the domain expert and the instructional designer.

3 Modeling the Learner

A learner/user model contains explicitly modelled assumptions that represent the characteristics of the student which are pertinent to the system. The system can consult the user model to adapt the performance of the system to each student's characteristics. User modelling allows the system to personalize the interaction between the student and the content. To achieve effective learning this personalization should put the content in a context that the student can understand and to which they can relate.

3.1 Prior Knowledge and Learning Objectives

The learner model should be capable of storing the prior knowledge and learning objectives of the learner to facilitate the personalized delivery of content based on the learner's experience and goals. This raises a number of questions –

- What vocabulary should be used to describe the prior knowledge and objectives?
- What level of detail does this vocabulary need to describe?

As the narrative model is constructed by an expert(s) in the knowledge domain it is up to them to use whatever vocabulary they feel best describes the knowledge domain for which they are building the narratives. As they are responsible for the mechanism(s) that are used to populate the learner model, e.g. a knowledge pre-test, all they need to ensure is that the vocabulary is consistent between the learner model and the narrative.

The granularity to which the vocabulary exists and the scope of the pagelets determine the level at which the engine can adapt to prior knowledge and learning

objectives. For example, if a course author decides there are ten learning objectives in a course then the finest grain that the adaptive engine can personalize a course is at the scale of one of those objectives. This is true even if the pagelets are finer grained, as each learning objective may require several pagelets to fulfill it. On the other hand if there was a learning objective associated with each pagelet then the engine could personalize the course on a pagelet by pagelet basis. There is a balance between the vocabulary granularity and pagelet granularity that determines the level of content personalization that is achievable by the adaptive engine.

3.2 Pedagogical Considerations

Learning style is a term used to describe the attitudes and behaviors that determine an learner's preferred way of learning. Learning style preferences have implications for all types of learning, whether the learning is dedicated to the acquisition of knowledge through formal structured activities, e.g. lectures, case studies and books or through experiential learning, i.e. learning through experience [8]. For the online paradigm, as in traditional classroom situations, there is no consensus on how best to model the learner's preferred approaches to learning. Therefore, the approach taken in this design of the Adaptive Hypermedia Service (AHS) was to enable the instructional designers to impact the rendering of the personalized course at two levels –

- The structure/layout in which the content is placed.
- The type (or format) of content displayed.

To this end the AHS enables many candidate narratives, supporting different pedagogical approaches to structuring the content, to be associated with a single course. This association and an appropriate selection mechanism enables the AHS to deliver a personalized course that, while dealing with the same subject matter, can be structured in a way that best engages the learner's preferred learning styles. The subject matter, however, is not referred to directly in the narratives, but rather through the mechanism of candidate content groups (Section 2.3). At runtime the AHS can determine which candidate is most suitable (Section 5.4). The pedagogical approach used in the design and selection of the content can be defined by the instructional designer.

One such approach is the VARK (Visual, Auditory, Read/Write and Kinesthetic) [15] model that can influence the design of individual content candidates to emphasize one of these aspects – visual, auditory, read/write and kinesthetic. Using an appropriate instrument the learner model may be populated with these values. The AHS can reconcile the content model and the learner model to determine the appropriate candidate at runtime.

3.3 Describing the Learner – what to model?

The learner model employs a similar mechanism to the content model enabling an extensible metadata framework where information pertaining to how the adaptive engine creates a personalized course may be placed. There is an Adaptivity sub-

section in the metadata model that enables the definition of new adaptivity types. For example, these types may include competencies.learned, competencies.required and learningstyle. As this is an extensible framework the domain expert, who describes the learning content requirements of a course, and the instructional designer, who describes the pedagogy requirements of the course, can define new adaptivity types to facilitate other forms of adaptivity they may wish to implement in the narrative.

The learner model also includes learner information such as forename, surname and a unique identifier (within the adaptive hypermedia service). When the Adaptive Hypermedia Service is integrating with a Learning Management System (LMS) it is usual that some of this information is retrieved from the LMS (Section 5.6).

4 The Narrative Model

The narrative model for a course describes the rules, developed by domain and pedagogical experts, which govern the range and scope of personalized courses that the adaptive engine can produce for learners. The narrative enables the course author(s) to separate the rules which govern how the personalized course will be generated from the content that will be included in that course.

4.1 Encapsulation of Domain Expertise

The narrative is a representation of the expert's knowledge of a domain. Narratives can be used to generate courses that differ in ethos, learning goals, pedagogical approach and learner prior experience from a common content repository. The vocabulary used to describe the learning concepts embodied in the course is that of the domain expert. As the narrative does not refer directly to individual pagelets, but rather to candidate content groups using this vocabulary, the domain expert can create the narrative without being constrained by pedagogical or technical delivery issues at the content level. The author can simply refer to the Candidate Content Group in the narrative and allow the adaptive engine determine which candidate from the group is most suitable for delivery.

Using a similar mechanism to the candidate content groups it is possible to have several candidate narratives for a single course. The candidates have the same ethos, learning goals and require the same learner prior knowledge, but differ in pedagogical approach. Where these kinds of pedagogical issues, i.e. those which impact the course structure, are implemented the process of developing the narratives is often a collaborative process between instructional designers and the domain expert. The Personalized Learning Service is capable of selecting a narrative based on learner model values (e.g. learning style) or on external factors (e.g. is a revision course required).

4.2 Coherent Personalized Course Structures

The primary goal of the narrative is to produce courses that are structured coherently and fulfill the learning goals for the course. It is, therefore, the domain expert's task to ensure that each learning goal has sufficient appropriate pagelets to fulfill that goal and that those pagelets are sequenced in such a manner that engages the learner.

From this perspective the domain expert must consider how the exclusion or inclusion of pieces or sequences of content will impact on the intelligibility of neighboring content and on the personalized course as a whole. To this end it is often useful to determine, before designing a narrative, what is the granularity of content personalization that is to be achieved, i.e. personalization on the section, page or paragraph level. It is also useful to determine what content, if any, is considered core material and should always be present in all personalized courses. With these two factors set, the expert has a framework in which to consider the impact of the inclusion or exclusion of content based on the learners' expertise and preferences.

4.3 Reconciling the Learner Model and the Content Model

As the vocabularies used to describe the knowledge domain and the learner's prior knowledge and learning objectives are determined by the expert (Section 3.1), that expert must ensure that those vocabularies are one common vocabulary or that there is a translation mapping available between the two vocabularies. The adaptive hypermedia service does not place any restrictions on what constitutes the vocabulary, only that the narrative model and any elements of the learner model that the expert wishes to reference share that vocabulary or that there exists an appropriate mapping between the narrative and learner model vocabularies. This enables the narrative to reconcile learner prior knowledge and/or learning objectives with candidate content groups.

This reconciliation enables the narrative to select appropriate candidate content groups based on the learner's prior knowledge and learning objectives. The narrative is not directly concerned with learning style issues; only with the learning concepts the final course should include to meet the learner's learning objectives. Learning style considerations are catered for by the appropriate selection of narrative (Section 5.3) and content (Section 5.4).

5 Personalized Learning Service

The Personalized Learning Service (PLS) has been developed as a service to deliver personalized educational courses based on the multi-model, metadata driven approach outlined in this paper. The PLS is currently being used to deliver personalized online courses in SQL (Structured Query Language) to final year undergraduate students in two degree programmes in Trinity College, Dublin and a trial of eighty students, over a period of two months, was been carried out to assess the students reaction to using

an online adaptive hypermedia service. It is also being used within the EASEL [6] IST project to demonstrate the discovery and integration of Adaptive Hypermedia Services with traditional (static) online learning content.

5.1 Architecture

The architecture of the PLS has the three models – learner, narrative and content – as the basis of its design. The PLS utilizes three metadata repositories (Learner, Content and Narrative) and two information repositories (Content and Narrative). There are also two repositories that contain information about candidates – one dealing with Candidate Content Groups and one concerning Candidate Narrative Groups.

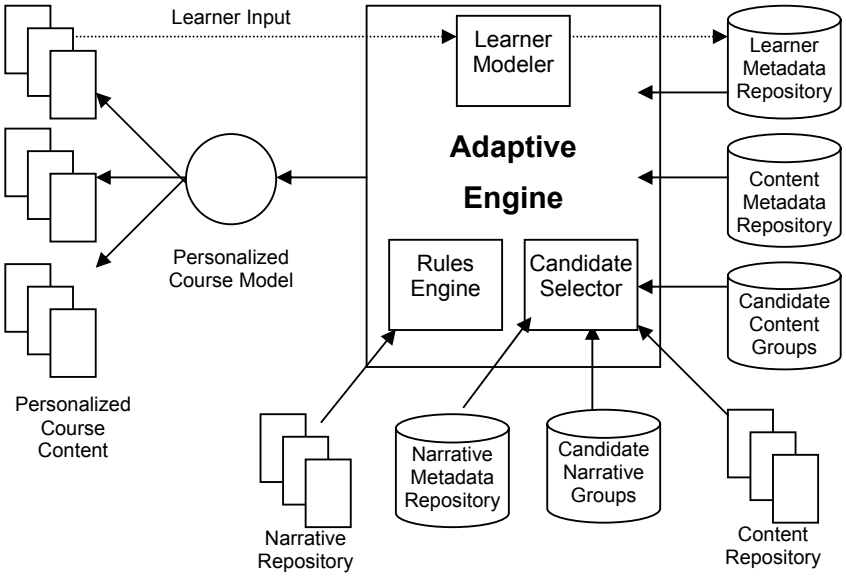

Fig. 1. Adaptive Hypermedia Service Architecture

At the core of the PLS is the Adaptive Engine (AE). The AE uses the Java Expert System Shell (JESS) [10] with customized functions as the basis of its rules engine. The rules engines role is to produce a model for a personalized course based on a narrative and the learner model. The XML-based [16] personalized course model encapsulates the structure of the learner's course and contains the candidate content groups that fulfill the learner's learning requirements in accordance with the narrative.

The AE also utilizes a candidate selector for choosing the appropriate narrative by reconciling information in the learner model with the candidate narrative groups. The candidate selector is also used to choose the appropriate piece of content to deliver from a candidate content group when the personalized course content is being generated from the personalized course model (Section 5.4).

The AE has a learner modeler component that enables input from the course or pre-tests to be translated into changes in the learner's information. This component is used to populate the learner's model when the learner initially enters the Adaptive Hypermedia Service. It can also be used at runtime to modify the learner's model – these modifications may either be initiated by the learner or by the engine itself and can be initiated directly from the JSP.

5.2 Building the Learner Model

Before the PLS can create a personalized course for a learner it must have some appropriate information about that learner. This information is obtained by asking the student to complete an online instrument, typically a prior knowledge questionnaire, that determines both their prior knowledge of the domain and any pertinent learning style information. This instrument uses the learner modeler component of the AE to modify the learner model.

The design of any instruments that determine learner information is the responsibility of the domain expert and the instructional designer. The learner is asked to interact with the instrument on their first visit to the PLS. The learner can access the instrument at any stage during their learning and modify their answers. This process gives the learner an indirect mechanism to change their learner model and rebuild their personalized course accordingly.

5.3 Selecting the Narrative and Creating the Personalized Course

The first step in creating a personalized course model is to select an appropriate narrative. For each course there may be several narratives available to achieve the same learning objectives. These narratives differ in the pedagogical approaches used to structuring the content they implement. The adaptive engine calls the candidate selector to choose the best candidate narrative from the candidate narrative group for the course. The selection is based on the metadata in the Narrative Metadata Repository and on the learner's metadata. For example, if the learner's preferredcoursestructure is abstract the candidate selector will select the narrative that matches this preference most closely.

Once the narrative, which is represented by the JESS [10] language, is selected the rules engine is invoked to interpret the rule set. This rules engine has access to the learner model to determine which candidate content groups should be added. It can compare elements of the learner model with rules in the narrative. In the PLS the rules engine is primarily concerned with reconciling the learner's prior knowledge and learning objectives with appropriate candidate content groups.

The rules engine generates an XML representation of the personalized course model that is described in terms of organizational structures such as sections, modules or units (as determined by the narrative designer) and candidate content groups.

5.4 Selecting Content and Delivering the Course

Once the Personalized Course Model has been generated it needs to be translated into a structure and format that the learner can access easily. The appropriate candidates (chosen from the candidate content groups) need to be included in the delivered course as well. These steps are performed by passing the XML representation of the Personalized Course Model through as XSL [17] transformer. The transformer produces many Java Server Pages (JSP) from the XML representation. The JSPs give HTML form to the Personalized Course Model. During the transformation the candidate selector is called to choose the content that best fits the learner's VARK [15] preferences. The candidate selector chooses this content by comparing the prospective candidates metadata with the learner model and uses server-side includes to include the content in the JSP files. The course is delivered as HTML using the Jakarta Tomcat [14] JSP engine.

5.5 Initial Learner Trial Results

After completing the personalized SQL course, produced by the PLS, and a related database design project, the eighty final year undergraduate students who took part in the trial were asked to complete an evaluation questionnaire.

The evaluation of these results is currently being performed, but the initial findings have shown that –

- 30% of the students had no prior experience of online learning, while only 6% said they had much online learning experience.
- Over 80% said the personalized course generated represented the answers they gave in the online pre-test instrument.
- 60% of the students believed the online instrument gave them sufficient control over the content contained in the personalized course generated.
- 87% of the students were happy with how the content was structured in the personalized courses.

These results appear to show the students' satisfaction with the personalized courses generated by the PLS, although some of the comments on the evaluation questionnaires indicated that some students desired a finer level of content control than that offered via the online instrument.

Also observed was a behavior that was not originally anticipated – some students used the instrument to regenerate a personalized course for each study period. They interacted with the instrument is such a way that the personalized course produced contained only the content they wished to study for that period. This gave the students greater control over their learning, echoing some of the fundamental concepts of constructivism.

5.6 PLS as a Remote Third Party Service

In order to be called a service the Adaptive Hypermedia Service (AHS) must facilitate ease of integration with heterogeneous Learning Environments (LE) in such a way that learners are able to seamlessly launch and use the AHSs adaptive content from within their preferred LE, e.g. WebCT, Blackboard, etc. This process, as far as the learner's interaction with the LE is concerned, should appear no different from regular (LE native) content. It may be the case that the learner is studying content from both native and adaptive sources to achieve a learning objective. Within the EASEL [6] IST project the Personalized Learning Service has been successfully integrated with Fretwell-Downing Educations [7] Learning Environment using the Content Interworking API initially defined by the AICC [2]. The API version and data model utilized is a JavaScript implementation of the ADL SCORM [1].

The information exchanged between the LE and the PLS is learner identification, and performance and assessment information. The PLS requests the learner's identification from the LE when the service is initially launched and returns assessment information when the learner has completed their personalized course.

The PLS can be a Third Party Service residing on a separate server from the learning environment. The advantage of this approach it that there is a clear separation of responsibilities – the LE provides the learning support facilities and the PLS provides personalized content. If the learning support features of a Learning Environment are not required the PLS can be launched as a stand-alone service or integrated with other learning content.

6 Conclusions

This paper has presented an approach for developing Adaptive Hypermedia Services based on separation of the narrative, content and learner into individual models. This approach encourages the reuse of content, as the content does not embed the logic used to produce personalized courses. The pedagogical approach and course structure is instead embedded in the narrative model. This approach enables a single course to support many pedagogical approaches to structuring learning content. Also proposed is a mechanism to enable course authors to reference learning objectives, rather than individual pieces of content, from the narrative, thus facilitating the selection of learning content at runtime. This content is selected in accordance with the learner's content presentation preferences.

The paper also presents the Personalized Learning Service, an implementation of the multi-model, metadata approach. The PLS is currently being used to successfully generate and deliver personalized courses in SQL to eighty final year undergraduate degree students in Trinity College, Dublin. Presented are some initial evaluation findings from this trial.

Finally the paper discussed the PLS as a service, highlighting how the service approach enables personalized learning content to be integrated with existing learning content.

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