

Developing Active Learning Experiences for Adaptive Personalised eLearning

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Abstract. Developing adaptive, rich-media, eLearning courses tends to be a complex, highly-expensive and time-consuming task. A typical adaptive eLearning course will involve a multi-skilled development team of technologists, instructional developers, subject matter experts and integrators. Even where the adaptive course attempts to reuse existing digital resources, considerable effort is still required in the integration of the adaptive techniques and curriculum. This paper tackles the fundamental challenges of extending adaptivity across not only content (based on prior knowledge, goals, learning styles, connectivity etc.) but also across adaptive pedagogic approaches, communication tools and a range of e-activity types which are required for effective, deeper learning. This paper identifies key activities and requirements for adaptive course construction and presents the design of a tool to allow the rapid construction of such courses. The paper outlines the usage of this tool in the form of a case study and presents its research findings.

1 Introduction

Adaptivity in eLearning has become one of the key areas in which adaptive hypermedia (AH) is being applied and extended [1]. However, such adaptivity has tended to focus on adaptive content retrieval and (simple) content sequencing based on domain models, or more recently ontologies [2]. From an educational (learning) perspective, this adaptive content retrieval typically supports lower cognitive aspects of learning (recall & understanding) [3]. To provide support for higher cognitive skills in areas, such as analysis, synthesis and evaluation, the adaptivity needs to be intimately integrated with sound pedagogic approaches and models [4], [6].

A second problem with current adaptive web based systems is the difficulty of authoring adaptive experiences. Because of cost and difficulty (complexities) in authoring it is not scalable within learning institutions, typically schools, higher education and further education. The complexity, cost and effort required to develop adaptive eLearning experiences is very high in traditional adaptive systems (or intelligent tutoring systems) [7], [8], [9].

This paper tackles the fundamental challenges of extending the axes of adaptivity across not only content (based on prior knowledge, goals, learning styles, connectivity

etc.) but also across adaptive pedagogic models, communication and e-activities which are required for effective, deeper learning. The paper argues that for successful adaptive authoring, a single tutor/teacher needs to be empowered to rapidly develop adaptive experiences by constructing and controlling adaptive narratives (based on sound pedagogic models), adaptive content composition, adaptive e-activities, adaptive layout (presentation) and adaptive connectivity as well as prescribing adaptive learner controls to empower greater learner control over the experience. The paper also presents the research and development of an Adaptive Course Construction Toolkit (ACCT) which supports an adaptive eLearning activity management approach to eLearning. The paper presents a process to illustrate the multiple axes of adaptivity which can be specified in such an environment, and describes the empowerment such systems offer both the tutor and learner

2 Adaptive/Non-Adaptive Course Composition for Personalized eLearning

Personalized eLearning employs an active learning strategy which empowers the learner to be in control of the context, pace and scope of their learning experience [10]. It supports the learner by providing tools and mechanisms through which they can personalize their learning experience. This learner empowerment and shift in learning responsibility can help to improve learner satisfaction with the received learning experience.

Two of the predominant difficulties with authoring and building adaptive personalised eLearning systems are complexity and lack of course developer support. The restraining complexity of the course construction process can be somewhat alleviated by providing the course developer with a support-oriented environment in which they can create, test and publish adaptive courses. Some systems, for example LAMS, actively support the creation of activity based learning experiences [11]. These systems however do not support the description and application of adaptivity to the created course models in order to produce an adaptive personalized eLearning experience.

A direct requirement from teachers is the ability to choose passages of a lesson which are group adaptive, to fit with a curriculumized classroom scenario, so that the information domain appears the same to all members of the “class”. This type of functionality requirement can be realised by the construction of adaptive personalized eLearning experiences.

To support the construction of adaptive and non-adaptive courses this research has extended the multi-model metadata-driven approach [12] to define requirements for constructs such as pedagogical modelling and adaptivity modelling. The modelling of pedagogy and adaptivity has formed the basis for Narrative Structures, Narrative Concepts and Narrative Attributes. This extension of the multi-model metadata-driven approach has led to the creation of the Adaptive Course Construction Toolkit (ACCT) which provides a course developer-oriented support framework.

2.1 Multiple Models

The Architecture for multi-Model Metadata-driven Adaptivity [12] created at Trinity College Dublin attempts to rectify these flexibility and reusability issues by adopting a separation of concerns. Current approaches to AHS development combine the content with the intelligence that describes the adaptive delivery of the content. The multi-Model Metadata-driven approach is to separate the content from the rules that govern its adaptive delivery. This separation of concerns increases the potential for reuse, not only of the content but also the intelligence (pedagogy and narrative structure) behind how to adaptively deliver such content.

2.1.1 Concept Space/Domain Ontology

One of the key challenges of the adaptive course construction process is to identify the abstract domain of information within which the adaptive course will exist. To describe the concepts from which a course is to be constructed, a subject matter expert specifies and describes the course concepts in a content independent way. This creates a flexible abstract overview of the concepts of the adaptive course. Learning resources can be abstractly referenced by the concepts of the ConceptSpace model.

2.1.2 Narrative

The Narrative Model captures the semantics of the pedagogical strategy employed by a course. It describes the logic behind the selection and delivery of learning activities/concepts within the scope of a course. Using the narrative, the adaptive course can be personalized towards the goals and objectives of the learner, the preferred learning style of the learner, the prior knowledge and learning history of the learner and the context in which they are learning [12].

The Narrative Model is the mechanism through which the separation of intelligence (adaptivity) and content is realized. This separation increases the potential for the reuse of the learning resources involved, i.e. the content, the intelligence and the teaching strategies. It does not reference physical learning resources, instead it references Candidate Content Groups (CCG) [9]. CCG are used to group pedagogically and semantically similar learning resources into virtual groups from which the Narrative Model, during execution, can reference and use.

The Narrative is used during the reconciliation of the multiple models used by the Architecture for multi-Model Metadata-driven Approach. For example, the learner model can be used to make candidate selection decisions based on the characteristics and learning preferences of the learner. The tutor model is reconciled by the Narrative to specify scoping boundaries on the subject matter concept space/domain ontology. This notion of bounding course scope gives the tutor the flexibility to use the same narrative across different classes or different groups within a single class, while concurrently producing differently scoped courses. The candidate content groups are used by the narrative during the candidate selection process, whereby the narrative chooses the most appropriate candidate(s) to deliver to the learner.

2.1.2.1 *Narrative Concepts*

Narrative Concepts are used to create conceptual containers for elements of narrative structures. They are organized to provide a detailed description of a narrative domain in terms of learning activities. Narrative Concepts are concepts that are utilized within the narrative description process. An example of a Narrative Concept (learning activity) might be “Observation and Discussion”. This activity may use resources and tools that are simulation-based and collaboration-based. While the simulation-based resources may be adapted based on learning style preferences for example, visual and kinesthetic, the collaboration-based resources may be adapted based on the learners’ environmental characteristics for example, device type, network type and latency and context. This flexibility allows the course developer to rapidly build adaptive courses which contain both simple and complex storylines (plots).

2.1.2.2 *Narrative Attributes*

Narrative Attributes consists of adaptive axes, adaptive techniques, associated descriptions and usage guidelines. Adaptive Axes are high-level descriptions of learner and learning environment characteristics to which narrative concepts can be adapted. For example, an Adaptive Axes may describe adaptation based on a learner’s prior knowledge of the subject matter, learner’s goals and objectives, learner’s communication needs or learner’s learning style preferences. Adaptive Techniques are the low-level mechanisms which adaptive axes can employ to fulfill an adaptive task. For example, through the adaptive axes “prior knowledge”, I would like to use a learning object inclusion/exclusion technique or a link hiding technique depending on the level of granularity that exists with the content-space, i.e. whether the content is “pages” or “pagelet” [12] size.

Narrative Concepts are used to create the custom teaching structure for a non-adaptive online course. To make an online course adaptive, the course developer must choose which sections, concepts or learning activities they would like to be adapted to the learner. Narrative Attributes can be used to describe the behavior of a Narrative Concept. A narrative attribute may, for example, be used to describe some adaptive context in which the Narrative Concept will exist. The course developer can associate narrative attributes with narrative concepts indicating their desire for these concepts to be adaptively delivered. Such association may infer that concepts be rendered in a particular fashion, for example; adapt this concept to the visual preferences of the learner, while at the same time insuring that a set curriculum is adhered to and that the overall course is delivered based on a learner’s prior knowledge.

Narrative Attributes can be used, for example, to apply adaptive effects to concepts based on learner characteristics, tutor characteristics, learning context and device specifications. Narrative Attributes are key elements in the conversion of a non-adaptive online course to a personalized adaptive online course.

2.1.2.3 *Narrative Structures*

Instructional Design Principles, Pedagogical and Andragogical theory formalize and describe learning and teaching strategies. Narrative Structures are a model-based representation of these descriptions. The models can be used as templates when con-

structuring an online course and the descriptions can be presented as usage guidelines for the strategy. The combination of guideline and model can be used during reconciliation and validation of the online course.

Narrative Structures are used to provide the course developer with a solid foundation, based on sound pedagogical and instructional design principles, from which to build their online course. These models are interpreted to produce real-time support for the course developer. This support forms a framework for the online course based on the selected narrative structure(s). The use of Narrative Structures allows the course developer to produce online learning based on single or multiple instructional design principles. For example, the course developer could be assembling a course on “How to teach online”. The general course structure may follow a didactic approach. Within the scope of this course however there may be lesson activities that are best taught using a case-based or a web-quest approach.

One key challenge of online learning is to facilitate the reuse of all learning resources within a knowledge domain. Narrative Structures are formalized metadata models outlining the general narrative concepts and the flow of narrative concepts outlined by a particular instructional design strategy. They can be used in whole or as part of a customized teaching strategy. They offer guideline support to the course developer by offering usability information. Narrative structures can then be used by course developers to share their particular teaching strategy for a domain of information.

2.1.3 Actors

During the process of specifying and creating an adaptive/non-adaptive course there are two major roles to be considered, the learner and the tutor. The desired effects from each are quite different yet both are equally important to the produced course. The role of the learner is fundamental to the active learning pedagogy which specifies a learner-centric learning environment. The role of the tutor is fundamental in directing the scope of the learning environment.

2.1.3.1 Learner

Constructivism implies that the learner become active and interactive within their own learning experiences to develop their own understanding of the knowledge domain. One key goal of the multi-model approach taken in TCD involves the empowerment of the learner. The learner should be in control of their learning experience and should have the capability to modify and abstract their personal learning path. Through learner empowerment [13] the reach and effectiveness of adaptive personalized eLearning can be extended [10].

The Learner Model (LM) is defined as a schema representing the layout and the elements that must be present. The schema will define the structuring of the LM to provide a mechanism for cross-session interoperability and consistency. The ACCT will produce this LM schema which can be used when testing and publishing the course. The ACCT will update the LM schema automatically with regard to the changing characteristics of the Concept Space (Both Subject Matter and Narrative).

Since the LM is only consulted during the decision making phase of the candidate selection process, the main influence of the attributes of the LM will be the narrative concept space since it is here that the adaptive axes are applied to the narrative concepts.

2.1.3.2 Tutor

The Tutor model can be used to scope the course towards a group of learners or the curriculum of the domain ontology. It allows the course developer to specify semantic boundaries around the information space. The tutor model will also influence the learner modelling instrument. Based on recommendations made by the Tutor, the pre-course questionnaire can be dynamically generated in line with the tutor restrictions. The Tutor model will also feed into the candidate selection process, i.e. if the tutor decides that a specific concept must always be taught, adaptively taught, or never taught. The learner model would then reflect the curriculumized decisions of the tutor.

2.2 Adaptive Course Construction Toolkit (ACCT)

Due to the complex and dynamic process of authoring Adaptive Hypermedia, the need for author support in creating pedagogically sound adaptive personalized eLearning is evident [2], [14], [9]. From current work in adaptive hypermedia and personalized eLearning it is evident that there are two areas of research which need future development, the design of pedagogically sound courses and the support offered to the course developer during the construction of pedagogically sound courses.

This need for a pedagogical and course developer support framework has led to the development of the Adaptive Course Construction Toolkit (ACCT). The ACCT is a design-time tool which allows the course developer to create adaptive and non-adaptive activity-oriented course narratives based on sound pedagogical strategies in a developer-supported environment. The ACCT provides the course developer with such tools as concept space/domain ontology editor, custom narrative builder, content package assembler, learning resource repository interactivity and a real-time course test and evaluation environment. The architecture of the ACCT is built upon a reusability-focused, developer-supported and service-oriented architecture. For example, the ACCT allows the course developer to interact with the learning resource repository, searching for candidates based on keywords and contextual prior use, through a web-service interface.

The abstraction mechanisms employed by the ACCT allow the course developer to define their teaching strategies and subject matter domains in a reusable and collaboratively supported way. This active promotion of reusability not only at the asset level but also the pedagogical, instructional design, concept and activity level will aid in the rapid construction of pedagogically sound online adaptive learning experiences.

Pedagogical and instructional design principles were studied and modelled to form reusable and scaleable design guidelines for writing narratives supported by the selected principles. The guidelines will identify and describe the abstract logic and reasoning behind the conceptual layout of the course. The guidelines are also represented in model form whereby the course developer can see and interact with the model

structure during the creation of their customized course narrative. The developed model guidelines, or schema, will be translated into the model support framework for the adaptive hypermedia authoring architecture of the ACCT.

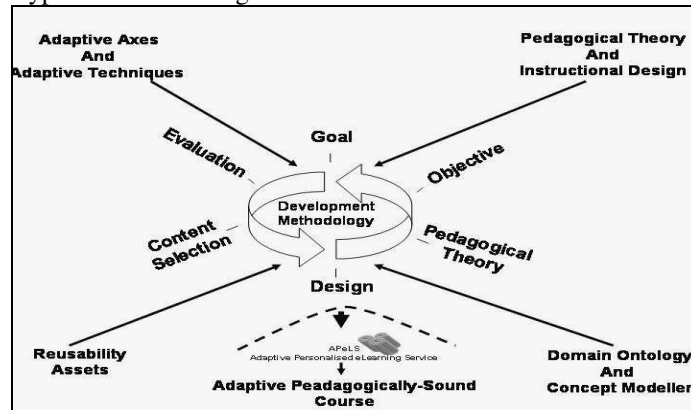


Fig. 1. Sample Methodology for Constructing Pedagogically-sound Adaptive Courses.

The sample methodology in fig. 1 outlines an adaptive course construction process whereby the course goals and objectives are initially identified, a pedagogical strategy(s) for the course is chosen, the subject matter domain is modelled and applied to the chosen pedagogy(s), the learning resources are selected, the adaptivity is applied to the pedagogically-based course structure and the course semantics are tested. This rapid course prototyping approach can be achieved with the ACCT.

2.2.1 Subject Matter Concept Space Creation

The Subject Matter Concept Space (SMCS) is a light-weight ontology describing the relationships and interrelationships that exist within a subject matter domain. The ACCT actively supports the course developer during the creation of the SMCS through facilitating addition, deletion and modification of subject matter concepts.

The ACCT allows the course developer to describe the relationships between the concepts of the SMCS. The relationships are provided as a set of guidelines that the course developer can utilize to create relationship definitions. These relationships however can be customized. The ACCT allows the course developer to create and define new customized relationships, hence offering more control to the course developer during the course construction process.

2.2.2 Customized Narrative Model Creation

The custom narrative model editor is used by the course developer to describe the course structure in pedagogically-supported narrative terms. The course developer is supported with a drag and drop interface providing tools built from sample pedagogical models, pedagogical narrative concepts, narrative attributes, previously defined subject matter concept space model, learning activities and collaboration paradigms. A learning resource repository interaction service is provided allowing the course developer to search for learning resources.

A Narrative Structure consists of a collection of Narrative Concepts. The Narrative Concepts allow the course developer to apply aspects of pedagogical strategies to certain parts of the adaptive course. For example, the sample pedagogical model for a case-based approach might contain narrative concepts to represent learning-activities such as “The Case-study introduction”, “The Context of the case-study”, “The Problem to be addressed”, “A collection of Resources”, “A mixture of activities”, “A Collection of case tools”, “An Epilogue” and “Some case evaluation”.

The ACCT pedagogically supports and guides the course developer during the design of the custom course narrative by providing a palette of fully customizable sample pedagogical models. The sample models provided are used to form the basis for the customized course narrative. Narrative Structures have been created to represent pedagogical strategies such as case-based, didactic and web-quest teaching. This approach implies that the course developer has the flexibility to apply a blend of pedagogical strategies. For example, a course on “How to Program” may follow the general didactic pedagogical strategy but certain sections within that course may better lend themselves to be taught through a case-based pedagogical strategy. This flexibility empowers the course developer with a tool that is capable of creating complex, and realistic, pedagogically-sound adaptive course offerings.

The course developer will be offered guidance on how to best use such Narrative concepts within the scope of the sample pedagogical model. Based on course developer preference, all or part of the supplied sample pedagogical model can be used. There is also a “blank” Narrative Concept which will allow the course developer to customize and expand the supplied sample pedagogical models.

The Narrative Structures allow the course developer to build a non-adaptive narrative model based on sound pedagogical strategies. To make the narrative model adaptive the course developer must select Narrative Attributes from the available palette. The course developer will associate the Narrative Attribute with the Narrative Concept to which they want the adaptivity to be applied. Narrative Attributes are defined to facilitate adaptivity on axes such as prior knowledge and learning objectives, learning context, preferred learning modalities and delivery device. By “tagging” the Narrative Concept with the Narrative Attribute the course developer is saying that he/she would like to have this Narrative Concept delivered in an adaptive way based on the adaptive axes that has been applied. The course developer is supported during this process through guideline information and sample implementation domains. The course developer can view examples and best practice information based on the current selected Narrative Attribute.

The ACCT has a plug-in service that allows the course developer to search across multiple remote learning resource repositories to identify and select appropriate learning resources based on keywords and prior usage information. The ACCT actively promotes the reuse of learning resources by empowering the course developer to select learning resources from a shared repository. The course developer can then associate learning resources with the concepts of their narrative model. Multiple resources can be associated with multiple concepts. It is the role of the candidate selector to choose the appropriate candidates during the execution of the customized Narrative Model. Note that the learning resources do not necessarily have to exist. One of the features of the ACCT is to act as a content specification tool whereby the course de-

veloper can describe the concepts of the course and their context in a content-independent way. This implies that the content need not exist during the building of the ACCT courses.

2.2.3 Course Verification

One of the key challenges of authoring adaptive and non-adaptive courses is the ability to test the output of the course. The ACCT offers the course developer a mechanism to test, evaluate and re-develop their course through a multi-Model Metadata-driven Adaptive Engine service that can interact with and interpret the course and models produced by the ACCT.

The ACCT allows the course developer to publish their course in the form of a content package. The content package contains such information as the course manifest, subject matter concept space and relationship definitions, the custom narrative model, narrative/pedagogical structures and the narrative attributes/adaptive axes. The content package is then used during the runtime execution/reconciliation of the course allowing the course developer to test the pedagogical coherence of their adaptive course.

2.3 Initial Evaluation

The initial evaluation of the ACCT, ending 05/06, concerned its user-friendliness, the user's ability to create short adaptive courses and the user's understanding of the models used by the ACCT. The evaluation process involved initial presentations of the functionality of the ACCT, a demo of how it can be used, followed by a description of the content and concept space (SQL) in a workshop environment. The testers were provided with a pre defined SMCS and asked to develop custom narratives based on the supplied SMCS. The users were satisfied with the interface provided and the ability to create and describe the subject matter area. They felt empowered by the ability to describe pedagogically-based course narratives in a graphical manner. By allowing real-time course verification the testers felt it would increase the potential stability of the end course. However, users felt the view of the SMCS was confusing at times, the narrative creation process could be made easier by using examples and certain look and feel characteristics were inconsistent.

The second phase of evaluation will be carried out in both the Centre for Learning Technologies in Trinity College Dublin and the IT Innovation Centre at Intel Ireland, the latter being the sponsor of this research. The results and feedback from both evaluation phases will influence the future development of the ACCT.

3 Conclusion

The paper introduced research in the area of authoring and developing adaptive personalized eLearning which resulted in the development of the Adaptive Course Construction Toolkit (ACCT). The paper described a framework for supporting the course developer during the process of creating adaptive and non-adaptive learning experiences. The paper identified and described the core models required for building adap-

tive personalized pedagogically-sound courses. The paper introduced an adaptive course construction methodology for building adaptive courses based on sound pedagogical strategies in a content-independent way. The paper concludes by outlining the initial ACCT evaluation results.

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