Enforcing reuse and customization in the development of learning objects: a product line approach

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ABSTRACT

The growing use of information technologies in the educational cycles has raised new requirements for the development of In-teractive Learning Materials in terms of content reuse, customization, and ease of creation and efficiency of production. In practical terms, the goal is the development of tools for creating reusable, granular, durable, and interoperable learning objects, and to compose such objects into meaningful courseware pieces. Current learning object development tools require special technical skills in the instructors to exploit reuse and customization features, leading sometimes to unsatisfactory user experiences.

In this paper, we explore a new way to reuse and customization following Product Line Engineering principles and tools. We have applied product line-based document engineering tools to create the so-called Learning Object Authoring Tool (LOAT), which supports the development of learning materials following the Cisco's Reusable Information Object strategy. We describe the principles behind LOAT, outline its design, and give clues about how it may be used by instructors to create learning ob-jects in their own disciplines.

Keywords

E-learning; Learning Object; Content Model; Document Product Line; Authoring Tool

1. INTRODUCTION

The efficient development of instructional materials is one of the major challenges of the e-Learning communities. The high di-versity of (sometimes overlapping) domains, along with the diversity of learners in terms of languages, skills, and achievement, have led research and development efforts towards the development of course materials, training materials, instructor/learner guides, and assessment units, just to name a few arti-facts used in learning processes, from sets of reusable, granular, interoperable, and durable pieces.

The IEEE Learning Technology Standards Committee (LTSC) [1] was the first group that used the term Learning Object to describe these small pieces of educational content: *"a learning object is defined as any entity, digital or non-digital, that may be used for learning, education or training"*. This definition led to a new vision centered on reusability and interoperability of the Learning Objects through the educational lifecycle. Learning Objects became the basic building blocks of learning materials which can be reused in different learning contexts.

Building a Learning Object requires, on one hand, a *content model* able to address the domain requirements, and on the other hand, a Learning Object development process supported by the appropriate technologies. Such a process should be reuse-aware and grant a high degree of customization in the production of the Learning Objects. To do this, most learning Management Sys-tems offer a metadata-based catalog of Learning Objects and retrieval tools as the main support for content reuse. However, the elaboration of the learning materials is done manually.

In this paper, we introduce an alternative approach to Learning Object development that borrows principles and techniques from the Software Product Line Engineering (SPLE) field to define Learning Objects development processes with high levels of flexibility and reuse. Our approach, the so-called Learning Ob-ject Authoring Tool (LOAT), is based on the *Document Product Lines* (DPL) method for Document Engineering [6], and sup-ports the product-line based development of Learning Objects following the Reusable Information Object Strategy (RIO-RLO) content model developed by Cisco systems [2, 3].

This paper is organized as follows. Section 2 introduces a back-ground on the RIO-RLO content model and DPL method. Sec-tion 3 describes how DPL is used to create Reusable Learning Objects (RLOs). Section 4 outlines the LOAT tool which we are developing to provide a domain oriented layer to the system, and Section 5 presents the conclusions and future work.

2. Background

2.1 The RIO-RLO content model

In 1999, Cisco Systems Inc. developed a Reusable Information Object (RIO) strategy for developing and delivering the learning content in the form of RLO [2]. The Cisco RLO/RIO model is based on the Learning Object Strategy of Merrill [4] and Clark [5]. A RIO is a granular, interoperable, reusable piece of information which contains a metadata level to describe its characteristics, purpose and relationship with other objects. Each RIO consists of three parts: content items, practice items, and assessment items. All these items are grounded upon a single learning objective. Content items are classified as a definition, example, review, next steps, analogy, topology illustration, block diagrams, etc. [2]. Practice items are activities that give the learners the chance to apply their skills and knowledge. Practice must have a direct relationship with the learning objec-tive of the RIO. The last component of RIO is the assessment, used to determine gaps in knowledge and skills before taking the RLO and to ensure that the learner has mastered the objective of the RIO. There are two types of assessment, namely pre-assessment and post-assessment.

RIOs can be combined together to form a larger structure called a RLO. The Cisco RIO-RLO model states that the number of RIOs needed to construct a new RLO are from five to nine; RLOs are completed with an overview and a summary. The structure of RIOs depends on the type of RIO being defined. RLO components are structured items, as summarized in [2]. Figure 1 shows the UML class diagram representation of the Cisco RIO-RLO model.

2.2 Document Product Lines

DPL applies product line engineering principles to the semi-automatic generation of documents in domains with high content variability and reuse. Central to DPL is the notion of family of documents. By family we mean a set of documents that share some common parts while differ in other parts. Every member of the family is built by assembling a set of content components. The DPL process is composed of two main activities: Domain Engineering and Application Engineering. The Domain Engi-neering starts with the specification of a family of documents in terms of content features, which represent document fragments that either must or can be included in a specific document. Every content feature must be linked to one or more technology fea-tures, which define how a particular content feature is represent-ed. Additionally, every content feature is associated to actual content by linking it to some content component.

Reusable content assets, called *InfoElements*, are organized and stored in the DPL Repository. Each *InfoElement* has a specific content plus some descriptive metadata, and can be reused just by attaching it to a particular document feature. There is no pre-scription about the granularity of *InfoElements*.

Given a document family specification (that is, a document fea-ture model), a specific member of the family is defined by means of a configuration in the Application Engineering stage of the DPL process. There, the user selects which optional features are to be included in the document along with the mandatory ones, which are common to all the members of the family. After the configuration, an automatic process assembles the document taking the *InfoElements* from the Repository, as described in [6].

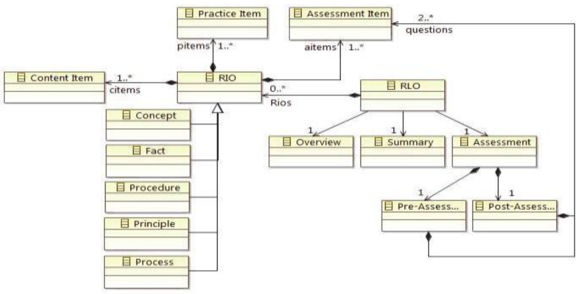


Figure 1. UML representation of the Cisco RIO-RLO model

We have applied the DPL principles to the development of RLOs. With this aim, we have performed a DPL process from the Domain Analysis to the Application Engineering using DPLFW, an implementation of the DPL method. We have de-fined the family of RLOs, and we will use it as the starting point for the generation of instructional materials. However, DPLFW is not an end-user tool, that is, its intended users are not instructors but document engineers. To provide both instructors and stu-dents with a friendly environment, we are developing LOAT, a Learning Object Authoring Tool that will use DPL FW services to provide variability and reuse management as well as customiza-tion to Learning Object authors.

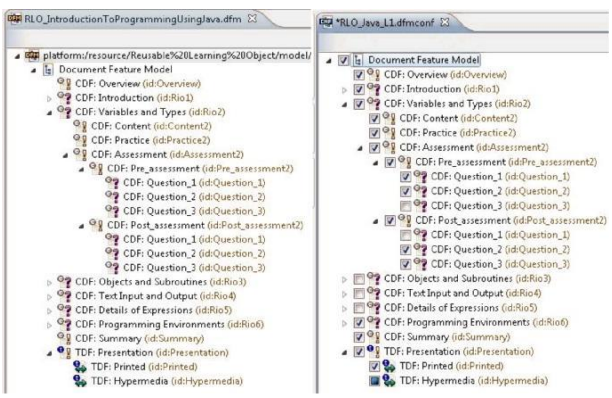
3. Using DPL to Engineer Reusable Learn-ing Objects

In this section, we detail the principal steps in the creation of the RLO document product line using DPLFW:

STEP 1. THE RLO DOCUMENT FEATURE MODEL — We show how a family of RLOs is defined in DPL. To do this, we recall the RLO structure depicted in [2], which will guide the definition of the feature model. As described in Figure 2.a, a RLO includes three components: Overview, Summary and a set of RIOs which, in turn, include content, practice and assessment ele-ments, and so on. The only difference to the Cisco model [2] is that, for the sake of flexibility, we have removed the 7±2 RIOs per RLO constraint. To illustrate the process, we use as example a course entitled "Introduction to Programming using Java". Figure 2.a shows the DPL document feature model of the course. The notation uses exclamation marks to denote mandato-ry features, and question marks for the optional ones; double-head arrows denote for alternative features. Content features are represented as CDFs whereas the TDFs represent the presenta-tion of the document generated.

At this point, we are just modeling what a RLO will be com-posed of, without any mention to actual content. To link CDFs with content, we have to search the right content components at the DPL Repository, as we illustrate in the next step.

STEP 2. CREATING AND STORING RIO COMPONENTS — Building a RLO with DPL depends on the presence of its components in the Repository. As we mentioned earlier, the content compo-nents of the Repository are called *InfoElements* [6] and contain two types of properties: data (i.e. the actual content), and metadata (data used to describe the *InfoElement* and serve as criteria to retrieve components from the Repository).



(a) **(b)**

Figure 2. The RLO document feature model(a) and Configuring a specific RLO (b)

STEP 3. RLO CONFIGURATION — After every content feature in the model has been linked to one *InfoElement* in the Repository, the generation of documents can start. To do this, one specific RLO has to be selected by means of a document configuration model. A configuration consists of the features that have been selected according to the variability constraints defined by the feature diagram, as shown in Figure 2.b. There, a particular con-figuration for our course on Java Programming is set. Every different configuration represents one of the members of the document family that was defined in the document feature mod-el. Notice that adding or removing components to a given doc-ument is a matter of clicking on a checkbox, since all the engi-neering work was done in advance. This is a new approach to the authoring process, facilitating reuse at large scale.

STEP 4. RLO GENERATION — When the configuration concludes, an automatic process generates the RLO in the format selected. Adding or removing is as simple as modifying the configuration and re-generating the document.

4. LOAT: towards a new Learning Object Authoring Tool

All the DPL functionality shown so far is related to the pure document engineering tasks of defining RLOs. This means that there is a need for a domain layer, that is, a wrapper that hides the DPL complexity to the intended users of the RLO authoring tool. Such a layer will be implemented in LOAT, a new tool that enforces reuse and customization to increase the efficacy of Learning Object authoring processes. Three basic principles have been considered in the design and implementation of LOAT: the cognitive level, learning object classification and content-model architecture. The first one derives from the com-bination of the best practices described in Merrill's Component Display Theory [4], Bloom's Taxonomy of Educational Objec-tives [7], and Clark's Developing Technical Training [5]. The second one is derived from [5] (concept, fact, procedure, pro-cess, or principle). The third one is the content-model architec-ture for designing a reusable and granular learning object de-fined in RIO-RLO content model.

LOAT follows the classical component content management system strategies. In other words, LOAT is a part of Learning Content Management System that manages content at a granular level (component or asset) rather than at the document level. Each component represents a single topic or asset. Upon this we have a great flexibility in re-using and producing mass customi-zation e-learning materials in different delivery formats.

The LOAT architecture is divided into three layers (Fig. 3). The first one is the Repository Layer, which provides persistence to the artifacts (both RIOs and RLOs) generated. The repository layer uses the DPL Repository for saving the assets and the LOAT Repository for the created RIOs and RLOs. The second layer is the Services Layer, which contains a content authoring tool for the creation of assets and Learning Objects. The Content Model feature in the services layer determines which content model will be applied in the learning object creation process. Collaborative Authoring is an important feature in our tool that allows many partners to share the Learning Object creation pro-cess. Finally the Presentation Layer handles how Learning Ob-jects are displayed in different output format for the purpose of delivery in different mediums.

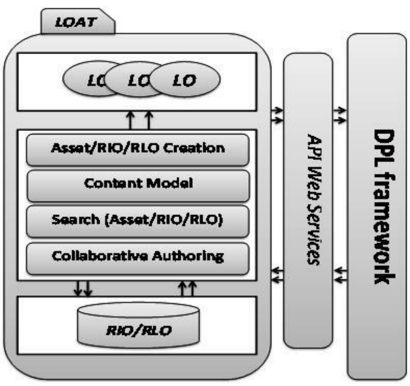


Figure 3. LOAT Architecture

5. Conclusions and further work

The efficient development of instructional materials is one of the major challenges of the e-Learning communities. With the aim of facilitating the construction and production of instructional materials with higher levels of reuse and flexibility that the one provided by current authoring environments, we have introduced a new approach to RLO development based on product line engineering principles. The Document Product Lines method, and its implementation DPLFW, have been used to define fami-lies of RLOs whose components may be selected dynamically from a set of previously developed content pieces that are as-sembled automatically according to predefined rules.

This is our first effort towards the design and implementation of LOAT, a new authoring tool based on the principles described in this paper. LOAT will act as a wrapper of the DPLFW function-ality so that friendly interfaces will be offered to instructors. LOAT will be integrated in a learning management system, providing interoperability with existing tools in order to reuse existing content in different learning context.

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