A Semantic Approach to Automated Content Augmentation for eLearning Objects*

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Abstract

Over the last years IEEE LOM eLearning Objects have been well established as the basic building blocks for educational online content. Equipped with an expressive set of metadata and structured by a variety of named relations, they are nicely suited for self-explorative learning approaches within adaptive hypermedia applications. The authoring of such 'Knowledge Nuggets', though, not only requires content editing, but the provision of meta descriptors and numerous interrelations. Facing the latter in the context of large repositories, where a new object may attain relations to any previously filed entity, clearly demonstrates the effort to be requested from an author.

In the present paper we update the status of our educational content management system HyLOs. We introduce instructional design concepts and tools, as well as a content acquisition and analysis toolset, targeting at the semi-automated generation of eLearning Objects. Starting from classroom recordings or offline content production, automated keyword extraction and classification is applied to the raw learning object.

In the second part of this paper we redefine and sharpen the semantic of LOM relations, thereby extending its set by entities missing from the educational perspective. We construct an ontology and inference rules for these inter–object relations. Based on this newly introduced Ontological Evaluation Layer and the automated classifications, appropriate relations between learning objects are autonomously derived.

These solutions have been implemented in the Hypermedia Learning Objects System (HyLOs), our prototype of an eLearning content management system. HyLOs is built upon the more general Media Information Repository (MIR) and the MIR adaptive context linking environment (MIRaCLE), its linking extension. MIR is an open system supporting the standard XML, CORBA and JNDI. HyLOs benefits from manageable information structures, sophisticated access logic and high-level authoring tools like the eLO editor responsible for the semi-manual creation of meta data and WYSIWYG like content editing, allowing for rapid distributed content development.

Keywords: Educational Content Management, LOM, E-Learning Objects, Semantic Web, Educational Semantic Net

1 Introduction

Since hypermedia systems have been introduced to teaching and learning environments, the composition and reception of learning material have undergone a shift in paradigm. Linear instructional designs manifested in books or scripts are now complemented by meshed

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knowledge networks. Content access no longer follows a single predefined path, but multiple, associative rules driven by individual inquiries. Portable electronic formats and hyperreferences in addition stimulate content exchange and interrelations between authors. Following these changes a new perspective on content as confined, self–consistent 'knowledge nuggets' has been developed.

In the field of educational content management the concept of atomic, self–consistent content units became standardised as IEEE LOM eLearning Objects (eLOs) [1]. eLOs may combine rich media content, a significant set of meta-data and structural relations. eLO content itself may be composed from other eLearning objects, constructing a self–similar knowledge tree for navigation in this fashion. The LOM metadata subsume technical, textual and educational information, which are complemented by a set of named relations. The latter are intended for constructing a dense mesh of interobject guidance to the learner. LOM has been chosen as part of the high–level exchange format SCORM, the Sharable Content Object Reference Model [2].

LOM named relations form a key concept to content coherence. While single eLearning content objects should sustain isolated, and content composition only allows for hierarchical structuring along a single perspective, the relational part gives rise to a semantic net interconnecting different objects from mutually unaware authors. However, an author adding any eLO to some repository faces the challenge of discovering and defining relations between his object and the remaining repository. This task becomes intractable for large eLO collections. As part of our presently ongoing work on automated eLO recording and processing, we formalised the semantic of eLO relations within an ontology and an additional set of inference rules. Starting from some initial relations, any new object entering a repository can then automatically harvest named links to any other object from concurrent processing of an inference engine.

In the present paper we first briefly introduce the Hypermedia Learning Object System HyLOs, our eLearning content management platform used for all implementations. We present the newly released instructional designer and our ongoing project on automated eLO content acquisition. In section 3 we propose extensions to the LOM relations, their semantic and discuss an automated inference processing. Finally, section 4 is dedicated to a conclusion and outlook.

2 eLO Management and Content Acquisition

2.1 The Hypermedia Learning Object System HyLOs

The Hypermedia Learning Object System [3, 4] has been designed to provide full educational content management based on the eLO information model. All knowledge bricks are composed of rich media content elements decorated with a complete set of IEEE LOM metadata and interconnected by qualified relational pointers. They reside within the Media Information Repository [5]. The rigorous use of the XML technology framework ensures a consistent separation of content, structural information, application logic and design elements. HyLOs provides adaptive eLearning functions and may attain any look & feel by applying appropriate XSL transforms. The system is used in several eLearning deployment projects within our institution.

HyLOs offers variable content access views to the learner. Besides the primary content tree elaborated by the author(s), instructional design hierarchies may be compiled from repository objects for each teaching trail. Based on its qualified relations, the content additionally is organised in a semantic net, suitable for individual exploration in a constructivist fashion. Traditional hyperreferences, which provide a separate layer of content traversal, may be customized within HyLOs, as well. By means of the MIR Adaptive Context Linking Environment MIRaCLE [6], different hyperlink layers may be applied on the same content, as have been predefined by the teacher or selected by the learner. Links are represented within contextual containers, each one suitable to express a narrative of a specific hyperlinking scheme. These link contexts may be understood as a composition of link rhetoric as suggested in the early work of Landow [7]. Note that textually coherent hyperlink collections provide an additional, meaningful structure to be harvested in future applications.

A fully distributed authoring environment is part of the HyLOs suite, as well. While authors are enabled to edit eLOs in full detail, i.e., rich media content, the LOM metadata tree and all types of relations, great care has been taken to simplify content elaboration wherever possible. An 'easy authoring sheet' within the SWING application provides WYSIWYG XML editing combined with extensive automated harvesting of metadata. Manual provision for only seven LOM attributes are needed, i.e., keywords, semantic density, difficulty, context, learning resource type, structure and document status, if presets taken from previous editing do not apply. While creating subsequent eLO content, authors implicitly generate an object tree. Assisted by an additional authoring sheet, the Instructional Designer (iDesigner), any instructor will be enabled to compose overlay trees individually designed for a specific teaching trail. Re–use of content and structures is supported at any level of complexity. A variety of specific editors for glossaries, (TEX–complient) bibliographies and taxonomies complement this high–level authoring suite.

2.2 The HyLOS iDesigner

The process of forming a didactically structured outline from single learning compontents is commonly known as instructional design. This task of arranging the eLOs in different courses or units, thereby superimposing assisting interconnects, is not provided within the eLO paradigm.

The HyLOS iDesigner, the instructional designer of our eLearning content management system, is an advanced authoring tool enhancing the process of eLearning course production by providing an additional layer for didactical setup. The I Designer allows for the definition of course structures and visual units which could be filled easily with content selected from the eLearning object content repository.

Our approach to instructional design introduces the idea of an instructional container object (ICO). ICOs are inherited from eLOs retaining the complete LOM meta data set and the nesting facility. They implement either a structural container nesting other ICOs or a visual container embedding eLOs. In addition they offer appropriate instructional types and an optional prolog or epilog. Instructional types are courses, sections or pages for example, which are be named via the LOM general title property. The nesting of sections allows for the expression of a section subsection relationship. The page type addresses the problem of visual units composed of eLOs, which are to be rendered onto the same visual. A page enables authors to restructure the content of compound eLearning objects by explicitly selecting desired children from the parent object. Thus the author may mask parts of eLearning objects, which do not fit textual, didactical or educational needs without affecting the eLO itselves. This gives rise to a very flexible, unrestricted approach in course design.

Setting up an instructional design using the HyLOS iDesigner starts with implementing the desired course structure consisting of arbitrary sections and pages resulting in a hierarchy of ICOs. Sections are named by setting the LOM general title property and may be annotated with LOM compliant meta data for further processing or search operations. Filling pages with content requires to select eLearning objects from the repository. Therefore the author may opt in either browsing or searching the repository. Search queries are based on the restriction of LOM meta data properties, e.g., title, keywords, description or context. The iDesigner support the user in generating search queries by providing a

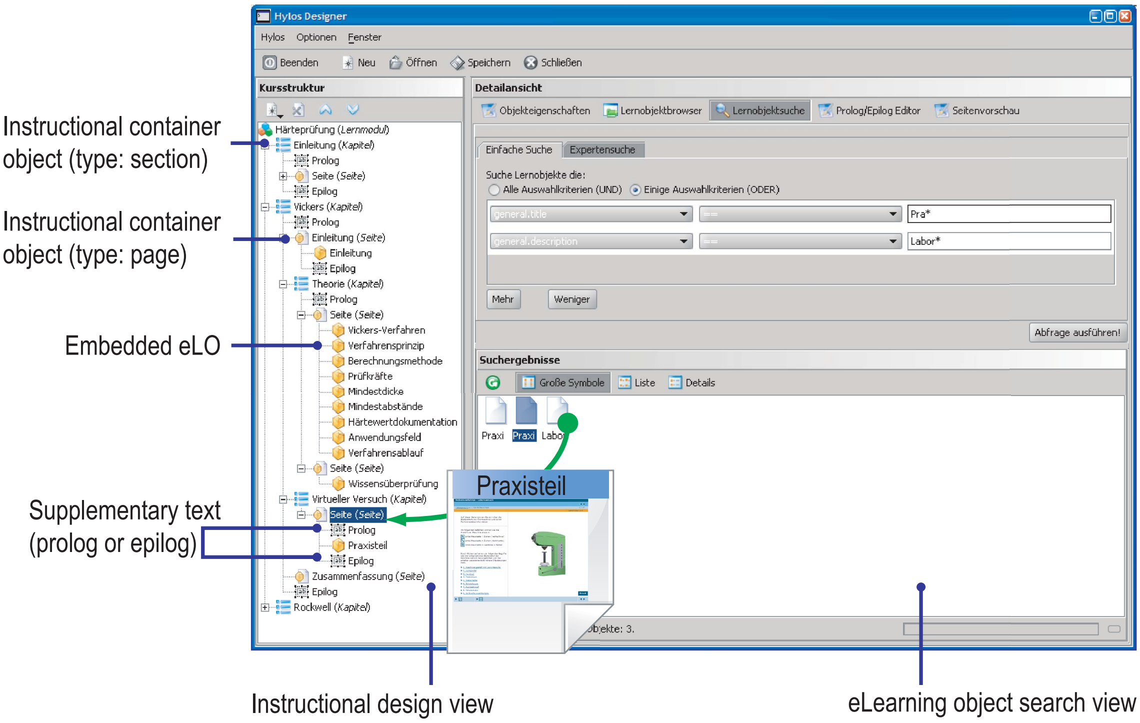

Figure 1: HyLOS iDesigner Application View

form-based interface. Matching objects are presented to the author in a file system like view, from which the user may drag desired eLOs and drop them onto the specific page in the instructional design view.

For convinient selection compound eLO structures are presented to the author linearily in a normalized view. To assist a fluent learning process, authors may glue together aggregated learning trails with transition texts, foreseen in a prolog or epilog of the instructional container object. From the technical point of view the instructional design is stored within instructional container objects, which remain distinct from constituting eLOs. ICOs of the instruction type "page" referring to eLearning objects stored in the repository by an explicit ordered enumeration. Thus changes to the content of referred eLOs automatically apply to the course content whereas structural alterations remain unseen.

The HyLOS iDesigner bridges the gap between reusability and atomicity of eLearning objects on the one hand and individually and coherently designed courses on the other. It very flexibly imposes instructional overlays onto any, possibly loose collection of eLearning objects.

2.3 The Content Acquisistion Subsystem

A manual preparation of eLearning objects remains a tedious undertaking, no matter how well it is supported by appropriate tools. In addition, most presentation material currently in use is brought to lecture rooms by notebooks or offline media, not compliant to the LOM/IMS packaging standard. It is therefore the goal of our ongoing project to add an automatic content acquisistion subsystem to HyLOs, which will produce eLOs 'out of the lecture room'. Complying to a predefined quality standard, these objects may then be used for rapid playout or manual refinement.

We start from the observation, that audiovisual streams are available for capturing within modern equipped lecture halls and concentrate on visual presentation material in combination with spoken audio. These signals, images and audio streams, are continuously captured and segmented, triggered by a change of slide or presentation material. After segmentation the appropriately encoded media will be packaged and – annotated with technical metadata – stored as raw eLOs within HyLOs as shown in figure 2. Satisfying the full LOM data structure, the eLearing objects obtained so far are suitable for online consumption, manual refinement or further automated processing.

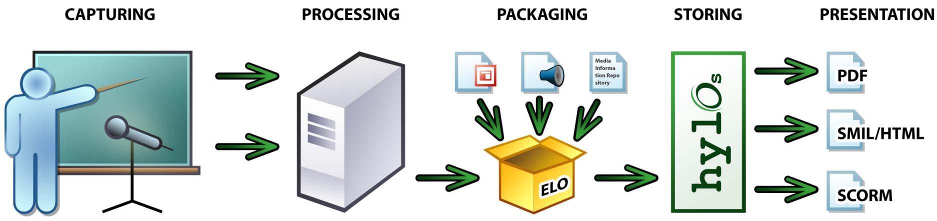

Figure 2: Process Flow of the Content Acquisition Subsystem

The raw eLOs do not contain any semantically valuable metadata nor do they admit qualified relations to the remaining repository. Subsequent postprocessing therefore will assign key words and a classification from a predifined taxonomy to the newly acquired objects. To achieve this goal, all available sources of information are used, which consist of a predefined context, text written on slides and the spoken words from the audio. As little textual material is available, pure statistical techniques cannot be used. Instead we employ a controlled vocabulary for keyword spotting. A selection of several thousand pre–classified technical terms is searched within the text and audio files. We further proceed in a dictionary based approach to derive the classification indices of the object by using our previously statistically classified keyword set [8, 9]. Current classification is done with respect to DDC [10] and ACM CCS [11].

This approach of keyword spotting has proven to work reasonably well with currently available untrained speech recognition systems, provided the employed number of terms remains small. For optimisation we segment our dictionary into sets of 50 keywords, selected according to an iteratively narrowing context along the classification hierarchy. Speech recognition is done using the Philips Speech SDK. Currently available preliminary results indicate that calculation efforts remain close to real-time.

By analyzing text and speech content the recorded eLearning objects can thus be enriched by a title, the author, keywords and classification categories.

3 An Ontology Based Approach to an Educational Semantic Net

3.1 Advancing LOM Relations

eLearning objects compliant with the LOM metadata standard provide a section of qualified interobject relations, which allows to interconnect any two objects in a meaningful fashion. Facing a well maintained mesh of eLOs, a semantic learning net may be presented to the learner for navigation and knowledge exploration.

However, the expressiveness of LOM relations is limited to the administrative view of librarians, as types and semantics of these relations have been directly adopted from the Dublin Core library metadata set (see table 1). To gain expressions suitable for educational hypermedia, the semantic of DC relations needs adaptation, sharpening and a careful extension, which has been addressed in parts by several authors of educational systems [12, 13, 14].

For an elaboration of a fairly comprehensive, viable notion on a semantic educational net, we proceed in three phases: At first, we select those relations from the DC set,

Is part of	Is version of	Is format of	Is referenced by	Is based on	Is required by
Has part	Has version	Has format	References	Is basis for	requires

Table 1: Original Dublin Core/LOM Relations

which sustain suitable under minor modifications and specifications in the educational hypermedia context. The results are shown in table 2. The major, unobvious change consists in turning 'isFormatOf' into a symmetric property. While the corresponding DC inverse property pair expresses bibliophilic editorial hierarchies, such phenomena remain absent in hypermedia systems.

At second, we redefine the semantic of those DC properties, which had been bound to pure technical terms. Even though similar reinterpretations have been commonly undertaken in LOM based educational contexts, an explicitly stated semantic is lacking, but needed for further operations. Table 3 displays the corresponding entities and their semantic values. These three DC property pairs now essentially express thematic dependencies with increasing strength. 'references' and 'isBasedOn' both admit mandatory roles and thus fail to reach transitivity.

Relation	Semantic
hasPart/isPartOf	This inverse pair of transitive properties expresses the structural relation of nesting eLOs. There is no additional meaning related to content.
hasVersion/isVersion	This pair of inverse properties describes versioning. A new version of an eLO is generated by updates or redesigns. Different versions may deviate in content and author, preserving the format, though.
isFormatOf	This symmetric property relates eLOs, which essentially cover the same content in different formats. It does not imply interchangeability, but a persistence of educational context.

Table 2: Modified Semantic for Selected DC Relations

Relation	Semantic
references/ isReferencedBy	This inverse property pair describes a weak form of content relation: An author references another eLO for mandatory information extensions, similar to common use of hyperlinks.
isBasedOn/ isBasisFor	This inverse property pair relates an eLO carrying content fundamental to another. It expresses a strong, but mandatory textual relation.
requires/ isRequiredBy	This inverse pair of transitive properties denotes an obligatory content dependence in the sense that eLO A cannot be understood without knowledge of eLO B.

Table 3: Redefined Semantic for Selected DC Relations

Finally we choose a set of additional relation properties, which are missing in the LOM standard. Most importantly the taxonomic interdependence 'isBroaderThan' has been raised to the eLO net. Guided by the maxim of restraint, only three horizontal relations have been introduced for improved orientation in content access. Any additional values representing a meta discourse on content, as introduced by [12], were omitted for the

Relation	Semantic
isNarrowerThan/ isBroaderThan	This inverse pair of transitive properties encodes the standard taxonomic relation.
isAlternativeTo	This symmetric transitive property connects interchangeable eLOs. Alternative eLOs are meant to be of equivalent content, pedagogical and structural properties.
illustrates/ IsIllustratedBy	This inverse property pair expresses illustration in an open fashion. To illustrate an eLO need not be of specific content type.
isLessSpecificThan/ isMoreSpecificThan	This inverse pair of transitive properties relates two objects, which are of strong thematic familiarity, but differ in generality. A more specific object may cover subaspects or the identical subject in more detail or exhibit a thematic overlap while being more specific.

Table 4: Additional Educational Relations

sake of simplicity and clarity. Types and semantic of these newly introduced relations are visualised in table 4.

Note that all relations occur symmetric or in inverse pairs. Besides systematic considerations, this characteristic covers an important technical consequence. Any author may denote any relation by just requiring write access to his own objects.

3.2 Ontological Evaluation

A learner, meeting a well maintained educational semantic net tied by the relations described above, will greatly profit in content navigation, orientation and exploration. It is moreover easy to implement, as has been done within the HyLOs application. Any author exploring the current state of an eLO repository will likewise benefit from a dense mesh covering his region of interest. Adding a new eLearning object, though, will require to identify and update appropriate relations with a possibly large amount of repository entries. Objects entering the repository by automated acquisition as described in section 2.3, will be predisposed as unconnected entities.

To overcome the obstacle of manual netting, an *Ontological Evaluation Layer (OEL)* has been designed and implemented in HyLOs. The core concept consists in encoding relation semantics within an OWL ontology [15], which then can be processed by an inference engine. At this first step, relation properties/pairs along with their characteristics can be distributed across a repositories. To account for logical dependencies between related properties, additional inference rules may be supplied to the inference engine. As outcome of a careful overlook we identified about 50 of such rules, giving rise to a dense inference set. Some typical examples of inherent conclusions read:

- A is narrower than $B \wedge B$ is format of $C \Longrightarrow A$ is narrower than C
- A is based on $B \wedge C$ has part $B \Longrightarrow A$ is based on C
- A requires $B \wedge B$ is based on $C \Longrightarrow A$ is based on C
- A is more specific than $B \wedge B$ has part $C \Longrightarrow A$ is more specific than C
- (A is version of $B \vee A$ has version B) $\wedge A$ is format of $C \wedge B$ is format of C $\Longrightarrow A$ is alternative to B

Our implementation uses the JENA framework [16] to operate the reasoning combinedly following the extended relation ontology and the additional inference rule. A daemon triggered by object insertion or update within the repository concurrently adds appropriate relations to the new or changed object. By following a strategy of concurrent evaluation leading to immediate persistence, our HyLOs implementation accounts for the rather slow reasoning process of the JENA framework, which is unsuitable for real–time interactivity. The algorithm employs immediate initial values from classification, structural attributes and preset relations. Additional approaches to relation inheritance following heuristic schemes are subject to future investigation.

In implementing the logic of extended LOM relations within the repository, HyLOs can ensure that all eLearning objects take part in a consistent semantic net.

3.3 Results

An example of a semantic net derived from extended LOM relations is visualised in figure 3. All chosen subjects from the Semantic Web context are connected via qualified relations, which allows for a semantically guided content navigation. Any manually inserted object or relation will lead to a chain of subsequent link placements within the HyLOs system.

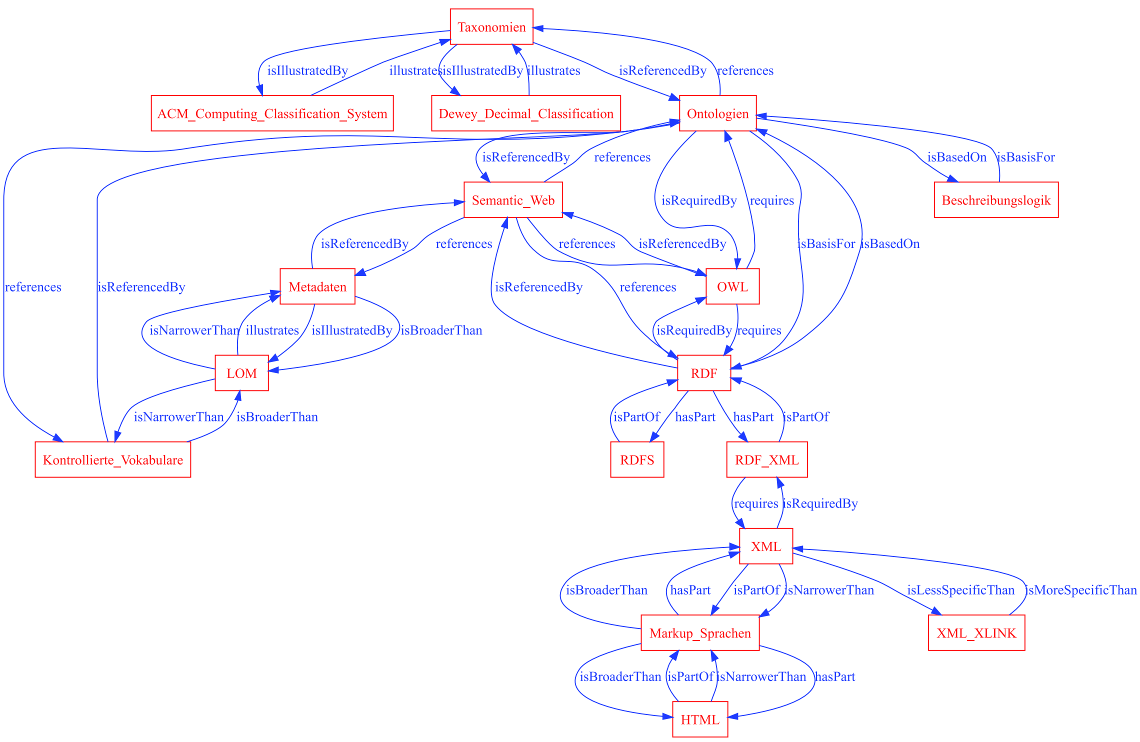

Figure 3: A Resulting Semantic Net

Inserting the objects "HTML" or "Markup_Sprachen" in our example will initiate a fully automated generation of named interconnects. Authoring thus is enriched by a forceful augmentation intelligence. Learners will profit from automated reasoning and envision a consistent and supposably dense educational semantic net.

4 Conclusions and Outlook

In this paper we discussed key aspects of automated eLearning object acquisition and content augmentation. Starting from our LOM based Hypermedia Learning Object System

HyLOs, we briefly introduced our ongoing activities of eLO generation and classification from lecture recordings. Focussing on the application of an educational semantic net, a detailed evaluation and a suggestion for improvement of the LOM semantic relations has been presented. It was shown that by turning the inherent relational logic into operational reasoning, a semantic learning net will actively evolve and remain consistent.

Our future work will concentrate on conservative heuristic schemes, which will allow objects to inherit additional relations from repository knowledge. Evaluations and improvements for our automated context recognition and classification schemes are under preparation, as well.

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