Semantic Overlays in Educational Content Networks — The hylOs Approach*

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Abstract

Over the last years networking technologies and distributed information systems have moved up the OSI layer and established well within application–centric middlewares. Most recently, content overlay networks have matured, incorporating the semantics of data files into their self–organisational structure with the aim of optimising data–centric distributed indexing and retrieval. In educational content management simple file distribution is considered insufficient. IEEE LOM standardised eLearning Objects have been well established as the basic building blocks for educational online content, instead. They are nicely suited for self-explorative learning approaches within adaptive hypermedia applications. Even though eLearning objects typically reside within content repositories, they may propagate metadata relations beyond repository limits. Given explicit meaning of these interobject references, a semantic net of content bricks can be knotted, overlaying the repository infrastructure.

In this present paper we briefly introduce our educational content management system hylOs. Enabled through an advanced authoring toolset, hylOs allows to define instructional overlays of a given eLearning object mesh. Based on a newly introduced Ontological Evaluation Layer, additional meaningful overlay relations between knowledge objects are shown to derive autonomously. Further on a technology framework to extend the resulting semantic nets beyond repository limits is presented. The Hypermedia Learning Objects 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 XML–content editing, allowing for rapid distributed content development.

Keywords: Educational Content Networks, Metadata, eLearning 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 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 a net of confined, self–consistent 'knowledge nuggets' has been developed.

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In the field of educational content management the concept of atomic, self–consistent content units became standardised as IEEE LOM eLearning Objects (eLOs) (LOM 2002). eLOs may combine rich media content, a significant set of metadata 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 can be exploited 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 (ADL Technical Team 2004).

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 following 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 discuss the eLearning object approach to content management and briefly introduce the Hypermedia Learning Object System hylOs, our eLearning content platform used for all implementations. In section 3 we propose extensions to the LOM relations, their semantic and discuss an automated inference processing. These procedures are shown to naturally extend beyond repository limits, facilitated by standard metadata transport protocols. Finally, section 4 is dedicated to a conclusion and outlook.

2 eLO Content Management

2.1 eLearning Objects and Related Work

Several years of online learning experiments and debates have brought up a standardised container for educational content: the eLearning Objects (eLOs). eLOs denote the smallest, atomic learning units covering a single, self-consistent subject. Following the IEEE LOM (LOM 2002) standard eLOs are composed of

- a possibly composite content element, which is intended to be suitable for online display. No rigid restrictions on scale or media types are placed;
- a metadata set, describing educational, technical and administrative properties of the object in a standardised vocabulary, thereby giving rise to automated semantic processing;
- an option for named interrelations to express content information structures and their educational semantic. Structures may form nonlinear and non-hierarchical meshes. Note that eLO provide self-typed pointers by means of which large learning repositories of agglomerated eLOs may be constructed in a self-similar, intermittent fashion.

The creation of such rich educational 'information cells' was mainly motivated from three perspectives:

Modularisation: Courses and lectures commonly cover a variety of topics and aspects. Content material is considered more valuable, if split up into distinct 'minimal units' of well identified subjects. Modular online material not only promises ease for rearrangement and re-use, but also may enhance clearness to the learner on the subject presented. Decomposing content into consistent parts of manageable size, in addition, is a vital step towards its use in hypermedia: Besides the obvious need for digestible portions at online displays, any segmentation requires a rule set of glues, giving rise to the second perspective.

Structural transparency: Complex knowledge clearly carries a large variety of interrelations, which in general form an open mesh of references and reference context descriptions. Along with the separation of content into distinct parts, eLearning Objects provide a reference set for defining those interrelations. In this way content structures are made transparent to eLearning applications and may be processed for hyper-referential displays. Additionally, references may carry its context information in a standardised, simplified manner (e.g. IsPartOf, IsBasedOn...), which can be offered to the learner by applications, as well.

Re-use and exchange: Well prepared eLOs cover a specific topic in a self–consistent manner, provide meta information on its coverage and the intended context of use. It is the idea that such generally shaped content blocks are much more suitable for re-use or exchange between teachers than commonly used documents. Each eLO is also meant to be an accessible Web resource (equipped with URL), so that access and exchange of these units, available in partly standardised formats, can be promoted to global ease.

Even though there has been very limited effort to explore online capabilities of eLO based educational content management to its full potentials, a harsh and controversial debate arose on this issue. The principle feasibility of these information objects as well as of metadata annotations is questioned in a surging pedagogical dispute (Wiley 2000, Krause & Kortmann 2002, Arnold et al. 2003). Several, often commercial systems to generate SCORM packages are for authors around. Few of them address issues of complex content editing and exhaustive metadata support. A carefully prepared hypermedia editing environment, the hypermedia composer HyCo, has been introduced by García & García (2005). Like hylOs, HyCo aims to seamlessly guide authors, while provisioning structural and semantic information for educational content objects.

2.2 The Hypermedia Learning Object System hylOs

The Hypermedia Learning Object System (Engelhardt et al. 2002, Schmidt & Engelhardt 2005, hyl 2006) 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 (Feustel et al. 2001). 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 institutions.

hylOs offers variable content access views to the learner (s. fig. 1). Each view presents the content of underlying eLOs according to a certain learning methodology. The first one is based on learning path hierarchies, each of them representing the instructional design as defined by a teacher. Those learning paths may be composed with the help of the instructional designer (s. section 2.3) by arranging appropriate eLOs from the knowledge repository. The second view is formed from the primary content structure as defined by its authors. This hierarchical content organization is visualized as a tree. The root of the tree could be viewed as the most common description of the subject, whereas the leaves are the most detailed information. In contrast to the different possible instructional views, this hierarchical presentation is unique to the content. The third view provides a set of constructivist tools supporting self-explorative learning. In contrast to the preceding access methods, which are more focused on eLO structures, the perspective here is switched to an eLO centered view. Starting from the current context node, qualified relations to other eLOs are displayed, which are taken from the LOM metadata "relation" section. Based on those qualified relations, the content is overlaid by a semantic net, suitable for meaningful exploration.

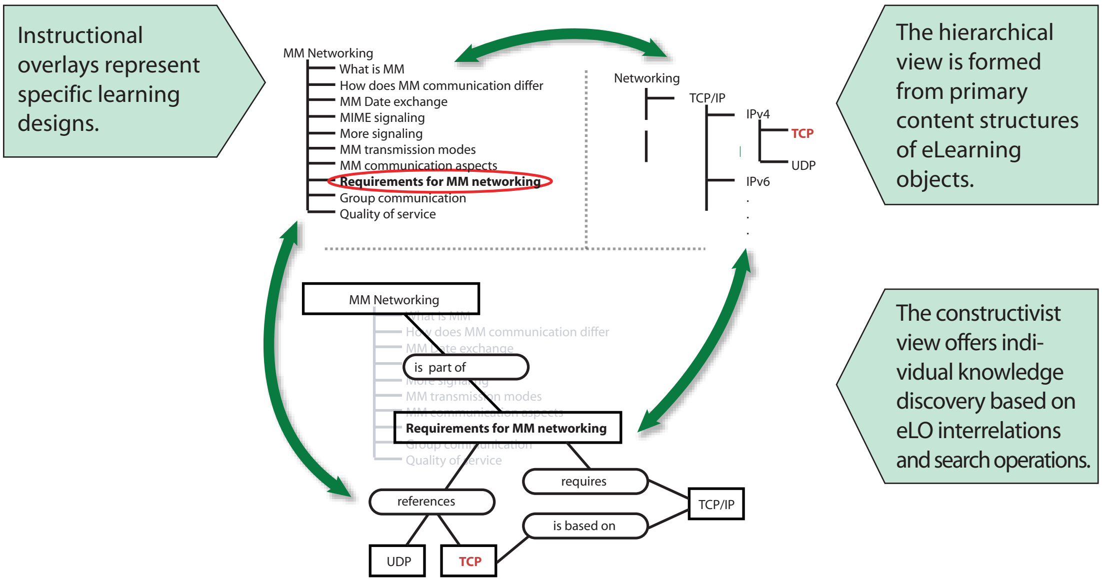

Figure 1: Use Scenarios for hylOs Navigation

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 (Engelhardt & Schmidt 2003), different hyperlink layers may be applied onto 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 (1989). Note that textually coherent hyperlink collections provide an additional, meaningful structure to be harvested in future applications.

To illustrate the aforementioned, imagine a learner, a bachelor student, working on a unit on "Multimedia Networking" provided by his professor within the introductory class "Computer Networks". At some time he reaches the subject "Quality of Service", which introduces QoS aspects in networks. The student is not satisfied by the introductory content given in this course and wants to acquire background knowledge. For this task he switches the perspective to the constructivist view, where related topics of his present subject (eLO) are offered. By navigating along the relations or searching for similar 'knowledge nuggets' the learner may find a new learning path called "Advanced Internet Technologies". Here the student switches back to this newly discovered instructional path and works along this course, intended for masters students. After studying the whole QoS lecture, the student wonders wether there is more about networking and changes to the primary content view. Thereby the system will show the complete structure of networking related objects within this authoring trail, disclosing subjects and details never mentioned in the course our student has enrolled for.

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 (including mathematical formulae), 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 is 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

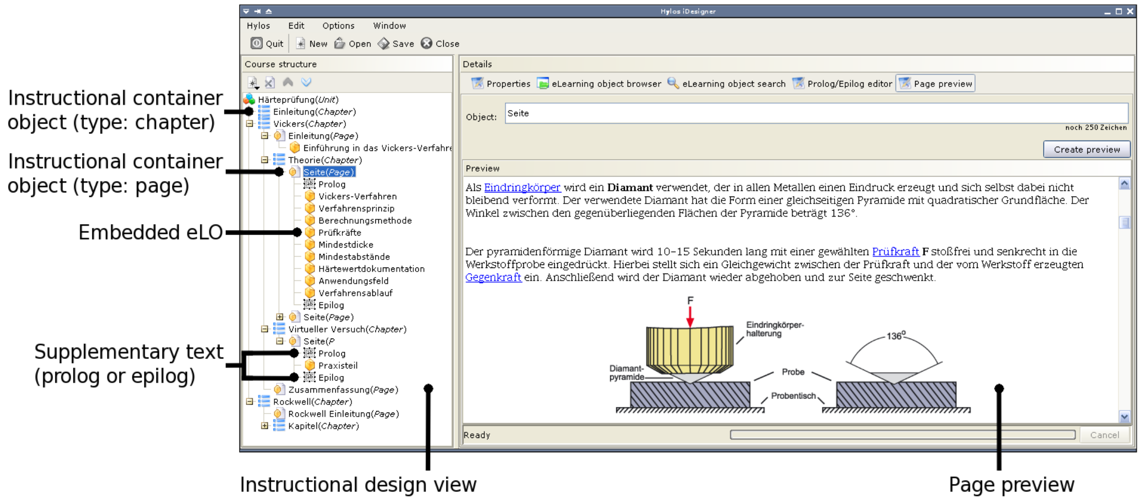

Figure 2: hylOs iDesigner Application View

trail. Re–use of content and structures is supported at any level of complexity. A variety of specific editors for glossaries, (TEX–complient) bibliographies, rich media content and taxonomies complement this high–level authoring environment.

2.3 The hylOs iDesigner

The process of forming a didactically structured outline from single learning components is commonly known as instructional design. This task of arranging the eLOs in different courses or units, thereby superimposing narrative 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 iDesigner allows for the definition of course structures and visual units, which can 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 derived from eLOs retaining the complete LOM metadata 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 prologue or epilogue. Instructional types are courses, sections or pages for example, which are 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 itself. 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 and resulting in a hierarchy of ICOs. Sections are named by setting the LOM general title property and may be annotated with LOM compliant metadata for further processing or search operations. Filling pages with content requires selecting 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 metadata properties, e.g., title, keywords, description or context. The iDesigner supports the user in generating search queries by providing a form-based interface. Matching objects are presented to the author in a file system like style with full content preview, from which the user may drag desired eLOs and drop them onto the specific page in the instructional design view.

For convenient selection compound eLO structures are presented to the author linearly in a normalized view. To assist a fluent learning process, authors may glue together aggregated learning trails, leading readers by texts foreseen in a prologue or epilogue 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 explicitly 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.

3 An Ontology Based Approach to Constructing Educational Semantic Nets

3.1 Advancing LOM Relations

eLearning objects compliant with the LOM metadata standard provide a section of qualified object 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, as well as to the author or instructional designer.

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; see Steinacker et al. (1999), virtual campus team (2003), Karampiperis & Sampson (2004).

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

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, 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. The corresponding DC inverse property pair expresses bibliophilic editorial hierarchies, which 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 of increasing strengths. 'references' and 'isBasedOn' both admit mandatory roles and thus fail to reach transitivity.

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 Steinacker et al. (1999), were omitted for the sake of simplicity and clarity. Types and semantic of these newly introduced relations are visualised in table 4.

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 as generated by updates or redesigns. Different versions may deviate in content and author, preserving thematic dedication and technical 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

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.

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 allow for a coherent, semantically guided content access. 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.

3.2 Ontological Evaluation Layer

Adding a new eLearning object 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 Engelhardt et al. (2006), will be predisposed as unconnected entities. Any classified object, though, may immediately inherit the relation 'isBroaderThan' from the taxonomy and 'isPartOf' from its structural disposition. Additional attributes may be conjectured from heuristic considerations, e.g., two eLOs of (almost) identical classification and keyword sets, as well as comparable educational attributes are likely to be 'AlternativeTo' each other.

To overcome the obstacle of further manual netting, an *Ontological Evaluation Layer (OEL)* has been designed and implemented in hylOs. The core concept consists in encoding taxonomic

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, but may deviate in formats.
illustrates/ IsIllustratedBy	This inverse property pair expresses illustration in an open fashion. For illustration 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

dependencies and relation semantics within an OWL (2004) ontology, which then can be processed by an inference engine. At this first step, relation properties/pairs along with their characteristics can be distributed across repositories. To account for logical dependencies between related properties, additional inference rules need to 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 $B \wedge B$ is format of $C \Longrightarrow A$ 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 (JEN 2005) to operate the reasoning, combining 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.

Any newly inserted object or relation will lead to a chain of subsequent link placements within the hylOs system. Authoring thus is enriched by forceful augmentation intelligence. Learners will profit from automated reasoning and envision a consistent and supposedly dense educational semantic net.

3.3 Results

An excerpt of the reasoning results for a sample set of 18 eLOs consisting of the two thematic islands "OO Programming" and "XML Technologies", exhibiting "DOM" and "SAX" as points of contact, are displayed in figure 3. We arrived at a dense mesh of 300 relations between those

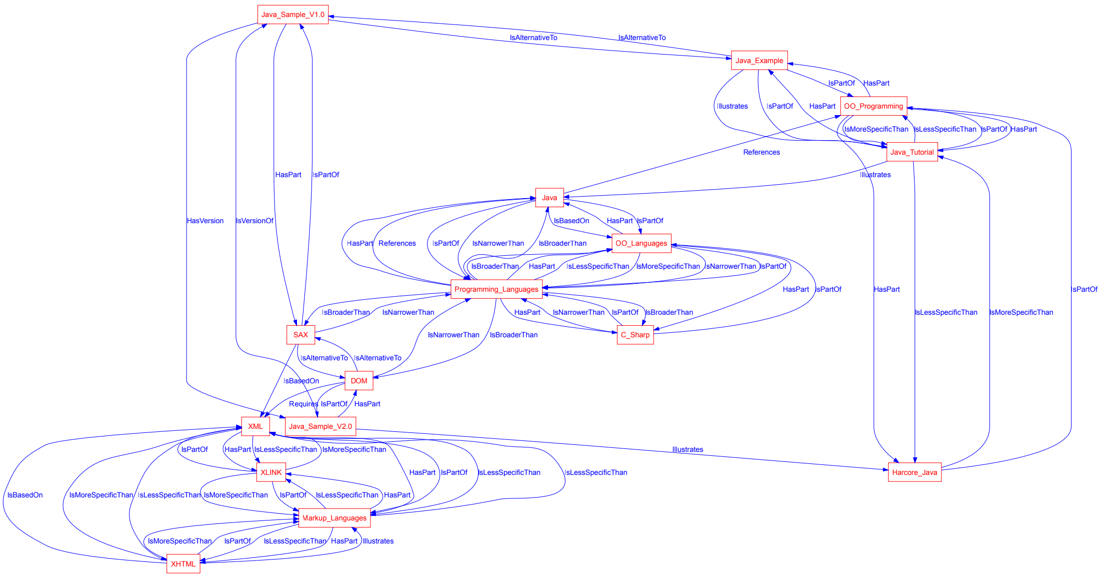

Figure 3: Excerpt from a Resulting Semantic Net

objects, following a three–step procedure. After initial object creation, 66 relations were inherited from structure, classification and heuristic conclusions. In the second step we manually added 12 relations from table 3 as a typical contribution of an author, who sparsely overlooks thematic dependencies. Subsequent reasoning could identify 162 conclusions from the set of 78 given relations. Finally we added 7 major relations identified as missing and received additional 53 links from the inference process.

Besides quantity, it should be noted that the inferred relations are not at all limited to the obvious; according to the underlying effective rule set quite surprising results occur. The two initially unrelated eLOs "Markup Languages" and "Java Sample 2" inherit for example the relation "isRequiredBy" through the following logical chain.

1. "Markup Languages" $\overset{hasPart}{\longmapsto}$ "XML"
2. "DOM" $\overset{requires}{\longmapsto}$ "XML"
3. "Java Sample 2" $\overset{hasPart}{\longmapsto}$ "DOM".

To gain evidence that our axiomatic rule set is contradiction–free and semantically sound, an extensive theoretical and empirical analysis is ongoing. For an example, we monitor inconsistencies, which also may result from manual editing, by encoding incorrectness–relations in a separate ontology, e.g.,

- A is part of $B \wedge B$ is part of $A \Longrightarrow A$ incorrectPart B
- A is format of $B \wedge B$ has version $A \Longrightarrow A$ incorrectFormatVersion B

and apply the reasoner likewise. It thereby has been our steady experience that erroneous inferences are quickly discoverable, since the outcome of rule–reasoning rapidly spreads among entities and soon leads to obvious incorrectness. For further methodology, experiments and results we refer the reader to forthcoming publications.

3.4 Inter–Repository Overlays

The above semantic reasoning approach proved its strong ability to derive non–trivial results, admitting enhanced efficiency when interconnecting previously disjoined "islands" of densely meshed eLearning Objects. Starting from this observation we now derive an approach to extend our internally applicable scheme to an automated generation of inter–repository overlays. Learners and authors will gain through this a view on external resources within their navigational context.

Our approach relies on the availability of LOM metadata, retrieved by the widespread OAI (2004) protocol, and the pairwise occurrence (symmetric or inverse) of relations. It proceeds as follows. Starting from a predefined perspective, related metadata of the distant repository are retrieved and proxied. Initial links between local and proxied data then are identified from classification terms and heuristics, just as done within hylOs for newly inserted objects. Inference further on operates jointly on initial interconnects, internal relations of the local and proxied repositories and manually authored links, if provided. Semantic reasoning will result in a set of named referential pairs, out of which the outward directed part is written into the local system. Semantic overlay nets can thus evolve grounded on standard technologies without taking effect on knowledge peers.

As multiple large learning depots may be involved in this reasoning process, scalability issues arise. Algorithmic complexity here is a superlinear function of data sizes, i.e., the numbers of objects and relations involved. However, data may be presented to the reasoner in limited, preferably related subsets. Subsequent steps of reasoning on a sliding data window will derive the same semantic net, provided the window is sufficiently large for rules to apply. The validity of this iterative approach follows from the observations that inference processes are idempotent and self–healing.

4 Conclusions and Outlook

In this paper we discussed key aspects of eLO–based educational content networks and automated content augmentation. Starting from an introductory discussion of IEEE LOM eLearning objects, we introduced our Hypermedia Learning Object System hylOs, and ongoing activities of eLO generation and management. 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 monitor its consistency.

The approach of generating a learning net can be extended to inter–repository overlays in a straightforward way, by using standard metadata transport protocols such as OAI. Our future work will concentrate on the design of semantic peer–to–peer networks formed between distributed eLearning Objects, delivering content on demand within individual educational contexts of learners and authors.

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Arne Hildebrand is a Ph.D. student within the hylOs project team. He completed his Diplom thesis in technical computer science from FHTW Berlin in 2004 on concept and implementation of an XML-based object-relational I/O data bridge. His current work concentrates on intelligent information retrieval, automatic context recognition and mobile content processing. Besides advanced software development Arne's expertise includes signal processing and communication interface design.

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Dagmar Lange recently received her Diplom degree from TFH Berlin with a work on semantic processing of IEEE LOM eLearning objects. Her work on LOM relations forms a basis for this article. Dagmar got deeply involved in formal semantics and inference programming.

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Thomas Schmidt is teacher of Computer Networks & Distributed Systems at HAW Hamburg and project manager at FHTW Berlin, where he was head of the computer centre for many years. He studied mathematics and physics at Freie Universität Berlin and University of Maryland, USA. Since the late 1980s he has been involved in many computing projects, focusing on simulation and parallel programming and distributed information systems. His current fields of interest lie in the areas of next generation Internet (IPv6), mobile and multimedia networking and XML-based hypermedia information processing, where he has continuously conducted numerous projects on national and international level. Together with his R&D group he designed and implemented the Multimedia Information Repository (MIR), an Internet meta-information management system, running productive in several instances for years now. Current work concentrates on the field of IEEE LOM based educational content management, releasing the Hypermedia Learning Object System (hylOs).