

Mobile eLearning Content on Demand

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Abstract: *Advanced mobile devices suitable for rich media content reception escort a strong majority of the people. Mobile information technologies today are pervasive and prevalent across most generations and countries and augur well for knowledge reception and learning processes within everyday life. In ubiquitously advising life long learning opportunities the paradigm of mobile users questions our common approaches of implementing teaching and learning: Mobile use patterns are short and fast, they frequently interrupt established contexts while nomadic users commonly are on edge with multiple activities taking place in parallel. Handheld devices in addition admit specific, non standard designs and are considered personal companions. In this paper we present an approach to dynamic, "on demand" production of content, which is personalized and specifically adapted to dedicated mobile devices. Starting from IEEE LOM eLearning Objects, i.e., small standardized self consistent knowledge entities; we process formats, appearance and contextual structures to transform re-usable content objects into the desired target context. Beside Web data for mobile browsers we will detail out an example of feeding the specific iPod potentials, i.e., its navigation, and a handheld Sony gaming station. All implementations are based on the educational content management system hylOs, which we will briefly introduce. Enabled through an advanced authoring toolset, hylOs allows defining contextual hyperlink overlays, as well as instructional overlays of a given eLearning object mesh. Based on a powerful Ontological Evaluation Layer, additional meaningful overlay relations between knowledge objects are derived autonomously within hylOs. These resulting semantic nets form a basis for perpetuating contexts, when mobile users re-access interrupted learning sessions.*

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

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1 Introduction

The technical and cultural presence of 'infotainment' at the one hand, shortened cycles in knowledge acquisition and revocation at the other, have tightened the demand for fundamental changes in our educational systems. The traditional exclusive separation of educational and productive phases has ceased to persist in peoples lives, but require compensation by an increasing portion of life long learning elements. Many educational institutions, i.e., schools and universities, training departments and institutes for professional development simultaneously struggle for effective methods in producing pervasive learning offers. Significant effort thereby is centered on new learning technologies, as they promise to permanently reach learners by their ubiquitous presence of networked devices. Student's views of life and dedications have equally changed. Spatial and temporal occupancies have undergone a major paradigmatic shift, accessibility and trendiness play important roles in utilizing services and devices. Especially younger students tend to admit rapid

apprehension and enhanced concentration, but for short times only, while frequent distractions request for interrupt options to be available in any occupation exceeding a few minutes. Current hypermedia learning technologies conceptually account for these requirements in providing segmented, adaptive building blocks or Media Bricks [15]. The concept of flexible "knowledge nuggets" of limited extend has been standardized as IEEE LOM [13] eLearning Objects (eLOs). As atomic, self-consistent entities eLOs combine hyper medial content with standardized Meta descriptors, transparently revealing their mutual relationships via textual and structural reference pointers, i.e. hyper references. Further on, following the ADL-SCORM Sharable Content Object standard [3], eLOs can be designed to be portable, interoperable units, which may be executed on any standard-compliant environment. Mobile end systems today escort people from puberty to sagemess. Standard systems such as mobile phones or PDAs, but also specialized gadgets, i.e., MP3-players,

gaming stations or dedicated professional equipment, must be increasingly considered as people's primary access devices to information, communication and entertainment. They all remain with us in unoccupied times and are particular candidates to serve for learning content feeds in every day's life. Thus for no surprise, a recent study [12] identified a majority of German enterprises to count on the early employment of mobile learning offers.

Mobile systems though admit limited capacities and frequently are of highly specialized nature. In particular, they most often do neither support standard presentation formats and keyboards nor SCORM players. Instead these "personal companions" normally entail their dedicated appearances and paradigms of use. eLearning content and applications on mobile gadgets consequently need specific adaptation, in order to meet the requirements of technology and style. Standardized eLearning Objects need a device dependent refinement and shaping prior to their use. Any support of such new, variable presentation channels — if not undertaken manually — requires qualitatively new capacities in publication oriented content management systems (P-CMS) [4].

In the following we will describe our general approach to adaptively produce variable content feeds from eLearning Objects as produced within the Hypermedia Learning Object System hylOs [5, 14, 10]. hylOs addresses the production of mobile content on demand from two perspectives: At first, all eLearning content elements are rigorously stored in presentation-independent XML formats, fully preserving structural transparency. Dedicated publication generators for mobile devices can thus be added seamlessly. At second hylOs semi-autonomously embeds its eLOs within semantic overlay networks, providing the opportunity to superimpose contextual learning steps onto device-specific interactivity schemes. Prototypic solutions for the Apple iPod and a Sony playstations are subsequently presented.

The Hypermedia Learning Objects System is built upon the more general Media Information Repository (MIR) [9] and the MIR adaptive context linking environment (MIRaCLE) [8], its linking extension. MIR is an open system supporting the standards XML 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.

This paper is organized as follows. In the following section we briefly introduce hylOs, donating special focus on its semantic overlay capabilities to achieve

content coherence. The subsequent sections introduce our approaches and prototypic solutions to exemplarily serve specific mobile devices. The paper closes with a conclusion and an outlook.

2 Semantic Overlays for Educational Content

2.1 hylOs Educational Content Management

The Hypermedia Learning Object System has not only been designed to provide full educational content management based on the eLO information model, but also to enhance content access by means of coherent, contextual overlays [7]. 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, as well as distinguished hyper-link layers, which may be applied onto the same content. 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 and feel by applying appropriate XSL transforms. The system is used in several eLearning deployment projects within our institutions.

A fully-distributed authoring environment is also part of the hylOs suite. 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 as shown in figure 2. 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 trail. Re-use of content and structures is supported at any level of complexity. A variety of specific editors for glossaries, (L^AT_EX-compliant) bibliographies, rich media content and taxonomies complement this high-level authoring environment. hylOs offers variable content-access views to learners, following different structural relations indicated by distinguished arrows in figure 1 or specialized publication channels. Each view presents the content of underlying

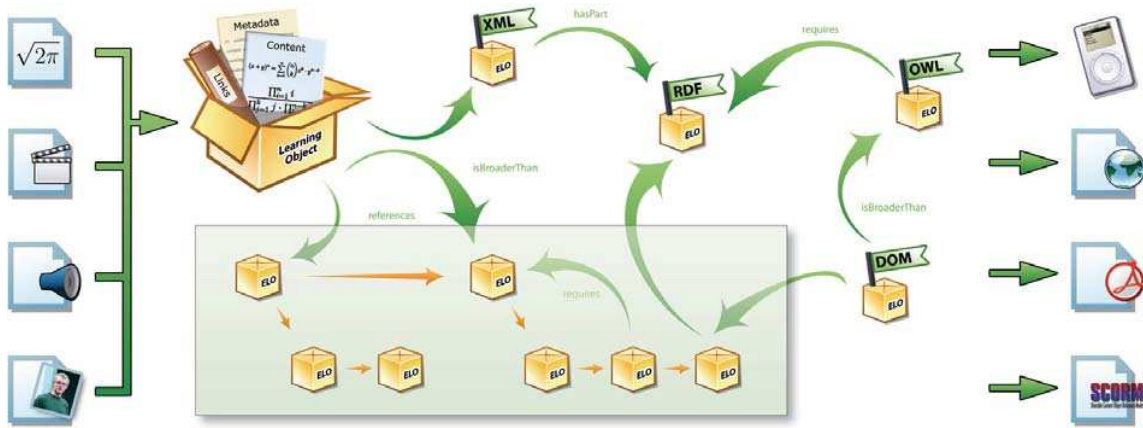


Figure 1: Building Blocks in hylOs

eLOs according to a particular learning methodology or publication context. They may be based on learning-path hierarchies, representing the instructional design as defined by a teacher. Those learning paths may be composed with the help of the instructional designer, an additional authoring sheet, by arranging appropriate eLOs from the knowledge repository. Another 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. A set of ~~constructivist~~ tools supporting self-explorative learning complements the more teacher-oriented approaches. In contrast to the preceding access methods, which are more focused on eLO structures, the perspective here is switched to an eLO-centred 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.

2.2 Educational Semantic Nets

On the basis of named inter-object relations hylOs intends to derive a semantic learning net, which may be presented to the learner for navigation and knowledge exploration, as well as to the author or instructional designer. The expressiveness of LOM relations, though, is limited to the administrative view of librarians. To gain expressions suitable for educational hypermedia, the semantic of relations needs adaptation, sharpening and a careful extension [17]. For a fairly comprehensive, viable notion on educational semantics, we identified the

1	isNarrowerThan	isBroaderThan
2	isAlternativeTo	
3	illustrates	IsIllustratedBy
4	isLessSpecificThan	isMoreSpecificThan

Table 1: Additional Educational Relations

following four relations/inverse pairs displayed in table 1. The first relation represents taxonomic dependencies, while the remaining reflect educational uses. Note that relations 2 and 4 express thematic relatedness, but pair 3 does not.

Adding a new eLearning object into the repository will require to identify and update appropriate relations with a possibly large amount of present entries. Objects entering the repository will be subject to auto-mated classification and 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 relation semantics within an OWL ontology, which then can be processed by an inference engine. At this first step, relation properties or 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.

Our implementation uses the JENA framework [11] to operate the reasoning, combining the extended relation

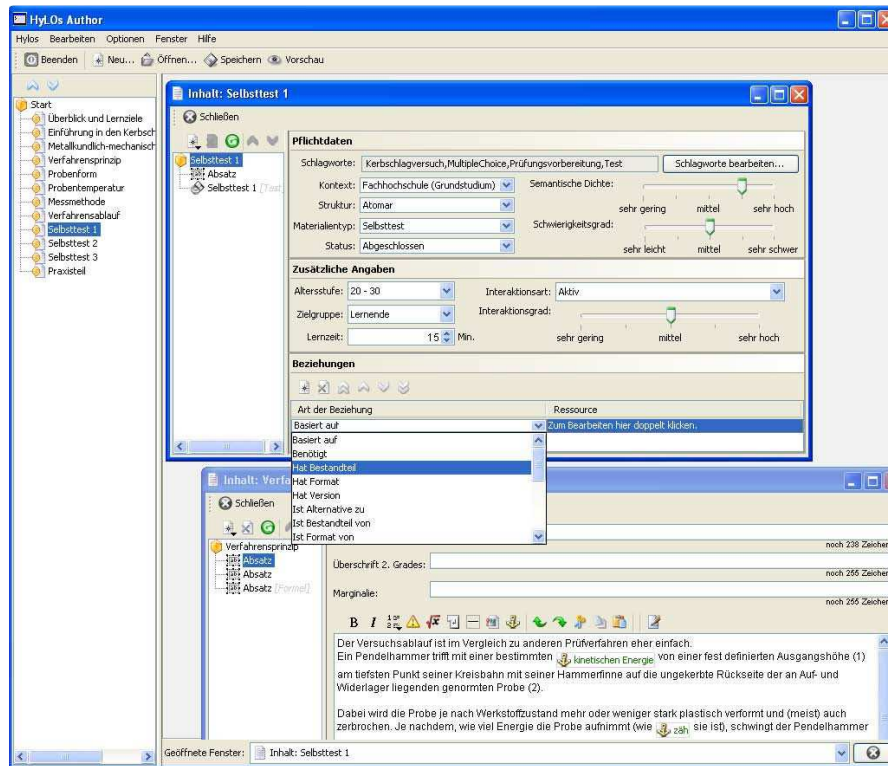


Figure 2: eLearning Object Author: Combining Access to Content and Metadata

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 a forceful augmentation intelligence. Learners will profit from auto-mated reasoning and envision a consistent and supposedly dense educational semantic net, as is visualized in a mind map based navigational approach in figure 3.

3 eLO Content for Mobile Devices

3.1 Background Concepts and Related Work

It is the desire of teachers, eLearning content providers and thus of publication oriented educational content management systems to simultaneously feed online- and print-oriented publication channels as well as to serve various mobile and handheld devices automatically and always from the same content sources. While the support of standard markup or print formats is easily

achieved in hylOs on grounds of its rigorous employment of the XML framework, the inclusion of the mobile gadget world must be recognized as an ambitious under-taking. Not only are these devices limited in display, processing or transmission capacities, nor only diverge their support for default markup or rich media formats, but primarily they require adaptation to their full context of use as manifested in the sum of hardware, software and paradigmatic layout.

Any flexible, self-adaptive solution to the mobile content generation problem needs at first to ensure appropriate media selection, i.e., in type, format and resolution. At second it requires to adjust interactivity types and navigation complexity to be manageable by device-specific players, which then handle hardware and software controls in an appropriate fashion. To master the latter more than technical format modifications are required: A semantic notion of interactive elements will be needed by a system to accomplish their meaningful transformations.

Hyperreferences are the essential building blocks of interactivity in hypermedia systems. In hylOs, references are dynamically built either from the linking layer or from inter-object relations, which both carry well defined meaning. The system thus offers the powerful opportunity to sensibly reshape interactivity without manual intervention. As an example, consider a system with

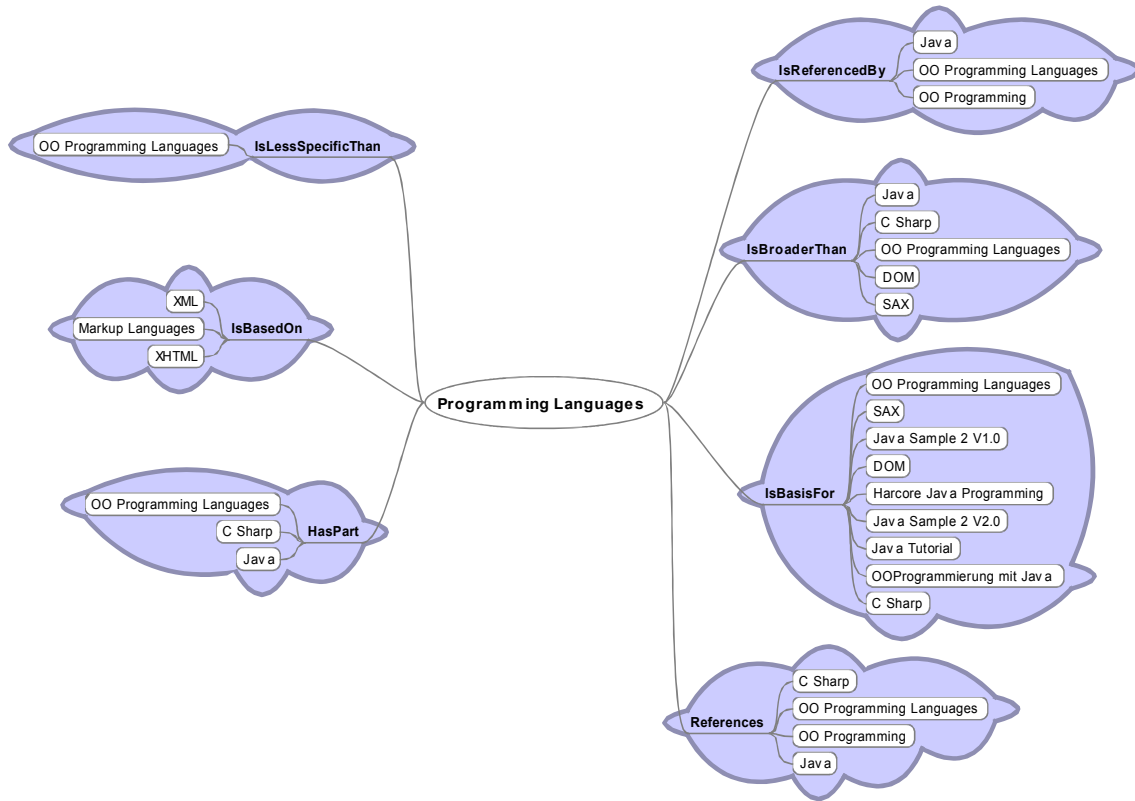


Figure 3: Application Example: Mindmap Navigation

a four-directional joystick to be used for navigating the semantic eLearning object net. For this purpose the relational mesh needs to be coarse grained and weighted, so that immediate inter-object navigation can take effect. While there are many ways to reduce the relational complexity, a simple, straight forward approach is displayed in table 2: Semantically related pointers are grouped and projected onto simple associative categories. More sophisticated extractions, accounting for short- and long-distance correlations, are currently in experimental status.

Up until now very little work on publication format standards for mobile content players has been completed. For a limited number of devices RSS feeds [1] have well established as content distribution format, most popularly known as 'Podcasts' in conjunction with the Apple iPod MP3 player device. Numerous institutions publish audio or video recordings of their lectures via such Podcasts, e.g., 'The Educational Podcast Network' [2] or Stanford University "on iTunes" [16] to name prominent examples.

3.2 Use Case: iPod MP3 Player

Apple Podcasts are an approach to audio news channels, containing an MP3 audio file, a brief description

Navigation	Qualified Relations in hylOs
Examples	isIllustratedBy
Theory	illustrates isBasedOn requires isBroaderThan
Apply	isBasisFor isRequiredBy isNarrowerThan
See Around	isAlternativeTo isLessSpecific isMoreSpecific isVersionOf hasVersion

Table 2: Projective Mapping of Relations to Navigations

within the feed and a backward reference to its original source. The mpeg audio format itself may contain meta descriptors including a self-description of 255 characters length. The iPod navigation then is built upon these meta descriptors, attaining non-normalized contextual hierarchies with respect to the meta tags (e.g., title, author). Optimized for music consumption, this set-up attains rather limited capabilities for visual presentation

and interaction design. However, in their fifth generation iPod machines offer notable displays for visual and textual presentations, the latter rendered from a rudimentary HTML-like markup. These options are tight to the iPod 'Notes' section, which browses a hierarchical file system within the device. The navigation for directory browsing as well as available hyperlinks is likewise based on the trendsetting iPod Click Wheel. As we aim at preserving visual data as well as the semantic navigation, our approach combines audio Podcasts with these notes.

At first we publish the audio material of our eLearning objects as a Podcast by dynamically generating an appropriate RSS feed. Each feed contains besides its short self description as extracted from metadata a link to its html-type documents. Prior to transferring the visual content from hylOs to notes on the iPod, the content is transformed into the suitable markup and chopped up following the paragraph-wise content segmentation of hylOs. Menu files needed for the semantic navigation are a priori generated from hylOs' named relations, as well. These menu files are created, each subsuming references to a specific semantic category, by parsing the corresponding content structures in hylOs and subsequently rebuilding the target content tree.

To reduce the navigational complexity of the mesh, the relational pointers are grouped under associate categories and - to allow for a OneClick navigation - a most significant eLO is extracted under each category. Finally, while rendering the content to iPOD, each eLO is provided with the reference topic (if exists) placed under associated categories within its notes file. The reduction of semantic net complexity is explained in detail as follows: At first, the meanings of each of the extended LOM relations are carefully examined from the semantics defined for each relation by Engelhardt *et al.* [6]. Semantically similar relational pointers are selected, grouped and projected onto associative categories. In this process, we realized that the relations "isBasedOn", 'Requires', 'illustrates', and 'isBroaderThan' are used to interconnect the current eLO with the eLO that provide the basic conceptual details and background information for the current eLO. Hence, a category is defined to group these relations and it is given a name 'Theory'. Our reduction algorithm is used to extract the most significant eLO for this category. Similarly, "isBasisFor", "isRequiredBy", and "isNarrowerThan" relations are grouped under the category 'Apply' and the relations "isIllustratedBy" under the categories 'Examples', a less specific group of references are finally subsumed under a "See Around" option. For each category, a most significant eLO is extracted using the reduction algorithm described below. The grouped semantic relations and the

resultant associate categories are displayed in the table 2.

3.2.1 Extraction Algorithm for a Primary Semantic Path

To reduce navigational complexity one "most significant" eLO for every relation needs determination. The following assumption is made, before extracting such most significant related eLOs from the available related eLOs of a current eLO A.

- In a general learning scenario, while learning a course, if a related topic is to be selected from a set of topics for any current eLO, then choice is made for a topic, which is fundamental (or required by) or useful for further learning (or for more number of eLOs).

Hence in our approach, following the above assumption, the most significant eLOs are discovered for any eLO from the available educational semantic net. To do this we examined all the 18 relational pointers and determined four relations namely "IsRequiredBy", "IsBasisFor", "IsReferencedBy" and "IsBroaderThan", which satisfies the above mentioned requirement i.e. if any eLO contains these relational pointers then it implies, the corresponding eLO will be useful or basis or required for other eLOs. Therefore, these relations are selected and given weights according to their priorities. For example, "isBasisFor" relates an eLO carrying fundamental knowledge to another eLO and "isRequiredBy" denotes an obligatory content dependence in the sense that eLOA cannot be understood without the knowledge of eLOB. Hence, after having a close look at the meaning of these two relations, more weightage is given to "IsRequiredBy". A similar approach is followed for all the relations and depending on their priority the weights are assigned to them. In our approach, the priority order of the relations starting from low priority relation to high priority relation and their corresponding weights are given below:

- IsBroaderThan — w_1
- IsReferencedBy — w_2
- IsBasisFor — w_3
- IsRequiredBy — w_4

The weights are chosen in such a way that, if the lowest priority relation is assigned a weight w_1 , then the next priority relations will be assigned weights $w_2 = w_1(k + 1)$, $w_3 = w_2(k + 1)$, $w_4 = w_3(k + 1)$, where k

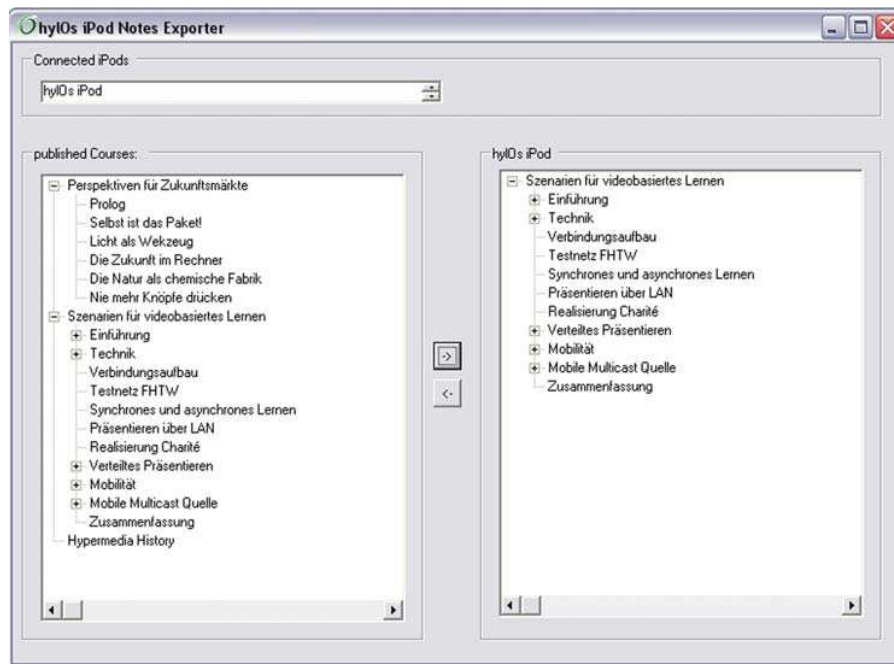


Figure 4: hylOs iPod Notes Exporter

is the maximum number of eLO's that are to be considered under each relation. Thus, to avoid confliction, only equal number of eLO's are considered under each relation and the weights are assigned accordingly. Therefore in the next step, any eLO containing any of the four relations ("IsRequiredBy", "IsBasisFor", "IsReferencedBy" and "IsBroaderThan"), is assigned with a weight equal to the total weight assigned to the relations which it contains. In this procedure all the related eLOs of the current eLO are assigned weights. The resulting structure of the semantic net with weights is analyzed and the maximum weighted eLO is extracted.

3.2.2 Realization

Presently there is no tool for the synchronization of notes data. Also, our specific content regeneration needs implementation. For this purpose we designed the hylOs iPod Notes Exporter as shown in figure 4. The exporter will browse, analyze and extract eLO collections, build notes file hierarchies and menus and finally will transfer the structured data to a connected iPod device for offline use.

A resulting example is displayed in figure 5: A learner starts a course with the object "XML Overview", chosen from the general course navigation, and listens to the underlying audio recording of the lecturer. After completion he navigates into the sample section and browses "XML Samples", which continue into underlying theory of "XML Goals" and follow ups, which are omitted in this comprehensive presentation.

3.3 Use Case: Handheld Gaming Station

The adaptation of elearning content to each mobile device requires a close look onto their technical capabilities. Sony's Playstation Portable supports, aside from the classic gaming environment like a memory card and device dependent disk drive, wireless network, a web browser and a flash player, as well as a subscription access for podcasts.

The portable playstation is equipped with specific haptic controls designed for an adequate and easy game control like an analogue joystick, a keypad and several action buttons. One major issue must be seen in the support of these special input devices for steering an eLearning browser. The device's ease of use can be inherited from seamlessly integrating the gaming controls, and thereby, indirectly the fun of gaming may evolve.

To play out a multimedia learning object on a the portable playstation, rich media content like images or videos must be rescaled to fit the technical restrictions like resolution of the display, memory capacity and the available network access. Correspondingly, the client browser needs to perform latency hiding by pre-loading 'nearby' content, thus to avoid interrupts of the flow of learning. In order to enhance the level of interactivity the hylOs learning objects, composed of discrete paragraph objects, are split off and presented sequentially. In this way the amount of content for simultaneous display in one learning step is reduced. We call this a 'mission'-like learning scenario, where a single e-learning object is discovered in several parts or mission steps.

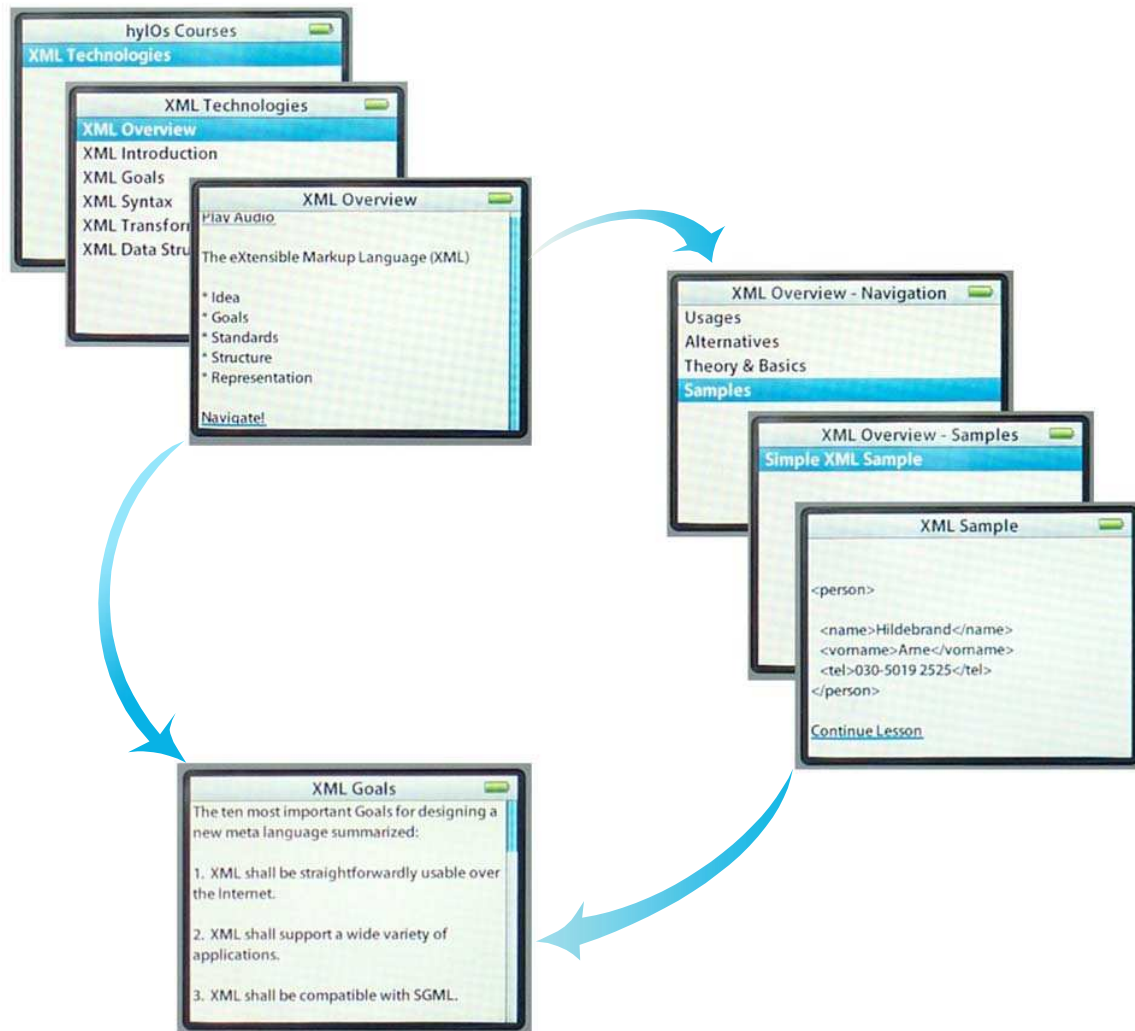


Figure 5: iPod Navigation — Learning Path and Related Resources

So an e-learning course can be seen as an collection of learning missions. In most cases an e-learning course is completed by a (self) test. The typical gaming complement is a final challenge, so e-learning contents can be transferred to a game-typical scenario.

eLearning content in hylOs powerfully features inter-object relations. As described in the previous sections, any content object will be arranged in guided learning paths and will attain semantic relations to related learning content, as well. Applying a mind map based navigation, semantic structures of the knowledge can be easily visualized. Tying the mind map traversal to the directional game buttons, learners will easily find their way through related content in a clearly arranged, inter-active way, thereby preserving the gaming character of the playstation. These related content paths can be seen as optional “special missions” for each single learning object. A reduction of the semantic net to perceptible groups of relation types likewise simplifies the knowledge browsing in an intuitive fashion.

Content itself may be narrowed prior to download by applying semantic filters, each of them customizing a contextual perspective onto the learning material stored in the eLearning repository. Appropriate context presets may be adjusted interactively or predefined for publication channels specific to individual target groups.

In our ongoing project we implemented a flash-based content browser prototype as shown in figure 6, which mostly relies on a server-side content pre-processing to balance the client side processing effort. In order to adapt the haptic input types, the content should be scrolled using the keypad, interactive elements, like the mind map, can be accessed by using the joystick like a mouse. The action buttons are used to confirm or cancel operations and to show or hide information panels, for example switching to the navigation screen.

Based on the *Ontological Evaluation Layer* the playstation client obtains possible related learning objects, followed by local selection of suitable objects and thereby adjusting the current user context. A relational



Figure 6: Mobile Content Browser on Sony Playstation Portable

significance level, is used to rate the semantic distance to the current topic in order to load semantically near content. This heuristic processing is done by the OEL and based on metadata of visited learning objects paired with the current course and user preferences.

Ongoing work aims to increase the gaming character of learning content browser. We will investigate ways to create automatically generated self tests, integrate the semantic net directly into the game play and to provide a more interactive content presentation. Furthermore we focus on the distribution of playstation specific offline content, which can be accessed by CDs or download platforms.

4 Conclusions and Outlook

The provisioning of mobile learning content raises new challenges for educational content management solutions. In this paper we discussed key problems and issues to be addressed in a mobile gadget-oriented infotainment world. Starting from our hypermedia learning object system hylOs, we introduced approaches to automatic content on demand generation for mobile systems, focusing on prototypic solutions for the Apple iPod and a Sony play station.

In future work we will refine and elaborate these works, thereby concentrating on systematic data format preparation capable of serving high-level interactivity on a fairly general set of mobile device platforms.

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Arne Hildebrand is member of the hylOs project team. He completed his Diploma 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 semantic content augmentation for educational eLearning Objects. Arne is co-founder of the start-up link-lab.

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Thomas Schmidt is teacher of Computer Networks at HAW Hamburg and project manager at FHTW Berlin, where he was head of the computer centre for many years. 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). Thomas has published more than 90 research papers in international peer-reviewed journals and conference proceedings, works actively in Internet standardization within IETF and is member of several international program committees. Thomas is co-founder of the start-up link-lab.

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Michael Engelhardt was a member of the hylOs project team. He completed his Diploma thesis in technical computer science from FHTW Berlin in 2003 on concept and implementation of a semantic approach to hyper linking. His work concentrates on eLO management and editing within the HyLOs system and semantic content augmentation for educational eLearning Objects.