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Abstract

This study is devoted to the problems of development of digital resources for education based on use of semantic technologies and knowledge management models aimed at the analysis of educational content. Digital transformation is a complex problem, therefore, we analyze only the semantic representation and search of learning objects (LOs) used for construction of personalized learning trajectories (PLT) that takes into account complex set of their properties and analyzes both LO metadata standards and elements of domain-specific characteristics of LOs.

We consider the use of semantic retrieval system that process formalized knowledge about learning course and student needs to find pertinent LOs that can be used in student PLT. An ontological approach provides creation of learning course thesaurus, and this thesaurus is processed as an input of retrieval procedure. Search results need in additional indexing with use of LO metadata standards and individual estimates of andragogue that transforms information into the LOs. Semantic Wiki environment is used for support of such indexing and storing of retrieved LOs and their structure.

Keywords

Learning object, thesaurus, digital resources for education, personalized learning trajectory, andragogy, semantic search

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1. Introduction

The specifics of digital transformation of adult education significantly relate not only to the acquisition of basic knowledge in a certain specialty (such basic knowledge usually can be proposed by variety of relevant textbooks or video lectures) and use of pertinent digital educational resources, but also to the improvement and deepening of already existing competencies, as well as the updating of existing knowledge and skills with the most relevant achievements in the chosen domain focused on the practical application of acquired competencies that have to be reflected in the semantic descriptions of these digital resources. Therefore, professional activity of andragogue requires use of means of knowledge processing that can help in solving of this complex problem. In this research we consider the task of informational support of andragogue by use of semantic technologies that is chosen for several reasons:

- `actuality` – now in Ukraine the number of adult learners who need to obtain new professions or improve and update already existing ones, is significantly increasing, while the number of andragogues and their level of competence is not increasing sufficiently, and that is why it is necessary to automate (at least partially) their activity on base of digital transformation of education;;
- `complexity` – the activity of an andragogue requires the analysis and matching of various objects and subjects of the educational process, understanding their structure and properties, and this analysis requires mechanisms of integration and coordination of different terminological and knowledge systems used for creation of digital educational resource based on existing common standards;
- `openness` – now an important component of effective learning is the search and use of new sources of information from the external open environment, and therefore it is necessary to develop retrieval instruments that support both regular information needs of andragogue aimed on creation and update of educational resources by search in various open repositories and storages and semantic filtering of search results;
- `knowledge orientation` – an andragogue needs to apply decentralized knowledge of both the subject domain of learning course, as well as specific knowledge from the andragogy area, to integrate various models of these areas, and this processing of information requires the use of modern methods and technologies of knowledge management and means of acquisition new knowledge from already available information, and therefore it is necessary to develop such tools that are able to apply the andragogue's beliefs about the subject domain of learning course and select pertinent Web resources that contain semantically similar knowledge, based on existing standards for describing the semantics of these resources – such as an ontology representation language OWL proposed by the Semantic Web [1] .

In our previous studies, determine the ways of applying semantic technologies for informational support of professional activity of andragogue. These studies define methods and software solutions proposed for identifying the subsets of current competencies of education seekers that are relevant to the selected learning course, and propose means for formal semantic description of such course based on the thesaurus. The obtained results are demonstrated on

example of creation a repository of *learning objects* (LOs) that provides detailed annotations of LO properties and supports the execution of semantic queries. The results of these queries are used as a basis for construction of *personal learning trajectories* (PLTs) that take into account individual informational needs of students, their previous experience and abilities to perceive new knowledge.

But the search for new LOs corresponding to the single *learning course* (LC) or group of interconnected LCs appears beyond the scope of previous research (we assumed that the andragogue finds and evaluates these LOs independently based on his/her own experience and learning goals). Practical use of proposed approach shows the need in automated means of LO retrieval that are based both on LC semantics and student specifics. Specific activities of andragogy introduce additional criteria in the selection and evaluation of LOs, namely:

- `actuality` (representation of the most modern achievements) into learning domain aimed at modernization of adult student knowledge and skills;
- `depth and fundamentality` of domain representation oriented on specialist with significant practical experience;
- `methodological and terminological integration` with other LOs previously used by adult students in different time.

Searching among LOs already indexed and described by metadata in some storage or repository is not sufficient for this purpose, because the criteria of selecting LOs included in the repository remains open. In order to find new LOs in the open information space, the andragogue needs to perform routine queries to various types of information retrieval systems – global and local ones. At the same time, the specifications of these queries at the semantic level can be permanent or be some modification (clarification or expansion) of previous queries.

2. Problem formulation

The conducted research is a component of informational support for the construction of the PLT that takes into account semantics of learning course. We propose to create LO search tools based on the description of the semantics of the learning course. This approach expands the existing means of LO description and search that are based on various schemas and standards meta-descriptions (a comparative analysis of the advantages and disadvantages of such meta-descriptions is given), and allows users to take into account a larger number of special needs in the search process. Semantic expansion of the Wiki technology used for creation repository of selected LOs provides the basis for defining various properties of LOs. Such meta-descriptions can contain both standard metadata elements and user-defined semantic properties. This solution provides a more flexible search and matching of LOs with other information objects in the process of PLT building.

Digital transformation of learning increase its quality and share results within the community (for example, teachers of semantically close courses). Preconditions of this study are:

- `large number of open-access LOs` with different levels of modularity, granularity and forms of representation are developed and accessible into open information space;

- `different metadata schemes` used for LOs descriptions (both general purpose metadata schemas and specialized for learning activities ones) that represent various LO aspects are created, and a certain number of standards fixes these schemes;
- `various LO repositories` contain a large number of LO meta-descriptions, but they describe only a small subset of all LOs;
- `the main part of LO descriptions` is focused on use by relatively homogeneous groups of students and practically does not take into account the specifics of the work of andragogues who teach adult students with significantly different competencies, experience and learning goals.

Problems in existing approaches used for LO search:

- it is rather difficult for teachers to understand all aspects of available meta-descriptions that define properties and meaning of digital objects;
- most LO repositories offer a rigid schemes of LO descriptions that do not involve adding additional parameters for LO in accordance with the semantics of a certain knowledge area or specifics of students;
- such repositories are more focused on the work with large communities of teachers and educational institutions, rather than on individual andragogue work or collaboration of small groups with similar interests.

Therefore, it is advisable to supplement the existing approaches with tools that supports development of structure and content of digital resources used for educational purposes on base of semantic technologies allow creating a personalized information environment of the andragogue. One of the main preconditions for the use of these tools is the formalization of search domain that causes development of the formal model of the learning course. In our previous study, we proposed a method for building a course thesaurus and an algorithm for its matching with meta-descriptions of the LOs [2]. At the same time, elements of LC thesaurus are used as semantic properties of LOs. Wiki technology and its semantic extension Semantic MediaWiki allow users to directly supplement the meta-description of LO with relevant elements that characterize the existing and desired competencies of students.

3. Personalized learning and learning objects

Personalized learning is an important condition for ensuring the quality of adult education. Such learning is based on humanistic values related to the recognition of persons as individuals, their rights to free development of abilities. Design and implementing of PLTs is one of the ways to implement personally oriented learning in adult education. PLT design in adult learning has to take into account the specifics of personality-oriented, object-oriented, activity-oriented, andragogic, competence-oriented, interdisciplinary, object-oriented approaches that correspond to different aspects of the organization of the learning process and complement each other. Thus, the activity-based approach is a source for describing the stages of learning, and combination of personality- and object-oriented and competence approaches provides PLT elements based on matching of student competencies with learning course requirements before and after

training. The andragogic approach is used to describe the interaction between a student and an andragogue in the process of particular LO use. Interdisciplinary approach helps to integrate student skills and knowledge from different subject domains and uses them for LO choice. In this work we consider PLT support based both on digital recourses and software tools for their representation and processing. PLT is a complex information object that defines goals, means and procedures of learning process for particular student in interaction with teacher and with use of LOs that describe course-pertinent knowledge and skills. PLT contains models of student and of learning course and is aimed to transform and enlarge student competencies according to curricula requirements. One of the basic PLT elements is a set of LOs selected according to personified characteristics and skills of particular student. Parameters used for LO analysis can be defines by various metadata standards and by specific properties proposed by andragogue. PLT is characterized by such properties as interoperability and modularity. We understand the interoperability of PLT in such sense that PLT developed by one specialist is unambiguously interpreted by another. This property related to the possibility of PLT storing, transfer and use by other persons without additional explanations. Modularity is a PLT property that allows both to use it separately for teaching a certain LC and to combine several separate PLTs. LOs play an important role at all layers of PLT implementation, namely:

- for content layer LOs provide the selection and systematization of information used for learning;
- for procedural layer LOs involve connection with learning technologies and assessment procedures;
- for context layer LOs enable the performance of specific tasks based on the actual individual, professional, educational and social context of learning process.

In this research, we use the PLT concept to represent a personified process of student learning and sequence of elements of this process specified for adult education institutions. This learning process is based on the individual style of learning activities of students and contains a sequence of learning steps, a set of tools, techniques, methods, and ways of performing cognitive activities that meet the needs, interests, and capabilities of adult learners. PLT choice involves [3, 4]: joint actions of students and teachers aimed at developing students' skills by independent learning activities; selection adequate general educational goals and relevant local tasks; choosing learning content, methods and forms; self-assessment of personal achievements; initiative and responsibility for decision-making and solving tasks. Ability to PLT construction helps students to learn independently throughout their lives. Personality- and object-oriented approaches lead to individualization of learning by personified selection of information objects, knowledge sources and data used for educational purposes [5, 6, 7].

According to the analysis of sources [8, 9], the activity-based approach provides active learning and cognitive activities, development and implementation of individual learning strategies. The andragogic approach makes it possible to build the educational process taking into account the individual age, psychological and physiological characteristics of students [10, 11, 12]. The competence-based approach is based on the results of education and training [13, 14] and needs in use of appropriate diagnostic tools that can be used for student model construction. An interdisciplinary approach [15], makes possible the coherence of curricula based on didactic

goals and learning content. Element of these approaches can be used for PLT construction by choice of course-relevant LOs based on their meta-descriptions properties.

4. Models and characteristics of learning objects

Various researchers propose different definitions and descriptions of LOs that complement each others and reflect various aspects of LO processing. IEEE Standard for Learning Object Metadata defines LO as an information object, software object or resource containing elements of animation, multimedia, graphics, text that can be used for education. This definition does not provide any possibilities to select LOs from other types of IOs [16] consider LO as a set of educational content modules, lecture materials, practical tasks and knowledge assessment methods, combined on the basis of a specific educational goal. This definition is more useful for practical needs by defining of LO aim but does not take into account all possible types of LOs (such as tests and computer simulations). In this work we consider LO as an *information object* (IO) supported by metadata relevant to learning process. Every IO can be transformed into LO by its structures meta-description pertinent to some learning course or group of learning courses. Such meta-description provides the base for use of LOs into PLT content set. The main goals of LO concept deal with some aspects of learning process:

- unified indexing of various IOs for learning needs that provides their search, storing and selection in special repositories;
- reuse of information modules developed for learning;
- interaction between such objects and possibilities of their comparison.

Analysis provided by [17] distinguishes various types of LO models such as: Verbert and Duval model; Santiago and Raabe generative model; Meyer model Boyle model; NETg LO model BNTOPM model; Cisco DNMO/DNIO model, etc. These models take into account different components and their features: content parts, shared content objects, learning objects, content objects, type of LO content, LO compounds, LO reusability, didactic, social and technological aspects of LOs, level of LO in content hierarchy (from raw data and media items through information objects and software items to sets of tasks and lessons). Models of LOs can describe them in various dimensions such as LO subject (domain), lessons and topics [**?**]. These models use various classifications of LO content element that can include such types as overview, definition, block scheme, illustration, guidelines, demonstration, example. Development of LOR can use ontologies of different types:

- curricula structure ontologies;
- learning course ontologies;
- ontologies of pedagogical and andragogical strategies.

We consider various solutions and pay attention to fact that use of the Semantic Web technologies provides possibilities to change ontologies of every type without fundamental changes in LOR software implementations – usually, these changes affect modifications in LO structure and visualization but don't need to change existing services.

Transforming existing content into reusable LOs is an important task that is aimed at faster and better creation of new LCs by semantic indexing of existing learning content. The beginnings of the LO concept is caused by the need to divide the educational material into parts that can be used in different courses. This makes sense if such activities involve a significant number of people who can benefit from the intelligent activity of other members of the community. The advantages of such a solution for improving the quality of education are determined by the shared use of open information resources, increased flexibility and support for personalized selection of learning materials. An object-oriented approach to the development of learning materials was introduced many years ago by such companies as Netg and Cisco. These approaches provide various means to reduce the time of development of learning courses.

In 1997 Netg proposes one of the first attempts to define LO with the help of the smallest (atomic) reusable object called a topic. Such topic consists of one learning objective, one learning activity and assessment. In [18] NETg learning object (NLO) is modeled with four levels. Cisco uses a different terminology to describe LO: they developed a model based on the smallest reusable element is a Reusable Information Object (RIO). Such RIO consists of content items, practice items, and assessment items united by single learning objective. The primary purpose of the LO in this approach is to define content elements and provide information that is necessary for the execution of other RIO elements. The design of RIO elements depends on the learning goal to be achieved and the aimed cognitive level, as well as on the types of analyzed LOs.

Thus, from the beginning researchers take into consideration that there is no single "correct way" to create LOs, but some general principles for their construction can be identified. A common metadata system needs to be developed so that each LO can be easily found and identified. The level of detail of such descriptions can vary significantly and depends on the purposes of their application.

It is necessary to compare the cost of LO decomposition and the benefit of their repeated use. The structure of LO, their permissible and necessary elements are also determined by the problems they solve. Some general aspects of LO that can be considered as requirements to their development:

- LOs are modular, that is, they can be stored and be accessed through different technological environments that are oriented on support the learning process;
- LOs are non-sequential;
- LOs are able to satisfy one or more learning goals;
- LOs are a subset of open resources that are available to a wide audience;
- LOs must be coherent with predefined schemes, that is, their semantics has to be represented with use of a limited non-empty set of metadata;
- LOs can be used in different combinations to the defined learning objective.

This set of requirements is not complete and can be expanded according to the specifics of practical problems. In the structure of LO, three main elements of educational materials can be distinguished: learning activity, content and assessment.

The Educational Modeling Language (EML) [**?**] is an example of the first implementations of a general set of notions proposed for representation the domain model for integrated e-learning. This language is based on XML and is intended for the redesign of learning courses. Its basic

principle is quite simple and requires s the separation of actions and environments: people carry out learning activities in a context that allows and/or supports them in performing these actions, that is, established by the presence of an appropriate environment and/or means of support.

There are two types of activities: learning activities performed by a student and support activities performed by a teacher. A learning activity can contain different types of learning objectives and consists of at least a description of the activity and a completed learning outcome statement that indicates when the activity is completed.

The problems of LO reuse are related to the fact that often the materials for the course are not independent objects, but they are embedded in the learning services and combine the content and the performance of practical tasks. Thus, we can single out several preconditions for the effective transformation of existing learning material into reusable LOs:

- decomposing learning materials into smaller, reusable elements requires expert time and effort, and thus becomes useful only if experts expect that they or others plan to reuse existing material;
- anticipating the reuse of LO, it is necessary to clearly define what exactly we expect as a result of the transformation of existing materials into reusable objects – direct use, reshaping (reuse in another context) or customization (reuse with adaptation to another technological environment);
- if the reuse process extends beyond the boundaries of one institution, this process requires some standardization means.

The process of LO decomposition consists of the set of checks, analysis and decision-making. Every part of existing courses has to be defined as "content", "activities" (learning or support), "assessment" or "services". This process requires several checks, analyzes and decisions, as not all existing course materials are immediately ready for decomposition: some course materials are not be available electronically, or there can have some problems with copyright or intelligent property rights restrictions. Thus, the decomposition process begins with the study of available materials and includes the following stages:

- determine which course material can be useful for reuse in new courses;
- check the availability of material for reuse: copyright and property rights;
- check the availability of the material in the original format and in a format that is acceptable for reuse.

After selecting the available material, the information is divided into separate LOs, for each of which its function in learning is determined - for example, "content", "activity", "element of assessment" or "service" and their subtypes. Further preparation of LO for reuse is mostly about content, because it is this information that can be integrated into another course with minimal changes. The following steps in the process of decomposition of LO:

- determine the smallest internally significant parts;
- check whether they are independent and self-sufficient (it is necessary that LOs do not contain any links to other LOs);

- determine the beginning and end of each significant part of LO (modularity).

After that, for re-use, a meta-description describing the semantics of this LO and its characteristics should be created for each LO. Openness of LOs is an important factor or their reuse and digital transformation of other educational elements, and such transformation of *LO repositories* (LORs) into integrated environment can be based on Semantic Web technologies.

From this point of view, important characteristics of LO are [19]:

- reusability;
- flexibility;
- accessibility;
- interoperability;
- manageability;
- scalability.

In the most general understanding, the Semantic Web is aimed on transformation of the World Wide Web content with large number of heterogeneous applications and websites into global knowledge base where individuals are connected by semantically defined relations. In much the same way, such approach can be applied to management of LOs as a specific subset of the Web content. This transformation has to cause extended means of LO search and matching with use of domain knowledge. The most important influence of the Semantic Web on the LO search deals with the forms of the practical use of LO standards applied for semantic markup of LOs. Analysis of existing LORs shows that they use various metadata schemas for general description of LO content. Meta-descriptions of LO processed by LOR services have to contain sufficient information for generation recommendations about their use in some learning courses in general and in PLTs of particular students that learn these courses. Generation of recommendations can be partially automated and provides to teacher filters in the context of current problems and more structures sets of LOs. The task of LOR services is to create semantically defined links between LOs and other information objects (courses, ontologies, competencies, etc.) and subjects (students, teachers, experts, LO authors, etc.) of learning process. LORs can be used not only for storing but also for LO sharing, and reuse. Examples of LORs based on IEEE-LOM metadata standard are: MIT Open Courseware (OCW); CLOE; VCILT; CAREO; NDMA; OLI; Commonwealth of Learning Object Repository; Ed-clicks; Encore; GEM; LOLA repository for LO and different educational activities design and store. Most of these LORs need in manual creation of LO metadata.

5. LO metadata standards and repositories

Now we have a variety of tools, repositories and environments for processing and analysis of LOs that provide their search an indexing. Learning Objects Metadata (LOM) describes LO as a source of knowledge and define various LO aspects. In this research we define LO as combination of IO and LOM that define properties of this IO that can influence on its choice for use in learning of some course or achievement of some competence. Metadata standards define various sets set of attributes that can be used to organize, locate, search and evaluate LOs.

The most widely used LO attributes are: object type, object author name, object owner name, distribution terms and object format. We analyze the most widely used metadata standards used for LO descriptions that support their reuse and availability: Dublin Core, IEEE LOM, SCORM, xAPI and IMS Global Learning Consortium.

IEEE LOM is a standard for LOM representation that provides a conceptual data scheme for LO elements. LOM facilitates LO finding, selecting, evaluating, retrieving, and sharing. This standard defines various LO aspects and dictionaries for their descriptions, defines data model and provides binding of the LOM data model to XML and RDF. LOM distinguishes the types of information resources that can be included in the LO and its metadata. LO properties in this standard are: LC description; content elements such as text, web pages, images, sound, video, etc.; LO version and status; glossary of LO terms and definitions; LO cost, copyrights and restrictions; relations with other courses; grade level, age range, typical learning time, acronyms.

Dublin Core is a general-purpose standard for representation of metadata for various types of real and digital objects. It is intended for the unification of metadata for describing a wide range of resources (real and digital) [20]. The standard contains 15 defined elements to describe the "essential" properties of information: title, creator, subject, description, publisher, contributor, date, type, format, identifier, source, language, relationship, scope, and rights. Dublin Core provides guidelines for encoding Dublin Core metadata in XML and RDF/XML to enable interoperability between different platforms, languages and systems. This general-purpose metadata standard can be used for describing of various information including LOs.

IMS Global Learning Consortium Standard [21] provides an efficient exchange of data and content between different educational platforms, facilitating the integration of educational applications with learning management systems, portals and other educational environments. However, the implementation and converting metadata formats to other standards from this standard are difficult and needs in specialists with high qualification.

Sharable Content Object Reference Model (SCORM) is the most common standard for e-learning systems that enables developers to create reusable LOs objects [22]. The purpose of SCORM is to increase the interoperability of educational materials in different e-learning systems. The scope of SCORM applications extends from simple content delivery to more complex learning scenarios that include student assessment, progress tracking and personalized learning models. The main SCORM advantages are based on its interoperability, reusability and adaptability. It is easier to implement and widely supported by existing LMS systems. Its disadvantages are the lack of widespread adoption and support among for e-learning tools and platforms.

Experience API (xAPI) is a standard that allows recording, monitoring and analysis of learning experiences both online and offline. It is designed to overcome some of SCORM's limitations, and provides ability to track a wider range of learning activities (such as reading a book, attending a seminar, or interacting with a simulation). This standard is platform-independent and can work on various technologies. The reviewed standards that can be used for LO metadata – Dublin Core, SCORM, xAPI, IMS Global Learning Consortium, and IEEE LOM – have their unique advantages and disadvantages:

- IEEE LOM standards offer a comprehensive set of recommendations for structuring and organizing of learning content and data, ensuring a high level of manageability

and scalability, but have some difficulties in implementation. The IEEE LOM standard provides a valuable framework for structuring and describing the content and data of an LO repository. Its implementation can increase the consistency, stability and scalability of the LO repository systems. IEEE LOM is the more complex standard among these five ones. The ability to create complex hierarchical relations facilitates interaction with search services.

- Dublin Core is very popular for LOM representation because it allows easy adaptation to metadata processing by software applications. It can work with RDF used for the Semantic Web resources describing. But Dublin Core is not specifically focused on LOM descriptions, therefore it can represent incorrectly some LOM elements.
- SCORM is an established standard that enables the packaging and tracking of learning content in an LMS, but it has limitations in tracking the learning experience outside of the system.
- xAPI is efficient for tracking heterogeneous learning experiences across platforms and offers detailed learning analytics, but it is difficult to implement.
- IMS Global Learning Consortium provide a wide range of standards that promote effective integration and interoperability between different learning systems and tools, despite requiring technical expertise for implementation. These standards are focused on system integration and interoperability.
- Various tools for data conversion between Dublin Core and IEEE LOM are developed, but the correct conversion requires significant costs and needs in improvement.
- LOM SCORM and xAPI standards are focused on tracking and delivering learning experiences.

All these standards indicate promising directions corresponding to the development of technologies for support of pedagogical strategies. Choosing the standard for LO repository largely depends on its specific needs and goal.

Digital repositories of LOs created both in foreign and Ukrainian universities use the metadata standards considered above. LOs into this LOR are small, semantically and functionally autonomous, reusable, indexed by metadata and open. They are cataloged for educational purposes and supported by the management, search, and access mechanisms. The metadata scheme of this LOR is based on the specifications of the IEEE LOM standard. This analysis allows us to draw the following conclusions:

- a majority of LORs are multilingual and provide open access to LOs for their registered users, but vary significantly in learning disciplines, target audience, educational level of students, and detalization of LO descriptions;
- there is no single standard approach to organization of the LOR structure, the system of LO search and semantic analysis of LO metadata;
- a significant part of LORs with large volumes of educational content is inaccessible to the general public (with commercial or corporate approaches);
- LORs use their own fixed schemas of metadata that can be converted to other representations but cannot be expanding by users according to their personal needs;

- development of integrated (centralized or decentralized) meta-LOR or unification of a certain subset of LORs with unified set of search and analytical services is advisable but not realized now.

6. Retrieval of learning objects in the Web

The considered LOM standards provide schemes for describing the most typical and common LO parameters that should be determined for all such objects. But the andragogue quite often works in situations where it is necessary to take into account for construction of PLT more specific properties of LOs, which are not usually defined into LORs. Andragogue need be able to create such additional LO properties, define their names and possible values, and then define those values for a specific subset of LOs into some individual LO storage. Let's consider several examples of such situations. *Situation 1.* One of the students studying the course is colour-blind person (daltonian) and does not distinguish colors. Therefore, it is necessary to select into student PLT such LOs that contain only monochrome illustrations and graphics. Then the andragogue creates the LO property "Type of graphic elements", which is not present in the LO standards, and defines its values "monochrome", "multicolor" and "no graphics". *Situation 2.*. Part of the student group has hearing problems and therefore cannot freely perceive video lectures. The expressiveness of most standards is sufficient to define this type of LO, but such students can use videos with subtitles in natural languages that they understand. Then the andragogue creates the "Subtitle language" LO property, which is not present in the standards, and defines its value.

Situation 3. Students have limited access (by speed or volume) to the Internet (for example, caused by blackouts), and then the andragogue tries to select LOs with smaller file sizes. A parameter such as file size is not present in all repositories (parameters such as number of pages or playback time are more often used). Andragogue can create the "File size" LO property and defines its values for LOs, which further allow choosing among LOs with similar content the most compact ones (for example, with illustrations of a lower resolution).

Situation 4. Students do not have any problems with health and technical support of the educational process, but they live in cultural environment where certain images or videos (for example, images of certain species of animals) are unacceptable by certain ethical or religious reasons, and therefore it is advisable not to expose them these students. Then the andragogue creates the "Image of animals" LO property and defines its meaning for the LO – for example, "pig" and "dog", which further allows choosing among the LOs those ones that do not cause problems for students.

Situation 5. Andragogue teaches a course to groups of students with different professional areas where they plan to use of the acquired knowledge. Therefore, it is advisable to use examples and methods related to different areas of application. For example, the "Pattern Recognition" course for medics and drone pilots can use different examples – images of the results of human research and object recognition from various cameras and surveillance satellites. It is advisable to index the examples in LO to speed up the formation of the desired course modification. Thus, all additional properties of LOs can be divided into several categories:

- properties related to the specific perception of learning materials by individual students

or groups of students;
- properties characterizing the technical features of LOs and access to them;
- properties that characterize specific elements of educational content that can cause ambiguous reactions from different communities of people;
- properties related to the specifics of the use of learning results and the possibility of creating more specialized modifications of LCs.

It is important to understand that use of such additional LO properties in a large-volume repository is impractical – it significantly reduces the search speed due to an increase in the number of processed parameters; for the vast majority of LO, the values of such properties are not be determined; it is very difficult to ensure uniformity and consistency of input of additional properties for a large number of users. Therefore, it is advisable to create more local LO repositories focused on individual use or on a relatively small community. Specifics of LO retrieval into the Web Queries that oriented on retrieval of course-relevant LOs can contain information from:

- thesaurus of the learning course [2] ;
- descriptions of learning outcomes and course competencies (more narrow requests related to the selection of educational materials for individual competencies) [23] ;
- elements of descriptions of previously found LOs;
- transformations of the thesaurus elements of the learning course to other terminology systems (for example, translation into other natural languages).
- elements of meta-descriptions of LOs related to their structure and taxonomy.

These elements can be processed by information retrieval systems (IRSs) that support search on semantic level and provide possibilities to differ query elements that represent various aspects of user information needs. Usually IRSs (such as Google) process keywords without defining of their role in the query. Search into LORs takes into account such roles but it can analyze only structures IOs with metadata placed into repository. We can partially solve this problem by use semantic IRS that proposes additional instruments in query construction and result filtering with use of knowledge about search domain.

Search of LOs in the Web requires to use semantic retrieval systems that allow to apply knowledge about the area of information interests of users to obtain more relevant results. Now such systems that differ significantly in the formats of knowledge representation, thematic orientation and request complexity are developed and proposed for utilization. Most of them are not directly focused on educational content and learning goals, but can be effectively used for these tasks. In our research, we demonstrate the possibilities of semantic search of LO on example of MAIPS retrieval system that allows users to specify explicitly the model of their information needs at different levels of understanding with use of external knowledge sources.

LO search based on *MAIPS* (maips.isofts.kiev.ua) is an example of semantic search that demonstrates how clearly defined descriptions of the user's informational interests based on the ontological model can be transformed into requests to external information retrieval system (IRS) and how filtering of the obtained results is carried out. It should be noted that this IRS, as well as the means of formalizing knowledge about the learning course, are only one of many

possible variants of semantic search and can be chosen according to the user goals and beliefs about subject domain.

MAIPS is a multi-agent IRS with advanced means of intelligent representation of user information needs. It is designed for retrieval of information in relatively narrow subject domains related to the professional or scientific interests of users. It can be considered as a recommender system, focused on the formation of recommendations for natural language and multimedia information resources (IRs) available through the Web. In this work, we consider only those MAIPS services that can be directly used for LO search.

The basis of MAIPS is the Semantic Web technologies, in particular the OWL ontology representation language. MAIPS is based on multiagent paradigm for describing system behavior and interaction between system subjects. Conception of intelligent Web services is used to describe the functionality of system elements and support their integration with other Semantic Web application. Some elements of Web 2.0 technologies (such as tag clouds applied for visualization of search thesauruses) help to adapt thesaurus models of tasks with current information needs of users. This system use domain ontologies and task thesauri to formalize sphere of user interest. Users have to select ontologies that represent spheres of their research interests from the set of domain ontologies offered on the MAIPS site by the system developers. The task thesaurus used by MAIPS is a special case of ontology that can be built by the user according to the appropriate ontology independently [2].

In the task of LO search user select the ontology of the learning course domain and then inputs the thesaurus of this learning course built by andragogue. MAIPS system is aimed at users who have permanent informational interests and need continual access to relevant information (this type of user includes andragogues who teach a set of courses in a certain domain). MAIPS enables such users to save and repeat requests, takes into account the user's reaction to previously offered results (personal filtering), monitors the appearance of similar requests from other users (collaborative filtering), stores a formal description of the user's field of interest in the form of an ontology (semantic filtering), etc. In addition, in the process of user profiling, MAIPS uses an evaluation criterion specific to natural language IRs – the difficulty of the text for understanding that can also be used to personalize learning. The specifics of this system is the use of an original knowledge-oriented algorithm that determines this difficulty of understanding the text for particular user (task thesaurus is used to select domain subset that is known to user).

User interaction with MAIPS requires much more effort at the beginning compared to the use of non-semantic IRSs or those semantic IRSs where knowledge processing is closed from the user, because MAIPS demands from users an explicit definition of their informational interests based on a formalized representation of domain knowledge. Such approach to information retrieval is oriented on highly specialized professional tasks where utilization of search experience of other people is not effective due to the small volume of similar queries. In addition, only the first access to the system takes a lot of time, and in subsequent iterations, the user's time is significantly saved due to the possibility of reuse saved requests with the possibility of making changes and clarifications in them.

Therefore, use of MAIPS is effective only if the user plans to perform repeatedly a certain set of complex queries in the subject area defined by domain ontology. Such situation is typical for andragogue who teaches a certain set of related learning disciplines in which he specializes,

who seeks to find new LOs to support the already existing structure of the learning course and to expand and refine it according to the needs of students and learning conditions. We can define some main stages of user interaction with MAIPS aimed to search LOs pertinent for learning course.

Stage 1. Registration in the system and selection of domain ontology. The user receives login and password, and then chooses an ontology that characterizes his/her area of interest (in this case, area of interest reflects domain of the learning course). Due to the fact that the processing of complex and incorrectly constructed ontologies requires a lot of time, users cannot independently include authoritative ontologies to MAIPS knowledge base. Therefore, if the list of ontologies registered in MAIPS does not contain the required one, then the user has to send pertinent ontology to the MAIPS developers and ask them to add it. After verification, if the ontology corresponds with the system conditions, it becomes available to the user.

*Stage 2.*Creating a task thesaurus for search. The user has to enter the thesaurus of the learning course. At this stage andragogue can use learning course thesaurus developed according to course content and structure. Unlike traditional thesauri, MAIPS allows users to explicitly determine the quantitative assessment (positive or negative) of each element of the thesaurus that defines importance of this thesaurus concept for current user task – for example, user can single out concepts of some lecture or competencies of particular student that needs in additional LOs. A single user can create more than one thesaurus for different aspects of his/her activity, but at least one thesaurus is necessary for every request. In addition, MAIPS provides the following tools for thesauri modifying (figure 1):

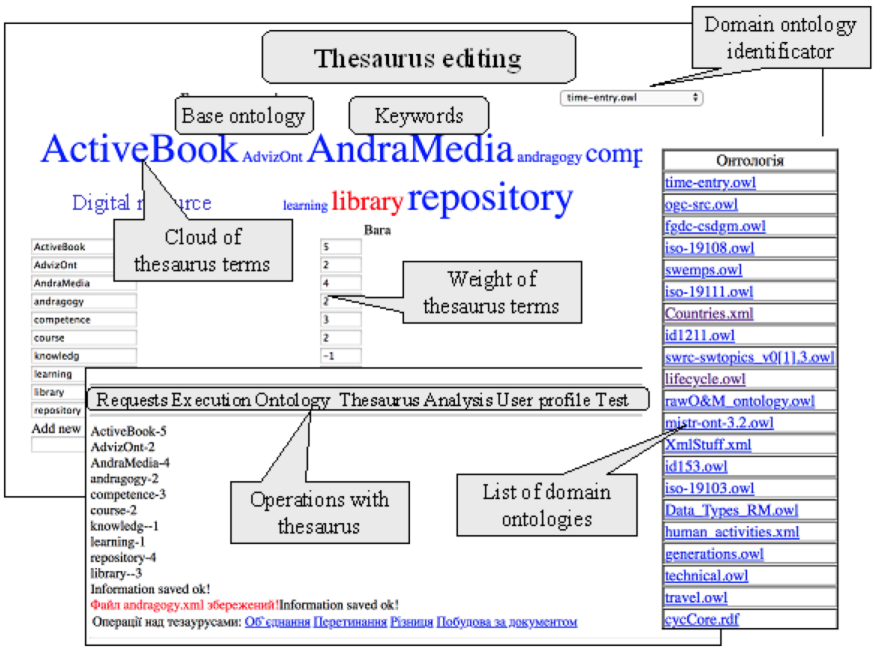

Figure 1: Editing of learning course thesaurus.

- support of the set theory operations of union, intersection, and addition on previously constructed thesauruses;
- manual replenishment thesaurus by corresponding terms from external knowledge sources;
- thesaurus replenishment by selection of the set of several classes from the basic domain ontology and expansion of this set by ontology classes that have some semantic distance from selected ones (value that is not greater than the specified by the user constant).

Andragogue can create independent thesauri for the learning course and for the LO classification (with typical elements of various LO metadata schemas that can be used for selection of representation form of information), and then combine them set theory operations according to their own needs.

Stage 3. Creating LO search request Generation of user request contains such elements (figure 2):

Figure 2: Editing of learning course thesaurus.

- choose a basic ontology;
- choose one of the previously built user thesauri;
- enter a set of keywords characterizing a specific information request;
- save the request with unique name.

Stage 4. Query execution The set of keywords from user request is redirected to external IRS (for example, Google), and then MAIPS receives the found results and reorders them according

to the number of thesaurus terms found in them and their weight. In addition, other properties of the IRs can be taken into account for ordering, for example, the user can indicate the desired level of IR reading complexity, and this parameter also affects the IR rating. If some of the found IRs have previously been offered to other MAIPS users, then ratings of these user can be taken into account either directly, or with taking into account the degree of similarity between domain of interests of these users and their thesauri that are calculated by various information about them from social networks, as well as taking into account the statistics accumulated by MAIPS.

7. Stages of local LO repository construction

The above studies showed the expediency of forming a local LO repository (LLOR) where the andragogues select the pertinent LOs (from other LORs and from the Web) according to personal criteria and supplements their meta-descriptions in accordance with their own information needs. In our previous research, we considered the feasibility of using the semantic extension of Wiki technologies to create such a repository: semantic properties and Wiki-templates allow users to describe flexibly the IO structure and import such structural descriptions from other repositories, storages and libraries. Semantic Wikis allows user to represent by semantic markup [24] an arbitrary set of properties to describe each Wiki page corresponded to LO as smart data with values that reflect personal opinion of user about this object. In order to facilitate the work of the andragogue, templates can be used in which sets of properties are already specified that correspond to various standards and schemes for describing metadata for educational objects Stages of LLOR building:

- choose a basic metadata scheme for describing LOs and other objects that can be contained into the repository (based on existing standards and examples of repositories);
- if necessary, create additional properties for the LO description, determine the types of these properties, their semantics and possible values;
- import from external repositories to LLOR those LOs that are relevant to LC that andragogue teaches or required for the work of an andragogue;
- convert the metadata of imported LOs to the LLOR scheme (automated or manually, depending on the semantic similarity between them);
- provide the Web search for relevant LOs and place them in the LLOR with creating a complete set of metadata for them in accordance with the chosen metadata scheme;
- if necessary, update the information about LOs, repeatedly performing searches both in the LORs and on the Web.

It should be noted that LO importing from repositories provides the user with more relevant results and requires less effort, because a significant part of their metadata is already defined. The Web search provides access to a much wider set of information objects but requires subsequent additional verification of their relevance to the user's interests and defining all necessary values of their metadata. Therefore, practical applications commonly use both methods.

8. Conclusion

The use of semantic technologies is a necessary condition for digital transformation of education and development of applications aimed on learning management. They provide processing and analysis of knowledge, support intelligent retrieval of digital educational materials and defining semantic links between LOs selected according to the personalized characteristics and skills of an student.

In this paper, we consider the parameters of metadata schemas that can be used for LO search in repositories and analyze practical situations that need in additional LO properties fixed into local repositories of digital educational resources.

We also substantiated the expediency of the Web search for digital resources that can be transformed into LOs and means of semantic support of such search by use of formalized knowledge about learning course. Semantic retrieval system MAIPS allows to process not only keywords and formal characteristics of retrieved information objects, but also to use a thesaurus of the learning course that describes the search domain.

LOs generated on base of retrieved digital resources are placed in a personal repository for reuse in learning process with metadata schema elements and specific properties that represent personal user beliefs about them. Such properties increases the expressiveness of the knowledge representation model and can be used both for searching and for comparing various digital objects and subjects of learning process.

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