

Supporting Ontology-Based Personalization for Improving Learning during Pandemic Situation

Tatyana IVANOVA

Technical University of Sofia

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Introduction

Scientific research in recent years has shown that ontologies can improve access and quality of information processing and propose possibilities for information processing automation in many practical fields as Information Extraction, Information Retrieval, Information Integration, E-Learning, E-commerce, Digital libraries, Bioinformatics, etc. During the COVID-19 pandemic, the need for personalized, adaptive student-centric e-learning software is increased. This need requires adaptive learning materials and its dynamic adaptation to the learners' educational needs. Ontology-based adaptive and personalized learning was discussed in grand variety of e-learning-related research projects, but in practical computer systems ontologies are still used very rarely. One of the main reasons for this is the fact that ontology development and management is difficult, time consuming, and requires some knowledge-management skills. The ontology learning is a process of (semi) automatic extraction of data, concepts, properties, relations, and axioms from a given corpus, textual document or other kinds of resources to organize them in semantic machine-processable format as ontology (Asim et al., 2016; Maedche et al., 2016). Automated ontology development and management facilitates are not integrated in application development environments, as E-Learning resource development IDEs, web development IDEs, etc. In this paper we analyze and classify an ontology learning methods and algorithms, and discuss which of them may be useful for adding as (semi) automatic ontology learning or management capabilities to Integrated E-learning Resource Development Environments (IERDE) for learning content development in E-Learning domain. Our main research questions are:

- For development of what types of ontologies in e-learning automation is important?
- What are important specifics of application of ontology learning and management in educational field and how ontology learning can improve tutoring in the context of pandemic situation, requiring wide application of e-learning?
- What ontology learning techniques are the most important to use in e-learning resource development environments?
- How to implement ontology learning and management methods and algorithms in IERDEs

Analysis and classification of Ontology Learning Methods and Algorithms

The automatic development of ontologies is a task that involves many disciplines: information retrieval, information extraction, information integration, natural language processing, and knowledge management. A lot of methods for ontology learning have been developed in recent years. Usually, the process starts by extracting terms from plain text or other type resources, recognizing them as concept names, relation names, property names, or individuals. This usually involves linguistic processing (e.g. part of speech tagging, phrase chunking). Statistical, semantic or symbolic techniques are also used. Ontology learning approaches, techniques and algorithms can be classified according to several dimensions (Figure 1.). Classifications according to all these dimensions are important for selecting and using the most appropriate methods or algorithms in every specific context.

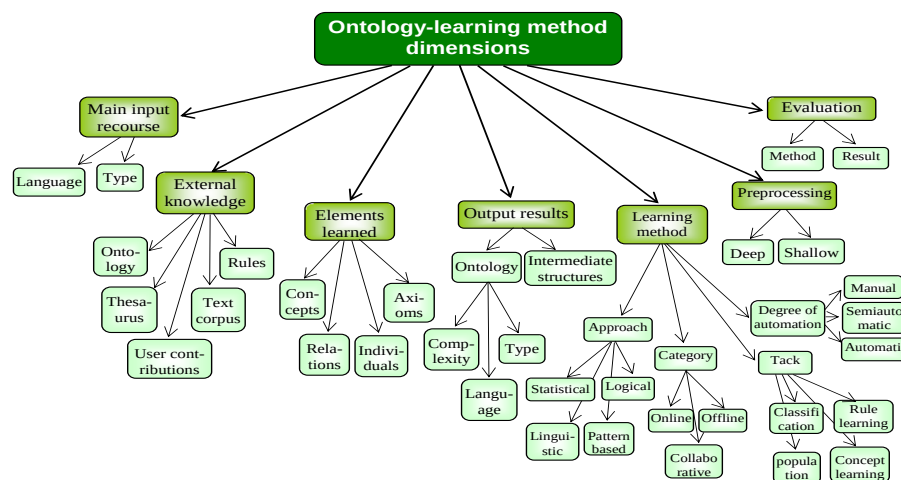


Figure 1. Main dimensions for classification of ontology learning approaches.

All three types may be used in different learning or resource development situations (see figure 2). For example, usually external (web-based) sources for LO development are HTML or plain text documents, and there are many free web ontologies, representing in machine-processable way some knowledge in almost every domain.

That is why the methods for every type of resource are needed for automating ontology learning in e-learning context (see figure 3). While highly structured data as found in databases or ontologies are proper for the application of rule-based or pure machine learning techniques such as Inductive Logic Programming (ILP), or ontology mapping, unstructured data requires some preprocessing, which are typically performed by natural language processing methods and semi-structured – NLP + document structure processing algorithms, to extract terms before recognizing or classifying them. For processing free text, the language-specific natural language processing systems (GATE's library for example, <https://gate.ac.uk/download/>) should be used. Most of the listed above approaches and algorithms are applicable both for building ontology schema (T-box) and for ontology population. Classification of ontology learning methods according to used resources is presented in Table 1.

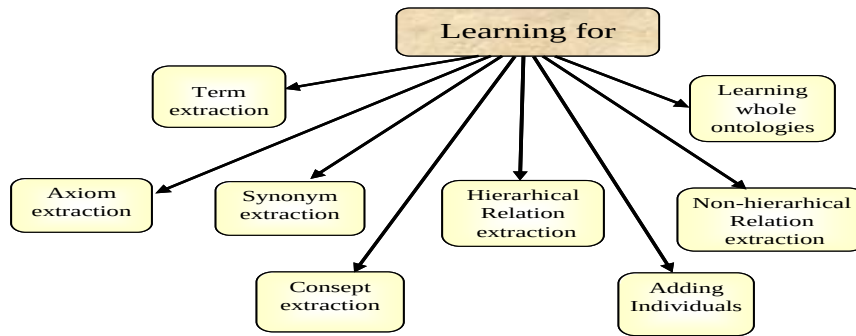


Figure 2. Classification of ontology learning algorithms according to learning elements

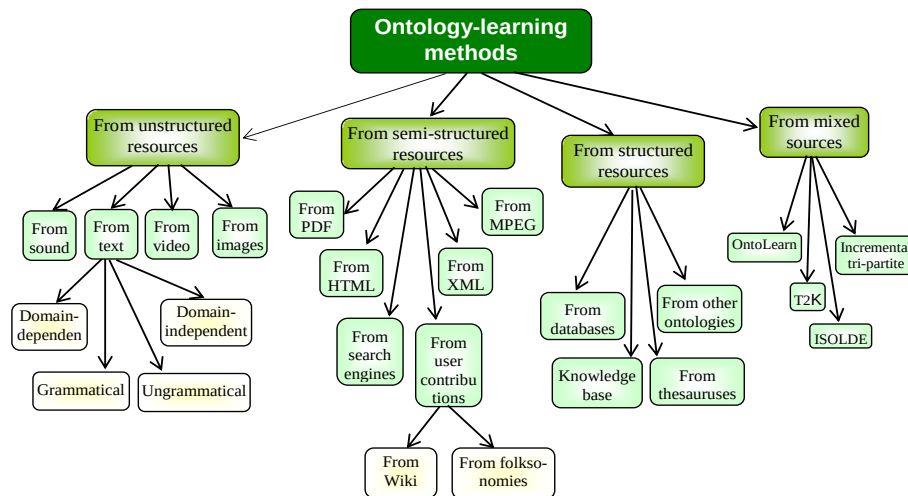


Figure 3. Classification of ontology learning methods according to used

When we concern with the concrete algorithm, it may be most appropriate for schema generation (for example, mapping – based algorithms), or for ontology population (for example, named entity recognition algorithms), but concrete usage depends from the specificity of learning task.

Ontology learning methods are far from his maturity and it is important to evaluate the quality of every method in the domains of interest. Results usually depend from the quality of used resources, as well as from the domain characteristics and requirements to the developed ontologies. As a whole, the evaluation of ontology learning procedures is still an open problem. The measurement of the correctness of the learning procedure is very important for automatic learning method selection, but it is very difficult to make good estimation, as the results depend from many external parameters, as quality of used resources, domain, concrete requirements and so on.

Table 1. *Classification of ontology learning methods according to used resources*

	Algorithm types	Subtype	Examples	Use in e - learning
Using document content	Linguistic (syntactic or semantic)	Linguistic processing	Information retrieval methods for term indexing- chunking, parsing	Extracting earning domain terminology to annotate LO
		Machine learning	SVMs, Naive Bayes, kNN (Monzur et al., 2020), multi-strategy learning and result combination	For document classification
		Word Sense Disambiguation	Differential Semantics WordNet/EuroWordNet - based	Learning synonyms, homonyms
		Pattern – based (Konys, 2018)	Hearst-patterns, Formal Concept Analysis, <i>k</i> -values, lexico-syntactic patterns	learning specific terminology and relations, synonyms, building hierarchy
		Ontology - based	Upper ontology – based, partition – based, mapping - based	For terminology extraction, resource annotation
		Thesaurus - based	WordNet based, gazetteer – based, Dictionary Parsing, Tree ascending algorithm	Extracted from LO Term and named- entity recognition
	Statistical analysis	Machine learning	SVMs, Naive Bayes, kNN, supervised or unsupervised learning	For determining the domain of the resource
		Clustering or classification text mining	kNN , hierarchical clustering, genetic algorithms, non-hierarchical clustering, Harris’ distributional hypothesis	For terminology extraction and understanding hierarchical relations
		Information retrieval	Distributional Semantics, Google-based analysis	Using external web resources
		Logical (Calegari et al., 2020)	Deductive logic programming	Resolution - based
	Quinlan’s FOIL algorithm		for classifying resources	
Inductive	(First Order Logic) based clustering, inductive logic programming		For synthesizing new knowledge from experience, and visualization of that process	
Propositional learning	Decision tree learning algorithms		Learn association rules, or other attribute-value rules	
Higher order logic	(First Order Logic) based clustering		Recognize relations by reasoning, explain reasoning	
Using document structure	Document structure - based	Information extraction	Corpus – based, Ontology learning from web, SVM (Support Vector Machine)	Estimating external web resources

The learned ontologies can be compared by evaluating them in a running application, a posteriori evaluation by experts, or evaluation by comparison of learned results

against a predefined gold standard. Manual evaluation has some advantages, since experts are supposed to know the concepts and their relationships in their domain of expertise and, but it is not feasible for dynamic ontology learning. The comparison against a gold standard is preferable when ontologies for evaluation exist.

As a conclusion we may say that there is a lot of various ontology learning algorithms. Many of them are only tested in research projects and rarely are used in practice. For enhancing and simplifying practical usage of ontology learning algorithms in the process of learning resources collaborative searching and development, they should be implemented, tested in various contexts, classified in context of its applicability, stored, described by using semantically structured programmatically processable format (may be as metaontology), and be accessible from standardized development libraries. Above presented classifications will be very useful for structured organization of ontology learning algorithms in ontology building or management libraries.

Ontology Learning for the E-Learning Domain

Ontological approach has been used in many learning resource development environments. (Bouihi et al., 2019) Defines a conceptual model that introduces an intermediate level between learning design and learning objects called the learning object context. They develop and use ontologies LOCO, based on IMS-LD, ALOCoM describing learning objects, and LOCO-Cite for the learning object context model. The CCOnto ontology describes situation-based human behavior and can be used for predicting student's behaviour including in the context of COVID-19 situation. (Ullrich, 2007). Uses resource description ontology and specific ontology mapping algorithms to access resources, distributed in distinct repositories, and axioms, operators and methods that provide a basic set of functionality to perform course generation. A presented in (Tane et al., 2004) learning resource recommender system uses a domain ontology which describes the knowledge structure of the domain. All the resources and user portfolio are described with this ontology. Resource description framework and a set of reasoning rules based on pedagogics are used to support semantic inference.

It is clear that many adaptive e-learning systems need of fast and easy development and maintenance of several type ontologies (learning domain, learner, pedagogy). Ontology learning proposes techniques to automate ontology construction tasks to simplify the ontology building and customization and decrease development time and cost. The complexity of the e-learning domain, level and specificity in requirements to educational ontologies make difficult the application of ontology learning in this domain. Latest research in the area of ontology learning is targeted to ontology learning from textual learning resources, as well as from databases and mixed web-based resources. Semi-automatic mapping of previously developed and tested small ontologies, modeling specific features of the participants of the learning process (as dyslexia ontology, LMS ID ontology or mall domain ontologies, developed by learners). So, semi-automatic mapping of previously developed ontologies is a specific approach for automation of ontology development in e-learning domain.

A framework to construct and extend Educational Ontology to describe systematic knowledge of learning subjects automatically is proposed in (Chen et al., 2021). This ontology learning framework is called ADOL, and can convert domain textbooks into a corresponding ontology automatically and efficiently. A case study on High School Physics shows feasibility and efficiency of the proposed approach.

A method to extract the possible relationships between knowledge points by analyzing e book log and mining quiz data and mining Wikipedia articles is presented in (Wanget al., 2017). This method can be implemented in an ontology-based visualization support system to support the teachers or knowledge engineers to construct course-centered ontologies semi-automatically.

A stable, web-based, multi-lingual, user-adaptive learning and authoring system for mathematics domain is proposed in (<http://www.activemath.org/Software>). It is a Semantic Web application with a number of services. Active Math's knowledge base stores semantically encoded learning objects annotated with metadata, which are encoded in a pedagogically extended OMDoc. (Li et al., 2019) uses collaboration context ontology to analyze and evaluate the success of collaborations supported by digital technologies.

Many LMS store information about learners in relational databases (RDB). In this context methods for learning ontologies from RDB are very important for fast and automatic transformation of data about learners in semantics – based format as ontologies. (Louhdi et al., 2013; Hssina et al., 2017) proposes an approach for building owl ontology from the RDB of the open source LMS Moodle. This work proposes also rules for analyzing stored data to detect disjointness and totalness constraints in automatically-generated hierarchies. The proposed technique can be applied to any RDB.

A semi-automatic approach for learning process activity ontology from event logs is proposed in (Sadeghianasl et al., 2021). Crowdsourcing and gamification techniques are used for the task of ontology learning. Semantic relations synonymy, hypernymy, holonymy, and antonymy are used in the process activity ontology. This approach can be used for learning educational process-related characteristics from logs of LMS.

Technology became crucial for learning in COVID-19 pandemic and the lockdown. It also became important for computers to be able to interpret and represent human behavior. Learner interaction with computers should be improved as it became the only tool for communication between learners and teachers during learning. (Bolock et al., 2021) present a psychologically driven computing ontology, CCOnto, describing situation-based human behavior and its relations to psychological states. This ontology also categorizes psychological factors that influence student behavior during the COVID-19 situation. It should be mapped to learner profile ontology and used in intelligent e-learning systems.

Ontology learning is the most applicable and most useful for development and evolution of tutoring domain ontologies, as changes in these ontologies are most frequent, and learning process is close to ontology learning from textual or mixed web sources in corresponding scientific domain. NLP techniques work well for knowledge

extraction from unstructured or semi-structured textual e-learning content, as these recourses are grammatically correct and have clear linguistic structure (Khadir et al., 2021). Patterns finding techniques work well when using e-learning content, as this type textual content has good and well-known structure (e.g., contains definitions, explanations, examples, etc.). (Asim et al., 2017; Somodevilla et al., 2018).

All above mentioned works use ontologies, APIs or reasoners in some way in resource and ontology development or selection process, but they can't support the whole cycle of ontology learning and evaluation for every type of ontologies, needed in adaptive e-learning environment. In the next section we will answer the question how all the functionality, needed for learning ontologies to support adaptive e-learning can be implemented in learning resource – development framework.

An Approach for Extension of Integrated Development Environments for E-Learning Resources to Ensure Ontology Learning

Ontology learning is a complex task and usually includes complex sequence of algorithms. We classify ontology learning techniques in two main classes, in dependence of its application in the main steps of the learning process: techniques for information extraction and techniques for ontology building. In many cases it is difficult to divide the complex algorithm in several simple independent subalgorithms, as it single steps may depend each other. So, complex sequences of different techniques can be dynamically generated and used in ontology learning. Clear classification and semantic description of well working modules, implementing all the needed techniques is very important for making possible automation of ontology learning.

Implementation of ontology-based information extraction techniques are needed to be added to learning content development tools (and to be integrated in integrated E-learning environments) for supporting automated ontology development and maintenance. Actual ontologies, describing learning content or learners are very important for many tasks, related to learning content development as performing automatic semantic annotation, classification of resources, etc. We will first discuss requirements to the methods and tools for automatic extraction of information from learning content and ontology building, maintenance and use, extending resource development environments, and then propose architecture for software organization of the implemented methods and tools.

Main requirements to E-learning IDE ontology learning extension

There are two main questions, related to the discussed extension: what ontology learning algorithms to integrate for facilitating E-learning resource development task, and how to organize implemented in the library algorithms.

Requirements, related to needed ontology learning algorithms

As E-learning resources may be of various types (plain text, pictures, diagrams, multimedia, and so on), algorithms for information extraction from all of these popular types resources are needed to be implemented in the library. Also, algorithms for extraction of emerged from folksonomies semantic and social intelligence, as FolkRank are needed to use voluntary social annotations for facilitating searching and

ranking web resources. So, algorithms for various input type resources, including text, graphic, multimedia, video, special pedagogical metadata, stored in databases, or folksonomies should be included in the library.

Algorithms, realized which approaches should be included in the library? Latest research shows, that ontology learning is a complicated task and no one single method or approach can guarantee high quality results. That is why all the linguistic, statistical, and knowledge-based methods should be presented in the library. As good learning resources are highly structured, pattern-based information extraction algorithms are of great importance. As e-learning systems usually incorporate a grand amount of structured knowledge and metadata, algorithms, used external knowledge would be working properly in such environments. Concept, relation and axiom extraction algorithms will be very useful in automatic analysis of free answers, as well as in automatic annotation of texts, used non described in previously developed ontologies or non traditional for learning area terminology.

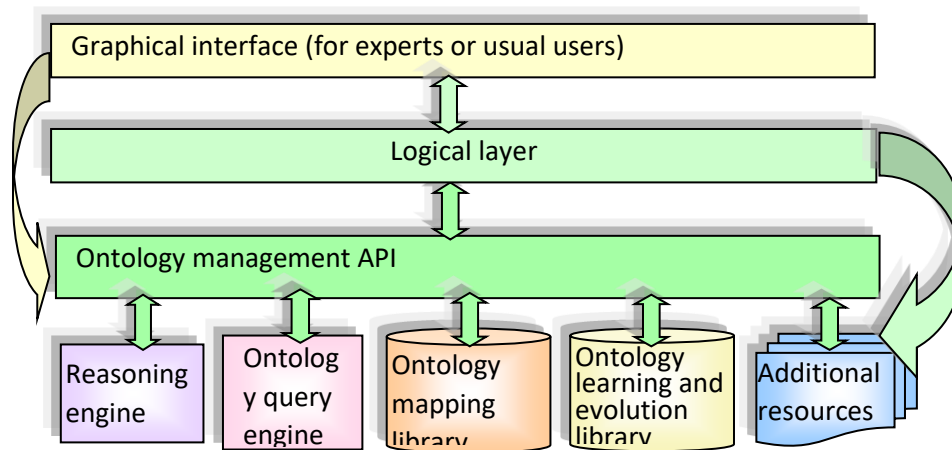


Figure 4. *The layered architecture of ontology learning extension*

Requirements for the extension architecture

The main requirements are flexibility (easy dynamic combination of algorithms); maximal simplicity (every function should realize minimal complete algorithm, not system of algorithms); presence of planning functionalities to make dynamic learning strategies; presence of evaluated good static strategies, realizing the whole complex evaluated learning algorithms; presence of metadata, describing the quality of realized methods, domains and tasks where it have been evaluated; maximal possible quality of learned ontology; recommendation assistant; graphical interface for displaying ontologies, learning process dimensions, reasoning process.

The layered architecture of the needed ontology learning extension module

Direct calling of library functions using ontology management API requires programming and knowledge management skills and is not appropriate for domain experts. As above classifications show, there are a lot of algorithms of various types, and choose the best one for concrete task isn't easy even for professionals. In order to make realized in the libraries ontology management algorithms easily usable for

teachers and LO developers, only libraries, containing realized algorithms aren't sufficient and additional software is needed. That is why we propose layered architecture of the needed ontology learning extension module (Figure 4).

On the lowest layer there are libraries, containing ontology learning and ontology mapping algorithms, reasoning engines and used resources. The reasoning engine is needed in the integrated development environment for checking the learned ontology consistency, and for reasoning in the process of resource searching and development. Learned or additional ontologies may contain instances and ontology query engine is needed for extracting those of them, relevant to specific restrictions. For every implemented function in the library, important metadata for making informed choice are stored. Quality – related characteristics of the functions in the library are domain – dependent. For every domain or specific task, in which they are tested, the precision, recall and F-measure should be stored as its important metadata.

Ontology management API includes function headers, directly invoking library functions or engine functions, or static compositions of library functions. Its usage from graphical interface is needed for example to verify and correct automatically learned ontology. Knowledge – management professionals may use it directly for performing specific tasks, but it is too complicated for LO developers and teachers. In many cases, the dynamic, context dependent composition of library functions is needed. For example as it is discussed in survey section, to analyze textual resource, syntactic, lexical and semantic analysis needed, textual resource is appropriate for pattern – based ontology learning only if it contains specific textual patterns, and statistical or knowledge-based approaches should be applied in other cases. The purpose of the logical layer is to make dynamic context-dependent function invoking and compositions, and propose various strategies for ontology mapping, learning, querying and evaluation. It ensures flexibility and automation of knowledge-management processes and for this reason. Multiagent architecture is appropriate for its implementation. This layer also supports functionality of various intelligent assistants for helping users in performing collaboration, resource searching, integration, and so on.

A number of algorithms are provided for the extraction and maintenance of the ontology elements. The most useful ones for e-learning are linguistic based methods for terminology extraction from text and some ontology learning algorithms from databases. In order to be able to combine the results of different learning algorithms, it is necessary to standardize the output in a common way. If several extraction algorithms obtain complementary results, they should be combined. All strategies for selection of basic functions to realize sophisticated learning methods, learned ontology evaluation and searching external resources in the web should be implemented in the logical layer.

By means of easy to use graphical interface, logical layer proposes various strategies and realizations of ontology learning strategies and methodologies.

Conclusion

Use of ontologies and ontology learning methods can result in more effective tools and services that increase the level of LO reusability and collaboration, effectively annotate and organize available content to facilitate effective sharing, reusability and customization. Ontology learning is the most valuable for developing and evolving tutoring domain ontologies as these types of ontologies are the most frequently used in adaptive e-learning systems and are tightly related to their specific learning content. Logically simple and terminology classification ontologies are easy to learn and most often used for resource recommendation and organization of personalized learning. Textual educational content and many other external textual or semantic resources are good sources for learning these ontologies, and possible need of frequent changes in these ontologies makes automation in ontology development very important. Semi-automatic mapping of previously developed ontologies is specific approach for automation of ontology development in e-learning domain.

To increase ontology usage and decrease the cost, many ontology learning and mapping algorithms should be integrated in E-learning resource development environments, described by sufficient amount of machine-processable metadata, and presented to the resource developers by means of user friendly graphical interface. We propose a comprehensive classification of ontology learning methods and techniques to support description and selection of ontology learning algorithms. Ontology learning and semi-automatic ontology evolution are very important for supporting actual metadata, describing e-learning resources. Well – described educational content can be in the base of personalized semantics – based tutoring. To organize personalized e-learning and resource recommendation is very important in situations when widely usage of e-learning is a must (for example, during pandemic situations, as COVID - 19 pandemy). High-quality learning content, learner interaction with computers and categorization of psychological factors that influence student behavior are important during learning in pandemic situations, requiring wide usage of e-learning. These facts lead to the increasing need of high-quality actual semantic models and importance of automated ontology development and maintenance.

We also present a flexible and scalable approach for extension of practical E-learning environments by implementing ontology learning and mapping facilitates. Practical realization of this approach require implementations (and evaluation) of many ontology learning or mapping algorithms. This big and ambitious tack will be facilitated by usage of the open research and software, developed in many resent related research projects.

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