SEMANTIZATION OF THE WEB-ORIENTED ADVISORY SOFTWARE: MODELS, METHODS AND TECHNOLOGIES

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Abstract: *We consider actual trends in use of semantic technologies for development of the Web-oriented advisory software. Requirements and expressiveness of knowledge representation in this domain cause use of ontological knowledge model, and the Semantic Web standards and tools provide the technological foundation for creation of intelligent advisory applications that use external ontologies as sources of domain knowledge.*

Personification of advisory services needs in analysis of learning outcomes of informal and non-formal learning, and therefore we propose method of their formalization with use of background knowledge about with classifications of professions and qualifications in agricultural domain. This method is based on matching of semantic properties of information objects with different structure represented by atomic competencies. Services provided by advisory system are considered from the point of view of semantic technologies. Proposed approach is used for development of applied advisory system AdvisOnt aimed to combine the market of educational services with the labor market. AdvisOnt characteristics satisfy requirements to distributed semantic application.

Keywords*: semantic application, advisory system, ontology, knowledge representation.*

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Introduction

Semantic technologies considerably change methods and models used for development of information systems. Processing and representation of knowledge becomes the significant component of such systems, influence on their functionality and effectiveness.

One of the important actual trends of intelligent information systems (IISs) deals with migration from the processing and storage of large amounts of data (Big Data, data lakes, etc.) to processing and storage of more compact knowledge acquired from this data by various techniques of Data Mining, Artificial Intelligence (AI) and Business Analytics (BI). IISs have to process information resources (IRs) with a much more complex structure and big number of relations between elements of content. Here we consider IR in the most general understanding as various data with infrastructure for its storage, retrieval and processing that can be estranged from sources and authors that is represented in digital forms that use computers, networks equipment and appropriate software. Domain knowledge formalized in various ways provide basis for semantization on all steps of information processing [Warren, 2006]. One of the most used approaches for interoperable representation of domain knowledge is ontological analysis [Guarino, Oberle and Staab, 2009].

Now semantization of the Web-oriented applications is based on standards of the Semantic Web (SW) [Decker et al, 2000]. This project is

aimed to transform the Web into global knowledge base (KB) [Berners-Lee, Hendler and Lassila, 2001] and defines the set of requirements for applications functioned in this environment. Now SW provides a large number of standards and tools for knowledge representation and processing by intelligent applications [Sabou, 2008]. The main components of the Semantic Web are:

- ontologies for knowledge representation [Obrst et al, 2007];
- Web services [Studer, Grimm and Abecker, 2007] for knowledge processing;
- software agents for representation of individual needs of users [Hendler, 2001].

SW proposes open standards that allow formalizing the semantics of information resources (IRs) and software tools for their search and processing:

- metadata description language RDF [Lassila and Swick, 1998];
- ontology representation language OWL [Bechhofer et al, 2004];
- query language SPARQL [Pérez, Arenas and Gutierrez, 2009] for RDF and OWL.

Semantic applications (SAs) are considered in this work as a subset of IISs with some specific features of knowledge processing [Hoppe, Humm and Reibold, 2018]. The most important of these features is the requirement for differentiation of processing tools and processing information: Such approach ensures use of various external knowledge bases (KBs) without changes of software, and the same KBs can be used

by different IISs without data transformation. In practice selection of the knowledge representation tools and languages depends of specifics of domain and task of IIS, but large majority of them are based on the Semantic Web standards OWL and RDF.

Semantic technologies (STs) are the technologies of software development that allows efficient creation and support of SAs aimed on meaningful processing of information. Ontology-based STs use knowledge representation grounded on ontological analysis. Effectiveness of STs depends on relevance of solved tasks with used IRs, knowledge representation models and software solutions. Therefore we have to match possibilities and restrictions of analyzed ST with information needs of potential IIS user.

In this work we consider the specific features of advisory SAs and demonstrate advantages of STs on example of the Web-oriented advisory system AdvisOnt [Pryima et al, 2020]. Advisory SA is a special case of recommender system oriented on specific classes of information objects (IOs) such as competencies, vacancies, professions, etc. such systems are defined by combination of advisory, competence and agricultural knowledge from national and international standards, KBs and IRs processed by the search and matching services.

Problem definition

Aimed by development of advisory SA, we analyze tasks caused combining of the market of educational services with the labor market that can solve problems caused by informal and non-formal learning. Therefore, we take into account specifics of educational domain, its subjects and objects and their relations into the labor market. We use

information about them from open sources and apply methods of knowledge acquisitions and semantic matching.

Goals of advisory system

Agricultural advisory systems are widely used now for fast dissemination of agricultural knowledge and information, introduction of modern scientific re- search and technologies in production, mobility and constant advanced training of agricultural specialists. Their implementation becomes an important factor in competitiveness of rural economy.

Development of the agricultural sector causes the dissemination of modern knowledge among agricultural manufacturers, relevant and efficient training and information support of their employees. In this work we describe the development of AdvisOnt. This SA is an agro-advisory system that ensures consulting services for the agricultural sector of economy. It implements an ontological representation of advisory knowledge. Now AdvisOnt provides formalization and harmonization of semantic models of advisory objects with use of semantic identification and documentation of non-formal and informal learning outcomes and competence-based representation of advisory IOs [Rogushina and Priyma, 2017].

AdvisOnt is intelligent software that provides wide number of advisory functions. This system is developed for automated semantic matching [Giunchiglia, 2009] of qualifications and competencies of various IOs (humans, organizations, learning courses, requirements of employer, etc.). Information about structure of these IOs is acquired from external KBs that represent knowledge about competence standards of various countries and international communities (selection of KBs depends on particular

task of system, and their collection can be changed and extended without changing of advisory services). From the other point of view, the set of advisory services can be changed and extended without additional requirements to external IRs.

As a SA, AdvisOnt needs in dynamically updated external knowledge sources and in non-trivial methods of their processing on semantic level with use of this domain knowledge. Therefore we have to use the Semantic Web standards that supports these possibilities that can't be achieved in other ways: system solves the problem of integration with various external KBs by use of knowledge representation based on ontological approach and SW standards. AdvisOnt provides processing of ontology formats (OWL and RDF) and their transformation into more usable representations.

Advisory services are considered as special cases of ontology matching [Shvaiko and Euzenat, 2008] where ontological structures (from one common ontology or from different ones) define compared IOs. Ontology of competencies and methods for processing of atomic competencies become the ground for semantic matching of such objects described by different terms from various qualification systems.

Related work

In general, the content of advisory services is any information relevant to the decision-making of the advisor. We consider literature review of advisory software proposed by [Mommsen-Ghosh, 2004] that defines investment advisory services and their role in solving of problem of information transmission into customer-specific process. Advisory tools vary from simple presentations to complex software for mathematical

simulations and statistical analyses. Education and the contact frequency with the advisor affect the level of his/her individual knowledge that influences on advisory results.

Advisory tools can be used either as a part of a service module where the advisor interprets the results of the tool, thereby enhancing the service brought to the customer; or they can be sold as an isolated module where the tool is put at the customers' disposal via the Web. Service modules serve as the conceptualization to understand the involved domain knowledge.

Knowledge used by advisory services includes organizational routines, processes, practices and norms, framed experiences, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information.

Modern Web-oriented systems use ontological approach for interoperable and personified representation of advisory knowledge [Erriquez and Grasso, 2008]. Important part of this background knowledge [Sabou, 2008] represents learning outcomes of various forms of learning.

Semantic technologies

Semantics allows to define explicitly meanings and relations between domain concepts represented by data (words, phrases, symbols, etc.) that depend on context. Semantics of the same piece of information, can be defined differently depending on formalization and the user's view of the world. Ontologies can be used as a formal, explicit specification of conceptualization of terms at a certain level of details [Guarino, 1998] that can fix various believes of users about some domain and process them in objective way.

In the most general understanding, semantic processing of information includes:

- means of knowledge representation that can be used to define meaning of considered IOs, their properties and relations between them;
- methods of integration and logical inference of new knowledge from existing heterogeneous information (knowledge and data);
- retrieval of IRs based on knowledge about user information needs and acquisition of knowledge from them.

Semantic processing of information by the Web-oriented SAs has some specific features:

- means of knowledge representation are oriented on the distributed heterogeneous information that changes dynamically and includes inconsistent elements;
- integration of knowledge supports various knowledge models and needs in alignment tools;
- retrieval of IRs based on knowledge about user information needs supports processing of big amounts of information (the Web resources, Big Data storages, etc.).

In [Gorodetsky and Tushkanova, 2018] STs are described through a combination of three main components: ontologies; semantic resources; models of semantics of natural language (NL) entities. This approach is concentrated on NL processing. In our study we take into account more wide classes of IOs with various structure defined by appropriate ontologies. For example, advisory systems analyze people, organizations,

vacancies, learning courses, etc. that cam contain NL definitions, multimedia elements and structured data.

We analyze use of SW technologies in design of informational retrieval systems [Gladun and Rogushina, 2009] and increase models of processed information for more general types of IO that can contain multimedia elements and structured data.

From the point of view of SA development, we distinguish three hierarchical ST components:

- ontologies and other KBs are the upper abstraction level of the knowledge structure;
- IO models represent the intermediary level that allows to distinguish typical IOs and their properties and characteristics;
- semantic IRs are the lower level that provides information about individuals of classes.

Semantic IRs can include links between content elements (IOs of various types and structure) and with elements of IO models (for example, links with other Wiki pages or with data). Meaning of links is provided by means specific for IR representation and markup. For example, Semantic MediaWiki uses semantic properties.

Semantic IRs explicitly define relations between content elements and formalized knowledge representations. Usually they use some common standards (such as MPEG21 for multimedia) or problem-specific domain ontologies. Structure of IO models can contain relations with other IOs (for example, some IO of category "Person" has semantic link with IO of category "Organizations" by relation "Place of work", and such link can be used into page content only if is present into the IO model). IO models can

be formalized by various representations such as templates and forms. Domain ontologies contain classes and individuals of concepts and formalize their properties and characteristics.

Processing of learning outcomes in advisory systems

Learning outcomes of some person consist of his/her knowledge, skills, abilities and competencies. These outcomes are statements that describe personified knowledge or skills should acquire by the end of a particular assignment, class, course or program, and define for students why that knowledge and those skills can be useful to them.

Important part of advisory services deals with processing of non-formal and informal learning outcomes that characterize a significant part of employees` competencies. Official recognition of non-formal and informal learning outcomes obtained outside formal learning systems of partial qualifications has to take into account all outcomes obtained by persons in process of lifelong learning. Lifelong learning is a key factor in personal and professional development of human defined by Global Standard for Lifelong Learning and Worker Engagement to Support Advanced Manufacturing (http://www3.weforum.org/docs). Validation of the results achieved in the process of non-formal and informal learning (knowledge, skills, competencies, etc.) with use of open educational IRs is necessary for access to the labor market and lifelong learning [Colardyn and Bjornavold, 2004]. Information about these outcomes can be proposed by person or be acquired from various external IRs.

Recognition of such outcomes that is achieved through non-formal and informal (spontaneous) learning with the help of various open educational resources is necessary for semantic matching of resumes with vacancies

of labor market and propositions of learning organizations. Validation allows the recognition of learning outcomes obtained outside the institutions of formal learning (in non- formal and informal education) and is necessary for access to the labor market and lifelong learning [Pryima, Rogushina and Strokan, 2018]. In previous research we produce some algorithms that provide matching of non-formal learning outcomes with more formal advisory IOs on base of atomic competencies that are used as values of semantic properties for IOs with different structure [Rogushina and Pryima, 2017].

The tools used in this process have to take into account changes in the open world and be dynamic, and they need in semantic retrieval components based on ontological models of user and domain [Pryima et al, 2020].

Ontologies in semantic advisory system

Ontological analysis is widely used now for formal modeling of various domains [Gruber, 1991]. Ontology provides a formal explicit description of domain concepts (classes and individuals), their properties, attributes and relations. Moreover, ontology can contain some domain-specific restrictions on use of all these elements and their combinations. Modern intelligent applications use ontologies as interoperable KBs [Staab and Studer, 2013].

A lot of SW-oriented SAs use ontologies as a source of domain knowledge for semantic markup of various documents (NL texts, Wiki resources, other semi-structures and structured texts, multimedia context etc.) and for creation of their metadata. For example, Wiki resources can be semantizied in this way. Widely used semantic markup of the Web resources is realized by various intelligent extensions of the Wiki resources (such as Semantic MediaWiki [Krötzsch, Vrandečić and Völkel,

2006], OntoWiki [Auer, Dietzold and Riechert, 2006], IkeWiki, SemanticXWiki, and KawaWiki [Kawamoto, Kitamura and Tijerino, 2006]). There is a number of Wiki software that provides semantic functionality. Some of them are standalone Wiki applications, and others are realized as extensions or plugging to standard Wiki software. Semantic Wiki-based IRs differ in their degree of formalization. Some of them support integration with external ontologies (RDF and OWL) and can generate local ontologies for group of the Wiki pages. For example, Semantic Media Wiki provides to users such tools of semantic structuring as categories and semantic properties.

Advantages of the ontological approach for semantic representation for learning domain and competencies ([Miranda et al, 2016], [Lundqvist, Baker and Williams, 2017]) are substantiated by many researchers. The most important reasons for their use deals with:

- explicit representation of knowledge with unambiguous interpretation,
- availability of common standards, languages and tools;
- theoretical background of descriptive logic.

Categories help to link Wiki pages with more general terms and group them, and semantic properties allow defining various semantic features and their values of concept linked with some page. Categories and semantic properties of the Wiki pages can be used as classes and object properties of domain ontology, and names of Wiki-pages – as individuals of ontology. Such domain ontology can be built automatically by special functions of Semantic Media Wiki or by special algorithms according to personal needs of users. Unfortunately, there are no logical or semantic restrictions on ontology building in Semantic Media Wiki. Therefore,

ontologies provided such possibilities remain the important content of semantic technologies as a source of domain knowledge

In order to support the process of validation of learning outcomes in both formal and non-formal and informal learning, the European Commission has developed a free internet portal for multilingual classifier ESCO (European Skills, Competencies, Qualifications and Occupations – https://ec.europa.eu/esco/portal/home). ESCO that joins the labor markets of the EU member states and allows jobseekers and employers to communicate more effectively with definitions of skills, training and work in all European languages. The main elements of ESCO are professions, skills and qualifications related to the labor, education and training market in the EU (see Figure 1). Current number of these IOs is represented on ESCO Web-site.

Figure 1. ESCO taxonomy of professions and skills

ESCO allows users to determine what knowledge and skills are usually required to work in a particular profession. Important feature of ESCO is orientation on multi-linguistic information. Each ESCO concept is associated with at least one term in all ESCO languages. Thus, ESCO is a source of information on competencies relevant to the labor market in the international dimension, both for the development of higher education standards and for the review of educational programs in higher education, given that professional standards are currently lacking in many professions. ESCO is published as Linked Open Data, and developers can use RDF format. In this work we consider ESCO as source ontology for semantic application that needs in information about structure of skills and competencies. Information from ESCO can be used for creation of IO structure for advisory SAs.

AdvisOnt architecture

The general architecture of AdvisOnt defines relations between main subjects of advisory activities (see Figure 2):

- applicant – person needed in some work in agricultural domain and has a set of relevant competencies and skills;
- employer – person or organization needed in employees for execution of some task or work on some position;
- providers of learning services – organizations that propose various (formal, non-formal and informal) learning means for expansion of personal competencies;
- advisors – experts specialized in agricultural domain of fixer region that can use domain knowledge for refinement

of mutual interests of employers and applicants and provides advising services if applicant qualification needs in additional learning according to employer demands.

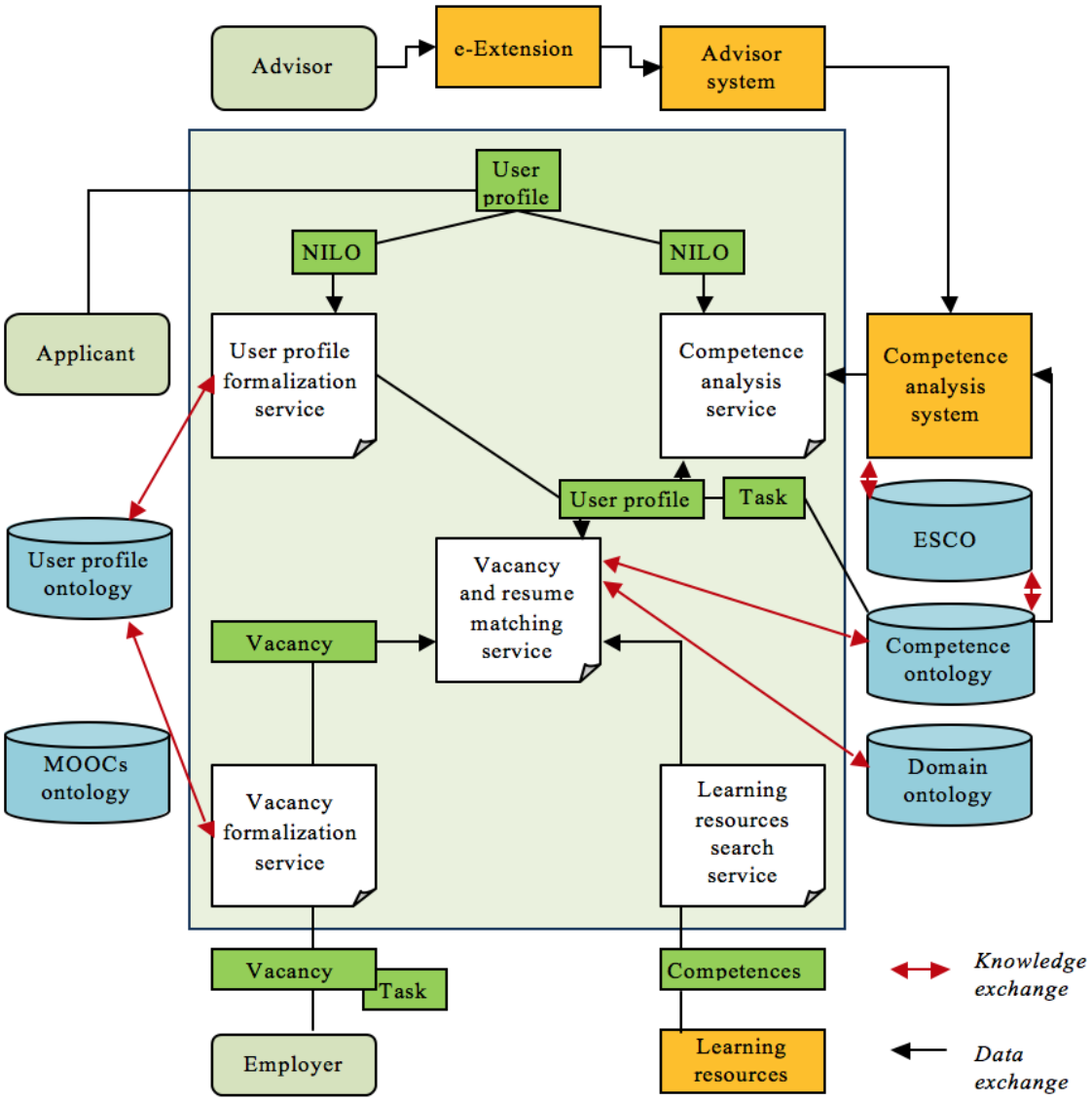

Figure 2. General architecture of AdvisOnt advisory system

AdvisOnt provides the set of traditional advisory services such as:

- user profile formalization;
- generation of formalized resumes;
  - vacancy formalization;
  - matching of resumes and vacancies;
  - matching of resumes and learning courses;
  - recommendation of learning programs.

It is important that all these services can use not only built-in knowledge but support export of domain knowledge from external KBs. AdvisOnt helps in interaction between expert-advisor and other subjects by e-Extension interface and uses external semantic IRs and knowledge bases: ESCO as a source of structured representation of domains competencies and qualifications; user profile ontology to determine the structure of the applicant's model; domain ontologies containing facts and rules of specific agricultural tasks; expert knowledge and soft skills used for semantic formalization and matching of vacancies and resumes; ontology of open online learning services (such as Massive Open Online Courses (www.mooc.org)).

All classes of ESCO ontology used by AdvisOnt are stored into Turtle file. SPARQL queries and connectors are used for selection of skills and occupations from this RDF repository. The answers of SPARQL queries can be represented as result sets or RDF graphs. In the same way, the results of requests are returned to the RDF repository. Analysis of this ontology is used to define semantic similarity estimates for competence concepts [Rogushina, 2019]. Domain ontologies are integrated into the RDF repository with use of database of semantic graphs GraphDB. This database complies with W3C standards and links data from various IRs,

indexes them for semantic search and uses elements of NL analysis. GraphDB connectors provide fast search for keywords and aggregations usually realized by external services with use of synchronization on level of entities defined by URI, properties and property values.

Semantic components of AdvisOnt

We can distinguish such components of SA that AdvisOnt contains:

- external KBs represented by ESCO ontology, MOOC ontology for learning courses, various agriculture domain ontologies and user profile ontologies from other IISs and internal ontology of competencies and qualifications;
- ontological models that formalize structure and features of typical advisory IOs AdvisOnt (competencies, skills and professions, applicants, vacancies and resumes, etc.) that supports system integration with other SAs;
- semantic IRs used by AdvisOnt that contain markup based on structure of typical IOs and provide additional actual information about individuals of classes: semantic Wiki resources that can contain marked NL text and multimedia – such as vue.gov.ua (see Figure 3).

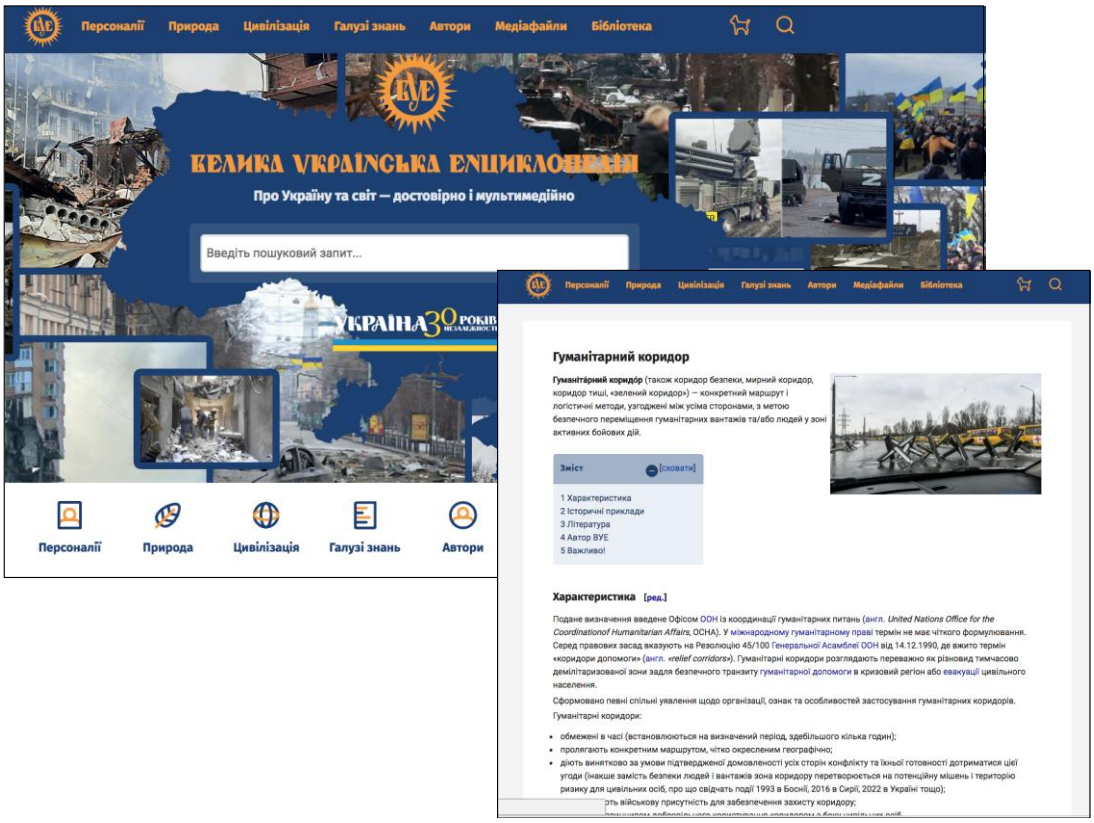

Figure 3. Example of Semantic Wiki resource pages.

External semantic Wiki resources and domain ontologies that are used for their semantic markup provide AdvisOnt by current and dynamic information from open environment and support system adaptation to new tasks.

All these elements are integrated with the help of AdvisOnt ontology that defines relations between main components of advisory process and information sources used in this process. Main class that is used as object property for other AdvisOnt IOs is “Competence” (see Figure 4). is

“Competence” (see Figure 4). AdvisOnt ontology shows the meaning of relations between subjects (employers, tutors, organizations and persons) and objects (competencies, skills, professions, resumes, vacancies) with the help of names and annotations of relevant object properties.

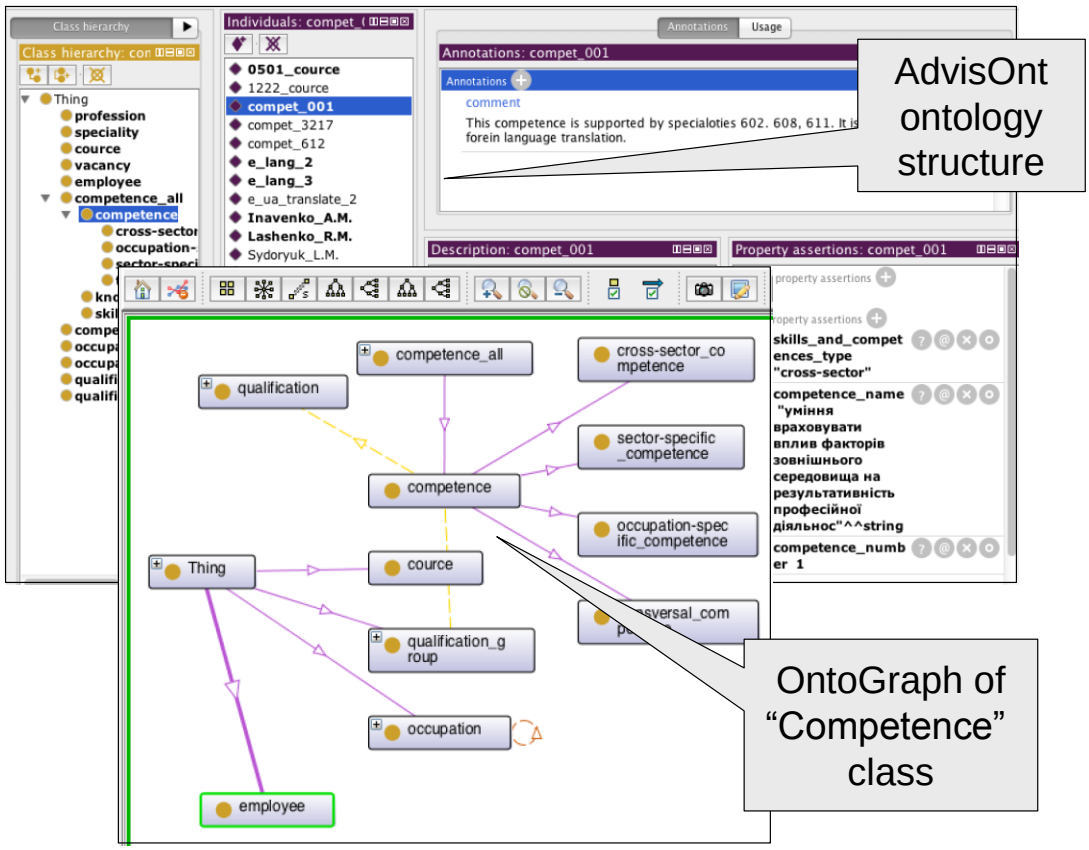

Figure 4. AdvisOnt ontology

AdvisOnt as semantic application

We match characteristics of AdvisOnt and can consider this application as SA (according to SA requirements from Semantic Web Challenge. URL: http://challenge.semanticweb.org/) because it requires the most important SA conditions [Pryima, Strokan et al, 2020]:

- AdvisOnt supports personified interaction for potential employers and job seekers based on use of personal intelligent agents that acquire user preferences from his/her profile;
- registration services for vacancies and resumes transform used terms according to common terminology on base of analysis of their semantic (with the help of NL texts markup bases on ESCO and other domain ontologies);
- comparison of resumes and vacancies is executed with use of semantic similarity evaluations of domain terms and semantic relations between professions, knowledge, skills, competencies and qualifications defined by ESCO ontology;
- search of educational services and training courses is personified on base of analysis of formal, informal and non-formal learning outcomes of person (processing of the informal and non-formal learning results is a specific feature of AdvisOnt that differs this system from similar ones);
- system provides comparison of requires professions from vacancies with training courses and programs that can improve employee competencies for vacancy satisfaction –

on base of ontological model of atomic competencies [Gladun, Khala et al, 2015].

We can rate AdvisOnt as semantic application because this IS conforms to the requirements of the Semantic Web Challenge: Minimum requirements of the Semantic Web application for AdvisOnt can be interpreted like this:

- data meaning plays a key role in its functioning: AdvisOnt process meaning of vacancies and resumes with use of ontologies to link various terms with concepts and realize original non-trivial approach based on atomic competencies for matching of IOs that cannot be obtained without analysis of their semantics;
- AdvisOnt uses ontologies and IRs from different owners (ESCO, MOOCs, etc.) that can be hanged by other ones (for example, by ontology of national qualification system or other e-learning platform) without changes of software, these sources are heterogeneous syntactically (ontologies, Wiki IRs, thesauri, etc.) and semantically (use different NL languages and describe various domains), and contain real-world data used by other commercial applications;
- Search for information is carried out in the real information space of the Web: results of AdvisOnt depend on user requests and actual information retrieved from the Web about vacancies, resumes and learning courses.

AdvisOnt works into the open information space, i.e. recommendations are not absolutely optimal but are based on available data and knowledge of system. This system is based on processing of semantic IRs that are

represented on languages developed by the Semantic Web – RDF and OWL.

Conclusion and future work

Semantization of the Web-oriented advisory software needs in specific models of knowledge representation, methods of their processing and integration with up-to-date distributed information technologies. In this research we consider advantages and problems caused by semantic approach to development of applied advisory software.

Results obtained in process of AdvisOnt development show necessity in methods and software tools for automation of semantic markup of the Web information resources (natural language and multimedia) and for retrieval of domain ontologies that can become a meaningful basis for this markup. Other important problem deals with dynamics of information that can be acquired from available data. Therefore we propose to increase the set of traditional advisory services by elements of artificial intelligence and machine learning.

The advisory Web-oriented intelligent system AdvisOnt, developed by us, expands the functionality of traditional advisory systems by validating the results of informal and informal learning, applying ontological representation of domain knowledge and semantization the services proposed to users. An important feature of AdvisOnt is the focus on interoperable knowledge representation formats based on SW standards, which provides the ability to apply new external ontologies without additional changes in the basic architecture of the system.

Semantization of the advisory system requires external sources of information regarding various elements of advisory activity, in particular,

repositories of ontologies, electronic encyclopedias and dictionaries, data obtained from social networks. The analysis of information in AdvisOnt performed at the semantic level uses this knowledge to compare the values of various complex IOs and their advanced characteristics (hierarchical relations with other IOs, synonymy, homonymy, semantic similarity of concepts and relations, etc.). Competence classification systems, information about open educational resources, the structure of user profiles and the needs of employers should be obtained from relevant ontologies.

One of the most important tasks of AdvisOnt development is a generation of the theoretical basis for comparison of real and reference competencies, which is included in the analysis of competencies by the apparatus of atomic competencies. Such fixed finite sets of atomic competencies are acquired from NL descriptions of professions, qualifications, vacancies, etc. and various learning courses and disciplines.

Employees obtain a significant part of new knowledge and skills as a result of informal and non-formal learning, and informality of such learning results greatly complicates their analysis and matching with vacancies. Differences in the terminological base and competence classification systems of educational institutions and the requirements of employers require the use of the domain knowledge for their semantic comparison.

We associate the further development of AdvisOnt with algorithms and methods of Data Mining and Machine Learning to solve the problems of classification, clustering and prediction that provide separate policies for semantically similar groups of users.

In addition, we plan to integrate AdvisOnt with social networks, retrieval and recommender systems that can both import information from AdvisOnt

user profiles to adapt work of these software to the individual needs of users and export knowledge about users to supplement their profiles in AdvisOnt. Social networks are carriers of Big Data, so we plan to use semantic analysis of metadata to select and filter relevant, reliable data obtained from the external environment and for selection of relevant ontologies in repositories.

The increase and accumulation of knowledge into AdvisOnt on base of the integration with a wide range of national and international knowledge bases and structured information resources ensures the improvement of its services.

Bibliography

[Auer, Dietzold and Riechert, 2006] Auer S., Dietzold S., Riechert T. (2006): OntoWiki – a tool for social, semantic collaboration. In: International Semantic Web Conference, pp. 736-749. Springer, Berlin, Heidelberg.

[Bechhofer et al, 2004] Bechhofer, S., Van Harmelen, F., Hendler, J., Horrocks, I., McGuinness, D. L., Patel-Schneider, P. F., & Stein, L. A. (2004) OWL web ontology language reference. W3C recommendation, 10(2), 1-53. https://www.w3.org/TR/owl-ref/. Last accessed 6 Feb 2021.

[Berners-Lee, Hendler and Lassila, 2001] Berners-Lee T., Hendler J., Lassila, O.: (2001). The semantic web. Scientific american, 284(5), pp.34-43. DOI 10.1038/scientificamerican0501-34.

[Colardyn and Bjornavold, 2004] Colardyn, D., Bjornavold, J.: Validation of formal, non-formal and informal learning: Policy and practices in EU

member states. In: European journal of education, 39(1), 69–89, 2004. DOI:10.1111/j.0141-8211.2004.00167.x

[Decker et al, 2000] Decker, S., Melnik, S., Van Harmelen, F., Fensel, D., Klein, M., Broekstra, J., ... & Horrocks, I, (2000) The Semantic Web: The roles of XML and RDF. IEEE Internet computing, 4(5), 63-73.

[Erriquez and Grasso, 2008] Erriquez, E., Grasso, F. (2008). Generation of personalised advisory messages: an ontology-based approach. In Proceedings of 21st IEEE International Symposium on Computer-Based Medical Systems, pp. 437-442). DOI:10.1109/CBMS.2008.103.

[Giunchiglia, 2009] Giunchiglia F. Giunchiglia F., Shvaiko P., Yatskevich M. Semantic matching. Encyclopedia of Database Systems, 2009.

[Gladun et al, 2015] Gladun, A., Khala, K., Sammour, G., Al-Zoubi, A., Schreurs, J. (2015) Semantic web and ontologies for personalisation of learning in MOOCs. In: Proceedings of IEEE 7th International Conference on Intelligent Computing and Information Systems, ICICIS-2015, 185–190. DOI: 10.1109/IntelCIS.2015.7397219.

[Gladun and Rogushina, 2009] Gladun A., Rogushina J. (2009): Use of Semantic Web technologies in design of informational retrieval systems. In: Book "Building and Environment, pp.89-103.

[Gorodetsky and Tushkanova, 2018] Gorodetsky, V.I., Tushkanova, O.N.: Semantic technologies for semantic applications. Part 1. Basic components of semantic technologies, In: Artificial Intelligence and Decision Making, 4, 61-71, (2018). DOI:10.3103/S0147688219050022

[Gruber, 1991] Gruber, T.R. (1991) The role of common ontology in achieving shareable, reusable knowledge bases, Kr, 91, 601-602,

https://pdfs.semanticscholar.org/0256/614d1dc55962708db9b791f70a29370f1d76.pdf. Last accessed 6 Feb 2021.

[Guarino, 1998] Guarino N. (1998) Formal Ontology in Information Systems. Formal Ontology in Information Systems. Proc. of FOIS'98, 3-15. https://www.ukma.edu.ua/~gor/courses/AIUS2009/LecturesAndMaterials/Formal%20Ontology%20and%20Information%20Systems.pdf. Last accessed 6 Feb 2021.

[Guarino, Oberle and Staab, 2009] Guarino N., Oberle D., Staab S. (2009): What is an ontology?. In: Handbook on ontologies, pp. 1-17. Springer, Berlin, Heidelberg.

[Hendler, 2001] Hendler, J.: Agents and the Semantic Web, IEEE Intelligent systems. 16(2), 2001.30-37. DOI: 10.1109/5254.920597.

[Hoppe, Humm and and Reibold, 2018] Hoppe T. , Humm B. G. , Reibold A. (2018) Semantic Applications – Methodology, Technology, Corporate Use. Springer Verlag, Berlin. 2018. pp. 1-12.

[Kawamoto, Kitamura and Tijerino, 2006] Kawamoto K., Kitamura Y. and Tijerino Y. (2006). Kawawiki: A semantic wiki based on rdf templates. In: Proceedings of 2006 IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology Workshops, pp. 425-432.

[Krötzsch, Vrandečić and Völkel, 2006] Krötzsch M., Vrandečić D. and Völkel M. (2006). Semantic mediawiki. In: Proceedings of International semantic web conference, pp. 935-942. Springer, Berlin, Heidelberg. link.springer.com/content/pdf/10.1007/11926078_68.pdf. Last accessed 6 Oct 2022.

[Lassila and Swick, 1998] Lassila O., Swick R. (1998) Resource Description Framework (RDF) Model and Syntax Specification, W3C Recommendation. http://www.w3.org/TR/REC-rdf-syntax. Last accessed 6 Feb 2022.

[Lundqvist, Baker and Williams, 2017] Lundqvist K.O., Baker K.D., Williams S.A. An ontological approach to competency management, 2017, http://www.eife-l.org/publications/proceedings/ilf07/Contribution110.doc.pdf. Last accessed 5 Feb 2021.

[Miranda et al, 2016], Miranda, S., Orciuoli, F., Loia, V., Sampson, D.: An Ontology-based Model for Competence Management, Data and Knowledge Engineering, 107, 51-66, 2016. https://doi.org/10.1016/j.datak.2016.12.001.

[Mommsen-Ghosh, 2004] Mommsen-Ghosh, D. (2004). Ontology Based Repository for Specifying Investment Advisory Services as a Knowledge Product. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.144.4017&rep=rep1&type=pdf

[Obrst et al, 2007] Obrst, L., Ceusters, W., Mani, I., Ray, S., Smith, B.: The evaluation of ontologies Semantic Web. In: Springer US. 2007, pp. 139–158.-http://philpapers.org/archive/OBRTEO-6.pdf. Last accessed 12 Feb 2021.

[Pérez, Arenas and Gutierrez, 2009] Pérez, J., Arenas, M., & Gutierrez, C. (2009). Semantics and complexity of SPARQL. ACM Transactions on Database Systems (TODS), 34(3), 1-45. https://doi.org/10.1145/1567274.1567278.

[Pryima et al, 2020] Pryima, O., Rogushina, J., Gladun, A., Mozgovenko, A. Ontology-based Methods and Tools for Validation of Non-formal Learning Outcomes. 12th International Scientific and Practical Conference of Programming (UkrPROG 2020), CEUR Workshop Proceedings, 2866 50–60, (2020). http://ceur-ws.org/Vol-2866/ceur_50-60Priyma5.pdf. Last accessed 12 Feb 2021.

[Pryima, Strokan et al, 2020] Pryima, O., Rogushina, J., Gladun, A., Lubko, D., Malkina, V.: Ontological Analysis of Outcomes of Non-formal and Informal Learning for Agro-Advisory System AdvisOnt, International Conference on Technologies and Innovation, pp. 3-17, Springer, Cham, (2020). https://link.springer.com/chapter/10.1007/978-3-030-62015-8_1. Last accessed 12 Feb 2021.

[Pryima, Rogushina and Strokan, 2018] Pryima, S., Rogushina, J., Strokan, O.: Use of semantic technologies in the process of recognizing the outcomes of non-formal and informal learning, 11th International Conference of Programming UkrPROG, CEUR Workshoop Proceedings, 2139, 226–235, (2018). http://ceur-ws.org/Vol-2139/226-235.pdf.

[Rogushina, 2019] Rogushina, J.: Use of Semantic Similarity Estimates for Unstructured Data Analysis, XIX International Scientific and Practical Conference "Information Technologies and Security" (ITS 2019), CEUR 2577, 246-258, (2019). http://ceur- ws.org/Vol-2577/paper20.pdf. Last accessed 8 Dec 2020.

[Rogushina and Pryima, 2017] Rogushina J., Priyma S. (2017) Use of competence ontological model for matching of qualifications. In: Chemistry: Bulgarian Journal of Science Education. 2017. Vol. 26. N 2

[Sabou, 2008] Sabou M. Exploring the semantic web as background knowledge for ontology matching / Sabou M., d'Aquin M., Motta E. // Journal on Data Semantics,(2008). DOI:10.1007/978-3-540-92148-6_6.

[Shvaiko and Euzenat, 2008] Shvaiko P., Euzenat J. Ten challenges for ontology matching. Proc. of the 7th International Conference on Ontologies, DataBases, and Applications of Semantics (ODBASE), 2008. https://hal.inria.fr/hal-00825956/document

[Staab and Studer, 2013]. Staab, S., Studer, R.: Handbook on ontologies, Springer Science and Business Media, (2013).

[Studer, Grimm and Abecker, 2007] Studer, R., Grimm, S., Abecker, A.: Semantic web services. Springer, (2007).

[Warren, 2006] Warren P. Knowledge Management and the Semantic Web: From Scenario to Technology. IEEE Intelligent Systems. 2006. V. 21, 1.53-59.

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