Adult Learning Ecosystem: Ontological Approach for Integration of Services for Andragogue Activities*

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Abstract

This study is devoted to the problems of the andragogue activities informational support based on use of semantic technologies and knowledge management models. aimed at the analysis of educational content. In this work we analyze the use of ecosystem paradigm for modeling the learning process that takes into account the specifics of adult students and analyze service-oriented approach for representation of andragogue activities.

We consider existing ecosystems developed for modeling of software design and learning process and select their components that can be used in adult learning and represent specifics of this domain that influence on selection of semantic technologies used for facilitation of andragogue activities.

We develop an ontological model of the ecosystem of adult learning that defines relations of its biotic and abiotic components and provides the basis for descriptions of the semantics of intelligent services used for learning support. Examples of service integration bases on this model are considered.

Keywords

Adult learning ecosystem, ontology, andragogue activities, intelligent service

1. Ecosystems as a modeling paradigm for collaborative activities

In our study aimed to highlight the specifics of the adult learning we use ecosystem paradigm as a background for the integration of andragogue activities with semantic technologies that support these activities. Ecosystem of adult learning use relevant components of various ecosystems of software and digital learning supplemented by specific andragogue objects and characteristics of ecosystem components.

Andragogues are specialists who carry out teaching, educational, methodical, research, project, cultural and leisure activities in the field of adult education. Andragogues can be considered as drivers of modern transformations and professional "agents of change" [1] who have a wide range of competencies that allows them to implement professional activities in the conditions of formal and informal education of adults, taking into account the possibilities of informal learning [2]. EU Council Resolution on the new European agenda for adult education for 2021-2030 [3] predicts that

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the competence potential of adult education professionals, the definition and verification of their key competencies can become additional value in the field of life-long education. The professional activity of andragogues makes it possible to meet the cultural and educational needs of various target groups of adults in accordance with personal learning trajectories constructed for optimization of forms, methods, technologies and content of learning. These complex tasks require both means of modeling the learning process with appropriate expressiveness, and the use of modern technologies of knowledge analysis to support the main types of andragogue activities.

The ecosystem paradigm is quite widely used not only as a description of the cohabitation of a certain set of living organisms (ecological objects) in a common environment, but also as a metaphor for modeling various types of systems characterized by a fixed set of subjects, objects and types of interaction between them during joint work (for example, the educational process, software development) [4]. Each ecosystem subject has its own set of interests and goals that can be carry out in relations with activities of other subjects and the ecosystem as a whole.

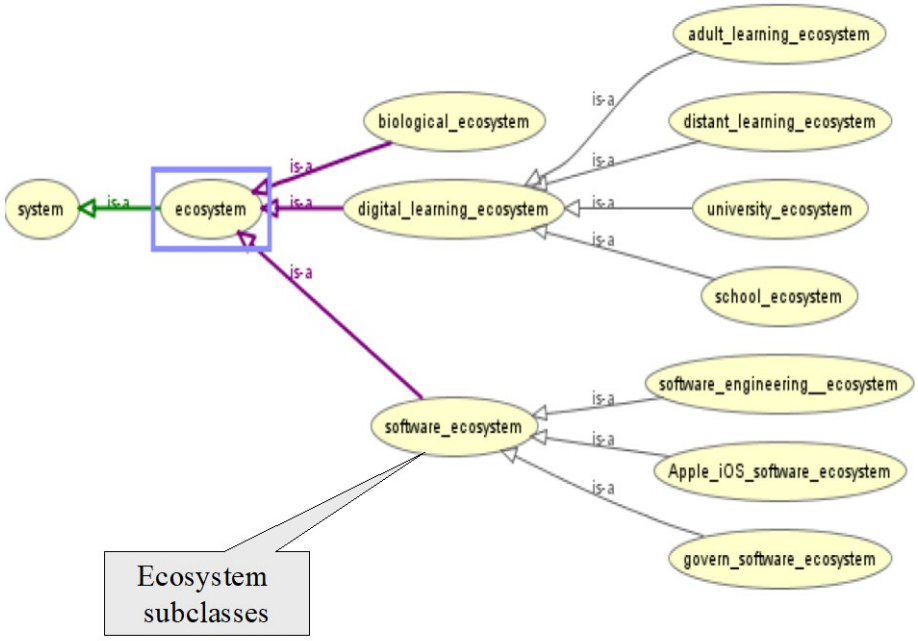

Figure 1: Taxonomy of ecosystems (fragment)

Activities of ecosystem determine their functions and the services that these subjects can provide to each other. In this context, it is possible to distinguish biotic and abiotic components of the system that are determined depending on its specifics (Fig. 1). Such modeling, in contrast to system analysis, enables increased attention to common resources, the cyclical nature of their use and formation, as well as the interaction between relatively independent subjects of the system in the process of using these resources. In the most general case, use of resources reflects the exchange of information that has a certain value for both sides between system components.

We propose to use this paradigm as a base for modeling of collaborative activities of andragogue that define their relations with other elements of learning process. Let's consider main features and components of these ecosystems.

2. Software ecosystems

Software Ecosystems (SECO) are intended for modeling the process of design and programming large-volume information systems from heterogeneous components developed by both internal and external participants that use some common software platform. SECO allow describing the activities of software developers and users by displaying the results of such activities [5]. At the high level of abstraction, software ecosystems can be considered as sets of organizations that have various

relations with software and services, their development and use [6]. They differ by technological platforms(such as iOS, Android), users (such as scientists, managers, educators, government [7], environment, etc.

Historically, the first definition of SECO [8] given in 2003 describes a software ecosystem as a set of software products developed together in one technological environment. Some authors add to this definition a set of companies-developers that interact with the common market of software tools, applications and services together on the basis of a common technological platform and exchange information, resources and artifacts [9]. Most definitions of SECO refer to software (software systems, products, services, software platform, etc.), software engineering and various aspects of its relations with people (developers and users), both technical and social, economic.

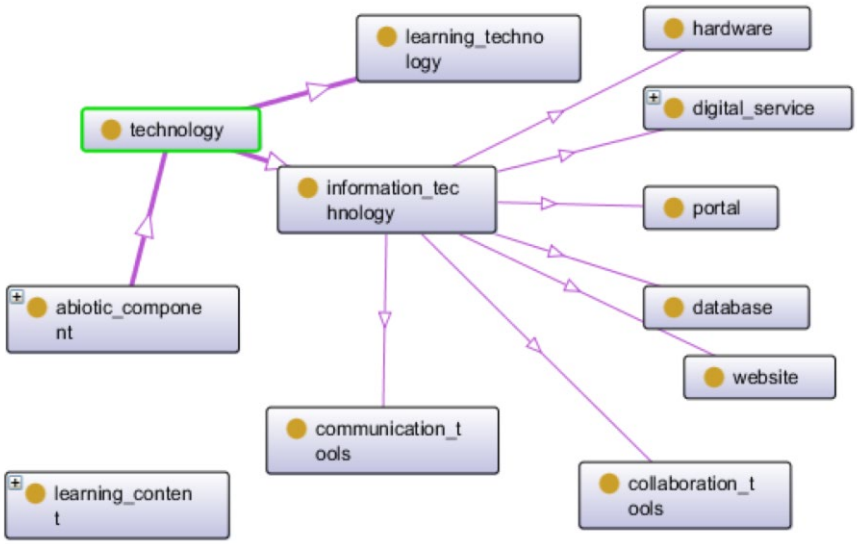

Figure 2: Representation of information technologies into adult learning ecosystem based on SECO (fragment)

Thus, the software ecosystem represents the interaction of a non-empty set of participants on a common technological platform that results a set of software solutions and services. The adult learning ecosystem can use SECO components to describe the features of information technologies, software platforms and services that are created to support the work of andragogues. The implemention of SECO components makes it possible to determine the relations of andragogues and students with software developers that support the learning process and to formalize the requirements for information technologies and knowledge analysis models that these technologies provide (Fig.2).

3. Digital learning ecosystem

Digital learning ecosystem (DLE) is used to model the educational process and its environment, as a rule, using various types of digital learning resources and intelligent learning tools [10, 11]. In DLE, biotic components are students, teachers of educational institutions, and other physical and legal persons participating in the educational process. These biotic components can create, change and share abiotic components of, such as educational resources, equipment, technologies, and tools [12]. Some researchers extend these ecosystem components with additional elements, for example, by adding system administrators, content providers, designers, experts to the biotic component, and hardware, databases, open educational resources, learning environments, and learning tools to the abiotic ones.

DLE can process various information objects with complex structure such as profile of learners [13] that represent their skills, motivations and needs.

All biotic elements of DLE (such as educators, students, experts and technological staff) have specific roles in learning process and execute some activities to provide learners with knowledge, experience and skills [14]. For example, educators have to acquire knowledge about learning course from relevant information objects, transfer it into learning matherials and effectively delivere these matherials to students [15]. Domain experts evaluate the quality of learning matherials, prepare various reserch works and reports that can be used for renovation of learning content, Technological staff supports management of e-learning systems and environment. Students have to work with learning matherials, execute tests and recommendations of educators.

In our opinion, the ecosystem of adult learning requires additional parameters for modeling the experience and competencies of education seekers, as well as the features of learning materials that take into account different abilities to perceive new knowledge and the dynamics of the structure of the terminological system of education domain.

In addition, the subjects (participants) of the learning ecosystem need to exchange, share and disseminate knowledge, and this actualizes the need to separate elements of the ecosystem that provide presentation and analysis of knowledge – ontologies, knowledge bases, analytical services, etc. [16]. For adult education, it is also important to be able to reflect knowledge about the existing experience of learners that is relevant to the learning domain.

4. Adult learning ecosystem

Adult Learning Ecosystem (ALE) is a special case of DLE supplemented by elements of the software ecosystems used for describing of ITs and knowledge bases aimed on support the professional activities of andragogue (Fig.3).

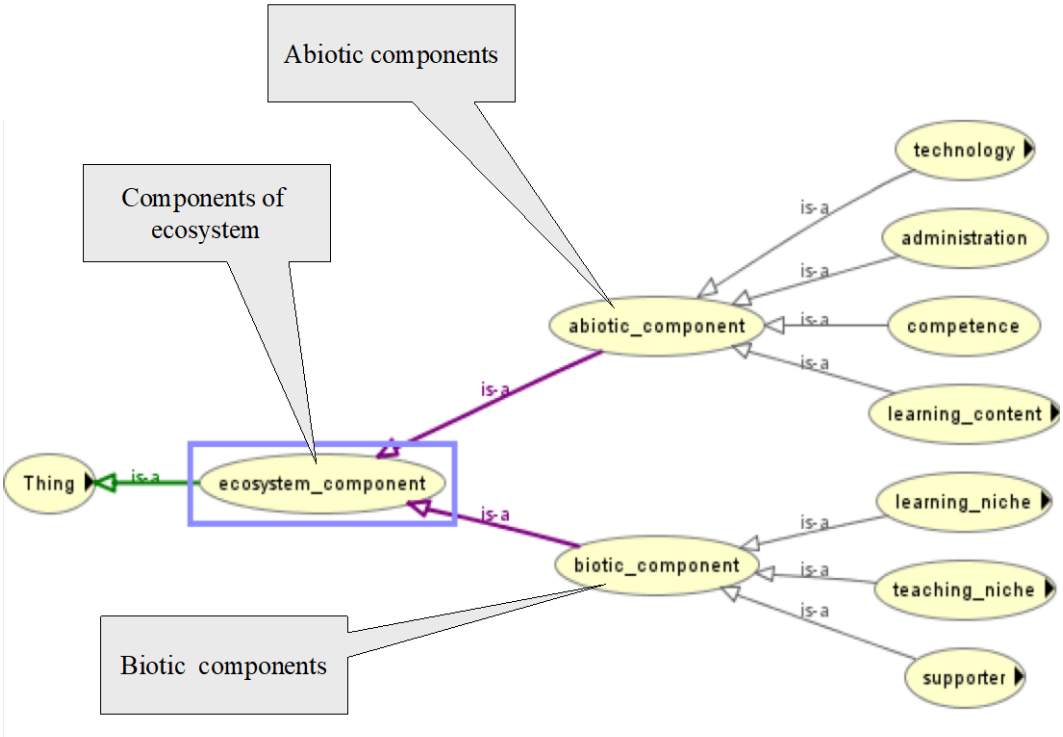

Figure 3: Biotic and abiotic components of ecosystems (on ALE example)

Special attention in this analysis is paid to the elements that ensure collaborative use and creation of new knowledge on base of semantic technologies of information processing.

ALE differs from DLE by a larger number of parameters of biotic components for describing specifics of knowledge and competencies of people with heterogeneous work and learning experience, as well as transforming some elements of the educational process in accordance with the motivation and characteristics of knowledge perception by people of different ages.

Usually, adult students have one or several reasons for selection of learning course that provides some competencies:

- they have to carry out some work but they understand the lack of appropriate skills and knowledge;
- they contact in their practical work with specialists of relevant professions and know advantages, disadvantages and requirements of this activity;
- they have an experience and knowledge (professional, social, etc.) that partially cover the requirements of specialty and can help in its learning;
- they are interested in learning domain but on the lower level;
- their health, social position, etc. require to change the profession with account of existing experience.

Therefore, andragogue has to take into attention their individual skills, motivations and learning possibilities and to reflect all these student properties into the model of their learning.

ALE structure makes it possible to single out the basic activities of andragogues and to determine their main tasks that require informational support of semantic technologies. Examples of such tasks are:

- organization of a repository of documents and reference materials directly related to the professional activities of andragogues;
- development of the learning course thesaurus on base of its content and domain ontology;
- determination of the set of competencies that the applicant should obtain as a result of studying the course;
- identification of a set of competencies that the student has before the start of studies;
- construction of the applicant's personal learning trajectory;
- selection of a personal set of learning objects and educational facilities for the applicant.

All these andragogue activities differ from the similar activities of pedagogue by more complex model of student. This set of tasks can be replenished, and individual tasks can be divided into subtasks.

In order to support these tasks by semantic technologies, it is necessary to define clearly and unambiguously the elements of the adult ecosystem and the relations between them by moving from natural language descriptions of the domain formal models.

5. Problem definition

We propose to use ontological analysis to create a formal model of the adult learning ecosystem, because now domain ontologies become the most common type of knowledge representation for a variety of distributed Web applications, and existing standards and software tools support their development.

This model provides the base for description of andragogue activities on semantic level and can be used for integration and composition of intelligent services that facilitate these activities.

The concept of ecosystems allows to distinguish biotic and abiotic components. The specifics of the approach proposed in this work consists in supplementing the ecosystem model with components that characterize information technologies used to support various types of activities of the andragogue, and means of representation and analysis of knowledge that andragogue transforms

as a result of such activities and which is exchanged both with students and with other ecosystem entities, namely with developers of relevant software and digital educational resources.

The scientific novelty of the proposed approach consists in the formal definition of the components of the adult learning ecosystem that takes into account the existing developments in this area and is aimed at creating interoperable descriptions of the semantics of this ecosystem components in the paradigm of service-oriented programming.

6. Ontological model of the adult learning ecosystem

ALE ontology reflects the connections and relations between class individuals that represent ecosystem components, as well as the activities of biotic elements to transform abiotic ones.

The classes of such ontology correspond to the main subjects (andragogue, student, expert) and objects (learning materials, individual learning trajectory, competence, training course, etc.) of the learning process (Fig.4).

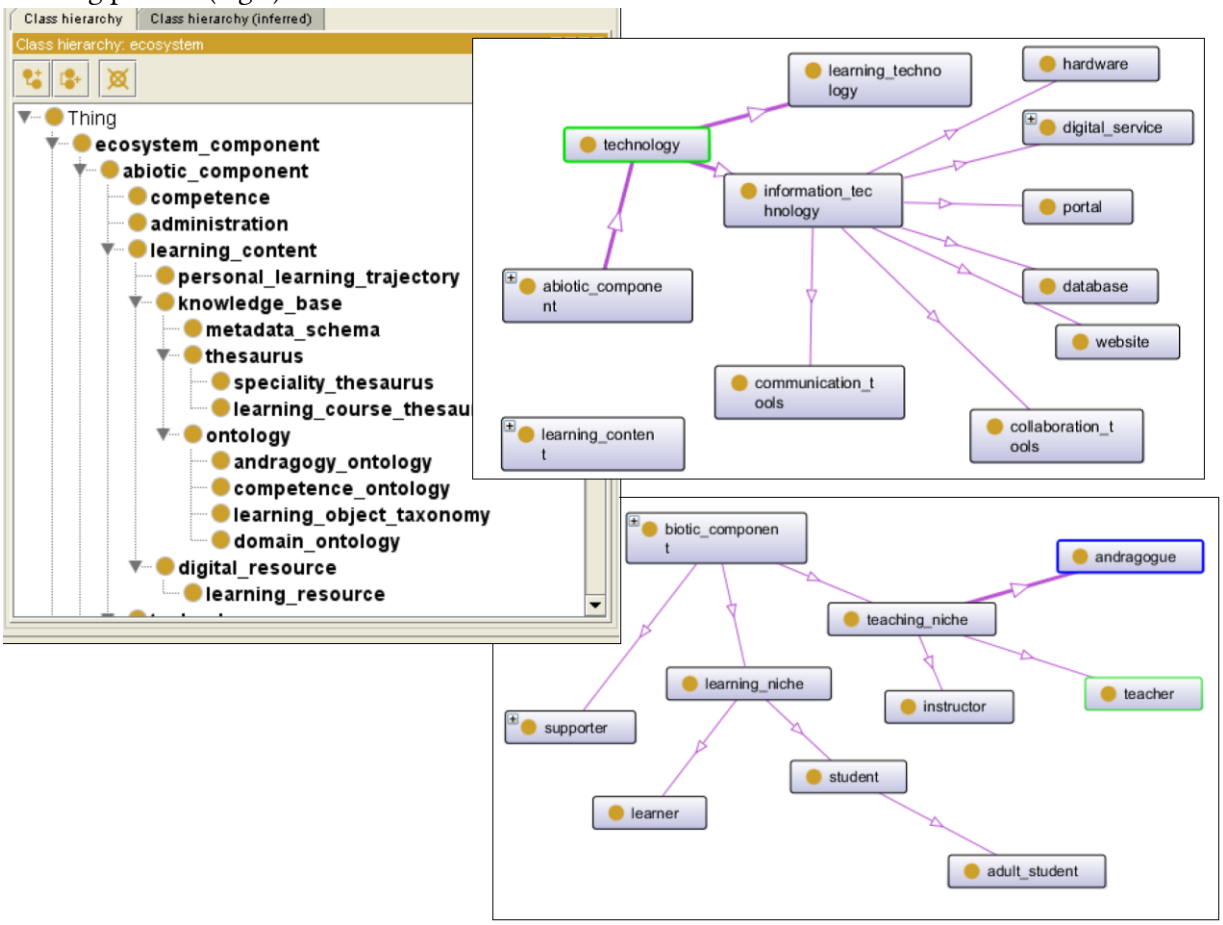

Figure 4: Hierarchy of classes in the ALE ontological model

The activities of ALE subjects are represented through the object relations of the ontological model (Fig.4). To formalize the semantics of these transformations, it is advisable to use the concept of intelligent Web services: each activity can be described as a service through a set of input and output data and the semantics of their transformation.

7. Intelligent Web services

Service-oriented architecture (SOA) is a conception of design, development and management of independent functional modules that are accessible through the network (Web, corporate and local

networks, etc.) and are able to perform some actions [17].

Web services are software systems uniquely identified by URI address with a standardized description of the interface and functions. They are supported by the following standards:

- SOAP (Simple Object Access Protocol) – message exchange protocol;
- WSDL is a language for describing software interfaces of Web services;
- UDDI (Universal Description, Discovery and Integration) is a classifier of Web services.
- For ALE, the SOA elements are interpreted as follows:
- service provider – developers of educational information support tools;
- service consumers – andragogues, students and other participants of the educational process;
- service register – description of services that are used to ensure the learning process and to transform information about ALE components.

Information about the functions provided by some specific Web service of SOA is contained in its WSDL description.

Intelligent Web services that extend the concept of traditional Web services have to described explicitly service semantics based on ontologies and, as a result, they are suitable for automatic search, composition and execution.

Intelligent Web services use an ontological representation of knowledge about their functionality. OWL-S (Web Ontology Language for Services) [18] is the tool of semantic description of Web services that provides declarative descriptions of service properties. This description contains the service profile, its model and grounding.

Ontological model of ALE provides a unified vocabulary for describing the input and output data of services that support the activity of an andragogue, and can be supplemented with ontologies of learning domain.

8. Services for Andragogue Activities

Well-known autonomous Web services used for adult learning are:

- MOOCs course services such as Coursera, edX, LinkedIn, Skillshare, FutureLearn that contribute to the development of various professional skills of adults who value the ability to access high-quality educational content from reputable institutions and teachers, as well as the flexibility to study on their own schedule;
- Web services used for discussion forums, learning management systems (LMS) that increase cognitive presence of adult students, allow to achieve learning goals independently and provide feedback and support from educators and other students;
- analytical Web services used to adapt the learning experience of adult students to their personifies needs, goals and preferences (for example, by development of personal learning trajectories and selection of learning resources);
- specialized services for life-long learning and professional development.

Web services that offer flexible learning opportunities play a critical role in adult education support. The following key characteristics of Web services used in andragogy are:

- learning independence: services allow students access to learning content anytime, anywhere, allowing and at their own pace because adult students need in the flexible balance of learning process with work and personal commitments;
- micro-learning approach where Web services facilitate breaking down of learning content into small, manageable blocks and allow students to acquire quickly new skills that are immediately applicable in their jobs or personal projects;

- access to interactive content, such as simulations, multimedia, videos, infographics, etc. that facilitate learning process;
- skill-based training support based on application of new knowledge to real-life situations (work, personal development, solving current problems);
- social learning and cooperation that support learning by discussions, collaborative work and knowledge exchange with other subjects of learning process;
- personalized and adaptive learning supported by processing of student personal data to adapt the content to individual preferences, restrictions and motivation.

Security and digital rights management (DRM) are also becoming an important issue of learning process, and Web services help protect intellectual property of content publishers while providing students with access to various learning objects.

Therefore, Web services are powerful tools for adult learning, providing flexibility, scalability and availability. These services align well with the andragogy principles by offering a self-directed, practical and effective learning experience. Development and semantization of information technologies make services more personalized, interactive and effective to meet the growing needs of adult learners.

A large number of scientific publications dedicated to the use of Web services in andragogy analyze various theoretical and practical aspects of their development and spheres of their application into adult learning ecosystem. Such services facilitate dynamic content distribution, personalized learning, collaborative knowledge sharing, and secure content management.

For example, the educational ecosystem proposed by [19] is based on autonomous Web services designed to create an adaptive, personalized and effective learning environment.

Web services provide adults with educational content (digital textbooks, articles, tutorials) and provide them according to their preferences and learning style. Depending on the student progress in learning, Web services regulate the level of content complexity and can be integrated interoperably with different software platforms and data formats. Important feature of Web services into this ecosystem is their support of modularity of educational content.

These Web services offer solutions for personalized learning, dynamic content delivery and collaborative knowledge creation, they are well aligned with the dynamic needs of adults in the digital age.

Other important problem concerned with use of Web services is their integration into existing e-learning systems to create a more effective and dynamic learning environment. Such services are aimed on increasing accessibility, personalization and collaboration of educational content is emphasized, especially in the context of the knowledge society.

This integration allows learning content to be distributed and managed in a more flexible and learner-centered way [20]. Aggregation and distribution of content using Web services enables the creation of platforms where content can be collected from multiple sources and distributed dynamically according to student needs. For example, all student with access to some e-learning platform receives personifies lists of learning resources: textbook chapters, scientific articles, technical reports adapted to their specific interests, learning course and field of study. Recommender systems based on Web services can propose additional literature, scientific articles or multimedia content based on current knowledge and skills of the learner.

Some researchers [21] consider services integrated with Learning Management System (LMS) software and take into account the integration of LMS with Web 2.0. Service-based approach is aimed on support of personalization of open learning environments. Others [22] analyze use of Web services for creation of adaptive content aimed on personalized learning: services are used to refine the model of learner and to select learning materials according to needs of this learner.

Currently, a large number of various Web services for general raining and learning purposes are developed. Many of them can be used with certain clarifications to support the professional activities of an andragogue or are designed directly to support the activity of an andragogue.

Some of learning services are described at the semantic level with use of OWL-S and other relevant ontologies, but most of them do not have such descriptions and are implemented as part of heterogeneous software systems and educational portals. Lack of semantic description makes it difficult to find them and access users to their functionality.

Therefore, it is advisable to create formal descriptions of particular functions of such systems on base of terms and relations from the ALE ontological model described in the previous section.

In the ALE paradigm, services are defined as the activity of biotic components of this ecosystem aimed at the transformation of both biotic and abiotic components. In the ontological model of the ecosystem, they correspond to the object properties of biotic components that are considered as service consumers (Fig.5). The proposed approach makes it possible to create more unified descriptions of service semantics that prevents the creation of functionally similar services. For example, AdvisOnt [23] and AndraMedia [24] systems that can be used for andragogue activity support provide various intelligent services with similar functionality. These systems use ontology-based knowledge representation of the main elements of common learning ecosystem that helps in integration of their services according to user needs.

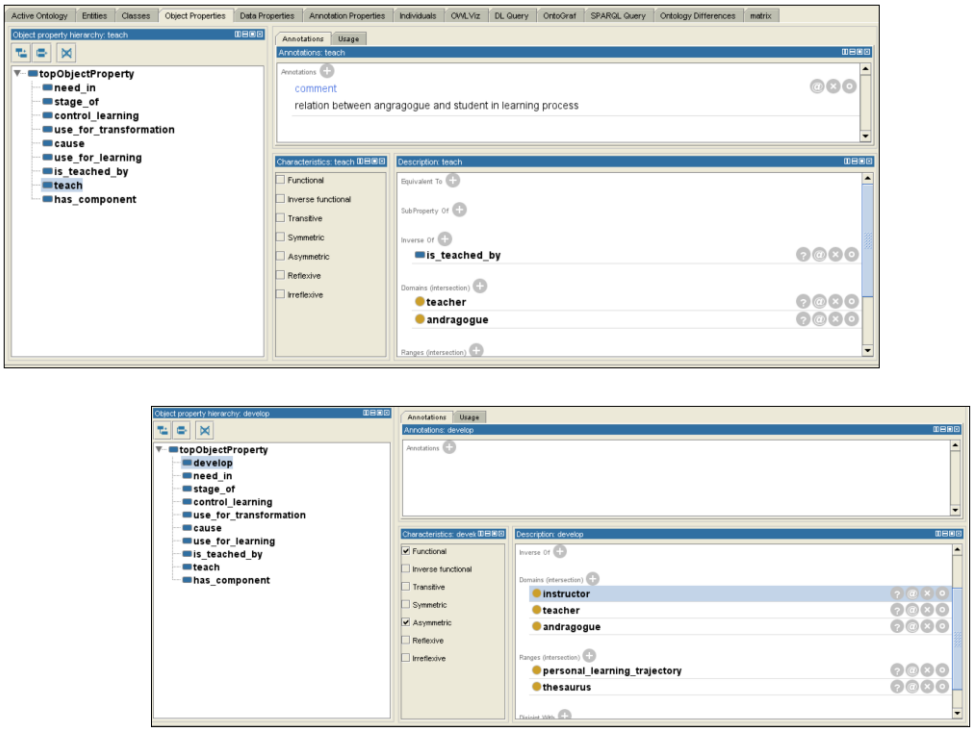

Figure 5: Representation the activities of ALE subjects in the ontological model

Let's consider this task on example of two services for matching the current competencies of a person with a set of some formal requirements.

The first service – matching the competencies of a potential employee with a set of vacancy requirements – is implemented in the advisory system AdvisOnt, which allows validation of the results of informal learning and selection of relevant learning courses that employee need to learn.

Service 1. Matching the competencies of a potential employee with vacancy requirements:
• service provider – advisory system AdvisOnt;
• service consumers– job seekers and consultants who help job seekers;
• input data: a set of competencies of the job seeker; set of competencies required by the vacancy; the ontology of domain where competencies are defined;
• output data – a set of competencies that are present in the vacancy and absent from the applicant (if this set is empty, it can be assumed that the applicant satisfies the vacancy).

The second service – comparison of the competencies of the education seeker with the set of competencies proposed by the learning course – is implemented in the AndraMedia system

developed for semantic support of the andragogue work aimed at automated construction of personalized educational trajectories.

Service 2. Matching the student competencies of with competencies of the learning course:
• service provider – AndraMedia advisory system;
• service consumers - adult students and andragogues who design personal learning trajectories;
• input data: a set of competencies of an education seeker; a set of competencies that are the result of studying the course; ontology of the learning course domain.
• output data – a set of competencies that are present in the results of studying the course and are absent in the learner (if this set is empty, it can be assumed that the learner has already fully mastered the relevant course).

Both services match sets of competencies on base of their transformation into atomic ones, and try to search semantically similar elements of person competencies for elements from the sample [25].

Services have different input data of different information objects but they process their similar characteristics. Their output data are different too, but these outputs are generated by simple transformation of the sets of similar information objects (atomic competencies). the first service reports whether this set is empty, and the second one orders the elements of this set alphabetically.

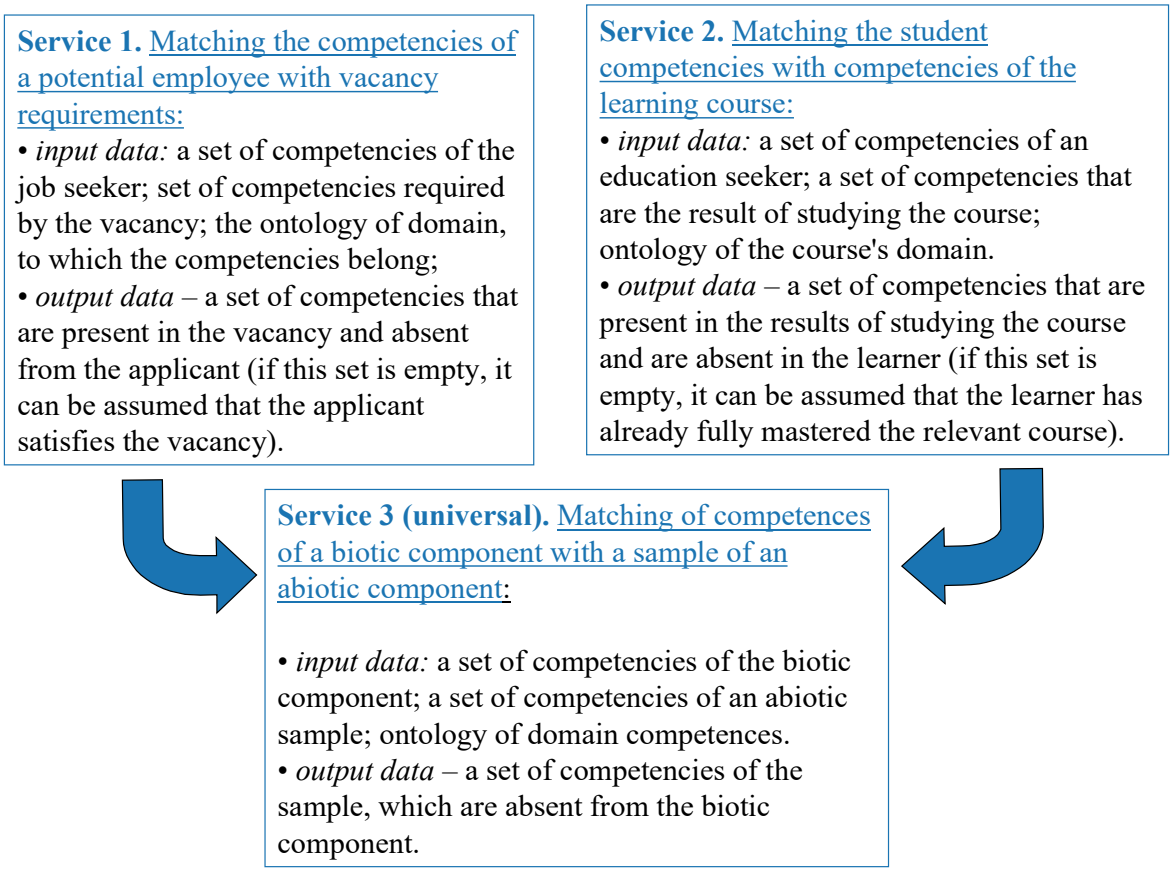

Figure 6: Integration of services based on ALE ontological model

Analysis of the semantics of transformations performed by these services and their input and output data on base on ALE hierarchy of classes allows to replace these services with a more universal service that provides comparing the competencies of a biotic component with a sample – a set of competencies of some abiotic component (Fig.6).

Service 3 (universal). Matching of competences of a biotic component with a sample of an abiotic component:
• service provider – adult learning ecosystem;
• service consumers – system users;
• input data: a set of competencies of the biotic component; a set of competencies of an abiotic sample; ontology of domain competences.
• output data – a set of competencies of the sample, which are absent from the biotic component.

Description of Service 3 characteristics such as input and output data, semantics of its functions uses ALE term system that provides unambiguous understanding of results generated by this service.

This approach facilitates the execution of services by users. Let`s consider an example of a request to this service in Python for matching of student Petrenko A.M. competencies with learning course "Artificial Intelligence" using the SPARQL language.

SPARQL query is made to find competencies of learning course (abiotic ALE components of type dbo:Competence) represented by course thesaurus in the semantic store that have a given title "Artificial Intelligence" (in this case, containing part of the title entered by the user) with the set of student competencies (abiotic ALE components of type dbo:Competence) that are linked with biotic component of type dbo:Person that have a name "Petrenko A.M.".

This query is based on SPARQLWrapper library eveloped for executing SPARQL queries to semantic Web services. Fig.7 shows an example of a Python query for semantic service that matchs competencies of biotic component (such as student competences) with competencies required by sample (such as an employer's position or learning course results) and an example of a response to this query of the semantic Web service of competencie matching about the probability.

Proposed example assumes that this service is accessible through an API (for example, via HTTP requests) and responds to requests in JSON format.

query for semantic service

```
url = "https://example.com/api/match_competencies"
# biotic competencies
biotic_competencies = {
    "skills": [
        {"name": "Python Programming", "level": "advanced"},
        {"name": "Data Analysis", "level": "intermediate"},
        {"name": "Machine Learning", "level": "basic"}
    ], "experience_years": 5,
    "certifications": ["Certified Data Scientist", "AWS Certified Solutions Architect"]}
# abiotic competencies
abiotic_competencies = {
    "job_title": "Data Scientist",
    "required_skills": [
        {"name": "Python Programming", "level": "intermediate"},
        {"name": "Data Analysis", "level": "intermediate"},
        {"name": "Machine Learning", "level": "intermediate"}],
    "desired_experience_years": 3,
    "preferred_certifications": ["Certified Data Scientist"] }
# Forming a service request
payload = {
    " biotic_competencies ": biotic_competencies,
    " abiotic_comp
# Sending a POST
response = reques
```

response to the query

```
# A function to check the appropriateness of the skill level
def match_skill_level(worker_skill, required_skill):
    levels = {"basic": 1, "intermediate": 2, "advanced": 3}
    worker_level = levels.get(worker_skill["level"], 0)
    required_level = levels.get(required_skill["level"], 0)
    return worker_level >= required_level
# Function for checking the compliance of competences
def match_competencies(worker_data, employer_data):
    worker_skills = worker_data.get("skills", [])
    required_skills = employer_data.get("required_skills", [])
                matching_skills = [] missing_skills = []
    # Checking the suitability of each skill
    for req_skill in required_skills:
break
 if nc
=
set(pr
 ret
```

Figure 7: Example of semantic service query and its results

Images for service interface based on request description are generated with the help of AI program DALL-E2 (https://openai.com/dall-e-2/), developed by OpenAI. It uses a combination of GANs (generative adversarial networks) based on neural networks and transforms to create images

9. Conclusion

The use of modern semantic technologies and knowledge processing tools to support the professional activities of andragogue requires the creation of a formal model of this subject area and the definition of the structure and relations of its basic elements.

Ontological model of the adult learning ecosystem combines elements of existing ecosystems of digital learning and software engineering but complements them with components specific to the professional activity of andragogues.

Development of adult learning ecosystem ontology allows determining the main types of activity of its subjects that require to develop semantic Web services or to transform existing services for the purpose their universalization and reuse.

An important element of the proposed model is the formalization of relations between the professional tasks of andragogue and those semantic technologies that support corresponding intelligent transformation of relevant knowledge.

Declaration on Generative AI

During the preparation of this work, the authors used AI program DALL-E2 (https://openai.com/dall-e-2/) to generate image for figure 7. After using these tool, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

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