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Web Service-Oriented E-learning: Proposition of Semantic Approach to Discover Web Services Related to the E-learning System

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Abstract

Service Oriented Computing (SOC) is a new paradigm for the flexible, scalable, and cost-effective development of distributed web applications and software. SOCs are widely used for their combination of existing web services, to efficiently create value-added applications. This paradigm, which has proven its efficiency in many fields and various information systems such as e-commerce, is considered to be very beneficial in the field of e-learning. This approach introduces the concept of discovery and invocation of web services published in service directories. Indeed, this document offers an infrastructure to discover web services related to the field of education. This proposition is based on the use of the e-learning domain ontology, the semantic descriptions of web services by OWL-S Language (Web Ontology Language for Web Services) as well as a matching algorithm, to find the adequate services that best meet the requests of users of the e-learning system.

Keywords: Discovery of Web Services, E-learning Domain Ontology, OWL-S Semantic Descriptions, E-learning System.

1 Introduction

Nowadays, e-learning environments are distributed and based on service-oriented architectures (El Ghouch et al., 2020; Cubric and Tripathi, 2009). The components and resources of these systems are implemented using web services. However, their use creates problems in discovering the services that

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best meet the needs and specificities of the various users of the e-learning system. The first service discovery approaches proposed in the literature were syntactic approaches based on the WSDL (Web Services Description Language) description and the UDDI (Universal Description, Discovery, and Integration) directory. With the emergence of the new generation of the Web, semantic approaches have appeared (Brindha Merin, J., 2023; Ahmed, 2019). Features are used to identify the applications in various applications (Trivedi et al., 2023; Camgozlu et al., 2023). They present a semantic description of web services using a new generation of web languages as features, such as RDF (Resource Data Framework) and OWL (Web Ontology Language). This semantic description can be interpreted by an application to ensure a high degree of automation (Karthik et al., 2019; Mathur et al., 2024; Snousi et al., 2022).

The services associated with the e-learning system, cannot be discovered by the UDDI directory, because it does not allow the storage of information relating to the semantics of the teaching content; hence, they need a semantic description by the OWL-S language. This proposal consists of developing a service discovery approach adapted to the needs and specificities of users of e-learning systems. It is based on a matching algorithm that allows the filtering of the most relevant web services to respond to the user's request as well as two types of ontologies: E-learning domain ontology which characterizes knowledge, concepts, and properties of the domain, and service ontology which gives a semantic description of web services associated with the e-learning system.

2 Theory

The Semantic Web

The Semantic Web (El-Seoud et al., 2015), is a new vision of the Web that promises to ensure better collaboration between humans and machines. Semantic Web technologies, developed primarily by the W3C, complement the current Web with semantic tools. Figure 1 presents an infrastructure of technological bricks (W3C, 2007), which shows the arrangement of the different technologies of the Semantic Web.

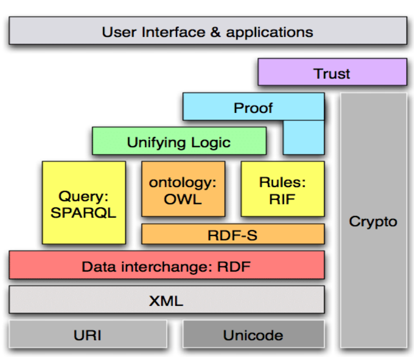

Figure 1: Architecture of Semantic Web

The architecture is composed of different layers. The lowest layers ensure syntactic interoperability, which means that they are independent of the Semantic Web. The RDF (W3C, 2008) and RDF Schema layers are considered to be the first foundations of semantic interoperability (Merin, 2023). The Ontology layer brings an evolution for describing heterogeneous information sources. The role of ontology is therefore to help humans and machines communicate, by prioritizing the exchange of information semantics rather than syntax and by using precise rules. To implement the Semantic Web, many technologies are specified such as the Rules layer, the Logic layer, and the Proof and Trust layers.

It is observed that ontology is a fundamental concept of the Semantic Web; it produces a good description of the information contained in the Web. Ontology bears resemblance to a dictionary or glossary, albeit with a more intricate and extensive structure designed to facilitate machine processing of its content.

Semantic Web Services

Semantic Web services (Varga & Hajnal, 2005) are Web services whose WSDL description is augmented by additional semantic descriptions. These descriptions are explained in separate ontologies so that other applications or other Web services can understand their semantics and can perform automatic, dynamic, and intelligent behaviors.

In the literature, we note four specifications WSDL-S, SAWSDL (Semantic Annotations for WSDL) (Farrell & Lausen, 2007), OWL-S (Martin et al.,2004), WSMO (Web Service Modeling Ontology) (Roman et al., 2005). The first two are semantic annotations of the WSDL standard, while the last two are service ontologies that are indirectly related to WSDL.

OWL-S (figure 2) is a high-level ontology for the description of semantic web services. Its objective is to ensure the automation of the service life cycle, i.e., the phases of discovery, composition, selection, invocation, and monitoring.

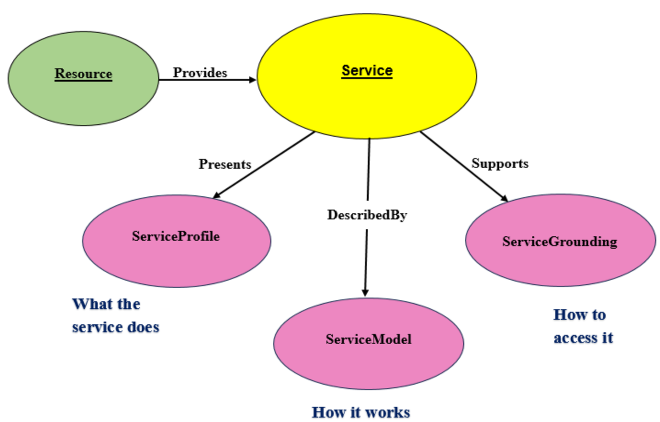

Figure 2: The Main Classes of the OWL-S Ontology

As illustrated in Figure 2, OWL-S comprises three core concepts. Firstly, the "service profile" concept streamlines discovery and selection processes, offering a comprehensive overview of a service and its provider. Secondly, the "process model" concept outlines the control and data flow within a composition of services. Lastly, the "Service grounding" concept delineates the access methods to the service, bridging the "process model" with the underlying WSDL description.

Synthesis

The semantic web is a vision towards the automation of web resource management. Its intersection with web services technology gives rise to semantic web services, characterized by their intelligence. Then, it is determined by prior to discovering this advanced type of service, using in particular the semantic modeling language OWL-S and ontologies. Indeed, a dynamic approach to the discovery of Web services is proposed by projecting the architecture of this approach in the context of e-learning.

3 Material and Methods

Conception of E-learning System

1) Adaptative E-learning System

Learner autonomy is one of the major challenges of e-learning. Current computer resources make it possible to define teaching that adapts to the behaviors, results, and preferences of learners. It is therefore noted that the exploitation of adaptive e-learning platforms is necessary to avoid the risk of failure and abandonment that always remains an obstacle to the successful use of e-learning. In this work, we propose a UML (Unified Modeling Language) modeling of an e-learning system that adapts to learner profiles (figure 3).

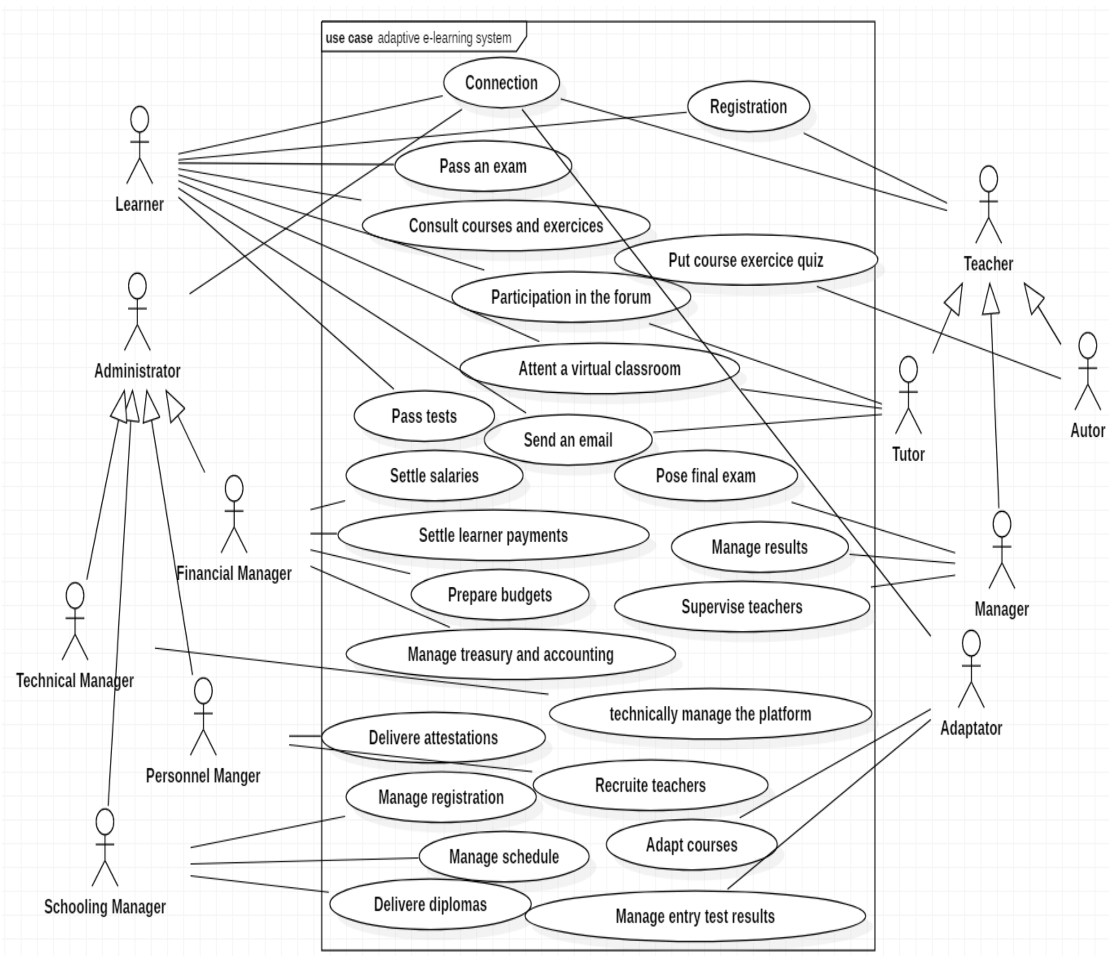

Figure 3: Adaptive E-learning System Use Case Diagram

Four actors exist in this diagram:

First, the Administrator has several roles; and also works in several categories, to have a better organization, and thus to manage successfully access to the data present in the system. Components of these categories are listed as follows:

The financial manager is responsible for preparing budgets, negotiating purchases, settling learner payments and teacher salaries, and managing cash, accounting, and banking relations. The technical manager takes care of the technical part of the platform and has different functions such as: responding to requests and questions from different users of the platform, helping them solve problems related to the operation of the system, and possibility of modifying the profile of a learner or teacher. The schooling manager is responsible for managing learner registrations, the calendar of virtual classroom sessions, and diplomas. The personnel manager is responsible for recruiting teachers and issuing certificates and personnel contracts.

Second, the Learner supervises many tasks. He must first register on the platform by providing a lot of information requested from him to be able to manage his profile and for the adaptation of the courses. Once registered, he can participate in forums, attend virtual classes, consult pedagogical resources (courses and exercises) tailored to his level, take tests, and ultimately complete an exam to validate his training.

Third, the Teacher has several roles: tutor, author, and manager. By all means, a teacher must first register on the platform and choose an appropriate status. The tutor can communicate with the learners to support them via a virtual class or a forum on the platform. The author bears the responsibility of posting his courses, exercises, and tests on the internet. The manager assumes the role of overseeing other teachers, as they have the authority to approve or adjust teachers, determine the final exam for the training program, oversee learners' results, and evaluate the efficacy of teachers' courses based on learners' performance.

Fourth, the Adapter plays a pivotal role in this system. he customizes courses based on the learner's profile and review the results of an assessment conducted by the new student to suggest a course suitable for their level. While the Adapter provides guidance, the learner ultimately has the discretion to follow or disregard the advice given by the Adapter.

2) Service-oriented Adaptive E-learning System

The Service-oriented adaptive e-learning system is similar to that of the system which does not integrate the use of services (figure 3) except for some additions which are described in Figure 4. Example: The addition of the Expert actor whose role is to design the ontology of the domain, the definition of the concepts and the semantic links, the ontological description, and the publication of the web services associated with the pedagogy, as well as their update. The other actors remain the same by adding some use cases such as “search for services”; “invoke a service”.

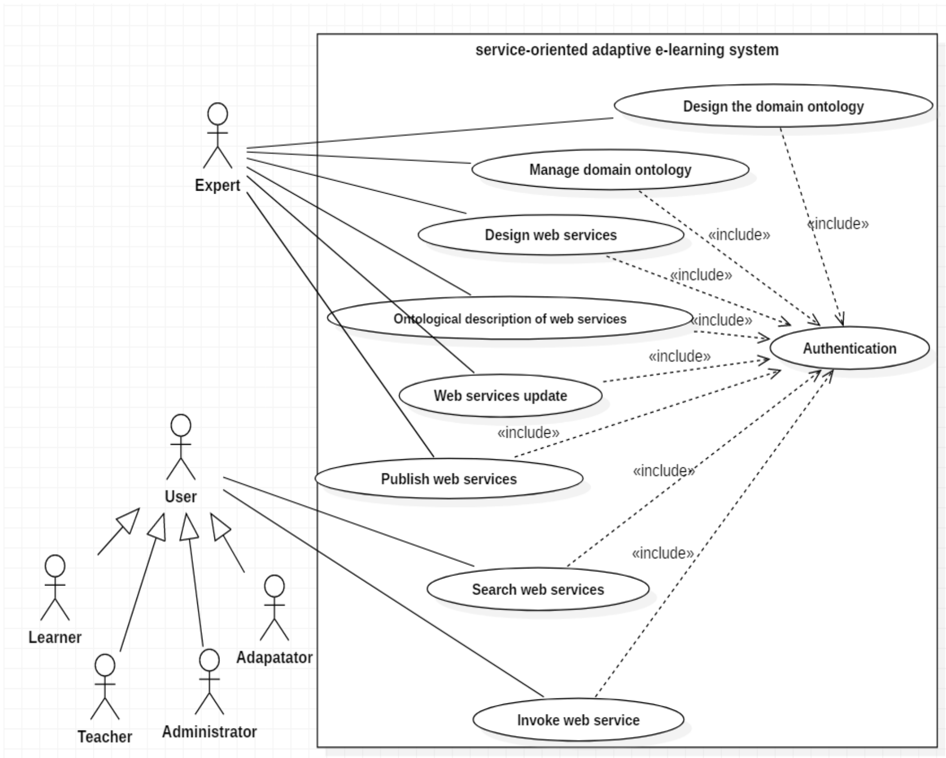

Figure 4: Service-oriented E-learning System Use Case Diagram

3) E-learning Case Study

Various processes can be implemented based on specific requirements, desired outcomes, and requests made, as well as the nature and format of the student's training. This section outlines a scenario that can serve as a practical application for our web services discovery approach. The selection of this straightforward scenario is warranted as it effectively illustrates the process of online learning within a limited context, without necessitating numerous services. The following figure describes a typical e-learning scenario (figure 5). At each stage of this scenario, the actors use the services of the system to meet their needs.

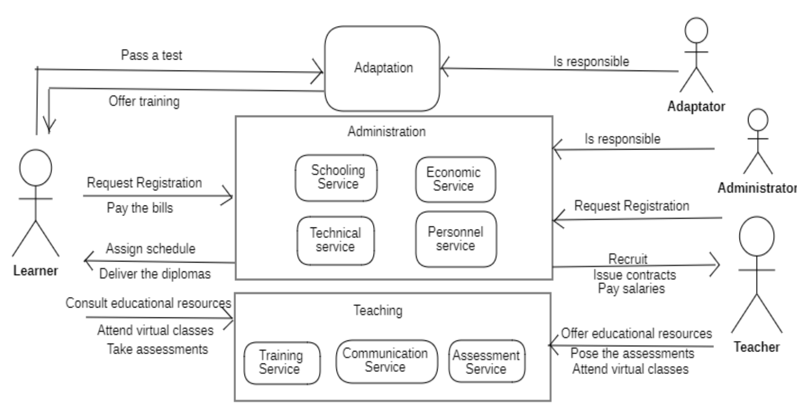

Figure 5: E-learning Process

From this scenario, we can extract the services used in the system: "Administration", "Technical service", "Registration", "Timetable", "Diplomas", "Economic service", "Personnel service"; “Teaching service”; "Schooling Service"; "Pedagogical resource", "Quiz"; "Virtual classroom", "Assessment"; "Forum"; "Training"; "Communication" and "Adaptation".

Proposed Approach

The proposed approach (figure 6) offers the various actors of the e-learning platform the following two functionalities, which are the publication of web services of the e-learning system with a semantic and pedagogical description and the discovery of web services that best meet the needs and specificities of different users.

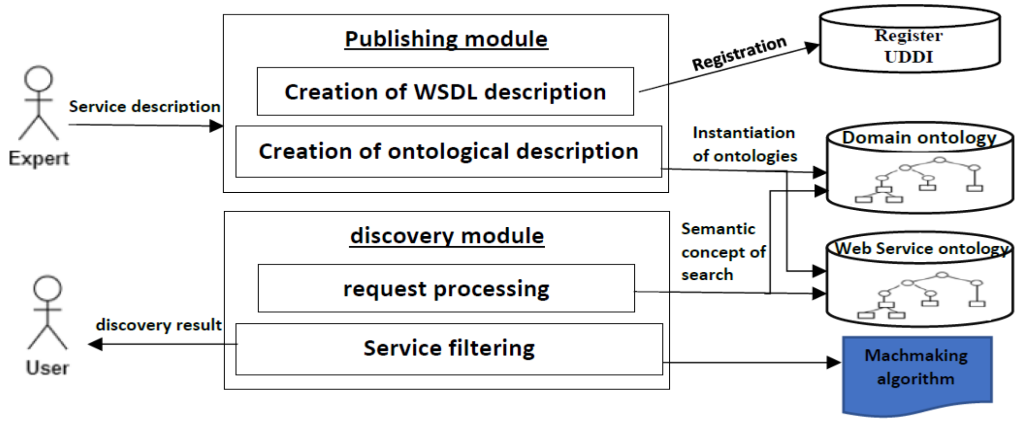

Figure 6: Architecture of the Proposed System

Publication allows the expert to publish internal (i.e. accessible by learners and registered users) or external (i.e. usable by other e-learning platforms) web services. By publishing a service, a WSDL description is created containing the information necessary for the invocation of this service and registered in the UDDI directory, as well as a semantic description registered as an instance of the OWL-S ontology in the directory of semantic services.

The discovery and invocation of web services are based, in our approach, on two ontologies; the ontology of the e-learning domain allows to exploit the semantic coverage of the concepts of the learning domain and the ontology of the OWL-S services allows us to determine the services semantically related to the request. A filtration is then carried out using a matching algorithm on the results of the discovery according to the semantic density. This mechanism thus makes it possible to select the services that best meet the needs and specificities of users.

4 Result and Discussion

Creation of the Domain Ontology

The domain ontology describes the vocabulary related to a given domain. By using this ontology, it is aimed to integrate a layer of knowledge from heterogeneous sources. Designing ontologies is a complex task. Faced with such a mission, two approaches are possible: designing the ontology from scratch or adapting an existing ontology.

Albeit, it is generally accepted that formalizing a new ontology by reusing existing ontologies is "more advantageous" in terms of time, cost, and effort, it is not always the right route to take. Indeed, most existing ontologies, open sources, in particular, are difficult to handle and customize. The benefit of re-engineering an ontology, thus becomes uncertain, since the investment required to understand existing ontologies could be even greater than building an ontology from scratch.

Given this, since we are working on a case study, we have chosen to design and develop a partial e-learning ontology with a level of granularity adapted to our case study. An ontology is always linked to a construction methodology, a construction tool, and an ontology representation language.

1) Ontology Development Method and Tools

From the study of different development methodologies, only METONTOLOGY is recognized as the most mature and complete method. This is the method that we use in this prototype. This method makes it possible to construct ontologies at the knowledge level using an intermediate conceptual model, without the need for a priori knowledge of concepts. The construction of the ontology is carried out according to a cycle consisting of seven stages: (1) specification (goal and intended users of the ontology), (2) knowledge acquisition (data collection), (3) conceptualization (structuring the domain at the knowledge level), (4) integration (integration of sub-ontologies) (5) implementation (expression of the formal model using an implementation language), (6) evaluation (validation and verification) and (7) documentation.

At the development language level, we adopt OWL presented in section 2 as the ontology specification language. This language, characterized by its formal semantics, was chosen for its quality of calculation of consistency in control and classification which is a crucial criterion for the correct and coherent development of an ontological model of complex domains.

Concerning the development environment, Despite the existence of a software platform, ODE, specially developed to guide the use of METHONTOLOGY we propose to work with Protégé which supports METHONTOLOGY and OWL but with more intuitiveness and more openness technological. Protégé is the graphical ontology development environment most used for building ontologies with multiple languages. It is free-to-use software that supports the frame model containing classes, slots (attributes) and facets (property values and constraints), as well as instances of classes and properties to allow control and visualization of ontologies. It brings together a fairly large community of users and constitutes a reference for many other tools.

2) Domain Ontology Design

The objective of the design stage is to extract knowledge from several sources and then organize and structure it using an external representation independent of the language and the implementation environment. It is therefore a question of constructing a concept diagram to specify the support classes and the subclasses.

The ontology of the e-learning domain is made up of several concepts, attributes, relations, and instances. Indeed, it can be organized in a set of sub-ontologies that revolve around structuring concepts (administration, teaching, adaptation, etc.). The diagram (Figure 7) presents an excerpt from the diagram of the e-learning domain ontology concerning the Teaching sub-ontology.

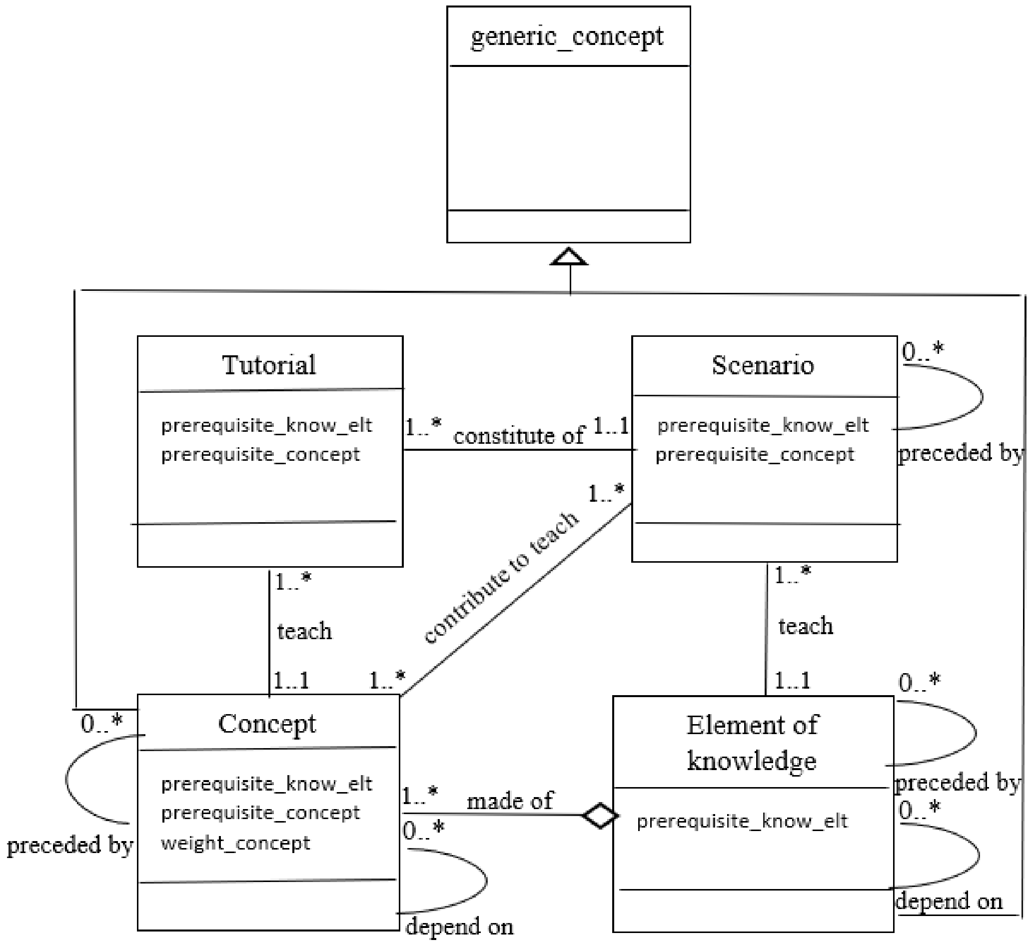

Figure 7: An Excerpt from the E-learning Domain Ontology Diagram

- Tutorial: A tutorial is a dedicated educational software, teaching aid, and/or personalized training. It is made up of a collection of scenarios and teaches concepts.
- Concept: A concept is made up of a set of knowledge elements, it can be linked to other concepts by various relationships.
- Element of knowledge: This is the "granule" of the material to be taught. It is presented alone or combined with other knowledge elements.
- Scenario: It is a set of presentations, courses, assimilation, and knowledge control exercises.
- Initial profile: The initial profile is described by the list of concepts that the student is supposed to possess a priori.
- Final profile (teaching objective): The teaching objective is a set of concepts to be acquired by the learner.

1) Domain Ontology Implementation

Following the conceptualization phase, the ontology was formalized using the Protege tool (Figure 8) by converting the conceptual model into an operational model.

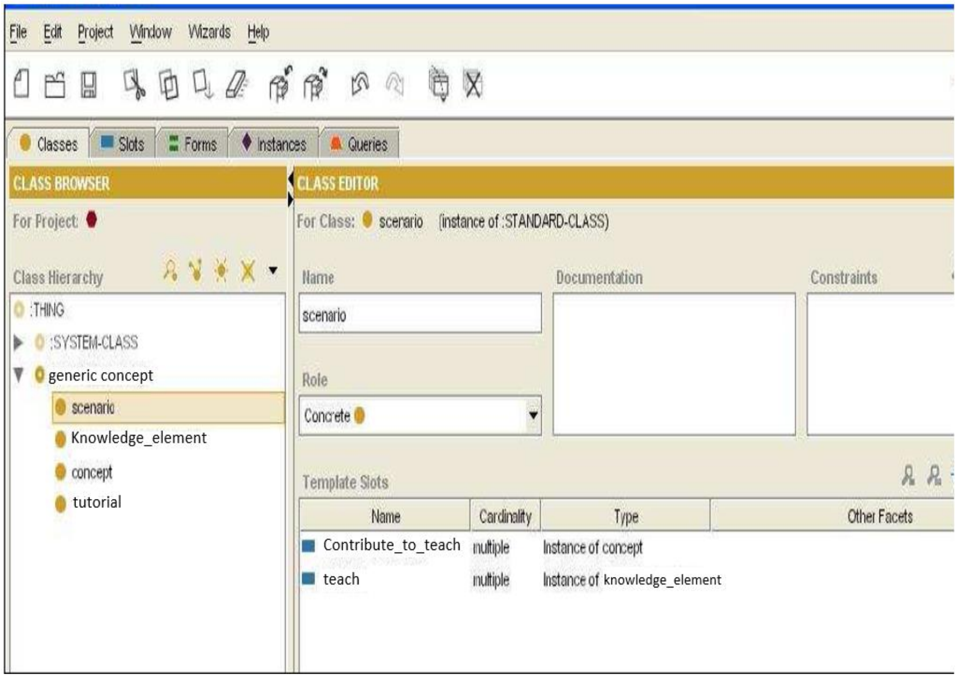

Figure 8: Formalization of Domain Ontology with Protege

The translation into ontological specification language of the modeling carried out in the design phase is automatically generated with the protege tool in the form of an OWL file, the following program (figure 9) is an overview of this file.

```
</owl: Ontology>
<owl:Class rdf:ID="concept">
<rdfs:subClassOf>
<owl:Restriction>
<owl:minCardinality
rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
1</owl:minCardinality>
<owl:onProperty>
<owl:ObjectProperty rdf:ID="made-of"/>
</owl:onProperty>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
<owl:Class rdf:ID=" generic_concept"/>
</rdfs:subClassOf>
</owl:Class>
<owl:Class rdf:about="#generic_concept">
<protege:abstract>true</protege:abstract>
</owl:Class>
```

```
<owl:Class rdf:about="#generic_concept">
<protege:abstract>true</protege:abstract>
</owl:Class>
<owl:Class rdf:ID="Knowledge_element">
<rdfs:subClassOf rdf:resource="#generic_concept"/>
</owl:Class>
<owl:Class rdf:ID="didacticiel">
<rdfs:subClassOf rdf:resource="#generic_concept"/>
</owl:Class>
<owl:Class rdf:ID="scenario">
<rdfs:subClassOf rdf:resource="#generic_concept"/>
</owl:Class>
<owl:ObjectProperty rdf:ID=" preceded_by">
<owl:inverseOf>
<owl:ObjectProperty rdf:ID=" precede"/>
</owl:inverseOf>
<rdfs:domain rdf:resource="#Knowledge_element "/>
<rdfs:range rdf:resource="# Knowledge_element "/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:about="#forme-de">
<rdfs:domain>
</rdfs:domain>
<rdfs:range rdf:resource="#element_de_connaissance"/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:ID="preceded_by">
<owl:inverseOf>
<owl:ObjectProperty rdf:ID=" precede"/>
</owl:inverseOf>
<rdfs:domain rdf:resource="#concept"/>
<rdfs:range rdf:resource="#concept"/>
</owl:ObjectProperty>
…
</rdf:RDF>
```

Figure 9: Overview of E-learning Domain Ontology File

A much more detailed ontology would be needed for using the system with real-world settings. In fact, the purpose of this experiment is to demonstrate the technical feasibility of the approach. Thus, the current size is sufficient.

Creation of Semantic Web Services Ontologies

This implementation step consists in creating the different OWL-S descriptions of the services supposed to be discovered.

1) Semantic Web Service Ontology Design

The high-level design of E-learning process, shown in figure 5, provides a list of 17 abstract services from the discovery phase. In this manuscript, we propose to present the ontology of the “Pedagogical Resource” service.

The ontology of the "Pedagogical Resource" service is defined as a sub-ontology of the "ServiceProfile" ontology. The classes of this ontology give a description of the pedagogical and semantic content of the service as well as the technical and financial characteristics deemed necessary for the description of the pedagogical resources. The main classes of this ontology are therefore linked to the pedagogical, technical, and financial aspects. Figure 10 schematizes these classes with their subclasses and attributes.

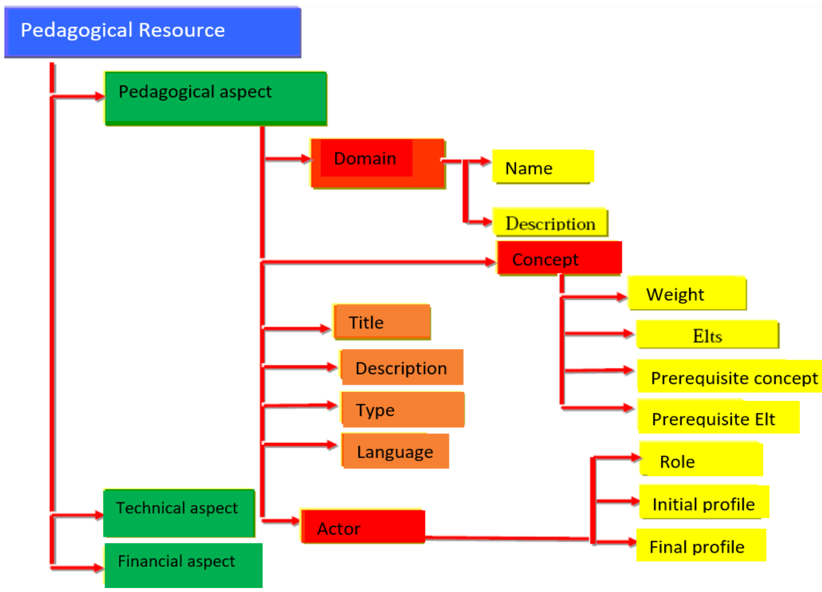

Figure 10: Description of the Classes and Attributes of the Service Ontology "Pedagogical Resource"

- Pedagogical aspect: The subclasses of this class describe the pedagogical aspect of the resource and its content; it includes as subclasses:
  - Domain: This class, as its name suggests, describes information relating to the learning domain such as:
    - Domain name: designation of the learning domain.
    - Description: textual description of the subject area.
  - Concept: indicates the concept taught by the resource.
    - Weight: semantic density of the concept in the pedagogical resource.
    - Elements of concept knowledge: List of knowledge elements associated with the concept.
    - Prerequisite concept: defines all the prerequisite concepts for using the educational resource.
    - Prerequisite element: defines all the prerequisite knowledge elements necessary for the acquisition of the concept taught by the resource.
  - Title: indicates the title of the resource
  - Description: gives a textual description of the resource.
  - Type: describes the pedagogical type of the resource which can be a learning activity, a lesson, a scenario, a learning module, an exercise, a test, specific software, etc.
  - Language: language in which the resource is described.
  - Actor: describes the recipient user of the resource. It is the superclass of the following classes:

- Role: the role of the user who can be, depending on the case, a learner, a trainer, an author, or an administrator.
- Initial profile: defines all the concepts and elements of knowledge that must already be acquired by the learner.
- Final profile: defines all the concepts and elements of knowledge that will be acquired by the learner after using the resource.

- Technical aspect: includes all information regarding hardware, security, collaboration, size, format, and learning time.
- Financial aspect: it has the following classes as subclasses:
  - Cost: the cost of the resource.
  - Right: the right to use the resource

2) Implementing the Service Ontology

This step is mainly about manipulating semantic Web services described in OWL-S language. For this need, the development environment “Protégé” is used. With this tool, the work done in this step is to create the classes and attributes of the "Pedagogical Resource" ontology to generate the OWL-S description of this service ontology. Figure 11 presents the implementation of this ontology.

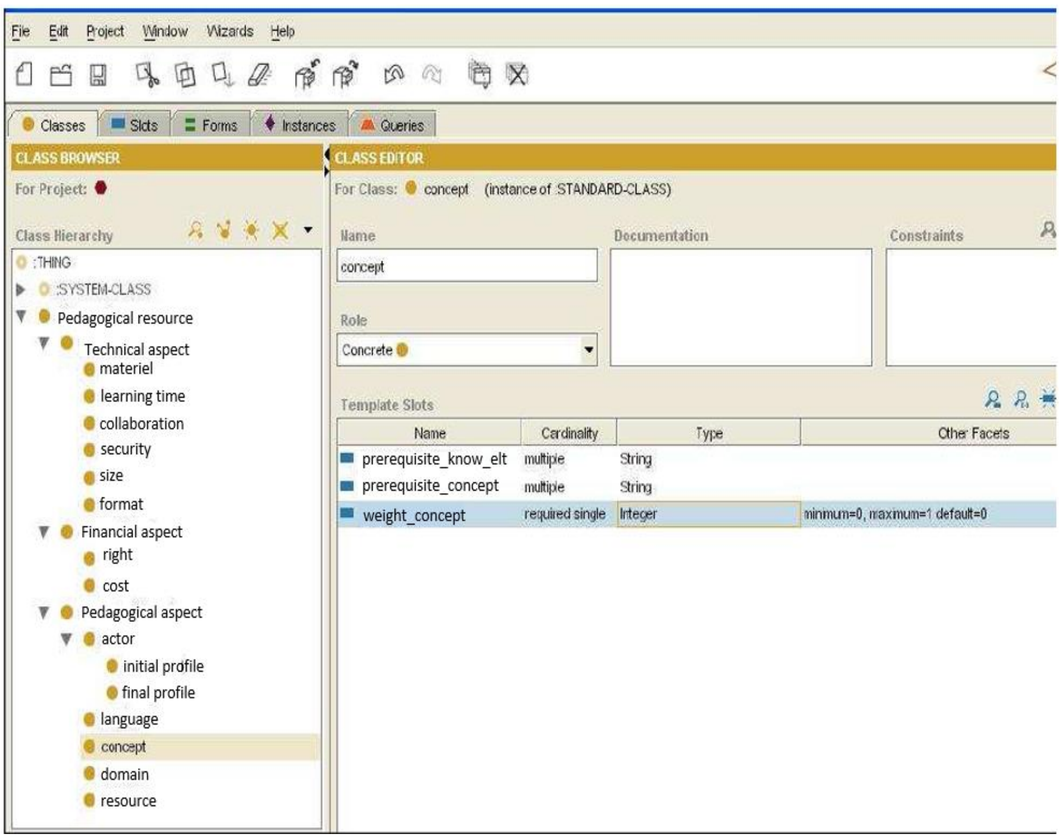

Figure 11: Implementation of the Service Ontology “Pedagogical Resource”

This ontology includes the sub-ontologies: ServiceProfil, Process Model and ServiceGrounding. Indeed, the OWL-S description of the “Pedagogical Resource” service is made up of the files: PedagogicalResourceProfil.owl, PedagogicalResourceProcess.owl and

PedagogicalResourceGrounding.owl. The following program (figure 12) presents an extract from the PedagogicalResourceProfil.owl file.

```
<owl:Class rdf:ID="pedagogical_resource"/>
<owl:Class rdf:about="#pedagogical_aspect">
<rdfs:subClassOf rdf:resource="#pedagogical_resource"/>
</owl:Class>
<owl:Class rdf:ID="language">
<rdfs:subClassOf>
<owl:Class rdf:about="#pedagogical_aspect "/>
</rdfs:subClassOf>
</owl:Class>
<owl:Class rdf:ID="domain">
<rdfs:subClassOf>
<owl:Class rdf:about="#pedagogical_aspect"/>
</rdfs:subClassOf>
</owl:Class>
<owl:Class rdf:ID="role">
<rdfs:subClassOf>
<owl:Class rdf:ID="actor"/>
</rdfs:subClassOf>
</owl:Class>
<owl:Class rdf:ID="concept">
<rdfs:subClassOf>
<owl:Class rdf:about="#pedagogical_aspect "/>
</rdfs:subClassOf>
</owl:Class>
...
 <owl:DatatypeProperty rdf:ID=" prerequisite_know_elt">
<rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string">
<rdfs:domain rdf:resource="#concept"/>
</owl:DatatypeProperty>
<owl:DatatypeProperty rdf:ID=" prerequisite_concept">
<rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string">
<rdfs:domain rdf:resource="#concept"/>
</owl:DatatypeProperty>
...
</rdf:RDF>
```

Figure 12: Extract from the PedagogicalResourceProfil.owl file

Discussion

The advent of web services technology has brought numerous advantages to the field of e-learning. One significant benefit is the integration of content into a learning-as-a-service system. This integration streamlines maintenance processes, as the content is stored centrally on the provider's server, allowing learners to access it consistently. Updates to this content only need to be performed once, eliminating the need for physical distribution to all learning management systems (LMSs) that have imported it. Additionally, the configuration of platforms can be tailored to meet user needs, and their functionalities can be reused across different platforms. This underscores the growing demand for e-learning services on the web, highlighting the necessity for automated research in this area.

In other parts, the idea pursued with Web services is to better exploit Internet technologies (Semantic Web, domain ontology, services ontologies…) by replacing, as much as possible, humans who currently carry out a certain number of tasks, with machines to allow an automatic and dynamic management of services on the Web. Automation and dynamics are therefore key concepts that must be taken into consideration in the process of designing and implementing a system based on service-oriented architecture, such as an e-learning system.

The objective of this manuscript is to create domain and service ontologies. These will be used by a matchmaking algorithm (Halim et al., 2023) which makes it possible to search a service register for services and detect the most relevant services at the functional level. These services must be composable because they will be brought to the composition stage (Adadi et al., 2019).

5 Conclusion

Web service discovery involves automatically finding a suitable web service that fulfills particular user requirements. Various methods have been suggested in research literature to achieve dynamic service discovery. Initially, syntactic approaches dominated the field. However, with the evolution of the web, semantic approaches have emerged. These semantic approaches offer a descriptive framework for web services that applications can interpret, enabling a high level of automation.

In this article, we proposed the conceptual and architectural framework of an approach for the publication and discovery of web services related to the e-learning system. The approach developed is based on two ontologies: the e-learning domain ontology, and the OWL-S semantic descriptions of web services. The use of these ontologies makes it possible to improve the process of discovering web services linked to the e-learning system by selecting those that best meet the needs and specificities of the different users. Our future works consist of the implementation of our approach in an e-learning platform, as well as the implementation of principles making it possible to locate and compare services to select services entering into the composition of another (Halim et al., 2022 a; Halim et al., 2022 b).

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