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Enhancing Online Teaching Laboratories with a Semantic-based Search Mechanism

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Abstract. This paper presents an ontological design to search laboratory instruments and devices on distributed networks. The model was designed to locate learning services semantically, facilitating collaboration and user customization. A semantic-based online laboratory is presented, which provides students and instructors with a search mechanism for laboratory resources, such as instruments and devices. The use of ontologies is the primary mechanism that allows devices and instruments to be defined semantically. This model can be used in any teaching laboratory. A case study of an Optoelectronics online teaching laboratory is presented; in this, undergraduate students can remotely control instruments and devices. The effectiveness of our approach has been measured and evaluated through usability methods.

Keywords: online labs, ontologies, personalized e-learning, semantic search.

1 Introduction

The use of ontologies in general and the semantic description of web services, in particular, is becoming more relevant for interactive learning scenarios because it provides a mechanism to describe the resources and functional capabilities distributed across networks that can be centralized through portals and presented to students in different types of devices. [1] present how the personalization of students' learning process is achieved through leveraging the use of the social semantic web, using resource description framework models, ontologies, social networking, and collaborative tagging. Personalization allows new e-learning environments to act as intelligent systems that best fit the needs of their users and especially students according to their interests, preferences, motivations, objectives, and knowledge.

In this work, we propose a semantic model for online laboratories with the capability to search distributed resources on the Web, which allows semantic browsing of remote instruments and devices, collaboration among participants and customization.

To this end, in the rest of this paper, we first present related work with semantic descriptions for online laboratories; we then introduce the semantic modeling of online laboratory elements and discuss how it can be used to discover resources in a network. Next, we present an optoelectronic online laboratory implementing a common access point for instruments and devices, making them searchable by non-functional properties described in a semantic model. We evaluated our approximation in terms of the System Usability Scale (SUS).

2 Related Work

Recent work in semantic search and ranking is concerned with addressing the challenge of finding entities in the growing Web of Data [2]. In that sense, there is some important research work that deals with semantic search mechanisms based on an ontology for virtual laboratories. Lab2Go of the Carinthia University of Applied Science [3] presents a potential solution in the form of an online portal supported by the Semantic Web. The basic idea of the Web portal is a repository that offers a common framework to collect and describe laboratory data from different laboratory providers located all over the world. They define a general model for online laboratories and a Web repository based on Semantic Web technologies to facilitate the use of new tools to publish and exchange online laboratories and other related resources. As a search tool, the project uses OntoWiki. This tool enables search mechanisms like faced based browsing which allows the user to search for information according to the properties of a particular object. We share all these ideas in the development of our ontological model and search mechanism. Library of Labs (LiLa) [3] has been a European Community funded project to network remote experiments and virtual laboratories. The goal of this project has been the composition and dissemination of a European infrastructure for mutual exchange of experimental setups and simulations, specifically targeted at undergraduate studies in engineering and science.

Go-Lab [4] offers teachers with the capability to create dedicated inquiry learning spaces (ILS) and support this process by proposing scenarios and lesson plans. For apps, Go-Lab follows the OpenSocial metadata specification and the ROLE Ontology. For Smart Device specification, they have opted for Swagger that is strongly focused on automatically generating user interfaces. Swagger is based on JSON Schema to specify the data format of requests and responses. These labs can be searched based on an extensive set of metadata that offer direct links. Students do not need an account to use an ILS shared by the teacher with a secret URL. In its next stage, this project continued with the creation of a complete Cloud Ecosystem for Supporting Inquiry Learning with Online Labs [5]. It relies on two core open access platforms, a sharing one (golabz.eu) offering open educational resources supporting science and technology education, and an authoring one (graasp.eu) enabling the construction and the personalization of such resources directly by teachers for teachers. The laboratory experience generated by the teacher can be privately shared with the students as a standalone Web page using a secret URL displayed when clicking a button.

The FORGE initiative (Forging Online Education) [6] aims at promoting the notion of Self-Regulated Learning (SRL) using a federation of high-performance testbeds and at building unique learning paths based on the integration of a rich linked-data ontology.

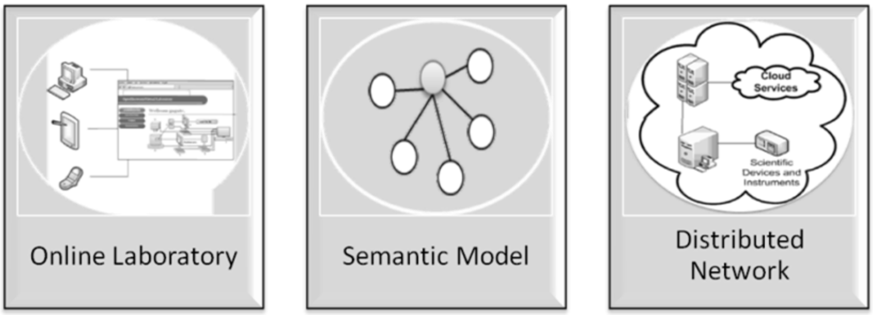


Fig. 1. Online laboratory portal based on a distributed network.

A FORGE vocabulary builds upon existing ontologies such as Metadata for Learning Opportunities (MLO), eXchange of Course-Related Information (XCRI-CAP), or the Teaching Core Vocabulary (TEACH) Through FORGE; traditional online courses are complemented with interactive laboratory courses, supplying an in-depth and hands-on educational experience. To search for learning resources, the student uses a 'goal-setting' widget to record a list of its goals and then uses the Linked Data-enabled Educational Widget Store to discover suitable facilities available as widgets inside interactive learning resources.

Concluding, in the case of Lab2go, they present a complete ontology to describe online laboratories. LiLa presents an ontology that is even more complex than the one used in Lab2go, which is also used to search laboratories. FORGE relies on the use of external ontologies. There are also generic ontologies for the description of instruments, such as the case of SSN (Semantic Sensor Network) [7] or the N8EO project. These works use essential technological solutions, which in all cases describe the components of online labs semantically, in some cases through an ontology and in others through a metadata system, but in all cases, they implement a mechanism of semantic search.

3 Ontology Design of Online Teaching Laboratory Portal

In the online teaching laboratory (Fig. 1), users can connect from various types of devices, such as personal computers, tablets or cell phones, and have access to a centralized portal offering the resources on a distributed network and services. The core functionality of the portal is based on a semantic model, which works as a data container for linking the different services available through the interactive learning environment. As main features of this environment, we can distinguish instruments and device remote control, a role-based access control module, cloud services supporting collaboration and interaction, as well as semantic search of services depending on functional characteristics according to each type of laboratory.

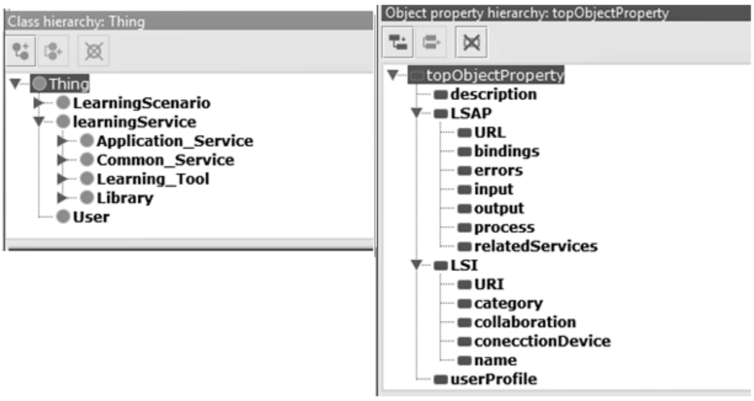


Fig. 2. Online laboratory class.

3.1 Semantic Representation of Services for Online Laboratories

Based on the interaction of the user with the learning environment, the main classes of the ontology and their relationships were identified: User, Learning Scenario, and Learning Service (Fig. 2).

User: This class defines the person, group, or process that uses the learning scenario. Its unique property is userProfile that defines the profile that makes use of a service (learner, teacher, another process, etc).

Learning Scenario: This class defines the stage where the learning process is performed. It allows the interaction between users and the services requested. Its unique property is a Description in which the ontology associated with the learning scenario can be defined.

Learning Services: It is the main class of the model, where, one the one hand, we identify the principal characteristics of Learning Services related to a learning scenario and the activities that support it. On the other hand, we consider Learning Services like a granular functional component with some input information, functional activity, and some output information. In this sense, we form two conceptual groups of properties to achieve a complete description of Learning Services: The Learning Services Identification (LSI) and the Learning Services Access Point (LSAP).

The basic elements used for representing the Semantic Web consist of the use of two core standards: The Resource Description Framework (RDF) [8] and the Web Ontology Language (OWL) [9]. This semantic representation can be extended depending on the specific attributes of the type of laboratory it is intended to put online. RDF Schema defines some classes, which represent the concept of subjects, objects, and predicates. OWL defines ontologies that include classes, properties, and their relationships for a specific application domain. In the case of building an online teaching laboratory aimed at developing experiments using web services, many characteristics of its semantic domain are more significant than merely the learning service name, syntactic description, inputs, and outputs.

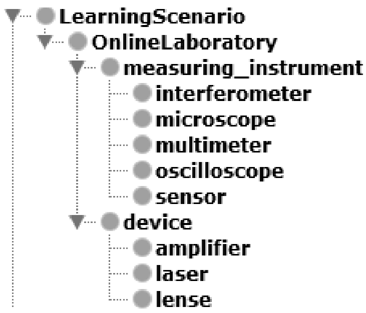


Fig. 3. Optoelectronic class.

4 Case Study: Semantic Search of Devices and Instruments on an Optoelectronic Laboratory

Our semantic model was implemented in an optoelectronic laboratory intended for both teaching and research. On the one hand, this online laboratory was helpful to learn the control of optoelectronic devices through computer equipment. Figure 3 shows the classes related to an optoelectronic laboratory. On the other hand, to access and use equipment managed on servers in various school departments. A computer controls each device or instrument connected to the Internet. Both students and teachers can control all these devices or instruments in real-time, while they manipulate data acquisition as well.

The idea of using a semantic model in an online laboratory is that students when carrying out an experiment involving remote control of instruments and devices can have tools in the same environment that can help them browse and search for these services and publish the URLs to access them. The laboratory aims to provide students with a tool for improving usability and learning experience with less cognitive load and thus more satisfactory. In the case study in which we experimented with an online laboratory, we have focused on defining instruments and devices. However, it can be extended to any object that can be accessed through a URL, such as documents, videos or other types of learning tools defined as a web service.

The process for registering an instrument is that once the service is registered on the Labview server, the administrator or teacher will have to enter the online laboratory to add its access point (URL) and information related to: the name, description, category, type, user profiles for which it will be available, connection device, collaboration, laboratory device and measurement instrument. In our case, these parameters are necessary, and they can be adapted according to the needs of the learning scenario.

This information is stored in an RDF container (called Fuseki in this case). This information can be verified in the instrument catalog, from which we can delete and update elements. When the instrument registration is completed, the functionality is accessed to generate JSON files. Fig. 4 shows the JSON information and the related SPARQL code to generate it.

```
if( !$db ) { print sparql_errno() . ": " . sparql_error(). "\n"; exit; }
    sparql_ns( "labclass","http://www.liberoeducacion.com/laboratories/classes#" );
    sparql_ns( "labdata","http://www.liberoeducacion.com/laboratories/data#" );
$sparql = "
SELECT  ?s ?name ?description ?URI ?category ?type ?userprofile ?collaboration
 ?connectiondevice ?laboratorydevice  ?measuringinstrument WHERE {
    ?s   labclass:name   ?name.
    ?s   labclass:description ?description.
    ?s   labclass:URI ?URI.
    ?s   labclass:description ?description.
    OPTIONAL {?s   labclass:category ?category.}
    OPTIONAL {?s   labclass:type ?type.}
    OPTIONAL {?s   labclass:userprofile ?userprofile.}
    OPTIONAL {?s   labclass:collaboration ?collaboration.}
    OPTIONAL {?s   labclass:connectiondevice ?connectiondevice.}
    OPTIONAL {?s   labclass:laboratorydevice ?laboratorydevice.}
    OPTIONAL {?s   labclass:measuringinstrument ?measuringinstrument.}
        }"  ;
```

Fig. 4. SPARQL code to generate JSON information.

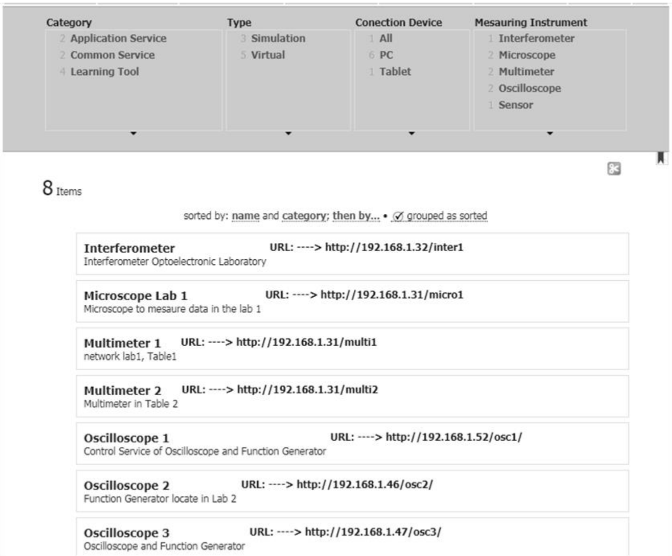
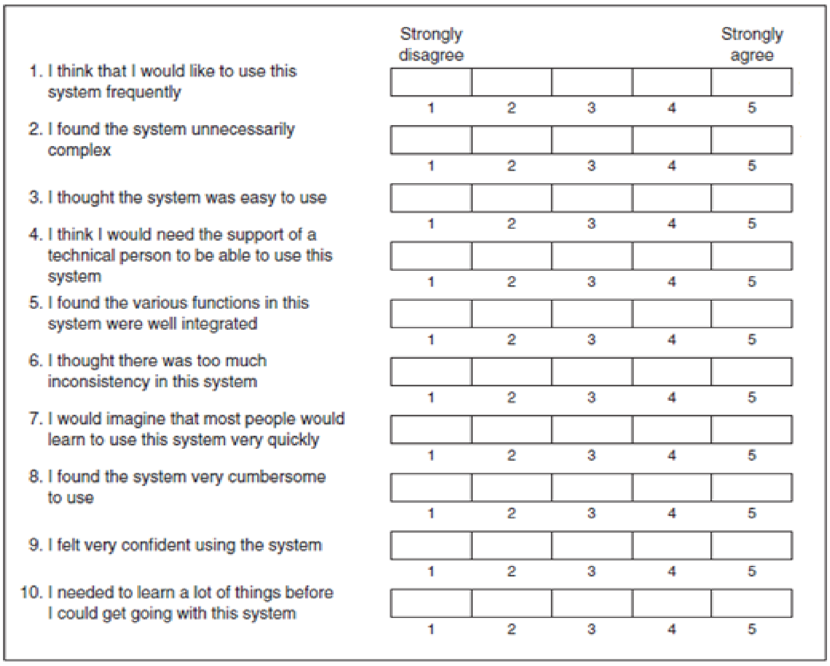


Fig. 5. Exhibit and search screen.

Once JSON files are generated, students, teachers, and administrators can perform search and navigation of services based on their categories and semantic classification using the Exhibit tool (Exhibit). Figure 9 shows the Exhibit functionality and the screen of semantic search. (Figure 5).

4.1 Experimental Procedure

The online optoelectronic laboratory portal was used for practical work in the courses of Electronics, Analogical-Digital Control, Optical Instrumentation and Optoelectronics taken by undergraduate students (N=25). It could be transferred to any engineering curriculum that includes these courses. Students knew laboratory instruments and devices and had basic knowledge of virtual instrumentation with LabView.



	Strongly disagree 1	2	3	4	Strongly agree 5
1. I think that I would like to use this system frequently					
2. I found the system unnecessarily complex					
3. I thought the system was easy to use					
4. I think I would need the support of a technical person to be able to use this system					
5. I found the various functions in this system were well integrated					
6. I thought there was too much inconsistency in this system					
7. I would imagine that most people would learn to use this system very quickly					
8. I found the system very cumbersome to use					
9. I felt very confident using the system					
10. I needed to learn a lot of things before I could get going with this system					

Fig. 6. The System Usability Scale (SUS) questionnaire.

Table 1. SUS score.

n	max	min	M	SD
25	92.5	80	87.7	2.969

n= students, max= maximum value, min = minimum value, M= Mean, SD = standard deviation

After students completed the experiment, they were asked to answer the System Usability Scale (SUS). SUS is a simple, ten-item attitude 5 points Likert scale (ranging from 1-strongly disagree to 5-strongly agree), giving a global view of subjective assessments of usability [10]. In particular, [11] showed the following qualitative interpretation of SUS scores:

- SUS = 51 => Poor/OK,
- SUS = 72 => Acceptable/Good,
- SUS = 85 => Excellent.

Figure 6 presents the ten questions used in the SUS questionnaire. The analysis reflects the max, min and mean of SUS score (M) (Table 1). Comparing the final mean SUS score (87.7) that our laboratory with the results of [11], we can conclude that the laboratory usability can be placed in the third quartile, which is a very good result which can be considered on the grade scale “excellent” (SUS > 80).

5 Conclusions, Limitations and Future Research

This work presents an ontology design approach that automatically discovers semantic concepts from online resources. This ontology design integrated into a web application for an online laboratory, which is based on non-functional attributes of learning services of distributed networks, especially those based on cloud computing. This provides a complete semantic description of Web services, setting aside the traditional technologies of syntactic search methods, allowing a complete semantic description based on functional and non-functional properties of Web services. Being a limitation of the current work, it would be interesting to experiment with a larger ontology and with a greater number of instruments. Future work is now centered on other important issues that include technical aspects related to the incorporation of new functionalities based on cloud-services and the semantic composition of new services from existing ones.

Future work also needs to address methodological aspects that explore new approaches of instructional design to further enhance collaborative and personalized learning, as well as to deal with the problems related to access laboratories such as authentication, scheduling, and interoperability.

References

1. Halimi, K., Seridi-Bouchelaghem, H., Faron-Zucker, C.: An enhanced personal learning environment using social semantic web technologies. Interactive Learning Environments, 22(2), pp. 165–187 (2013). DOI: 10.1080/10494820.2013.788032.
2. Butt, A.S., Haller, A., Xie, L.: Ontology search: An empirical evaluation. In International Semantic Web Conference, Springer, Cham., pp. 130–147 (2014).
3. Richter, T., Boehringer, D., Jeschke, S.: Lila: A european project on networked experiments. In Automation, Communication and Cybernetics in Science and Engineering Springer Berlin Heidelberg, pp. 307–317 (2010).
4. De Jong, T., Sotiriou, S., Gillet, D.: Innovations in STEM education: the Go-Lab federation of online labs. Smart Learning Environments, 1(3) (2014).
5. Gillet, D., Rodríguez-Triana, M.J., De Jong, T., Bollen, L., Dikke, D.: Cloud ecosystem for supporting inquiry learning with online labs: Creation, personalization, and exploitation. In 4th Experiment@International Conference IEEE, pp. 208–213 (2017). DOI: 10.1109/EXPAT.2017.7984406.
6. Marquez-Barja, J.M., Jourjon, G., Mikroyannidis, A., Tranoris, C., Domingue, J., DaSilva, L.A.: FORGE: Enhancing elearning and research in ICT through remote experimentation. In Global Engineering Education Conference (EDUCON´14), pp. 1157–1163 (2014). DOI: 10.1109/EDUCON.2014.7130485.
7. Compton, M., Barnaghi, P., Bermudez, L., García-Castro, R., Corcho, O., Cox, S., Huang, V.: The SSN ontology of the W3C semantic sensor network incubator group. Web semantics: science, services and agents on the World Wide Web, 17, pp. 25–32 (2012). DOI: 10.1016/j.websem.2012.05.003.
8. Cyganiak, R., Wood, D., Lanthaler, M., Klyne, G., Carroll, J.J., McBride, B.: RDF 1.1 concepts and abstract syntax. W3C recommendation, 25(02) (2014).

9. Motik, B., Grau, B.C., Horrocks, I., Wu, Z., Fokoue, A., Lutz, C.: OWL 2 web ontology language profiles. W3C recommendation, 27, 61 (2009).
10. Brooke, J.: SUS-A quick and dirty usability scale. Usability evaluation in industry, 189(194), pp. 4–7 (1996).
11. Bangor, A., Kortum, P.T., Miller, J.T.: An empirical evaluation of the system usability scale. Intl. Journal of Human–Computer Interaction, 24(6), pp. 574–594 (2008). DOI: 10.1080/10447310802205776.