Lab2go - A Repository to Locate Educational Online Laboratories

Danilo Garbi Zutin, Michael E. Auer, Christian Maier, Michael Niederstätter
Center of Competence in Online Laboratories and Open Learning
Carinthia University of Applied Sciences
Villach, Austria

Abstract— **This paper discusses the creation of a common framework to describe online laboratories according to the semantic web technology. The so called Web 3.0 technology is actually growing daily and is proposed to be one of the leading Web technologies within the next years. Improved search mechanisms and facet based browsing are only some key features which enhance the data handling within the repository. Online laboratories are interactive experiments which are available over the Internet and can be divided into two main groups, software simulations and laboratories made up of real hardware equipment. Technology-enhanced learning is becoming a new important trend in higher education worldwide. In particular, engineering education is becoming an exciting emerging field of research because it involves a multitude of disciplines which aim to resolve the pedagogical problems that arise with the advancement of technology. With the help of the semantic web technology a significant step forward can be made in terms of a general description model for online laboratories and the location of laboratories with requested properties.**

Online Laboratory; Semantic Web; Ontology; Web Repository

I. INTRODUCTION

With the excessive supply of broadband Internet at the end of the last decade many research groups all over the world have started the exploration of ways to support and facilitate the learning activities of students by using new possibilities. Important outcomes of these efforts are online laboratories. Since nowadays many modern universities, schools and other organizations started programs to offer, in addition to their traditional laboratories, a wide range of online laboratories in different scientific fields. Like traditional laboratories this type of laboratory provides students with particular engineering experience and allows them to explore systems and their real behaviors. Online laboratories are fundamental for home experimentation because they are especially designed for distant learning students to acquire introductory hands-on experience and familiarize themselves with real-life phenomena. These online experiments can be found in different fields, including electronics, mechatronics, informatics, etc [1].

In traditional laboratories most of the equipment is not efficiently used because of the fact that the laboratories are used for other experiments or very specific equipments are only used for a very short time period of the year. Online laboratories are a suitable instrument to solve these problems by sharing the labs. Since some years there are a number of initiatives to share laboratories among different institutions by the use of a common architecture such as the iLab Shared Architecture from the MIT (Massachusetts Institute of Technology) [2].

Currently, available online laboratories are often hidden from the public education community. The most significant reason for this problem is the current lack of information about online laboratories that provides potentially interested parties the ability to search for adequate laboratories. This lack of information regards almost everyone in the online laboratory community such as students, administrators as well as lecturers even if this influence them in a different manner. The fundament of this problem is the lack of information which describes the resources. This is not a specific problem of online laboratories but rather a general problem of the current Web and concerns many content types of special interested communities. A solution to solve this problem can be realized by using Semantic Web technologies to describe these content types, establish a framework and create a base for new searching mechanisms. This paper discusses the creation of an online laboratory portal in the form of a repository, where information about specific properties of these laboratories is collected. The basic idea behind the Web portal is a semantically linked repository for the e-learning community that reduces the efforts of researchers as well as lecturers and students to find and share information about online laboratories all over the world.

II. ONLINE LABORATORIES

Online laboratories are interactive experiments that are provided over the Internet. Online laboratories can be divided into two main groups, software simulations and laboratories made up of real hardware equipment.

Figure I describes the classification of laboratories in general. Our focus is the right field of the depicted.

Software simulations are often used in the field of mathematics and in particular simulations where either the setup of hardware is too expensive or the setup of a laboratory is too difficult or even impossible, due to security reasons. Simulations help students to improve their knowledge and an approximate idea of the behaviour of the "real" world [1].

A large amount of currently used software simulations are already Web based and thus allowing learners to get access to these laboratories at any time and from any place[1] .
Web-based software simulations are so called "Virtual Laboratories" and differ from remote laboratories in that way, that they only use software while “Remote Laboratories” consist of real hardware equipment. In comparison to “Virtual Laboratories” remote laboratories allow persons to manipulate real hardware. Because of the fact that laboratory experiments and instruments are becoming increasingly sophisticated and expensive for universities to purchase and maintain remote laboratories is getting more and more interesting. Remote laboratories

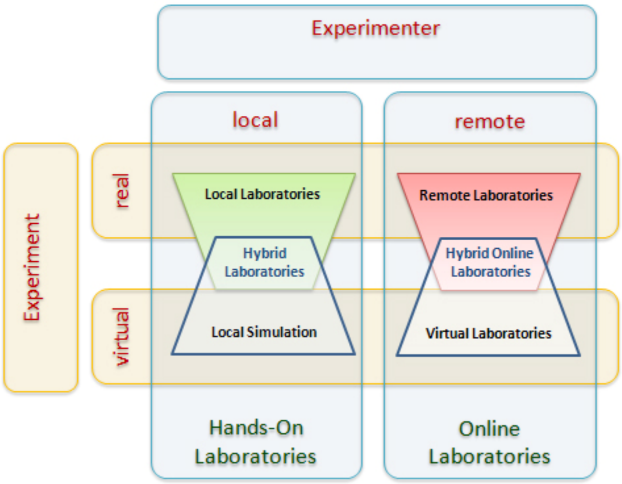

Figure 1. Classification of Laboratories

offer a solution and represent a practical alternative through which students may conduct experiments online, regardless of time and space limitations. Compared with traditional laboratory practice, remote laboratories offer flexible learning in time and place, access to a wide number of distributed experiments and cost-cutting strategies. Furthermore, as collaborative educational strategies become more widespread, remote laboratories offer great possibilities for students to interact as they work towards a common goal.

III. SEMANTIC WEB

At the beginning, the Web consisted basically of many Websites containing only unstructured text. Web 2.0 extended this traditional Web with a few extremely large Web sites specialized on certain specific content types like YouTube for Videos and Flickr for pictures. The transition from Web 2.0 to Web 3.0 implies a growing transition from receiver to producer of information, from static to dynamic content, from control of the few to the wisdom of the crowds. In contrast to Web 2.0, in Web 3.0 many Web sites will be hosting arbitrarily structured content what will be realised by using Semantic Web technologies.

The fundamental characteristic of the Semantic Web is the description of various content or information with metadata. In the traditional Web anyone can write a page saying whatever they please and publish it to the Web infrastructure. In the case of the Semantic Web, it means that our data infrastructure has to allow the individual to express a piece of data about some entity in a way that it can be combined with information from other sources. This sets some of the foundation for the design of RDF (Resource Description Framework) [3]. It means also that information is not managed for a large corporate data center.

The Semantic Web standards have been created as a medium in which people can collaborate on models that they can use to organize the information and share models that can be used to advance the common collection of knowledge.

The Semantic Web also uses the idea of class hierarchy for representing commonality and variability. Differently to OOP (Object Oriented Programming), Semantic Web is not focused on software representation, classes are not defined in terms of behaviours of methods, although the notation of classes remains and plays much the same role. Higher level classes represent commonality among a large variety of entities and lower level classes represent commonality among a small, specific set of things [4].

This is the essence of modelling in the Semantic Web: providing an infrastructure where not only can anyone say anything about any topic, but an infrastructure that can help a community work through the resulting chaos that is present on the Web concerning different viewpoints about a determined subject [4]. A model can provide a framework (like the described classes and subclasses) for representing and describing commonality and variability of viewpoints when they are known. But, in advance of such an organisation, a model can provide a framework for describing what sorts of things we can say about something.

The Resource Description Framework (RDF) is a W3 Consortium recommendation used today as a general method of modelling information by different syntax formats. The idea of RDF is a metadata model that describes Web resources in the form of subject – predicate – object expressions. This form is called triples in the RDF terminology. The subject denotes the resource and the predicate denotes the aspects of the resource and express a relationship between both.
Another important document of the W3 Consortium recommendation is the RDF – Schema (RDFs) which enables the description of so called lightweight ontologies.

IV. BASIC DEFINITIONS OF THE ONTOLOGY

One of the first steps to make use of the semantic web technology is to create an ontology, or in other words a generalized, formal representation of the domain. This general model consists of various properties, data types and relationships representing various types of online laboratories in a generic model. To develop a model, which is accepted by the end users it is essential that the model is easy to understand, well structured and a very close representation of the real world situation. At this point several discussions about various general states have to be made to ensure that the model is really applicable to the current real-world-situation.

When starting with the model definition, a lot of questions about very principal things come up. For example how is an online laboratory defined? Should we differ between an experiment and a laboratory? These fundamental questions are very important and only with the right definitions of the basic description model, it can maturate in the right direction.

Because of the various possibilities and terms to describe this domain, a general definition of the basic terms and principles in an online laboratory grid is required. In our general definition the following terms and definitions are used to describe an online laboratory:

TABLE I - PROPERTIES OF AN ONLINE LAB

Property	Description
Access URL	Every online laboratory has a URL (Unique Recourse Locator) which gives access to the online laboratory directly or via a middleware. In the last case, different laboratories can have the same access URL if they are connected to the same middleware and one laboratory can have one or more access URL if it is connected to different middleware.
URI	The property URI is the Unique Identifier of the Online Lab.
Name	The property title describes the name of an online laboratory which has not to be unique. (An online laboratory can represent in different languages).
Experiments	The property experiments represent virtual and real experiments of online labs.
Owner	The property owner represents a person or an organization (like universities or companies) which offers the online lab.
Administrator	The property Administrator represents a person which is responsible for the online lab.
Creator	The property Creator represents a person which is the developer of the online lab
Description	The property description is a textual description about the online laboratory without semantically linked data which is available in different languages.
Languages	The property language represents the available languages of the online lab.
Release date	The property release date represents the release date of the laboratory
Access Requirements	The property access requirements will give information about the access of the online laboratory (open access, access upon request, restricted access)
Lab Status	Defines whether the laboratory is online or offline.
Costs	This property represents the access costs
Technical Data	This property provides information about the technical background for the online laboratory developers
Client Requirements	This property provides information about requirements for the clients. (Client Technology, Runtime engine, Client OS, Browser)
Documentation	Documentation of the online laboratory including Hardware and Software
Architecture	This property describes the architecture that a specific laboratory belongs to.

Online Laboratory

An online laboratory is an environment which allows a person to perform experiments and or simulations over the Internet. Online laboratories consist basically of software based simulations or hardware based experiments.

An online laboratory can be divided further in the following three types of labs:

Remote Laboratory

A remote laboratory is an online laboratory which provides real experiments. This definition implies the control of real hardware and the realization of real measurements.

Virtual Laboratory

A virtual laboratory is an online laboratory which provides software simulations or applications.

Hybrid Laboratory

A hybrid laboratory is an online laboratory which combines virtual laboratory and remote laboratory technologies. It provides real hardware experiments and software simulations as well. All types of online laboratories have several properties, which are described more in detail in Table I.

As already mentioned an online laboratory can have one or more experiments. An experiment is defined as follows:

Experiment

An experiment in the current domain is defined as the smallest enclosed unit of an online laboratory. It provides the execution of virtual or real experiments to observe the behavior and output of a system. An online laboratory consists of one or more experiments in different fields of science and engineering.

Moreover according to the interactivity between experiment and experimenter an experiment can be categorized further:

Observation Experiment

The experiment parameters as well as the experiment environment are fixed. This kind of experiments allows users only the observation of an experiment.

Fixed Experiment

The experiment environment is fixed but the experiment parameters are remotely tunable. Furthermore it is possible to control one or more measurement instruments also remotely.

Adaptive Experiment

The experiment parameters as well as the experiment environment are remotely changeable. This definition includes for example the modification of a circuit.

Every experiment of an online laboratory is described by certain properties which are defined in Table II.

V. TERMINOLOGY

For the terminology existing vocabularies and bindings were inspected more in detail. The focus was on several well known standards such as Dublin Core [5], LOM [6], SKOS [7], vCard [8], FOAF [9] and WGS84 [10]. With the analysis of the various standards it could be seen that mostly only parts of the

/

standards can be adopted and that a definition of various new terms for the definition of an online laboratory model is required.

TABLE II - PROPERTIES OF AN EXPERIMENT

Property	Description
URI	The property URI is the Unique Identifier of the online laboratory.
Name	The property title describes the name of an online laboratory which has not to be unique. (An online laboratory can represent in different languages).
Type of Experiment	The property type of experiment describes the type of the Experiment (Virtual experiment or Real experiment)
Description	The property description is a textual description about the experiment without semantically linked data which is available in different languages.
Scientific Field	The property field represents the division of the experiment like engineering, science as well as their subdivisions like electronics, mechatronics …
Educational level	The property educational level represents the current educational level (primary, secondary, tertia, research)
Creator	This property represents a person which is the creator of the experiment.
E-learning material	This property informs about additional e-learning material for the experiment
Difficulty level	This property represents the level of difficulty of the experiment.
Online lab	An experiment is part of one online laboratory. This property represents these online laboratories.
Documentation	Documentation of the experiment including Hardware and Software
Duration	The time a user needs to complete the remote experiment.

After the evaluation of the different standards it was made the decision to adopt basic terminology and data types from Dublin Core to the model. Examples for adopted terms are such as *title*, *description* or the *type* data which are also defined in Dublin Core.

It is not planned to make use of SKOS and LOM in the online laboratory description because only small parts are fitting to the current model and can be used to describe the online laboratory domain.

It was therefore decided to adopt some basic terminologies from the not included standards. An example here is the property difficulty from LOM [6]. This property describes very well the difficulty level with a pre-defined range [Very Easy, Easy, Medium, Difficult, Very Difficult].

Besides describing all technical aspects of the laboratory itself, a model to describe persons, organizations and projects has to be found. This will be used for properties like creator, administrator or rights holder. As already mentioned vCard and FOAF were inspected more in detail. The decision was to make use of the FOAF ontology because on one hand it allows more possibilities to define relationships between agents and on the other it is much more used as vCard in RDF representation. Within the portal it would be very useful to see which person knows whom. It facilitates then the organization and establishment of connections with other persons and groups of researchers more easily.

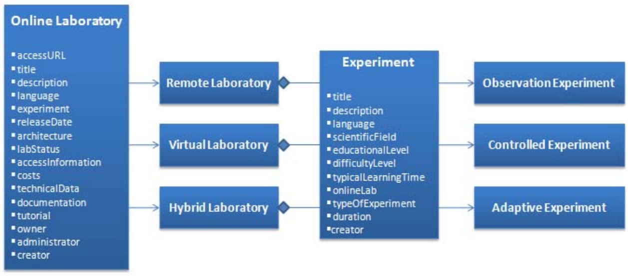

Figure 2. Classification of Laboratories

VI. ONTOLOGY DESIGN

The first milestone is to develop an ontology which is easy to understand and to apply. Right now for the first approach the ontology includes only fundamental descriptions and properties which are not too detailed. It is advisable not to implement a too detailed description at the beginning, so that the users have some freedom and the model can grow with additional user's feedback regarding inputs and terminologies. With this practice a creation of an ontology which can't be understood and would not be accepted by the end-user could be avoided. It is a very important point in defining a description model for a domain, as it could help users to get in touch with the description model and gives them also the possibility to contribute to the model development, what might increase the acceptance of the model by the users.

According to the basic definitions which are described in section IV and on the use of standard vocabulary described in section V the first draft of the ontology was made. Before starting to build the ontology a class diagram for the model was designed.

As can be seen in Figure 2 we used two main classes to describe an *Online Laboratory* and an *Experiment*.

The online laboratory class contains all properties which were defined in table II. The different types of laboratories are designed as subclasses of the online laboratory class. Depending on the type of experiment each subclass is linked to one or more experiments of a specific type. Furthermore, a class of type remote laboratory can be linked only to experiments where the property *typeOfExperiment* is set to "Real experiment".

The *Experiment* class contains all properties which are described in table II. Additionally three subclasses were created to determine whether the experiment is an observation, a controlled or an adaptive experiment. With this further division it is easier for users to differ between the interactivity types of experiments. To differ trough various interactivity types also a further property in the class *Experiment* could be used, but in terms of model readability and the implementation of facet based browsing it is much better to make use of subclasses.

Afterwards the software Protégé [9] was used to design the ontology itself. Protégé is a freely available tool to design ontologies. It has a lot of useful plug-ins and extensions such as the reasoner *Pellet* to check the ontology's consistence and the *Property Matrix* plug-in make the ontology design easier. That plug-ins will help through the development process.

As already mentioned above, the idea is to let the ontology grow together with user inputs. It is now questionable how this can be realized? We assume that users would not send e-mails or insert various comments in a forum if they have any improvements. Therefore next to the definition of the properties in our ontology the user has the possibility to add additional information. This will be realized similar as in Wikipedia. The user could write additional descriptions by setting tags. The evaluation and analysis of these tags will give the developer very useful hints to find out which additional properties are desired by the end users. Afterwards it is apparently which tags can be adapted to the model as a new property or also which properties can be renamed that they are used in the proposed way.

VII. The Aims With the Lab2go Repository

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 turns out to be necessary to continually foster the development of laboratories and exchange of knowledge among interested parties. This Web portal will host information about running research projects, researchers, organisations, existing state of the art technologies, etc, in order to strengthen the collaboration in this field of science as well as providing knowledge about the laboratories and their operating institutions.

To solve this problem this paper shows the fundamental problems that exist today and the resulting requirements which are necessary to implement a successful platform. One objective of the platform is the improvement of the search process for online laboratories with the use of Semantic Web technologies. Due to the particular way used by the Semantic Web to describe resources, not only full-text search can be supported. This kind of description enables new ways for the implementation of search mechanisms like facet based browsing which allows the user to search information according to the properties of a special object. Furthermore it is possible to query resources based on specific criteria. To outline the differences between the well known Web 2.0 methods and the Semantic Web a typical information searching scenario can be used:

- A user wants to search for all online laboratories which contain experiments in a specific filed, have a specific difficulty level and are freely available.

Using today's available Web searching tools such a query is not possible as these tools make use of keywords to perform a search. On the other hand such a scenario is perfectly supported by the Semantic Web. This new possibilities provided by the Semantic Web is one of the important keys to advance the information exchange in the community.

The fundamental concept of this project is based on the idea of making use of already existing solutions. Therefore the semantic collaboration platform OntoWiki which was developed by the research group AKSW at InFAI (Universität Leipzig, Institut für Angewandte Informatik) was chosen. OntoWiki is an open-source Platform which can be installed by any Web space and accessed by an ordinary Web browser [11] and is easily adjustable by writing customized plug-ins. Differently to MediaWiki [12], the base platform of Wikipedia, where the metadata can be directly included into the text, OntoWiki is completely based on tags and can be called as a data wiki.

OntoWiki is the base for the portal and provides a framework for the development of Semantic Web application and was therefore used to create a customized solution for online laboratories. Mostly users are not familiar with the concepts of Semantic Web or are not willing to spend time writing the metadata manually. For that reasons Lab2go is also a tool to create metadata for the online laboratory resources.

VIII. Ontology Design

The focus of this chapter is to figure out the main functionalities which will be available within the lab2go repository.

Every user has the right to browse through the repository content and search information about online laboratories. With a free registration a user gets the rights to add, edit and evaluate content. When creating or editing a contribution, the user can set group policies to control the level of access other users have over it. In terms of evaluation there are the possibilities to rate and to comment a resource. With this functionality a user gets a better feeling of the relevance of a resource.

A significant new functionality is the searching possibility. As already explained in the previous chapter by using facet based browsing customized views can be generated. Property values can be filtered out from a list of resources. This so called filtering can be applied to any type of resource and also to any relation within the description model. With a combination of two or more filters the list of results becomes more precise. Another possibility is to display various properties directly in a resource list that the property values can be recognized very quickly.

To manage the data easily an editor and additional plug-ins were developed. It looks like a common html-form when entering new laboratory data or changing some contents. In the backend the data is converted automatically to metadata and then saved in the store. Features like auto complete for pre-defined property values or resource names (if already existing) make the data input more comfortable. Also visual inputs like a calendar or the possibility to add multiple values of a property makes the editing of resources easier.

Additionally to the pre-defined description model a user can set individually tags for each resource. This has the advantage that in case a user wants to describe his laboratory with a specific term or property he has the freedom to do this without any limitation. In a second stage exactly these tags can be inspected and evaluated. The result represents a significant input for the ontology development. Misuse of terminology and need for additional terminology could be detected easily.

Not only searching, evaluation and data management tools were implemented in lab2go. One of the most important key points remains as in so many applications the data handling. Filter out data which is not interesting for certain views; finding the right order of the displayed information and make use of an impressive style are only a few considered key points. The developments in this field are going on continuously.

CONCLUSIONS

Semantic Web technology is a very broad field that can be applied in many distinct areas. In this paper very specific use-case scenarios are mentioned. There exist however many other possible extensions beyond the main scope described here. It proposes an approach on how to provide such specific type of information using Semantic Web technologies, and comprehends a first implementation attempt of an open source platform.

Summarizing this paper shows an overview about the Semantic Web (Web 3.0) and the most important differences to Web 2.0. Furthermore it covers the problems of lack of information channels for online laboratories and presents a potential solution in the form of an online portal.

REFERENCES

[1] M. E. Auer, A. Pester and D.G Zutin, *Open Source Portal for Online Laboratories,* Proceedings of the 4th International Conference on Remote Engineering and Virtual Instrumentation - REV 2007. Kassel University Press, ISBN 978-3-89958-278-9

[2] Icalmpus. URL: http://icampus.mit.edu/ilabs/architecture, last visited 25.05.2009

[3] Resource Description Framework. URL: http://www.w3.org/RDF/, , last visited 10.03.2009.

[4] D. Allemang ,J. Hendler, Semantic Web for the Working Ontologist: Effective Modeling in RDFS and OWL, Elsevier, 2008.

[5] Dublin Core. URL: http://dublincore.org/, last visited 10.08.2009

[6] Draft Standard for Learning Object Metadata, IEEE-publication 2002. URL: http://ltsc.ieee.org/wg12/, last visited 12.08.2009

[7] SKOS – Simple knowledge Organization System. URL: http://www.w3.org/2004/02/skos/, last visited 14.08.2009

[8] vCard. URL: http://www.w3.org/TR/vcard-rdf, last visited 10.08.2009

[9] Protégé – an ontology editor and knowledge-base framework. URL: http://protege.stanford.edu/, last visited 12.08.2009

[10] World Geodetic System. URL:http://www.w3.org/2003/01/geo/, last visited 05.10.2009

[11] Ontowiki. URL: http://www.ontowiki.net, last visited 03.04.2009

[12] MediaWiki. URL:http://www.mediawiki.org/wiki/MediaWiki, last visited 25.05.2009