DEPARTAMENTO DE ENGENHARIA ELÉTRICA

Internal Research Reports

ISSN

Number 46 | June 2016

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PUC RIO

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CREDITS

Publisher:
MAXWELL / LAMBDA/CCPA/VRAc
Sistema Maxwell / Laboratório de Automação de Museus, Bibliotecas Digitais e Arquivos
http://www.maxwell.vrac.puc-rio.br/

Organizers:
Alexandre Street de Aguiar
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Cover:
Ana Cristina Costa Ribeiro

This article was originally published in the Proceedings of the ACE 2016 – 11th IFAC Symposium on Advances in Control Education; Bratislava, Slovak Republic, Jun 2016.

An Overview of Repositories of Learning Objects

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Abstract: This work addresses the dispersion of learning resources on the Internet – many languages, all areas of knowledge, aims at different audiences, many "sizes" and varied quality; many are open to all. This paper presents the results of some searches on the Internet for Control Systems resources and suggests the implementation of a union catalog of metadata of contents from cooperating institutions. Union catalogs of theses and dissertations are mentioned as possible models.

Keywords: learning objects; shareable content objects; union catalogs; institutional repositories; metadata; metadata harvesting; reuse, share.

1. INTRODUCTION

Over five years ago, Pavani (2010) proposed the implementation of union catalogs of learning contents in Engineering to be populated with works from institutions in different parts of the world. A little earlier Ternier et al. (2008) proposed a query language to search repositories of learning objects for the sake of interoperability. About the same time, the Open Archives Inititative (OAI) presented OAI-ORE (2008), the Open Archives Initiativte Object Reuse and Exchange.

The three facts mentioned in the first paragraph are related to ICT – Information and Communication Technology support for education. A little before these facts, a new concept was created by UNESCO (2002): OER – Open Educational Resources. This concept is important because it stimulates cooperation among educators and content developers. ICT tools provide the infrastructure for the cooperation to happen.

OER is considered so important in Engineering Education that in November 2014 the IEEE Education Society published a special issue of the IEEE Transactions on Education devoted to this subject (IEEE, 2014).

One last point is worth mentioning – ACE 2016 (http://www.ace2016.sk/Scope) includes the following topics of interest for the symposium: (1) Teaching aids for control engineering; (2) Virtual and remote labs; (3) Open Educarional Resources; (4) E-learning and blended-learning in control engineering; and (5) Internet-based control systems materials. No doubt, all of them are deeply related to each other and to the three facts in the first paragraph..

This work addresses the availability and the easiness to find Learning Objects in Control Systems on respositories connected to the Internet. It also proposes the implementaion of union catalogs of learning contents in Control Systems to host the contributions from institutions and individuals all over the world. In order to state the scope of the work, some definitions are presented in subsection 1.1 and the objective of this paper in subsection 1.2.

1.1 Some Definitions

- Learning Objects (LO) and Shareable Content Objects (SCO)

Learning Object (LO) and Shareable Content Object (SCO) are two expressions related to the definition of educational resources in ICT supported learning.

LO is defined (IEEE, 2002) as: **"For this standard, a learning object is defined as any entity – digital or non-digital – that may be used for learning, education, or training."** LOs are "pieces" that can be used separately or that can be combined for teaching and learning. An important observation is that LOs are not necessarily digital. Thus, traditional laboratory equipment can considered LOs. This is nice in the context of Engineering Education – lab activities are an important requirement in engineering courses. In this paper, LOs are digital entities though.

"The Shareable Content Object Reference Model (SCORM) is a model that references and integrates a set of interrelated technical standards, specifications, and guidelines designed to meet high-level requirements for e-learning content and systems." (ADL, 2004). The SCORM defines: **"SCOs are the smallest logical unit of information you can deliver to your learners via an LMS."**.

The two definitions have differences and similarities.

- Differences: SCOs are to be delivered via LMSs and must be compliant to SCORM specifications so that they can be delivered by any SCORM compliant LMS. LOs can be non-digital, thus not to be exclusively delivered via LMSs.
- Similarities: The similarity is that SCOs and LOs have educational purposes and are units/entities.

Two key concepts associated to learning resources are share and reuse. Associated to reuse, it is important to mention that Wiley (2000) introduced the terms reusable chuncks of instructional media, reusable instructional components, reusable digital resources, reusable learning objects. Besides Wiley, Alsubaie (2009) used the term Reusable Learning Objects (RLO). This is a set of terms that have much in common and, therefore, fuzzy boundaries.

- Institutional Repository (IR)

"A university-based institutional repository is a set of services that a university offers to the members of its community for the management and dissemination of digital materials created by the institution and its community members. It is most essentially an organizational commitment to the stewardship of these digital materials, including long-term preservation where appropriate, as well as organization and access or distribution." This is the definition introduced by Lynch (2003) and covers all types of digital resources – learning contents included.

- Union Catalog

The online version of the Oxford Dictionaries (http://www.oxforddictionaries.com/us/definition/english/union-catalogue) defines Union Catalog(ue) as: **"A list of combined holdings of several libraries."** This concept has been used in digital libraries and institutional repositories. Three examples of union catalogs can be mentioned:

- BDTD – Biblioteca Digital de Teses e Dissertações (http://bdtd.ibict.br/) hosts over 271K metadata records of ETD – Electronic Theses and Dissertations of 101 Brazilian Institutions.
- NDLTD – Networked Digital Library of Theses and Dissertations Global ETD Search (http://search.ndltd.org/) hosts over 4.3 M metadata records of 158 institutions of higher education, consortia and other union catalogs.
- SHARE (http://www.share-research.org) hosts over 6 M metadata records of assorted scholarly contents – ETDs, articles, books, research data, LOs, etc.

The first two are specific for full-text online theses and dissertations and the third is for all types of scholarly resources. Though they offer different types of contents they have points in common:

- Their databases store only metadata sets – all contents are on the repositories of the original institutions.
- They are compliant with ISO 15836.2009 standard of digital contents description.
- Metadata are transferred from the original repositories to the union catalogs in an automated way based on OAI-PMH – Open Archives Initiative Protocol for Metadata Harvesting (2001).

At the same time, they have a significant difference – since the first two are specific for ETDs, their metadata sets have additional elements along with the ISO core in order to satisfy the needs of a more accurate description. Addition of elements is an international practice. Another example is the LOM set that contains the ISO core plus many other specific to LOs.

1.2 This Work

This work has the objective of examining the existence of LOs on the Internet. It tries to identify IRs, union repositories and different types of websites, and the ones that host resources in Control Systems. It mentions the types of contents, open access (versus with some restriction), description (to allow ease of finding), persistency (versus broken links), granularity (to allow redeployement, rearrangement, repurpose, and reuse) and the resource language.

Section 2 presents the results of some searches. Section 3 resubmits the suggestion presented by Pavani (2010) of creating a union catalog of LOs, this time focused on a narrower audience – those involved in Education in Control Systems. The suggestion is resubmiited due to the enhancement in the culture of sharing digital contents. Section 4 comments on the results.

2. AN OVERVIEW OF REPOSITORIES OF LOs AND THE AVAILABIBLITY OF LOs IN CONTROL SYSTEMS

The audience interested in LOs is divided in two large groups: (1) faculty; and (2) students. Some smaller groups may be involved: (1) librarians; (2) IR administrators; and (3) software developers. The first two groups are players in one of the main objectives of higher education – teaching and learning. The other groups support the activities of the first two.

Two words express very important concepts in dealing with LOs – share and reuse, presented in section 1. To get to the point of sharing and reusing, it is necessary that LOs (as any other resource) be found. This means that they must be searchable and retrievable; search and retrieve are two keywords too. Once a LO is found and retrieved two other concerns arise. The first is the size of the LO in terms of its educational content. This is associated with its granularity and indicates how "flexible" a LO is to be reused. The second is the language of the LO.

This section is devoted to presenting some results of searches performed on the Internet to find LOs in Control Systems. The results will be commented in terms of: searchability, retrievability, granularity and language. Subsection 2.1 describes the searches that were performed and subsection 2.2 comments the results.

2.1 Searches and Results

The searches were of different natures: (1) known repositories of LOs; (2) links found in articles or other known links; and (3) one search engine. Only higher education resources were examined; collections that did not include contents for this level were not examined. All searches were

perfomed in Dec.2015, Jan.2016 and Apr.2016. Only some repositories found in papers were searched.

- Known Respositories of LOs – a Brazilian and some international repositories were examined.

  - **AGORA: Ayuda a la Gestión de Objetos Reutilizables de Aprendizaje** (http://www.agora.uady.mx/) – repository that allows authors to contribute as long as they register (it is free). It has a very reach description using LOM. There is no browsing but the search can be performed using subject area only.

Numbers of titles in Science & Technology: (1) 192; and (2) in Higher Education: 170 (88.54% of total).

A search using "control systems" as the argument yielded no results. When "sistemas de control" was used, the result was 307 items because all subject areas are searched.

  - **ARIADNE: Alliance of Remote Instructional Authoring and Distribution Networks for Europe** (http://www.ariadne-eu.org/) – various European countries. The results were obtained by partially browsing the collection. There is no browsing option besides education level.

Numbers of titles: (1) 392,050; (2) in Higher Education: 46,550 (18.87% of total).

A search using "control systems" as the argument yielded 30 items; some of them were MIT Open Courses. When "systèmes de contrôle" was used, the result was zero. Using "sistemas de controle" the result was 17 items that included MIT Open Courses and others with broken links. ARIADNE stores only the catalog description of resources.

  - **BIOE – International Database of Educational Objects** (http://objetoseducacionais2.mec.gov.br/) – Brazil. The results were obtained by browsing the collection.

Numbers of titles: (1) 19,842; (2) in Higher Education: 9,206 (46.40% of total); (3) in Engineering: 144 (1.56% of HE); (4) in Electrical Enginering: 26 (18.06% of Eng); (5) related to Control Systems: zero.

BIOE stores only the catalog description of resources. There are resources in many languages, e.g. Catalan, English, French, Portuguese. It stores images, that according to SCORM should be considered Assets, as Learning Objects. Assets are lower level digital pieces that do not have an educational purpose and do not communicate with LMSs. .

  - **Coursera** (http://www.coursera.org/) – 29 countries. The results were obtained by browsing the collection.

Number of titles: 1,500+

The browsing of courses is difficult – the courses are separated in nine areas and listed in no obvious order. The area Physical Science and Engineering has filters for six subareas, one of which is Electrical Engineering. The number of Electrical Engineering courses is 40 in English, French, Mandarin, Russian and Spanish. The courses seem to be of different objectives and scopes. Only one is on Control Systems and is an introduction to control systems in every day life associated with a historical review; it is in Spanish.

  - **edX** (http://www.edx.org/) – 16 countries. The results were obtained by browsing the collection.

Number of titles: 800+

As in Coursera, the courses are grouped in areas – one area is Engineering with 138 courses that can be filtered by level and language; there are other filters too. There are engineering courses in English, French, Mandarin and Spanish. Many courses are subject to a schedule of offers because tutoring is available. A search using "control systems" yield 330 items and for "control" only 124. In both cases many were not in the topic, as for example Calculus, Linux system administration and management accounting. Both Coursera and edX refer to the contents as "courses".

  - **Fondation unit – Université Numérique Ingénierie et Technologie** (http://www.unit.eu/) – France. The results were obtained by browsing the collection.

Numbers of titles: (1) 4,654; (2) in Automation(*): 149 (3.2% of total); and (3) in Robotics(*): 53 (1.14% of total). (*) Includes industrial automation and other topics.

Fondation unit stores only the catalog descriptions of resources.

  - **NSDL – National Science Digital Library** (https://nsdl.oercommons.org/) – United States. The results were obtained by browsing the collection.

Numbers of titles: (1) 89,722; (2) in Applied Science: 18,888 (21.05% of total); (3) in Engineering: 8,150 (43.15% of Applied Science); (4) in Automation(*): 58 (0.7% of Engineering); (5) in Controls Systems(*): 113 (1.4% of Engineering); (6) in Robotics(*): 397 (4.9% of total). (*) Results of searches using these arguments.

NSDL offers learning contents of more than 25 types in 10 educational levels. Their descriptions are very rich. NSDL stores only the catalog description of resources.

  - **MERLOT – Multimedia Educational Resource for Learning and Online Teaching** (http://www.merlot.org/) – United States with contributions from all over the world. The results were obtained by browsing the collection.

Numbers of titles: (1) 62,673; (2) in Science & Technology: 29,107 (46.44% of total); (3) in Engineering: 2,043 (7.02% of S&T); (4) in Electrical Engineering: 475 (23.25% of Eng); and (5) related to Control Systems: 14 (2.95% of EE).

MERLOT stores a catalog description of resources that are hosted by the institutions that developed them.

- **OpenStax CNX** – (http://cnx.org/) – United States. The results were obtained by browsing the collection. There is no browsing option besides the educational level; there is a list of keywords.

Numbers of titles: (1) 27,609 pages organized into 1,644 books; and (2) in Science & Technology: 12,383 pages (44.85% of total) organized into 782 books (47.66% of total).

The list of keywords did not contain any term related to control systems or robotics. A search with "control systems" in the title yieded a book and four pages, and the same expression in keywords returned a book on communication systems.

OpenStax CNX stores the catalog of resources and the resources themselves – it belongs to one instituition.

- **sup-numerique.gouv.fr** – Le portail du numérique d'ans l'enseignment supérier (http://www.sup-numerique.gouv.fr/) – France. The results were obtained by browsing the collection.

Number of titles: (1) 33,807; (2) in Science of Engineering: 27,797 (82.22% of total); (3) in Automation(*): 215 (0.77% of Sci of Eng); and (4) in Robotics(*): 54 (0.2% of Sci of Eng).
(*) Includes industrial automation and other topics.

sup-numerique.gouv.fr stores catalog descriptions of resources that are hosted by the institutions that developed them. Some broken links were found.

An interesting resource is brer – banque de ressources éducatives en réseau (http://brer.licef.ca/index.php). It is a portal that yields access to learning objects collections in French for all educational levels and in different areas.

An examination of the websites of the repositories did not indicate that they rely on OAI-PMH. MERLOT for sure does not use it; registered users submit LOs..

- Links Found in Articles or other known links.

- **ContLab – Automatic Control Laboratory** (http://www.contlab.eu/en/) – This virtual laboratory offers many experiments. It is described in Cech (2013).

- **UNILabs – University Network of Interactive Labs** (http://unilabs.dia.uned.es/) – This is a network of virtual and remote labs of different universities that support courses. Only the first course is in open access. It is mentioned in a foot note of Guinaldo (2013).

- **relle – Ambiente de Aprendizagem com Laboratórios Remotos** (http://www.rexlab.net/)

- **Online Experimentation @ FEUP** (http://onlinelab.fe.up.pt/)

The last two examples come from websites of project partners and are well known to the author.

- Results Using the Most Ppopular Search Engine – Google (http://www.google.com/). It was chosen because it is the way students search on the Internet. Currently social media are playing an important role too, but this was not addressed. Terms in English were used and results (not filtered) are shown in table 1.

Table 1. Results – Google

Argument	Number	Obs
Learning Objects Repository	998 K	(1)
Learning Objects Repositories List	1,610 K	(2)
Learning Objects Sharing and Reusability	146 K	(3)
Learning Objects Repositories Networks	1,470 K	(4)
Free Learning Objects Repositories	2,320 K	(5)

(1) Significant results were found in the first three pages; webpages, papers and other texts came along. Some webpages only had links to repositories. This search yielded many repositories of American universities and consortia. Repositories and consortia in Canada were found too. Some resources were in open access and others were not.

(2) Same as (1) and many repositories appeared in both. An interesting result was a directory of open elearning content repositories available from WikiEducator (http://wikieducator.org/Exemplary_Collection_of_Open_eLearning_Content_Repositories). Many repositories were examined and many broken links were found.

(3) This search had some of the repositories that appeared in the other two, but a lot more articles and other texts.

(4) This search yielded interesting results of consortia in different parts of the world. Many results were the same as in the previous searches.

(5) The first two pages of results were very similar to the other four searches results.

2.2 Comments on the Results

The searches obviously were empirical and did not cover all possibilities. At the same time, they yielded interesting results that after being examined allowed the following comments:

- ARIADNE, MIT Courseware (http://ocw.mit.edu/), MERLOT, NCLOR (http://explorethelor.org/), OER Commons (http://www.oercommons.org/), TAMU CC (https://iol.tamucc.edu/repositories.html), TxLOR (http://www.txlor.org/) and WikiEducator come as results in many searches and/or after following many links.

- NSDL and OER Commons have very good filters to find resources – they run on the same platform. Specially useful filters are subject and education level.

- There is no standard or best practice structure for the information on the LOs/courses. This yields the conclusion that there is no minimal metadata description and automated metadata harvesting. The exception among the ones that were examined is Citidel (http://www.citidel.org/) that runs on DSpace (http://www.dspace.org/) – a free and open Institutional

Repository software. Information uploaded to MERLOT requires a personal action of the author or the manager of the resource; this author contributes to MERLOT

- All types of LOs/courses are available – they differ in discipline, target audience, educational level and granularity. They come in many different languages which is quite good.
- A sad comment is that following the links trying to reach the LOs, many subsequent links were broken.

This was a very superficial search whose objective was to assess the availability of contents on Control Systems on the Internet. It also was meant to identify ways of finding them, their sizes and the languages that were used.

The results show that the number of educational contents available on the Internet is very large and this is no surprise. At the same time, they are spread among websites, systems and repositories all over the world. MERLOT is an organized and useful aggregator of information that has a good description of the contents that it hosts. WikiEducator comes as a result in many searches. Its directory seems to be updated manually; the last update was in Nov.2015. Some very rich collections are presented there and two are worth mentioning. The first is iLumina (http://www.ilumina-dlib.org/), a digital library of shareable contents in science for undergraduate students. All items are described with international standard MARC – Machine Readable Catalog and the metadata set developed for NSDL – National Science Digital Library. The second is OER Commons that offers over 86K+ titles in many different areas but does not focus on higher education.

Since there is no centralized repository for the LOs, either the user goes to specific systems or uses a search engine. Many resources may not be found or will require a lot of effort. Broken links are a problem too – the resource is found but can not be retrieved. For the user this has the same result. Persistent URIs should be used.

Granularity was not common to all resources, as it would be expected. There are complete courses, as for example the MIT undegraduate courses on Signals & Systems – Part 1 (https://www.edx.org/course/signals-systems-part-1-iitbombayx-ee210-1x-0#!) and Part 2 (https://www.edx.org/course/signals-systems-part-2-iitbombayx-ee210-2x-0), and also images, as for example The 12 Most Wanted Insects (http://nsdl.oercommons.org/courses/the-12-most-wanted-insects/view) that belong to a set images of 12 insects. According to the SCORM classification, this would be an Asset and not a LO or SCO. Some experimental resources are well organized – they are hosted on websites/systems that aggregate many of them. This is particularly true in the case of remote and virtual labs; ContLabs, UNILabs, relle and Online Experimentation@FEUP are examples. There are portals of organizations devoted to remote and virtual experimentation that offer access to resources; one example is lila – Library of Labs (http://www.lila-project.org/) that lists available resources in different countries.

Concerning languages, there was a wide variety among the resources found, but the most common was English. Another positive finding was that many used Creative Commons Licenses that allow translations.

3. A UNION CATALOG OF LOs IN CONTROL SYSTEMS

The suggestion to create a union catalog of learning resources for Engineering Education (Pavani, 2010) was based on the successful experience of ETDs. It addressed the players involved and the steps to be followed. At the same time, in the last few years, the idea of OER is getting more popular and content developers are engaging in cooperation. The current suggestion is to have a narrower scope – Control Systems (Robotics and Automation included).

The creation and the operation of the union catalog should be supervised by an organization or a pool of organizations, the same way NDLTD does to the union catalog of ETDs. The steps to follow are well known. Metadata elements have been defined by LOM, harvesting of metadata can be performed by the use of OAI-PMH – Open Archives Initiative Protocol for Metadata Harvest that is widely used. The cooperating institutions would be required to use repositories with OAI-PMH data provider functions and this would not be a problem since DSpace is a free solution. The union catalog would bring some benefits such as:

- A central repository of metadata of OER for interested persons to search. A minimum set of metadata elements should be agreed upon for institutions to cooperate.
- The metadata description would be suited not only for end users to find resources but also to persons who want to reuse and/or translate and/or enhance resources.
- Retrieval of the resources should be performed from the developer's systems. To avoid broken links, persistent URIs should be used. PUC-Rio assigns DOIs to ETDs and senior projects, and is in the process of assigning to articles. A proper metadata description for LOs to receive DOIs has not been defined so far. As soon as this description is available DOIs will be assigned to LOs.
- LOs derived from the original ones should go the union catalog too.
- The use of OAI-PMH would make updates of contents information automatic.

PUC-Rio is a member of NDLTD and cooperates with metadata of its ETDs to the union catalog. The Maxwell System (http://www.maxwell.vrac.puc-rio.br/) is the institutional repository that also hosts LOs. Currently there are 118 LOs and a set of Interactive Books with 685 exercises in Electrical Engineering in open access. Among these, 52 LOs and 237 exercises are in Control Systems. All resources are described using ISO 15836.2003 plus many elements from the LOM set. The Maxwell System is an OAI-PMH data provider. PUC-Rio would cooperate.

Figure 1 shows a possible architecture for this cooperation.

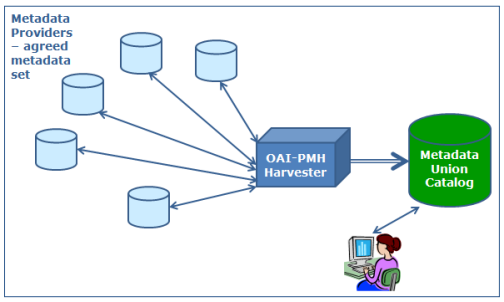

Figure 1 – Suggested architecture.

4. CONCLUSIONS AND NEXT STEPS

The existence of such catalog would require a long work of a team of experts; they should come from the ICT supported education community with specific skills in Control Systems and related areas. The supporting organization(s) should provide organizational support for the work to be developed. The hosting of the union catalog should be decided too. During the planning and implementation activities the Control community should be contacted so that resources are identified and potential members start to get ready to join the project. Social professional networks could be used to identify potential members. Once the model is ready and the infrastrucure implemented, the catalog must be populated. To do it, the solution must be based on the OAI-PMH so that metadata can be collected from the cooperating repositories and transferred to the union catalog. Cooperating repositories must identify LOs in Control Systems and any other related area that is chosen to be hosted on the union catalog.

Concerning the next steps of this work, there are different tracks to be followed: (1) explore the searches in different languages (some repositories are national and have most LOs in the local languages); (2) examine search engines besides Google; and (3) suggest that the implementation of the union catalog including a classification of the granularity of the LOs – this is due to the considerable differences found (videos of courses versus small simulators).

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