



The Global Online Laboratory Consortium and its Role in Promoting a Global Cloud of Cyber Physical Laboratories

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1. Introduction

The NMC Horizon Report lists Virtual and Remote Laboratories as one of the most important future technologies in learning.¹ With this in mind researchers and academics have made considerable advances in the design and development of online laboratories. These laboratories are accessible via the Internet 24 hours a day and 7 days a week. These advancements have been possible because of the growing advancement of Internet and networking technologies as well as new developments in e-learning and e-work tools. The forerunners in this area are engineering disciplines and the natural sciences.

Active learning by means of online laboratories is especially valuable for blended learning approaches. Students can access online laboratories from almost any location and the only need is web access. This flexibility is vital for enhancing traditional education as well as for expanding further education and lifelong learning. Online engineering is one of the future directions for advanced teleworking/e-working environments not only in engineering and science (economics and informatics) but also other disciplines that are affecting our society. Especially in engineering education there is an enormous educational value in hands-on laboratory experiences. However, conventional laboratories are becoming increasingly expensive, have complex logistics, limited access time, and cannot be easily shared beyond the physical laboratory's boundaries. Using online laboratories has the potential to significantly reduce obstacles related to cost, time/inefficient use of facilities, inadequate technical support, and limited access. This is especially important for engineering education in developing nations.

Different solutions and technologies exist today to implement online laboratories as well as different communication standards and data exchange protocols. Therefore, each institution/university is likely to adopt its own standards and approaches to performing tasks, such as handling users' accounts and managing experiment data. Because of these challenges, sharing remote laboratories is more difficult. To address these issues as well as to promote and develop the online laboratories through international collaboration, the Global Online Laboratory Consortium (GOLC) has been established. As the first step, a group of enthusiasts and visionaries met in June 2009 at MIT and discussed the objectives and principles of such an association. In June 2010, the GOLC was official founded in Villach (Austria) during its first annual general meeting.

2. What is GOLC?

The mission of the consortium is the creation of sharable, online experimental environments to increase the educational and scientific value of learning that may not be accessible, scalable, or efficient through traditional methods. The GOLC is focused on promoting the development and sharing of, and research into, remotely accessible laboratories for educational use. As the usage of online experiments gains traction in the educational community, there is increasing interest in developing online labs on a common infrastructure. A unified and interoperable architecture is essential to convert the tremendous current interest for online experiments into an economy of labs that can be efficiently shared around the world. The GOLC strategic objectives are ²

- to encourage and support the creation of new online laboratories and associated curricular materials
- to sponsor the design of an efficient mechanism for sharing, exchanging and trading access to online laboratories by the creation of a global network of shareable experiments
- to support communities of scholars created around online laboratories
- to lead the evolution of an architecture that enables the sharing of online laboratories by unified standards.

3. Activities through GOLC

GOLC is very active in developing collaboration between its members and partner organizations, initiating projects and activities that promote online laboratory area, and organizing and sponsoring professional events (e.g., conferences and workshops). Some of the activities include iLAB Alliance, organizing international conferences and workshops, publishing books, developing reference collection systems, and standardizing activities.

3.1 iLAB Alliance

The iLab Alliance started as an initiative of several partners who agreed to share their online experiments within this network. It is, in this context, a step toward a broader usage and dissemination of online laboratories and has helped to raise issues that must be addressed for the implementation of a more efficient model to govern the practice of sharing labs on a cross institution basis. The software architecture used to maintain the laboratory sessions as well as scheduling service and experiment data storage is the iLab Shared Architecture (ISA) described in the previous section. ISA has an important characteristic, namely its distributed topology that has made it the ideal solution for implementation. ISA has already built-in mechanisms that allow setting up trusted connections between its autonomous network nodes (service brokers) so online laboratories can be seamlessly shared between them. This means that the institutions are free to manage their own online laboratories and their own user accounts and to deliver these labs via their own server. In this way, access for their users to their own laboratories does not depend on the status of other service brokers. On the other hand, to be able to use laboratories from other universities, a user has to authenticate in the main service broker. Each institution member of the network is expected to set up one service broker and deliver at least one experiment via this server. This means that from a pool of laboratories available at one institution, it is up to the institution to decide which laboratories will be available to the other members of the network.

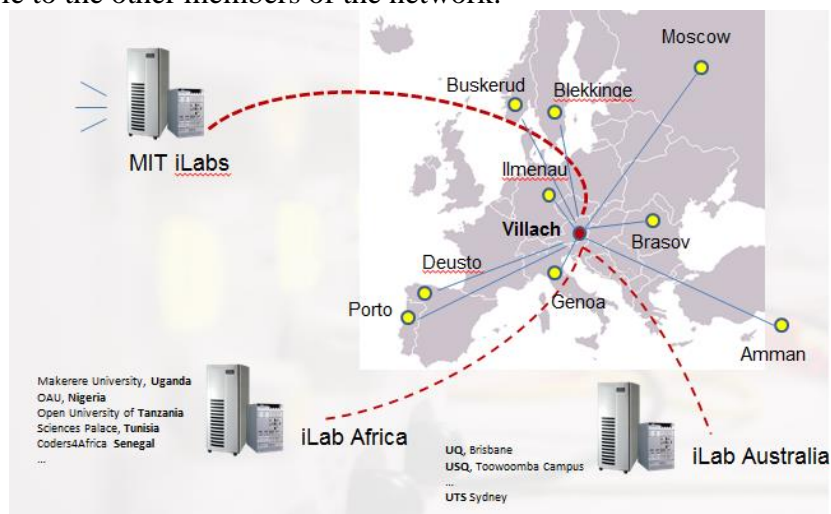


Figure 1: iLAB Alliance network.

Currently a number of entities are connected with this network. These include iLab Europe, MIT iLabs, iLab Africa, and iLab UQ Australia. Figure 1 shows the network layout. In this way GOLC helps to make global learning in engineering a reality. Nowadays more than 100 different laboratories are accessible via the iLab backbone.

3.2 *International Conferences*

Together with the International Association of Online Engineering (IAOE) GOLC organizes the annual International Conference on Remote Engineering and Virtual Instrumentation (REV). These conferences are a forum for specialists in the fields of Online Laboratories, Internet of Things, Cyber-physical Systems, Collaborative Networks and Grids, Cyber Cloud Technologies, and Service Architectures. An important concern of this conference series is the close collaboration between academic research and industrial partners. The companies supporting the activities include National Instruments, MathWorks, EMONA, Digilent, Keysight, etc. These companies are also members of GOLC. This year's REV2016 conference in Madrid, Spain, was again a very successful one, with more than 120 participants from 29 countries. The next REV conference (REV2017) will be held in New York at Columbia University (US).

An important medium to disseminate the idea of online laboratories is the GOLC *Online Laboratory Award*. The award is presented for outstanding solutions for stable running laboratories in the categories: *Visualized experiments, Simulated experiments, and Remote controlled experiments/laboratories*. Following the REV2015, this award was presented during REV2016 as well. This year's winners came from Greece, Germany, and Czech Republic.

3.3 *Organizing Workshops*

GOLC organizes workshops in the field of online laboratories to promote and encourage new laboratory development as an emerging area and to disseminate major developments around the world. To ensure an interactive working atmosphere, the participants for these workshops are kept between 20 and 30. The workshops were well attended, and a number of GOLC members took an active part to make these events successful. Typically, we have a mix of onsite and remote presentations during the workshops to show the technology under real conditions.

The first event of this kind was organized during the ASEE Annual Conference in June 2015 (Seattle, US). The second workshop was organized in Pune, India, on January 10 during the third International Conference on Transformation in Engineering Education (ICTIEE 2016). The next two workshops are planned for during the ASEE Annual Conference in June 2016 (New Orleans, US) and in November 2016, during the World Engineering Education Forum in Seoul, Korea.

3.4 *Edited Books*

In 2011, members of GOLC published an edited book on online laboratories, titled *Internet Accessible Remote Laboratories: Scalable E-Learning Tools for Engineering and Science Disciplines*³. The initiative was to document current developments in the multidisciplinary creation of Internet accessible remote laboratories. This book offers perspectives on teaching with online laboratories, pedagogical designs, system architectures for remote laboratories, future trends, and policy issues regarding the use of remote laboratories. It is a useful resource

for educators and researchers who are interested in learning more about the current status of the field as well as various approaches to online laboratory design.

After the success of the first book, we are currently working on a second edited book on online laboratories. The proposal has been reviewed by Springer and we are now in the process of finalizing an agreement. As proposed, the book will have five sections: State of the Art and Future Developments, Mobile Learning with Online Labs, Pedagogy of Online Experimentation, Online Labs: Case Studies from Educational Practice, and Commercial Tools for Online Labs. Call for chapters will be circulated in due course.

3.5 Reference Citation System

Online laboratories are becoming more and more appealing in many educational scenarios due to technology advancements and the rising pedagogical interests. Proper qualitative and quantitative analyses are needed to profile publications and their authors, to highlight trends and most promising research areas, to identify leading authors, and to drive the scientific community toward the right publication targets. Since no tools are currently available to achieve such purposes, a few GOLC member have taken the initiative to develop a data processing pipeline capable of producing a dataset of cleaned and normalized bibliographic references (namely the GRC2014)^{4,5}. The initiative has been led by our Italian partners. This will be a biographical reference with an extensive overview of current and historical research and publication trends in the GOLC scenario. A Global Online Laboratory Repository will also soon be available for public use.

3.6 Standardization Activities

As indicated earlier, the potential of online laboratories has generated substantial interest in the areas of research and development. However, the interdisciplinary nature of this research makes the development process rather complex. Various researchers have ventured into the field of remote laboratory development as individuals without having a complete picture of the current status of development by their peers. In the absence of any common framework, each development initiative starts from scratch, working from different assumptions and premises, and making the resulting work *sui generis*, as there is currently little transferability or integration of the different efforts of persons involved in the development of online laboratories. To address this issue, the GOLC has undertaken an initiative to work on the standardization of remote laboratory development. The initiative was organized via three committees: a technical committee, an education committee, and a membership and communication committee. The technical committee has played a vital role in developing a technical metadata profile and in setting up normative references, terms and definitions. Recently the GOLC has teamed up with the IEEE Standards Committee *P1876* in an effort to drive the initiative forward.

3.7 International Projects

GOLC is also a partner in international research projects. Two recent examples are

- The eScience project funded by the European Union with the aim to establish a network of remote laboratories in the North African countries.
- “Laboratory Pedagogy Action learning based open MOOC” coordinated by the University of Southern Queensland, Australia.

One of the GOLC tasks in the near future is to include online laboratory providers from Asia. In this effort, during the ICTIEE 2016, we have opened an IAOE Indian Chapter.

4. Conclusion

The paper describes the background of the GOLC and its efforts and activities to promote online laboratory discipline. With the seven years since its initiation, the organization has made its mark within the community. The types of activities involve facilitating alliances among the members and organizations, sponsoring and organizing conferences and workshops, driving publications in terms of edited books and technical papers, developing a bibliographic repository system, and collaborating through international projects. The last, but most important, item is to drive a standardization effort for a remote laboratory discipline that will have a long lasting impact for the coming years.

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