

REMOTE LABORATORIES IN ENGINEERING EDUCATION

Ahmed NADDAMI¹, Ahmed FAHLI², Mourad GOURMAJ³, Zoltan GERMAN-SALLO⁴,
Horațiu-Ștefan GRIF⁵, Adrian GLIGOR⁶

^{1,2,3} Hassan University

1, Laboratoire MATIC, 26000 Settât, Maroc

¹ahmed.naddami@gmail.com

²fahli@uhp.ac.ma

³mourad.gourmaj@gmail.com

^{4,5,6} “Petru Maior” University of Tîrgu-Mureş

Nicolae Iorga Street, no. 1, 540088 Tîrgu-Mureş, Romania

⁴zoltan.german-sallo@ing.upm.ro

⁵horatiu.grif@ing.upm.ro

⁶adrian.gligor@ing.upm.ro

Abstract

The remote laboratory experiments in engineering education became a useful tool as a great challenge for specialists. Setting up a new educational platform with remote laboratory experiments, many students from many countries can access them in order to complete, enhance their education in engineering. This paper presents a new and full functionally remote laboratory in electronic engineering field and some criteria for technical evaluation in order to be integrated in engineering education

Keywords: remote laboratories, engineering education, technical evaluation, functional suitability

1. Introduction

Education in the applied sciences and engineering disciplines requires practical experimentations to complete educational activities. However virtual campus and distance learning environments remain incomplete, therefore, hands-on laboratories should be included. In engineering education, practical work is an important and academic complement to theoretical courses. Students come to the laboratory to conduct experiments and appreciate the discrepancies between their observations and predictions according to the theoretical courses. They need to acquire knowledge and skills of control systems modeling in order to develop and test experiments. This requirement represents a serious drawback for the distance learning process. Yet, due to several limiting factors in traditional laboratory experiments, students cannot get the necessary experiences. As a result, several institutes have adopted online laboratories as a solution to reduce those obstacles.

Remote sessions/ remote laboratories are another kind of online labs, which are based on the development of Internet technologies, implementation of information and telecommunication technologies. They have been considered as an increasingly popular

innovation in engineering education. Moreover, remote labs have had an enormous impact on engineering as they help both students and teachers to access real experiments on real hardware at anytime they want and from anywhere through Internet. Over the last decade, and due to many factors, more web-based laboratories have been integrated into educational process; and many institutes have explored the WWW to transfer their theoretical and the activities of their laboratories towards distributed contexts [1-2]. A remote laboratory presents high quality features and an easy way to perform experiments, the thing that distinguishes it from other simulated laboratories which do not use real equipment.

2. Khouribga OnlineLab for Engineering Education

Khouribga OnlineLab in Hassan 1 St University in Morocco is one of several laboratories developed in Tunisia and Algeria within the eScience project (rESeau maghréBIn de laboratoirEs à distaNCE) [3]. It was inaugurated on the 28th of June 2013 in Khouribga and considered as the first laboratory developed in the eScience project group, available via <http://www.onlinelab-uhp.ma/> [4-5]. Khouribga

OnlineLab provides many remote experiments in Electrical engineering. It also covers many engineering curricula in different levels, which includes several experiments, as part of the lecture class, in electrical machines and digital electronics accessible via the internet 24/7 from anywhere. Additionally, the instruments of this laboratory can be conducted across OnlineLab intranet or via Internet. Since 2013, Khouribga OnlineLab (online laboratories and online courses via Learning Management System Moodle) has been being used by more than 600 students from the several institutes of Hassan 1 St University, as well as the different Engineering degrees: Physic Sciences, Industrial Engineering, Automatic & Telecommunication, and mechanical engineering [6].

The team of Khouribga OnlineLab has developed within the “eScience” project two remote laboratories in Electrical machines and Digital logics:

The first Laboratory of electrical machines

A choosy challenge for this experiment is how to implement and develop a real-time platform for controlling and monitoring electrical drives that reaches 380 V. Not to mention, permitting remote students to access to the platform for remote experimentation as well as performing several measuring and monitoring experiments through any web browser as in physical laboratories.

Hence, to answer that challenge, the team has developed an internet application using LabVIEW software to control distance laboratory concept for electrical drive using the NI CompactRIO platform

[7]. The chosen solution is known as a low cost platform that offers reconfigurable control and acquisition, deterministic system control with multiple proportional integral component, control loops and protection methods. Beside these it also helps collecting data from a variety of equipments installed in the system as well as numerous analog and digital I/O allowing a full control (Figure 1).

The Second laboratory of digital electronics: combinational and sequential logic circuits

The challenge of this laboratory is how to develop a digital online laboratory that supports experiments in the fields of combinational logic circuits and sequential electronics identically to hands-on labs.

Therefore, using NI LabVIEW software and NI Educational Laboratory and Virtual Instrumentation Suite II (NI ELVIS II) to create a series of labs in combinational and sequential logic circuit was the right solution. The NI ELVIS II platform is designed for learning through interactive virtual instrumentation to test and see the behavior of circuits (Figure 1) [7].

The Khouribga Onlinelab is based on the MIT ilab Shared Architecture (Figure 2) [8-10]. It licenses users to conduct and run experiments remotely. They can manipulate real hardware over the Internet using a web client.

The GUIs of remote experimentation are designed using LabVIEW and considered as a fundamental factor that enhances the student’s experiences.

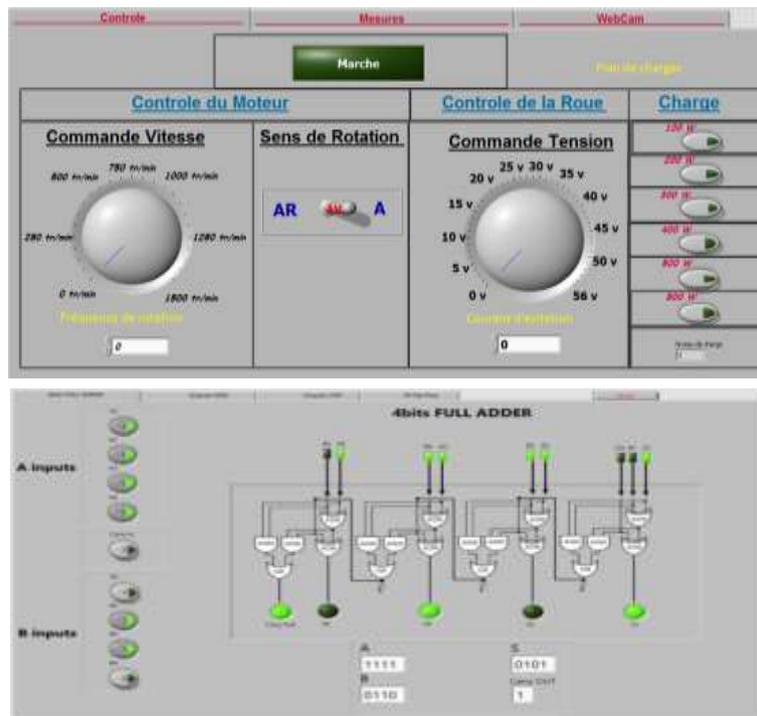


Fig. 1: Example of client interfaces (screenshot)

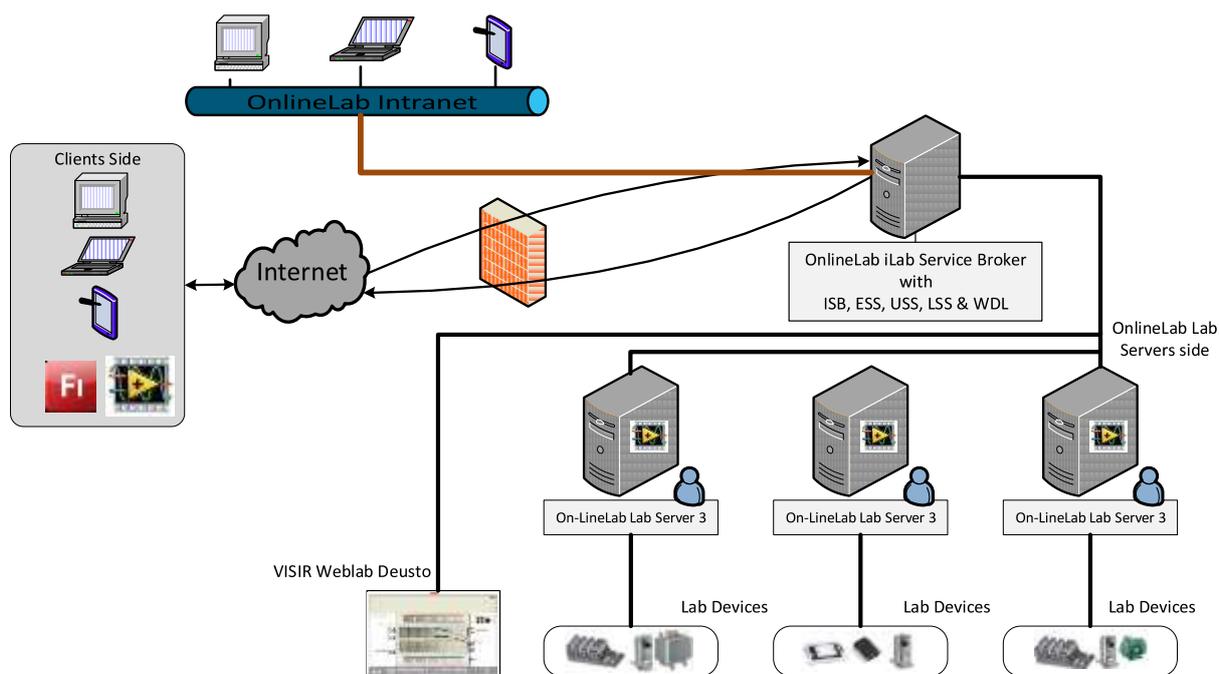


Fig. 2: Khouribga OnlineLab Architecture

These understandable interfaces have a vital impact on the student experience since it is the only means that allows the establishment of a mutual connection between the user and the physical experiment. It also minimizes the distraction between those constituent and the actual equipment. By contrast, in an inadequately designed interface the collaboration between the laboratory elements can be distracted due to many factors. A short description of Khouribga Online Lab Architecture can be found in [3].

During the Khouribga OnlineLab experience, students from these institutions were encouraged to use the new web-based remote laboratories system to perform their practical works [11]. Some preliminary results of an online evaluation of students were extracted and analyzed in [12]. More specifically the proposed evaluation strategy was focused on five different but interrelated directions

- a) usability of remote labs;
- b) learners' attitude towards remote labs;
- c) technical evaluation of remote labs operation;
- d) evaluation of the e-learning content namely the teaching units previously described;
- e) learning outcome.

The results of the study revealed that the learning outcomes of the control (students using traditional labs) and treatment groups (students using remote labs) are statistically similar.

In addition, the results disclosed that the students who participated in the remote labs session were

satisfied and had a positive opinion about the ease of use, usefulness and ease of learning and usefulness of the remote labs used.

3. Example of experiment

Here we would like to use an exemplary of experiment available via Khouribga OnlineLab. The experiment is a typical 3rd year experiment for students enrolled in electrical engineering programs. Its aim is to determine in real-time the parameters of Open Circuit characteristics (OCC), short circuit characteristics (SCC) and synchronous reactance X_s . A standard set of equipment of this experiment are shown in (Figure 3), which includes loads, a synchronous and asynchronous machines, a variator speed, excitation and digital displays etc. The system allows students to interact remotely over the Internet with the real equipment that is placed in one of the laboratories at the polydisciplinary faculty in Khouribga.

The GUIs of this laboratory presents a window with indicators and knobs for a full control. It provides the user with the ability to control the system: Run and stop the system, varying the speed frequency of machines, control of voltages and currents, activation and deactivation of desired loads flows the plan presented in the interface.

During the experiment besides the online tutorial, also a descriptive manual about the studied circuit and parameters is available. The visualized data and obtained waveforms can be noted by the students in order to perform a postprocessing of measurements.

Real-time Visualization

The Subject and the most important characteristics of this remote experiment is the visualization of equipments located in the physical laboratory. Thus, there are two web cameras installed to help student during the manipulation execution, so (Figure 3):

- The 1st is used to give student a global vision on the system ‘loads, test bed, machines...’ by this way students feel like if they were in a real physical laboratory manipulation real hands-on machines.
- The 2nd is directed to the digital display’s. So student can make a look instantly to different values of current, voltage,...in each adjustment of the parameters that govern the system.



Fig. 3: General view of laboratory equipment

4. Technical evaluation

As the role of the created remote lab was already mentioned above, a report on their efficiency and impact would result from the evaluation that rely on two aspects: technical and didactical. The technical evaluation is very important because it can assure the best suitable test bed for the didactical evaluation side.

In the implementation cycle of the eScience project for technical evaluation there are two distinct phases. This aspect is very important, because the covering in a unitary manner of a multidisciplinary platform may constitute a real challenge.

In the literature are presented many solutions for remote laboratories related to different target domains, most of them oriented on niche areas. All of them are based on ISO/IEC 25010:2011 standard specifications [16] For these cases were defined various evaluation criteria, such as user-friendliness interface [13], user communication quality [13-14] or usability [15] purely applicable for evaluations of some fundamental technical functional aspects.

eScience remote lab technical evaluation methodology

In the present paper is proposed a technical evaluation methodology able to offer a high degree of

generality with applicability in the case of any engineering education remote laboratory.

The specifications of the proposed evaluation solution were developed starting from ISO/IEC 25010:2011 standard specifications [16].

The technical evaluation is very useful because it covers the necessity of evaluating the entire eScience educational network characterized through a large diversity of engineering teaching units.

The technical evaluation it is proposed to be accomplished during two phases: an initial phase when the evaluation is performed by accessing the remote labs in brief usage and a second phase designed for detailed evaluation mostly focused on achieving predefined indicators and metrics.

It is worth to be mentioned that detailed technical evaluation is focused on measuring the functional suitability of the remote labs.

The functional suitability, as defined in ISO/IEC 25010:2011 shows the degree to which a product or system provides functions that meet stated and implied needs when used under specified conditions, has the following three components: functional completeness, functional correctness and functional appropriateness (Figure 4)[16,18]. The three components are related in order to give a complete evaluation as seen in figure 4.

The functional completeness is defined [16] as the degree to which the set of functions covers all the specified tasks and user objectives and is expressed through three parameters: the *matching degree* (between tutorial provided requirements or specifications and functions of remote lab, meaning how the remote labs satisfy the tutorial provided requirements), the *degree of measurability of parameters* (meaning how the parameters can be measured on user interface and compared with the digital instruments’ values) and the *quality degree of provided feedback*

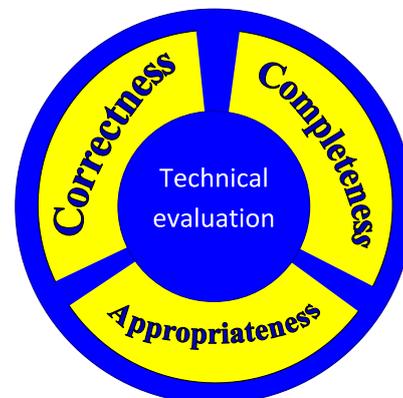


Fig. 4: Technical evaluation approach for functional suitability

The functional correctness is defined [16] as the degree to which a product or system provides the correct results with the needed degree of precision.

Table 1

Criteria	Obtained parameters	%
Functional completeness	All the provided facilities of the remote laboratories satisfy the tutorial provided requirements	100
	The parameters can be viewed and measured on user interface very precisely, the realized graphical interfaces are user-friendly and facilitate the understanding	100
	The function of remote laboratories can be viewed and heard by the user. The visualization of parameters as measured data is of high quality	100
Total functional completeness		100
Functional correctness	The resolution of displayed (on User Interface) and measured (measuring instruments) values is suitable for this kind of experiment	100
	All expected functionalities are provided in good conditions, the user can easily access all features in order to have a good control	100
	The resolution and format of provided measured data is suitable for a good understanding and correct interpretation of synchronous motor functionalities	100
Total functional correctness		100
Functional appropriateness	The user interface and tutorial assures a high level of facility is use, the interface is responding clear and quickly to all commands, the messages are clear and easy understandable, the user has the whole control during the experiment	100
	The tutorial and user interface cover entirely the created topics, there is no need to access other references, and both of theoretical and practical issues are well suited to the proposed topic	100
	The remote laboratories are build in a pragmatic manner, every step in execution is well thought and there are no unnecessary steps in execution. All these experiments are repeatable with a convenient scheduling	100
Total functional appropriateness		100
Total functional suitability		100

To evaluate this three parameters are used, *the degree of measurement accuracy* (meaning the resolution of displayed and measured values, graphics and other parameters, *the matching degree between*

provided and expected functionalities, and the provided data's resolution and format.

The functional appropriateness [16] is the degree to which the functions facilitate the accomplishment of specified tasks and objectives and is carried through by *facility degree in use* (meaning usability, user-interaction, expressed by degree in percentage of message's clarity, of provided tutorials correspondence, by *cognitive ergonomics* (meaning if the tutorial and user interface can cover the created topics), by *degree of compliance* (measuring pragmatism of execution).

All these parameters are expressed in percentages.

A general synthesis of Khouribga OnlineLab technical evaluation, regarding the mentioned parameters is presented below in Table 1.

5. Conclusions

The main contributions of authors are the building of a functional online laboratory structure and the elaboration of technical evaluation strategy. The remote laboratory experiments are fully functional and in daily use in the mentioned educational institute. The implemented educational network can enrich the teaching and learning strategies or culture in engineering education programs and helps them to become more student-centered, encouraging individual work, offering solutions for both, problem-based and project-based learning.

After the technical evaluation which is a small scale supervising over functional suitability, a large scale pedagogical evaluation will be performed. This will focus on usability of remote labs; learners' attitude towards remote labs; evaluation of the e-learning content; and assessment learning outcome [17].

The presented evaluation methods can emphasize the most important tasks from technical and pedagogical point of view, offering a general but measurable view of the present situation. The project is still under development, other important results are expected to emerge until the end of projects period.

The evaluation demonstrates that this kind of remote laboratory experiments can strength the training of engineers and technicians with innovative and accessible technology.

Acknowledgement

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

References

- [1] Tawfik, M., Sancristobal, E., Martin, S., Diaz, G. and Castro, M. (2012), Stateof-the-art Remote Laboratories for Industrial Electronics Applications, presented at the

- Technologies Applied to Electronics Teaching (TAEE)*, pp. 359-364.
- [2] Mohtar, A., Nedic, Z. and Machotka, J. (2008), Remote Laboratory for Inspection of Silicon Wafer, in *The International Conference on Frontiers in Education: Computer Science and Computer Engineering*, pp. 144{148, Las Vegas, Nevada, USA.
- [3] Naddami, A., Fahli, A., Gourmaj, M. and Moussetad, M. (2014), Determination of the synchronous machine's parameters using the iLab Shared Architecture ", *IJOE*, Vol 10, No 3 .
- [4] Zimmer, T., Geoffroy, D., Pester, A., Oros, R., Tsiatsos, T. and Douka, S. (2013), eScience: Setting up a network of remote labs in the magrebian countries, *ICEEL*, Marrakesh, Morocco, 1–5 July 2013
- [5] The eScience website (2015) <http://www.esience.org>
- [6] Naddami, A., Fahli, A., Gourmaj, M. Pester, A. and Oros, R. (2014), Importance of a network of online labs in magrebian countries *Proceedings of the IEEE , REV14 Conference*, pp.77-78, Porto 26-28 February, 2014
- [7] The National Instruments website (2015) <http://www.ni.com>
- [8] Harward, V.J., et al (2008), "The iLab Shared Architecture: A Web Services Infrastructure to Build Communities of Internet Accessible Laboratories," *Proceedings of the IEEE* , vol.96, no.6, pp.931-950.
- [9] Orduña, P. (2013). *Transitive and scalable federation model for remote laboratories. PhD Thesis*, Universidad de Deusto. http://www.weblab.deusto.es/pub/dissertation_pablo.pdf
- [10] Kimberly DeLong, V. Judson Harward, Philip Bailey, James Hardison, Gordon Kohse, Yakov Ostrotsky, Three Online Neutron Beam Experiments Based on the iLab Shared Architecture, *Education Engineering (EDUCON)*, Madrid, pp .145 – 150,14-16 April 2010.
- [11] Tsiatsos, T., Douka, S., Mavridis A., Tegos S., Naddami A., Zimmer T, Geoffroy, D. (2014), Evaluation plan and preliminary evaluation of a network of remote labs in the Maghrebian countries, *iJOE*, Vol 10, No 5, pp. 15-20.
- [12] Naddami A., Fahli A., Gourmaj M., Moussetad, M. (2014), Online laboratory in Digital Electronics using NI ELVIS II+, *Proceedings of the IEEE , IMCL14 Conference*, pp. 120 - 124.
- [13] Monsef, E., Gilliland, S., Anjali, T., Saniie, J. (2014), Remotely Accessible *Computer Network Laboratory with Hands-on Experience*, *IEEE International Conference on Electro/Information Technology (EIT)*, pp: 367 – 372.
- [14] Melkonyan, A. ; Akopian, D. ; Chen, C.L.P. (2009), A Remote Over-Internet Hands-on Laboratory, *IEEE International Conference on Systems, Man and Cybernetics*, San Antonio, TX, USA, pp: 4634 – 4640.
- [15] Garcia-Zubia, J., Orduna, P., Angulo, I., Hernandez, U., Dziabenko, O., Lopez-Ipina, D. and Rodriguez-Gil, L. (2011), Application and User perceptions of using the WebLab-Deusto-PLD in Technical Education, *Frontiers in Education Conference (FIE)*, pp: GOLC1-1 - GOLC1-6.
- [16] ***, (2011). ISO/IEC25010:2011, Systems and software engineering-Systems and software Quality Requirements and Evaluation (SQuaRE)-System and software quality models. International Organization for Standardization; p.34.
- [17] Tsiatsos, T., Douka S., Zimmer T., Geoffroy D. (2014), Evaluation plan of a network of remote labs in the Maghrebian countries. *11th International Conference on Remote Engineering and Virtual Instrumentation (REV)*, 2014 , p. 200 – 203.
- [18] German-Sallo, Z., Grif, H. S., and Gligor, A. (2015), Technical Evaluation of Remote Laboratories in an Engineering Educational Network. *Procedia Technology*, 19, 1136-1141.