Evolutionary Analysis ofOnline Labs

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ABSTRACT
Our intention with this work is to analyze the evolution of online lab systems, from theirorigins in 1898, with the radio-controlled missile made by Nikolas Tesla,to the present day. We also propose to analyze the evolution of the severalonline labs lines of development throughout their history, in an attempt to foresee their future development, taking into consideration the factors that condition each particular line and the actual state of development. We also intend toanalyzewhy some development lines are deadand why they did not survive, especially when considering the human factors associated with each online lab system.We intend to prove that we can apply the "Origin of Species" laws in Online labs.

Categories and Subject Descriptors
• **General and reference~Experimentation** • *General and reference~Surveys and overviews* • Information systems~Content ranking

Keywords
Online labs, remote labs, virtual labs, e-learning, b-learning, engineering education, engineering pedagogy.

1. CONTEXT AND MOTIVATION THAT DRIVES THE DISSERTATION RESEARCH
The motivation that drives us to perform this analysis is the fact we believe there is an almost "biological" development pattern in online lab systems, which particularlydepends on the human factors and the conditions of the scientists and technicians that create, operate and maintain these systems.

The people that create, operate and maintain the various existing online lab systems have done so in the course of their desires, motivations and objectives.In addition, the surrounding environment is another important factor that strongly conditions the progression of each development line and online lab system.

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"Adaptation to the environment" is a strong link to the system proposed by Charles Darwin in "The Origin of Species", so the "Origin of Species" can likely be applied not only to biological systems but also to other system types. This is especially true due to the fact that the definition of a "system" is today much widerthanthat proposed at the end of the 19th century / beginning of the 20th century.

To this respect, an "online lab" is a system. Today, every system is also considered a mental construction, a mental model.However, some systems have a real existence, with real components; and this is the case for online labs. Like all systems that interact with the external environment, online labs are also a mental model of an open system, and have a mathematical image and model.

The concept of a "system" is more than a mathematical model and abstract idea. Since the reference book, *General Systems Theory*[1], by Bertalanffy,systems philosophyhas changed.Nowadays, the concept of "system"has a new scientific paradigm, far from the simple mechanistic vision accepted during the 1960s. In particular, the term "system" can be applied not only to scientific, mechanical and electric devices, but also to emotional and social events and phenomena. These kinds of events can also be analyzed and studied as a "system".

In our case study of online labs, besides the electronic and physical aspects of an online lab, there is also a social aspect related to all the people and groups that build the online lab and work with it, keeping it "alive".

Anonline lab system has not only the technical, physical and electronic parts of a"system", but also the social components of a"system", formed by the people that create, operate, maintain and use it. We defend that this "social component" is very important in the evolution and survival of the online labsystem, following a particular group, school or trend. Sometimes, this component is more important than the "technical component" as, if for some non-technical reason, people stop maintaining or using a given online lab, then it will not evolve and will eventually "die".

After the introduction presented above,section 2presents and analyses the actual state-of-the-art for Remote and Virtual Labs (RVL). In section 3, our hypothesis is presented and discussed. The concepts of structural and energetic coupling are also discussed. The research question is presented, and also a timeline and possible evolution lines for online labs. In section 4, the goals of this research are presented.The approach to develop this work is presented in section 5. In section 6 we present the "results to date" and discuss theirvalidity. The present dissertation status is presented in section 7, and finally the current and expected contributions are presented and discussed in section 8.

2. STATE-OF-THE-ART

Today,online laboratories are becoming more and moreappealing in many educational scenarios due to technologyadvancements and the emergence of pedagogical interests. The scientific community around Online Labs Research (OLR) is growing aswell, as denoted in [2]. In fact, according to [2], and also to [3][4][5] and [6], online labs present a number of advantages in educational contexts, such as:

- reach geographically scattered students;
- manage complex and expensive equipment with fewer maneuvering risks;
- experience emerging technologies in learning activities;
- create networks of researchers and educational institutions.

Additionally, almost all technological & scientific areas are now covered (even if partially) by online labs, for instance:

- chemistry[7];
- pharmaceutics[8];
- healthcare[9];
- mathematics;
- physics;
- electronics;
- instrumentation;
- hydraulics;
- nuclear energy [10];
- androbotics, among others.

This and other progresses are being supported by the already cited community on OLR [2] (or Online Labs Community, OLC, in short), who has been publishing intensely on the subject, since 1996. The most recent data, reported in [2] and respecting to 2014, shows that the main publishers of scientific articles about OLR are the International Association of Online Engineering (IAOE) [11] and the Institute of Electrical and Electronic Engineers (IEEE) [12].The core publication forumsof the OLC[2]are the Remote Engineering and Virtual Instrumentation (REV) Conferences[13] and the international Journal of Online Engineering(iJOE) [14].

Focusingon the pedagogical point of view, although there are today several theories about the use of online labs, thecommon belief is that Online Labs contribute to a better understanding of technical contents like physics or electronics. There is no doubt that lab-based courses play an important role in scientific education [15]. Remote and simulated laboratories (i.e. online labs) may provide a way to share specialized skills and resources, thereby reducing overall costs and enhancing the educational experience [15].

Presently, itis considered pedagogical advisable that the same experiment exists in both environments, i.e.in a virtual lab and also in a remote lab. This allows students to tryout the same experiment several times, and repeat the acquisition of real-world experimental data, the number of times necessary to completely understand the experiment. In a virtual lab there is no concurrent access to real equipment, therefore there's no restriction in the number of simultaneous accesses. Students can access a virtual lab whenever they want and, if the lab allows it, run the experiment in slow / fast motion, freeze the experiment, i.e. play with the time dimension. In a remote lab there is always access to real equipment, therefore the number of students that can be served in simultaneous is restricted. Remote labs that work in batch mode allow serving a larger number of students, as typically in this kind of labs all experiments run in fractions of a minute or even of a second. Therefore, students only experience a certain delay if other students are accessing the same lab, at the same time. The other type of remote labs corresponds to remote labs that support experiments requiring several minutes or hours to complete. This type of remote labs require scheduling mechanisms to deal with concurrent accesses, therefore presenting restrictions to the total number of students that can be served, even if running in a 24/7 mode.

A few examples of online labs that support the two dimensions (both virtual & remote) are labicom[16], UNED "UNILabs"[17], and also Intelligent School Experimental System (ISES) [18].

Finally, we can observe that the majority of remote and virtual labs fall into the engineering domain, although there are also online labs in natural sciences, and a few others in other scientific categories.

3. HYPOTHESIS / THESIS / PROBLEM STATEMENT

3.1 Structural coupling and energetic coupling

We live today in a materialist and mechanistic society and system, where the human factor(s) tends to be devalued. The objectives and the goals are normally of physical and especiallyof financialorder.Theindividualswho work with the systems are normally forgotten, and everything and everyone tends to forget the human factor.So what we find in all the systems is mostly a **structural coupling**[19]. The systems also have a human component, where this component sometimes works as a group and with group dynamics. A system also depends of the energy that people send to it, and that act as a group with the system. So the connection between the physical structure and the energy given by the people that work with the system,to the system itself, is what we identify as the "missing link". This "missing link" may be called **energetic coupling**, as depicted in Fig.1.

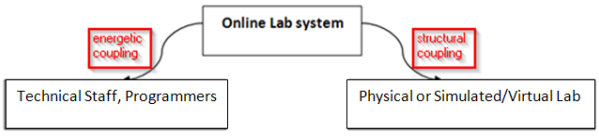

Figure 1. Energetic coupling and Structural coupling.

A system depends on the energy that the people, who construct the system and use it, invest in the system. Those people act as a group influencing the behavior and the "life and death" of the online lab, when considered as a general system.

3.2 Research Question

If online labs are a natural consequence of their creators (who are an animal species – humans – that follow the "Evolution of Species"), we can probably apply the Darwin's theory of evolution to online labs, especially if we consider online labs to be a kind of "living system", in face of the new definitions presented by Bertalanffy [1].

In this line of reasoning, it may be possible to identify common origins in some lines of development observed in online labs. After making a careful analysis of each one of these lines, it will probably be possible to establish if the evolution of a particular online lab was motivated by surrounding environmental factors, or if two different online labs diverged from a common line, among other aspects.

All online labs experience an evolution since theirinception.Accepting that the first device similar to a remote lab appeared in 1898, developed by Tesla, we can say that Table 1 represents the chronological evolution of online labs.

Table 1. Timeline of online labs

TIMELINE

1900's	1950's	1980's	1990's	1990-2000	2000-2010	Today
Mail Delivery teaching materials	Distance teaching using TV	Distance teaching using video cassetes	**Internet BOOM**	E-learning: LMS & CMS	B-learning philosophy and systems	Integrated E-learning System with LMS, pedagogical support contents and Online Labs
Radio controled missil by N. Tesla	1st article Electronically Controlled Manipulator	Labview by National Instruments	Remote Labs appears in several universities, Carisa Bohus Article- 2nd Best Thing...	Mercury Project, RemLab, Netro Lab, VISIR	Online Labs applied to teaching and Industry	

A further aspect proposed in Table 1 is the relation between evolutions in online labs and in distance learning, so as to introduce, at this point, the structural coupling between these two kind of systems.

A conceptual representation of the evolution experienced by online labs is depicted in Fig. 2.

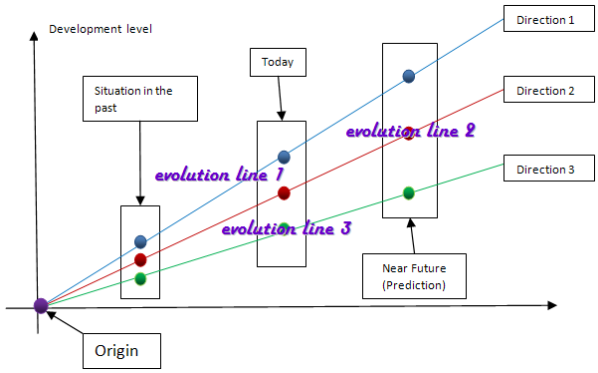

Figure 2. Online labs lines of evolution.

If we consider the development stage of each one of these lines, immediately after the birth of the corresponding online lab, and if we consider its actual point of evolution, then we can examine and consider all the factors that influenced those lines of development until now. We can therefore estimate what their natural evolution will be, if new lines will appear or if existing lines will merge or naturally disappear.

Following the same reasoning, we can try to analyze whichare the environmental factors and energetic couplings that cause some lines to end and/or new ones to develop.

So, by making a detailed analysis of the online labs timeline, their surrounding environment and their energetic couplings, we can try to predict what kind of future is expected for each group/line of development.

So, the main "Research Question" defined for this work is:

"Is it possible to predict the evolution of (some) online labs by analyzing the overall development history and the reasons (structural and energetic couplings) behind their adaptation to the surrounding environment?"

We can also establish the followings additional questions:

"Does the evolution of online labs follow the laws of nature?"

"Do online labs systems adapt themselves to the surrounding environment?"

As a direct result of the proposed research question(s), another line of study that may help with conclusions and predictions will be the characterization of the environment surrounding each school/online lab pair, and its corresponding development history. This characterization will take into consideration the capacity to adapt to the surrounding environment and the energetic couplings with the people that created and maintain the online labs being studied.

4. RESEARCH OBJECTIVES/GOALS

The aim of this work is to define/suggest a number of lines of development of current online labs, taking into consideration the systems that have already existed for a long time, others that have stopped and "died" because nobody develop and maintain them anymore, and others that are emerging in the present time.

The "starting point" of several online labsnetworks will be analyzed, along with the reasons why they followed different lines of development, or why some have disappeared.

As shown in Fig.2, which represents the lines of development and prediction, we can observe and analyze these lines in four stages:

- the most remote past (origin);
- the past;
- the present times;
- the future.

We believe that it will be possible to advance some considerations about future evolution, taking into consideration the factors that have guided the online labsevolution until the present day. We will especially consider the structural coupling; the technological evolution [20]; and also the human factor connected to each system, building the energetic coupling that may have potentiallyinfluencedeach line of development and research.

We also intend to demonstrate and postulate that through this"energetic coupling" and other technical and economical reasons online labs and the lines of development associated with them, somehow, follow the "Origin of Species" Darwinian laws and also that they are strongly influenced by the surrounding environment in terms of people, geographical conditioning factors, economical conditioning factors, political factors, etc.

5. METHODS AND APPROACH

The strategy to conductthis analysis is divided in two phases:

5.1 First-Phase – Research

The research method proposed to analyze the evolution of online (virtual and remote) labs is to analyze and quantify the number of

publications and their relevance, trying to classify the forums that have been selected to carry out the study.The forums can take different forms: (online) journals, scientific databases, conference proceedings, websites, etc.The selected forums will be first organized into three layers with differing importance to the core of the study, i.e. online labs. Each layer corresponds to an area that can be more or less related to online labs. We can consider these areas as shown in Fig. 3, i.e. in a "common-center circle philosophy":

- Hardware and Software Infrastructure (HSI);
- Engineering Education and Pedagogy (EEP);
- Remote and Virtual Labs (RVLs).

Figure 3. Scope Analysis Areas.

In a first phase of research the following forums will be chosen:

- 3 forums for RVLs;
- 6 forums for EEP;
- 9 forums for HSI.

The time period for this study will range from 1995 to 2015 (20 years). In a first instance, and for each one of these forums, 3 keyyears will be chosen: 1995,2005 and 2014, which corresponds to an initial point in time (1995), a present point in time (2014), and an intermediate point in time (2005), respectively.

What happened in the world of online labs will be analyzed for each of these particular years.

This will be done also considering the geographical distribution: a world map will be shown with the indication of the most important cities and countries with electronic "marks". For each system we will identify:

- The place (city and country);
- The labs (structural coupling);
- The people working with labs, the leaders of each system (energetic coupling), etc.

In the "core area" of RVLs, the chosen forums were:

- REV Conferences
- iJOE
- IEEE Frontiers in Education Conferences

The main reason for this choice is the large quantity and the high quality of the papers and articles found in these forums, and also because there is information (i.e. papers) from the beginning of the 1990s.

In the secondary area of EEP, the chosen forums are:

- EDUCON Conferences
- IEEE Transactions on Education
- IEEE Transactions on Learning Technologies
- Journal of Engineering Education
- European Journal of Engineering Education
- theinternational Journal of Engineering Pedagogy (iJEP)

The reasons that led to this choice are the quantity and quality of the information found in the articles and papers, and the fact there is a significant number of articles since the 1980s.

Finally, in the general area of HSI, the chosen forums are:

- Proceedings of the IEEE
- IEEE Transactions in Industrial Electronics
- IEEE Transactions on Industrial Informatics
- ICL Conferences
- TALE conferences
- Research Gate Network
- ACM Computer-Human Interaction (CBI) Conferences
- IEEE Publications (referred as "Others IEEE Search" in the Mendeley Structure shown in Fig. 4)
- and, finally, all sort of books devoted to or including chapters dedicated to online labs

These data is stored in a group, represented by a "Mendeley tree", shown in Fig. 4 and accessibleat the following URL: http://www.mendeley.com/groups/6538621/onlinelabs-evolution/

Figure 4. Mendeley Tree of "Online Labs Evolution" Group.

At this point of the work, the choice of groups is not definitive, as it is also possible to find some more good sources of information in other forums, i.e. research continues everyday.

For each year verified, the main aspects of that year are processed categorized, and displayed in a Radar Graph similar to the one illustrated in Fig.5.

Figure 5. Radar Graph for each year.

The range of radar branches shownfor a particular year reflects the importance of:

1. Hardware structure/structured coupling
2. Broker server
3. Information Technology(IT) and network security
4. Upgrades/interfaces for the user/energetic coupling
5. Pedagogical aspects, connection to a Learning Management System (LMS) with theoretical and pedagogical support

We intend to use this method to discover which subjects have been considered in less depth or even abandoned from year to year, and analyze the situation to define a line of evolution for each kind of online lab.

5.2 Second -Phase – Verification

The starting point was choosing a forum with a high level of information and inputs and excellent scientific and pedagogical quality. After this,theanalysis considers two additional "intermediate years": 2000 and 2010.

All the analysis already done for 1995,2005 and 2014, is repeated for these intermediate years, and 3 steps are performed:

- Search for samples;
- Match against initial samples;
- Match against control samples.

A double analysis method can therefore be achieved:

- One forum with detailed analysis for every year between 1995 to 2015; after more research, the forum will be chosen and an intensive year-by-year analysis will be made starting with 1995; at the moment there is not enough information to make this definitive choice.
- Analysis of two specific years, considering all possible forums for these years: 2000 and 2010.

Using this method we will try to establish the "Evolution line" for each family of online labs.

6. RESULTS TO DATE AND THEIR VALIDITY

The hypothesis that we postulate is to be confirmed by the results that we seek to find during the development of our study.

At the moment, our observation of the environment permits us to verify some development lines that converge to our hypothesis about the importance of the energetic coupling in online labs systems. Thefollowing examples already indicate some connection points between the development of online labs lines and networks, and the Darwinian "Origin of Species" theory of evolution. These examples also illustrate some situations of adaptation to the environment.

6.1 Some examples that validate the Hypothesis

Analyzing the evolution of online labs from the very beginning, in the last years of the 19th century (the Tesla controlled missile), to the present day, we can observe various lines of development. We can also note that the evolution of these lines follows different routes and directions,in accordance with the environment surrounding each institution that developsaparticular line, and especially considering the people that work on and maintain the line and update this set of online labs.

There are some lines that arise from energetic coupling; if there is a complete absence of energetic coupling that line ends up dying, as do the labs and systems connected to it. They finish, and the systems are shutdown, no longer being online on the web.

We argue here that the systems essentially depend on people and the environment surrounding the institutions where the systems are developed.

The following four examples point out to this hypothesis:

- The Indian national network of online labs, which is supported by the Indian government, was built as a strategy to make laboratories, and laboratory work, reach all the students around the country, even in the most remote areas and schools.The system is targeted at universities but also secondary schools. Some small schools in the countryside do not have the chance to uselaboratories, and this network makes it possible, so it is really an adaptation to the surrounding environment (large distances) and limited budget resources [21].
- The Labshare network in Australia is another example. It was developed by the University of South Australia and aims to make a complete set of online labs in several fields of science (electronics, physics, etc.) available to all students in all universities in Australia and abroad, especially off-shore territories like Singapore, Indonesia, andMalaysia.Of course one of the main reasons for developing this system is the large distances between Australian cities and also the economic advantage of attractingoff-shore students to university. This is another proof of adaptation to the surrounding environment like Darwin's "Origin of Species" theory. Unfortunately, its energetic coupling is now very weak because the website (which is still online) and the online labs have not been updated since May 2012 [22].
- The NetLabis another example of a project that is being developed as part of the University of South Australia's policy and commitment to innovation and its support for the development of new technologies. NetLab is an online remote laboratory, which is used by academic staff for teaching and demonstrations during lectures and by students for conducting their experiments remotely on real laboratory equipment. The application presents users with graphical user interfaces (GUIs) that look like actual laboratory instruments. Users click the buttons and turn the knobs with their mouse, interacting with it as they would with the real device. The network around this remote laboratory is smaller and has a more local scope than Labshare, but it is very lively and several teachers and studentsuse this network.Theyfeed the system and keep it "alive", so its energetic coupling is very strong [23].
- The VISIR network started in Sweden at the Blekinge Institute of Technology (BTH) and was developed by Professor Ingvar Gustavsson. It is very "alive"today because it works as a federation of online labs composed of several universities and institutions. The institutions that are part of the VISIR network today are:
  - BTH, Karlskrona, Sweden
  - Polytechnic of Porto – School of Engineering (ISEP), Portugal
  - University of Deusto (UD), Bilbao, Spain
  - Technical University of Vienna, Austria
  - Carinthia University of Applied Sciences (CUAS), Villach, Austria
  - Spanish Distance Teaching University (UNED), Madrid, Spain
  - Indian Institute of Technology (IIT), Madras, India

  The energetic coupling is very strong in the VISIR network because it can be found at several universities and many people from different institutions are working on new materials and on its development. As it is a federation of institutions, each one with its own online lab, each group develops its own structures and labs.The labs are, however, interconnected and this creates a dynamic between all the participants because they have regular meetings to discuss the evolution of the network and there is a very active energetic coupling between the system and the people that create and maintain VISIR network. There is also a Special Interest Group (SIG)associated with VISIR, which is formed by all the people that maintain the VISIR systemandthat can be reached at (http://www.online-engineering.org/index.php). This SIG is a sound evidenceof the very active energetic couplingthat exists around VISIR [24][25][26][27][28][29].

7. DISSERTATION STATUS

A number of stepsare necessary to accomplish all the proposed work and study. These steps are numbered below, following the proposed general strategy.

1- Studying Darwin's Theory of Evolution and understanding all of its foundations and concepts.
2- Studying the "General Systems Theory" by Ludwig van Bertalanffy[1] and the "*TeoriaGeral de Sistemas*" by JoãoBosco [19].
3- Defining the concept of "Energetic Coupling", as acomplement to the "Structural Coupling" concept presented by JoãoBosco in [19].
4- Defining a remote or virtual laboratory as a system with "structural coupling" and "energetic coupling"; developing and analyzing the actor-network interactions in each casestudy.
5- Presenting an analysis of the origins of remote labs.
6- Producing a timeline of the history of online labs from the beginning until the present day.
7- Analyzing the different lines of development exhibited by online labs.
8- Presenting an evolutionary analysis of online labs in relation to evolution defined in Darwin's "Origin of Species" theory and establishing the "adaptation to the environment" in each of the identified lines.
9- Considering the remote past, the recent past, the present and the future to analyze future directions in each of the development lines of online labs "alive" today.
10-Postulating the conclusions reached in the study.

At the present moment all points from 1 to 6 are accomplished, while points 7 to 10 are still being pursued, in the course of a PhD work.

8. CURRENT AND EXPECTED CONTRIBUTIONS

The current and expected contributions for this work are thought to help understanding the evolution of online labs. Additionally, they can serve as a guide for those groups already maintaining a given online lab and wishing to devise further developments and also to those willing to create a new online lab, from the scratch. Understanding why some online labs died and why some are still

operating is also an important contribution to the OLC and some of the associations that deal with this important topic, such as the IAOE and the Global Online Laboratory Consortium (GOLC).

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