VIRTUAL LABORATORIES AT COMPUTER SCIENCE DEGREE IN PALERMO UNIVERSITY: A CASE STUDY

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Abstract

Complete learning in science and engineering requires a mixture of theoretical and practical sessions carried out in specific labs. Some issues, such as the reduced accessibility to labs and the expensiveness and fragility of instruments, prevent the fully utilization of those labs. To overcome these problems, a virtual laboratory can be used. A virtual lab (or V-Lab) allows full availability of the labs and its instruments but avoids the physical interaction between the students and the lab apparatuses.

Two virtual labs have been recently activated within the Computer Science curriculum at the University of Palermo. They belong to the “Computer Networks” and “Operating Systems” courses. In this work, we will present the architecture and implementation details of those labs. In particular, the labs allow students to perform some exercises (router configuration for Computer Networks and visualization of OS details for Operating Systems) made of several steps where the student has to issue specific commands. At each step, the student can require some help and at the end a final score is provided.

The virtual labs are used during the Computer Networks and Operating System courses and provide practical support to the theoretical topics. Students will provide feedback and suggestions to improve the labs and will also actively participate in their evolution.

Keywords: Virtual Lab, High Level Education, On line Education, Computer networks, Operating Systems.
1. Motivations and objectives of a Virtual Lab

Complete learning in science and engineering requires a mixture of theoretical and practical sessions carried out in specific labs [1]. Some issues prevent the fully utilization of those labs. Examples are:

- Reduced accessibility to labs (time and space)
- Expensiveness and fragility of instruments
- Lack of safety and control
- Lack of help and support on usage of instruments

To overcome these problems a virtual laboratory can be used [2], [3], [4]. A virtual lab (or V-Lab) allows to perform practical experiments but avoids the physical interaction between the students and the lab apparatuses. A V-Lab can be accessed anytime and anywhere by a standard web browser and students carry out interactive experiments over the Internet as if they were working in the actual labs. Moreover, they get help if required but, at the same time, have maximum freedom to try different paths. Finally, students are provided with a feedback on the achieved learning level.

A V-Lab presents in general a flexible structure and allows students to use different terminals and network technologies in order to remotely experiment on the lab devices [5] (Fig. 1).

![Fig. 1. V-Lab structure.](image-url)
Moreover, a virtual interaction of a student with a tutor and the other students is possible. To this end, two scenarios are commonly followed:

1. **One group (tutor + students) working at the same time**  
   In this scenario people connect from remote locations and tutor-student and student-student interactions happen in real-time. Of course, in this case, a specific time must be chosen for the common session.

2. **One student working alone on the remote lab**  
   This is the scenario when the V-Lab can be accessed at any time but only one student at a time can work on a single apparatus. In this case, the student can only exchange messages (not in real-time) with the tutor and the other students.

2. **Architecture of a V-Lab**  
The architecture of a V-Lab implies the presence of a standard browser (in the student PC) which communicates to a web server through the Internet. The web server connects the student to the instruments of the lab through an instrument controller (Fig. 2).

![Fig. 2. Architecture of a V-Lab.](image.png)
The student performs some guided exercises where he/she issues some commands to the instruments in order to perform a task. The web server receives the commands issued by the student and forwards them to the instrument controller. The instrument controller, in turn, verifies that the commands are “valid”, executes them on the instrument and sends the output back to the student. The student examines the results of the performed operation and continues with the next operation. At the end, the student is provided with a feedback of the whole exercise so to understand the reached learning level.

3. The Virtual Lab of Computer Science at the University of Palermo

The software architecture used for the V-Lab implemented in Palermo is shown in Fig. 3.

A brief description of the different components is the following:

- **Client.** It is the workstation of the student used to access the lab. It can run any operating system (Windows, Linux, …) and only needs to have a generic web browser (Internet Explorer, Netscape, …) in order to communicate to the web server and download the proper pages.

- **Web Server.** It contains the http server that receives the requests from the client through the Internet and provides the related web pages. It also contains a Java servlet that represents the intelligent part of the V-Lab. In fact, the servlet handles the user requests, provides the syntactic and semantic control on the user strings (filtering them when appropriate) and creates the related answers providing the proper input to the http...
server which, in turn, prepares and sends the web pages. The web server runs on a Linux operating system and uses a Tomcat server and Java for building the servlet.

- **Instrument Controller.** It is realized in Java and contains a common part for all the devices so that the same methods can be used to control the different devices plus a specific instrument interface for each device that is the SW part that directly interacts with the device SW.

- **Device.** It is the physical lab apparatus that, as said above, is controlled by the user through the instrument controller.

The V-Lab architecture presented above offers a great modularity. In particular, it is possible to add network devices very easily (only a specific instrument interface must be added for each device).

Note that an access control (login + password) is implemented. This is to ensure on one hand that only allowed people access the devices and on the other hand that only one person accesses a specific device at a time.

Note also that the commands provided by the user are filtered so to avoid that the devices can be inadvertently spoiled. Moreover, a multilevel help is provided (e.g., `man`, `command`, `command + options`).

Finally, to help the student in the use of the devices and in the execution of a specific exercise, some basic information on the devices is provided. Moreover, when an exercise on a device is executed, a self dynamic evaluation based on soft-heuristic is available to the student. In particular, a 30 start score is assumed (similarly to the highest grade of an Italian university exam) and 1 point is subtracted for each help request of a command and 3 points are subtracted for each help request of a command plus options (no points are subtracted for a ‘man’ request). In this way, the student will obtain a final grade at the end of the exercise that will provide him/her with an idea of the performance reached. In any case, the tutor can be contacted by email for further questions on the exercise (an on-line collection of FAQ is also available).

Using the architecture shown above, two experimental V-Labs have been developed, one for the Computer Networks course and the other one for the Operating Systems course. The V-Labs are used as teaching support of those courses for the Computer Science bachelor at the University of Palermo.
### 3.1. Computer NEtworks (CONE) Lab

The CONE Lab (Fig. 4) is integrated in the web page of the Computer Networks course (http://math.unipa.it/~malfano/cone). Students can access the lab network devices from anywhere (different terminals and networks) and at anytime.

![CONE Lab web page](image)

**Fig. 4. CONE-Lab web page.**

A router that connects two LANs is the main apparatus of this CONE-Lab (1st implementation) and a training exercise is created to guide the student in configuring the router and make the two LANs to communicate between them and with the rest of the network (Fig. 5).

The student may require help on the router commands and parameters and the final result of the exercise depends on the number and types of requested helps. The student cannot harm the router because his/her commands are filtered by a proper application. Moreover, the student can exchange messages with a tutor for specific questions.
3.2. Support for Operating Systems (SOS) Lab

The SOS Lab (Fig. 6) is thought in order to help the students to experiment with the Linux operating system and consists of a training exercise on the Linux commands integrated in the web page of the Operating Systems course (http://math.unipa.it/~lenziitti/labso).
A workstation with the Linux Operating System is the main apparatus of the SOS Lab. The student is required to issue specific Linux commands and he/she may ask for help on commands and parameters during the exercise (Fig. 7). The final result of the exercise depends on the number and types of requested helps.

The student cannot harm the Linux workstation because his/her commands are filtered by a proper application. Moreover, the student can exchange messages with a tutor for specific questions.

4. Conclusions and future work
Computer Networks and Operating Systems are being taught in a mixed mode at Computer Science, University of Palermo, making use of front lessons and e-learning methodologies.

The students have access to the online contents to “walk” again through the topics after class. This gives him/her the opportunity to learn with his/her own rhythm and to deepen specific topics.

The on-line sites provide both theoretical contents and practical exercises and experiments (through the V-Labs) because all those aspects are essential for an integrated and complete learning and must advance at the same speed. The sites
also contain means to evaluate the achieved learning level useful to both students and teachers. Students will provide feedback and suggestions to improve the sites and will also actively participate in their construction by proposing new contents, developing new experiments and new interfaces. Finally, new means are being explored to improve the “learning” path of the students and it is being evaluated whether traditional front classes, e-learning courses or a combination of the two provide the best results in terms of learning performance [6], [7],[8].

References
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