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IFAC PapersOnLine 50-1 (2017) 13492–13497

Online Laboratory Manager for Remote Experiments in Control

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Abstract: The aim of the paper is to contribute to the area of online experiment management. Although such systems already exist, the proposed solution tries to enhance their features by providing users with an extended user interface. The paper suggests the most efficient architecture and explains the reasons for using each component. After the examination of the system interfaces and their role in the overall data flow, the paper focuses on the achieved functionality and its benefits. The attention is devoted to the modification of control algorithms by the user, running experiments in prescheduled time and also in the batch mode. The experiments are supported by various simulation environments – e.g. Matlab, SciLab, OpenModelica. However, the use of classical program language, as the C language, is also supported. What differentiates this system from others like it, is the added value of social networking enabled by several communication tools.

Keywords: Remote control, control education, online experiments, software tools, open technologies.

1. INTRODUCTION

Whether proving a hypothesis or making uncertain first steps on a journey to master a subject, everyone can appreciate the benefits of a well-equipped and easy to access laboratory. While some may take it for granted, others might find it rather difficult to visit such place. Living too far away or an inability to walk are just some of the reasons why one can abandon their dream to pursue scientific research.

One way to solve this problem is creating an online laboratory which provides its users with real devices capable of running various experiments. It also has to return and display the results or any other output that the scientist can find beneficial. The ability to communicate, collaborate and share ideas among multiple participants is also integral to a working laboratory.

The number of internet based experiments is growing steadily, with examples from numerous areas of technical education, such as Physics, Electronics, Signal processing and Control engineering. Some examples are summarised in Table 1. Very detailed overview of publications about online experimentation is done in Heradio et al. (2016). The introduced online experiments are mainly from Control Engineering, Chemistry, Electrical and Electronic

Table 1. Examples of provided remote experiments

Project Title	Provider	Topic	Web page
UNILabs	National Distance Education University (UNED), Madrid, Spain	Physics, mechatronics, optics, robotics, control	http://unilabs.dia.uned.es/
Online experimentation	Faculdade de Engenharia da Universidade do Porto, Portugal	Electronics, metrology, mechatronics, environment	https://remotelab.fe.up.pt
Remote Laboratories @ UP	Universidade do Porto, Portugal	Physics, mechanics, metrology	http://remotelabsup.fe.up.pt/experiments.htm
WebLab Deusto	University of Deusto, Bilbao, Spain	Electronics, physics	http://weblab.deusto.es/website/
OpenLabs	Blekinge Institute of Technology, Sweeden	Antenna theory, electronics, security, vibration analysis	http://openlabs.bth.se/
Internet shared instrumentation laboratory	University of Genoa, Italy	Electronics	http://isilab-esng.dibe.unige.it:9999/ISILabWeb/ISILab.aspx
NetLab	University of South Australia	Electronics	http://netlab.unisa.edu.au/index.xhtml
Relle	Federal University of Santa Catarina, Brazil	Electronics, optics, physics	http://relle.ufsc.br/labs/
Grid of Online Laboratory Devices (GOLDi)	Ilmenau University of Technology, Germany	Robotics, mechatronics	http://www.goldi-labs.net/
REX controls	REX controls, Czech Republic	Control	https://www.rexcontrols.cz/virtualni-laboratore
iLabs	Massachusetts Institute of Technology (MIT), USA	Microelectronics, chemical engineering, signal processing	https://icampus.mit.edu/projects/ilabs/
Remotelab	University of Trnava, Slovakia	Electronics, physics	http://remotelabN.truni.sk/ where N = 1, 2, …11

Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2017.08.2332

measurement area. Authors introduce 189 references and they reference not only experiments, laboratories and environments, but also the used methodology. So, it is clear, that the interest in this area is notable.

2. REQUIREMENTS

Experiments, that are available over Internet, are very often built from scratch, as standalone applications. However, there already exist tendencies to build complex frameworks to support faster, easier and safer development of remote laboratories. WebLab-Deusto (Garcia-Zubia et al., 2008; Orduña et al. 2011) and iLabs Shared Architecture (Harward et al., 2008) represent just two examples of such initiatives.

The first one is the remote laboratory management system developed at the University of Deusto. It is offered as open source and free software on GitHub under BSD 2-clause license.

The second represents a web service infrastructure, that was developed to provide a unifying software framework, which can support access to a wide variety of online laboratories. It is available on SourceForge under MIT iLab Software License.

This paper tries to introduce another solution. There can arise questions "Why?", "Is it still necessary? or "What new do you bring?". Our aim was not only to share online experiments but also:

- to enable feedback control of experiments by setting own control algorithm,
- to run experiments not only in scheduled time slot but also in batch mode,
- to let the users choose the background simulation environment according to their own preferences,
- to maintain modularity and scalability of experiments,
- to enable various forms of communication among users.

3. HARDWARE AND SOFTWARE

The aim of this paper is to propose a general framework for remote controlled experiments. The experiments will be oriented mainly to the area of Automatic control. The structure of the proposed ecosystem should consider various types of devices and software solutions. The tested alternatives are introduced in this section.

3.1. Connected Devices

The thermo-optical system TOS1A (Huba et al., 2014) shown in Fig.1 enables to control the light intensity and the temperature inside of the device body. These variables can be influenced by 3 inputs: performance of a light-emitting diode, a light bulb and a fan. The user can measure several outputs such as internal and external temperature, light intensity, rotation speed of the fan. The system enables to set several control tasks, for example keeping constant internal temperature while either the fan or the light bulb output fluctuates. The plant can be used during the basic control theory courses since it enables testing of various control algorithms (PI, PID, pole assignment design, etc.).

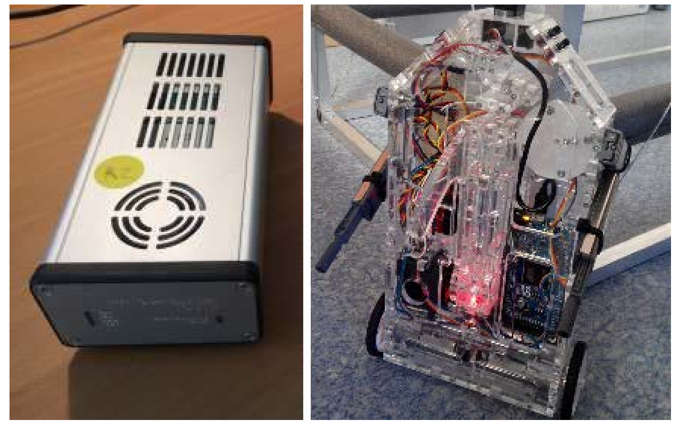

Fig. 1. Thermo-optical system (TOS1A) and Segway laboratory model.

The Segway device (Kňažek, 2016) illustrated in Fig. 1 belongs to systems with faster unstable dynamics. Therefore, it is more difficult to control. It can be considered an inverse pendulum on a two-wheel undercart that is driven by two DC motors. The centre of gravity can be shifted in vertical direction according to the user's specification by means of another servo motor. The Segway model has built-in gyroscope and accelerometer. The behaviour of the vehicle is controlled by an Arduino Due microcomputer. The plant can be used in courses dedicated to control of nonlinear systems.

The last device is not as typical for the control area. The introduced 3D LED cube is used mainly for teaching the basics of programming, where students can learn to use various loop structures and conditional commands (Žáková, 2016). Visualisation of commands can be more attractive for students. The plant is made of 512 light emitting diodes that are controlled via an Arduino Uno. The cube is connected to a Raspberry Pi computer that serves as a web server enabling remote control of the experiment.

3.2. Simulation Environments

Development of online experiments can be done by two approaches:

- with support of supplementary software packages such as Matlab, Maple, LabView, OpenModelica, Scilab, etc.
- without support of additional software.

In the first case, we can use the computing capacity of the chosen software package. The advantage is that these solutions are usually stable and can therefore focus mainly on Internet communication and control algorithm design itself.

The second approach enables direct access to the controlled systems and it removes an intermediate level between the application on the client side and server-side application. It is reflected on the speed of access to the controlled system.