

# DESIGN OF SERVO SYSTEM IN STATE SPACE USING DISTANCE LABORATORY SYSTEM (DLS)

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**Abstract:** During last decade, the Internet has been increasingly used for education and research purposes. As traditional face to face classroom became virtual classroom through Internet, traditional hands-on laboratories converted as remote and virtual laboratories that are at a technological crossroad. At previous papers was presented a Distance System Laboratory (DSL), developed for the purpose of teaching automatic control systems. The system consists of three parts, the user interface, the practices management and the practice processing. The developed DSL system allows users (i) learning and adjusting predefined controllers, (ii) designing new controllers, and (iii) testing and analyzing the performance of the predefined/designed controllers over a set of physical devices. Some technological update was made to DLS, than increase the performance and security of the system. In this paper is described an application of DLS through one case study practices of design of servo system in state space in the Control System discipline.

## 1 INTRODUCTION

The use of simulation tools for education and training has been increasingly becoming popular, mainly due to the high cost of maintaining and operating laboratories equipments. However, despite their advantages being low cost and relatively easy to use, the simulators do not simulate efficiently, noise, frequency responses, D/A conversion and other physical phenomena that characterize real systems. (Hites, 2002).

The emergence of the Web in the mid-1990 has added new opportunities for sharing expensive resources of software and hardware. This allowed the development of virtual (Anido and Fernández, 1999) and remote control (Ko et al., 2005) applications, offering the capabilities and

flexibilities of simulation tools, without losing the important characteristics of physical systems (Puerto et al., 2005), and hence distance laboratory applications. Remote experimentation facilities offered as part of a web-based learning approach, affords a number of critical benefits and for engineering distance education courses it is the only realistic method of performing many experiments. This approach allows remotely located students to complete laboratory assignments unconstrained by time or geographical considerations facilitating the development of skills in the use of real systems and instrumentation (Callaghan et al., 2007).

In (Gravier et al., 2008), the authors provide a literature review of modern remote laboratories and identify possible evolutions for the next generation of remote laboratories. Remote laboratories are

under a strong current of evolution and are not restricted to a single educational topic, where Automatics and Robotics are ones of the most used.

In the majority of cited remote control experiments, remote users can run an experiment and adjust the process or controller parameters from a set of predefined controllers. This limits the practice to some type of controllers (PI, PID, space of state, etc.). The Automatic Control Telelab (ACT) enables students to choose a control law, change the control parameters online, and even design their own controller (Casini et al., 2007). Our developed Distance Laboratory System (DLS) allows learning and adjusting predefined controllers, designing new controllers, and testing and analyzing the performance of the predefined/designed controllers over a set of physical devices. This has been made possible by using Matlab-Simulink, very well known software in the Automatic Control community (Sartorius et al., 2005). At this stage of development, our DSL allows several practices for the control of direct current motor and control of a robot manipulator. (Hernández et al., 2006).

## 2 CHARACTERISTICS OF THE SYSTEM

The DLS is a distance laboratory system allowing the users to learn how to adjust predefined controllers and to design their own controllers in order to test them in real devices through Internet.

### 2.1 Characteristics of Distance Laboratories

DLS exhibits some features in common with most distance laboratories in operation at present *easiness*, *availability* and *accessibility*. Some additional characteristics like *easy and fast user interface*, *management of multiple requests in parallel form*, *controller development using MATLAB and Simulink in a remote way*, *reference change* are given in (Sartorius et al., 2005). Various technological updates were made to DLS improving the performance and security.

The interface is based on HTML pages that use JavaScript and now uses PHP functions. A video feedback of the carrying out practices was incorporate to the Web interface. The integration with a pedagogical platform Moodle, was made too.

One of the most important features of DLS is the management of multiple requests in parallel form.

The SLD allows to take care manifold request in a parallel form managing centralized similar devices that are separated geographically but connected by (WAN).

### 2.2 DLS Architecture

In (Sartorius et al., 2005) is presented the DLS architecture. That architecture was update, the CGI located in the Web server was change for a Web Services developed with PHP technologies. On the other hand, in the Practice Management Client (PMC) was introduced another Web Services that permit communicate those parts via Web better than TCP/IP. The actual architecture is show in Figure 1.

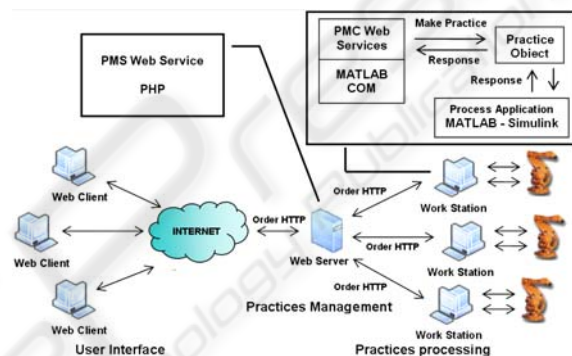


Figure 1: Software and hardware level architecture of DLS.

Now, the communications port used is a standard HTTP 80 port, rather than non-standard TCP/IP random ports, that can be blocked by firewalls. The system follows similar double client-server architecture as describe in (Yan et al., 2006).

The DLS is divided into three parts: user interface, practices management and practices processing. The users interact with the system through Internet. When accessing to the system Web site, first the users must register by giving their username and password and then choose the practice they want to carry out. There the user can fill all the data in the form associated to the practice in a correct way and finally choose whether to carry out the practice in a simulated or a real way.

The Web Service Practice Management Server (PMS) receives the data and verifies which workstation can carry out the practice order and sends the order to the Web Services Practice Management Client (PMC) located in the available workstation. When the order arrives at the PMC, the data are processed and the practice is carried out using Matlab-Simulink together with Real Time Workshop (RTW) Toolbox. Once the practice has

been processed, the response is a Web page showing the processing results. Throughout the practices carry out a video feedback with the real process is showing to the users.

### 3 DISTANCE LABORATORY SYSTEM USE

The system permits two types of practices: practices with a predefined controller and practices with a controller created by the user.

#### 3.1 Practices with a Predefined Controller

In this type of practices the users only need a Web navigator to access the DLS Web site. This type of page is shown in Figure 2, where it is shown a practice for testing decoupled PID controller performance in a robot manipulator with two degrees of freedom. In addition, the users can choose two execution ways: (a) a simulated way, where it is simulated the execution and is obtained an idealized response of the practice or (b) a real way.

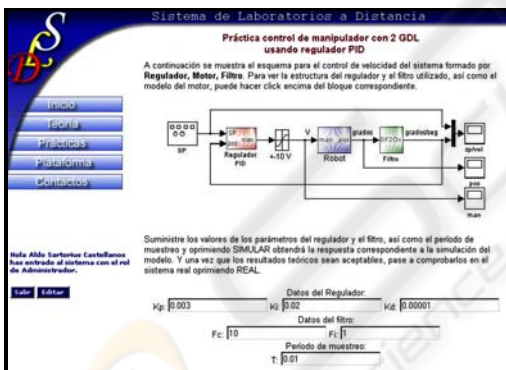


Figure 2: Web page and form for carrying out the practice with decoupled PID controller.

#### 3.2 Practices with a Controller Created by the User

When the users access some practices in which they can define the controller that they will use, it is shown a page as the one given in Figure 3.

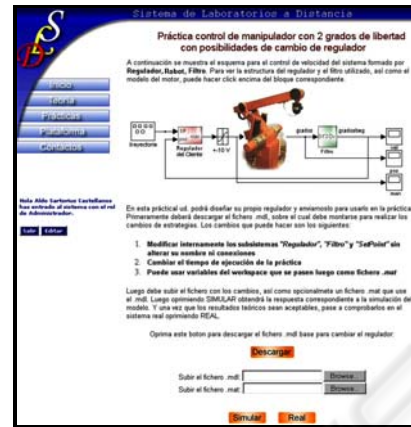


Figure 3: Web page and form for carrying out practice with a controller created by the user.

From this page the user can download a Simulink file containing the practice diagram block. For carrying out these types of practices the users need to have the MATLAB-Simulink software installed in order to modify the downloaded Simulink model, as it was explained in (Sartorius et al., 2005).

### 4 TEACHING EXPERIENCE USING DLS

The DLS has been used in activities of teaching as well as undergraduate and postgraduate course, inside and outside our country, standing out the accesses from Spain and Mexico, with very good response. In (Hernández et al., 2006) was summarized some topics, in Automatic Control Systems education, where the developed DLS could be effectively used.

At the next section is presented an application of DLS through one case study practices of design of servo system is state space in the Control System discipline.

#### 4.1 Design of Servo System is State Space

The design of control system by pole-placement is an interesting topic of Control Engineering subjects (Ogata, 2006).

We show the practices presented for the student in the UCLV for the design of servo system in State Space, using the distance real laboratory (DSL). The platform, described in the epigraph 2.2, is connected to a real DC motor.

The control system implemented in the DSL has the block diagram of figure 4.

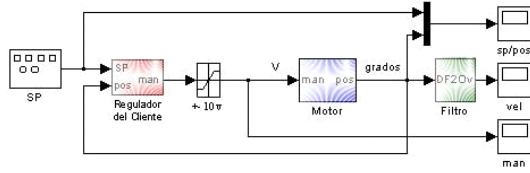


Figure 4: Block diagram of the control system.

The motor dynamic characteristic, well know by the student by previous work, are showed in the figure 5. The real system has an encoder for position measuring, and the velocity is obtained in the computer by the derivation of encoder signal.

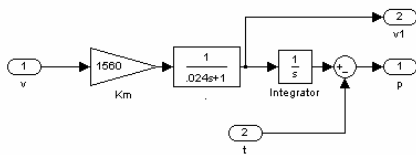


Figure 5: Block diagram of the motor dynamic characteristic.

In this case the open loop control system can be represented by:

$$\begin{aligned} \dot{x} &= Ax + Bu \\ y &= Cx \end{aligned} \quad (1)$$

Where x equal to state vector  $[\dot{\theta}, \theta]^T$ , motor velocity and position.

$$A = \begin{bmatrix} 0 & 1.00 \\ 0 & -41.67 \end{bmatrix}$$

$$B = \begin{bmatrix} 0 \\ 65000 \end{bmatrix}$$

$$C = [1 \quad 0]$$

In this case the task of the students is to design the regulator according to performance index given by the professors.

### 4.2 Student's Task

A typical presentation of student task can have the form:

*Designs of servo system in State Space for the system of figure 5, with closed loop response to step input with small overshoot, 0.15 s of setting time and zero steady-state error.*

The students have several possibilities, to make the design, according (Ogata, 2006) the servo system pole-placement designs with state observer solution is the best.

### 4.3 Student's Task Solution

The first step is to find the analytical solution. Following the Ogata method, (Ogata, 2006) we have to find:

- The wanted close loop poles:
 
$$P = \begin{bmatrix} -27.0000 & 13.0767i \\ -27.0000 & -13.0767i \end{bmatrix}$$
- The regulator gain:
 
$$K = [0.0138 \quad 0.0002]$$
- The observer gain
 
$$Ke = 10000 * \begin{bmatrix} 0.0219 \\ 1.1886 \end{bmatrix}$$

With these values we implement a servo system pole-placement designs with state observer with extra integrator (Ogata, 2006) and test the system solution, first in simulation in the web site with the result of figure 6.

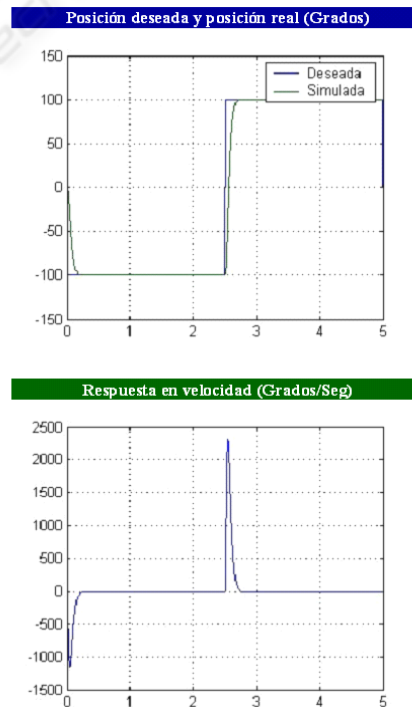


Figure 6: Simulation response.

In this case the results of simulation are according to the analytical analysis and the following step is test the regulator in the real motor. The results are showed in the figure 7.



Figure 7: Real response.

## 5 CONCLUSIONS

In this paper have been presented an updated Distance System Laboratory (DSL) developed for the purpose of teaching automatic control systems. The potential of the developed DSL system like learning and adjusting predefined controllers and designing new controllers have been showed. One case of study of practices with a real motor in the Control System discipline was presented. In the paper is demonstrated the capacity of the system to develop practices work in the topic of servo system design is State Space, specifically, an example of servo system pole-placement design with state observer have been presented with good results. This example demonstrated the real possibilities of the DSL for develop real practices in this and others topics of Automatic Control.

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