Complete Multimedia Educational Program of a DC Servo System for Distant Learning

Gábor Sziebig[1], Chen Hao[2], Lóránt Nagy[3], Péter Korondi[1]

[1] Department of Automation and Applied Informatics, Budapest University of Technology and Economics, e-mail: korondi@elektro.get.bme.hu

[2] Scientific and Technological Office, China University of Mining & Technology, e-mail: chenhaocumt@tom.com

[3] Kandó Kálmán Faculty of Electrical Engineering, Budapest Tech
e-mail: nagy.lorant@kvk.bmf.hu

Abstract: The paper presents a complete (animation, simulation and internet-based measurement) multimedia educational program of DC servo system for distant learning. The animation program includes screens for teaching in class and for individual study as well. The final and most important step in any kind of education in the field engineering is the measurement. This is the most challenging step in distant learning. The students should enter to a web page to access the experimental set up. The administration, queuing arranged by a framework. A DC drive can be switch on and off via internet. The students can write a simple controller program which is inserted into the communication frame program to operate the servo motor.

Keywords: Electrical engineering education, distant learning, e-learning, sliding mode control

1   Introduction

The DC motors have a special historical role in the field of industrial electronics since all industrial servo drives used DC motors in the past and the first microprocessor controlled drive [1] also applied DC motor. Even if they have several drawbacks they are used in recent applications. The main advantages of a DC servo motor drive are that it is simple from the point of view of control. Before the advent of micro controllers they were the only solutions for servo drive systems. It is easy to adopt any control method for a DC servo system. That is why the newly proposed control methods are frequently applied for a DC servo system first. On the other hand, there is a trend to control all kind of servo drives (field oriented induction motor drives and brushless drives) like a DC servo drive.

PID controller is still the most common controller method in the industrial applications. The other popular method is the sliding mode control which was introduced in the late 1970's [2] but it is used recently in high-performance motion control systems [3].

The organization of the paper is as follows: Section 2 describes the concept of the animation and presents an example of the animation program. Section 3 summaries simulations. Section 4 presents the internet based laboratory measurements. Section 5 concludes the paper.

2   Animation of a DC Servo Motor and Drive

2.1   Concept and Structure of Animation

Explaining the sophisticated processes of servo systems and their control methods is a real challenge by the traditional methods. The static figures shown by books or the computer projector with power point are not well suited for individual distant learning. On the other hand the possibilities by the modern multimedia methods can optimally be adapted in this area. Utilizing the opportunities of the technique, the sequence of topologies and transient processes of the system can well be shown by animated figures and understood easier. The basics of the method in most cases are the application of simulation techniques to obtain the results representing the complex processes. The advantages of animated representation are obvious in the study of both simple and complex units. Within the framework of the Leonardo da Vinci program of the European Union (EU), a project called **E-learning Distance Interactive Practical Education (EDIPE)** incorporating eight Universities from eight member countries is aimed at developing multimedia software for teaching the subject of Electrical Engineering (EE) [4-9].

There are basically two kinds of screens [4,5]: Main screens; Screens for teaching in class room (see in Fig. 1).
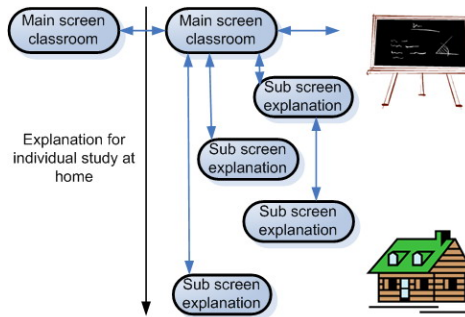
Figure 1
Structure of the screens

They are designed for projection in classroom. Only main screens are presented in this paper. Large letters, figures, tables are used. The information content is limited. They are explained by the professor. Sub screen; Screens containing Supporting Text for distant study at home. They are designed for using them out of class-room for individual distant learning. They apply smaller letters, figures, tables and contain substantial amount of information to. It makes possible to study and learn the material of screens at home for students without teacher. The Problems/Questions and Interactive Study are presented in the form of sub screens.

2.2 Example

Several advanced control methods are discussed. The sliding mode control is presented here partially as an example. The controlled plant is a DC motor, the actuator is a DC-DC converter and the control method is bang-bang type. This means that the DC motor is controlled by a 2 state relay which can accelerate or decelerate the motor (Fig. 2). The derivation of the simplified per unit equations of the error is shown in Fig. 2.
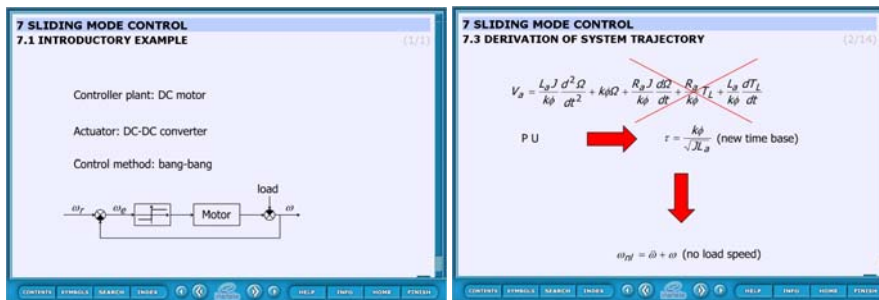

Figure 2
Simplified system and derivation of error trajectory

It is a second order differential equation with zero damping (since the armature resistor is ignored, see the bottom line of Fig. 2 (right), which means that the error trajectory moves along a circle. The center of that error trajectory circle depends on the switching state of the DC-DC chopper as shown in the animated Fig. 3. The suppressing process of the error is shown in the animated Fig. 4. Assuming that the system starts from standstill zero position and the reference signal ω_r is constant and it is a half of the no load speed ω_{nl} than $\omega_e = \omega_r$ and $\dfrac{d\omega_e}{dt} = 0$ at $t = 0$ time instant. Defining a switching line as $\omega_e + \lambda$, $\dfrac{d\omega_e}{dt} = \sigma = 0$, the DC-DC chopper is switched on when the system trajectory is above the switching line ($\sigma > 0$), it means the trajectory moves along a circle with a center of $\omega_e = \omega_r - \omega_{nl}$, $\dfrac{d\omega_e}{dt} = 0$ (like in Fig. 3 (left)). The DC-DC chopper is switched off when the system trajectory is below the switching line ($\sigma < 0$), it means the trajectory moves along a circle with a center of $\omega_e = \omega_r$, $\dfrac{d\omega_e}{dt} = 0$ (like in Fig. 3 (right)). The first part of the trajectory is a circle with center of $\omega_e = \omega_r - \omega_{nl}$, $\dfrac{d\omega_e}{dt} = 0$ (like in Fig. 3 (left)). When the trajectory crosses the sliding line a switch occurs. Since the error trajectory must be continuous, it is continued from the position where the switching occurred along a circle with a new center.
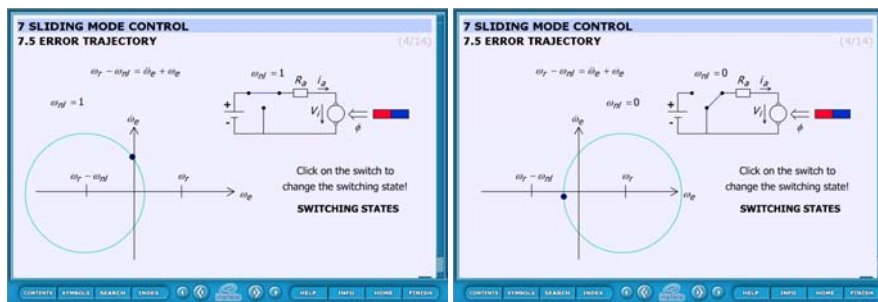

Figure 3
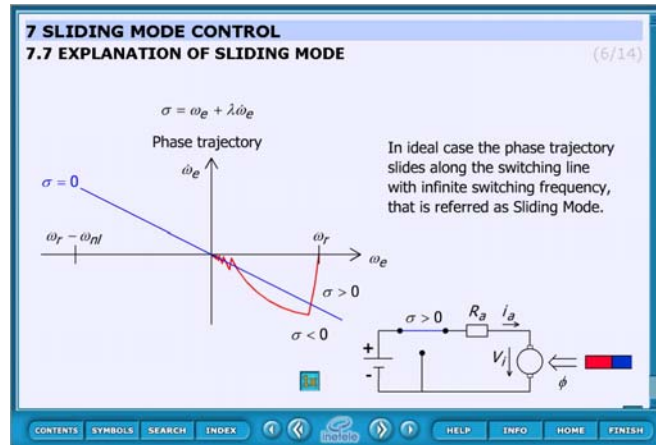Error trajectory when the DC motor is switched on and off

Figure 4
Sliding mode

An interesting phenomenon occurs after the second switch when the error trajectory moves above the switching line. A little delay is shown in the animated figure. If this delay is eliminated then the error trajectory returns back immediately below the switching line which initiates another switch. This phenomenon repeats itself in the opposite direction and finally the error trajectory remains on the switching line and the switching frequency is infinite. This is referred to as the siding mode. It is easy to explain the robustness of sliding mode by this animation. If the DC voltage of the DC DC chopper is changing a little than the center of trajectory circle is moving a little. If the armature resistor is not ignored than the error trajectory moves along a spiral with decreasing radius. If those modifications are within certain limits than they have no effect on the sliding mode i.e. the error trajectory always returns immediately back to the side of the switching line where it was before the previous switching. Fig. 4 shows the final state of this animation.

3   Simulation

The first step from theory to application is simulation. The students use Matlab-Simulink software. The simulation model of a DC servo motor and drive are shown in Fig. 5. The students can check the torque-speed characteristics by simulation and they can study the performance (overshot, settle down time, oscillation, robustness) of the cascade speed controller with different parameters and phase margins.
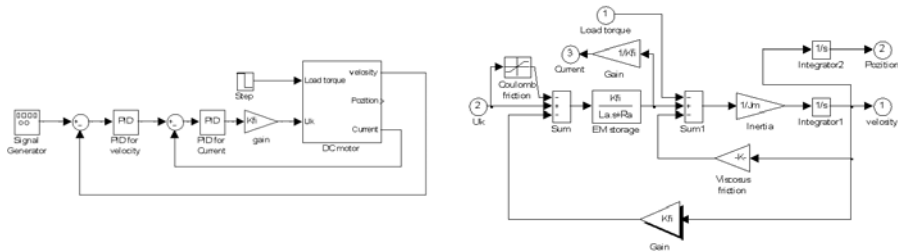
Figure 5

Simulink model of a PI controlled DC drive   Simulink model of a DC motor

4   Internet-based Laboratory Measurements

4.1   Cost Effective Remote Power Supply Switch

It is common, that the personal computers (PCs) are running 24 hours a day. But the laboratory equipment can not be turned on all day long because of security reasons. The idea of using the personal computer as a remote controllable switch, come up to expectations. It is common that a computer is able to turn on itself remotely (by Wake On LAN). This function is provided by the Power Supply Unit (PSU), which provides a standby voltage (+5V, max 0.5 mA) even if it is turned off. A normal PSU can also provide voltage for an experimental DC servo motor and controller.

4.2   Structure and Logic

As the network card can turn on a PSU, it is possible to turn it on remotely by voltage signal. The system architecture of the power supply switching personal computer can be seen in Fig. 6. The PC has a D/A card. The PC switches on and off the experimental DC servo drive by turning on/off the PSU. Also, the PC can be turned on or off remotely. One channel of D/A output cards is used for turning on and off the external PSU. The standby voltage is used to keep the PSU off and as the PS\ON pin is low active, a small circuit is needed to make the voltage change.
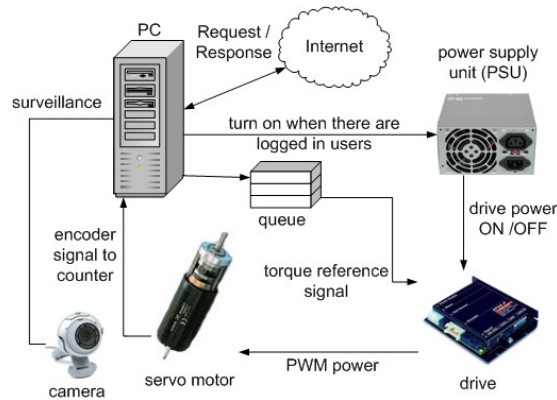
Figure 6
Remote laboratory with RDC architecture

4.3 Achieving RT (Real Time) with Windows

Real time response or scheduling have ever been hard under Windows environment. The hardware abstraction layer makes it difficult to achieve hard real time. This fact made many projects choosing Linux instead of Windows [10,11]. Ardence approached the problem from the lowest level [12]. Absolutely separated software architecture provides the power of the system. Even 'blue screens' are survived, without an affect to the real time applications. With Ardence Real-time Extension for Control of Windows is possible to create timers with 100 microsecond interval, with a maximum of 0.001 nanosecond yield. Not only the running environment was created, it seamlessly integrates itself to C++ compilers, which allows running programs without modification in real time environment. With this solution more user-friendly programming of real time applications can be achieved. The usability of the real time extension has been proven thousand times in industrial applications.

4.4 Remote Laboratory with Remote Desktop Connection

Remote Desktop Connection (RDC) is secure and built in function of every Windows based PC. A typical laboratory practice has to deal with 20 to 30 students. The students log in to the server with RDC connection. The working environment for every student is managed by group setting and can also be personalized. The architecture of the RDC based remote laboratory is shown in Fig. 6.

The system grants equal chances to all students, independently to persons' faculty. Not all faculties teach programming languages, such as C++. This problem is

solved by a framework consisting of a standardized interface for all tasks. The resources are controlled through semaphores. The task of the students is to write a controller for the DC servo system, based on the there previous learning experiments. For proper measurement data, high precision sampling timer is required. Standard Windows does not guarantee any interrupt or timer for this occasion; even it can not grant that an event will be dispatched. Fortunately an extension for Windows exists.

The framework separates the controller and the communication part of the DC servo program. This split in the framework allows any student to write his own controller. Only a header file has to be written where the controller function is located. The header file already contains the input parameters and the parameters that are required for calculations. After error checking the DC servo program compiles and runs the measurement. The result data is put into files separated by variables in the same directory in which the program runs. These files can be used also in Matlab or any kind of simulation program. The framework is written in C++ and for compiling and code editing the Microsoft Visual Studio 2005 is used.

A sample header file for a PI controller is shown later in Fig. 8.

Since the communication frame program is given, the students have to write the lines above only and they have to give value to P and I then they can run their programs immediately. After this introductory PI controller, the students have to code a model reference adaptive and a discrete time sliding mode controller as well. The simulated and measured phase trajectories are compared in Fig. 7. A discrete time sliding mode control is applied in both cases.
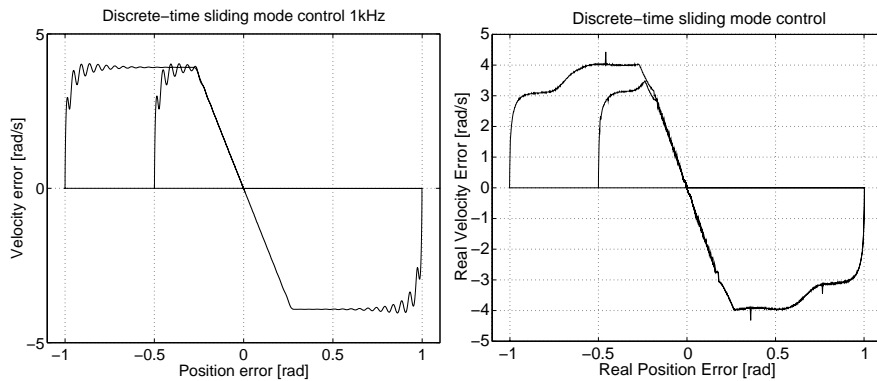

Figure 7

Simulated trajectory   Measured trajectory

4.5 Website-based Remote Laboratory

Remote laboratory is now web based. This reduces network traffic overload, which was caused by RDC protocol. Only the controller instructions are transmitted from the client browser to the server. The controller is added to the same framework. After the controller has finished running on the DC servo motor, the measurement results are available for download on the website. The website can be seen in Fig. 8. Instructions for users and user manual are also available on-line. The result of the measurement can be downloaded in various types, to suite the needs. Priority levels are introduced in measurement execution. Integration to existing e-Learning systems is easy, because of the modular structure of the website.

Figure 8
Website of remote laboratory

Conclusions

A complete distance learning program is presented starting from the animation and ending at internet based measurement. It is difficult to describe a dynamic and interactive animation by static screens. The problem is the same when the operation of a motor must be explained by static figures. Because of the separation of the communication frame program and the controller program, all students can carry out this simple measurement even if they are not good at programming. Since the actual measurement when the motor is allocated to one student takes only a few seconds, several students can measure the same motor virtually in the same time. The development of such educational program needs a complete new way of thinking, some elements of this new educational approach were presented

in this paper. The animation program can be down loaded from [13-17] (it is free for non profit education).

Acknowledgement

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