Mixed Reality Environment for
Web-Based Laboratory Interactive Learning

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Key words: *Web-based learning, Online interactive learning, Mixed reality environment, Laboratory learning, Fuzzy logic, Learner modeling.*

Abstract:

This paper presents a web-based laboratory for distance learners by incorporating simulation and hardware implementation into web-based e-learning systems. It presents a development consisting of laboratory course through internet based on mixed reality technique to setup, run and manipulate set of experiments. Each experiment has been designed in a way that allows the learner to manipulate the components and check if it works properly in order to achieve the experiment objective. The proposed laboratory e-learning tool has web-based components accessed by authorized users. Learners can acquire the necessary skills they need, while learning the theory of the experiment and the basic characteristics of each component used in the experiment. Finally, a case study was conducted to show the feasibility and efficiency of the proposed method.

1 Introduction

Today e-learning is becoming an increasing popular alternative to traditional programs[1,2]. Students may not have opportunities to acquire practical knowledge, which are very important in many courses. It is very difficult to offer such costly courses, for a number of reasons, such as; limited funds for running such programs, limitations on laboratory facilities, and insufficient support of qualified instructors[3,4]. In applied sciences, the education in classes should be completed by laboratory sessions, where students can get hands-on experiments [10,11]. However, laboratory instruments are expensive, so that a small number of them have to be shared by many students, who have to be scheduled for lab hours. E-learning course materials are available online, but a laboratory course either requires access to the instruments [12], or is restricted to simulation experiments [13,14]. While those still provide some insight, they don't show everything, especially in experiments where real-time requirements have to be checked and analyzed. Also, in e-learning, it is difficult to get our students to the university campus for a few days to complete required lab sessions. In order to tackle those problems, we can establish a laboratory course based on simulation together with actual components and instruments, and can be accessed through the internet. Students can acquire the necessary skills they need, while learning the theory of the experiment and basic characteristics of each component used in the experiment.

This project deals with the motivation, realization and experience of incorporating simulation and hardware implementation into web-based e-learning systems. One common solution is to provide an active learning environment for e-learning of applied sciences by incorporating

what is called mixed-reality instead of virtual reality. The proposed lab has web-based components accessed by registered students. By using such components, the student can;

- reserve experiments in advance,
- exchange experiences and skills between students during and after the experiments, and
- reconfigure experiments by the system.

In order to obtain an efficient web-based interactive learning and skills training environment for practical-based courses and laboratories, this research aimed at developing and implementing a Mixed Reality Environment (MRE). The MRE is an environment whereby virtual components can be applied on real plant components.

2   System Design

The proposed system can be implemented as a web service to take advantages of the possibilities of anywhere any time access from any computer connected to the internet. The web technology is very suitable for building an interactive e-learning system based on mixed-reality environment. Using the web as both a library for teaching materials related to the experiments and mixed reality hardware and software.

An authorized learner can access the server from a personal computer (client) connected to the server. After the home page has loaded, the learner is guided through a set of pages where the learner can (1) select a certain experiment; (2) read related teaching materials; (3) set-up the experiment components and parameters, and (4) get help or more related information.
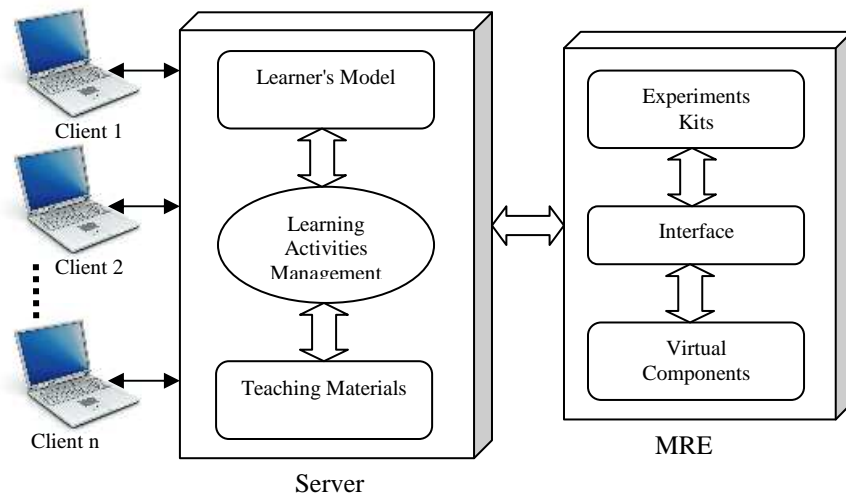

Fig. 1: System Design Layout.

The system software at the server side can be viewed as having four parts, as given in Fig.1. These parts are, teaching materials, learners' information, learning activities management and mixed reality environment.

A.   Teaching materials:

The teaching materials used in the proposed system are related to set of control laboratory experiments given in Philadelphia University-Jordan. The teaching materials have three

contents; brief, normal and detailed. These materials are prepared to cope with various learners attending the course.

B. Learning Activities Management:

One of the most important requirements that precede the design of an interactive e-learning system is to adopt software to deal with learning activities, which include;

- check if the learner is authorized to access the learning system or not.
- check the learner information, to provide appropriate teaching materials to each learner.
- manage the teaching materials.
- select the experiment setup.
- run the experiment and collect results.
- check the learner's degree of understanding.
- analyses the collected information about each learner to update his/her knowledge level.

The knowledge representation and learning activities management has a great importance in designing interactive e-learning systems. The sequence of the educational events instructor's experience is the core of such educational systems. Therefore, it is important to model the experience of the instructor in such away that the educational system should be flexible, easy, and at the same time enables the learner to deal with the course materials which are suitable to his knowledge level. Several papers [8,9] have mentioned that the modeling process of the instructor experience and course related physical world is not an easy task. Due to the knowledge acquisition vagueness, it is essential to use an efficient tool that is capable enough to model this knowledge in order to build a flexible decision rules. The fuzzy logic is the most suitable tool to deal with vague knowledge and the process of decision making in the educational system. In fuzzy sets, a linguistic variable takes on words or sentences as values. For example, the linguist variable "learner average result" can be represented by the following terms; Excellent (E), Very Good (VG), Good (G), Pass (P), Fail (F), Unsatisfied (U).

C. Learner's Model:

The flexible educational system provides an easy way to make possible the transformation from one learning level to another according to the learner background. In this case, three educational paths can be used;

- Learning path (A); includes a summary of the educational unit, which is quite enough for high quality learners.
- Learning path (B); includes the usual information as that given by the instructor for normal learners.
- Learning path (C); includes detailed information that facilitates the learning process for beginners.
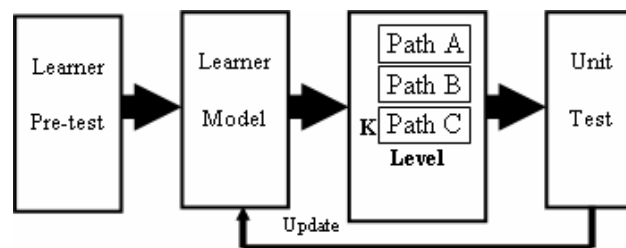

Fig.3:   Block diagram of the proposed educational system.

The above educational paths allow the high quality learner to go through the educational units so easily with minimum time while slow-witted learners take more time with high effort to pass each educational unit.

3 Mixed Reality Environment

According to the experiments setup in different engineering disciplines, some components can be substituted by its model and simulated in real time. The simulated components can be run in conjunction with real components under the same environment. This environment can be regarded as Mixed Reality Environment (MRE). Figure 2 shows the concept of the employed environment [10].
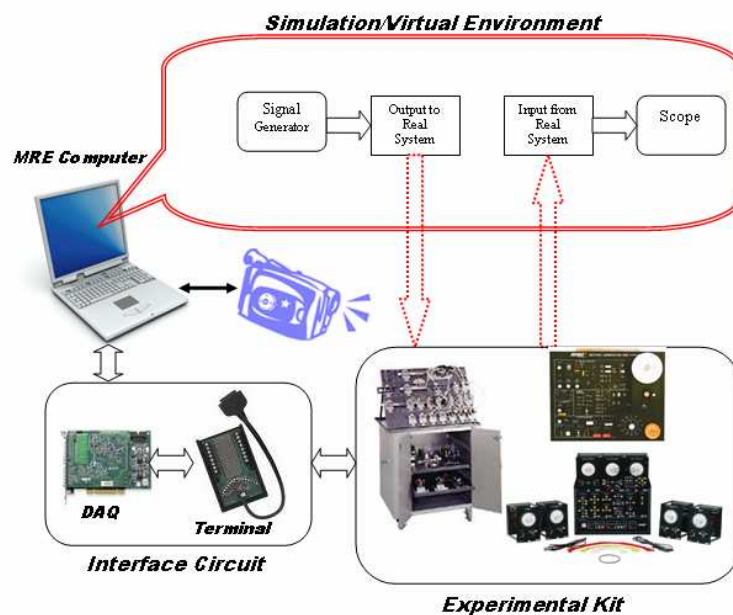

Fig. 2: MRE structure for online experiments.

The MRE is an environment whereby virtual components can be applied on the real system's components. Working with MRE can include "off-line" or "pure simulation" mode and on-line or Mixed Reality (MR) environment. Off-line simulation, on the one hand, will normally take place before moving onto MR environment, where the system should be tested and the system should be optimized. On the other hand, the MRE will be used to apply the virtual components on the real plant.

This environment should allow the experiments to be built and synthesized with different virtual components by simply replace the component according to the experiment requirements. Furthermore the MRE gives the capability to monitor the system's behavior by observing the output signals such as speed and position signals in the control experiments. These signals can be stored and used to fill the experiment sheet which should be submitted at the end of the session. Moreover, these signals should facilitate the student's appreciation for the experiments which is normally difficult to be achieved in the case of distance learning.

4 Experiment Setup

The most important part of the laboratory interactive e-learning system is the experiment setup, which is achieved by selecting the appropriate hardware kits and required software components. To facilitate the validity of the proposed

environment, the DC motor control experiment was considered. The PID control algorithm was designed and implemented by the Matlab/Simulink software package with real-time workshop target toolbox [16]. These tools are able to automatically generate real-time applications from the Simulink models that run on the MRE computer., while their development is carried out on the host computer (server). The following activities can be operated from the target computer:

- setup an experiment.
- Start/stop an application.
- Change control algorithm parameters.
- Trace signals.

Case Study: DC Motor Control Experiment

At first, the students will be introduced to the experiment through its index page which includes: objective, introduction, experiment setup, components details, experiment start/stop, and experiment datasheet.

In this case study, the learner will be given the experiment setup as shown in Fig. 5. The DC motor unit consists of conditioning block which includes chopper circuit, filters, and amplifiers. The DC motor has an optical encoder to measure the position and speed of the rotor. All signals are sent to a computer via National Instrumentation NI DAQ card model 1036E, conditioning terminal. The DAQ card has 16 analog inputs, 2 analog outputs, sampling rate of 200 KS/s, and input voltage range of $\pm$ 10 V. The final signals are used to activate analog input block of MATLAB/Simulink. The experiment datasheet that has to be filled by the learner is illustrated in table 2.
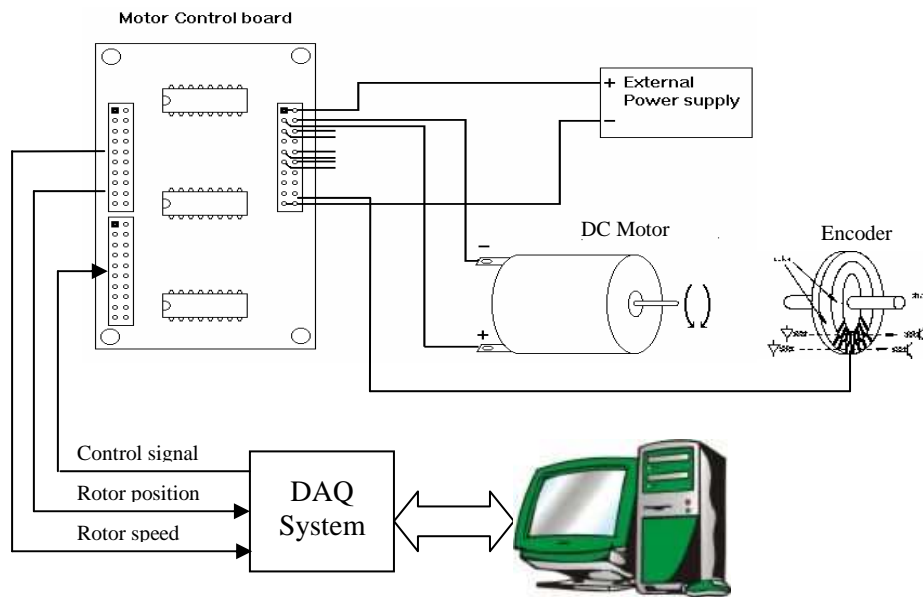

Fig. 5: Experiment setup for DC motor control

Table 2: DC motor experiment datasheet.

Characteristics Criteria	Trail 1				Trail 2				Student Remarks
	System Response	Controller Gains			System Response	Controller Gains			
		P	I	D		P	I	D	
Open loop (Without PID controller)									
Rise Time (s)		0	0	0		0	0	0	

5(8)

Overshoot (%)									
Settling Time (s)									
Steady state error									
Closed loop (With P controller)									
Rise Time (s)									
Overshoot (%)			0	0			0	0	
Settling Time (s)									
Steady state error									
Closed loop (With PD controller)									
Rise Time (s)									
Overshoot (%)			0				0		
Settling Time (s)									
Steady state error									
Closed loop (With PI controller)									
Rise Time (s)									
Overshoot (%)				0				0	
Settling Time (s)									
Steady state error									
Closed loop (With PID controller)									
Rise Time (s)									
Overshoot (%)									
Settling Time (s)									
Steady state error									

The learner then should build a Simulink block diagram to perform the experiment, as shown in Fig. 6. Basically, the experiment under the MRE consists of hardware and software components. The hardware components (DC motor, optical encoder and conditioning circuit) are located within the red frame named "Real System". The software components are the PID, profile generator, integrator, amplifiers, and scopes.

The controller parameters can be tuned using the function block parameter of the virtual PID controller given in Fig. 7. The dynamic behavior of the real system that the learner should obtain for the DC motor through the MRE is shown in Fig. 8.
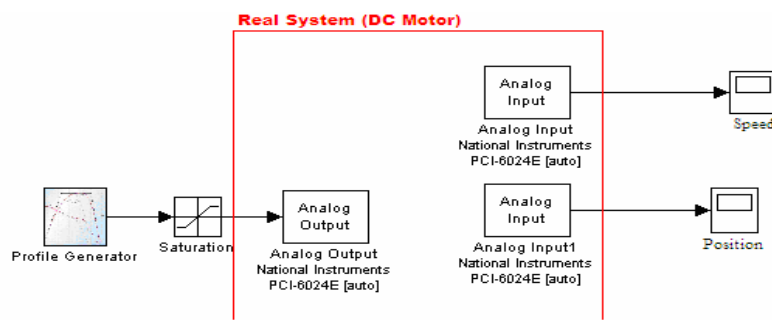
(a) open loop structure
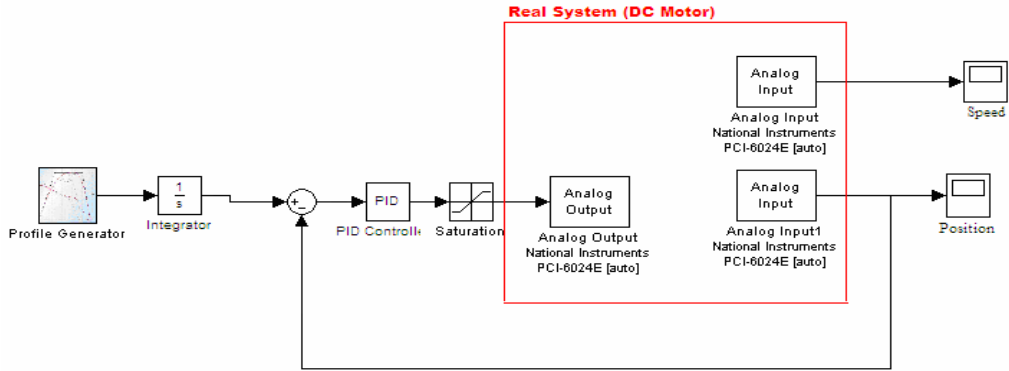
(b). closed loop with PID controller.

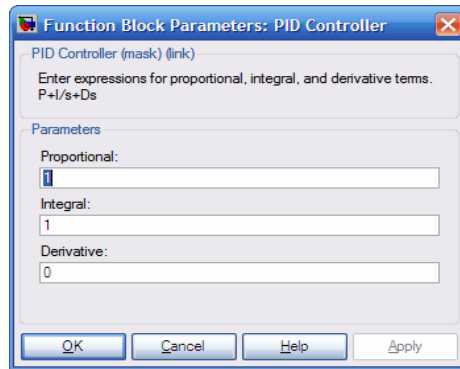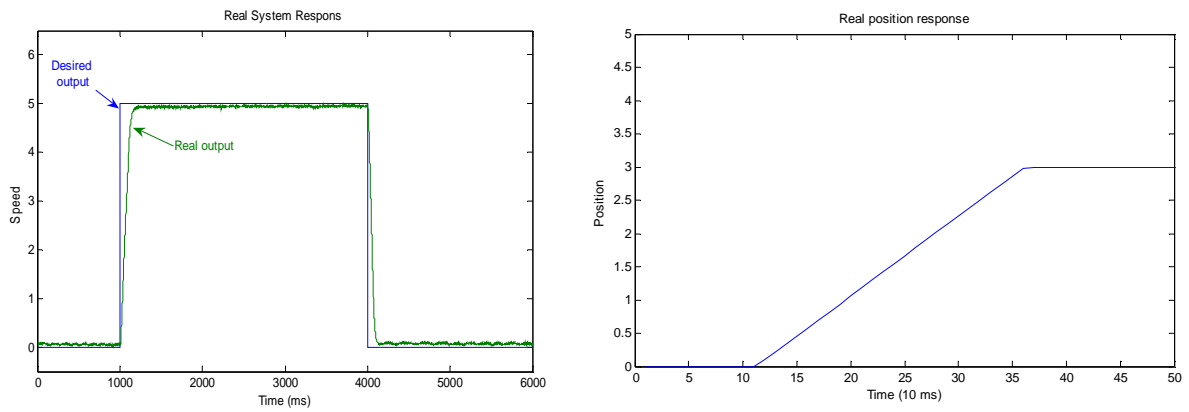Fig. 6: Simulink block diagram DC motor experiment.

Fig. 7: Function block parameter of the virtual PID controller

(a) *speed response.*   (b) position response

Fig. 8: Real system behaviors using virtual PID controller.

7(8)

5 Conclusion

This research reveals that adopting mixed reality environment in web-based laboratory is an efficient and feasible way to perform experiments through the internet for distance learners. According to the proposed methodology, the authorized learner can access the server select a certain experiment; read related teaching materials; and set-up the experiment components and parameters through the home page. Then the learner will be connected to the required experiment through the proposed mixed reality environment, whereby he should manipulate the software components in order to get the required results.

Laboratory experimentation has demonstrated the potential of the MRE for facilitating and improving the web-based laboratory sessions. The flexibility of the approach utilized in this research allowed for providing a conceptual structure to extend the MRE idea to include all engineering disciplines.

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