

# Remote Access to MATLAB-based Laboratories: Application to the Fuzzy Control of a DC Motor\*

MARINA VALLÉS, JOSE LUIS DIEZ, JOSE LUIS NAVARRO and ANGEL VALERA  
*Department of Systems Engineering and Control, Universidad Politecnica de Valencia, Camino de Vera, 14. 46023 Valencia, Spain. E-mail: {mvalles,jldiez,joseluis,giuprog}@isa.upv.es*

*This paper presents a straightforward and economical approach to the development of a fuzzy control remote laboratory using the MATLAB Web Server tool. The objective of the laboratory is to offer students and professionals a valuable tool for improving their fuzzy design abilities, and to test the performance of fuzzy controllers in a real DC motor. The advantages of using this approach are: cost reduction, with regards to the training of industrial operators in new techniques, and an increase in time and space flexibility in the use of limited resources at regular educational institutions. This laboratory was incorporated in a multilingual control repository and some evaluation results of the experience are shown here.*

**Keywords:** educational technology; laboratories; fuzzy control; DC motors

## 1. INTRODUCTION

FUZZY CONTROLLERS can be considered for controlling those processes for which a mathematical model does not exist or is very difficult to calculate [1–2]. Another advantage of fuzzy controllers is that they can easily be tuned by users who are non-experts in control theory [3]. These controllers can include heuristics and common sense rules that are easily understood by the experts for applications of specific interest, but not for control theory.

As such, it would be beneficial to develop a practical course concentrating on Fuzzy Control for the non-specialist who required control for their work or research. A valuable option is the use of Information Technology (IT) resources in this educational process [4] as this can lead to an increase in time and space flexibility. Distance learning benefits more from the new technologies than does standard education. However, when the latter makes appropriate use of IT as an effective learning support resource, then ‘blended learning’ [5] occurs and this seems to be the future educational trend. The extended use of these resources has been possible due to the increasing number of household computers with Internet access, and could reduce the actual teaching hours at University spent on undergraduate programs. Many applications, solutions and experiences on the implementation of remote laboratories can be found in recent special issues on e-learning and remote laboratories in different areas of engineering [6–12].

Nowadays, the relation between the Internet and Process Control is far removed from the experimental phase, and has reached a mature state [13], providing practical applications for those companies offering on-line courses [14, 15]. Internet-based learning is also of interest to companies in which staff training plays a role [16]. Apart from educational applications, remote industrial process monitoring and control through the Internet provide different advantages (i.e., optimization of infrastructures performance, preventive maintenance management, a reduction in staffing costs, etc.) and also represents a step forward for teleworking [17] in the area. Some relevant applications can be found for medicine [18], chemical plants [19], networking [20], power electronics [21], process control [22], and robotics [23].

Two different operating options are available for remote labs: batch and on-line operations. An on-line operation considers control algorithms at the remote computer, the control actions and sensors being the information transmitted through the Internet. The reference and parameters can be altered while the experiment is being carried out, however variable delays appear as a consequence of Internet traffic. A batch operation avoids Internet delays because the reference and controller parameters are sent to the server before the experiment begins and, once the process is finished, the process output is sent to the remote computer. In this case, it is necessary to add some interaction to the system to illustrate the dynamic evolution of the controlled plant. This can be carried out with a camera, a scope that shows the time evolution of the process variables (usually decimation and

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packing of the sample data should be used to reduce traffic overload) or both.

Nevertheless, in addition to current Internet delays [24, 25], complexity and costliness usually arise when trying to implement plant remote control [26–28]. Some insight into a solution for these problems is provided in this study, especially for those institutions where MATLAB is the standard tool. The proposed solutions complement MATLAB for remote control and are directed at two premises: it is simple to develop and economical to use (for remote user).

After outlining the configuration needs for virtual (simulated) and remote (real) MATLAB-based process control approaches, in Section 3, this paper presents a remote laboratory on DC-motor fuzzy control. Section 4 introduces the set-up of this laboratory in the framework of a control repository. This section also presents the remote laboratory evaluation design, its evaluation and results. The evaluators were students and teachers from university and vocational training and experts on long-life learning for engineers.

## 2. MATLAB-BASED CONFIGURATION FOR REMOTE PROCESS CONTROL

Based on the Internet, two different options can be found for setting up laboratories in learning environments: virtual laboratories and remote laboratories. For example, a virtual laboratory allows continuous access to a simulated process in a computer. Under this structure, a remote interaction between the student/operator and the virtual laboratory is possible.

Halfway between traditional and virtual laboratories are the remote laboratories that provide a real experiment for remote users. The incorporation of Webcams permits the observation of real systems evolution in addition to the variables of interest. Most of the equipment needed for setting up a virtual/remote laboratory is available in traditional laboratories. The only additional element required is an interface between the local application and the Web server.

A complete 'Systems Engineering and Control Web-based Laboratory' will include different components (organized as guiding steps for a student and in an increasing order of complexity):

Theoretical laboratory works where design techniques are explained (based on virtual laboratories)

Process simulation frameworks to test the developed control abilities of the user (also based on virtual laboratories), and

Remote industrial process control where tests on real systems can be observed (based on remote laboratories).

If MATLAB is used as a control design tool, then the MATLAB Web Server (MWS) can be both a very powerful and a very basic tool that

helps in the development of virtual laboratories [29, 30]. Other possibilities could involve using the MATLAB Builder [31] for Java or .NET tools [32], a common gateway interface (CGI) or other methods and tools that allow the MATLAB kernel machine to be connected to a web server such as JMatlink or EasyJava [33]. The main difference being that when the MWS is used, the code is executed over the server computer. Consequently, no portability problem arises with this solution.

In brief, the developer must design a web page to allow the user to introduce the experiment parameters (controller type, controller parameters, reference signal, sample time, etc.), send this data to the MATLAB application (a set of m-functions must perform the experiment) and return the results to the user using another web page or applet.

The MATLAB Web Server is integrated software enabling MATLAB programmers to create applications that use the capabilities of the World Wide Web to send data to MATLAB for computation and to display the results in a Web browser. A set of programs enables remote Web access to MATLAB applications [34]:

- `matlabserver`: a Multithreaded TCP/IP server that runs MATLAB programs (M-file) specified in HTML documents and manages communications between the Web application and MATLAB;
- `matweb.exe`: a TCP/IP client of `Matlabserver` (located at an HTML server) that uses the Common Gateway Interface (CGI) to extract data from HTML documents and transfer these to `Matlabserver`;
- `matweb.m`: calls the M-file that the Web application wants to run;
- `matweb.conf`: is a configuration file that `Matweb` needs for connection to `Matlabserver`.

For an extensive explanation of the main features of MWS and commands used in the development of basic applications see [35], where the configuration for the authors' equipment is explained and examples of virtual/remote laboratories are presented.

The required file structure and interaction between applications is shown in Fig. 1, an outline of which now follows. The process of developing MWS applications usually involves a combination of Simulink models, MATLAB M-files, HTML code and graphics. Therefore, in order to develop applications similar to those presented in this paper (see the next section) the following files will have to be generated:

- an HTML input document for data submission to MATLAB;
- a set of M-files with the required code for processing the input data and computing the results;

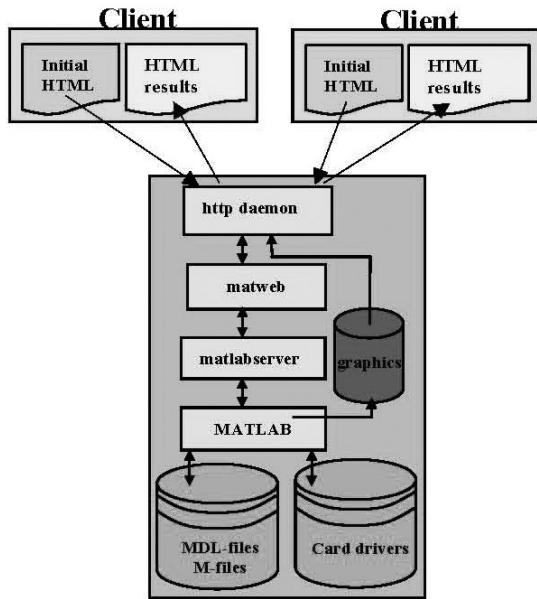


Fig. 1. Remote laboratory file structure.

- an HTML output document to display the MATLAB computations.

However, the MWS does not allow on-line access to low-level hardware. Therefore, to facilitate remote laboratories and the remote control of real systems using MWS, an additional configuration with several data acquisition cards must be used. A set of routines has been programmed to access these cards from the MATLAB environment and the web server.

Those routines that have been programmed to access these cards from the MATLAB environment allow A/D conversion, D/A conversion, encoder signal management, digital input/output access and timer programming. All these functions have been programmed using C++ language. The MATLAB executable functions are obtained as DLL files with the mex command, using a Visual C++ v6.0 compiler.

Also, a set of MATLAB functions has been developed to manage the acquisition card, to implement the controller, to perform the experiment, and finally to show the results using the MWS services. Figure 2 describes the data flows between the different modules developed:

- Scheduler: this function manages the execution of the controller. For every sample time, signalled by a timer, it captures the input data via the card interface, and then it calls the control algorithm function to obtain the control action that is then sent to the D/A converter. Finally, all the experiment data are collected and returned.
- Control algorithm: this function implements the controller code. In this case, it has been written in MATLAB functions for fuzzy controllers and PID controllers.

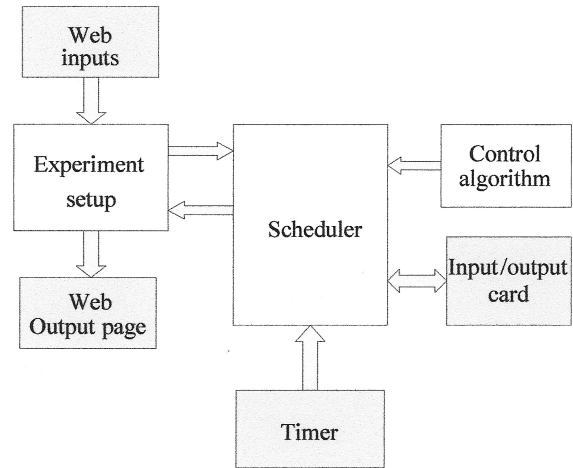


Fig. 2. Controller structure (each box represents an M-file).

- Experiment setup: the experiment is defined in this function. The reference signal, sampling time, controller type and parameters are assigned to internal variables. It also decodes the information that comes from the web page controls. With this information, the scheduler function is called for executing the experiment. When it has finished, the experiment data are collected and the output web page is constructed for displaying the results to the user.

Some systems will require safety measures in order to prevent damage to the system if any incorrect solution is used by the students, for instance overfilling in water tanks, limited working area in mechanical systems, collision avoidance, etc. Here, the scheduler file could include a call to an M-file that monitors the output signal and the experiment can be halted if any abnormal behavior is detected.

In addition, for unstable systems, it would be necessary to start the system near the operating set point (vertical upright position in inverted pendulum or near the reference position in a magnetic levitation system for instance). This can be accomplished using an external mechanical device or by a controller that leads the system to the set point. In both cases, this can be achieved by writing an M-file that is called before the experiment starts. When the system is near the set point, the controller is then switched to the student controller.

This proposal is very effective, flexible and user-friendly for developing the remote lab experiments: any controller algorithm written in MATLAB code can be used. In the experimental setup, the sampling time and reference signal can be chosen and a safety monitor or set point pre-positioning functions can be easily added. Of course, user interface html files must be created for every solution for capturing the experiment and controller parameters and also for displaying the experiment results. This methodology was used to develop remote lab experiments for automation technician courses. The position control of a DC

motor with fuzzy controllers is explained in the following section to illustrate the application of the proposed framework.

### 3. REMOTE LABORATORY: A FUZZY DC MOTOR CONTROL

In this study, a laboratory based on the MWS (and complementary functions) has been developed. This has been implemented as a batch laboratory because the lab operation will be conducted over the Internet and the on-line operation will produce large and unpredictable delays. In this way, any user with a PC connected to the Internet and a Web browser can control an industrial process in batch. Furthermore, a MATLAB version is not required on the remote user computer (see [29, 30] for details). Additionally, a webcam has been included. This camera allows the evolution of real systems to be observed.

Regardless of some other physical processes that have been used and tested [36], this work will present examples based on a DC motor. Any other industrial system can be used providing that the system signals (control actions and process outputs) are available. Figure 3 shows the general laboratory setup used for this experiment, where the Advantech™ industrial data acquisition cards PCI-1720 and PCI-1711 have been employed.

The DC Motor allows users to remotely control both the position and velocity. The motor used in this laboratory is the Mechanical Unit 33-100 of Feedback<sup>©</sup>, which consists of an open-board format assembly carrying the mechanics of the system together with its supporting electronics. The electromechanical components comprise a DC motor, an analogue tachogenerator, analogue input and output potentiometers, absolute and incremental digital encoders and a magnetic brake. The supporting electronics consist of the power amplification, a low frequency sine, square

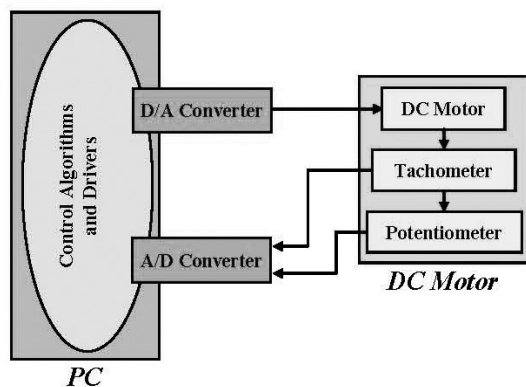


Fig. 3. Remote laboratory setup.

and triangular waveform generator for testing purposes and encoder reading circuitry.

The motor shaft carries an analogue speed transducer (tachogenerator) and a magnetic brake disk. The tachogenerator provides the output shaft speed in the range  $\pm 10$  V. The output shaft carries an analogue (potentiometer) and digital (64 location Gray code) angle transducers. The potentiometer supplies the output shaft  $\theta_o$  in the range  $\pm 10$  V.

This is a very fast response process; as such the batch operation mode offered by default by the MWS proves to be very convenient. The figures with the plotted variables are shown almost immediately after moving the motor and the real evolution can be observed through a webcam as mentioned in Section 2. In the case of a slower response process, having access to the system's time evolution in real-time will prove to be more useful. In order to achieve this, it is possible to program a Java applet for sharing data through a socket based communication where MATLAB is in charge of deploying the data to a shared file.

For the control implementation, different HTML files for data transmission have been programmed to specify all M-file variables and to submit user input for transferring data to the program. In this case, the initial web page submits to MATLAB reference values, controller parameters and experiment sample time (minimum sample time is 10 ms). For this application the experiment duration has been fixed at 5 seconds due to the characteristics of the process. Also, a hyperlink to the broadcasting images of the experiment has been added to the main page.

As far as the system used is a very robust educational prototype and it does not matter too much if an unstable controlled system is obtained (no damage will occur), safety measures have not been developed for this application.

Four different controllers have been implemented in this remote laboratory: a proportional fuzzy controller, a proportional and derivative fuzzy controller, a proportional and integral fuzzy controller and a discrete PID controller. The latter is used as a benchmark controller: first of all, the students develop the discrete PID controller and then they try to design a fuzzy controller that outperforms its response. This is not intended for comparison between discrete linear and fuzzy controllers, but to introduce a challenge to the design of the controllers.

Fuzzy controllers involve the adjustment of many parameters and users must be trained in the adequate design of these controllers. In order to help in the training of designers of fuzzy controllers, a remote laboratory, as illustrated below, has been developed, which focuses on this objective. In the exposed approach, the user can choose between a fuzzy P, PD or PI controller for the regulation of a DC motor axle position.

A Mamdani model has been used for the fuzzy controller without normalizing gains in the inputs

and outputs (the input and output domains can be altered). The controller parameters that a designer must select are:

- Domain of input/output variables
- Number of fuzzy sets for input and output variables
- Linguistic terms for every fuzzy set
- Membership function shape (triangular, trapezoidal . . .)
- Membership function parameters: determine the position of every fuzzy set in the domain
- Rule base: this defines how to connect the input to the output fuzzy sets and so determine the controller behaviour
- Functions for fuzzy AND, aggregation and implication operations.

It has been shown that the membership function type and fuzzy operators are not determinants of the overall controller behaviour. Therefore, for reasons of simplicity, some selections have already been carried out in the remote lab and could not be changed by users:

- triangular membership functions for input and output variables,
- min functions: for AND and implication operations, and
- max functions: for the aggregation function.

In line with a similar simplification philosophy, some parameters of the fuzzy sets are fixed:

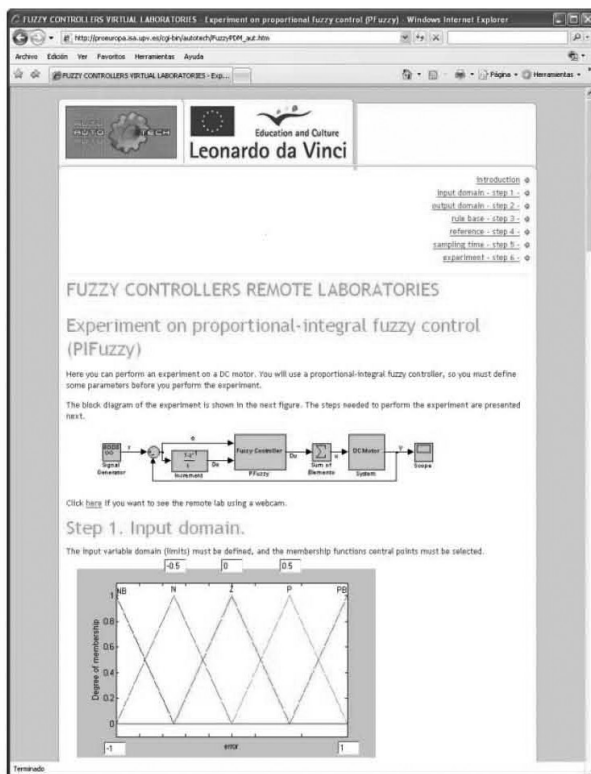
- number and name of fuzzy sets for input and output variables (NB: negative big; N: negative; Z: zero; P: positive; PB: positive big),
- a complete overlap between adjacent membership functions has been used in the input space. Subsequently, only one point for each function is needed (the vertex of the triangular mf),
- the same area is assigned to each fuzzy set in the output space, and hence, only the centre of the membership functions must be defined by the user.

### 3.1 Experiment Setup

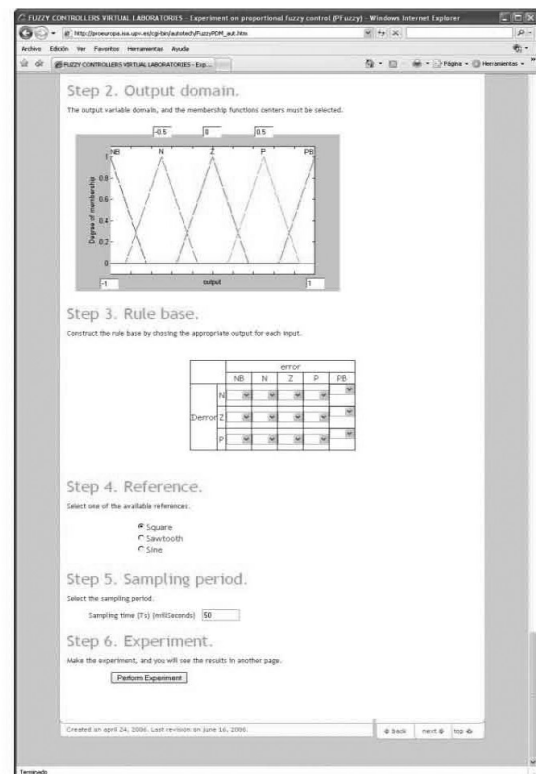
For every controller type, a web page has been developed to capture the experiment data. Figure 4 shows the input page for a DC-motor fuzzy controller. In this page the user introduces the controller parameters in text or list controls, depending on the parameter data type. In Steps 1, 2 and 3 the student can introduce the membership function parameters and the rule base. In Step 4 the user must choose the input signal between a step, a sawtooth or a sine signal. The amplitude and frequency are internally fixed. The sampling time for the controller execution must be chosen in Step 5. When all this is completed, in Step 6 the user presses a button to perform the experiment and all the data are sent to the web server.

### 3.2 Output Results

Figure 5(a) shows the DC-motor control output

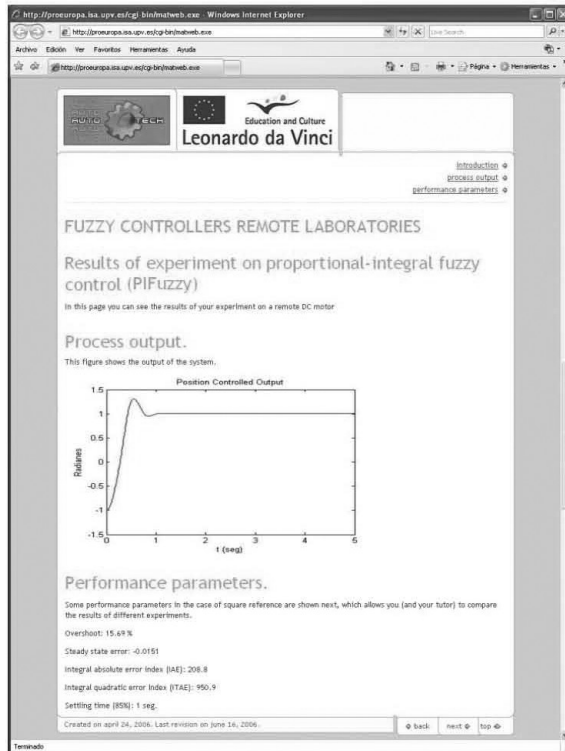


(a) Input page (upper part)

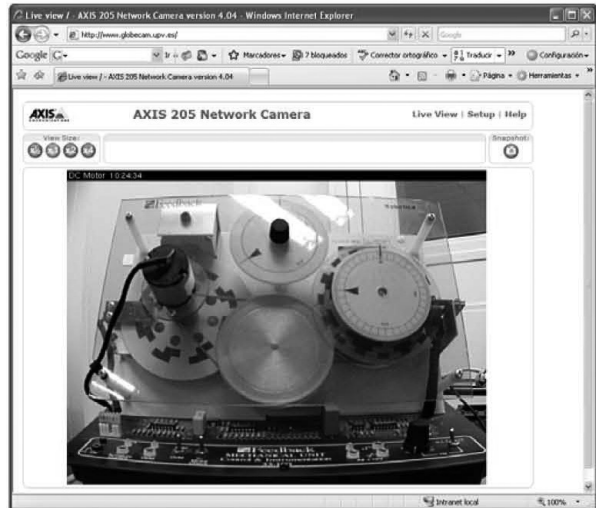


(b) Input page (lower part)

Fig. 4. DC-motor Remote Process Batch control input page.



(a) Output web page



(b) Page of the DC-motor webcam

Fig. 5. DC-motor Remote Process Batch control output pages.

web page that is generated. A scope with the references and outputs signals has been included in the output page. Also, for the user evaluation of the controller performance, some classic indexes have been included: overshoot, steady-state error, IAE, ISE, and settling time.

In addition to previous performance parameters, the user can compare the performance of the fuzzy controller to a discrete PID controller as mentioned above. In the case of the PID controller, the users must specify the control gain and the derivative and integration time constants.

In addition to the output web page, the DC-motor remote laboratory includes a webcam. The incorporation of this webcam allows one to observe the evolution in real-time of the system in addition to variables of interest. Figure 5(b) shows the webcam page.

#### 4. USER FRAMEWORK AND EVALUATION

##### 4.1 A Repository for Control Resources

The remote labs presented in the previous section are only a small proportion of all the innovative material being developed in the framework of the AutoTech Project (Fig. 6). This is a pilot project funded under the Leonardo da Vinci programme of the European Commission under contract N/04/B/PP 165.011 AutoTech. Nine partners from Norway, Spain, Germany and Romania

are involved in the project. In addition, there is one 'silent partner' from Switzerland. AutoTech was a 2-year project scheduled to end on February 28, 2007 ([37]).

The main objective of the project was to develop a set of new, motivating and innovative Internet-based training packages, with theoretical information about the practical work, the practices themselves, and evaluation exercises, mainly for Automation Technicians, but which would also prove useful for students currently involved in initial vocational training and formal learning (e.g. at vocational schools), or students in higher education taking introductory courses in automation and control. In addition, the learning resources will be valuable for other occupational groups such as control engineers, chemical engineers, process operators, etc.

The materials developed include:

- on-line interactive remote experimentation on real physical laboratory equipment for level, temperature, neutralization and pressure and position (DC and stepper motors, mobile robots) control and for the control of a railway based on PLC,
- motivating and industry-relevant learning material including innovative and motivating interactive dynamic simulators, games and competitions,
- a flexible web-based training repository to facilitate access to the learning material.

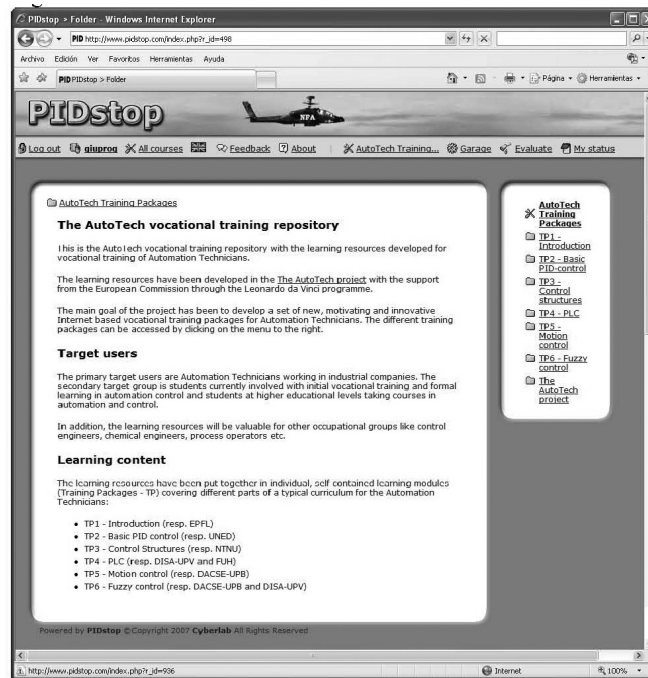


Fig. 6. Autotech project main page.

Figure 7 shows the multilingual access to the fuzzy control remote laboratories in the framework of the Autotech project. From the student's perspective, a login and a password for access to the experiments are required. These are also essential if the student is to answer the questions. If the use of a remote laboratory is required, the student must book a time slot for the experiment in order to avoid simultaneous access to it.

The final outcome of the project was five fully operational training packages covering important aspects of the automation technician's work tasks and training needs. The work presented here corresponds to the laboratory module of Training Package 6 'Introduction to Fuzzy Control'.

#### 4.2 Evaluation Design

To evaluate the Training Packages and the individual resources, A Common Framework for e-Learning Quality developed for Becta [38], the



Fig. 7. Main page for fuzzy remote laboratories on the Autotech framework.

strategic education and communications technology agency for the UK, and also relate the learning material to their Ten pedagogical principles for e-learning have been used. This approach for evaluation allowed the use of standards and criteria defined by an acknowledged organization outside the project.

The testers were not only the automation technicians, the primary target group, but also their teachers and employers as they are also future end users of the products. They provided important feedback as they had a close knowledge of the necessary theories, skills and competencies for the automation technicians' vocation, as well as their usual background, experience with use of ICT necessary for following the TPs.

For a coherent testing of all resources, and to keep the workload acceptable, questionnaires were the main method for data collection. The questionnaire, composed of 32 questions, was developed to gather user feedback on Learning Content, Simulations/games/tests, Technical issues, and Future developments. Additionally, open questions were prepared for the different groups. Both of these, questionnaire and open questions, followed the Becta's ten pedagogical principles for e-learning [39]:

- Match to the curriculum
- Inclusion
- Learner engagement
- Innovative approaches
- Effective learning
- Formative assessment
- Summative assessment

- Coherence, consistency and transparency
- Ease of use
- Cost-effectiveness.

The groups and the way that they provided the evaluation feedback are:

- Automation technicians: questionnaire (including open text responses)
- Students: questionnaire (including open text responses)
- Industry: written feedback on relevant topics
- Organization of industrial engineers: written feedback on relevant topics
- Teachers: written feedback on relevant topics.

#### 4.3 Data Analysis

In the particular case of the remote labs presented here, the evaluators were: vocational students and teachers in a vocational school (Vocational School 'Juan Comenuis', Valencia, Spain), university students and university teachers (Technical University 'Federico Santa María', Chile), and experts on long-life learning for engineers (Industrial Engineers Association of Valencia, Spain).

After two initial 'tuning' evaluations had been carried out by teachers and experts in the Spring and Autumn of 2006 (solely dedicated to the detection of technical problems), the final evaluation (with vocational students participation) was performed in the Spring of 2007. The amount of information collected in this evaluation was large (student questionnaires, interviews with teachers and experts, reports, etc.) and cannot be reproduced here, however the main findings are summarised next.

##### 4.3.1 Experts' evaluation

In the case of the experts (teachers of vocational students, university teachers, and experts on life-long learning for engineers), the evaluation was a qualitative analysis of their written feedback. In general, they found the simulations and remote laboratories very useful and more motivating than traditional exercises. From the expert's perspective, the use of technology in Vocational Education brought clear advantages to the learning process, as the IT resources really improved the understanding of complex concepts and significantly speeded up the learning process. Hence, topics could be explained in (approximately) half the time taken in regular lectures and there was more time for describing additional topics, offering more detailed explanations of some parts, doing more exercises, etc. The answer pages for the experiments were found to be very well suited for testing the effect of the changes in design parameters on performance. The use of plots in understanding remote data gathering was particularly relevant for the students.

However, some drawbacks were also reported. In the case of industrial training, the Training Package was satisfactorily matched to the learning

objective; however the use of fuzzy control in the industry is very limited. From the educational perspective, the level was high for Vocational Training, but it could only be used for demo purposes. However, the course seemed to be adequate with regards to an introduction for engineering degrees and especially as an introduction to the topic for Masters students. With regard to the possible mismatch between the level of the proposed courses and the expected level from external users, this was likely to be raised, given that the syllabus followed did not match any actual course but, more or less, consisted of a list of common subjects taken from the Vocational Training courses for all partners (and countries) participating in the project.

Therefore, when considering the reported evaluation regarding the validity of remote laboratories applied to Vocational Education, the main conclusion drawn is that this combination actually works. This kind of material can be used in continuous education and training, and for physically challenged or able-bodied students enrolled on regular university courses. The overall quality reported by experts was 'good quality' (scoring 5, from the scale—1(worst) to 6(best)).

##### 4.3.2. Students' evaluation

In the case of students, the information was mainly gathered through the questionnaire. The results are shown in Table 1.

The analysis of the data in the table allows us to definitely be assured that the training package on fuzzy control that was developed is well received by the final users. Only two questions don't have very good results and must be highlighted: the level and the pace of the course seem too high. This matches the results presented by the experts where the level was too high for Vocational Training.

The questionnaire also included open questions. The answers were a confirmation of their good experience because the suggestions usually made were: a request further similar material, and that the technology is exported to other areas in order to increase the sharing of equipment among students or researchers.

## 5. CONCLUSIONS

Virtual and remote laboratories provide an innovative experimental tool allowing lecturers in Control to optimize laboratory resources (for instance, by sharing plants or software); to develop innovative classroom material (making use of advanced pedagogical methodologies); or to reinforce student knowledge in a time-space flexible framework.

This paper presents an approach for developing virtual and remote laboratories on fuzzy control, based on commercial technologies (MATLAB by Mathworks). The objective of the laboratory is to offer students and professionals a valuable tool for



Table 1. Students' evaluation results

Questions	Answers <sup>1</sup>				
	1	2	3	4	5
How much of the subject matter in the training packages did you actually learn? (1: everything, 2: more than a half, 3: half, 4: less than half, 5: nothing)	11%	56%	33%	0%	0%
How would you rate your learning outcome compared with 'regular' learning? (1: a lot more, 2: more, 3: thee same, 4: less, 5: a lot less)	11%	33%	56%	0%	0%
How would you rate your learning efficiency compared with 'regular' learning? (1: a lot faster, 2: faster, 3: at the same speed, 4: slower, 5: a lot slower)	1%	33%	44%	22%	0%
To what extent did the tests (quizzes) contribute to your learning? (1: to a large extent, 2: to some extent, 3: to little extent, 4: not at all)	22%	78%	0%	0%	–
The training package description was comprehensive.	0%	33%	67%	0%	0%
The training package description was precise.	0%	67%	11%	22%	0%
The training package was clearly structured.	56%	44%	0%	0%	0%
The level of difficulty was (1: far too low, 2: too low, 3: appropriate, 4: too high, 5: far too high)	0%	0%	89%	11%	0%
The pace of the course was (1: far too low, 2: too low, 3: appropriate, 4: too high, 5: far too high)	0%	0%	89%	11%	0%
Which of the following learning resources did you learn most from? (1: Theoretical texts, 2: Teacher, 3: Other students, 4: Simulation, 5: Game)	0%	44%	0%	56%	0%
The remote laboratory made the objective of the training package clearer.	22%	67%	11%	0%	0%
The remote laboratory increased my learning outcome.	22%	67%	11%	0%	0%
The remote laboratory increased my motivation.	33%	67%	0%	0%	0%
The simulation increased my learning outcome.	22%	78%	0%	0%	0%
The simulation increased my motivation.	22%	78%	0%	0%	0%
The simulation made the objective of the training package clearer.	22%	78%	0%	0%	0%
The quality of the simulation was	0%	10 0%	0%	0%	0%
The quality of the remote laboratory was	22%	78%	0%	0%	0%
The navigation was easy.	0%	10 0%	0%	0%	0%
I managed to complete the training package without any help.	0%	33%	11%	56%	0%
This training package was relevant for me.	22%	67%	11%	0%	0%

<sup>1</sup> If other answers are not specified, the numbers refer to the following list: (1: strongly agree, 2: agree, 3: neither agree nor disagree, 4: disagree, 5: strongly disagree).

improving their fuzzy design abilities, and to test the performance of fuzzy controllers in a real DC motor. Its integration in a repository of control resources has also been presented. In this way, by combining the resources developed by different universities from different countries, a set of training packages covering important aspects of automation and control can be made available for use by many students who are not necessarily at the same physical location. The proposed approach

provides straightforward methodologies for the developer of the teaching material (Control lecturer) and represents low costs for the user (student).

The work has also shown the remote laboratory evaluation design and the experts' and students' evaluations. In general, the users found the laboratory very useful and motivating because it improves their understanding of complex concepts and significantly speeds the learning process.

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**Marina Vallés** received her degree in computer science in 1996, completed her Master's Degree on CAD/CAM/CIM in 1997 and her Ph.D. in 2004 from the Universidad Politécnica de Valencia (UPV), Spain. Since 1999, she has been a lecturer at the Department of Systems Engineering and Control (UPV). She currently teaches automatic control and computer simulation. Her research interests include real-time systems, automatic code generation, and control education.

**José Luis Díez** received his M.Sc. in industrial Engineering in 1995, and his Ph.D. in control engineering in 2003, both from the UPV. At the Department of Systems Engineering and Control (UPV) he has taught courses on automation, linear systems control theory, and digital signal processing. His interests include complex systems modelling, clustering techniques, intelligent control, and control education.

**José Luis Navarro** received his M.Sc. in Industrial Engineering in 1987 and his Ph.D. in control engineering in 1994 from the UPV. He has been a lecturer in the Department of Systems Engineering and Control (UPV) since 1988. His interests include systems biology, bioprocess control, systems modelling, and intelligent control.

**Angel Valera** received his degree in computer science in 1990 and his Ph.D. in 1998 from the Universidad Politécnica de Valencia (UPV), Spain. He joined the Department of Systems Engineering and Control (DISA) in 1989. Since then, he has worked as a lecturer and assistant professor. He currently teaches automatic control, robotics, and Mechatronics. His research interests include robot control, real-time systems, and control education.