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JBODE: A JAVA TOOL FOR UNDERSTANDING THE BODE DIAGRAM

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Abstract: This work describes JBODE, a computer application developed in Java, HTML and ASP to study and understand the Bode diagram. This is achieved by means of Web theory pages for learning/refreshing basic concepts. Once the theory has been mastered the student can draw the real and asymptotic Bode diagrams of any transfer function. Also, there are on-line exercises for testing the understanding. The students' progresses are recorded in a database where the instructor can follow them. The final objective is to build a tool for learning basic control without using typical process control software. *Copyright© 2002 IFAC*

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1. INTRODUCTION

During the last years, Internet has been increasingly used as a learning tool (Poindexter and Heck, 1999; Vlacic and Brisk, 2001). So, students who cannot attend lessons or want to do extra work, can login and work on-line. As time goes by, more people has developed different ideas: virtual laboratories (Dormido *et al*., 2001; Torres *et al*., 2001; Valera *et al*., 2001; Widener University, 2001), remote laboratories (Junge *et al.*, 2000; Meléndez *et al*., 2001; Moreno *et al*., 2001; Overstreet *et al*., 1999; Pyaget, 1999; Ramos *et al*., 2001; Röhrig *et al*., 2000; Schmid, 2001), Internet based material (Antsaklis *et al*., 1999; Aptronix, 2001; Gómez *et al*., 2001; John Hopkins University, 2001; Jugo and Sagastabeitia, 2001; Morilla and Fernández, 2001; Valera *et al*., 2001).

The work presented in this paper is the result of a final year project (Ramos and Zamorano, 2001). JBODE draws the asymptotic and the real Bode diagram via Intenet using Java programming. But, it is more than that. It has been developed considering the suggestions done by former students on how they would like to learn the diagram. That is, it is not only important to draw it but to justify the different steps and to compare results between the asymptotic diagram and the real one.

So, taking this into account, there are four different parts:

- theory pages where basic concepts and definitions can be found;

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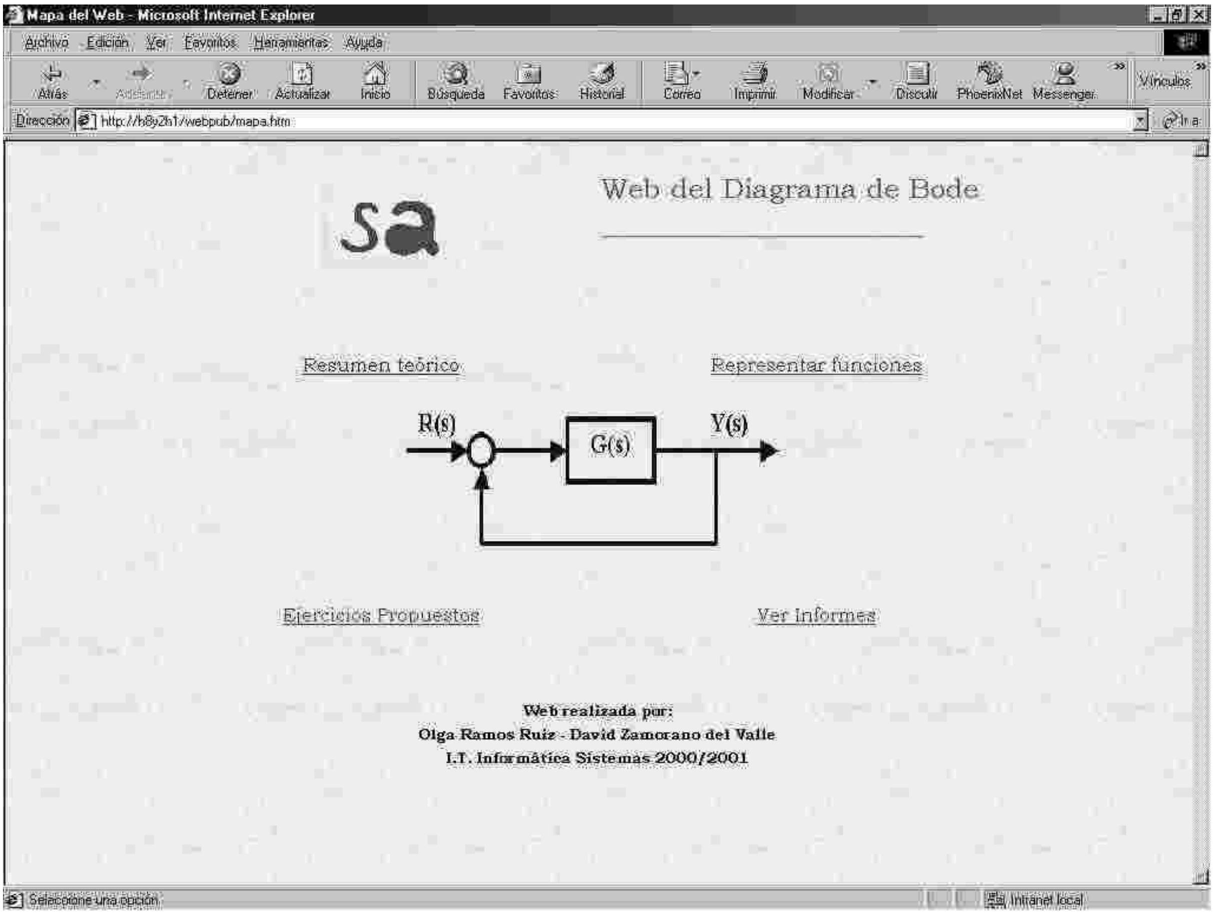

Fig. 1: Menu screen

- the drawing tool where the diagram is drawn;
- a set of tests to verify the knowledge. It is open to anybody although it is necessary to be registered
- the instructor's page that allows the lecturer to follow the progress of the students.

Everyone can connect to the Internet address http://157.88.32.178 to work with the first three sections (building new drawings, learning theory and tests). The fourth section allows the instructor to follow the progresses of the students: number of people using the application, how many students have finished the test, how many users need to repeat them, etc. It is also possible to remove/add new users, etc.

The developed tool is half way between a virtual laboratory and a tutorial: there are HTML (Powell, 1998) theory pages (Nise, 1995), Java programs (Sun Java, 2001; Jars, 2001; Java, 2001; Java graphics, 2001) for drawing the diagram and database management (Kauffman *et al.*, 1999; Keyton, 2000; Kroenke, 1999).

It can be discussed that the work presented in this paper could have been programmed using Matlab© or Scilab more easily instead of Java; as in the works by Morilla and Fernández (2001) and Jugo and Sagastabeitia (2001) that cover other topics of the control theory. But the final objective was an application that used so little commercial software as possible, that it was absolutely portable and that worked through Internet. The programming in Java offered the answers. Of course, the programming effort has been huge because Java is not a process control oriented language and no Matlab or Scilab software was used, but the results have been worth the trouble. It should be noted that all the graphics have been fully programmed as there are no high level drawing facilities in Java. Poles and zeros of the transfer functions are calculated using the root finder of the freeware Java software MathTools Package (2001). The result is an independent platform application that once is running in the computer does not need to access the web. The web will only be accessed for updating the database when the tests are done.

The analysis of feedback systems via the Bode diagram has been discussed in other works: Benvegnu (2001); Boggio and Li (1999); Mehra and O'Hare (2001). Let's discuss briefly the similarities and differences among them and JBODE. The first difference is that these works cover plotting of the Bode diagram, but the instructor cannot follow the students progresses. Benvegnu (2001) has developed a shareware multimedia tool for learning the asymptotic Bode diagram and the real one. It is a nice and powerful application, but it does not function via WWW and the data entry is not as powerful as the rest of the tool. Boggio and Li's (1999) Bode diagram has as main advantage that the source code can be accessed, but it is not very easy to work with. Mehra and O'Hare (2001) have implemented a convincing and effective Java applet that draws the real Bode diagram. The data entry is rather simple, but it should have been desirable the possibility of seen the transfer function corresponding to the poles and zeros diagram.

Summing up, JBODE is an interactive tool for learning/revising basic control theory, drawing Bode diagrams and testing knowledge in a friendly interface. Following sections describe the application in-depth.

2. JBODE

This section describe the foremost points of JBODE This application could be used on-line or off-line, after copying the files onto the hard disk (in this last case, no database update takes place). The main screens are now discussed. The first screen (Fig. 1) gives the possibility of choosing amongst four options:

- *Theory* (Fig. 2): web pages (Powell, 1998) describing relevant theoretical (Nise, 1995; Ogata, 1996) points. All the pages follow the same structure: on the upper border a menu showing the covered topics and below it, the explanation of the selected topic.
- *Plotting the Bode diagram* (section 2.1). This icon gives entrance to the plotting area using a Java applet.
- *Tests* (section 2.2): worked examples, following step by step design of controllers, illustrated with graphics from the Java applet.
- Instructor's page (section 2.3). Statistics of use and relevant information regarding the use of the tool are shown.

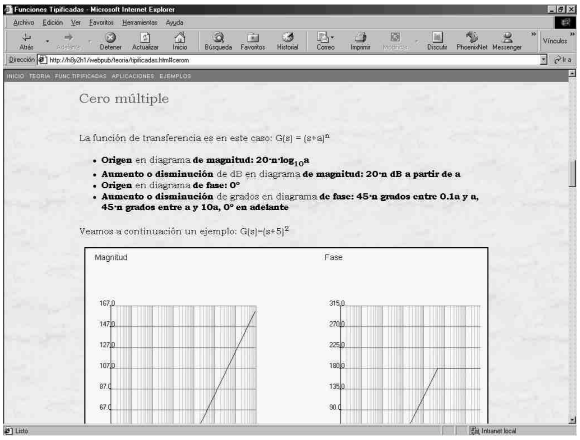

Fig. 2: Theory page

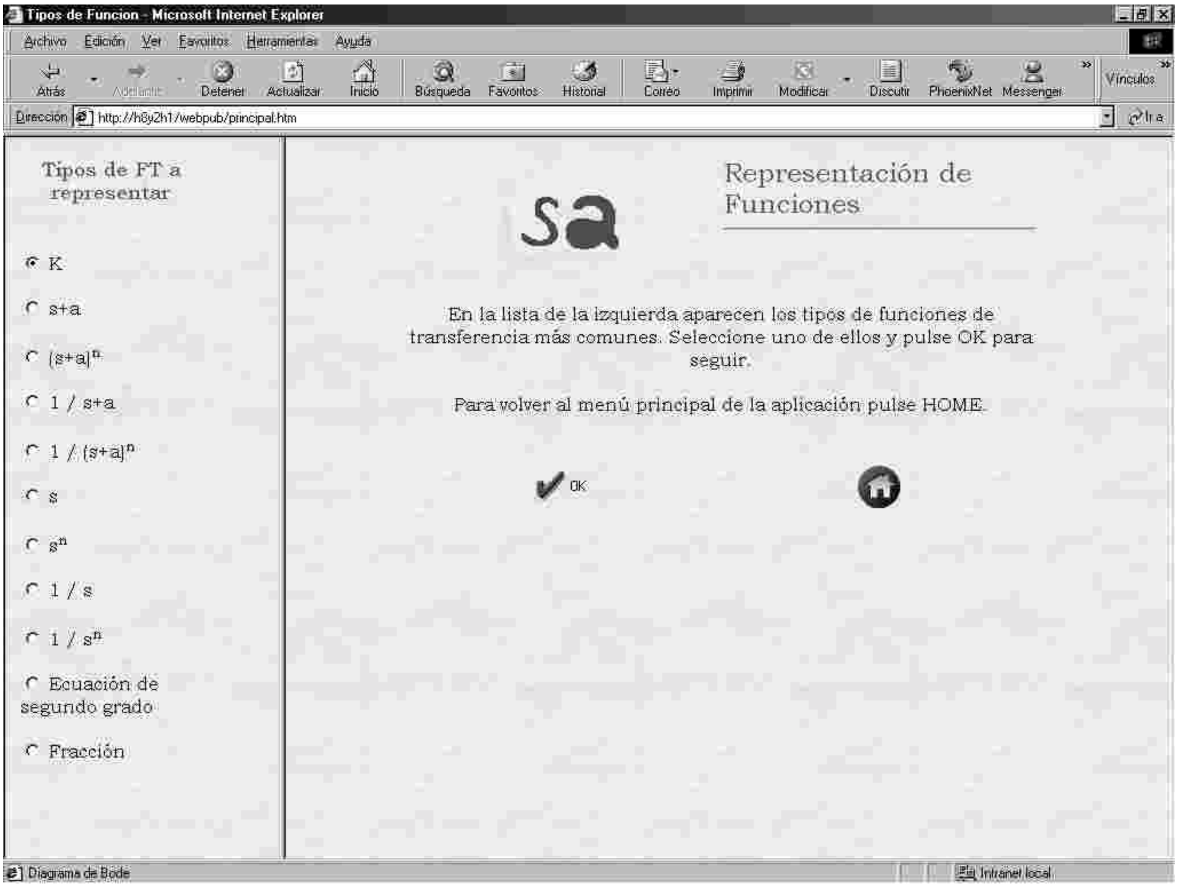

Fig. 3: Data entry screen

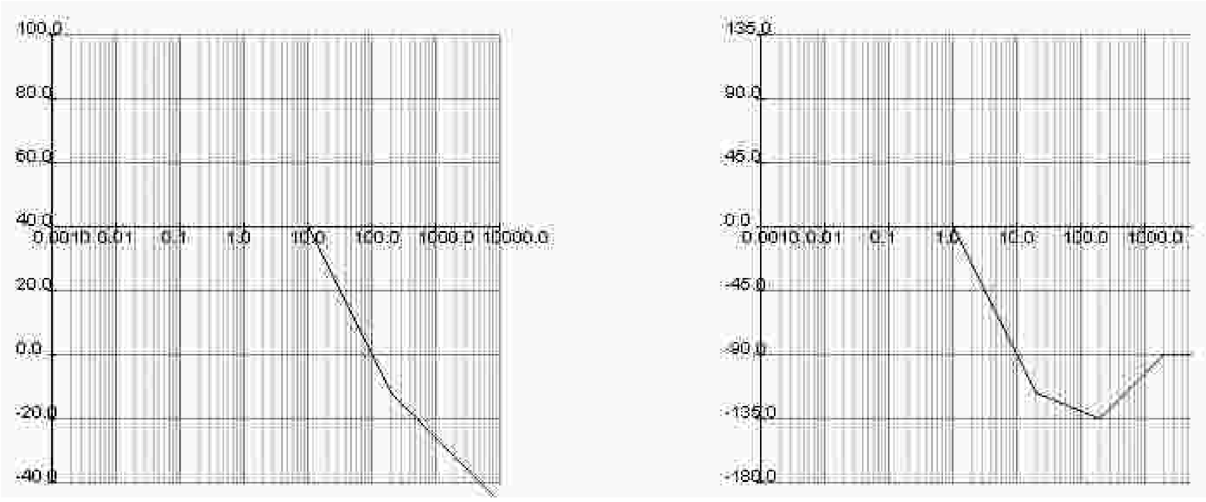

Fig. 4: Asymptotic Bode diagram

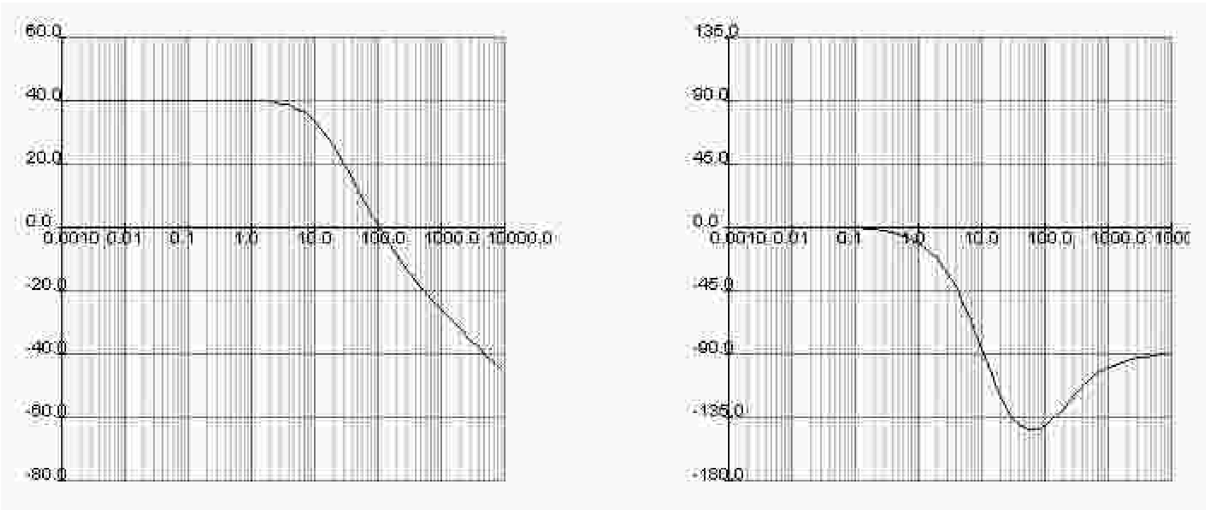

Fig. 5: Real Bode diagram

2.1. Plotting the Bode diagram

When selecting this option, the screen in Fig. 3 appears. The most common transfer functions are shown on the left hand side: gain, zero, pole, multiple zero, multiple pole, integrators, second order system and the general transfer function. The last case includes all the others, but from a didactic point of view it is useful that the student can proceed step by step from the simplest transfer functions to the most complicated ones.

Every time that some kind of input from the user is required, it is checked that the values are of the right type and within the defined bounds. If the application has asked for a numeric value and the user introduces any other symbol, an error message will appear.

Once the system has been introduced (for example, $G(s) = \frac{50(s+200)}{s^2 + 20s + 100}$), the asymptotic (Fig. 4) and the real (Fig. 5) Bode diagrams appear in the screen. Comparing both plots, the user can learn the differences between the asymptotic and the real case and appreciate when these differences are greater. At any point, the student can go back and introduce a new transfer function.

2.2. Tests

The tests are a set of exercises in increasing order of complexity where students can check their knowledge. In order to maintain an updated register regarding information on how well or bad someone is doing, there is a database (section 3) where relevant information is stored. When someone clicks the tests option, the following steps are followed:

1. Ask for the user's identification.
2. Search the database.
3. If he/she has not been previously registered, then ask for personal data and create the new user, else show the user the first non-solved problem.

At any point the student can log off. A later visit will be resumed at the corresponding exercise. The database is run-time updated.

To simplify the process of learning to use the tool, the structure of all the exercises is the same. First the problem formulation, for instance: 'Which of the following four figures corresponds to the Bode of G(s)=10?'. Then, the user can observe the four plots as long as (s)he wants. And finally, (s)he introduces an answer. If it is the right one, the following exercise is shown, and if it is not, (s)he is given another chance. A second wrong response implies the automatic log off and the suggestion of going to the theory pages. The next visit, (s)he will be shown the very same exercise as starter!.

Once all the exercises have been successfully answered, a final message is shown.

2.3. Instructor's page

This page can only be viewed by the instructor or super-user. After introducing the login and the password, a page containing several statistics of use and database management is shown.

The statistics give details about:

- The number of users.
- How many exercises have been solved.
- How many students have successfully finished the tests.
- How many students are having problems with the exercises.

Using this information, the instructor can change the content of the exercises or suggest extra work to those students having problems.

If a user has not entered the tests in a certain time, (s)he can be shut down permanently. This is done to maintain an updated list of people interested in the subject.

3. THE DATABASE

Using a database in the application has increased the tool functionality. This way, customised contents are offered to the users transparently. Management of the web site is facilitated to the instructor and different statistics about tests fulfilment and use are shown in the instructor's page.

The database has been created using Microsoft Access©. The reasons for these have been that the complexity required was not very high and the remote Web access was straightforward using ASP. This language provides objects for very fast access to the database. Moreover, it is as powerful as SQL but more intuitive and easy to use.

As it has been previously said, the database is not very complex. There are three tables where important information is stored, such as student data and exercises solved by each user. The database content is modified on-line, for instance, every time a user logs in or an exercise is solved. All of this can be done thanks to ASP. This way changes are inluded the moment they occur.

4. CONCLUSIONS

This paper has presented JBODE, a tool for aiding in the study of the Bode diagram using a friendly interface. Theory web pages and tests have been included to give the student a broad view of what should be taken into account.

The tool can be useful in different ways. We can distinguish between the benefits for students and the benefits for instructors. Among the benefits for students, it is possible to point out: learning basic control theory, plotting real and asymptotic Bode diagrams and testing the knowledge with the exercises. The statistics showing the performance of how well or not so well the students are doing are a clear help for the instructor. This way (s)he can follow their progresses and give personal advice to each of them before doing the real examinations.

The utility of ASP has long ago been established. But JBODE has shown that Java can be used in the learning of process control via Internet and that no additional software (for instance, Matlab or Scilab) are required.

As the tool stands now, it is quite easy to use and gives a broad view in the subject of plotting Bode diagrams. The Java applets are fully programmed using freeware software, so they are absolutely portable. The applets are independent of the tests and database management. Nevertheless, it should be reckoned that the programming has been cumbersome, as basic graphics in Java are not straightforward. The software behind is of wide use.

Future work includes: the plot of the asymptotic and the real diagram on the same graph; improving the tests capability so the student can 'draw' the diagram and then the application would mark it; plotting both the system open and closed loop transfer function.

As it has been said, the work can be improved, but the results are encouraging and more work will be done in this area.

REFERENCES

Antsaklis, P., T. Basar, R. de Carlo, N. H. McCkamroch, M. Spong and S. Yurkovich (1999). Report on the NSF/CSS Workshop on New Directions in Control Engineering Education. *IEEE Control Systems Magazine*, **19**, 53-58.

Aptronix (2001). Inverted pendulum example. http://www.aptronix.com/fuzzynet/java/pend/pendjava.htm

Benvegnu M. (2001). http://web.tiscali.it/hiforce/winbode/indexeng.htm

Boggio B. And T.Li (1999). http://www. enme.umd.edu/ice_lab/java/SP99/bog/applet.htm

Camiña, C., A.Cuenca, E. Ballester, A. Montes, "Diseño multimedia de material docente para una asignatura de control", *EIWISA 2001*, Madrid, 26-27 Abril 2001.

Dormido, S., J. Sánchez, F. Morilla (2000). Laboratorios virtuales y remotos para la práctica a distancia de la automática. *XXI Jornadas de Automática*, Sevilla.

EIWISA'01 (2001). II Jornadas de trabajo "Enseñanza vía Internet/Web de la Ingeniería de Sistemas y Automática. *EIWISA 2001*, Madrid.

Gómez, E., J.A. López-Orozco, J. Aranda, B. Andrés (2001). Aplicación de un sistema generados de cursos para la enseñanza de automática a través de Internet. *EIWISA 2001*, Madrid.

Jars (2001). Java tutorial. http://www.jars.com

Java (2001). Tutorial de Java. http://www. programacion.net/java

John Hopkins University (2001). Control Systems Signals. http://www.jhu.edu/%7Esignals/.

Java graphics (2001). Graphic programming in Java. http://www.sci.usq.edu.au/staffleighb/graph

Jugo, J. and I. Sagastabeitia. Prácticas de control vía WWW usando Scilab. *EIWISA 2001*, Madrid.

Junge, Th.F. and Chr. Schmid (2000). Web-Based Remote Experimentation Using a Laboratory Optical Tracker. *Proc. American Control Conference ACC'2000*, Chicago, pp. 2951-2954.

Kauffman, J., D. Buser, T. Willis and K. Spencer (1999). *Beginning ASP databases*. Wrox Press Ltd., New York.

Keyton Weissinger, A. (2000). *ASP in a nutshell*. O'Reilly UK, London.

Kroenke, D. (1999). *Database processing*. US Imports and PHIPES, New York.

MathTools Package (2001) http://brain.babst.org/ ~jhuwaldt/MathToolsPackage/MathToolsPackage .html.

Mehra S. and T. O'Hare (2001) http://www.ee.usyd. edu.au/~hansen/bode/bode.html

Meléndez, J., J. Colomer, J.L. de la Rosa, D. Macaya (2001). Experiencias en teleoperación de procesos y teleenseñanza en la universidad de Girona. *Eiwisa 2001*, Madrid.

Moreno, J.C., M. Berenguel, F. Rodríguez, J.F. Sarabia, R. Garrote, J.L. Gúzman, O. López (2001). Proyecto de Aplicación de telerobótica a un minirobot móvil. *Eiwisa 2001*, Madrid.

Morilla., F. and A.W. Fernández (2001). Servidor WWW para el análisis de sistemas de control. *EIWISA 2001*, Madrid.

Nise, N. (1995). *Control Systems Engineering*. John Wiley and Sons, New York.

Ogata, K. (1996). *Modern Control Engineering*. Prentice Hall, New York.

Overstreet, J. and Y. Anthony Tzes (1999), An Internet-Based Real-Time Control Engineering Laboratory. *IEEE Control Systems Magazine*, **19**, 19-34.

Pyguet, Y. And D. Gillet (1999). Java-based remote experimentation for control algorithms prototyping. *ACC'1999*, San Diego, pp. 1465-1469.

Poindexter, S.E. and B.S. Heck (1999). Using the web in your courses: What can you do? What Should you do?. *IEEE Control Systems Magazine*, 19-1, 83-92.

Powell T. (1998). *Manual de referencia de HTML.* Ed. McGraw Hill , Madrid.

Ramos, C., J.M. Herrero, M. Martínez, X. Blasco (2001). Internet en el desarrollo de prácticas no presenciales con procesos industriales. *EIWISA 2001*, Madrid.

Ramos O. and D. Zamorano (2001). *JBODE: una herramienta para el aprendizaje del diagrama de Bode*. Proyecto fin de carrera de la Universidad de Valladolid, 2001.

Röhrig, C. And A. Jochheim (2000). Java-based Framework for Remote Access to Laboratory Experiments. *IFAC/IEEE Symposium on Advances in Control Education, ACE 2000*, Gold Coast, Australia.

Schmid, C. (2001). A remote laboratory experimentation network. *EIWISA 2001*, Madrid.

Sun Java (2001). Java web pages. http://www.java.sun.com/

Torres, F., S.T. Puente, J. Pomares, F.A. Candelas, F.G. Ortiz (2001). ROBOLAB: Laboratorio virtual de robótica básica a través de Internet. *EIWISA 2001*, Madrid.

Valera, A., J.L. Diez and M. Vallés (2001). Creación de un laboratorio virtual para prácticas de control en MATLAB Web Server. *EIWISA 2001*, Madrid.

Vlacic, L. and M. Brisk (2001). *Advances in Control Education 2000*. Elsevier Science, The Netherlands.

Widener University (2001). Virtual Control Laboratory. http://quantum.soe.widener.edu: 280/ProcessLab.html