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Abstract

We describe the development and the current implementation of a web-based study support environment that is used for teaching systems and control courses at Delft University of Technology, The Netherlands. The aim of this web-based study support environment is to increase the study effectiveness in systems and control courses. First we describe the new course format that has been introduced to successfully implement the web-based study support environment. We also give a brief overview of the study support environment itself and discuss our experiences with the environment, which is currently being used for the third consecutive year. We also compare our experiences and the results in using this study support system with those of the preceding years, in which the system was not yet used.

1 Introduction

Systems and control courses have a strong foundation in theoretical mathematics on one hand, but also need to develop the student's intuition for bridging the gap between theory and practice on the other hand. As mentioned in [2], interactive tools are considered to be a great stimulus for developing the student's engineering intuition. Many successful initiatives were taken to develop such interactive tools for education in automatic control [2, 3, 4]. These interactive tools attempt to simplify theoretical and mathematical concepts through visualization by using concrete and realistically chosen examples. As a consequence, they are especially suited for dealing with those topics in systems and control courses that are usually detected by the instructors as "bottleneck" topics, i.e. topics that are usually not very clear to most of the students (unless additional explanation is given) or topics that require extra effort to understand them thoroughly. The transfer of insights from the teacher to the students will be limited when the students do not attend the lectures in which

special attention is given to these bottleneck topics, no matter what efforts the teacher makes. So, for improving study effectiveness, not only the development of attractive interactive visualization tools is necessary, but some additional measures seem to be appropriate:

- The creation of a web-based study support system to inform students and to communicate with them at all times. The system should also allow students in the course to learn from questions raised by other students (at any time) and from the answers given by either the teacher or other students.
- Offering frequent advice on the progress of a student in mastering the course content. This advice is based on the student's performance in electronically accessible exercises. These exercises are dedicated to both the bottleneck topics in the course and the refreshment of (elementary) material that has been treated in other preliminary courses.

We present the results of the use of a web-based study support environment for improving study effectiveness based on the measures mentioned above. This environment is used in an introductory undergraduate course on system identification within the curriculum of electrical engineering with a study load of 100 hours (3.5 ECTS credit points). This environment is currently being used for the third year. A detailed description of the web-based study support environment as it has been implemented in the first year is given in [1]. In this paper we will especially focus on the changes we have introduced in comparison with the first year after extensive discussions with selected students and after a detailed analysis of the results and experiences of the first year. We will also discuss the costs of the introduction of the web-based study support environment, and the results related to the improvement of the study effectiveness of the students.

2 New course format

Before the web-based study support environment was used, the format of the course was based on conventional lectures in which all the topics that appear in the lecture notes were treated extensively. In this format there was little interaction between teacher and students, and class-room attendance (and related study effort) decreased gradually during the course quarter, which had a negative impact on the final grades. Augmenting the interaction and the involvement of the students was the main motivation for introducing the new web-based study support environment. In addition, we have introduced a new course format that was more suited for the web-based study support approach and that basically consists of three parts: a *preparation phase*, in which the students prepare for the lecture; the *lecture* itself; and a *final phase*, in which the students process the subject matter that has been studied in the preparation phase and/or presented during the lecture.

We have also taken care to keep the overall study load for the students at approximately the same level as in the previous years in which the conventional lecture format was used. This was possible due to the fact that we changed the focus of the lectures from treating all material to treating the bottlenecks only. As a consequence, we could decrease the number of lectures by half. The time gained in this way compensates the extra effort students have to spend in the preparation and (post)processing phases.

2.1 Preparation phase

Each lecture is aimed at dealing with one of the bottleneck subjects in the course material. To prevent students from getting lost during the lecture, they need to be stimulated to prepare themselves properly. This is achieved in three ways:

1. The students are informed about which parts of the course book they have to read in preparation of the following lecture. By using an on-line study guide, students know which subjects will be discussed in a lecture and which parts of the course book are related to these subjects. The students can also download the transparencies of the coming lecture in advance.
2. The students are given the option of making a voluntary on-line self-test exercise. The exercise consists of several questions alternated with small assignments, and is constructed in such a way that it functions as a recapitulation of the course material and as a preparation for the bottleneck, which will be discussed during the upcoming lecture. After submitting the solution for an exercise, the student immediately receives feedback. The feedback consists of the result (i.e., the score) for the entire exercise, but also an evaluation of each individual question of the exercise. For each question the student will see if the given answer was correct or not. In the latter case he or she will receive the correct answer and some more explanation on why the given answer was wrong (see, e.g.,

Figure 4). This way, the student gets a sense of how well he or she masters the basics of the studied subject. More detailed information on the implementation of the exercises is presented in Section 3.2.

3. The students are stimulated to email questions to the teacher concerning the subjects to be treated in the coming lecture, or questions on problems they encountered during their preparation of the indicated course material. The teacher then makes a distinction between problems that are of interest to individual students only and to which an immediate personal reply is given, and more fundamental problems that are of interest to a wider group of students. These problems are then treated in the subsequent lecture. If the students use the bulletin board instead of email to ask their questions, electronic communication is open to other students as well. In that way students can learn from one another, and they are also stimulated to help each other.

2.2 Lecture

In the new course format the focus of the lectures has changed from covering all subjects to dealing with the bottlenecks only and with selected problems raised by the students during the preparation phase. A topic from the course material qualifies as a bottleneck if in previous years students have demonstrated great difficulty in mastering it. This observation is drawn from the interplay between the teachers' expertise, the grades of the students on certain types of examination exercises, and through individual discussions with students. As a consequence, not all the study material that students have to learn is treated during the lectures as is done conventionally. Some subjects are left for self-study. This includes background material, material taught in previous courses, and material considered to be straightforward. In previous years, these subjects were often considered dull during the lectures, resulting in a decrease in attention.

To improve the interactivity during the lectures, several means are used. Firstly, a selection from the questions emailed to the teacher or posted on the bulletin board is discussed in the lecture. Secondly, students are stimulated to ask additional questions at any time. Thirdly, the teacher is challenging students with short and simple questions about detailed elements of the material treated in the lecture.

2.3 Post-processing phase

To stimulate students to actively process the course material immediately after the lecture and to help them apply and test the knowledge gained on the bottleneck subjects, they are provided with two aids:

1. The students are provided with a short on-line summary of the lecture and with the transparencies, which can be read on-line or downloaded for printing.
2. To apply and test the knowledge gained, the students have to take an on-line mandatory exercise. This mandatory

exercise has a similar setup as the self-test exercise, but its purpose is to reach more deeply and there is no extensive feedback except for the result. We grade the mandatory exercise, enabling us to give students an idea of the progress they are making, but also giving them the opportunity to gain points as part of their final grade.

3 Realization of the web-based environment

Now we discuss the actual realization of the web-based environment using WebCT [5] and Blackboard CourseInfo [6]. We will mainly focus on the differences between the WebCT implementation used in the first year and the implementations used in the second and the third year. More detailed information on the system as it has been implemented and used in the first year, can be found in [1].

3.1 WebCT and Blackboard CourseInfo

WebCT and Blackboard CourseInfo are tools that facilitate the creation of sophisticated web-based educational environments, which can be used to create entire on-line courses, or to simply publish materials that supplement existing (traditional) courses. There are several other good products that compete with WebCT and Blackboard CourseInfo, and each has its advantages and disadvantages. We have looked into some of the other programs as well, but finally decided to use first WebCT and later Blackboard CourseInfo for our web-based educational environment. Some helpful evaluation studies on the WWW on these and other programs can be found at [8, 9, 12]. The following issues played a role in our decision to select WebCT and Blackboard CourseInfo: low cost, cost-effectiveness, simplicity and ease of use, and good (technical) support.

During the first two years we used have WebCT but now we have changed to Blackboard CourseInfo, mainly since this study support environment has now been adopted on an institution-wide scale at our university. Blackboard CourseInfo is comparable to WebCT, but has an easier to use interface for both instructors and students. Moreover, the use of one study support environment for several courses offer several advantages for both instructors and students.

WebCT and Blackboard CourseInfo facilitate the creation of sophisticated web-based educational environments by providing

- an interface allowing the design of the presentation of the course (color schemes, page layout, icon style, use of a counter, background image, etc).
- a set of educational tools to facilitate learning, communication and collaboration (study guide, course calendar, quiz tool, bulletin board, chat, presentation tool, etc.)
- a set of administrative tools to assist the instructor (student management tool, course backup tool, etc.).

Figure 1 shows a screenshot of the tools that are available to the students when they log in on the WebCT home page

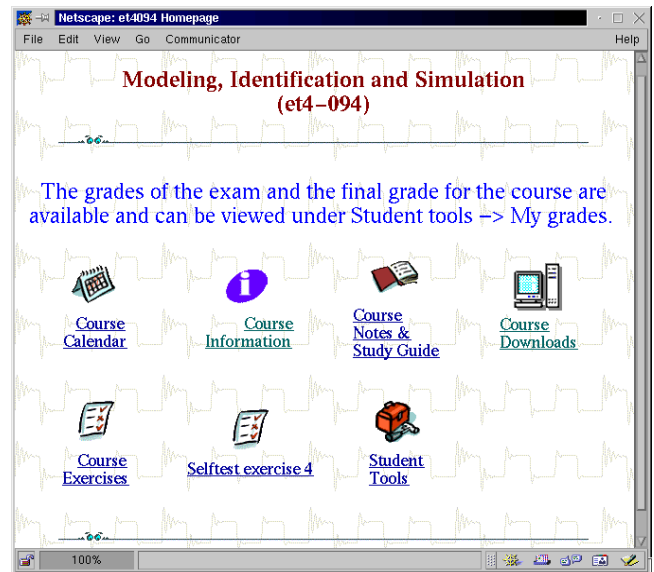


Figure 1: WebCT home page for our course (student view).

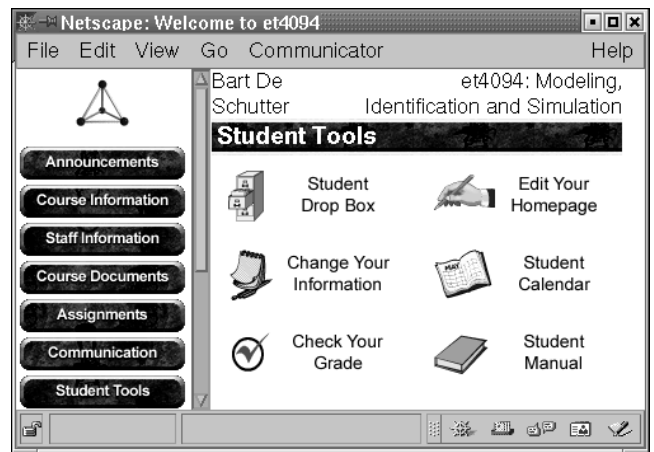


Figure 2: The Blackboard CourseInfo student tools page contains several communication and information tools for the students.

for our course. Figure 2 shows a screenshot of some of the students tools that are available in Blackboard CourseInfo.

3.2 On-line exercises

In order to improve the study effectiveness the students should be advised frequently on their progress in mastering the study material. For this purpose we have developed electronically accessible exercises, which are dedicated to both the bottleneck topics and the refreshment of material that was offered in previous courses.

The on-line material related to each lecture is split in three parts: a small introduction, a voluntary self-test exercise (which has to be done before the lecture, i.e., in the preparation phase) and a mandatory exercise (which has to be done after the lecture, i.e., in the post-processing phase). Both

the self-test and the mandatory exercises are set up in such a way that the problem is tackled in a step-by-step manner: the problem is split up into subproblems. Each subproblem first starts with a small description of the problem. If necessary, some calculation data (measurement data, variable values, etc.) for the problem are provided. Next, there are some questions and/or on-line laboratory assignments.

We use different types of questions, such as multiple-choice questions, yes-or-no questions, small calculations and fill-in questions (see Figure 3). After all the questions for a given exercise have been answered, the student immediately receives feedback on his or her answers (see, e.g., Figure 4). This feedback is very important: it offers the student immediate knowledge about the correctness of his or her answers and, if necessary, it also provides additional information that is needed to find the correct answer. The latter means that the feedback also has a learning effect.

To help students develop the engineering intuition needed to bridge the gap between theory and practice, small on-line simulation and visualization assignments are added to some of the exercises. Each of these assignments attempts to “demystify” the abstract mathematical concept that is put forward in the bottleneck topic in question. This demystification is reached by offering visualization of concrete, realistic examples. To that effect we use the simulation and calculation possibilities of the mathematical software program MATLAB, which is integrated with the on-line electronic exercises using the VCLab plug-in [10]. For detailed information on the implementation of this feature the interested reader is referred to [1].

In comparison with the implementation used in the first year [1] we have introduced some changes in the second year:

- In order to speed up the graphical display of formulas we do not use the Java applet HotEqn [11] any more, but we now use static GIF images which are generated using latex2html [7]. The reason for this was the massive use of formulas in the on-line exercise, which caused slow page-loads when using the Java applet.
- In the first year we used a quiz tool that we had developed ourselves. However, this quiz tool had many problems in connection with security (using client-side cookies and javascript for checking the answers), stability (browser crashes occurred too often, sometimes with severe consequences), and user-friendliness. That is why in the second year we have used the built-in quiz tool of WebCT (and currently of Blackboard CourseInfo). The types of questions used in our own quiz tool could be transferred to the built-in quiz tools of WebCT and Blackboard CourseInfo by making some minor and sometimes some major adjustments. But the advantages were big in all three areas (security, stability and user-friendliness). The security was improved due to the use of server-side scripts for handling the input and checking the answers. The stability was also improved significantly. Moreover, the built-

in quiz tool is very user-friendly: all the questions that belong to the same exercise can be grouped into one long page. Furthermore, the built-in quiz tool contains nice feedback options, which were not included in our own quiz tool, such as feedback on the score and an evaluation per question on one page.

Transferring the system from WebCT to Blackboard CourseInfo was rather easy (especially since we did get sufficient technical assistance for the transferral process). The main effort went into transferring the on-line exercises.

4 Evaluation

4.1 Development costs

The benefits in increased student participation during the entire course and the improved final marks are obtained at an additional cost. Although developing a new course format and restructuring the course requires a large (often unnoticed) initial investment in manpower and money, the presented web-based initiative is even more costly because of the necessity for teachers, developers and students to get acquainted with the new technology. Next we give a brief overview of the four main phases of the project and a qualitative assessment of the corresponding investments.

- Scanning the technological possibilities: New possibilities and investigating their use and integration in a new course format has required approximately two months of time. Additionally, approximately 10 discussion sessions (in which a technical specialist, a didactical expert and the responsible teacher participated) took place during this phase. The discussions were about analyzing the possibilities and difficulties of new Internet facilities (e.g., FAQs, chat rooms, a mailing list, on-line exercises), and their use in a new course format (less lectures, more self-activation of students, lots of practice material, mandatory exercises, etc.).
- Definition of the on-line material dedicated to the course: Apart from standard information (course outline, calendar, material used, etc.), a major investment in setting up the current web-based infrastructure was the detection and formulation of the so-called bottlenecks, and the design of 6 interactive exercises and feedback to the students. The investment time for each exercise was equivalent to the design of one full final exam.
- Implementation: The acquisition and installation of the new hardware and software, the development of the environment, researching literature, training, and taking care of startup problems equaled approximately 1 man-year.
- Usage and maintenance: Once the investment costs, as qualitatively outlined in the previous points, have been made, the maintenance and use of the new course tools is comparable with the costs (time) in the conventional way of teaching.

Netscape: Welcome to et4094

File Edit View Go Communicator Help

Bart De Schutter et4094: Modeling, Identification and Simulation

Selftest exercise lecture4

Announcements
Course Information
Staff Information
Course Documents
Assignments
Communication
Student Tools
 Resources
 Course Map
 My Blackboard
 Search Logout
 Control Panel

Powered By Bb Blackboard

Instructions:
 It is important that you do the (matlab-) exercises in the order they are presented in. There is a logical order in the questions and in the building up of data for the matlab exercises.

Question 1 (20 points)
 Consider the stochastic process y_k generated by:

$$y_k = \sum_{l=0}^n b_l e_{k-l}$$

with e_k a zero mean white noise sequence with autocorrelation function $R_e(\tau)$ given as:

$$R_e(\tau) = E[e_k e_{k-\tau}] = \sigma_e^2 \delta_\tau = \begin{cases} \sigma_e^2 & \text{if } \tau = 0, \\ 0 & \text{if } \tau \neq 0 \end{cases}$$

(In the remainder of this selftest-exercise we will use the above given process)

Compute $R_y(\tau)$ analytically for the following values of $\tau = -3, -2, -1, 0, 1, 2, 3$ (use this order when filling in the box below) and for $y_k = e_{k-1} + 2e_{k-2} + e_{k-3}$ and $\sigma_e^2 = 1$.

Example on how to answer: (1,2,3,4,3,2,1). Do not use spaces in the vector-notation!!

Figure 3: One of the self-test exercises.

Netscape: Welcome to et4094

File Edit View Go Communicator Help

Bart De Schutter et4094: Modeling, Identification and Simulation

Question 4 (Received 0 out of 10 points)

Question: The auto-correlation function does not highlight the frequency content of the stochastic process. Therefore, we are going to compute the spectrum $\phi_y(\omega)$ of y_k . It will be assumed that the sampling interval is 1 sec.

X Since $R_y(\tau)$ is a symmetric function in τ , i.e. $R_y(\tau) = R_y(-\tau)$, the signal spectrum defined as

$$\phi_y(\omega) = \sum_{\tau=-\infty}^{\infty} R_y(\tau) e^{-i\omega\tau}, \quad \omega = \frac{2\pi}{N}l, \quad l = 1, 2, \dots, N$$

Your answer: complex-valued
Correct answer: real-valued
Feedback: Wrong! It is real-valued since

$$\begin{aligned} \phi_y(\omega) &= R_y(0) + \sum_{\tau=1}^{\infty} R_y(\tau) (e^{-i\omega\tau} + e^{i\omega\tau}) \\ &= R_y(0) + \sum_{\tau=1}^{\infty} 2R_y(\tau) \cos(\omega\tau) \end{aligned}$$

Powered By Bb Blackboard

Figure 4: If an answer to a question is wrong, the student receives some feedback.

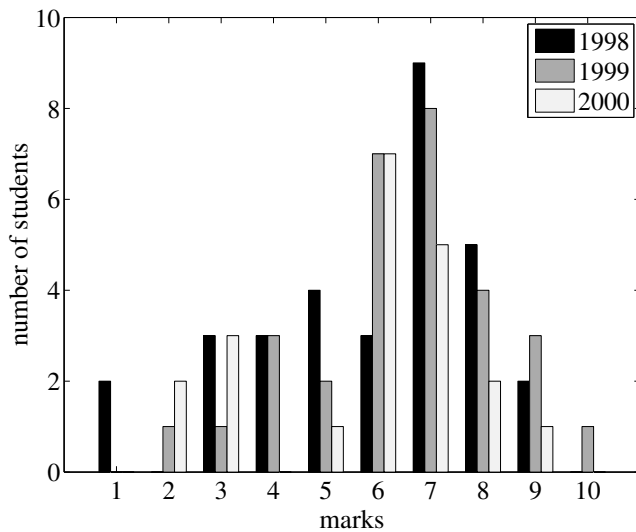


Figure 5: Final marks in the last three years. The web-based study support environment was used in 1999 and 2000. The marks for 1998 are representative for the results in prior years.

4.2 Results

Figure 5 shows the final marks in the last three years. The web-based study support environment was used in 1999 and 2000. The marks for 1998 are representative for the results in prior years. Note that the number of students varies from year to year. The percentage of students that passed the exam (i.e. had a score larger than 5) are 61 %, 77 % and 71 % for respectively 1998, 1999, and 2000.

After the first and the second year of using the web-based study support system, the course was evaluated by means of a questionnaire. Furthermore, after the first year we have held a two-hour interview with three volunteer students. The evaluation showed that students were very positive about the design of the environment. They especially appreciated the self-test exercises and the information tools, such as the calendar and the download page with the sheets of the lectures. They showed slightly less appreciation for the mandatory exercises and the possibility to send in questions to the lecturer by means of email. This last opportunity was used once or maximally twice by only 50 % of the students, while their questions addressed mainly technical matters instead of questions about content. Furthermore, the students indicated that the environment indeed seemed to improve their study effectiveness. Other observations that support this conclusion are the fact that the students were more motivated to attend the lectures (class-room attendance improved significantly in comparison with the previous years), the increase in the communication/interactivity (both between students and teachers, and among students themselves), and last but not least the good results achieved by the students for the final exam (more students passed the exam compared to previous years).

5 Conclusions

We have described the web-based study support environment that we use to teach a systems and control course. The main motivation for introducing this environment is to increase the involvement and the study effectiveness of the students. The system is now being used for the third consecutive year. After the first year and the second year we have implemented several modifications in order to improve the system and in order to address the remarks and comments of the students. The results for the first two years show that the student react very positively to the system and that their study effectiveness indeed seems to improve. Furthermore, the results we have obtained have motivated several other instructors at our lab to use the system (or some of its components) in their own courses.

In the future we will further adapt the set-up and organization of the environment to take the remarks and the complaints the students made in the questionnaire and during discussions into account.

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