Far Beyond Simple Administration

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***Abstract* – Starting from innovative distance labs in embedded systems courses with hardware-in-the-loop, this paper focuses on the surrounding environment necessary to efficiently hold courses in distance education. After a short overview of administration issues, we discuss ways to retain personal contacts vital to learning in distance lab setups. We present replacements for class lectures & supervised labs, and introduce web forums as a method of building and retaining knowledge. Combining these methods yields a complete e-learning solution. However, conducting examinations still requires the physical presence of students. Therefore, the second part of this paper addresses the issue of distance exams. We describe an implementation of an online multiple choice tool and a custom automated test system for verifying the correctness of solutions of embedded systems problem assignments, and address the issues of supervision and cheating.**

Index Terms – automatic testing, distance labs, embedded systems education, forum, remote teaching, video tutoring

STARTING POINTS

Embedded systems education has gained importance in the last decade. Hands-on courses with hardware-in-the-loop require high effort both with respect to lab resources and staff. The increasing numbers of students further stresses the situation. On the other hand, handicapped or working students request better support and more flexibility. We addressed these issues in our project *Seamless Campus: Distance Labs* (SCDL)[1], where we developed distance labs for some of our embedded systems courses. Basically, we deployed two different concepts: Remote access to lab equipment and duplication and distribution of lab kits.

I. Distance Labs

In the "Microcontroller" course [1], carry-out lab kits aim to get the lab directly to our students. A lab kit contains all hardware (boards, wires, and power supply), software and documentation needed to directly start with the courses' tasks. A modified version of the “Knoppix”-CD – a bootable Linux environment – is included in every lab kit. Students do not have to install any software, they just have to insert the CD and reboot their computer – all software needed for development is already pre-configured and ready to use. Students do not need an Internet connection to do their work in the course, and – apart from lab kits – no further investment in hardware or lab facilities is needed on our side. This approach requires inexpensive and robust hardware for mass production. Since we did not find any suitable hardware on the market at a reasonable price, we developed our own hardware that enables us to hand out lab kits for a deposit of 70 €. The most crucial benefit of this approach is scalability – once production is inexpensive, it’s just a matter of logistics.

Due to hardware and/or software constraints (e.g., licenses), the lab kit approach is not suitable for all lab courses. For example, a workstation for our “Digital Design” course accounts for 18.000 €, mainly due to the need for a logic analyzer. Therefore, this course is prone for an implementation using remote-controlled workstations, one of our approaches within the remote-access concept. There are several tools available on the market for remote control; a remote desktop is even built-in into Windows XP (and available for Linux too, called “rdesktop”). Working at the client provides exactly the same user interface like working locally in the lab. Keyboard and mouse inputs are transmitted in one direction, the screen’s content in the other. As all software is bound to the lab workstation, no specific software is needed at the client’s side and therefore no operating system or license related issues arise. As a side benefit, this approach can even bridge the gap between Windows and Linux. Our software used for development is bound to Windows, but many of our students use Linux-based systems. Using “rdesktop” those students can directly work on our Windows-based workstations.

If lab hardware is easy to duplicate and software is open-source, a client-server approach is preferable over the one to one matching of the remote controlled workstations in regard to scalability and administrational effort. We used this approach in our implementation for "Embedded Systems Programming" [2] where several target boards with integrated measurement hardware are connected to a server. The server handles authentication and dynamically assigns each remote user one of the targets. Just measurement data and debugging streams are transferred between client and server, requiring less bandwidth than transmitting a computer screen at high resolution. At the client's side, we again use the “Knoppix”-CD that includes our self-developed visualization software as

[1] The "Seamless Campus: Distance Labs" project (SCDL) received support from the Austrian "FIT-IT: Embedded Systems" initiative, funded by the Austrian Ministry for Traffic, Innovation and Technology (BMVIT) and managed by the Austrian Research Promotion Agency (FFG) under grant 808210. See http://www.ecs.tuwien.ac.at/Projects/SCDL for further information.

well as all development tools requiring no installation procedures on the student's PC.

II. Computer Aided Course Administration

To support distance education, we restructured our course organization and developed a web portal that provides students with dates, enrolments, grading information and course materials. Our students can download their personal electronic task assignments and submit their work electronically. Within their personal area – called "myTI" – students are informed about upcoming deadlines and, due to our electronic reminders, also receive emails on those deadlines. Professors can use a messaging system with template-support to send emails to one, some or all of their students. A resource reservation system guarantees fair sharing of (online) lab time. Resources can be shared over multiple courses. The system automatically calculates the amount of time available for a single student based on the total number of students in all courses. We distinguish between core hours (weekdays 9am-18pm) and free lab hours and grant different limits for both classes. Unreserved slots can be taken by any student without adding to his balance. The resource reservation system is connected to the electronic access control system of our department. Thus the Chipcard-permissions of every student are automatically set corresponding to his or her course enrolments.

On the administrational side, the system contains a grouping module allowing automatic creation of groups depending on student's preferences regarding team members or on students' grades in other courses. Administration of our courses is workflow-based and optimized to reduce administrational tasks, thereby saving valuable time for education. Within our courses we partly use rather complex grading schemes. For example, for a passing grade a student has to submit three out of four assignments, participate in four quizzes and attend the final exam. We require a minimum of 30% of the maximum points for each quiz, 50% on the final exam. Still, this reflects just a condition to reach a positive grade, another formula is used to calculate the grade itself (and still other conditions might be used, e.g., requiring 80% on the final exam for an excellent grade). We implemented a highly flexible system of grading formulas to address this issue. The system is active throughout the whole semester, not just for the grading session at the end. As soon as the condition for a positive grade cannot be met by a student any more, he is automatically excluded from further enrolments, resource reservations or access permission to the lab.

The system described has been developed by the authors of this paper (and with the help of skilled computer science students) using the open-source framework "Zope" with "PostgreSQL" as a database backend. For content management, we use the open-source content management system "Plone", again in an enhanced version. We already published some of our add-on products to the community, and more will follow after summer.

STAYING IN CONTACT

Before starting our distance labs, our courses consisted of lab classes with accompanying lectures. Within our labs we used a hierarchic organization of professor, teaching assistant, and a couple of tutors (senior students). Our students had both free lab time and weekly scheduled supervised lab hours. Attendance of the latter was not compulsory but highly recommended. Supervision means answering students' questions, checking homework assignments and progress, helping with debugging problems, and – most importantly – keeping up the student's motivation by lending an ear in case of problems in general. We found out that tutors have a tremendous influence both on motivation and performance of our students.

I. Electronic Lectures

Moving to distance labs suddenly implied the need for adapted lecturing approaches. Naturally, weekly lectures are incompatible with distance labs. Just putting all our slides and documentation online for self-acquisition was not the way we wanted to go either. Looking for a more dynamic, more vivid solution, we came to the concept of electronic slides. Basically, electronic slides are presentation slides enhanced with the professor's voice. An overview on recording, format, distribution and acceptance issues can be found in [3], an implementation and a case study in [4]. This approach is especially useful, if well-established courses should be moved to distance education. In contrast, the authors of [5] create new content up from the scratch using Flash-format and evaluate the student's acceptance, while the authors of [6] propose an approach for automatic synchronization of speech transcript and slides.

Due to our existing rich and proven course materials we decided to go for slide recording. Using tools like "Macromedia Captivate" or "Camtasia Studio" we recorded the professor's computer screen as well as his voice resulting in a video available in several standard formats. As the software captures the screen with all windows on it, this offers a quite flexible way of creating content. For example, a professor could use his or her normal lecture slides and present to an invisible audience. Afterwards he or she can correct errors by re-recording individual sentences as well as add remarks and highlights to certain slides. The professor could also use an additional camera as an overlay image to the slides to capture his or her gesture or facial expression. Within the slides, he or she could embed small demonstration videos, for example, on how to use a logic analyzer. Besides our electronic slides, our course homepages host additional resources in a structured manner, e.g., links, manuals, and related publications.

II. Supervision in Distance Labs

Second, we had to find a feasible solution to substitute our supervised lab hours. Our main goal was to retain the communicational aspect within the student-tutor relationship. The personal face to face contacts are the backbone for keeping track of each student's progress and motivation as well as for keeping the low border for our students to talk about their problems. Therefore, we completely retained the system of weekly supervised lab hours but moved them to a higher level. Instead of physical presence in the lab, students and tutors now meet virtually using voice/video over IP technologies. This was the birth of our "video-tutors". It is important to note that students do not contact just any of our tutors. Each student is assigned to one tutor at the beginning of the course. This enables the establishment of a relationship between each student and his or her tutor. Therefore, our tutors can keep track of their student's progress and monitor their steps. Experienced tutors can identify problems in an early stage and react in an appropriate way, for example offering additional support or raising motivation.

III. Course Forums

The voice/video communication used for supervision is a form of (nearly) real-time communication. Transferred to written communication, a chat would be its best approximation. On the other hand, we mentioned email – again a written but asynchronous form of communication. Using emails in distance labs has both advantages and disadvantages. Students can address their professors directly at any time and, due to the medium, a professor can answer instantly or when he or she finds the time to write an answer. In either case, this shifts a bulk of responsibility to the professor as every single email has to be answered within reasonable time. The barrier to send an email is considerably lower than to ask the same question personally in the professor's consultation hour. As we always want to encourage students to communicate, low barriers are perfect, but on the other hand – and with respect to our high numbers of students – professors might drown in their emails. Finally, email-communication covers a closed audience. This implies that emails can just be answered by the addressee and that both questions and answers are only visible for people involved in this particular communication.

Summing up, an ideal solution would keep the low barrier while making questions and answers – as well as the process of answering itself – public. Fortunately, newsgroups and web forums have already been invented, a well known web forum, e.g., is "phpBB2". Students can post their questions, the professor can answer and the whole process of communication is visible to all members of the course. The professor's workload will be lower, as similar questions can be answered by linking to an answer already given – or ideally, as similar questions should not be posted at all. As stated above, the process of answering itself is public too, meaning that every member of the course could respond to a question. In our courses, in fact, we encourage students to answer their colleague's questions. The process of answering itself is pedagogically valuable. Students deal with the course subjects on answering and they improve their skills in explaining. Professors and tutors are intended to stay in the background, especially in the first time, when a new question arises. Their task is to monitor communication, review answers and create follow-ups to correct them, if necessary. This approach reduces workload of professors by quite a large factor as usually students give their colleagues at least partially useful and correct answers.

Using a web forum as the main communication platform has another great benefit. In recurring courses, every year the same web forum is used, therefore all previous postings remain available. The interplay of questions and answers builds knowledge – knowledge that is lost to the public if this process utilizes emails, voice/video transmission or personal contacts. Unfortunately, available web forums are not best suited to structure this knowledge base in an appropriate way – we will address this issue in the last section. Furthermore, web forums play a major role in creating a social atmosphere in e-learning approaches. Studies on social climate in virtual discussion groups can be found in [7].

In the beginning, text chat was referred to as the written form of the voice/video communication. As already mentioned voice/video communication strengthens personal contacts and our web forum builds a community creating knowledge. In contrast, text chats are fugacious. Archives created out of chats lack the structure necessary for a source of knowledge and therefore, we did not include chats in our distance labs. However, the authors of [8] recently presented an intelligent semantic agent for supervising English text chats as well as automatic generation of frequently asked questions. Possibly, such approaches can be adapted to other areas in the near future. Other e-learning concepts (e.g. [9]) use text chats for an online synchronous class meeting time (e.g., every Wednesday, 8-10pm) where all students have to participate in the chat at the same time. We discarded usage of text chats like this for the maximum of flexibility for our students as we believe that learning without time constraints is one of the best things distance education can offer. Still, accepting such a fixed hour, we would rather use some sort of video conferencing tool to stimulate social interaction and "face to face" contacts instead of text chats.

HOLDING DISTANCE EXAMS

Prior to the introduction of our distance labs, our courses used a mixture of written essay exams and oral exams on task submission. With an increasing number of students holding exams generated more and more effort every year: Grading more than hundred essay exams requires team work on our side. Grading of essay exams is always prone to some kind of "unfair" – meaning subjective – grading, especially, if several people are involved in the correction process. When moving our courses to distance education, another problem aroused. Distance labs would enable students from around the world to

participate in a particular course at our department. Still, physical presence would be required during our exams.

I. Online Multiple Choice Tests

We decided to implement an online multiple choice testing tool with automatic correction to address these issues. In addition, this approach has the positive side-effect of offering a fair grading scheme. A good starting point to multiple choice tests and guidelines for implementations as well as experiences can be found in [10].

Our multiple choice tests are conducted online. After a student finishes his or her test, neither result nor correct answers are displayed. All tests are corrected automatically, the algorithm grants +1 point for a correct answer, 0 points for no answer and -1 point for a wrong answer. After correction of all tests we run a statistical evaluation prior to final grading. For each question we calculate the percentage of correct, no and wrong answers. Questions with a high percentage of wrong or no answers are then carefully evaluated for correctness, clarity and complexity. If we find a question ineligible, it is removed from the test and thus does not influence final grading. In case of an error in our questions/answers database, the error is corrected and all exams run through the correction process again. We inform our students about this process to increase our student's trust in our questions. Details of our implementation can be found in [11].

Using our multiple choice framework we are able to conduct our tests in our laboratory. During the test, our tutors are available to answer questions and to help students (within limits, of course). Naturally, the main task of our tutors is guarding our students, preventing them from cheating. In distance education, this kind of physical presence limits flexibility. We would love to have students in Barcelona or Sydney participating in our courses. As shown in [12] even unsupervised online testing does not necessarily lead to cheating. Nevertheless, to guarantee integrity and provide fair terms for all students, we have voted for a different solution. Our multiple choice framework can be accessed using common browsers, therefore on the technical side, there are no barriers. Our tutors mainly have two tasks: supervision and assistance. Assistance can be achieved using the "video-tutor"-approach. Therefore, just supervision remains. Supervision can be performed by any trusted person locally at our partner university and thanks to our "video-tutors", this person does not necessarily have to have any particular skills regarding the actual course contents. This puts us in the position to conduct tests virtually everywhere around the world as long as an Internet connection and a trusted person are available there.

II. Automated System for Testing Embedded Software

In the "Microcontroller" course we primarily conduct practical exams where students have to solve programming tasks. We provide a framework consisting of a skeleton program with header-, object-, and makefiles. This enables us to place our exam tasks within complex settings while the actual task can be accomplished adding a few lines of code. During the practical exams, our students work directly on our lab kit hardware. Therefore they can try out their solutions and debug their programs – and again, our tutors are available for supervision and to help students with debugging issues or hardware problems. In the past, as soon as the students finished their exams, our tutors manually checked the correctness of their solutions.

Thinking of distance education we started implementation of an automatic test system. Basically, we do black-box tests supplying the tested target with input signals on its I/O pins and verifying the responses comparing those with predefined patterns. Test stimuli and estimated responses are written in a special meta-language and the results of those tests are displayed to the human operator. Reference [13] describes this approach in detail.

With the availability of this system we can conduct practical tests virtually everywhere, like our multiple choice tests. Students abroad can submit their programs at any time during the test. The data is sent to our university and processed by the test system and the corresponding report is sent back to the student. To prevent students from deploying a mindless trial-and error strategy, the number of verifications should be restricted. In fact, our tool could also give feedback on the nature of problems during the tests, a feature possibly useful for other applications. Besides online tests, the automated test system can also be deployed to validate students' homework.

CONCLUSION & FUTURE WORK

Starting from our standard undergraduate courses two years ago we managed to set up three distance labs and build the corresponding supportive environment.

I. Experiences

The "Microcontroller" course has been deployed in a test run last summer term and received very positive feedback. Students loved the lab kits for their flexible and interesting hardware as well as for the concept itself. Some of them kept their lab kits and started private projects. Student retention in the course was quite high (70%) and 73% of the students, who remained in the course, passed the final exam. This summer term the course is available regularly and conducted as a distance lab for all students. We added further controller boards, additional hardware and improved electronic slides and documentation. A full evaluation of this year's course will be carried out at the end of the semester.

The "Digital Design" course had its test run last winter term. Due to the high number of students attending the course and the fact, that we were uncertain about acceptance and stability, students could decide whether to work remote or locally. Fortunately, students liked the idea of remote-controlled workstations and our solution showed no bugs or

bottlenecks. Though we had few students working completely remote, many of them worked both locally and remote. For this year's lab we will create new electronic course materials and deploy "video-tutors" in supervision. The client-server approach of "Embedded Systems Programming" will be introduced in next winter term as this course is not on the schedule in summer.

II. Communication

As noted in the previous section, available web forums are not the best solution for our approach to "build knowledge". Furthermore, those forums are third-party products that cannot be integrated tightly in our systems. Our plan is to create an own product for seamless integration in "myTI" and our web portal. This "meeting place" will automatically create access rules and write policies out of student enrolments thus not creating additional effort. A "meeting place" can be moderated or not-moderated, despite automatic student access, more users can register using opt-in or invitation mechanisms. Anonymous read-only access can be restricted to our community or opened up to the world. Most important, we will include features to better handle archiving of knowledge, in other words, we will need means to structure postings in a meaningful way. Professors will be able to mark threads (e.g. as FAQ, interesting, additional information, ...) or make them sticky (or available in special sections). On the other hand – as we want to build a community – students will have similar (but logically separated) facilities among those tagging, a technique familiar to many of our students through weblogs. A major task is to make those mechanisms transparent and easy to use, most possibly the implementation will use asynchronous Java and XML (AJAX) for instant response without page reloads.

Another aspect that deserves closer attention is the student's feedback. We are planning to add an evaluation framework to thoroughly evaluate all courses twice a semester, one evaluation in the middle of the course and one afterwards. A specific evaluation should ideally consist of a couple of general questions identical for all courses of our groups and special questions added by the course's professor. This approach makes courses comparable throughout different groups. Our questions will consist of multiple choice questions with 2, 4 or 6 answers, an additional value for "no answer" and a comment field. We will force students to submit evaluations (e.g., the following electronic task description is not available until an evaluation has been submitted) insisting to receive at least datasets with all questions unanswered – assuming that if students already have to navigate to the evaluation page they will more likely answer the questions as well.

Finally, we want to further extend our distance labs in two directions. First, we have plans to introduce "team spaces" for group work in embedded systems lab courses. A group of remote student PCs is connected through the Internet and all computer screens display the same content. At any time, one of the students has control over the target system. The other group members view the scene and can interact with their colleagues using chat, voice/video over IP communication, file shares or a sketching tool. The active student can hand over control of the embedded target to one of his colleagues at any time afterwards on his part being a viewer. Second, we would love to implement a system of "high-tech" lectures. This approach will provide supporting facilities to teach local and remote students at the same time. Basically, the professor meets with his local students in the classroom. The session is recorded and broadcasted through the Internet, where remote students can join. A main element in class is again communication – students asking questions and thus participating in the course. This implies that broadcasting is insufficient. We will have to provide the line back to the classroom to enable remote students to ask questions. The whole session (the video, the professor's talk, the student's questions, the slides, and the sketches the professor produces during the talk) is recorded and available later for download like all other course materials. Students who missed the course or simply want to hear certain parts again can download the files and (re)view the course.

III. Going Public

The new TI web portal will be the main entry point for both researchers and students. The portal will have all computer engineering groups of our university under its umbrella. Basically, there are "global views" where visitors can browse content (e.g. research projects, publications, courses, thesis announcements) despite of its physical location in one of the work groups. Selecting an item for detailed information directly leads to the appropriate group – all within the same portal. If a visitor is just interested in a particular group, he or she can enter the group and will see similar views that differ from the global ones just by the fact, that only items of the particular group are displayed.

With our new distance labs (besides all our other courses), quite a load of valuable content is just available to students of our department. Our vision is to extend usage of our course materials to the public, no matter whether visitors are students or not. We want to follow the approach of the Massachusetts Institute of Technology (MIT) that, in 2001, started offering their course materials electronically on their homepage in an initiative called "OpenCourseWare" [14].

Based on our distance labs, we want to extend this approach to offer complete virtual classes for non-students (without grading, of course). Our valuable targets in "Digital Design" and "Embedded Systems Programming" do not have a uniform working load throughout the year. In times where few or no students are present, we could open those up to the public. In case of the "Microcontroller" course, non-students would have to invest less than 100 EUR for a lab kit. Of course, we could not support non-students answering their emails and helping with debugging their programs. But we can grant them access to all our materials and – most important – to our meeting place where they, together with regular

students, are part of a virtual community. Instead of regular tests according to the specific course structure, we would provide our non-students with regular self-assessment tests. Hence our approaches to distance labs and the surrounding environment could be easily adopted to a wider audience.

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