E-Learning in Theoretical Computer Science: Experiences From an Undergraduate Course

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1 The Project

E-Learning is a trendy subject: a lot of money is spent on it, there are hundreds of research papers, conferences, newspaper articles, and political statements on it. There are also several interesting and mature software and hardware solutions. However in most cases they involve a lot of resources, are costly or cover only a few components of courses. So – as it seems to us – up to now only few tools are suitable to be integrated into usual course production, mainly because they require excessive adjustments to the usual processes of course preparation and presentation. On the next pages we report on a modest but concrete project which is carried out with small resources (one scientific position for two years). Our aim is to set up and test a realistic and cost-effective environment for e-courses in theoretical computer science. This is a subject close to mathematics; so it involves longer lines of argument and proofs for which the classical blackboard technology has been extremely successful over centuries. For us, it was a challenge to see how slides from a beamer and some infrastructure around them would compete. The next two sections describe the "product" developed in our project; the last section summarises our experiences and conclusions.

Our e-lectures are developed within the project ULI ("Universitärer Lehrverbund Informatik").[1] Within ULI, the Aachen team has to develop course material in theoretical computer science. Four e-courses are being developed:

- the undergraduate course "Automatentheorie und formale Sprachen",
- the advanced courses "Angewandte Automatentheorie", "Automata and Reactive Systems", and "Model-Checking" (the latter two in English).

The courses "Automatentheorie und formale Sprachen" and "Automata and Reactive Systems" are completed, the other two are under preparation. In the sequel we concentrate on the undergraduate course (given in the second year of the curriculum). There were about 400 local participants and about a dozen external participants. The problems classes were organised in the standard

[1] See `www.uli-campus.de`

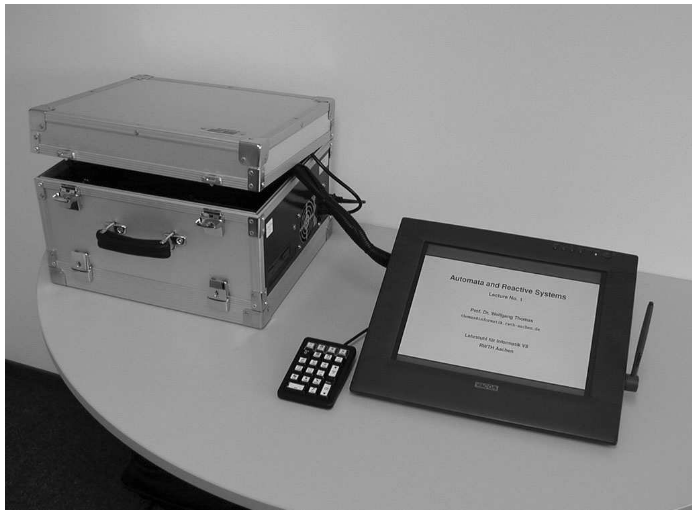

Figure 1: Portable solution: possible arrangement during a lecture recording

way with homework, weekly meetings, and intensive personal tutoring by student tutors. For the external participants, who could hand in their solutions electronically or on paper, a chat address and a web-based forum were offered (moderated by a student tutor).

2 Technical Infrastructure

During a lecture, the electronic slides are presented by a DV projector and grabbed by a software recording tool. The voice of the docent, the slides, and additional annotations like drawings on the slides are recorded. On the average, about two thirds of the material are prepared before, while about one third (mainly figures and illustrations) are added during the lecture. It does not pay to have an additional video of the acting docent.

To realise full mobility and to present and record the lectures in any lecture hall, we designed an integrated hardware solution, see Fig. 1. The essential idea is to use standard components – for the software as well as for the hardware – whenever available and to reduce the "in-house development". This approach allows to use professional support and updates, and thus to concentrate the efforts on the course material itself.

For the hardware we combined standard components of personal computers, professional audio recording tools for broadcasting tasks, and an input/output device which is normally used for graphic design/CAD. The graphic tablet Wacom Cintiq 15X consists of a TFT display, which is sensitive to inputs of a pen.[2] Therefore the docent can write electronically on the slides. An example slide is

[2]See `www.wacom.com`

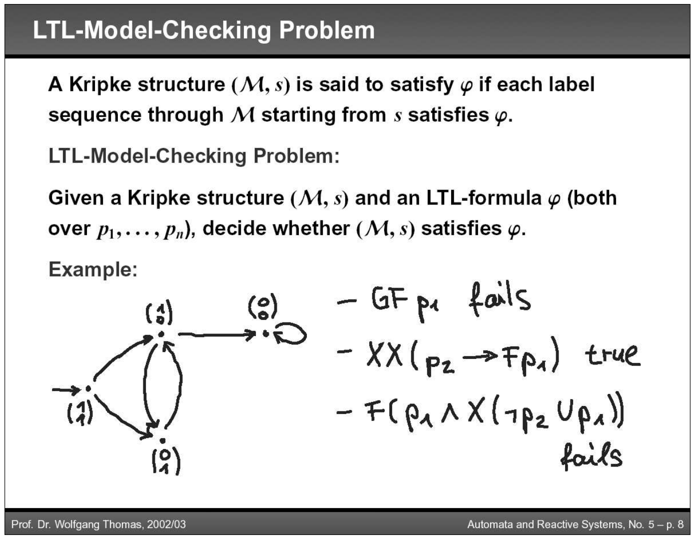

Figure 2: Example slide with annotations and illustrations

depicted in Fig. 2. We installed these components in a portable case (built by a company specialised in making cases for audio devices).

For the software we use the LaTeX publishing environment. This supports extensive use of mathematical formulas, and the docent can easily reuse material from his (electronic) lecture notes of previous courses. We combine common LaTeX packages with some in-house developed macros and features to obtain the desired layout. For display, the slides are converted to the Adobe PDF format. The presented slides are recorded together with the annotations and the voice of the docent. For that we use the screen recording software Camtasia by TechSmith, which was originally designed to produce software tutorials.[3] The raw material is edited and cut to create the video for download. We use the video editing software Adobe Premiere 6 and VirtualDub.[4] Two different video formats are produced: one uses the video codec TSCC (designed by TechSmith), the other uses the common codec DivX.[5] The audio stream for both formats is encoded by MPEG Layer-3 which offers a sufficient compression rate.[6] The file size of the produced videos can be reduced to about 10 MB for a 45 minutes lecture. Hence students with private internet connection of low transmission rate are able to download them.

[3] See `www.techsmith.com/products/studio/`

[4] See `www.adobe.com/products/premiere/` and `www.virtualdub.org`

[5] See `www.techsmith.com/products/studio/` and `www.divx.com/about/`

[6] See `www.iis.fraunhofer.de/amm/techinf/layer3/`

3 Course Material and Tutorial System

To give the opportunity to study the lecture material from the slides only, we additionally offer them for download without a video/audio stream – but together with the presented annotations and illustrations. The slides are available as PostScript and PDF documents to ensure platform independent access.[7] At the end of the course we offer a standard CD-ROM including all video files together with an integrated PDF video-script. This script contains a table of contents, index, bibliography, links etc. and navigation buttons on each slide to jump directly to the scene of the corresponding video where this slide is presented.

For the undergraduate course also a tutorial system was developed to enable the student to check his/her understanding of the concepts by solving simple exercises. The degree of difficulty in such exercises is above the level of multiple-choice questions, but below the level of exercises where some kind of invention is needed. The system was designed in the diploma thesis of Eva Giani and presently offers more than 40 exercises. Some of the exercises involve somewhat nontrivial aspects; for example, in one exercise the appropriate format of an induction proof has to be developed. The solutions are developed by the user in a dialogue of two rounds. This is a level of detail where the creation of a new exercise by the docent is still realistic. Each exercise has to be planned carefully, covering all branches of potential dialogues. A module which supports the docent in this task is part of the system.

4 Experiences and Conclusions

The Advantages:

1. In an evaluation based on questionnaires there was unanimous agreement that the recording and the tutorial system were a highly useful supplementary component of the course, for example by the possibility to replay sections which were not understood the first time. The vast majority of students voted for a combination of real and e-lectures.[8]

2. In some cases, the lack of social contact (by being absent from the lecture) was in fact compensated: There were students who listened to the lecture recordings in small groups of three or four, now even with some coffee.

3. The greatest advantage of the recordings was that students got more flexibility. This applies to all students who have to work part-time, who have children, or who have to postpone work on the course due to illness or exam preparation for other subjects. So the availability of e-lectures contributed indirectly to a higher success rate.

[7] For examples of the material of a course see `www-i7.informatik.rwth-aachen.de/d/teaching/ws0203/ars/`

[8] For the evaluation and its results see `www-i7.informatik.rwth-aachen.de/d/teaching/ss02/atfs/auswertung.html`

4. The recording of the lectures is a motivation for the docent to perform well which usually results in a good quality of the course material.

The Drawbacks:

1. For the explanation of complicated structures or arguments, great efforts are needed to break this into logical pieces which fit on single slides, as they are projected in an e-lecture. Sometimes this modularisation results in a lack of clarity. There are cases (especially in theoretical disciplines) where one needs two or three blackboards to have all relevant facts present. In comparison to this effect, the advantage of running animations is usually overestimated. They are nice but not essential. A well prepared figure developed at the blackboard (or on the e-slide) does the same, with a tiny effort compared to the programming of animations.

2. Our e-courses were successful because we organised the problems classes in the standard way, with a lot of personal feedback between docent, tutors, and students. In the present status of e-learning technology, we see no solution for this central "problems class problem", where mutual feedback between teachers and students has to be realised.

3. In our case, the effort required of the docent to prepare the e-lectures is about five times higher than usual. One could say that there is now a benefit because the existing lecture material can be reused. This however ignores the fact that in university education the contents are to be updated year by year. The ease of update is an essential advantage of the classical presentation of courses.

4. For a continuous involvement in e-lecturing, the effort of the docent is so high that it will seriously affect his or her performance in research. In view of the current scales of evaluation, a reasonable docent will give much higher priority to write research papers than to prepare e-lectures.

Potential Use

The discussion above shows that e-lectures are a very useful add-on to the conventional style of teaching but still have serious drawbacks. So we advocate their use only as additional modules in everyday university education. For the purpose of producing supplementary material, our solution, which can easily be integrated into the usual processes of course preparation and presentation, is useful.

A more systematic use seems adequate in the supplementary training of professionals who want to acquire an additional qualification in computer science. For example, teachers at school might wish to obtain a licence for teaching computer science. With their high qualification they would be able to work perfectly with recordings of lectures, and they could do this without travelling to the university too often. In view of the high priority which politicians attribute to this issue of providing competence in computer science to active teachers, it is surprising that there seems to be no "program" which supports the production of e-courses for this purpose.