User-driven Design of a Flexible Distance Education Environment – Rationale, Lessons Learned and Future Implications

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Abstract

This paper discusses the challenges inherent in distributed education and presents the development of a distance education environment to meet the needs of educators and geographically dispersed students at Luleå University of Technology in northern Sweden. The design rationale and experiences from teaching in the environment are discussed.

During the course of the research, several prerequisites for quality distance education were identified, one of which is the main topic of this paper. Here, the needs identified by the educators who are to use the created environment are discussed. Those needs have led to the design of the environment, including physical spaces, tools and technologies.

Our results indicate that it is now possible to design a highly useful environment for distributed education at a much lower cost-to-quality ratio than only a few years ago. Such a system may be created in a way that allows teachers to learn to use the environment self-sufficiently. Thereby, the need for support staff is greatly diminished.

The results indicate that the use of appropriate methods and tools lets teachers work in a distributed environment in a way that closely resembles their normal way of work in a teaching situation. In addition, a strategy for future development of the environment, based on the results presented here and on previous research, is suggested.

1. Introduction

With today's increasing industrial and educational need to create better, less costly products and services more efficiently, distance education may provide opportunities for considering regional policy with the introduction of remote campuses while supporting local entrepreneurs.

Luleå University of Technology runs a B.Sc. program in automotive engineering, designed to meet the needs of the automotive industries. Some main areas of education in the program are mechanics and electronics for automotive applications. The program is managed on campus in Luleå and students are mainly situated in Arvidsjaur, a town in central northern Sweden where automotive winter testing is a main industry. Students taking part in the automotive engineering program are also located in Arjeplog, where winter car testing is common as well. Luleå is a city on the coast of the northwest part of the Gulf of Bothnia, about 200 km south of the Arctic Circle. Arvidsjaur and Arjeplog are about 150 km and 240 km, respectively, west of Luleå both locations are situated in Sweden's northern interior.

Students engage in theoretical and practical studies related to the mechanics and electronics of different automotive systems. After the program, they will also have gained intermediate knowledge of computer-aided design (CAD), vehicle dynamics, ergonomics, design, combustion technology, etc. Upon completion of the B.Sc., students are eligible to pursue a M.Sc. degree locally at Luleå University of Technology.

The automotive engineering program is carried out using distance education technologies for the purpose of real-time classroom education, lectures and active student participation. This approach stands in clear contrast to web-based self-studies, which have hitherto dominated the distance education field and where little cooperation and communication takes place. Concurrently, the needs of the winter car testing industry are met by access to skilled students and future employees as well as by access to methods and tools for distance education.

There is a specific need for the winter car testing industry to shorten lead times while increasing product quality. General requirements for winter automotive testing are access to a cold-climate, intrusion-secure location, as well as qualified personnel, equipment and methods for testing. Vehicle control systems are becoming increasingly complex, so in the spirit of decreasing development cost, while at the same time increasing product quality, one approach supported by the introduction of tools and methods for interactive real-time collaboration is real time testing and validation from vehicles on the test track [1]. This approach drastically decreases travel costs while allowing instantaneous access to the most skilled personnel, people who do not have to travel to the (for them) remote testing facility. By exposing automotive engineering students to distance-spanning technology during the course of their studies, the students will be more familiar with tools, technologies and methods for distributed collaborative automotive testing.

In the above context, this paper discusses a user-driven study for design of an inexpensive distance education environment and describes rationale as well as outcomes for the teachers as well as students.

2. Background and Related Work

Distance education and distance learning are broad terms used to describe educational situations where the students are not at the same physical location as the teacher at the same time. Nowadays, this typically involves some form of computer and network-based tools, sometimes collectively referred to as electronic learning or e-learning systems [2, 3, 4]. These can be either asynchronous web-based systems by means of which the students get access to educational material and navigate through hyperlinked on-line media, or by using synchronous collaboration technology such as videoconferencing or distributed collaborative virtual environments (CVE). In this paper, we are primarily concerned with synchronous on-line educational environments, supported by video, audio and application sharing. Sometimes, the term *teleteaching* [5, 6] is used to describe such situations, emphasizing the teacher's role rather than the students'.

To some extent, the environment we have designed is intended to mimic traditional classroom education, i.e. mainly a one-to-many communication scenario, with a lecturing teacher and students asking questions. The main tool for realizing this is synchronous collaboration software.

Another kind of distributed education situation where such tools are involved is when student groups engage in on-line teamwork, for collective problem solving. This kind of "hands on" learning situation is sometimes known as Computer Supported Collaborative Learning (CSCL) [7, 8]. Whereas our environment was built primarily for the teleteaching scenario, it was based on software tools that have also been successfully used for CSCL.

A particular niche of distributed collaborative work wherein the authors have significant previous experience is distributed collaborative engineering (DCE) [9, 10, 11]. Although it would be an over-statement to conclude that experiences from the field of distributed work in general and from DCE in particular may be directly transferable to the field of distance education, we believe that there are nevertheless many similarities and a common scientific and technological base. Other related work by the authors includes video-mediated communication [12] and design of flexible collaboration environments [11, 13], as well as studies of challenges for creating true collaboration in global design teams [14].

3. The Design of the Distance Education Environment

The design of the distance education environment was initiated by a requirements phase, wherein the needs of the teachers and the students were captured. Then, the physical spaces were designed and the technical solutions in terms of hardware and software were chosen.

3. 1 Requirements and Needs

To understand the needs of the teachers, interviews were carried out. For the main teaching room, the teachers specifically expressed a strong wish to have traditional whiteboards available, and generally to have a teaching environment that as closely as possible mimics their regular teaching environment. The most prominent needs that were stated by the five interviewees were in order of importance:

1. a whiteboard and a way to share the whiteboard,
2. a way to interact with the remote students,
3. a flexible solution that would work with several different videoconferencing systems,
4. a low-cost solution.

Additionally, the scope of the project was, as a first step, to create a working environment with a design which, at a later date, allows gauging the specific needs of the students as well as of the teachers (for example, needs stemming from different courses). An additional requirement was to create an environment in which the teachers could work comfortably. Using the same argument, a similar environment was set up at one of the authors' offices as well as at the office of one of the teachers. This was done as a way to familiarize the teachers with the way of work and with the technology. Through this approach, it was hoped that the teachers would themselves think nothing of starting the equipment and initiating distributed teaching sessions without the help of support staff. Due to the need to familiarize the teachers with the environment, it was decided early on to use Windows XP rather than Linux as the operating system, as this would simplify procedures for the teachers, who were more used to the Windows platform.

From the requirements analysis, a number of important prerequisites for successful distance education were identified. The prerequisites include the following:

- suitable local equipment and software,
- local technical support,
- suitable remote equipment and software,
- remote technical support,
- an IP-network in good working order and sufficient bandwidth,
- local (and to some degree remote) understanding and support of the IP-network,
- teacher use case scenarios,
- knowledge concerning limitations in existing technology and budget.

Within the research reported here, the work has mainly focused on the issues concerning equipment and software, and to some extent on the networking and usability issues. It is important to point out that successful operation of a distance education environment is also dependent on the other issues identified, and possibly also on other as yet unidentified issues.

3.2 The Teaching Environment

The main teaching environment created at the university (in Luleå) is a classroom from which the teacher can transmit the lecture to the remote sites. Sometimes, but not always, students attend the lectures locally. The design of the room is shown schematically in Figure 1.

The lecture room is equipped with a computer that handles the audio and video communication with the remote students. The hardware setup was configured to be as flexible as possible, in terms of the types of video inputs supported, etc. Specifically, the computer is equipped with one high-end frame grabber card (Matrox Morphis), one low-cost frame grabber card (Pinnacle) and a ViVo (video-in video-out) graphics card. Having a ViVo graphics card allows use of the graphics card itself as an input for an s-video or composite signal from a video camera. Thus, the computer may simultaneously run three different video applications, should the need arise.

Other components of the computer responsible for handling audio and video include a high-quality sound card (HDA Explosion), a 2.67 GHz dual-core processor, 3Gb of RAM memory and an extra hard drive for storing material. The hardware was selected mainly on the basis of the price/performance ratio at the time the parts were ordered. In addition to the computer itself, some other hardware and software is included in the environment:

- echo-canceling microphone (Phoenix Audio Duet),
- video camera (Sony EVI.D71P),
- wireless microphone to be worn by the teacher,
- speaker system,
- projector (ceiling mounted),
- projection canvas.

Different kinds of collaboration software can be used on the computer, depending on the needs of the study program. The most frequently used software tools are discussed in section 4 below.

The decision to use a software-based collaboration platform for distance education also allows for a scenario where a teacher (who for the moment has no local students) may teach (and work) from his or her own office as well, by installing the necessary software components on the teacher's office PC. This is sometimes preferable, because it saves time and allows easy access to the information that the teacher has in his or her workplace or personal workstation.

3.3 The Students' Environments

The students, located in the towns of Arvidsjaur and Arjeplog, have two rooms at each site in which they can take part in the lectures: one larger room suitable for around 20 students, and one smaller for about 10 students. Sometimes, both studios are used at the same time for different classes. The smaller studio is also used for group meetings.

In the larger room at each location, the computer responsible for transmitting audio and video is a HP with two processors and approximately 1 Gb of RAM. The microphones include a wired table-top microphone as well as one hand held wireless microphone. The

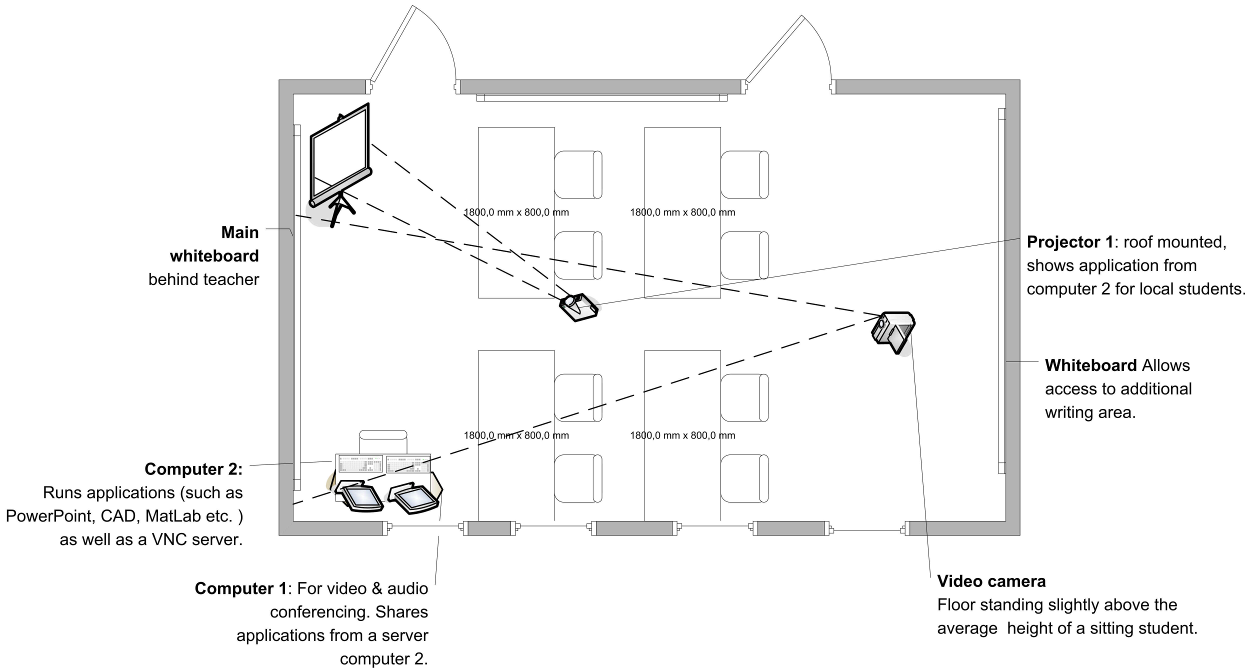

Figure 1. Schematic layout of the teaching environment

microphone signal is handled by a Gentner AP400 automixer and echo canceller. With this setup, an amplifier and a set of stereo speakers are installed to transmit audio to local students. (One of these machines is currently being replaced.) The cameras used are pan-tilt-zoom-capable analog video cameras.

At Arjeplog, two 50-inch plasma displays are used, while Arvidsjaur opted on one occasion to use two projectors, thereby increasing the size of the images.

The smaller environments at each location consist of single-processor computers with about 1 Gb of RAM. An inexpensive Phoenix Audio Duet echo canceling microphone is installed together with a set of stereo PC-speakers. A handheld wireless microphone is also available. The cameras used in the smaller rooms are inexpensive USB cameras (Logitech Quickcam).

In addition to the studio environments, the technology allows one or more of the students to access the lectures from home, or some other place. Since the video of the lecturer is typically of high quality, requiring fairly high bandwidth, the students partaking from home must have reasonably high-performance Internet connections. For this reason, and for social reasons, most students chose to be physically present in one of the studio environments made available.

4. Tools and Technologies

In order to support the distance education scenarios identified above, a number of main communication needs must be met, including:

- real-time audio and video communication between teacher and students,
- real-time sharing of digital educational material (slides, models, etc),
- a whiteboard.

A multitude of software collaboration tools supporting these tasks are available on the market. For the environment discussed here, a few tools were selected and evaluated, including Marratech Pro, VCON, Polycom PVX and Alkit Confero. The software used the most so far, Alkit Confero [16], was chosen due to the potentially high audio and video quality attainable, the possibility to share virtually any PC application, and the flexibility of the software to be adapted to different uses. Alkit Confero has previously been demonstrated to be well suited for CSCL applications such as collaborative work in distributed student groups [17]. Since we wanted the distance education environment to be useful both for distributed classroom teleteaching and for group collaboration, the flexibility aspect was very important. The needs of small group interactions are somewhat different from the classroom situation, with higher demands on interactivity and two-way application sharing, whereas in the teleteaching scenario, it is more interesting to have high-quality video from the teacher's site. The flexibility of the Alkit Confero tool makes it possible to use the same software in desktop settings and in studio (or classroom) settings. This makes it possible for the

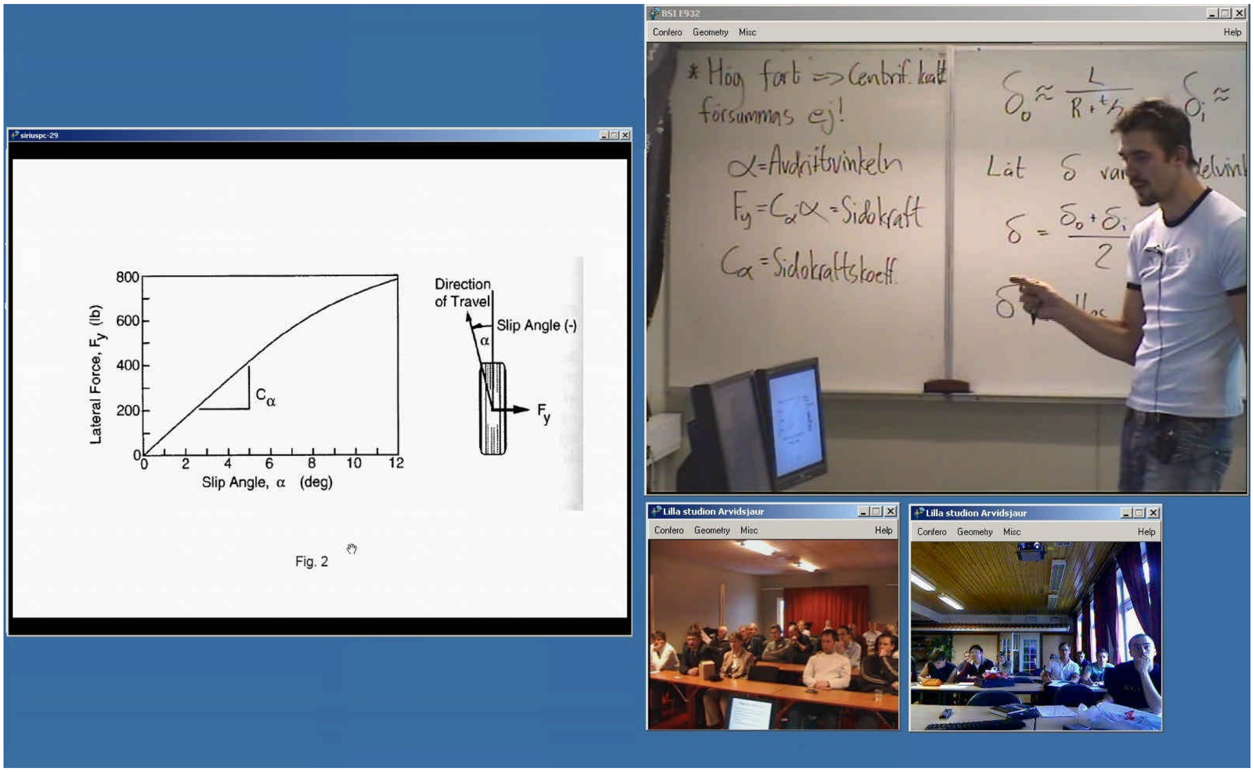

Figure 2. A screen shot of the collaboration software Alkit Confero during a distance-education session. Dr. Karlberg teaches vehicle dynamics. Note that the text on the whiteboard is fully legible. The image on the left (showing a graph) is the application being shared.

teachers to have the software installed on their ordinary office workstations, and when desired, do the teaching from their office environment, instead of using the classroom (studio).

A screen shot showing a distance education setting using Alkit Confero is shown in Figure 2.

4.1 Application Sharing

The collaboration tool Alkit Confero enables the teacher to show the view of any computer application to the remote students. The teachers involved in the automotive engineering classes relied heavily on the application sharing mechanism in order to show students lecture slides (PowerPoint), MATLAB data, simulation data and other kinds of data. The application sharing tool also lets the remote user interact with a local application, but this functionality was not used for the teleteaching scenario. For student group communication, however, it is very useful.

4.2 Whiteboard

For the whiteboard support, it was decided early on – mainly due to requests from the teachers – to rely on a traditional "analog" whiteboard, instead of the computer-based digital whiteboard tools available. This puts high demands on the quality of the video transmitted from the teacher's site, since the writings on the whiteboard must be legible. The reason for preferring a traditional whiteboard to a digital is partly that it is a habitually accustomed teaching device, and partly that it is more natural for the students to see the teacher in front of the whiteboard as he or she is drawing, as opposed to seeing the teacher in a video window and the digital contents of the whiteboard in another.

The video quality obtainable from the Alkit Confero system proved high enough to convey a good image of the teacher and the whiteboard. Since white surfaces behind a person can be problematic for video cameras, the lighting and camera settings are important considerations.

4.3 Network Issues

Since all applications are based on the Internet Protocol (IP), the university's normal network infra-structure can be used. The national Swedish academic network, SUNET, serving all universities in Sweden, provides more than enough communication capacity between the main sites involved. Although IP multicast is available in Sunet, it was decided to use a reflector software called Alkit Reflex to provide multipoint service. The reason for this is that it was desirable to be able to access the lectures from other networks that do not support multicast (such as students' homes).

5. Teaching in a Distributed Environment

The five interviewed teachers have with one exception 15 years experience of teaching co-located undergraduate and graduate courses. They all have an engineering background and to a degree work as engineers as well. The fifth teacher has about eight years of experience as a teacher. All have previous experience in teaching distributed courses. Their collective opinions concerning the functionality of the created workspace for distributed work are the basis for its design.

The interviewed teachers focused mostly on three to five points. The three points everybody agree on are:

- simplicity,
- robustness,
- similarity to a traditional lecture.

From there, three additional opinions were raised by the interviewed teachers; these are:

- multiple whiteboards,
- possibility of saving the whiteboard notes,
- increased local presence of the distributed students.

Simplicity has been shown through interviews to refer to both understanding and usage. As it turned out, based on their experiences in using the environment, designing the environment for simplicity of understanding made it easier for the teachers to learn to operate it.

Robustness refers in part to the stability of the whole environment. In the environment, other than the computers themselves, strict rules state where equipment must be stored, and to leave the room with the equipment stored properly. (The rules are still observed; perhaps because the room has not yet been fully booked for a long period of time.)

The other, main aspect of robustness refers to the prerequisites for successful distance education as discussed above. Suffice it to say that the university worked more on equipment and software early in the design process. Later in the process, work was focused on the networking and usability issues.

In other, traditional co-located classes, standard multiple whiteboards on rollers are used. One of the reasons for having such whiteboards in the newly designed room has to do with the need to mimic what is considered to be the normal classroom situation. Another is that multiple whiteboards allow teachers to easily refer back to previously presented material.

The possibility of saving the whiteboard notes for later use as reference material for students (or in other settings for distributed work in general) exists in the Alkit Confero software.

The video from the students gave the teachers an awareness of the students' presence, which was beneficial. However, the teachers expressed a wish for larger projection of the presented video, in order to get a better feeling of presence. With the current set-up, the video from the students was most beneficial when the teacher tried to start a dialogue with the students.

Students, on the other hand, focused mostly on the quality of the sound, possibly due to initial technical problems with the audio equipment. The video quality seemed to be good enough for the students to be able to follow the lectures, including the writings on the whiteboard. The teachers also expressed that the quality of the teacher's audio and video was more important for a successful teaching session, than the quality of the media in the opposite direction, although the feeling of presence of the remote students would have improved with higher quality video. We conclude that this asymmetry in quality requirements motivate a higher quality of the teacher's media, if a trade-off need to be made due to bandwidth (or other) limitations.

6. Conclusions and Future Work

We have presented a user-driven design of a distance education environment. Our main design goals, based on interviews with teachers and experiences from other distance education projects, were to keep the environment easy to use and as far as possible to mimic traditional co-locating teaching processes. The user experiences obtained through interviews with the teachers confirm that simplicity and robustness are key concerns. Specifically, the availability of a traditional whiteboard, conveyed to the remote students via high-quality video was expressed as an important feature.

The teachers expressed that student involvement (questions, discussions, etc) was lower when using the teleteaching environment compared to traditional co-located classroom teaching. As a consequence, the teachers felt they had to be more active in engaging the students in discussions. Higher quality video, with large wall-projection, was expressed by remote students as desirable for achieving a better feeling of presence. High-quality audio and video from the teacher in combination with high-quality application sharing were considered the most important factors for the students to be able to successfully follow the lectures.

All in all, we believe that the distance education environment presented here – created with a rather limited budget, mostly with pre-existing technological infrastructure – demonstrates that distance education can be successfully implemented with reasonable effort and within a modest budget. Moreover, our experiences from the use of the environment show that a distance education environment designed with a user-centered approach, with a strong focus on simplicity and usability, can be successfully operated by the users themselves, without the need for technical support staff.

As a continuation of the project, a pedagogy development process regarding distributed education will ensue. It is planned to be based on the points identified here and on the specific needs of the different courses. Therefore, robustness and usability (without the help of support staff for daily operations) will be a main priority. Issues which may be relatively easily resolved concern multiple whiteboards. Standard triple whiteboards (on rollers) may be installed at the present location or the entire technical set-up may (in about one day) be moved to a room where such whiteboards are already in place.

Another future development which would be interesting to implement is to install a second projector to project the video of the remote students on the back wall of the room. For the teacher, such a solution may conceivably meet the need for an improved sense of the presence of the remote students.

Another basis for the continuation of the project will be a literature review concerning the best practice of distance education. For example, Piskurich identifies a set of valuable lessons wherein, for example, Siemens and Yurkiw discuss the roles of the learner and the instructor in e-learning, in a university setting [4].

Designing criteria for assessing the quality of distance education programs is a challenging task. Simonson [18] describes signposts developed by the U.S. Department of Education's Office of Post-secondary Education in a report entitled "Evidence of Quality in Distance Education Programs Drawn from Interviews with them Accreditation Community". Those signposts may also be of interest in evaluating the quality of the distance education at Luleå University of Technology.

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