A Distance Learning System for Higher Education Based on Telecommunications and Multimedia - A Compound Organisational, Pedagogical, and Technical Approach[1]

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Abstract: This paper addresses the Semi-virtual Multidimensional Distance Learning System (SMDL), which is a technical, pedagogical, and organisational prototype-structure of a semi-virtual university. SDML includes both synchronous and asynchronous learning modes. During the initial stage of our project, we regularly transmitted a lecture from a specially equipped lecture room in one university to an equally equipped lecture room in another university using ATM technology. The project is evaluated with consideration to technical and pedagogical issues. A variety of technical problems could be addressed during the regular transmission of the lecture for the course of a semester. Empirical data suggested that the remote students were appreciating the new technologies, whereas the local students seemed to be somewhat sceptical. Moreover, the organisational problems in setting up a semi-virtual university seem to be vastly underestimated in comparison to the technical issues.

1 Introduction

In Germany distance learning in higher education is not as widely available as in other European countries. Traditionally, this stems from the institutionalised and teacher-concentrated German school-system as well as from the lack of government interest in distance learning facilities. Fundamental problems arise for regular higher education due to the accelerating trend towards differentiation, specialisation in many knowledge domains and also because of the growing demand for qualifications. Students will hardly get in touch with up to date „front-running“ research and technology, because universities are unable to cover subject matter in enough depth or breadth. Hitherto existing television- or video-based distance learning facilities have not allowed for highly interactive instruction, especially in the areas of discussion, feedback and instructional evaluation. With organisational, pedagogical, and technical efforts being combined, advances in telecommunications and multimedia now allow for a comprehensive Semi-virtual Multidimensional Distance Learning System (SMDL). SMDL includes synchronous and asynchronous teaching and learning modes as well as multimedia technology [Fig. 1]. In the joint research-project „TeleTeaching“ [Effelsberg 95] by the Universities of Mannheim and Heidelberg in Germany, we are currently developing a prototype system of a semi-virtual university.

2 Background and Goals

With both universities situated an hours drive from each other, students have always had to commute in order to gain a sound education in their fields of studies. The Universities of Mannheim and Heidelberg have now

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formally agreed to enhance co-operation in both research and education, e.g. through the sharing of facilities and mutually accepting students' credits and exams. This has provided the organisational basis for a semi-virtual university in which courses will consist of both local and remote (by means through telecommunications) lectures, seminars, workshops, and student cooperative workgroups. Students in the newly founded course of studies „Technical Computer Science", by need of taking courses at both universities, will be the first to take profit in this new educational setting. First trials have been made by providing lectures in computer science and theoretical physics for both Mannheim and Heidelberg students. Moreover, we are using multimedia technology to improve both local and remote teaching and learning.

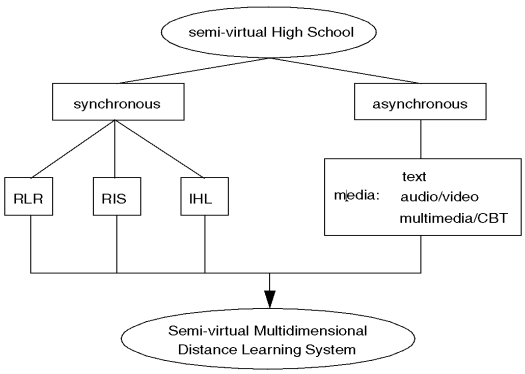

Figure 1: Semi-virtual Multidimensional Distance Learning System (SMDL).

The departments of Computer Science at the University of Mannheim and Computational Physics at the University of Heidelberg conduct the hands-on-business of designing and providing technical resources. A pedagogical and psychological evaluation conducted by the department of Educational Science at the University of Mannheim will gain empirical evidence about the feasibillity and effectiveness of the approach. This will in turn form the rationale behind the ongoing advice regarding the design and use of instructional settings and technical properties.

3 Distance Learning Modules

Figure 1 and 2 indicate three different modes of teaching and learning. We can distinguish between main modules and support modules. The main modules describe the types of instruction to be realised, based on multimedia and telecommunication technology. The support modules have a more technical character and are thought to account for an efficient use of the main modules. We first present the main modules followed by the support modules. The main modules are characterized by their scope of distribution, interactivity and individualisation of the learning process [Fig. 2].

3.1 Remote Lecture Room (RLR)

In the Remote Lecture Room scenario large lecture rooms are connected via a high speed network such as ATM. Typically, interactivity should be low and the consumption of knowlege would tend to be more passive. Each lecture room is equipped with state-of-the-art audio and video facilities and one high performance multimedia workstation. Lectures that are part of the common course of studies of the two universities are exchanged synchronousely between the two lecture rooms. The transmission runs in an interactive mode and we are using the following streams of information:

- The *teacher's video and audio stream*: captured by a local camera and a microphon respectively, these are connected to the workstation. The signals are then digitized, transmitted to the remote lecture room, and projected by a large-scale video projector.

- The *local student's video and audio stream*: are dealt in the same manner, namely the remote students are also able to receive the local student's video. Because of this the remote students become more involved, getting the feeling of sitting in a large,virtual class room.
- The *remote student's video and audio stream* are transmitted vice-versa.
- *Electronic slides of the teacher* and other course materials such as animations, visualisations, graphics and digital videos are transmitted also by using an electronic whiteboard and shared tools, respectively. Thus, in contrast to other approaches, we are actively using multimedia for the purpose of teaching.

In this concept, the two lecture rooms merge in to one large, virtual room wherein all students have the same learning experience.

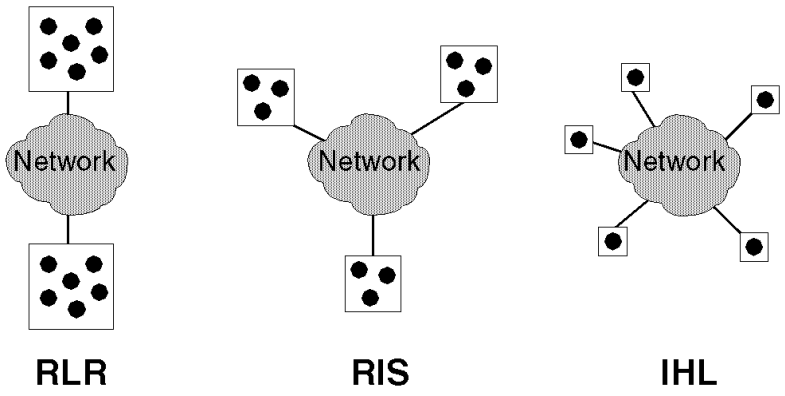

Figure 2: Distribution and individualisation degree of the three main modules.

3.2 Remote Interactive Seminars (RIS)

RIS describes a more interactive type of instruction. Small groups of participants are distributed across a few seminar rooms which are also connected by a network. The main goal in a seminar is to become more familiar with a specific topic, hence, groups of students have to formulate a small report about a certain topic which has to be presented in the seminar. This kind of learning includes two types of communication:

- *asynchronous*: during the formulation of the report students use e-mail or newsgroups for group-work.
- *synchronous*: students are using video conferencing systems to transmit their presentation to the remote groups and use CSCW tools for their group work.

RIS focuses mainly on the co-operative, on-line construction and presentation of reports. The equipment of the seminar rooms is comparable to the RLR module if somewhat less lavish.

3.3 Interactive Home Learning (IHL)

The IHL module is aimed at the maximization of the geographical distribution degree of all class participants. Each student learns at home in front of his PC asynchronously as well as synchronously. The teacher and the students are connected by low-bandwidth links e.g. ISDN. Asynchronous learning comprises of the retrieval of recorded lectures, lecture notes, work with CBT software and case studies and the participation in electronic discussion groups. In the synchronous mode, students should be able to participate interactively and live, in lectures, in seminars and in training courses whilst being at home. The major goal of IHL is the achievement of better preparation for exams and a further intensification of co-operative learning.

3.4 Teachware Authoring (TWA)

The construction of multimedia teaching material such as CBT software is a rather time-consuming process. For one hour of CBT approximately 200 hours of developement time are required [Kawalek 95], [Niegemann 95]. Novel approaches such as „Authoring on the fly“ [Bacher & Ottmann 96] seem very promising for reducing the time in effort considerably. Authoring also entails the developement of animations and simulations. We propose the following approach for the developement of teachware:

1. *Pre-Authoring* is the simple preparation of lectures, including all required media sources (slides, images, etc.)
2. *Recording*: The course is given in one of the instruction types RLR, RIS or IHL. The resulting media streams (e.g. audio, video, shared tools, etc.) are then digitally recorded.
3. *Post-Authoring*: Based on the materials obtained from the first two phases, a complete multimedia document, enriched with further multimedia components (e.g. animations) is then produced.

Obviously, the advantage of this approach is that production time is considerably reduced because materials of phases one and two are a spin-off of normal tele-courses. The obtained multimedia documents can be distributed off-line by CD-ROM or on-line via WWW.

3.5 Multimedia Database Support (MDS)

Storage and retrieval of multimedia teaching material requires multimedia databases. They have to be capable of supporting both discrete media such as text and continuous media such as audio and video media. We propose to combine the capacity of scalable video servers [Bernhardt & Biersack 94] (concerning storage space and real-time requirements) with the ability of hypermedia database systems.

3.6 Telecommunication Support (TCS)

The objective of the last module is to provide the network infrastructure and the communication software required by our three main modules. The live transmissions of lectures and seminars etc. is based on existing video conferencing systems, which though prove to be less than sufficient for the purpose of teleteaching. The systems are not powerful enough to support team work, they are not flexible enough for the use of media, whilst being somewhat difficult to handle by non-experts. We are currently developing an integrated tele-teaching communication software package, which supports group communication mechanisms such as floor control, „putting up hands“, and tele-pointers [Fluckiger 95]. These mechanisms mainly improve social awareness and the organisation of the geographically distributed group of people working together via computer networks. The transmission of the data streams (video, audio, etc.) is currently based on the Internet protocol stack. A gradual migration to native ATM is envisaged for the future.

4 Pedagogical and Psychological Integration

Traditionally, distance learning is characterized by alternating phases of mostly text-based isolated learning and face-to-face meetings which occur less often. Quite obviously, the „marriage“ of distance and „real world“ education [Fig. 1] requires not only technical solutions, but also an adequate organisational and pedagogical framework.

The pedagogical and psychological importance of the „TeleTeaching“ project lies in guiding the users of the SMDL (teachers and students) through design and usability questions. Research in distance education alludes to fundamental, organisational and pedagogical problems and the options that might arise. Moreover, there is profound research on the design and use of instructional multimedia. When considering the slight empirical evidence concerning joint telematically- and multimedia-based instruction, a thorough pedagogical and psychological evaluation of the SMDL is indispensable for a sound pedagogical and psychological consultation concerning instructional design and usability questions.

4.1 Pedagogical and psychological Evaluation

We chose the 5-data-boxes evaluation model in [Wittmann 90] to obtain a deep insight into the huge body of factors, which possibly influence the effectiveness of our approach [Fig. 3]. The model comprises 5 Boxes to be filled with data for a sound empirical evaluation. The EVA-Box contains the research questions and objectives (Evaluation-Box „EVA"). The ETR or NTR-Box contain the independent variables systematically manipulated by the researcher to answer the research questions in an experimental („ETR") or quasi-experimental („NTR") setting. The CR-Box contains the dependent variables to be influenced by the treatment and the indicators reflecting these effects (criteria „CR"). The PR-Box Contains information about the prerequisite systematical differences between the groups under observation and possibly having an influence on the dependent variables, as well (predictors „PR"). Whilst each of the boxes is being „filled" with information, the picture of potential causes and effects is being completed.

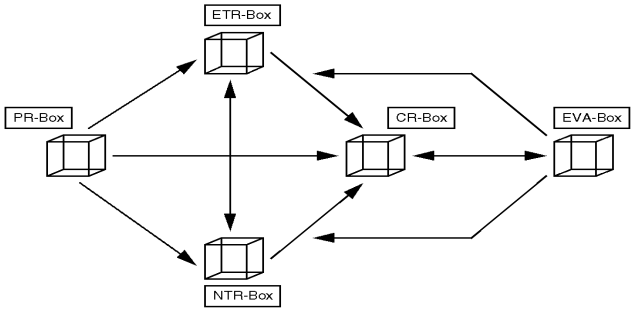

Figure 3: 5-Data-Boxes model of evaluation [Wittmann 90].

Our (quasi-experimental) studies using a multi-method approach (questionnaires, interviews, observation, log-files, etc.) are designed to compare local and remote student groups or likewise users and non-users of multimedia documents and programmes. For the „pioneering" steps, information about effects and constraints of organisational and technical conditions are most interesting. In taking these conditions into account, or optimising them, respectively, the pedagogical and psychological effects of the very instructional settings and designs will become increasingly clearer. The first results of the evaluation process are given in Chapter 6.2.

4.2 Pedagogical and psychological consultation

Teachers will need advice in how best to design course materials and handle the technical properties and tools to form an appropriate instructional setting. Students will need guidance in using the material and technical properties, selecting adequate courses with respect to their prior knowledge and plan of studies and suggesting effective learning strategies in order to support both self-regulated and collaborative learning phases. In planning, designing, and sequencing the subject matter of the synchronous and asynchronous modules of the SMDL [Fig. 1] we will rely on prescriptive instructional models. The „Learning Cycle" model [Mayes et al. 94] conceptualizes an ideal learning process as consisting of three phases (conceptualisation, construction, and dialogue). The model suggests technological and medial options to support the very instructional aims characterizing each of the three phases. As each phase corresponds losely to a certain type of instructional setting (lecture, seminar, etc.) the model might prove a valuable framework for instructional advice. For specific and content-oriented suggestions we will rely on principles of instructional design theories (see e.g. [Merrill 88]).
We plan to provide our advisory instructions in the form of „learning-by-doing" manuals in combination with (E-Mail-based) tutoring. The initial steps will be accompanied with seminar-like courses for potential tele-teachers and multimedia-designers.

5 Implementation

The TeleTeaching project currently runs in its pilot stage and in the beginning we implemented the RLR module between the University of Mannheim and Heidelberg as described in Chapter 3.

- *Network technique*: The computing centers of the two universities are connected via a 34 Mbps ATM link [de Prycker 93], [Händel & Huber 91]. Each lecture room is connected to the computing center via a dedicated 10 Mbps Ethernet segment and the university's 100 Mbps FDDI ring. We are currently using the Internet protocol stack on top of ATM, Ethernet and FDDI. This proved to be rather disadvantageous because resource reservation is not possible with IP, consequently, we had to share the link with all the other network traffic between and within the universities (see Chapter 6). However, to provide high quality video and audio streams a certain quality of service by the network, e.g. a guaranteed bandwidth, is required.
- *Application software*: Currently, we are using the Mbone toolset (Multicast Backbone) for the transmission of lectures, namely *visual audio tool (vat), video conferencing tool (vic), whiteboard (wb)* and *wbimport* [Macedonia & Brutzman 94]. These tools are very common in the Internet and are used for large-scale video conferencing by using IP multicast. With only two sites being connected, we deployed the tools for the establishment of a point-to-point connection. By using multicast, it is also possible to simultaneously transmit the lecture to many recipants [Deering & Cheriton 90]. Vat allows for the transmission of telephone quality audio signals using e.g. PCM encoding. Vic provides coding, compression and transmission of captured video streams. It supports compression schemes such as H.261 or M-JPEG. The slides or the multimedia teaching materials are sent to the remote site by using wb. Wb is a shared drawing tool which allows, amongst other facilities, the display of postscript pages to the remote students. Combined with wbimport it offers a comfortable access to all postscript slides used in a lecture. Furthermore, we developed a small tool that allows the electronic „putting up of hands". If a question occurs at the remote site, the remote students have to press a button which pops up a notification message on the teacher's screen indicating their request.

6 Experiences

6.1 Technique

In the summer of 1996 for the first time, we transmitted a complete course about computer networks consisting of 22 sessions from Mannheim to Heidelberg. From the technical point of view our experience was rather positive. Specifically the software proved to be very stable because we had no single failure. In contrast to other similar projects, we have been able to minimize the preparation and set-up time of a transmission, due to the fixed installation of all required facilities in the lecture rooms. Having formulated the slides for one session, it is possible to start transmission within 15 minutes. We did not encounter problems with the whiteboard, however problems arose with the audio and video streams of vat and vic. For the video channels we used the H.261 encoding standard with a frame rate of approximately 16-17 fps corresponding to a bandwidth of about 500 to 600 Kbps. Higher rates could not be achieved with the software codec (coder-decoder) on the multimedia workstation. When using the maximum frame rate for both the video of the teacher and the remote students, the frame rate even decreased to 10 fps for both streams. Thus, we reduced the frame rate of the remote students to 1 fps because the teacher's video is most important. Using the built-in hardware M-JPEG codec allows for frame rates of about 25 fps in TV quality but consumes up to 4 Mbps of bandwidth. We discovered that such a high bandwidth overloaded the connecting network and thus produced severe audio problems e.g. drop-outs. Even when using low-bandwidth video (H.261), from time to time we encountered audio and video drop-outs for a duration of about 2-3 seconds. Experiments showed that during these phases data losses of approximately 87% occured. The reason for this is mainly that it was impossible to reserve a guaranteed bandwidth on the network connection between the two lecture rooms. Heavy network usage of other network users thus produced

data losses. Another reason for the drop-outs is the high amount of active network components (such as routers and bridges) on the network connection between the lecture rooms. These components, not thought to transfer multimedia data, additionally introduced delays and losses. Since these disturbances did not occur very frequently and because we were successful in solving some of the problems with the active components, the first experiment with RLR can also, from a technical point of view, be considered as rather successful.

6.2 Pedagogical and psychological evaluation

The first lecture as described above was accompanied by observations, interviews with students and the lecturer on both local and remote sites. Moreover, we carried out four surveys, one at the beginning, two in the middle and one at the end. The two middle surveys were carried out before and after the lecturer temporarily moved from Mannheim to Heidelberg. With this variation it was possible to observe both student groups under the two quasi-experimental conditions. Data was gathered on motivation, concentration, problems in understanding, acceptance and technical aspects etc. In addition, the lecture was evaluated using a standardized questionnaire [Rindermann & Amelang 94].

6.2.1 Students

The data is not yet fully analysed and as yet only descriptive statements are possible. First results suggest, that

- the students' ratings concerning the quality of the lecture are rather high in all criteria.
- both local and remote students were able to concentrate and understand the content of the lecture.
- audio combined with the whiteboard were most important for the transmission of learning contents concerning understandibility, whereas video mainly intensified the social enrolment [see Bacher & Ottmann 96], [Kawalek 95], [Stucky et al. 95].
- the remote students accept the new technology, but were discontent with some audio and video problems in the beginning of the semester.
- there are differences between the student groups, in that Mannheim students constantly give lower ratings in acceptance of the technology. This tendency becomes even more salient in the data gathered whilst Mannheim was in the remote situation. Interview data suggests that this is mainly due to the higher level of noise in the lecture room with the lecturer not being physically present and hence the fear of not understanding all the relevant information.
- the interactivity was low on both sites, as could be expected for a typical lecture. Questionnaire data suggests that students did not feel the need to pose more questions or engage in discussions on both sites. But when asked whether they had the impression of always being able to pose questions, remote students, especially, felt that the threshold for starting an interaction was quite high because they would have to use a microphone and interrupt a distant lecture.
- organisational and informational shortcomings might be the core-problems in setting up SMDL. On average, only about 9 students in Heidelberg (as compared to about 90 in Mannheim) regularly attended the lecture. Interview and questionnaire data suggest, that this might be partly due to the fact that the field covered by the lecture was a specific field in Computer Science, hitherto only established as an original course of studies at the University of Mannheim. Heidelberg students attended the lecture as a subsidiary subject for physics or mathematics lectures. But there is also evidence especially from interview data, that most of the students merely „stumbled" over the lecture in the WWW or were informed by word of mouth. Moreover, the students appeared to be quite unsure about whether there was a possibility for passing an exam in the field covered by the lecture. However, it was highly relevant for Mannheim students. Most of the Heidelberg students did not know about the universities' formal agreement.

6.2.2 Lecturer

As the lecturer was an expert in Computer Science, he become used to using the technology quite easily. The situation of speaking in front of a camera to students not physically present, made him feel rather uneasy at

first. In a more interactive instructional setting lecturer-training might be required, especially if he/she is not as accustomed to using computers for teaching purposes as the „pioneer-lecturer“.

In summary, the initial phase of the SMDL was successful from a technical point of view. The new technology appears to be accepted by students, but it is capable of improvement as far as interactivity is concerned. The fact that Mannheim students constantly rated the experiment lower in most of the criteria, showing the quality and acceptance of the technology might be due to different motivational orientations. The lecture was very important as the Mannheim students had to pass exams in their chosen fields of study. Any technical „fooling around“ might be at their expense. A major pitfall for the success of the approach can be seen in insufficient organisational efforts. Therefore, analysing the demands of the teleuniversity in advance, in accordance with comprehensive information and marketing efforts, might prove to be the key to getting SMDL started.

7 Conclusion

We presented a Semi-virtual Multidimensional Distance Learning System (SMDL). The system includes synchronous and asynchronous modes of instruction as well as multimedia technology. The three modules - Remote Lecture Room (RLR), Remote Interactive Seminars (RIS), and Interactive Home Learning (IHL) - in analogy to traditional forms of university-learning, are the basis of a semi-virtual university. The first positive experiences have been gained in evaluating the RLR module from a technical and pedagogical viewpoint. Organisational problems proved to be the core of the problems when getting started. Students as well as local authorities at the remote university were badly informed about the possibilities of collecting credits for the tele-lecture or examination. Currently, we are trying to solve these problems for future lecture transmissions. Recently, we have begun to conduct seminars in the RIS module and first observations are promising. The IHL module has also started by creating the organisational framework. Furthermore, we are now developing more adequate and user-friendly teleteaching and -learning software, which should be suitable for all modules.

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