SweLL – Scientific Project Report APE - Track C, Jan - June 2001

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Project Name: CVEL experiments (3D communication and visualization environments for learning)
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Principal investigators:

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Collaboration partners:

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Project aim and goals:

Curriculum aims and goals

The main goal of the project is to:

- increase students' ability to understand complex spatial and dynamic relationships in a variety of disciplines;
- increase possibilities of collaborative interaction between students and shared; exploration of course contents from remote teaching settings;
- improve the ability to access and retrieve course material by visually exploring digital content archives.

Educational evaluation aims and goals

Proposed guiding questions at this stage focus on what a 3D experience can bring to the learning process in terms of:

- What impact on learning has instructional support such as a shared experience and/or mentoring by peers and teachers in a 3D environment?
- What impact on learning does the pedagogical support built into tools such as interactive 3D objects and shared 3D environments have?

The focus of the evaluation studies will be to explore whether the use of 3D tools enhance students ability to understand complex spatial and dynamic relationships in the chosen subjects. Another important aspect is to explore whether a shared 3D experience (sharing and interacting with the same 3D object) enhance students' ability to develop intuitive understanding of the "spatial anatomy" of a mathematical transformation.

Achieved Results:

a) Implementation:

DIS/UU activities and achievements

After completion of the course specific 3D content in the 2nd half year of the project (z-buffer experiment) we were aiming towards making the software developed so far more general and more functional such as to allow for real class experiments. Therefore, in the first half year of 2001 most implementation efforts were focused upon improving and stabilizing the generic features of the **Re**sponsive **E**nvironment for **Re**mot**e** **L**earning – **2ReeL**.
In this process we were reviewing the results of a previous user study of the CyberMath which was described in the previous project report. We were concentrating on finding efficient solutions within **2ReeL** in order to overcome the drawbacks most often experienced by the students. Here are some citations from this previous technical usability study:
"It was hard to grasp what the teacher was pointing to.", "It was difficult to see what other avatars were looking at.", "Some problems to move around and get a good viewpoint.", "It can be hard to see the mathematical objects if other avatars are standing in front of you".
Obviously, all those statements point out that viewing coherency amongst many participant within a collaborative virtual environment is must essential be maintained whenever visual artifacts are to be communicated. In fact, the

use of VR environments allows for the first time to accomplish “wysiwis” – what you see is what I see. Unlike in real physical space, in virtual spaces different individuals can share identical viewpoints without obstructing one another.

In **2ReeL** the problem was solved by providing a `gather` command, which allows any user in the current virtual space to gather all other participants in its own location. This function can be used for several purposes: First it is the inevitable tool to assure that students are in fact seeing what the teacher is seeing in the very moment when visual artifacts are discussed. In this working situation the teacher adopts a suitable viewpoint from where he/she thinks the visual artifacts (3D objects/experiments) can be viewed best from. Thereafter he/she applies the `gather` command which will make all the other avatars move into the same position/orientation of the teacher. This movement does not happen suddenly, instead the avatars of the other users are automatically moved in a smooth fashion towards the avatar which is issuing the `gather` command. A second nonetheless important effect is to “collect the pack”, which can be useful in large meeting places which have more advanced architecture, where it can easily happen that students get lost from the goup.

Other aspects which were addressed were related to self locomotion of individuals.
“It was difficult to move around, because there were often avatars and/or other artifacts in the way”, “Sometimes it was hard to handle the orientation”.
We learned that for establishing verbal communication, face-to-face contact is still a vital requirement in virtual environments, even if individual personal appearance is restricted to avatar representations. To be talked to by a third person which is not visible in ones visual field of view is in particular annoying when many participants share the same virtual space. In our daily live, social contact in form of verbal dialogue is preceded by a physical personal get-together. Manual self-locomotion in virtual environments for the purpose of initiating a verbal contact appears to our experience to be difficult. It takes quite some time to navigate towards the dialogue partner and while navigating towards the intended avatar, this one might move itself.
An automatism was therefore implemented which initiates social contact in the networked environment. A user point upon the avatar of another user and then click the right mouse button. This makes him “fly” automatically towards and in front of the avatar pointed at. This avatar will see the other avatar appearing in its own field of view. The entire procedure is automated and smoothly animated within a time-frame of one second.

While the development results of virtual z-buffer experiments from the beginning of the project had the character of custom tailored standalone applications, the improvements throughout the project and the recent generalization efforts towards **2ReeL** now provide a more generic platform for building open networked learning and teaching environments. Another step towards that direction was the incorporation of OpenH323 libraries into **2ReeL**. These open source libraries, which can be found, free of charge on the net (www.openh232.org) support voice communication standards and video conferencing standard protocols on LAN/WAN. This, together with embedded generic support for HTTP protocol adds new degrees of flexibility to the responsive learning environment. Figure 1 describes the conceptual framework of **2ReeL**. As can be seen, 2ReeL-clients are applications, which hook up upon a 2ReeL-server using an own protocol. The purpose of the 2ReeL-server is to maintain and propagate shared simulation states such as e.g.

- whiteboard content and state
- text chat messages
- avatar positions and features
- simulation states for the experiments
- shared pointers
- shared slide show content

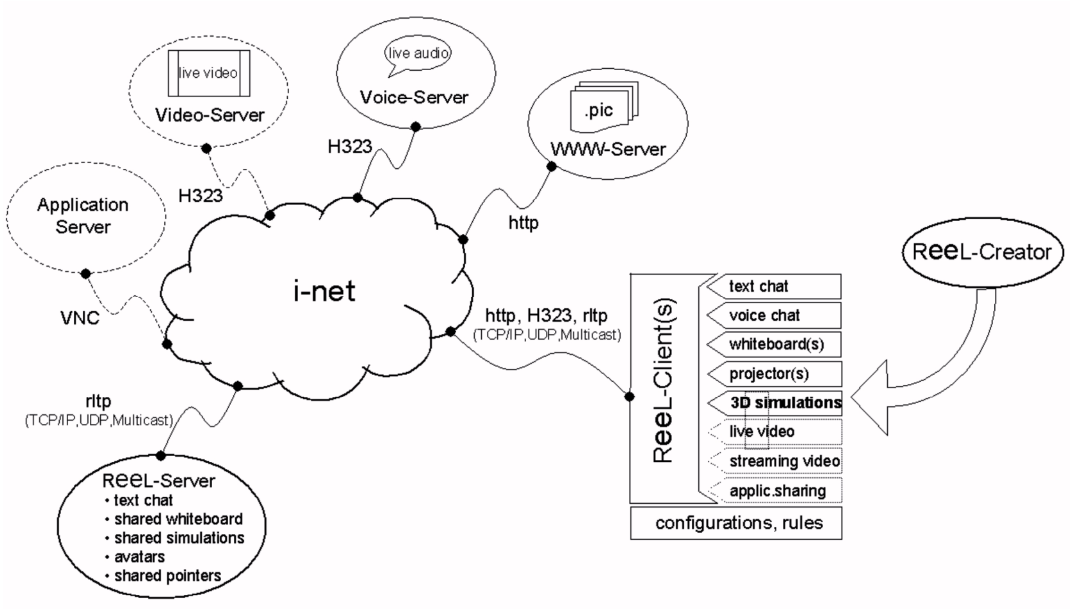

Fig. 1: The concept of the Responsive Environment for Remote Learning – 2ReeL

Apart from this simulation server, the clients retrieve other information via separate servers. E.g. real-time voice distribution is taken care for by another process, an OpenH323-server or any other server which supports H323. Also, what is visible on the slide projector surface (i.e. the slideshow of a teacher) is retrieved from any HTTP-server on the net. As a consequence of this, 2ReeL-clients can technically speaking, hook up on any audio conference running on the net and therefore e.g. participate in ongoing NetMeeting conferences. The retrieval of course slides from external HTTP-servers opens the system up to course content, which is already distributed via existing WEB-servers.

The concept depicted in figure 1, represents also our long term goal., which is to provide an author-ware system to the teachers, which enables them to custom tailor and build their own net based educational settings. At the present stage and within the framework of the CVEL project, 2ReeL-clients are still individually programmed and compiled applications.

As a proof of our concept of the Responsive Environment for Remote Learning, we created a demonstration application for the use in the area of dental education. From other concurrent research projects, we have available 3D simulations of dental jaw articulation. For the purpose of verifying the generic purpose character of 2ReeL, these simulations where ported into a 2ReeL-client for education and training in odontology (see figure 2). The significance of this action can not be emphasized too much:

- It clearly demonstrates that CVEL tools, in particular 2ReeL, are usable as generic education tools across many other disciplines than just mathematics or computer science (here also medicine or specifically odontology).

- The dental demonstration system was shown within 2 conferences talks in form of a 5 minutes live-demo without any technical complications. Both demonstrations received much appreciation by the audience. By that we gained attention in the medical and dental community but also showed that 2ReeL tools are maturing and are enough reliable and efficient for live demonstration within the tight presentation schedule of international conferences.

Fig. 2: 2ReeL-client application as used in the area of dental education. Observe that the slide presentation in the background is on-line provided by a dental colleague from Germany, while the client applications was running concurrently at a conference in Germany and Sweden.

CID/NADA activities and achievements

Interactive 3D learning environment for mathematics:
In the first half of 2001, further program implementations have been carried out at CID/KTH with regard to the 3D shared virtual reality based mathematical learning environment called CyberMath, which has been described in an earlier progress report. On the basis of user-feedback, the interface for controlling animations has been improved. The work on the transformation hall has continued and has been brought to a point where mathematical transformations from 3D to 3D can be studied in full generality. Moreover, the visual appearance and the functionality of the avatars have been improved.
The CyberMath system is built on top of a VR-system called DIVE, which has been in existence for about 10 years. User-testing of CyberMath has highlighted some inherent weaknesses and limitations of the DIVE platform. The most serious ones are the following: It is crash-prone, it has a dated graphics engine and it has a pre-determined feature set.

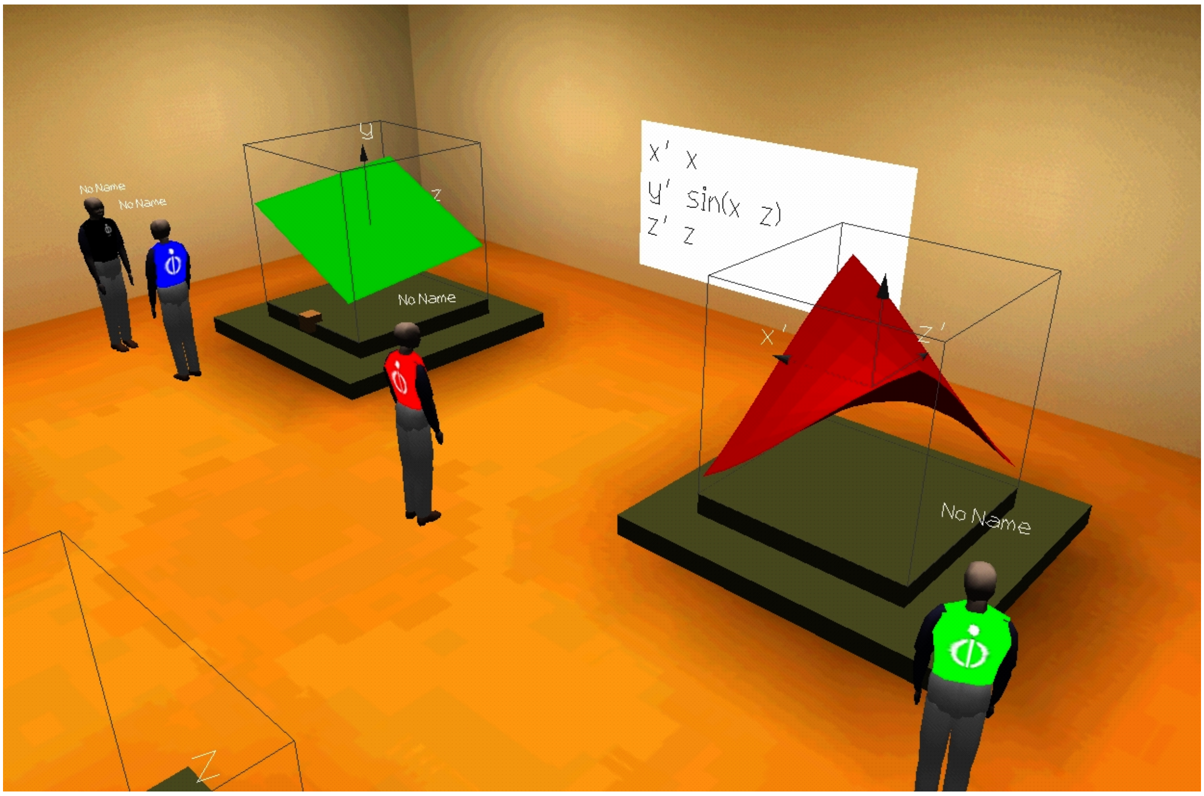

Fig. 3: CyberMath: The transformation exhibit hall, where mathematical transformations 3D → 3D can be studied.

WASA: the next generation of DIVE
The above mentioned limitations and weaknesses of the DIVE platform have lead to a decision at CID to develop a more powerful and flexible platform, called WASA, which will be robust and easy to operate, so that it can be used by teachers in a realistic educational setting. This work was started in February 2001. The overall aim is to develop a pedagogical framework (including teaching strategies) that describes how mixed-reality technology can be useful in order to implement techniques that support Question-Based Learning[1]. This will form the subject for the doctoral thesis of Gustav Taxén at CID.

The advantages of WASA will include:

- A set of open source programming libraries for graphically intense applications.
- More flexible scenegraph management.
- A robust, extendable feature set.
- Independence of the underlying distribution model.
- Support for application-driven development.

During the fall of 2001, WASA will be deployed in a public environment in connection with a mathematics exhibition at the Technical Museum of Stockholm. In connection with this exhibition a series of studies will be initiated aiming to explore the issues involved in designing learning environments that support QBL They include the impact on the learning experience of things such as visual richness, different visualisation techniques and user accomodation features.

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[1] The basic architecture of QBL is defined and described in:
Naeve, A., *The Garden of Knowledge as a Knowledge Manifold – a Conceptual Framework for Computer Supported Personalized Learning*, CID-17, KTH, 1997.
Naeve, A., *Conceptual Navigation and Multiple-Scale Narration in a Knowledge Manifold*, CID-52, KTH, 1999.

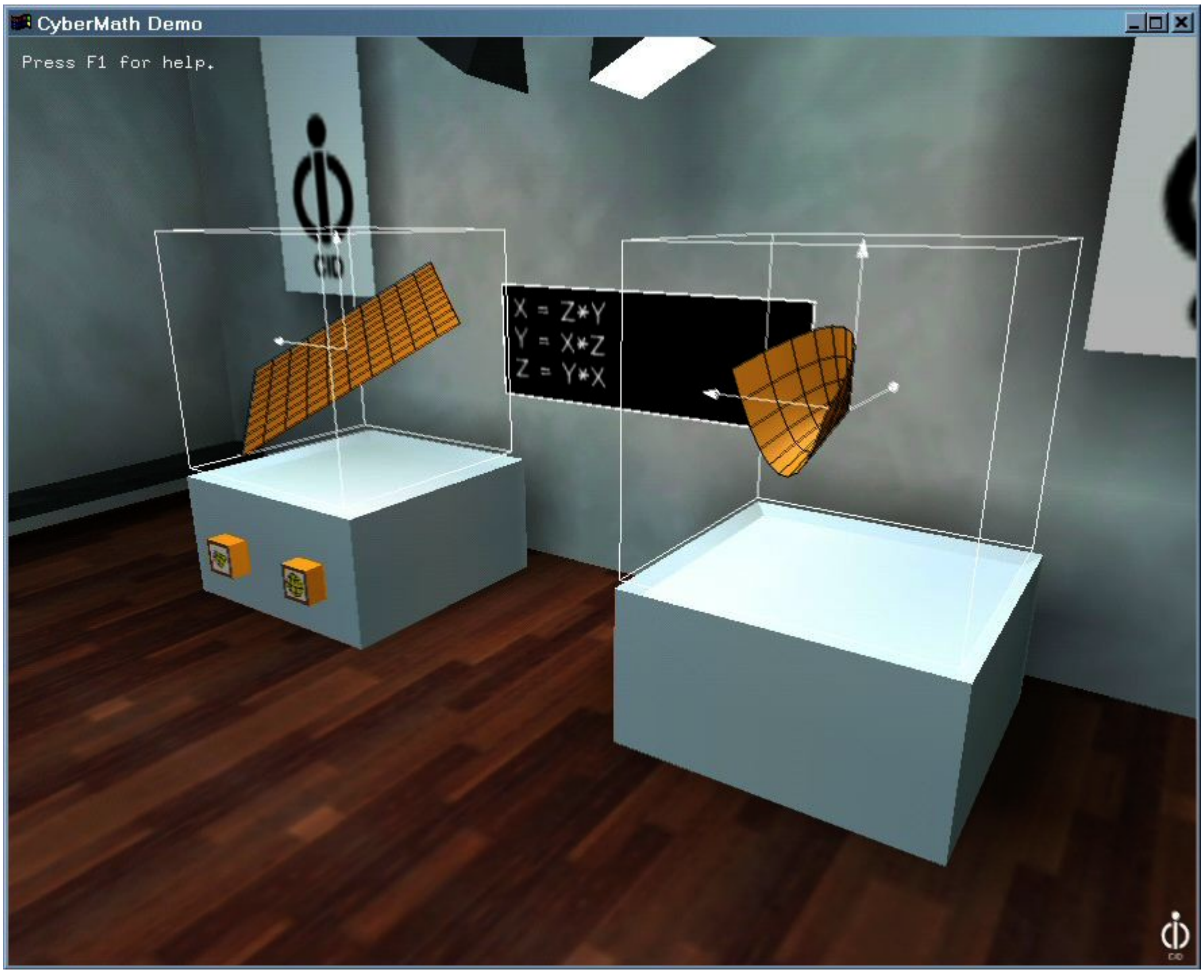

Fig. 4: CyberMath in WASA: a first version of the transformation hall.

b) Validation, educational evaluation and assessment results:

As described above, assessment of the validity and functionality of CVEL tools like the 2ReeL applications has been accomplished in the way of applying this technology to other educational domains than those originally specified in the initial work plan of the project. It speaks for itself that the approach developed throughout the project holds true for teaching in general, and not only for specific technical domains.

In regard to learning outcome and social effects of virtual meeting places for learning, another user study was carried out under the report period. On May 21, a class of students in the course Computer Graphics I, of the computer engineering program at Uppsala University was subject to an experiment. The objective of our study was to measure, if there is measurable and significant difference in examination performance for students which use 2ReeL based learning environment as compared to students who perform literature studies only.

Experimental setup:
The class of 15 students was randomly divided in a group of 8 students, to conduct literature studies on their own, based on clearly defined reading instructions and handed out literature (control group). The other group of 8 students (test group) was taken into a computer lab, where each individual was using its own PC to enter into a VR lecture on the same topic as the control group. The topic of the lecture and the reading was on z-Buffer algorithm.
The virtual lecture was carried out by the teacher who was an equal user amongst the students ion the same PC lab. Visual communication was strictly accomplished through the VR medium on the computer screen while due the technical complications, verbal communication was immediately propagated through the classroom rather than the networked audio sound.

The virtual lecture in the VR environment was divided into a conventional presentation of the topic content in form of a slide presentation in the virtual classroom and an interactive 3D visualization of the algorithm which could be collaboratively explored by the students and lecturer together.
The study time of both groups was 30 minutes each, where the test group had prior to the experiment a 10 minutes training phase to get accustomed with the navigation in the 2ReeL environment.

Immediately after the test, both groups had to undergo a written ad-hoc examination. The form of the examination was multiple choice questions. 6 questions had to be answered, 2 each on different cognitive levels according to Bloom´s taxonomy. Examination time was 15 minutes. The students were aware of the fact that result of the examination would not have any influence on their course grade. To engage the students in serious participation of the multiple choice tests, eight cinema tickets were promised to the best performing students.

Evaluation of the multiple-choice test resulted in a discrete score value for each individual in the tests. The test hypothesis was that students of both groups perform equally well. We used the two-tailed, non paired t-test in order to test if the hypothesis was to be rejected at a significance level of α=0,05.
The table below shows the results achieved by individuals in the different groups.

n	test	control
1	6	10
2	10	11
3	9	11
4	10	7
5	10	7
6	7	11
7	10	8
8	11	9
Average	9,125	9,25
oled Average	9,1875	

Table 1: The Table shows the scores of the individuals in the different groups.

For the t-test : H_0: m1=m2
T=0,18955
H_1: $|t|> t_{14;0.975}$
$t_{14;0,975} = 2,145$

Discussion of the test result:
As a result of the statistics, it can not be claimed at a 5% confidence level that there is a difference in the average multiple choice test performance between the two different student groups in the test. In other words, from the observed values in this test configuration it can not be drawn the conclusion that there is a difference in performance for virtual learning environment based lecture as compared to solely literature studies. The obtained T-value of 0,18955 does not even allow accepting the alternative H1 over H0 at a 20% significance level due to $t_{14;0,90} = 1,345$. It indicates that in fact performance is quite equal amongst the different groups, which also is evident from the rank sign table below.

n	test	control
>mean	5	4
<mean	3	4

Table 2: Number of students above and below mean score in different groups.

Despite one might have expected better performance of the test group (i.e. the group using the CVEL based teaching session) , the results point out that there were at least no negative effects of these teaching environments on the students learning outcome.
This must in fact be rated as a positive result of our study, because if this was not the case, one would have to seek the reasons for why it would affect learning negatively.

On the other hand, the significance of the results this first quantitative study must be seen in light of the test conditions. The size of the population in the study was relatively small, so the statement made by the test is not very strong. It is also a subject of continued discussions how well these multiple choice tests are suited to measure quantitatively the learning outcome.
In order to draw conclusions, more than only this quantitative measure must be investigated. Nevertheless, we see the result of this study as an acknowledgement of our work and a confirmation to continue our work towards the envisaged direction.

Experimental Lectures in CyberMath at CID/NADA/KTH

During the spring of 2001, three experimental lectures have been given in the CyberMath (DIVE) environment:

- On April 27, the new avatars and the new transformation hall was tested with a group of 8 student, who were given a CyberMath lecture in linear algebra by Ambjörn Naeve. The students were divided into two groups of 4 persons, and the lecture was given once for each group. After the lecture, the students were asked to fill out a questionnaire in order to assess their learning experince. These assessment results are presently in the process of being systematized for presentation.

- On May 4, a distributed CyberMath lecture with augmented reality interface was arranged in collaboration with Claus Knudsen at the Media Technology dept ant KTH and Hilding Sponberg at the Gjövik College. Ambjörn Naeve, who gave the lecture, was physically located in Stockholm, and Hilding Sponberg, with a group of students, were physically located in Gjövik. In addition to the avatar-based VR-interaction in CyberMath, voice- and visual communication vas set up through an augmented reality interface provided by Claus Knudsen, which provided simultaneous photo-realistic mediation between teacher and students. The lecture, which took approximately 30 minutes, was videotaped over the Internet (at both sides of the communication channel) using specialized technology provided by the Tandberg company. This lecture has lead to an interest from the side of Gjövik College to integrate this kind of teaching methodology into their future curriculum.

- On June 8, an informal lecture (= museum style walk-through) of the generalized cylinder exhibition hall in CyberMath was given to the CID scientific advisory board. The presentation was held in the VR-cube at KTH, which was connected with two other VR-cubes, one in Gothenburg and one in London. To our knowledge this was the first time ever that three VR-cubes have been virtually connected for a presentation like this. During the presentation we found that in order to control the animations within this embedded VR-environment, avatars from different locations had to cooperate in cyberspace. It was very interesting to observe how the necessary forms of interaction between the different avatars developed spontaneously in order to solve the presentational problems that occurred. We plan to study these kinds of research issues more systematically in a proposed collaboration project with prof. Ralph Schroeder and his team in Gothenburg.

c) Presentations and Publications:

During the spring of 2001 CVEL experiments and 2ReeL has been:

- presented by Stefan Seipel at the 6th International Conference on the Medical Aspects of Telemedicine, Uppsala, Sweden, 18th-21st of June, 2001, Oral presentation and real-time live demonstration of the 2ReeL environment (MEDLINE indexed abstract in the conference proceedings)

- presented by Stefan Seipel at the 47. ZAHNÄRZTETAG, Bad Salzuflen, Germany, March 15th- 17th , 2001 Oral presentation and video conference based demonstration of the 2ReeL environment using a dental teaching scenario.

- presented by Stefan Seipel at an international seminar on interactive computer graphics, University of Gävle, Sweden, 20th-21st of March, 2001, Oral presentation and real-time live demonstration of the 2ReeL environment

During the spring of 2001 the CyberMath system has been:

- presented by Ambjörn Naeve and Gustav Taxén (full conference paper + demo) at the 20:th ICDE world conference on distance education and e-learning (www.fernuni-hagen.de/ICDE/D-2001) in Düsseldorf, April 1-5, 2001.

- presented by Ambjörn Naeve in a performance lecture given on June 18 in the (former) nuclear reactor hall (R1) at KTH in connection with the WGLN workshop on performance learning.

- accepted for presentation by Ambjörn Naeve and Gustav Taxén in the educators programme at SIGGRAPH-2001, to be held in Los Angeles, August 12-17, 2001.

During the spring of 2001, the CyberMath project has been nationally presented on the following occasions:

- Ambjörn Naeve: KTH-Learning Lab, seminar 10/1 – 2001.
- Ambjörn Naeve: Uppsala Learning Lab, seminar 21/3 – 2001.
- Ambjörn Naeve: Seminar on school mathematical didactics, KTH/Kista, 22/3 – 2001.
- Ambjörn Naeve and Gustav Taxén: CONNECT exhibition in Älvsjö, 23-25/4 – 2001.
- Ambjörn Naeve: Luleå Technical University, seminar on mathematical didactics, 7/5 – 2001.
- Ambjörn Naeve: Mitthögskolan Östersund, e-Learning conference, 16/5 – 2001.

d) Goal accomplishment:
As for the 1st-3rd period of the project, we consider our goals as reached. In light of the various experimental pilot applications which have been created throughout the project so far, the WASA development, the VR-cube-applications and the upcoming museum connections, we even consider us to have reached beyond our initial goal expectations. See also comments on the state of the project (below) and results (above).

Current state of the project compared to the action plan

General note:
By the end of period 3, we have caught up delays caused in the 2nd period (see 2nd half-year report). At the time of writing this report, achievements are even covering activities, which were planned for the last period of the project.

Detailed review of action plan activities 2000 (original text grayed):

WP 1: (DIS)
Selection of appropriate topics from the course in Interactive Graphical Programming (IGP) at Uppsala University. Specification of 3D content and interaction to be created and how to insert it into the avatar based learning environment. Specification of content types and means of interaction with this content in the Active Worlds [1)] avatar based learning environment. In this working phase, teachers and a class of 40 students in the IGP course will be involved to help select appropriate content.

Comment: This work package is formally completed since 2nd half year period. It has proved fruitful to continuously observe potential application in other domains, and to make some efforts in creating demonstration content from other disciplines such as to gain attention across wider field.

WP 2: (NADA)
Selection of appropriate topics from the course in Mathematics at KTH Media Technology. Specification of 3D content and interaction to be created and how to insert it into the avatar based learning environment. Specification of content types and means of interaction with this content in the Active Worlds avatar based learning environment. In this working phase, teachers and a class of 30 students in the mathematical course will be involved to help select appropriate content.

Comment: This work package is formally completed.

WP 3: (DIS)
Implementation of interactive contents specified in WP1. Appropriate tools for implementation will be chosen depending on the type of content and type of interaction specified.

Comment: Implementation of one experiment within the selected course IGP is finished. Also content in the field of dental articulation has been successfully created and implemented.

WP 4: (NADA)

Implementation of interactive contents specified in WP2. Appropriate tools for implementation will be chosen depending on the type of content and type of interaction specified.

Comment: The work at CID has proceeded according to the action plan. The development and adaptation of the CyberMath system has been gradually transferred to the WASA platform.

WP 5: (DIS/NADA)
Specification and implementation of information representation landscapes. In this working phase, from selected areas of teaching (e.g. the above mentioned but also others) content is surveyed and catalogued, and visual representations of that content are created which can be explored by individuals in the Active Worlds environment. The work carried out comprises the design of a conceptual model for presenting those content archives and the implementation of those in Active Worlds landscapes.

Comment: During the course of the project it turned out that the loosely outlined concept of "information landscapes" and the metaphor of wandering through information spaces does no suit the context of 3D communication and experimental classroom environments. As such, we predominantly focussed on surveying and cataloging teaching content in a way that can easily be brought into virtual lecture halls and virtual experimental labs. Also, as already stated in the 1st half-year report, implementation within the ActiveWorlds environment posed heavy limitations to what we required to accomplish in the shared virtual meeting places.

WP 6: (DIS/NADA)
Identification of shortcomings of interaction mechanisms in Active Worlds. Specification of alternative means for interaction and navigation in Active Worlds (e.g. voice communication, gesture based navigation…). Specification and implementation of mechanisms to pick up content from an Active Worlds and to further process it using other application.

Comment: Shortcomings of functionality in existing tools have in an early stage been identified. Throughout the project proprietary solutions have been found based on DIVE, Mathematica, and finally 2ReeL which allowed us to overcome those shortcomings. Throughout the project, various learning scenarios have been implemented using those tools (Mathematics, computer Graphics, and Dental Anatomy), which are continuously used in small scale usability studies to identify potential shortcomings and improvements.
Finally two user studies have already been performed under real conditions, which generated numerous ideas about improved usability and interaction.

WP 7: (DIS/NADA)
In collaboration with the SweLL technology support team, implementation of appropriate functional extensions and mechanism defined in WP 6.

Comment: Functional extensions have been and are going to be implemented using our proprietary development platforms DIVE, WASA and 2ReeL.