SweLL Scientific Project Report APE - Track C, July - Dec 2000

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Project Name: CVEL (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:

Interactive 3D experiments:
In the second half of 2000, further program implementations have been carried out at DIS/UU with regard to the 3D interactive learning program for the *"virtual z-buffer experiment"* (based on the early prototypes generated in the first half-year period of the project). Functional specifications have been refined and implemented, and the experiment as such has been embedded into a virtual classroom environment framework. Under the course of this project, this virtual environment will serve as the main meeting place for student-teacher interaction also for other virtual experiments in the context of computer graphics lectures.
Data abstractions as required for networked collaborative performance of the *"virtual z-buffer experiment"* have been done, as well as implementation of network communication amongst many clients has been carried out. The virtual z-buffer tool can be used across multiple remote locations as of writing this report (for a snapshot of such a lesson see also figure 1 below).

3D interactive learning program for the *"virtual z-buffer experiment"* (based on the early prototypes generated in the first half-year period of the project).

Implementation study with a group of students:
Together with 32 students from the fall-course in "Interactive Graphical Systems", a specification experiment was performed in order to identify needs and requirements to another 3D classroom experiment, which was already draft

specified by students from the spring course. The interactive graphical performance analyzer is a learning medium to explore the relationship between graphical performance scene characteristics in graphical applications.
In this experiment, the previous draft specifications were turned into a formalized instruction to build such a interactive 3D performance analyzer tool. The formalized instruction was limited to a pure functional requirement specification (i.e. the students where told "*what*" to solve, rather than "*how*"). Therefore, in the student´s process of building such an application, their interpretation and understanding of the matter was expressed in a non-verbalized but still verifiable form. The students delivered eleven different implementations of the graphical analyzer program. The results were interesting, because some aspects which were not initially specified by the first student group as being essential to the problem, turned up in the delivered solutions. On the other hand, specific features identified as essential by the first group, were omitted in the implementations. This experiment gave some interesting ideas on how to build this interactive learning tool for the next generation of students.

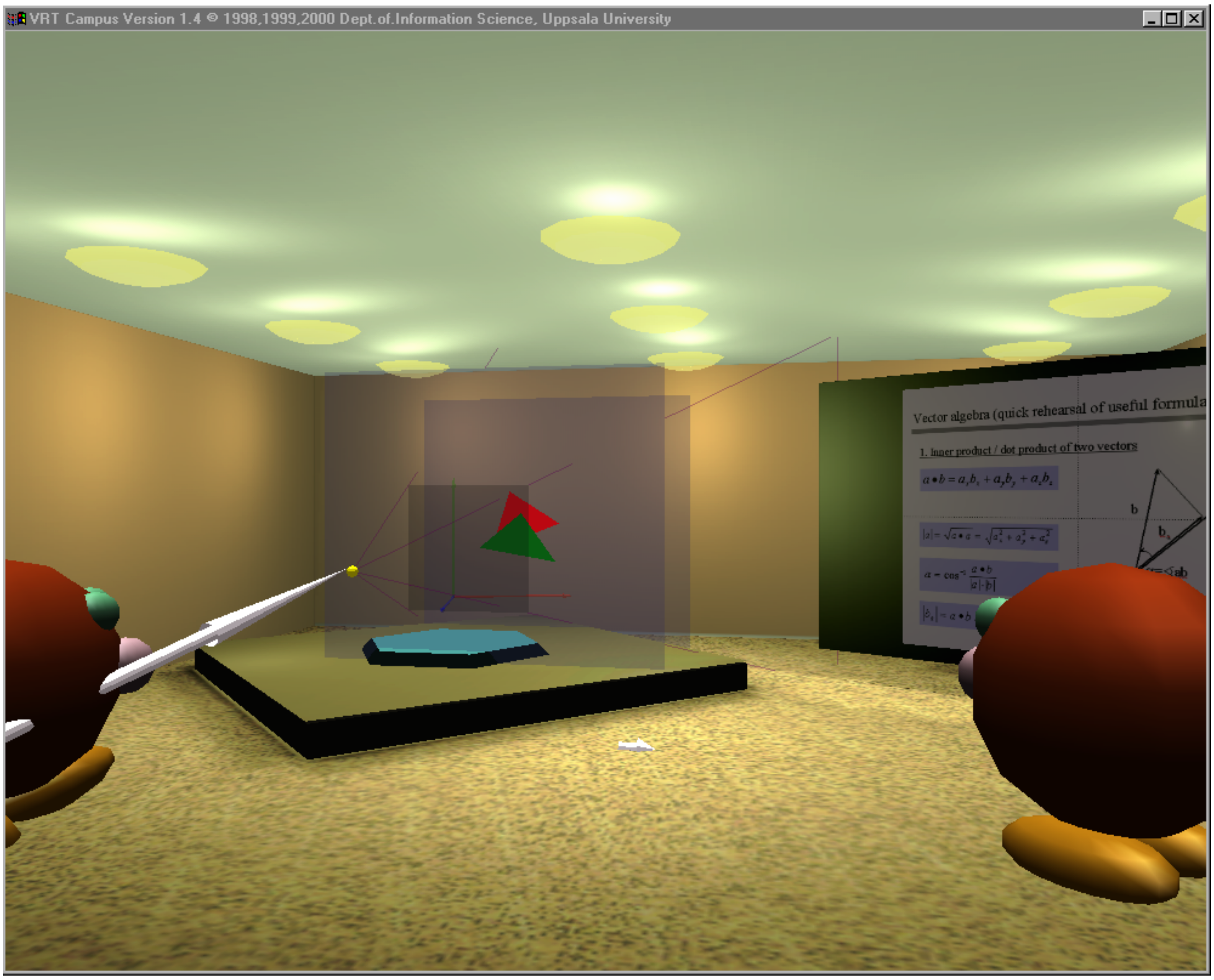

Figure 1: Scenario from the virtual z-buffer lecture, which is shared amongst three participants across the network. The avatar to the left is presently interacting with the interactive visualization of the z-buffer algorithm and exploring the effect of oblique viewing frustums upon the rendering result.

Interactive 3D learning environment for mathematics:
In the second half of 2000, further program implementations have been carried out at CID/KTH with regard to the 3D shared virtual reality based mathemathical learning environment called CyberMath, which has been described in an earlier progress report. An interface for controling animantions has been added to the exhibition halls, which includes starting and stopping as well as changing between displaying the animations in rendered or wireframe mode. Moreover, work has begun on the construction of a new exhibit called the transformation hall, where mathematical transformations from 3D to 3D can be studied in full generality. The implementation work on the transformation hall will go on during the spring of 2001 and educational testing will start during the fall of this year.

b) Educational evaluation/assessment results:
On 5th of October 2000, a preliminary assessment study was performed within the course "Interactive Graphical Systems", held by Stefan Seipel between September and October 2000. Within this study, the CyberMath system was installed at a computer lab in Uppsala, and at KTH in Stockholm. It was supposed to be used by a number of randomly selected students from above mentioned course.
Twelve students of the class where grouped into 6 groups with each 2 persons. Ambjörn Naeve held a virtual lecture on "generalized cylinders". He was physically located in Stockholm, while in Uppsala three groups at a time were using the 3D computer graphics display to attend the lecture in the Cybermath environment. Voice communication was facilitated through Cybermath as well as visual communication amongst the participants using their respective avatars. In addition to the pure avatar based communication, an "augmented reality interface" was provided by Claus Knudsen, in order to allow for simultaneous photo-realistic mediation between teacher and students.
The lecture, which took approximately 30 minutes, was performed twice for each three groups. The entire experimental lecture was video-recorded on both sides of the communication channels.
Prior to this virtualized lecture, the topic on generalized cylinders was also taught in form of a conventional lecture to the other students of the course on 27th of September.

The goal in this first study was to deliver a proof-of-concept for the usage of the CyberMath system in the context of lecturing the concepts of generalized cylinders.

Assessment study of the distributed CyberMath lecture:
After the lecture, the 12 participants were given a questionnaire to fill in and return. The average age of the participants was 23.5 years. They all claimed that they work with computers on a daily basis.

The first part of the questionnaire consisted of 20 statements to be commented on a scale from 1 to 5.
The meaning of the numbers were: 1 = I do not agree at all, … , 5 = I agree completely.

Statements (followed by answer average):
1. It was easy to grasp the position and orientation of the avatars. (3.5)
2. I talked to other people in the cyberspace environment. (3.1)
3. I used my laser pointer frequently. (2.3)
4. It was easy to grasp what the other avatars were pointing to (with their laser pointers). (3.6)
5. It was easy to hear what the other avatars were saying. (2.6)
6. It was easy to grasp who was talking. (3.4)
7. The cyberspace environment felt inviting. (3.8)
8. I felt as if I was present in cyberspace. (3.5)
9. I felt as if the teacher and the other students were co-present in cyberspace. (3.6)
10. I talked to people in the real (physical) test environment. (4.2)
11. I explored the 3D cyberspace environment while the lecture was going on. (3.2)
12. I was disturbed by things that happened in the real (physical) test environment. (2.2)
13. It was easy to grasp the shape of the mathematical objects in cyberspace. (4.5)
14. The cyberspace environment made it easy to understand the material of the lecture. (3.9)
15. The lecture was interesting. (3.8)
16. The teacher presented the material well. (4.2)
17. I asked the teacher questions. (2.0)
18. I often ask questions during lectures. (2.0)
19. It felt more difficult to ask questions in the cyberspace environment than during a traditional lecture. (1.7)
20. It was easy to move my avatar in the cyberspace environment. (3.0)

There were two complementing questions of a commenting nature:
1. What was good with CyberMath?
2. What was bad with CyberMath?

Comment (in order to interpret the answers to these two questions): On two occations during the lecture we experienced technical problems which forced us to reboot the system and restart the Cybermath environment from scratch.

These were the answers to the commenting questions:

1. It is new and exiting. The idea to move around in a room and give a lecture on its content is good.
2. It was difficult to move around, because there were often avatars and/or artifacts in the way. There were many things that distracted my attention, maybe because it was a new environment. It was hard to grasp what the teacher was pointing to.

1. It was easy to visualize the geometric curves. It was a relaxed form of teaching.
2. Some problems to move around and get a good viewpoint. The technique can obscure the content. Technical problems are never good, since a lot of time is wasted.

1. Good overview of the material, easy to explore the 3D shapes.
2. It was difficult to see what the other avatars were looking at. The sound delay (over internet) was a little too much to conduct a simple dialog.

1. Good visualizations that explains rather advanced subjects. A pleasant form of teaching.
2. More support for seeing where the other avatars were looking would have been nice. The environment felt a bit unstable - it was easy to move through walls etc.

1. Very good visualization of the different 3d-shapes! This made it much easier to understand how the different functions worked!
2. Maybe one shouldn't have to see the other avatars (except the teacher). It can be hard to see the mathematical objects if other avatars are standing in front of you.

1. Good idea! Nice with good visualizations!
2. It was bad that the other student avatars were visible. Also, the whiteboard was disturbing. It would be better if you could display it in a full-screen mode by pushing a button.

1. That you could get a good visual grasp of the mathematical shapes in 3D.
2. That it was too easy to move (very far) out of the room!

1. It was easier to understand the lecture since we could dynamically visualize 3D figures that are hard (or impossible) to visualize in a normal lecture.
2. Sometimes it was difficult to understand what the teacher meant, since he couldn't make use of gestures or other forms of body language.

1. Since the lecture was about 3D shapes, it was easy to understand their structure.
2. When you are new to this form of lecture, it feels a bit strange.

1. It was easy to understand the structure of the 3d-shapes. A good 3D environment to move around in.
2. It was hard to grasp what the teacher was pointing to.

1. You could see the shapes in a good way - as opposed to shapes being drawn on the blackboard.
2. Sometimes it was hard to handle the orientation. It was too easy to fly away far from the lecture room. It would be good if there were some more physical constraints in the simulation. Also, the environment was too sensitive to technical problems (our microphone didn't work).

1. The visualization of mathematical concepts made the lecture more interesting and easier to follow.
2. It was hard to discriminate between the different avatars.

Finally, the participants were asked a few questions aimed to give some information regarding their mathematical background as well as their prior experience in handling similar types of computer environments.

Question: How do you rate your own level of mathematical knowledge?
Answering scale: 1 = very low, 2 = low, 3 = rather good, 4 = good, 5 = very good.
Answering average: 3.8.

Question: How often do you work with 3D computer applications (e.g. Video games or visualization tools)?
Answering scale: 1 = never, 2 = a few times per year, 3 = a few times per month, 4 = each week, 5 = each day.
Answering average: 3.9.

As a final question, the participants were asked whether they believed that CyberMath would be a valuable tool to use in mathematics education at the university level. Out of the 12 participants 11 answered yes and 1 answered no.

c) International Presentations and Publications:

The CyberMath system was presented in Washington DC on October 27 at the CILT-2000 learning conference (www.cilt.org/cilt2000) arranged by the Centre for Innovative Learning Technologies. A report from this conference - in powerpoint format - can be found on http://www.learninglab.kth.se/library/presentations.

CyberMath was also invited for a special presentation at a workshop on modeling and visualization in Washington DC on October 25 arranged by EdGrid and NCSA (National Centre for Super-computing Applications) in connection with the CILT-2000 conference (www.eot.org/edgrid/mvworkshop.html).

CyberMath has also been accepted for presentation (full conference paper + demo) at the 20:th ICDE world conference on distance education and e-learning (www.fernuni-hagen.de/ICDE/D-2001) to be held in Düsseldorf April 1-5, 2001.

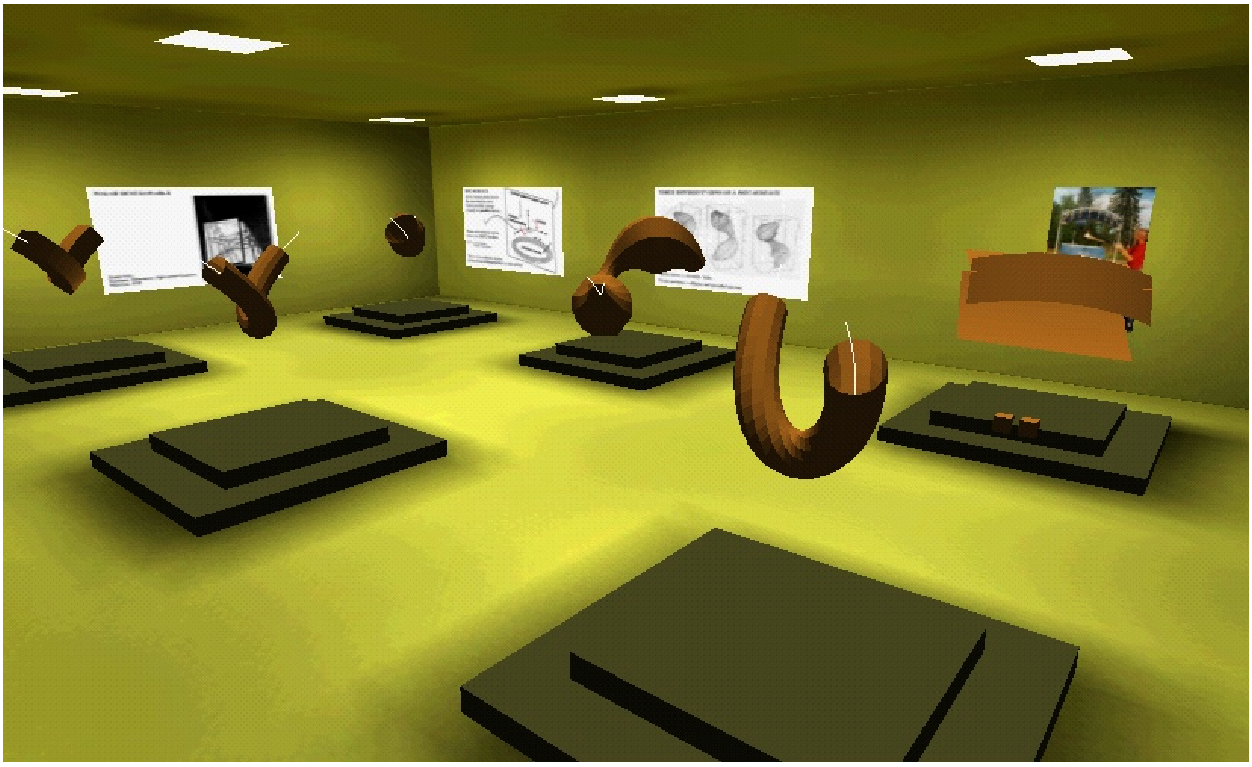

Figure 2: CyberMath: The generalized cylinders exhibit, where the distributed lecture described above was held.

c) Goal accomplishment:
As for the first year 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, 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:
Slight delay in experiment implementation at DIS as of 31st of December 2000, due to staff shortage. Appropriate measures have been taken so that delay will have been compensated after 1st quarter 2001 (see also comments below). This will not affect scheduling of assessment studies, because they are planned for may 2001.

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 has been completed according to specification. As described above, an additional second class of 32 students has been involved into an implementation study, which was to partly verify the specification outcome of the first student group.

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: The topics selected from the Media Technology courses in mathematics has centered around the visualization of Taylor expansions in several variables (calculus course) and the visualization of quadratic forms (linear algebra course). These topics are part of the basic mathematical curriculum on the university level, and they are experienced as difficult to grasp by many students. Moreover, the subject of generalized cylinders (from a more advanced course on computer graphics) was selected, since it was judged to be especially suitable for early testing of the CyberMath lecturing environemt (mentioned above).

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 almost finished, so this WP could be considered as almost finished. However, at the beginning of the project it was not defined how much content would be brought into the 3D communication platform. Instead this was rather an outcome of workpackage 1. Therefore, finalization of the first experiment in Computer Graphics as well as development of two other virtual class-room experiments in Computer Graphics are underway and will stretch into year 2001 activities.

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: Due to limitations discovered in Active Worlds (see below), this work package has been somewhat modified .Implementation has been achieved by using the Graphing Calculator for the Taylor expansions, and a combination of Mathematica and DIVE for the quadratic forms and the generalized cylinders.

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: At a quite early stage of the project we encountered serious limitations of the ActiveWorlds environment with regard to interaction between users and objects within the shared virtual space. In addition, there is no flexibility of individualized 3D content programming. Instead the building blocks available in ActiveWorlds must be used in order to accomplish the desired results. Another limitation relates to the type of display used. ActiveWorlds always requires a program framework to run a virtual scenario. Full-screen display, incorporation of advanced interaction devices, and eventually stereoscopic rendering are impossible to be accomplished in ActiveWorlds.

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

Comment: As a result of the shortcomings identified in WP 6, development partners at NADA and DIS fell back on alternative development tools (DIVE and VRT) for implementation of their respective pilot experiments. This approach, although being performed without the support of the technical development team, proved successful. We were able to implement tools like interactive 3D whiteboards, slide projection walls for running virtual lectures, and to accomplish highly efficient 3D interaction with 3D virtual experiments. It must also be pointed out that the accomplishments described here, naturally fall together with work being carried out in WP3 and WP 4, respectively.

Comments:

At DIS, Uppsala University, development activities have been reduced below what was intended in the action plan for the second half-year period of 2000, due to fact that Han Fei left from staff at our department. This lead shortly to a delay in regard to two experiments, while on the other hand for one experiment, development actually goes ahead schedule. Mikael Lindkvist, has been recruited to replace Han Fei from 1st of January 2001. Since he will work on a full time basis, we will use the allocated resources and catch up under the first quarter of 2001.