Virtual Reality in Denmark

Lisbeth M. Rasmussen
Senior Advisor
Danish Defence Research Establishment

1.0 INTRODUCTION

VR-projects in Denmark can be categorised as either civilian or military. Civilian projects are either commercial or research and development. They will be mentioned in the next chapter. Military VR-projects are either simulators or research and development. The military projects will be mentioned in the last chapter.

2.0 CIVILIAN PROJECTS

Commercially VR is used by television stations and advertising agencies. VR in research and development is of growing interest. Three universities have established VR laboratories or centres. These will be mentioned in the next section. Examples of research and development VR-projects will be mentioned in the following section.

A common event for both the civilian and military society is the founding in May 1999 of DK-VRS (Danish Virtual Reality Society). DK-VRS still exists, but its activities have stopped (for further information, see http://www.dk-vrs.dk/).

2.1 Civilian Research Laboratories

2.1.1 Centre for Pervasive Computing

Pervasive computing is the next generation computing environments with information & communication technology everywhere, for everyone, at all times.

Information and communication technology will be an integrated part of our environments: from toys, milk cartons and desktops to cars, factories and whole city areas – with integrated processors, sensors, and actuators connected via high-speed networks and combined with new visualisation devices ranging from projections directly into the eye to large panorama displays.

Figure 1: Large CfPC Displays.

The Centre for Pervasive Computing (CfPC) contributes to the development of:

- New concepts, technologies, products and services
- Innovative interaction between universities and companies
- A strong future basis for educating IT specialists.

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Figure 2: Small CfPC Device.

Pervasive computing goes beyond the traditional user interfaces, on the one hand imploding them into small devices and appliances, and on the other hand exploding them onto large scale walls, buildings and furniture.

The activities in the centre are based on competencies from a broad spectrum of research areas supporting pervasive computing.

Currently, the centre involves the following research areas:

- Ambient Intelligence with Tangible Objects
- Centre for Advanced Visualisation and Interaction – CAVI (described in section 2.1.2)
- Computer Supported Cooperative Work
- Database Technology
- Design Anthropology
- Embedded Systems – Embodied Agents
- Interactive Workspace
- Mobile Systems and Wireless Communication
- Modelling and Validation of Distributed Systems
- New Ways of Working
- Object Technology
- Sound as Media
- Tangible User Interaction

Some research areas are well-established, like Object Technology, some are emerging. Each area is headed by a research manager.

Most of the work in the centre is organised as research projects involving both companies and universities. Many projects cut across research areas.

Most of the work in the centre is organised as Research Projects involving both companies and universities. The 3D visualisation and interaction projects at CAVI will be mentioned later.

Further information on CfPC can be found at http://www.pervasive.dk/index.html.

2.1.2 Centre for Advanced Visualisation and Interaction

CAVI (Centre for Advanced Visualisation and Interaction) is one of the research areas in the CfPC (see section 2.1.1).

3D visualisation is becoming increasingly widespread in as diverse areas as industrial design, architecture, city planning, medicine, moving images as well as the arts. The ability to interact in new ways with 3D models offers new possibilities for the professionals in these areas.

In a unique combination, the following 3D visualisation technologies are available in CAVI:

- **3D Panorama Cinema**
  Curved screen
  Active stereo glasses
  Tracking

Figure 3: 3D Panorama Cinema at CAVI.

- The Panorama cinema is a cylinder shaped screen placed in a room that seats approximately 15-20 persons. The size and shape of the screen mean that the visual angle of the spectators is almost covered by the screen.

  Models are displayed in active stereo, i.e. a picture for the right and the left eye is displayed alternatively in a very high frequency. Without shutter glasses the spectator experiences the image as blurred. But with shutter glasses that alternate between closing off for the right and the left eye in the same frequency, the spectator experiences an illusion of 3 dimensional depth.

  The Panorama is particularly suited for displaying large-scale models within the domains of architecture and city planning.

Figure 4: 3D Panorama Cinema at CAVI in Use.

- **TAN Holobench**
  The Holobench is a combination of two 180x110 cm sized projection screens placed at right angles to each other in an L shape.

  Also here it is possible to show models in active stereo, i.e. the pictures on the screen draw a picture for the right and the left eye alternatively in a very high frequency. Without shutter glasses the spectator experiences the image as blurred. But with shutter glasses that alternate between closing off for the right and the left eye in the same frequency, the spectator experiences an illusion of 3 dimensional depths.

  A tracking system allows the spectator's gaze to be responded to through movement of the model and this heightens the impression of an object in front of the spectator's eyes.

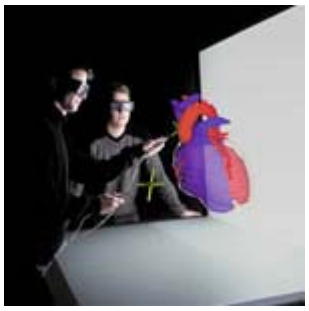

Figure 5: Holobench at CAVI.

- **Virtual Studio**
  The virtual studio or virtual stage set makes it possible to use digital 3D models as sets instead of scenography made from wood, steel, cardboard or other materials. Live recordings in a blue studio with real objects can be mixed with computerised models. It is, for example, possible for a studio host to walk into a completely blue room, sit down on a primitive wooden box and start reporting. What one sees on the television screen could then be that the host enters from a doorway, passes behind a row of plants to sit down at a speaker's desk to start reporting.

Figure 6: Virtual Studio at CAVI.

- **Performance Lab**
  The performance lab is an open space and a facility for several types of experiments including experiments using a reactive performance space, which is a theatrical environment that enables physical actions to effect and manipulate electronic media. These spaces allow performers to improvise with media through a variety of means.

  Electronic media consists of any media that can be controlled from a computer. These are generally divided into four categories: visuals, light, sound and mechanical systems. Physical actions within the space consist of anything that can be sensed and interpreted by a computer. This consists of things like video based sensing, tracking systems, sound sampling, pitch detection or analogue sensors (heat, touch, bend, acceleration, etc.).

  CAVI has a motion capture equipment as part of the laboratory. Motion capture is a technology that makes it possible to register the movements of a person and use the data to animate a digitally created figure. Cartoonists use motion capture equipment to animate their characters. The technology is also used in many other areas for example in the study of movement in dance, sport and medical research.

Figure 7: Performance Lab at CAVI.

  - Onyx2 Infinite Reality2 Rack, 6X250 MHZ MIPS R10000, 1.5 Gb RAM, 2 graphics pipelines (each 64 Mb texture memory)
  - Polhemus FASTRAK (3 sensors)
  - Stereographic glasses
  - 6 Octanes
  - 20-30 O2

Several CAVI-projects will be mentioned in a section 2.2.1.

For further information on CAVI see http://www.pervasive.dk/resAreas/CAVI/CAVI_summary.htm.

2.1.3 VR Media Lab

VR Media Lab (previously VR Centre North) is located at the University of Aalborg. Its main feature is:

- **Cave with 6 walls**
  Active stereo glasses

  The Cave is a room of 2.5 x 2.5 x 2.5 meters in which continuous images can be projected onto side walls, floor, and ceiling. This creates a complete spatial presentation of the scene/model being shown, which gives the viewer a total "immersion" into the spatial virtual environment when using the "active" stereo glasses.

  By using a so-called electromagnetic tracking system the viewer can move in (or around) the visualized object. This installation is preferably for one viewer only and is designed for research and design development.

Figure 8: CAVE with 6 Walls at VR Media Lab.

Figure 9: CAVE at VR Media Lab in Use.

- **3D Auditorium**
  Passive stereo glasses

  The 3D Auditorium accommodates up to 80 persons placed traditionally in from of a large screen measuring 8 x 2.85 meters. The 3D Auditorium shows computer graphics in both 2D and 3D. It is possible to use the so-called "passive" stereo glasses thus presenting the objects as spatial, i.e., objects are seen as if the are in front of the screen. A magnetic tracking system has also been installed making interaction with the graphics possible. Besides the computer graphic images from other sources can be projected (PCs, VHS video and DVD), when the auditorium is used for traditional presentations.

Figure 10: Powerwall at VR Media Lab in Use.

- **Panoramic Screen**
  Active stereo glasses
  Magnetic-tracking device

  The Panorama accommodates up to 28 persons placed in front of a large cylindrical screen with a diameter of 7.1 meters, 160 degrees and a height of 3.5 meters. Because of the shape of the screen, the viewers are given a convincing spatial presentation of the virtual world. As in the 3D auditorium the Panorama can present computer graphics in both 2D and 3D as well as images from PCs, VHS video and DVD. Stereo visualization augments the spatial effect, but the number of viewers is reduced. In Panorama a magnetic tracking system has been installed, and the experience is even more realistic as the screen to an even higher extent "surrounds" the viewers.

Figure 11: Panoramic Screen at VR Media Lab in Use.

These are run by:

- Onyx2 Infinite Reality2 Rack, 6 graphics pipelines
  The three installations are driven by on large supercomputer, an ONYX2 IR2 from SGI. The ONYX is installed in a specially cooled engine room together with several other larger servers. VR Media Labs ONYX2 IR2 has 16 parallel CPU's, 2 GB Ram, 288 GB HD in Raid3 system (transfers 100 MB/sec.) and 6 graphic pipes etc.
- PC cluster
  A PC cluster is being established.

For further information on VR Media Lab see http://www.vrmedialab.dk/pr/index_e.html.

2.1.4 Centre for 3D GeoInformation

Centre for 3D GeoInformation (3DGI) brings together research, public authorities, and business communities in a unique environment of developing 3D GeoInformation applications, all based on new Virtual Reality technology as well as on information regarding urban and rural areas. This is done by establishing a Virtual Geographic Infrastructure (VGI), enabling a wide range of geographically related information to be spread via new, netbased means of communication. One of the new aspects in the project is the user interface, based on intensive use of Virtual Reality (VR) and 3D. By creating a virtual 3D model of reality and then use it as an index for many other types of information, it becomes possible to use the general human ability to familiarize with the surroundings and navigate through space.

The goal is to establish a pioneering project, which will be the central force for the very latest within VR and GIS technologies.

The purpose of Centre for 3DGI is gathering knowledge and competence during the process of creating 3D models of cities and landscapes for organising and presenting GeoInformation applications.

This will be done by:

- Collecting competence and knowledge within the field by arranging seminars/ conferences, establishing international research networks and by employing researchers within this particular field.

- Collaborating with companies, who already possess the most recent competence within VR and 3D urban and rural models or are interested in acquiring this.
- Establishing a VR user interface for looking for position-fixed information in the northern part of Jutland.
- Creating a geographical model of North Jutland, which can form the basis of digital visualisation and the marketing of the resources of the region.
- By developing a basis of knowledge and documentation for the use of a geographical communication concept covering the northern part of Jutland, adapted to the expected increased band width in digital transmission medias (Fixed and Mobile Nets) and as a framework for developing virtual environments.
- Forming the basis for future research and for building up regional knowledge within field-gis (field registration with mobile units). augmented reality (a mixture of 3D models and reality), three-dimensional user interface and the use of broad band for mobile knowledge services.

3DGI is to be a virtual exploratorium in several dimensions. This exploratorium is created partly by gathering knowledge and competence at an internationally high scientific level and partly by developing and conducting a three-dimensional model of the North Jutland region. The 3DGI will then be able to form basis for developing VR technology for the benefit of research and development, strategic functions, operational functions and the mass market in the region of North Jutland.

3DGI is funded by: the European Regional Development Fund (ERDF), Aalborg University, the National Survey and Cadastre – Denmark, Kampsax A/S, and Informi GIS A/S (Danish distributor of GIS products from ESRI and Leica Geosystems (the home page is in Danish)).

Further information on Centre for 3DGI can be found on http://www.3dgi.dk/en/3dgi.html.

2.1.5 VR•C

VR•C is a VR centre at the Technical University (DTU) in Lyngby north of Copenhagen. It is collaboration between UNI•C (a national IT-centre under the ministry of education) and The Technical University (DTU).

The objective of VR•C is to further utilization, research and education in the field of virtual reality (VR) in Denmark and Scandinavia.

Primarily virtual reality is used in connection with building activities, architecture, design and research.

VR•C's main facilities are:

- **Holowall**

  TAN Powerwall (6.5 m x 2.5 m)
  2×3 projectors (TANORAMA/Electrohome) for passive stereo
  Ascension Flock of Birds Tracking system with 2 trackers +
  1 6-degrees-of freedom mouse
  8 active speakers
  3 subwoofers
  1 Microsoft SideWinder Forcefeedback Pro joystick
  1 control for audio panel and SGI terminal

Figure 12: Powerwall at VR•C's in Use.

In the Holowall as many as 50 people at a time can experience the virtual world. By means of stereo projection and polarized spectacles the 3D objects appear spatially in front of the screen. building trade, product development and research-oriented projects.

- **Holodeck**

  3 n-vision DataVisor HiRes Head Mounted Display
  See-through (augmented reality)
  2xXSGA CRT
  Headphones and microphone
  Ascension MotionStar tracking system with 8 trackers
  3x24" Monitors

Figure 13: HoloDeck at VR•C.

In the Holodeck the user wears a VR helmet and sensors on his/her hands to attain integration with the virtual world.

- SGI Onyx2 InfiniteReality2 Graphic Supercomputer
  16 195 MHz MIPS R10.000 CPU's
  8 GB RAM
  356 GB Hard disc
  3 graphic pipes each with 2 Rastermanagers and up to 24 displays
- Lake Huron 20 sound computer
  8 Quad DSP processors
  32 I/O ports
- 4 SGi O2 Workstations
- 1 SGi 320 Personal Workstation

Keywords for VR•C are industry, education and research. Areas of interest are architecture and landscape modelling, scientific visualisation, visual simulation and education, and collaborative VR. For further information on VR•C see http://www.uni-c.dk/generelt/english/research/vr-c.html.

2.1.6 FORCE Technology

FORCE Technology merged in 2002 with DMI (Danish Maritime Institute).

FORCE Technology offers simulator facilities and tools for all levels of maritime education from computer-based training to full-mission simulation.

FORCE Technology possesses a number of full-mission training simulators – one with 360º graphics on 18 m diameter screens and all with a full range of bridge equipment. All can be operated individually or interactively with full passage communication between the ships.

Figure 14: View from the 360° Simulator.

Bridge A, which is the largest, has a horizontal visual field of up to 360 deg. Bridges B and C have a field of 155 deg. and Bridge D of 130 deg. The vertical visual field is 15 deg. All 4 bridges are fitted with normal maneuvering handles (but can be fitted with handles chosen by client) and with radar screens.

Figure 15: Ship Simulator.

For further information on FORCE Technology see http://www.force.dk/gb/default.htm.

2.2 Civilian VR Research and Development Projects

The projects at each of the civilian research laboratories are described in the following sections. For each laboratory the ongoing projects are described first in separate sections, and then the recently ended/finished projects are mentioned.

2.2.1 Projects at Aarhus University

2.2.1.1 Virtual Urban Planning

Partners
The partners of the project are Aarhus University, Cadpeople and COWI.

Aim
The project's goal is to develop and investigate the use of virtual reality technology, as a basis for improvement of decisions to be taken in a city region that is continually undergoing development. Virtual Urban Planning (VUP) has to function as a combined tool for the benefit of politicians, public administrations, building constructors and architects, private businesses and the town's citizens. For example, the advanced visualisation technologies available to CAVI will provide citizens and politicians with the possibility of a simultaneous experience that can be discussed during the presentation and offer an opportunity for focusing on specific details, a particular view from a definite point in the city or something similar.

The research aspect initiates from a series of earlier projects with the feature in common that they all discuss the spatial planning with the aid of digital technologies. They range from *Karlskrona2*, an internet-based multi-user system for use in citizen-based discussion of town planning, to the mixed reality game *[kollision:6400]*, where a physical lp-record is augmented by 3D models and is used for illustrating complex interrelations in the city space. The project's motive, *the town in the computer, the computer in the town*, is to deal with planning our city environment, with the aid of dynamic models of the city's space, an environment that can be experienced purely digitally or by means of, say, augmented reality-technologies in interaction with our physical world.

Results
A 3D-model is created on many levels of detail-addition, where future alterations to the physical relation in the town space can be inserted and tested. In this way, the model becomes dynamic. If, for example,

there are several construction suggestions for the same project, they can be "turned on and off" in the model and the individual changes can be evaluated in a more extensive context, since the surroundings are created in 3D. After this, not only the building process, but also its relation to the surroundings can be evaluated.

Team
Kim Halskov Madsen, Morten Lervig, Rune Nielsen, and Bo Degn.

2.2.1.2 Visualization of the Cardiovascular System

The cardiac morphology in patients with congenital heart disease is often very complex and variable from individual to individual. Consequently, accurate morphological information remains of outmost importance when planning the surgical intervention. Magnetic Resonance Imaging (MRI) is the imaging modality that currently provides the best soft tissue contrasts. New visualization techniques based on three-dimensional MRI have been developed and is now being implemented and tested clinically at Aarhus University Hospital.

Partners

- CAVI, University of Aarhus
  - Thomas Sangild Sørensen
- Aarhus University Hospital
  MR Research Center
    - Erik Morre Pedersen, MD, DMSc, PhD
  Dept. of Cardiothoracic Surgery
    - Ole Kromann Hansen, MD
  Dept. Cardiology
    - Keld Sørensen, MD
- Systematic Software Engineering
  - Søren Vorre Therkildsen

Results
The preliminary results show that cardiac morphology in congenital heart disease can be accurately reconstructed and represented by virtual models. As MR image quality continuously improves, image processing times are being reduced rapidly. This will undoubtedly make three-dimensional MRI with virtual reconstructions an important clinical investigative tool within the nearest future.

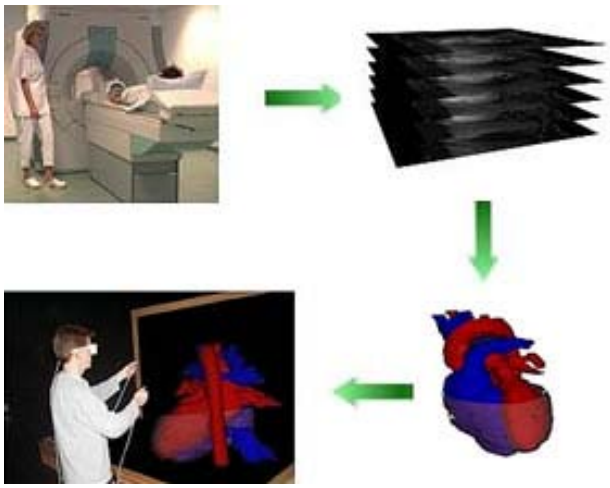

Figure 16: The Process from Scanning to Visualization on Virtual Reality Equipment.

Related research will implement elastic tissue properties, allow cutting the model and inserting patches, as first steps towards a surgical simulator/trainer.

Links
Systematic Software Engineering: Virtual Reality Heart.

2.2.1.3 Digital Theatre – Hyperopticon

The use of digital media in theatre and other time based art forms is increasing as the cost of computers decreases and the development of software programmes has been made more available to theatre technicians. Still there are many fields still to be researched and explored.

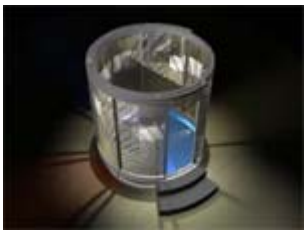

Figure 17: Digital Theatre.

The members of The Digital Theatre from the University of Aarhus have worked in the following fields of digital theatre research: the dramaturgy of digital media, virtual puppet theatre, motion capture/animation, and reactive spaces. Through experiments and productions The Digital Theatre group has explored the production and reception of theatrical spaces in order to explore interactive possibilities in digital media.

HYPEROPTICON was created from a concept of developing a particular site i.e. in a library, where a small audience might have the opportunity to explore a specific theme, a play or an event through interaction in a mixture of digital media and real-life performance.

Partners
The partners of the project are Aarhus University, Denmark, The Academy of Figurative Theatre, Norway, Studio di Progettazione, Italy, and CAVI, Aarhus, Denmark.

Goals
The scientific goal is to develop concepts and produce digital theatre experiments that can be used to further the knowledge of dramaturgical understanding and broaden the knowledge of perception of digital time based art.

One focus of the research has been to develop new forms of staging plays through an idea of exhibiting a story or a plot and to make this an interactive experience. So the investigation of space and digital technologies is also a crossover art experiment with digital media as means of production.

Themes
The last production An Angel's View was staged as an exhibition in seven stages and set up as a walk through elements of a theatre experience and an art gallery. The experiment was made to find a new concept of staging – or rather exhibiting – a text that would give the audience an opportunity to interact with this text and compose their own impression of the play.

The concept of Hyperopticon was created to bridge between the dream of being linked to everything everywhere and the nightmare of being seen everywhere by everyone to explore if there is still a human necessity in interesting interaction. The concept of an Angel's View was to see a "hyperoptic view" in light of the metaphor of an angel's view and apply this meta-view to a dramatic text (Beckett's That Time).

Results
A performance and dramaturgical theory of performance-based visual exhibitions based on a reactive space that can pick up inputs and make it possible to compose words and images.

People

- Torunn Kjølner
- Niels Lehmann
- Janek Szatkowski

Project Manager Torunn Kjølner

2.2.1.4 3D Experiences

Scandinavia and Denmark hold a prominent place in the film media. Good story telling is an imperative, and international successes are evidence of a high standard in both dramaturgy and production. 3D opens up completely new avenues and sets entirely new demands on all aspects of filming, whether dramaturgy, production or staging.

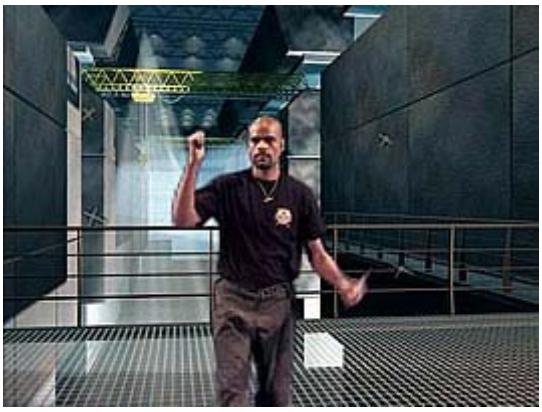

Figure 18: Using VR for Staging.

Also in the case of exhibitions, communication, entertainment and education, 3D technology is increasingly important. Today 3D is already in use in adventure parks, such as Legoland parks and Universal Studios, but 3D technology confronts great challenges and possibilities not only in this area but also in showrooms, exhibitions and education.

Partners
The partners of the project are Aarhus University and Zentropa Interaction.

Aim
The overriding aim is to investigate and develop the potential for 3D within film, interactive TV and other forms of sense-stimulating and educational areas.

The research goals are:

- To reveal and develop present and future technological possibilities and challenges within the 3D narrative and experiences;
- To investigate new possibilities and visions, which arise when classical film artistry meets virtual reality.

The industrial goal is:

- To contribute to Danish film production's development and expansion into new business areas in the context of 3D.

Results
As a result, 2 pilots will be available and one or more future scenarios:

- 3D short film pilot
- 3D pilot for interactive TV design
- Scenarios for 3D realistic experience space and communication

Figure 19: Filming Real Actors on a VR Background.

Team
Kim Halskov Madsen, Svend Erik Søfeldt, Morten Lervig, Ruben Borup, Bo Degn, Peter Friis.

2.2.1.5 3D Sound in 3D Space

3D visualisation in Panorama displays is a widespread means of communication within a number of areas including architectural-design and experience-oriented applications. At the same time, it has been confirmed that sound similarly provides a powerful instrument which so far has been exploited to a limited degree in 3D visualisation in panoramas and similar interactive 3D display facilities.

TC Electronic is unquestionably one of the world's leading developers and producers of sound effect equipment, including equipment for spatial simulation of multi-channel music, but has only worked to a limited extent with real-time design of the sound experience, where the listening position and the sound source are in relative motion to each other.

Partners
The partners of the project are Aarhus University and TC Electronic.

Aim
It is the project's overriding aim to develop and investigate the use of 3D sound in three-dimensional graphical spatial models.

The research goals are:

- To develop the immersion experience in 3D presentations in Panorama using the audio dimension;
- To identify future potentialities for exploiting the audio dimension in conjunction with 3D visualisations within architecture, design and experience-oriented applications;
- To improve simulations of the natural sound experience in an interactive environment.

The industrially oriented goal is:

- To develop real-time generation of 3D sound experience more fully, for example, by increasing the speed of sound processing.

Results
Software will be developed to make it possible in connection with a visual 3D model to move around in it, where 8 sound sources are positioned in the model and the sound reception corresponds to the sound position and orientation with respect to the sound sources and where the sound experience reflects the 3D room's acoustic properties. In this way the sound can be "coloured" so that it reproduces the virtual environment's sound-reflective properties more faithfully, and thereby strengthen the immersion experience, which the panorama provides.

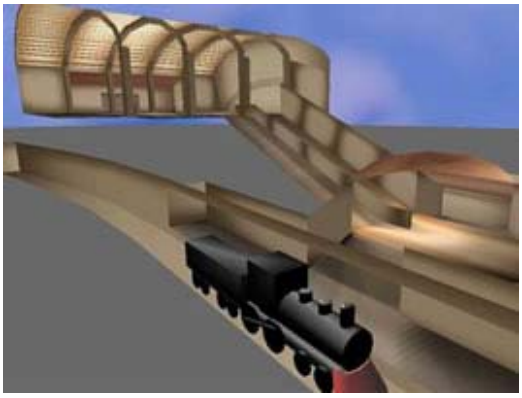

Figure 20: 3D Sound in 3D Space.

An algorithm will be developed, whereby the sound can find its way to the listener in the virtual world. That is, the sound's path to the listener takes the height of the walls, doors, corridors, etc. into account.

This has the effect that the sound not only reflects the single virtual room, in the way made possible by TC Electronic's System 6000, but also allows the sound experience to be simulated in virtual worlds consisting of many rooms.

Team
Kim Halskov Madsen, Morten Lervig, Gorm Lai, Bo Degn, and Peter Friis.

2.2.1.6 Interfaces for 3D Applications

3D models are becoming increasingly widespread and used in a diversity of areas, for instance architecture, product design, medicine, and art. At the same time pervasive computing brings us into the domain where software and 3D models must be portable between systems with different display and interaction systems some of which are integral part of physical devises or other parts of the environment. Whereas studies and development of interaction technology and styles for 2D user interfaces have a longstanding tradition, navigation and interaction in a 3D environment is fairly unexplored.

Partners
The partners of the project are Aarhus University, Personics Aps, Systematic Software Engineering A/S, RoninWorks BV (Holland) and CAVI.

Goals
The scientific goals are to advance the development of cross-platform independent interface technology for 3D virtual reality applications, and to develop a universal non-touch interface for navigation and

interaction in a 3D environment. The commercial goals are to expand RoninWorks strategy of leveraging the traditional developer base by integrating knowledge of newer devices and displays, to expand the applicability of Personics equipment into new domains and to advance the interface technologies available for Systematic's products.

Themes
The proposed interface technology will transfer human gesture into 3D navigation and interaction. The development of a cross platform independent layer and a platform independent interface framework for 3D interfaces, that makes it possible to move 3D models between platforms with different display and interaction technologies.

Results
A cross platform non-touch navigation system of 3D environments and interaction tool.

People
Kim Halskov Madsen and Thomas Sangild.

2.2.1.7 Finished Projects

- **3D image processing for cranium- and brain-surgical planning and simulation** at CAVI and PET Centre at Aarhus University Hospital.
- **Digital, 3D atlas of the receptor systems of the human brain** at CAVI and PET Centre at Aarhus University Hospital.
- **Product Development**
  CAVI has for 2 years cooperated with Centre for Product Development at the Technical University of Copenhagen on visualisation. The following are examples where 3D visualisation has been used:

Arla Foods	Packaging design
Kampsax/Lundbeck	Landscape visualisation
Arkitektfirmaet Schütze A/S	Architecture
CF Møller/CADpeople	City planning
Danmarks Radio	Virtual set activities / Ren Kagemand (Danish television show)
Jydsk Dykkerfirma (Diving firm in Jutland)	Beaching Museum St. George

- **The Family Factory**
  The family factory is a theatre show that combines ordinary theatre with traditional animation, puppet handling and live 3D computer animations. The virtual creations are not just programmed ahead with a limited set of actions. Actors control them with motion capture while they perform their one role. The project is a corporation between CAVI, The Danish Film School, and Schule für Schauspiel-kunst "Ernst Bush" Berlin. Further information can be found on http://www.multimedia.au.dk/JCal/ff/fabrikinfo.html.

- **The Digital Theatre**
  An Experimentarium in 1999 examined the artistic possibilities involved in the encounter between real and virtual performers, between virtual beings in real spaces and real beings in virtual spaces. These encounters were established by various means of digital technology transforming movements in

time and space into 3D-animations via digital data. The technology used for this purpose was motion capture technique, animation programs and projection techniques. Further information can be found on http://www.daimi.au.dk/~sdela/dte/index.html.

- **Whizbang**
  From a set of measurements of the seabed, a data file is created which is visualized by means of volume rendering. It is possible to cut in the large amount of data and manipulate the model in different ways so that the data is easy to grasp. A Master's thesis project by Niels Husted and Kaare Bøgh.

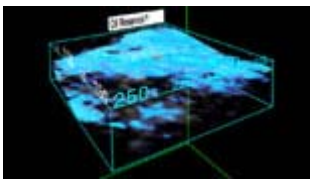

Figure 21: Whizbang.

- **Aarhus New Art Museum**
  A model of Aarhus's new art museum for the panorama cinema. The model was made in co-operation with the art department Schmidt, Hammer and Lassen for the Aarhus Art Museum and financed by the merchant department of the Aarhus City Council.

Figure 22: Aarhus New Art Museum.

- **The CAVI Building**
  A digital model of CAVI's building which was used in connection with planning and designing the building.

Figure 23: The CAVI Building.

- **Katrinebjerg Phase 2**
  A model of the Katrinebjerg phase II building was made to show visitors to CAVI how the next phase of the IT park extension will look.

Figure 24: Katrinebjerg Phase 2.

- **Katrinebjerg Phase 1**
  A 3D model showing an overall vision of the future Katrinebjerg IT City.

Figure 25: Katrinebjerg Phase 1.

- **Architectural Competition**
  Visualization of a project proposal for the TDC domicile made for the architecture firms of Jørn Schütze.

Figure 26: Architectural Competition.

2.2.2 Projects at Aalborg University

2.2.2.1 The Project of Sonderborg

Project Description

VR Media Lab has in collaboration with Cadpeople and COWI made a 3D model of some parts of the town of Sonderborg. The project was financed by the Danish National Research and Educational Buildings in connection to a new university building project.

Further information can be found on (page is under construction)
http://www.vrmedialab.dk/pr/activities/spatialmodeling/sonderborg.html.

2.2.2.2 Aalborg University Campus Model

Project Description

VR Media Lab is building a 3D model of the campus at Aalborg University. The model is going to be used as tool for the next 10 to 20 years when the university is going to be enlarged.

Further information can be found on (page is under construction)
http://www.vrmedialab.dk/pr/activities/spatialmodeling/campus.html.

2.2.2.3 CAE and CFD into Virtual Reality

CAE and CFD into Virtual Reality (CCVR) is a post-doc planning research activity at VR Media Lab by Truc Huynh and Henrik R. Nagel.

Computer-Aided Engineering (CAE) and Computational Fluid Dynamics (CFD) are developed for structural engineering application, typically on the personal computer monitor.

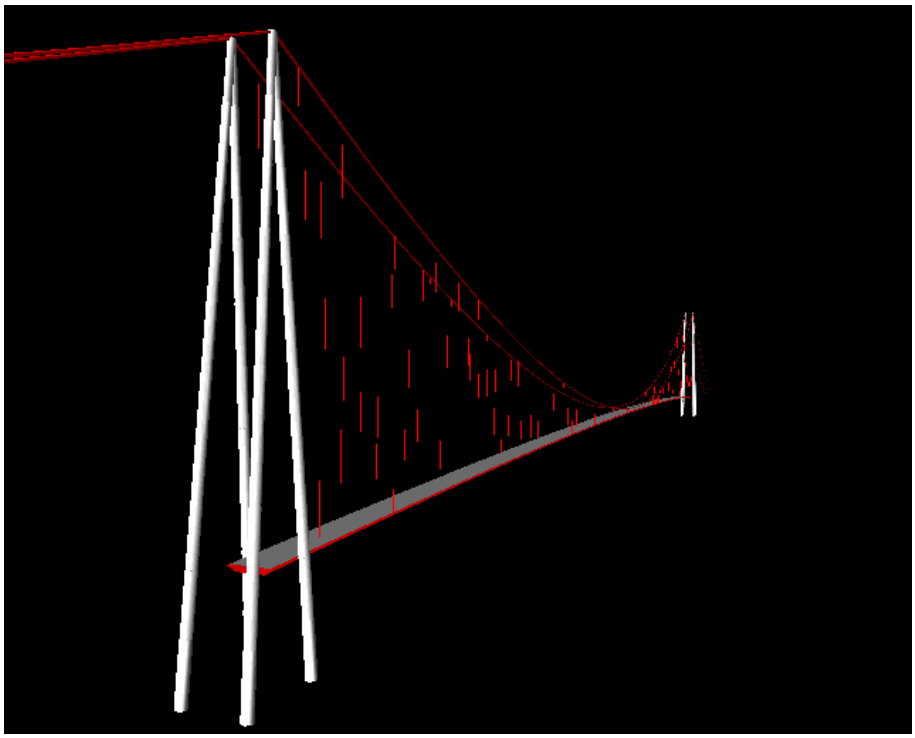

Figure 27: Computer-Aided Engineering (CAE) and Computational Fluid Dynamics (CFD) Visualized in VR.

However, it is a common desire for structural engineers that a large screen is needed for large structure, where the whole construction can be analysed in global dimension or zoomed in into a local part as well. Further, the large screen and the virtual reality device will also make the idea visible during the research step and the final presentation.

To this purpose the following is available at the VR Media Lab:

- Panorama wide screen in arc of a circle of 160°, 7.1m diameter and 3.5m height
- Wide screen of 8x2.85m
- Cave på 2,5 x 2,5 x 2,5m (C-language Application Virtual Environment)

The CCVR research is to the effect the creation and analysis of a construction in virtual reality (VR), where the suspension bridge is an example. A post-doc on "Wind-Bridge Interaction" is planed on the developing Ph.D.-thesis "Suspension Bridge Aerodynamics and Active Vibration Control", Truc Huynh, July 2000. The physical idea behind the thesis is that the girder-flap-wind interactions are studied theoretically and numerically with the goal to obtain the vibration reduction of the wind-exposed suspension bridge girder using the motion of the separate control flaps attached along the girder.

This problem can now develop graphically on the Panorama with full-span bridge-wind interaction analysis. Hence, the bridge and its motion due to the wind can be studied in three dimensional dynamic translation and rotation (also on Silicon Graphics computer monitor).

The research is planned to be a cooperation between VR Media Lab, Department of Building Technology and Structural Engineering, Aalborg University and Engineering Consulting with the similar interest to fund the project.

Step of work is planed to consist of two separated parts. One refers to CAE and CFD. The other is the transformation of the CAE and CFD graphical results into VR.

First step of CAE natural mode shapes into VR has been done sufficiently, where the bridge construction and its dynamic eigenvectors are transformed into virtual reality animation. Also the real box-girder can be animated together with the bridge vibration using geometrical assumption at the VR step.

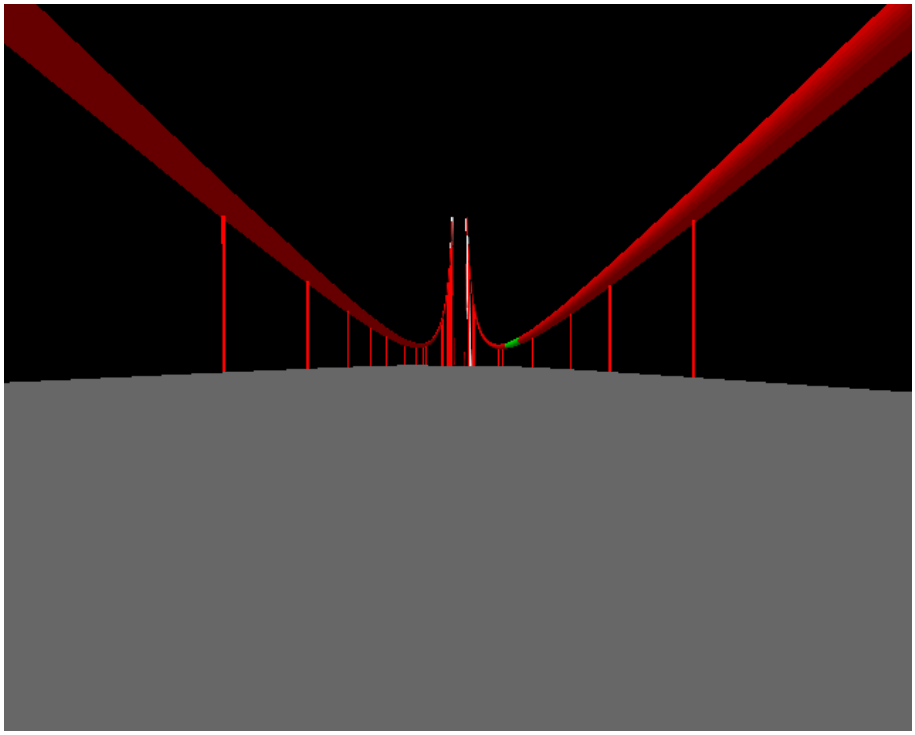

Figure 28: CAE and VR in Bridge Construction.

Further information can be found on http://www.vrmedialab.dk/pr/activities/simulation/ccvr.html.

2.2.2.4 3D Airflow

VR Media Lab has in co-operation with the Department of Building Technology and Structural Engineering (also at Aalborg University) worked on visualising airflows in buildings.

Aalborg University, the Danish Institute of Agricultural Sciences, and the Royal Veterinary and Agricultural University have concluded a five year framework program together focussing on computer simulation of ventilation, airflow, and indoor climate of stables.

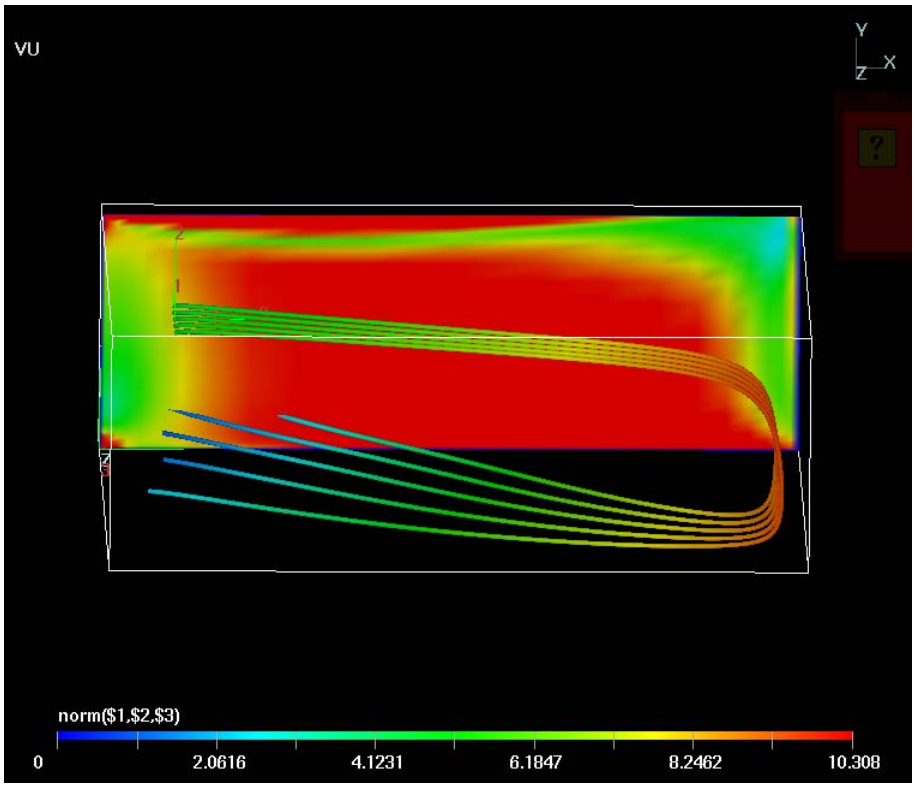

Figure 29: 3D Airflow in a Stable.

The purpose of the project is to understand and control the airflow in stables. This will make it easier to improve the working conditions for the farmers, the animal welfare, and the economy of the animal production.

The role of VR Media Lab's is to visualise the 3D computer simulations being run at the Royal Veterinary and Agricultural University and at the Department of Building Technology and Structural Engineering.

The purpose of the visualisations is to examine the details of the results of the computer simulations, which can be difficult to perceive on ordinary computer screens. The results have also been shown to consultants and companies in the ventilation business.

Further information can be found on
http://www.vrmedialab.dk/pr/aktiviteter/simulering/3dluft.html (in Danish. An English version will be up soon on http://www.vrmedialab.dk/pr/activities/simulation/3dluft.html).

2.2.2.5 3D Visual Data Mining

3D Visual Data Mining is a research project at VR Media Lab

Technology to store and process large amounts of data has during the last decades improved dramatically. This has led many companies to store ever increasing amounts of customer information in large databases. The hope has been that it would be possible to discover unknown relationships in the data, and thereby obtain a knowledge which could give commercial advantages. This could, e.g., be the knowledge of which good customers would soon leave the company. This knowledge could then be used by the company to make the customers concerned a more attractive offer.

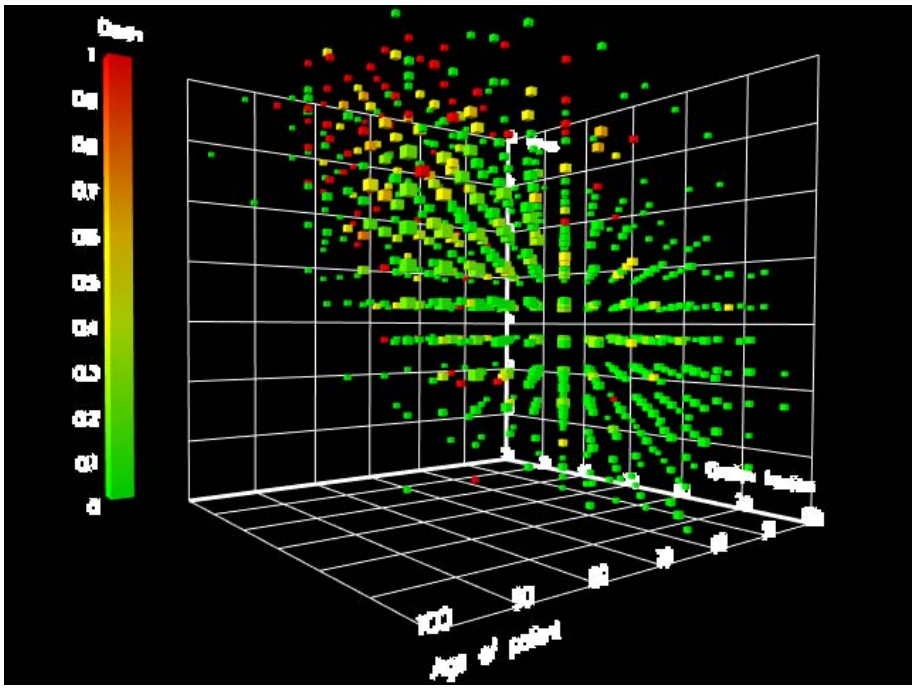

Figure 30: 3D Data Mining.

However, finding hidden relationships in large amounts of data is not easy. Purely numerical methods have been supplemented with visual methods. This has led to the emergence of "Visual Data Mining". Visual Data Mining has traditionally employed 2D techniques, such as geometric, icon-based, pixel oriented, hierarchical, and graph-based methods. With the 3D Virtual Reality (VR) facilities available at VR Media Lab it is now possible to explore how the ability to interpret 3D objects can be used in Visual Data Mining.

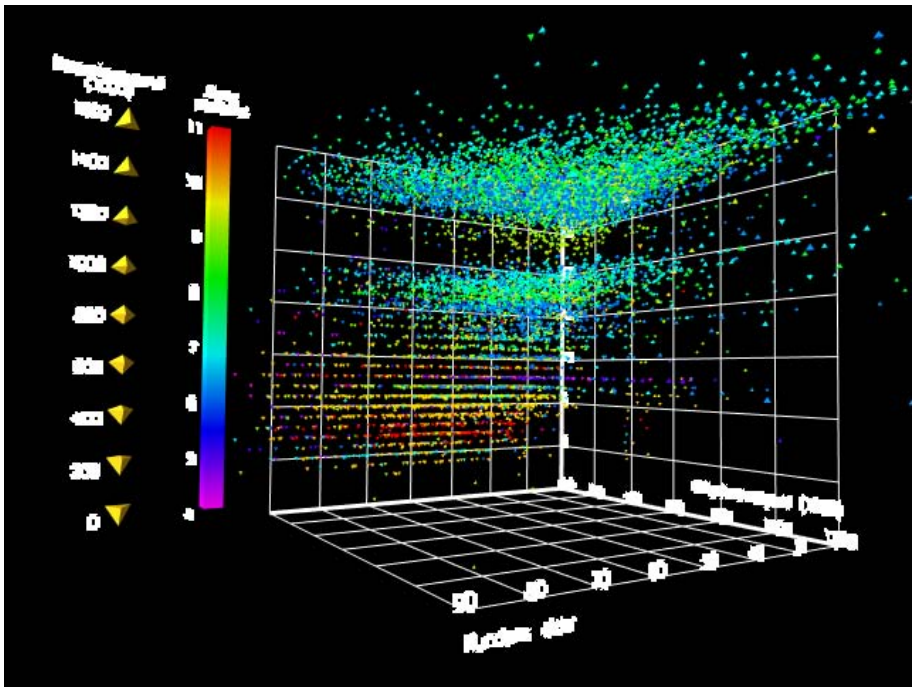

Figure 31: Visual Data Mining.

The 3DVDM project aims at exploiting all the possibilities that immersive 3D VR technology may provide to Visual Data Mining, and then adapt the data processing methods to this. The project has collaborators from four areas of science: Database Systems, Statistical Analysis, Perception Psychology, and Visualization. Researchers in the database area are responsible for handling and delivering large amounts of data from databases. Statisticians are responsible for finding interesting problems, creating statistical models for data analysis, and guiding the entire project in experiments of 3DVDM system. Perception psychology researchers are responsible for finding ways of good interaction and human perception of VR environment. Visualization researchers are dealing with the visualization of data using VR Media Lab facilities and implementation of a novel VR environment for data mining.

For further information contact Linas Bukauskas.

2.2.2.6 Learning

In cooperation with Vestas and Zenaria is VR Media Lab developing a pilot project in order to clarify the use of VR-technology in various learning situations.

This particular pilot project involves teaching of Vestas electricians thus enabling them to perform a more accurate repair of the windmill on-site.

This, however, requires a more thorough understanding of the theories behind basic electromagnetics.

The problems arise from the fact that foreign electricians do not have the same educational background as Danish electricians. Therefore the outcome of the project is an education, where the windmill electricians attend a course at VR Media Labs facilities followed by an introduction to a CD-ROM which contains VR-sequences from the course.

For further information contact John Tørring.

2.2.2.7 Vestas

One of the learning projects at VR Media Lab is called Vestas.

Project Description

The project addresses problems at two levels: at an abstract and method developing level as well as at a concrete application level.

At the first level the project presents the following problems:

- To include the newest forms of interactive multimedia and VR technology in order to develop and test new methods of learning in a virtual environment.
- To estimate to what extent different interactive technologies can be used in learning situations regarding with education and further training.
- On the basis of a specific education program to evaluate the use of educational methods and possibilities.

At the second level the following problems are presented:

- To develop a VR product for Danish as well as foreign wind turbine electricians in order to extend their qualifications.

The wind turbine industry has a considerable amount of export trade. The mounting and the following maintenance are done by foreign electricians who may not be fully qualified. Besides there may be cultural differences causing an incorrect translation of the Danish manual.

An incorrect mounting or maintenance may lead to a breakdown of the wind turbine causing unnecessary financial costs. This project aims at solving the above problems by using VR technology. By using visual means the project will give the necessary information thus being able to cope with any language or education related barriers.

Figure 32: Visualising in the Vesta.

Project Characteristics

- To be a method based on new digital technologies and interactive multimedia which improve the understanding of e.g., manuals.
- To develop a method for "digital interactive service manuals" which ensure the "on-location" use of maintenance/repair instructions.
- To develop a VR based teaching/education product.
- To develop a VR based method applicable when evaluating the influence of the mounting of a wind turbine regarding the environmental aspects; i.e., nature and town.

For further information contact Erik Kjems.

2.2.2.8 Finished Projects

- **A Music House in Aalborg**

  The city of Aalborg needs a new music house ("Musikkens Hus"). The new music house will be situated by the harbour right next to the old power plant.

  VR Media Lab made a visualization of the proposals, which were sent from several architectural firms from all over the world. These visualizations were presented to the committee of judges. Their decision was made based on the visualization of each proposal.

The winning proposal was presented at "Studenterhuset" (student house) in Aalborg in February 2003. Furthermore a report in collaboration with the Danish National Research and Educational Buildings has been issued. This report describes the entire project using the VR technology in an architectural competition.

Further information can be found on http://www.vrmedialab.dk/pr/activities/spatialmodeling/musikkenshus.html.

- **A Plan for New Housing Development**

The project of the town of Ans, Kjellerup Borough in mid Jutland is an ordinary plan for new housing development. These housing plans are made every year all over Denmark. The characteristics of this particular project are that the new housing area is at the outskirts of the town. The new housing area is situated in attractive natural scenery overlooking a meadow.

COWI, a Consulting Engineers and Planners firm in Aalborg, asked VR Media Lab if they were interested in visualizing this new housing development, as the borough of Kjellerup was very skeptical about the extent of the plan and the damage done to the area.

Figure 33: The Town of Ans.

The first step was to model the project area. COWI prepared the basic data from altitude information, ortho photos, and from a road project cut into the model.

VR Media Lab employed four students from the Architecture and Design study program, who prepared a first draft to the borough during the summer of 2000.

The next step was an alteration in the regional plan. The model was modified according to the alterations agreed upon, and the project was presented to all members of the Kjellerup Town Council in May 2001. Based on this presentation it was decided that the project was to be implemented. The area has been site developed and is now ready for its new residents.

VRML model of the project (download viewer here).

For further information see http://www.vrmedialab.dk/pr/activities/spatialmodeling/ans.html.

- **Highway at Holbæk**

  The project aimed at testing a large road project based on the facilities and equipment of VR Media Lab.

  Model conversion, model reduction, and navigation were at the top of list of things to be tested. A very simple model was presented. Only the most necessary parts of the project was modelled, i.e., all other spatial elements in the landscape (buildings, plants, or road elements) were not included in the model. Right now there are no plans for continuing this project, even though the Panorama is an obvious facility to present landscape constructions of this particular kind.

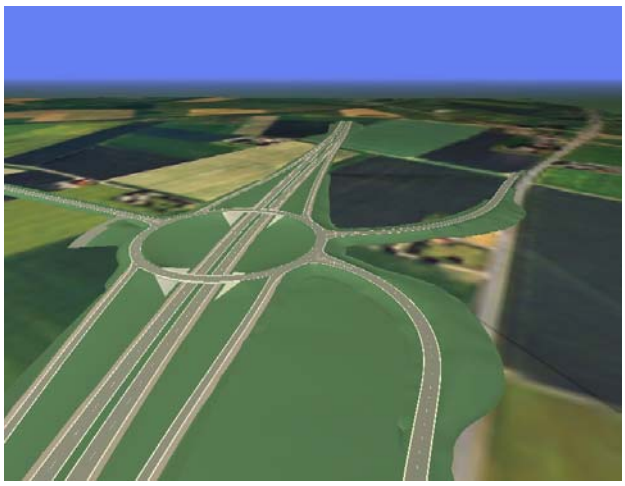

Figure 34: Highway at Holbæk.

  For further information see
  http://www.vrmedialab.dk/pr/activities/spatialmodeling/motorvej.html.

- **Model of NOVI 3, 4, and 5**

  The project aimed at modeling the NOVI buildings. This enabled a presentation of the models in the Panorama facility causing a discussion about the further building plans of NOVI.

  The project was divided into two parts: The first part deals with NOVI 3 and 4. This part was completed in the summer of 2000. Simultaneously models of NOVI 1 and NOVI 2 have been outlined.

  NOVI 5
  The model of NOVI5 was made at a very early stage compared to the construction itself, which was completed in the summer of 2001. VR Media Lab worked together with architect Peter Tybro from Vilhelm Lauritzen AS.

Figure 35: NOVI.

  The architect firm made traditional drawings of the building, and the modeling has been made from two-dimensional technical drawings of ground level and aspects.

  The model was being used to describe various light angles at different times of the year. These light angles were presented and evaluated in the Panorama facility. The model was also used to present choice of interior, colours and forms inside the building.

  For further information see http://www.vrmedialab.dk/pr/activities/spatialmodeling/novi.html.

- **Puppet** was a research project funded by EU-commission at the University of Aalborg. It involved developing virtual inhabited 3D rooms for educating pre-school children.

- **Staging of Virtual Inhabited 3D-spaces** was a research project funded by the Danish National Research Council involving the University of Aalborg, etc. It dealt with all kinds of aspects regarding the nature and usage of the signs system of interactive multimedia; which in general terms meant the semiotic of interactive multimedia systems. The purpose was to define a universal common language for 3D interactive multimedia systems.
- **Sound in Cyberspace** is a research project at the University of Aalborg.

2.2.3 Projects at Centre for 3DGI

The projects at Centre for 3DGI can be divided into the following Research/Development Tasks:

- Automated Extraction of 3D objects
- Qualification of 3D GeoInformation
- Queries for navigation in 3D Models
- Representation of objects
- Distributed Database System
- Viewer

Further information on 3DGI can be found on http://www.3dgi.dk/en/3dgi.html.

2.2.3.1 Qualification of 3D GeoInformation

3D models of landscapes based on orthophotos and laserscannings is becoming accessible on the internet and in other 3D environments. The technique of the software is advancing rapidly but not much guidance for building up models optimal for the users exists. The goal of the research group of 3DGI is therefore not only to develop 3D geographic software, but also to take user demands into consideration, both concerning graphical design of objects and data input, and the functional design like navigation and interaction. Developing interfaces, design and navigation at 3DGI is based on user tests and inspiration from classic and more well established research areas like cartography and web usability/GUI's.

Further information can be found on http://www.3dgi.dk/en/research/qualification.html.

2.2.3.2 Queries for Navigation in 3D Models

The main research focus lays on queries related to the 3-D Geographical database, i.e., a repository containing data related to the surface of the earth. The query result will be a pre-processed data set suitable for 3-D visualization. The aim of the queries is to enable an efficient navigation through huge amount of data stored in one or more interconnected databases. The amount of data transferred to a viewer should be minimized to potentially displayed data only.

The underlying query algorithms will take into account the level of detail of the geographical features. It will also perform automatic data pre-processing, regarded as cartographic generalization in 3-D. Only few working algorithms have been introduced, which deal solely with 2-D cartographic maps. A similar approach combined with the level of details could result in generating a more meaningful 3-D model, i.e., avoiding unnecessary details, while graphically emphasizing the features of interest.

Further information can be found on http://www.3dgi.dk/en/research/queries.html.

2.2.3.3 3DGI Viewer

The 3DGI viewer uses part of the ROAM algorithm to do level of detail on the terrain. The algorithm uses fewer triangles to represent the flat areas and more to represent the uneven areas like hills, cars, trees,

and houses. The images shown in the viewer are dependent on the viewpoint dependent version of the viewer. Not only does the viewer use fewer triangles to represent the uneven areas, now it also uses more triangles for the structures close to the viewer and reduces the number of triangles far away, but is also uses viewpoint dependent continuous level of detail on the landscape. Landscape patches are geo referenced, and the viewer can handle more than one. A segmentation process of the laser scanning groups points that belong to the same plane in the same segment. In particular this is noticeably on the larger segments such as the ground and the rooftops. The first rooftops have been reconstructed. The algorithm is still unstable and makes assumptions about the houses.

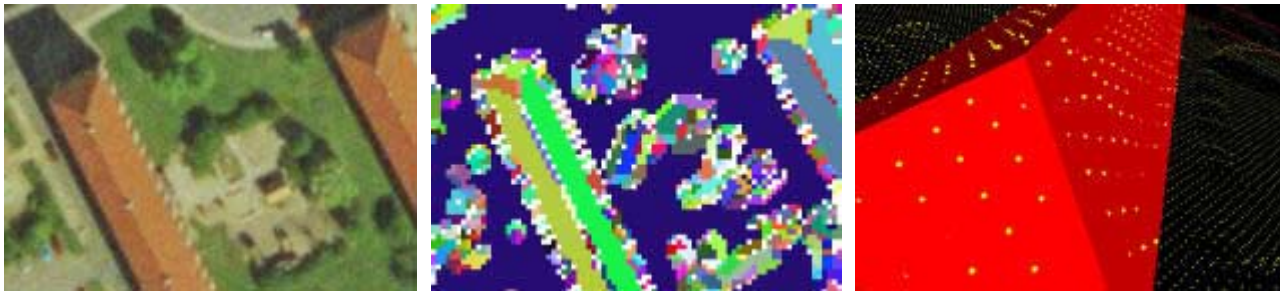

Figure 36: 3DGI Viewer.

Further information on 3DGI can be found on http://www.3dgi.dk/en/3dgi.html.

2.2.4 Research Projects at VR•C

The following sections gives short presentation of research projects at VR•C. For further information on the projects please contact info@uni-c.dk.

2.2.4.1 Interactive 3D Visualization of Projects

Interactive 3D visualisation is a growth area, where interactive virtual models are used to support decision-making regarding larger projects, and for design of new products. The virtual model is used to enhance the level of information and to further communication. The virtual environments are based on CAD models and technical 3D drawings. These are imported in the VR system, enabling the user to navigate and work interactively with the different 3D objects. Among others VR•C has provided visualisation solutions and software to SEAS Energy Group regarding visualisation of a windmill farm at Nysted, Radio Denmark with regard to the new headquarters in Radio Denmark City, and a larger visualisation of the dock area for the Municipality of Copenhagen.

2.2.4.2 Scientific Visualization

With scientific visualisation researchers are provided with a tool for handling and visualising academic results. It is possible to reach totally new insight by making abstract models and large complex data volumes accessible and intelligible in a so far unseen manner.

In cooperation with DTU (The Technical University of Denmark) VR•C has carried through projects for the oil industry regarding visualisation of seismic data, and for the windmill industry regarding visual analysis of turbulence at the tip of the wing of a windmill.

Presently VR•C is taking part in a research project with Grundfos and Force in a machine-acoustics project, with the objective of developing an interactive tool for visualisation of the stream flow in pumps.

2.2.4.3 Finished Projects

- **Network-Based VR Technology**
  Network-based VR technology is an innovative research area. With visualization and broadband technology it is possible for groups across subject boundaries and geographical distances to collaborate on complex problems in a virtual 3D environment.
- **VR in Neuro Informatic** at the Technical University.
- **Simulating a combine harvester** at the Technical University.

2.2.5 Projects at COWI

In previous sections it has been mentioned that COWI is involved with the Virtual Urban Planning project and the project of Sonderborg. COWI also has development projects by itself in the areas of GIS and VR. One of these is the Skyline project.

2.2.5.1 Skyline

Figure 37: Århus, Video sequence – Windows Mediaplayer vers. (3238 kb).

COWI is distributing 3D visualization software from Skyline Software Systems. With this software and the nationwide 3D model, you can make a virtual flight across Denmark. In the Skyline 3D-viewer, TerraExlorer, you can freely navigate in a 3D world. The photo-realistic, aerial image based terrains can be accessed on the Internet through video streaming – without appreciable loss of performance.

With TerraExplorer Pro, you can create or import all the desired terrain overlay information, such as routes or text, labels and graphics, to promote specific features in the landscape.

Imagine a 3D model for an area of natural beauty, with differences of height and many cultural landmarks. You are taken into the landscape through a predefined route passing signs that tell you the names of towns and landmarks, e.g. castles and churches. The trip can be interrupted whenever you like and you can freely navigate in the model. A click on one of the signs informs you about the subject, e.g. from a homepage. A click on one of the supplied surfaces gives you information about the use of a certain area. You can find 3D objects such as windmills or you can follow marked routes such as bicycle routes or scenic routes.

Skyline Project

Figure 38: Skyline Project for the County of North Jutland (click on picture to start simulator).

COWI has supplied the County of North Jutland with a Skyline 3D-model of the county, composed of a height model, draped orthophotos and supplied with building polygons from The National Survey and Cadastre Department. Everybody can go into the North Jutland County homepage, www.3d.nja.dk, and fly around in the county or you can key in an address and fly to the address in question.

3.0 MILITARY VR-PROJECTS

Military VR-projects are either ready-made bought simulators or research and development. Exceptions are VIKING GIS, and RTP 6.14 Virtual Environment in Military Decision Making mentioned below. Military research and development takes place at the Danish Defence Research Establishment (http://www.ddre.dk/).

3.1 HCI-Lab

The HCI-Lab at the Danish Defence Research Establishment is used for testing VR hardware and software. In 1999 the laboratory had the following hardware:

- Teranetix Blackbird XL Xeon
  - 2 x 3.06GHz Xeon 533 FSB
  - 2 GB ECC DDR memory
  - 182 GB hard disk
  - ATI FireGL X1 256 MB AGP Pro x8
- Assorted PC's
- Ascension's Flock of Birds
- V6 helmet
- I/O glasses
- Gloves
- Logitech Spacemouse

The laboratory has the following software:

- SuperScape
- Sense8
- Multigen Creator
- DI-Guy

3.2 F16 Flight Simulator

The F16 flight simulator is a readymade bought system from Hughes for the Air force. It consists of a mock-up of a cockpit standing in front of 3 screens as shown in Figure 39. The simulation is run on a Silicon Graphic's computer from a control room.

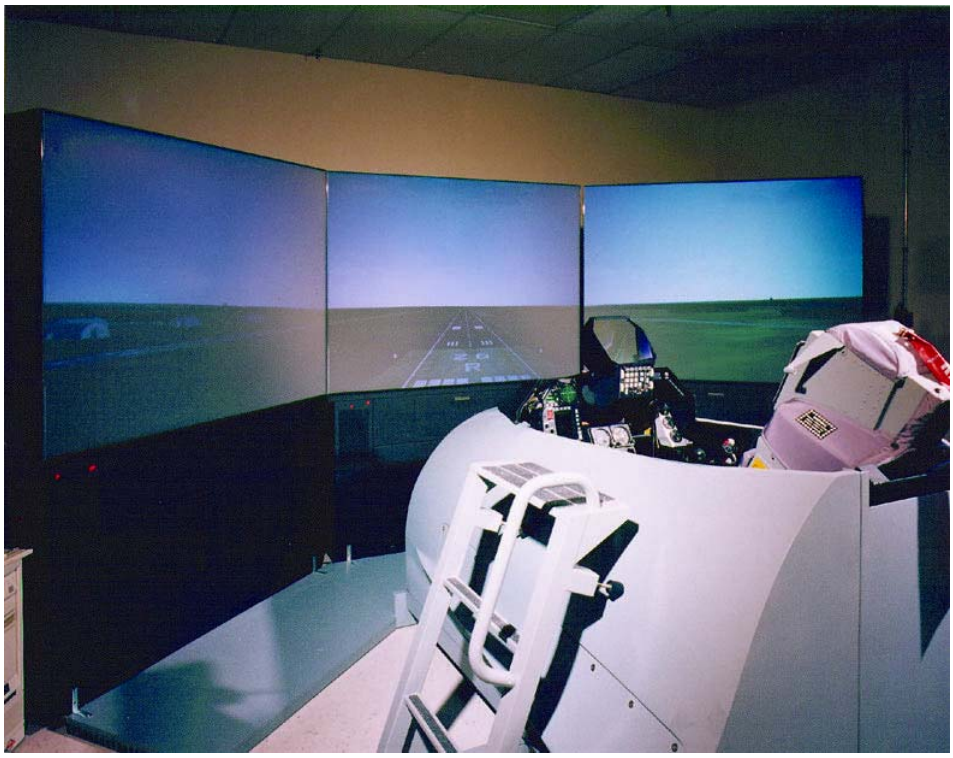

Figure 39: F16 Flight Simulator.

3.3 The Tank Simulator

The Tank simulator is a readymade bought system from Siemens (NL) and Simtech (Israel) for the Army. It is for shooting and battle exercises for platoon and below. The simulator has 4 40-foot containers. Three (3) of the containers have a technician room, a leopard 1A5 DK mock-up, a local instructor control panel, and a leopard 2A5 DK mock-up. The last container has a technician room, a central instructor control panel, and a report room with 12 seats. The set-up is shown in Figure 40 and Figure 41 show a picture from one of the containers.

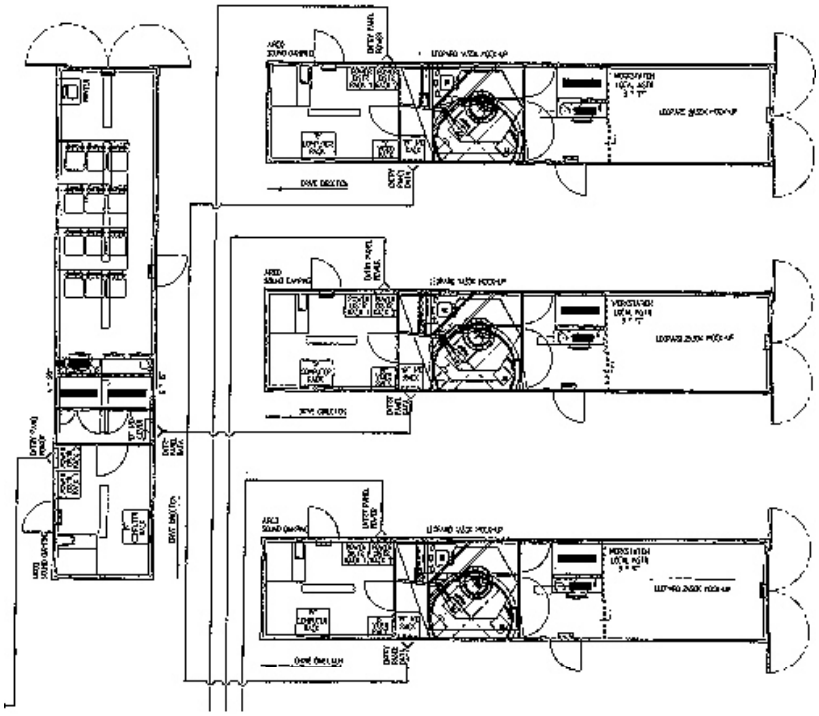

Figure 40: Tank Simulator.

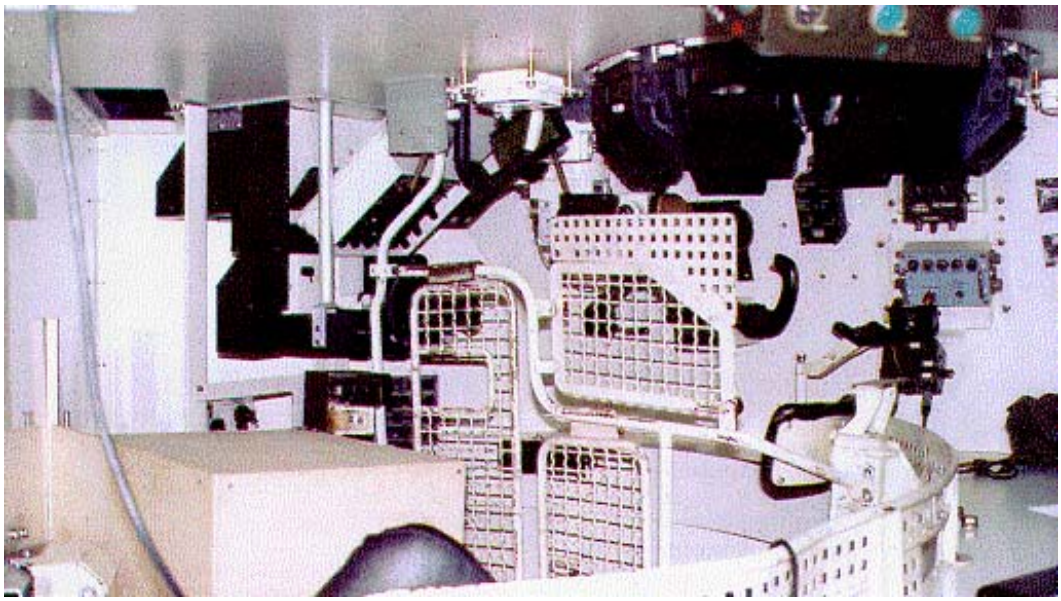

Figure 41: Tank Simulator.

3.4 Finished Projects

3.4.1 Tactical Trainer for a Group Leader

The tactical trainer for a group leader is a research and development project at the Danish Defence Research Establishment. It started 1998, and is a tactical trainer for education and training a group leader.

It combines a programmed simulation model with a geographical information system and a VR system and will have a speech interface. The duration is estimated to 5 years. The first prototypes are 'Attack of mechanised infantry'. The conceptual model is pictured in Figure 42.

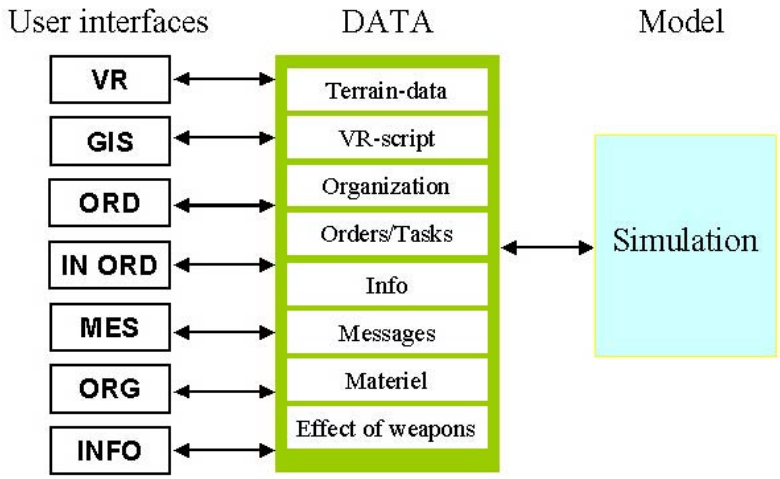

Figure 42: Conceptual Model.

The ordering of the soldier is done by voice. The VR part was developed in Superscape.

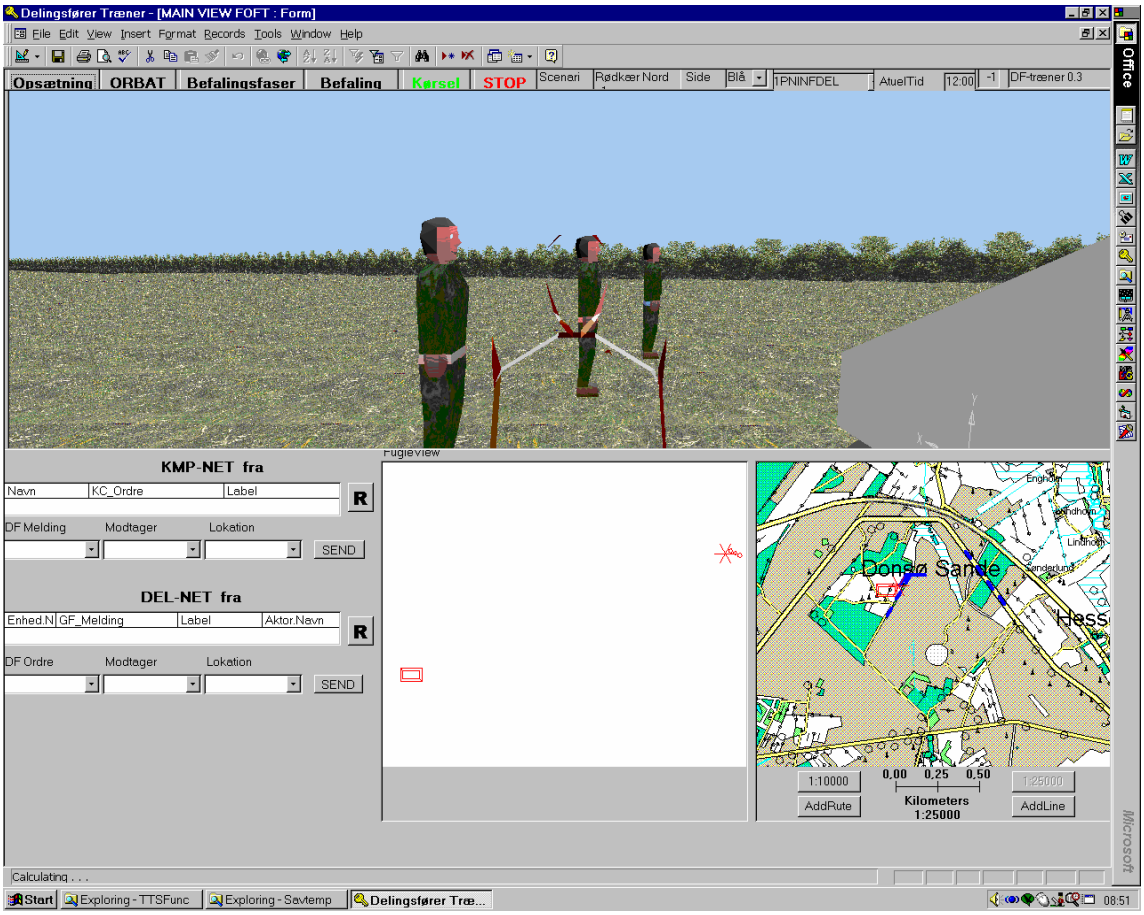

Figure 43: Screen Dump from the Tactical Trainer for a Group Leader.

The development of the VR in Superscape has stopped.

3.4.2 RTP 6.14 Virtual Environment in Military Decision-Making

The Western European Union (WEU) places contracts for research and development (R&D) projects under the European Co-operation for Long Term in Defence (EUCLID) programme. EUCLID's objectives are to provide European defence with basic technologies fully consistent with the aim of the Western European Armaments Organisation (WEAO) and to promote European industrial co-operation in R&D.

EUCLID consists of a set of Common European Priority Areas (CEPAs). CEPA 6 concerns "Advanced Information Processing and Communications". Within CEPA 6 the WEU is running a Research and Technology Project (RTP) number 6.14 entitled "Virtual Environment for military decision-making". The objectives of the RTP 6.14 project are to:

- Demonstrate the feasibility of using Virtual Reality (VR) techniques and a Virtual Environment (VE) in military decision-making in two functional areas: intelligence and logistics.
- Show how the military decision-maker's situational awareness is improved by using a demonstrator developed in the RTP.

The scope of RTP 6.14 is limited to decision-making at battalion and brigade levels during wartime and peace support operations on the (battle)field.

The RTP 6.14 project is being performed by an industrial team, led by Atos Origin (The Netherlands). Atos Origin's partners are IFAD (Denmark), INTRACOM (Greece) and DATAMAT (Italy). The industrial team is named "Military Applications for VE in Logistics and intelligence" (MARVEL). The demonstrator to be developed during the MARVEL project will be named the "MARVEL demonstrator". The client is the Western European Armaments Organisation's Research Cell (WRC). A Management Group (MG) of the Ministries of Defence of Denmark, Greece, Italy, and The Netherlands manages the RTP 6.14 project on the WRC's behalf. The Dutch Ministry of Defence leads the MG.

There are five Work Packages (WPs) in the RTP 6.14 project:

- *WP 0 Management and Integration*. The objective of WP 0 is to manage the project and to integrate the various components into the MARVEL demonstrator.
- *WP 1 Preparation Elements*. The objective of WP 1 is to prepare for the research and implementation phases of the project.
- *WP 2 Research Elements*. The objective of WP 2 is to perform research in the various areas that are relevant for the evaluation of VE for military decision-making.
- *WP 3 Implementation and evaluation of demonstrator*. The objective of WP 3 is to implement and evaluate a demonstrator supporting military intelligence and logistics decision-making for the land-battle domain using VE display and user-input devices.
- *WP 4 Presentation*. The objective of WP 4 is to communicate the technical results of the project to parties outside the MARVEL consortium.

The project finished June 2003.

3.4.3 VIKING GIS

Denmark, Norway, and Sweden have a joint project. They want to design a common new submarine that can be purchased for all three nations. In this project different studies are made. One of these is VIKING GIS. All the defence research establishments from the three countries participate in this study (which is the first common project between all three establishments).

The VIKING GIS is divided into two parts:

1) VIKING GIS, Part I
   a) Establishing a database describing available data and its sources and quality.
   b) Building a demonstrator to show how GIS can be used in the submarine.
2) VIKING GIS, Part II

3.4.3.1 VIKING GIS, Part I

The database will contain description of available digital and digitisable relevant marine geographic information from both civilian and military sources. An overview of future planed marine surveys shall be included. Special emphasis shall be given to the following parameters: depth, bottom characteristics, wrecks/objects, temperature and salinity or sound velocity profile, current, and acoustic and magnetic properties. The study shall include an assessment of data quality such as accuracy, resolution, and coverage. The database will have a graphical interface, where you can ask what information is available for defined areas.

A first version of a demonstrator package, named Concept Presenter (ConPres), shall be developed. Issues concerning modelling and visualisation of seabed terrain shall be addressed, especially evaluation of methods, technologies and functionality. ConPres shall demonstrate the use of GIS technologies for navigational purposes, more specifically:

1) Use of several types of marine geographical information such as seabed topography, sediment types, acoustic profiles and wrecks/objects;
2) Assess quality parameters as data resolution and data accuracy;
3) Illustrate compression and visualisation techniques for large amounts of data;
4) Use of sensor information.

ConPres is composed of individual, more or less coupled components as articles, pictures and software.

3.4.3.2 VIKING GIS, Part II

Second part of Viking GIS focus on the advantages of GIS for the Viking submarine. This part is not a visualisation project, but it specifies how GIS and visualisation can be used in the future submarine.

The study comprises internal GI systems, and only deals with external systems to an extent necessary for the overall information flow. The main emphasis is on the role of the submarine as a naval combat platform with advanced sensors. The work does not comprise detailed technical solutions or demonstrators. The work includes discussions of technology with respect to feasibility.

The main objective of the study is to explore the utilization of advanced GIS technology in a submarine for more effective and secure realization and completion of today's and tomorrow's missions. Emphasis is put on the exploration of the emerging GIS capabilities with other IT advances to meet the challenges of the 21st century battle space. The study is carried out using different perspectives of how GIS can be used in the following selected missions:

- Reconnaissance
- Special operation
- Mining and mine countermeasure

4.0 SUMMARY FOR THE DANISH VR PROJECTS

The previous sections have mentioned several centres involved with VR, and some of the VR projects going on in these centres. The table below is a summary. The hachure is centres, and the solid is projects. Red is military, and green is civilian. For each projects, the comments describe the type of project (divided into two categories), the techniques used (apart from VR) if any.

Table 1: Summary of VR in Denmark

	= Military
	= Civilian
	= Centre

NAME	ESTABLISHMENT	COMMENTS
HCI-Lab	Danish Defence Research Establishment	Testing VR software and hardware
Tactical trainer for a group leader	Danish Defence Research Establishment	R&D Simulation GIS Stopped
F16 flight simulator	The Air Force	Commercial Simulation GIS Completed
Tank simulator	The Army	Commercial Simulation Completed
RTP 6.14 Virtual Environment in Military Decision-Making	Atos Origin (Netherlands), IFAD (Denmark), INTRACOM (Greece), and DATAMAT (Italy)	Commercial, R&D Decision Support VR, GIS Concluded
VIKING GIS	Danish Defence Research Establishment, Norwegian Defence Research Establishment, Swedish Defence Research Agency	R&D (Study) GIS, 3D, (VR) Concluded
Centre for Pervasive Computing		Most of the work in the centre is organised as Research Projects involving both companies and universities
Center for Advanced Visualization and Interaction – CAVI	Centre for Pervasive Computing	3D Panorama Cinema TAN Holobench Virtual studio
VR Media Lab	University of Aalborg	Cave with 6 walls Powerwall (large flat screen) Panoramic screen (160° curved large screen)
Centre for 3DGI	European Regional Development Fund (ERDF), Aalborg University, the National Survey and Cadastre – Denmark, Kampsax A/S, and Informi GIS A/S	VR Media Lab

NAME	ESTABLISHMENT	COMMENTS
VR•C	The Technical University, UNI-C	TAN Powerwall (large flat screen) 3 n-vision DataVisor HiRes Head Mounted Display See-through (augmented reality)
FORCE Technology	FORCE Technology	Simulation(+VR+GIS)
Virtual Urban Planning	Aarhus University, Cadpeople, and COWI	Commercial, R&D Landscape, Decision Support VR, GIS
Visualization of the Cadiovascular System	CAVI, Aarhus University Hospital, and Systematic Software Engineering	R&D Medical VR
Digital Theatre – Hyperopticon	Aarhus University (Denmark), The Academy of Figurative Theatre (Norway), Studio di Progettazione (Italy), and CAVI (Denmark)	Commercial, R&D Entertainment VR
3D Experiences	Aarhus University and Zentropa Interaction	Commercial, R&D Entertainment + education 3D, interactive
3D Sound in 3D Space	Aarhus University and TC Electronic	R&D 3D sound in 3D models
Interfaces for 3D Applications	Aarhus University, Personics Aps, Systematic Software Engineering A/S, RoninWorks BV (Holland) and CAVI	Commercial, R&D VR, 3D
3D Image Processing for Cranium- and Brain-Surgical Planning and Simulation	CAVI, PET Centre	R&D Medical 3D Concluded
Digital, 3D Atlas of the Receptor Systems of the Human Brain	CAVI, PET Centre	R&D Medical 3D Concluded
Packaging Design	CAVI, Technical University of Copenhagen, Arla Foods	Commercial 3D Concluded
Landscape Visualisation	CAVI, Technical University of Copenhagen, Kampsax/Lundbeck	Commercial, R&D Landscape 3D Concluded
Architecture	CAVI, Technical University of Copenhagen, Arkitektfirmaet Schütze A/S	Commercial, R&D Architecture 3D Concluded
City Planning	CAVI, Technical University of Copenhagen, CF Møller/CADpeople	Commercial, R&D Architecture, landscape 3D Concluded
Virtual Set Activities / Ren Kagemand (Danish television show)	CAVI, Technical University of Copenhagen, Danmarks Radio	Commercial Entertainment VR Concluded
Beaching Museum St. George	CAVI, Technical University of Copenhagen, Jydsk Dykkerfirma (Diving firm in Jutland)	Commercial Architecture 3D Concluded

NAME	ESTABLISHMENT	COMMENTS
Family Factory	CAVI, the Danish Film School, Schule für Schauspiel-kunst "Ernst Bush" Berlin	Commercial, R&D Entertainment 3D Concluded
Digital Theatre	CAVI	R&D Entertainment 3D Concluded
Whizbang	CAVI	R&D 3D Concluded
Aarhus New Art Museum	CAVI, the art department Schmidt, Hammer and Lassen	Commercial Architecture 3D Concluded
CAVI Building	CAVI	Commercial Architecture 3D Concluded
Katrinebjerg Phase 1	CAVI	Commercial Architecture, landscape 3D Concluded
Katrinebjerg Phase 2	CAVI	Commercial Architecture, landscape 3D Concluded
Architectural Competition	CAVI, the architecture firms of Jørn Schütze	Commercial Architecture 3D Concluded
Project of Sonderborg	VR Media Lab, Cadpeople and COWI	Commercial Landscape
Aalborg University Campus Model	VR Media Lab	R&D Architecture
CAE and CFD into Virtual Reality (CCVR)	VR Media Lab	R&D Scientific
3D Airflow	VR Media Lab, the Department of Building Technology and Structural Engineering (also at Aalborg University), the Danish Institute of Agricultural Sciences, and the Royal Veterinary and Agricultural University	R&D Environmental, Scientific 3D
3-d Visual Data Mining	VR Media Lab	R&D Education, scientific 3D
Learning	VR Media Lab, Vestas and Zenaria	Commercial, R&D Education
Vestas	VR Media Lab	Commercial Education, architecture
Music House in Aalborg	VR Media Lab and the Danish National Research and Educational Buildings	Commercial Architecture VR Concluded

NAME	ESTABLISHMENT	COMMENTS
A Plan for New Housing Development	VR Media Lab, COWI	Commercial Architecture, Landscape VR Concluded
Highway at Holbæk	VR Media Lab	Commercial Landscape VR Concluded
Model of NOVI 3, 4, and 5	VR Media Lab	Commercial Architecture VR Concluded
Puppet	University of Aalborg	R&D Education VR Concluded
Staging of Virtual 3D-Spaces	University of Aalborg, etc.	Commercial, R&D 3D, VR, multimedia Concluded
Sound in Cyberspace	University of Aalborg	R&D Sound Concluded
Qualification of 3D GeoInformation	Centre for 3DGI	Commercial, R&D Landscape 3D, GIS
Queries for Navigation in 3D Models	Centre for 3DGI	Commercial, R&D Landscape 3D, GIS
3DGI Viewer	Centre for 3DGI	Commercial, R&D Landscape 3D, GIS
Interactive 3D Visualization of Projects	VR•C	R&D 3D
Scientific Visualization	VR•C	R&D Scientific
Network-Based VR Technology	VR•C	R&D VR Concluded
VR in Neuro Informatic	The Technical University	R&D Medical VR Concluded
Simulating a Combine Harvester	The Technical University	R&D VR, simulation Concluded
Ship Simulation	FORCE Technology	Commercial Simulation GIS
Skyline	COWI	Commercial Landscape GIS, 3D

As the table shows most projects can be categorised in the following categories:

- Landscape
- Architecture
- Decision Support
- Simulation
- Scientific
- Medical
- Entertainment
- Education

The categories are mentioned in the order of interest for the military.

The techniques are (apart from VR):

- 3D
- GIS
- Sound
- 3D sound
- Multimedia
- Hypermedia
- Real-time multi-modal communication
- Interactive TV
- Video

VR is a fertile research area in Denmark. The interaction between the military research and the civilian universities and research centres is improving. Several civilian research projects show great potential for military use.