MEDINFO 98
B. Cesnik et al. (Eds)
Amsterdam: IOS Press

Design of a Virtual Reality Laboratory for Interdisciplinary Medical Application

Marcus Mehlitz[a], Thomas Kleinoeder[b], Godehard Weniger[c] and Otto Rienhoff[a]

[a]*Dept. of Medical Informatics, Georg-August University, Goettingen, Germany*
[b]*Dept. of Hematology/Oncology, Georg-August University, Goettingen, Germany*
[c]*Dept. of Psychiatry, Georg-August University, Goettingen, Germany*

Abstract

The Department of Medical Informatics of the University of Goettingen sets up a medical interdisciplinary Virtual Reality (VR) laboratory. The interdisciplinary approach for the design of the laboratory is based on a systematic, technical and application-orientated analysis. Its result led to the decision for a CAVE-like multi wall stereo projection (MWSP) system with networked workstation hardware. Within the boundary of an exemplary evaluation of the laboratory, its technical specifications and the validity in neuropsychological tests are supposed to be improved.

Both techniques, Head Mounted Display (HMD) as well as multi wall stereo projection (MWSP) systems have a high degree of immersion. MWSP systems have a lower ratio of simulator sickness and a good visual fidelity. They can also be used as a multi-user environment. Networked workstations and high-end-computers are compared in view of their costs and possible expansibility.

Keywords:

Virtual Reality; User-Computer-Interface; Computer-Simulation; Neuropsychology; Validity

Introduction

Thanks to the considerable technological progress in software graphics and computer power in the last decade, Virtual Reality (VR) has become an important everyday tool in computer applications for engineering and architecture. In medicine, it will also be more and more implemented. The initial VR use in medicine was mostly characterized by applications in surgery. But since approximately five years there are convincing results in therapeutic as well as diagnostic domains thus increasing the motivation for a clinical use also outside the surgical field. This development has been documented at the yearly held conference „Medicine meets Virtual Reality" in San Diego which was initiated in 1992.

The tasks and targets of Medical Informatics include especially the improvement of medical imaging, aid to clinical action, evaluation and education (1). Furthermore, the rise of new technologies like VR stimulates further the progress in medical sciences.

The Department of Medical Informatics of the University of Goettingen therefore decided to set up a Virtual Reality laboratory for interdisciplinary use and its evaluation in the faculty of medicine.

Material and Methods

Most VR applications have emerged from problems in clinical practice. Their authors often do not come from the Medical Informatics field, but from surgery, psychology or clinical anatomy. The systematic scientific realization of the goal, the set-up of an interdisciplinary VR laboratory, is based on the work method recommended by *Shortliffe* (2) (posing questions, designing experiments, performing rigorous analysis). We have adapted this method for the design process (see figure 1). We have constantly kept track on the development of VR research since 1992 (3). It is based on formal (literature) and informal (conferences, professional discussions) information.

Results

An interdisciplinary VR laboratory in medicine should meet the requirements of most fields and application domains. This includes the concept for basic equipment that adapts the general requirements and which can be extended to specific field/ domain requirements.

The claim of VR to generate virtual environments with a high degree of reality has led to the idealistic concept of „Virtual Presence", the feeling of being present in such an environment. The determinants of Virtual Presence are *a.* the extent of sensory information, *b.* the ability to modify the environment and *c.* the control of sensors. The variables which depend on the quality of the Virtual Presence are the sense of presence, task performance and training efficiency (4). These dependent variables are used in several studies to evaluate VR components and their sensory cues.

A transfer of these determinants to the envisaged medical application is mandatory because of its special character. In addition to an objective evaluation of VR components, supplementary aspects in medical-related VR use have been taken into account: Every medical application domain whether education or diagnosis has distinctive requirements. The criteria of quality of these requirements do not forcibly correspond with the requirements of the engineering disciplines

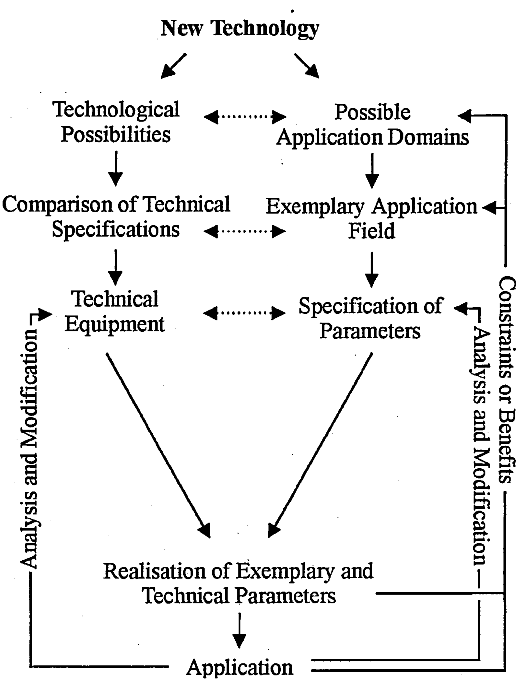

Figure 7 - Figure 1 - Model of the laboratory design process

In general, a Virtual Reality environment is provided by these systems:

a. *Real Environment Sensing System (RES)* to record user interaction like body gestures, movements etc.

b. *Virtual Environment Display System (VED)* which supplies sensory information.

c. *Virtual Environment Control System (VEC)* which supplies the hardware and software to compute and generate the input / output data.

(classification adapted from (5))

The comparison of different technical solutions of the afore mentioned systems led us to focus on the Virtual Environment Display System (VED), with the background of a possible application in neuropsychology

Virtual Environment Display System (VED)

Sensory information which is supplied by the Virtual Environment Display System (VED) may be visual, auditory, kinesthetic, tactile or olfactory. For basic equipment, we think that visual and auditory cues are most important, while kinesthetic or tactile use is subject to special application. Supposedly, olfactory displays improve the sense of presence, but their development is not yet advanced. Auditory displays in the form of spatial sound increase the sense of presence and are commercially available.

The crucial component of a Virtual Reality environment is the visual display. There are several types of visual displays: monitors, Head Mounted Displays (HMD), CAVE™-like Multi wall stereo projection (MWSP) systems, the Virtual Retinal Display and holographic systems. Monitors have a very little immersive effect, so that VR systems based on monitors are nicknamed „Desktop VR". The Virtual Retinal Display and holographic systems are still in prototype stage. Only Head Mounted Displays and Multi wall stereo projection systems can attain a strong effect of immersion with a high sense of presence. Table 1 gives a summary of the important specifications.

Table 1 - Important characteristics of Head Mounted Display (HMD) and Multi wall stereo projection (MWSP) systems (data collected from (6-11))

	HMD	MWSP
visual fidelity	sufficient	high, less distortions
field of view	20-120°	60-360°
body representation	artificial, simplified	full body, physical
simulator sickness	up to 60%	low ratio (few literature)
no. of users	one	up to 12/ depends on size
needed hardware	workstation	high-end computer or workstation network
costs	~ 1.000-50.000 $	~ 30.000 $ per wall

The simulator sickness mentioned in table 1 is a problem in creating virtual environments which has not yet been solved satisfyingly. Supposedly, the sensory mismatch is provoked by contradictory vestibular, proprioceptive and visual impressions. This can lead to momentary or up to hours-lasting symptoms like disorientation, vertigo, headache, nausea and eye-strain which probably also depend on the contents of the application (flight simulation – high ratio, architecture walk – low ratio).

Real Environment Sensing System (RES)

Headtracking systems seem to be mandatory for user interaction because of their easy and intuitive handling and their strong effect on the sense of presence (7). There are several possibilities to navigate in the virtual environment, e. g. 3D-mice, Data-Gloves, cockpits, bikes, wheelchairs, force feedback systems and biosensors .

Virtual Environment Control System (VEC)

The hardware and the software selection to set up a Virtual Environment Control System (VEC) depends on several factors. The necessary graphics and calculating performance scales of the employed hardware. This consists in general of stand-alone or a network of workstations or of high-end Silicon-Graphics computers. Concerning the VR software multiple solutions are possible which partly depend on the chosen platform. These solutions are based either on developments of research institutions or on commercial CAD-similar products.

Table 2 - Examples of VR use in medical fields and its display solution

Field	Description of the Applications	Domain	Visual Display
Internal Medicine	Ultrasound Teleconsultation (12)	Diagnosis	Monitor
	Support of Psychooncological Therapy (13)	Therapy	HMD
Psychiatry,	Desensitization of Phobia (14)	Therapy	HMD
Neurology	Play Environment for Autistic Children (15)	Therapy	Projection Screen
	Modification of Body Image at Eating Disorders (16)	Therapy	HMD
	Diagn. and Treatm. of Sensorimotor Disturbances (17)	Diagnosis/ Therapy	Monitor
	Neuropsychological Assessment and Rehabilitation (18)	Diagnosis/ Therapy	HMD
Surgery	Endoscopic Surgical Training Simulator (19)	Education/ Therapy	Monitor

Medical VR Application

Medical VR application can be classified by a description of application fields. We differentiate the following application domains to describe the principles of the applications:

- diagnosis
- therapy
- education and instruction
- research.

Whereas in the beginning, medical VR was mainly applied in surgery, radiology and for anatomical visualization, new areas with a promising future have emerged. Table 2 shows an extract of medical VR applications.

An initiating project has to meet the requirements of a possible use in diagnosis, therapy, education/ instruction and scientific visualization. Every field that can benefit from the visual, interactive and immersive character of Virtual Reality is a possible application field.

The fields of psychiatry, neurology, and neuropsychology take important VR applications into consideration (see table 2). Human neuropsychology e.g. evaluates the interrelations between brain and behaviour. For scientific progress, the validity of the applied test of a specified brain function is of very high importance. But for some neuropsychological functions like concept formation or topographical orientation, the validity of common paper-and-pencil tests, but also of most of the existing computer-assisted assessment is low. At present, VR-based neuropsychological testing offers the unique opportunity to reduce the gap between the neuropsychological test situation and the patients' performance in their real life. Furthermore, the precise analysis of the deficits is the prequisite for efficient function-orientated rehabilitation, which can improve the patient's ability in everyday activities and increase his life quality. Therefore, neuropsychology is a paradigmatic field where VR technology will improve diagnostic procedures and therapeutic rehabilitation for cognitive impaired patients. The visualization of the complex brain anatomy for the education of undergraduate students or the illustration of topographical lesions for clinical education and research are further applications.

Discussion

The extensive possibilities of simulation and interaction in Virtual Reality environments may lead to an extensive use in clinical medicine. Neuropsychology could serve as an example for the different application domains.

Most of the psychiatric applications are carried out by means of HMD technology or monitors. This fact has undoubtedly financial reasons because MWSP systems are much more expensive. A MWSP system with more than one wall can easily attain $ 100.000-200.000. But the modular concept of MWSP systems allows a step-by-step expandability. Comparing the available visualization techniques, HMD and MWSP, it becomes evident that different techniques generate different kinds of immersion: a completely closed immersion with artificial body representation (HMD) and a full body immersion with a wide field of view (MWSP). MWSP enables several users at the same time to move in a virtual environment. In a medical application this could be the patient and a mentor or a group of students. In case of applications that need constant immersion, e. g. desensitization of phobia, MWSP could be detrimental, unless it is a sophisticated six-wall stereo projection system. Concerning simulator sickness for HMD extensive literature exists while MWSP only has anecdote background. This indicates a considerably lower ratio of simulator sickness for MWSP. Applied in medicine, especially in neuropsychology, simulator sickness could cause detriments in diagnosis or in therapy. Due to their configuration, both displays could lead to claustrophobic effects. In summary, a MWSP system seems to be the most useful and neutral system.

According to the user variety, the most neutral and easiest forms of interaction will be chosen, a headtracking system and a 3D-mice. We think that other interaction devices, e.g. speech recognition or force feedback, applications and are not mandatory for the basic equipment. For a neuropsychological orientation test, there is no need for an additionally interaction device, because navigation is solved sufficiently.

A HMD usually requires stand-alone workstations, and the selection of a platform (SiliconGraphics/Unix, PC/NT) often depends on local circumstances. But only two systems are able to meet the enormous calculating and graphics requirements for the operation of a MWSP system: SiliconGraphics high-end computers and networked workstations. The former are extremely powerful, but their acquisition and expansion would be very expensive. The costs for the latter are much lower. This goes especially for PC-networks. The commercial availability of these networks is not yet advanced in contrast to SGI solutions. Networked workstations are as powerful as high-end computers, but more easily to be expanded and less expensive.

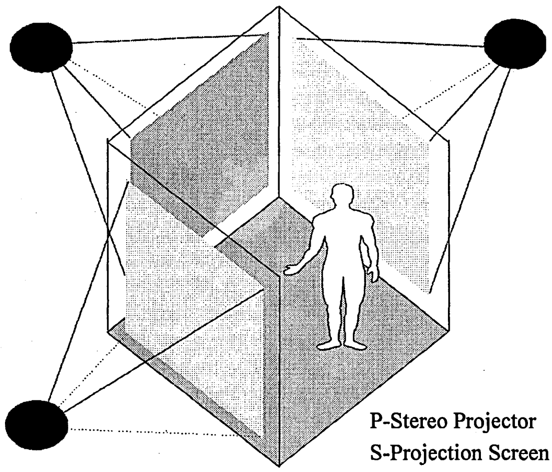

Figure 8 - Three wall stereo projection system

Regarding software there are mainly two groups: developments of scientific institutions and commercial products. Research solutions may be considerably less expensive than commercial products. They often have special features and can be programmed at a very low level. As in some respects, they were developed rather under research than under application aspects, they therefore need a lot of man-power. This has to be taken into consideration concerning costs of maintenance. Commercial products often come from engineering disciplines but they correspond best with our requirements. Summed up, purchase of commercial products seems to be much more reasonable under application and costs aspects for the set-up of a VR laboratory.

Conclusion

The design of the VR laboratory is based on a systematic, technical and application-oriented analysis. The implementation of a multi wall stereo projection (MWSP) system has been decided. The hardware system will consist of networked workstations to guarantee expansibility and to avoid huge and expensive high-end computers. In general, basic interaction forms will take place using headtracking and 3D-mice. Use of commercial VR software with sufficient features for the applications to reduce project and personnel costs seems to be the best choice.

The VR laboratory will be evaluated in the application field of neuropsychology to get a scientific feed-back. The following two factors dominate:

- the technical evaluation in order to improve and optimize the VR laboratory;
- the clinical evaluation in order to judge a VR-supported diagnosis, in this case to increase the validity of neuropsychological tests.

Consequently applied results of this evaluation can allow widespread, clinically first-class VR applications in an interdisciplinary VR laboratory.

References

[1] Grémy F. Medical Informatics as a Set of Human Sciences? Why Not? [Preface]. In: van Bemmel JH, McCray AT, eds. 1994 Yearbook of Medical Informatics. Stuttgart: Schattauer, 1993:1-3.

[2] Shortliffe EH. The Science of Biomedical Computing. In: Pagés J-C, Levy AH, Grémy F, Anderson J, eds. Meeting the Challenge: Informatics & Medical Education. Chamonix, France: North-Holland, 1983:3-10.

[3] Kaltenborn KF, Rienhoff O. Virtual reality in medicine. Methods Inf Med 1993;32(5):407-17.

[4] Sheridan TB. Musings on Telepresence and Virtual Presence. Presence 1992; 1(1): 120-126.

[5] Grimsdale C. Virtual Reality - key technologies, problems, and emerging solutions. In: Feldman T, ed. Virtual Reality International 92. Impacts and Applications. London: Meckler, 1992:14-22.

[6] Cruz-Neira C, Sandin D, DeFanti T. Surround-Screen Projection-Based Virtual Reality: The Design and Implementation of the CAVE. ACM SIGGRAPH '93. Anaheim, 1993.

[7] Hendrix C, Barfield W. Presence within Virtual Environments as a Function of Visual Display Parameters. Presence 1996; 5(3): 274-289.

[8] McKenna M, Zeltzer D. Three Dimensional Visual Display Systems for Virtual Environments. Presence 1992; 1(4): 421-458.

[9] Barfield W, Hendrix C, Bjorneseth O, Kaczmarek KA, Lotens W. Comparison of Human Sensory Capabilities with Technical Specifications of Virtual Environment Equipment. Presence 1995; 4(4): 329-356.

[10] Blach R, Simon A, Riedel O. Experiences with User Interactions in a CAVE(TM)-Like Projection Environment. In: Smith MJ, Salvendy G, Koubek RJ, eds. Advances in Human Factors/ Ergonomics (21B). Design of Computing Systems: Social and Ergonomic Considerations. Elsevier Science B.V., 1997.

[11] Deisinger J, Cruz-Neira C, Riedel O, Symanzik J. The Effect of Different Viewing Devices for the Sense of Presence and Immersion in Virtual Environments: A Comparison of Stereoprojections Based on Monitors, HMDs and Screens. In: Smith MJ, Salvendy G, Koubek RJ, eds. Advances in Human Factors/ Ergonomics (21B). Design of Computing Systems: Social and Ergonomic Considerations. Elsevier Science B.V., 1997.

[12] Berlage T. Augmented Reality for Diagnosis on Ultrasound Images. In: Troccaz J, Grimson E, Mösges R, eds.

CVRMed-MRCAS '97. Grenoble, France: Springer, 1997:253-262.

[13] Oyama H, Miyazawa T, Aono M, Ohbuchi R, Suda S. VR Medical Support System for Cancer Patients. In: Satava RM, Sieburg HB, Morgan K, Mattheus R, Christensen JP, eds. Interactive Technology and the New Paradigm for Healthcare. San Diego, California: IOS Press, 1995.

[14] Rothbaum BO, Hodges LF, Kooper R, Opdyke D, Williford JS, North M. Effectiveness of computer-generated (virtual reality) graded exposure in the treatment of acrophobia. Am J Psychiatry 1995; 152(4): 626-8.

[15] Kijima R, Shirakawa K, Hirose M, Nihei K. Virtual Sand Box: Development of an Application of Virtual Environments for Clinical Medicine. Presence 1994; 3(1): 45-59.

[16] Riva G. Virtual Reality and Body Image: New Perspective for Eating Disorders. In: Weghorst SJ, Sieburg HB, Morgan KS, eds. Medicine Meets Virtual Reality 4. San Diego, California: IOS Press, 1996:726.

[17] Kuhlen T, Kraiss K-F, Szymanski A, Dohle C, Hefter H, Freund H-J. Virtual Holography in Diagnosis and Therapy of Sensorimotor Disturbances. In: Weghorst SJ, Sieburg HB, Morgan KS, eds. Medicine Meets Virtual Reality 4. San Diego, California: IOS Press, 1996:184-193.

[18] Pugnetti L, Mendozzi L, Motta A, Cattaneo A, Barbieri E, Brancotti A. Evaluation and retraining of adults' cognitive impairment: which role for virtual reality technology? Comput Biol Med 1995; 25(2): 213-27.

[19] Edmond CV jr, Heskamp D, Sluis D, et al. ENT Endoscopic Surgical Training Simulator. In: Morgan KS, Hoffman HM, Stredney D, Weghorst SJ, eds. Medicine Meets Virtual Reality 5. San Diego, California: IOS Press, 1997:518-528.

Address for correspondence

Marcus Mehlitz
Dept. of Medical Informatics
Georg-August University
Robert-Koch-Str. 40
37075 Goettingen
Germany
Email: mmehlit@gwdg.de